NRRI
वार्षिक प्रतिवेदन
ANNUAL REPORT
2015-16

भाकृअनुप-राष्ट्रीय चावल अनुसंधान संस्थान
(पूर्ववती केंद्रीय चावल अनुसंधान संस्थान)
आईएसओ 9001:2008 प्रमाणित संस्थान
ICAR-National Rice Research Institute
(Formerly Central Rice Research Institute)
An ISO 9001:2008 Certified Institute

BSCIC NABCB QM 030
ISO 9001 REGISTERED

NRRI

वार्षिक प्रतिवेदन
Annual Report
2015-16

भाकृअनुप - राष्ट्रीय चावल अनुसंधान संस्थान
कटक (ओडिशा) ७५३ ००६, भारत

ICAR - National Rice Research Institute
Cuttack (Odisha) 753 006, India
An ISO 9001:2008 Certified Institute

भाकृअनुप
ICAR

Correct Citation
NRRI Annual Report 2015-16
ICAR - National Rice Research Institute, Cuttack

ISBN 81-88409-00-6

Published By
Dr. AK Nayak
Director, NRRI

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

Contacts
ICAR-National Rice Research Institute
Cuttack-753 006 (Odisha)
Phone : +91-671-2367768-83
Fax : +91-671-2367663
E-mail : crrictc@nic.in
director.crri@icar.gov.in
directorcrricuttack@gmail.com

NRRI Regional Station
Hazaribagh-825 301 (Jharkhand)
Phone : +91-6546-222263
Fax : +91-6546-223697
E-mail : crurrs.hzb@crri.in
crurrs.hzb@gmail.com

NRRI Regional Station
Gerua, District: Kamrup-781 102 (Assam)
Phone : +91-361-2820370
Fax : +91-361-2820370

Visit us at: http://www.crri.nic.in

CONTENTS


CRRI

PREFACE

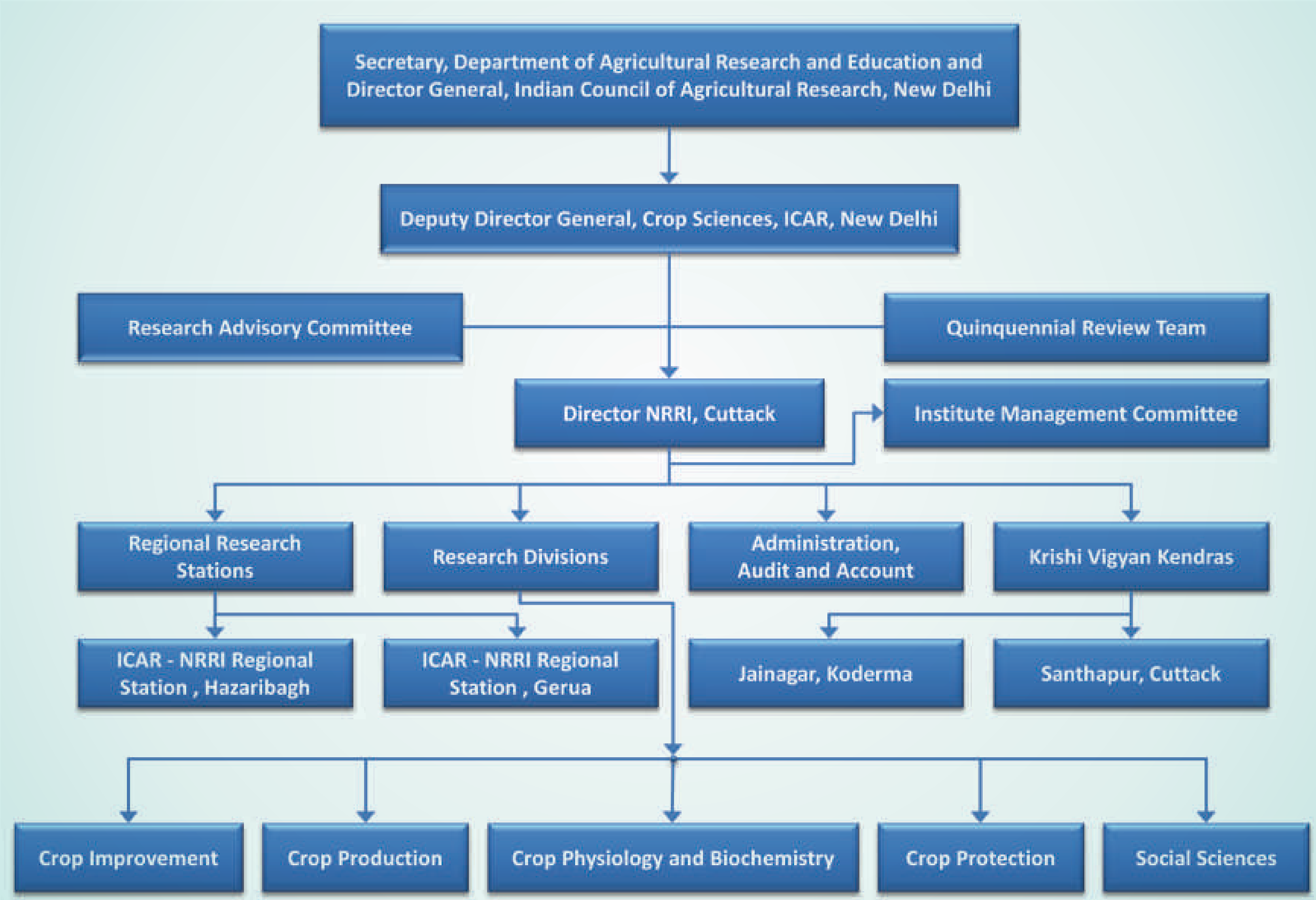
Rice plays an important role in country's food security, economy and equity. The declining resources base, falling factor productivity, increasing cost of production, emerging socio-economic changes such as urbanization, migration of labour, concern about farm related pollution & climate change related adverse effect are the challenges in the rice research required to be addressed. Rice also needs to become healthy and nutritious to meet the challenge of wide spread malnutrition and it must be produced, processed & marketed in more sustainable & environmental friendly ways. At the same time, climate change threaten the rice production through the effects of higher temperature & more frequent drought submergence & other related biotic & abiotic stresses which need an efficient adaptation and mitigation mechanism. The institute has also developed a web based mobile app-rice Xpert, which provides information on rice cultivation and enable farmers to consult panel of experts. The app provides real time information with two way information flows in text, voice and photo mode.

The research activities of the Institute are designed to improve rice production and productivity in multidisciplinary approach to address the constraints in favorable as well as in unfavorable rice ecologies. During the year 2015-16, the institute had a path breaking achievement of developing protein-rich rice variety, first of its kind in the world, which will be able to address the malnutrition problem of rice consumers.

I sincerely acknowledge the inspiring guidance of Dr. T. Mohapatra, Hon'ble Secretary, DARE & Director General, ICAR, New Delhi who spearheaded the Institute as Director till Aug 2015 under whose leadership, institute got recognition &visibility. The valuable support and guidance provided by Dr. S. Ayyappan from Secy, DARE and DG, ICAR is highly acknowledged. The inspiring guidance provided by Prof. V.L. Chopra, Chairman, RAC & Dr. J.S Sandhu, DDG(CS) ICAR, New Delhi, the esteemed members of RAC & IRC are gratefully acknowledged. I sincerely acknowledge the involved support of Dr. I.S. Solanki, ADG (FFC) & Dr. J.S Chauhan, ADG (Seed). The efforts of Heads of Division, OIC Regional Research Stations, Publication Committee, Administration, Finance & Publication Unit the institute and others compiling and editing the Annual Report are highly appreciated. I hope this Annual Report would serve as reflection of institute activities and performance.

(A. K. Nayak)
Director

ORGANOGRAM


Secretary, Department of Agricultural Research and Education and Director General, Indian Council of Agricultural Research, New Delhi
Deputy Director General, Crop Sciences, ICAR, New Delhi
Research Advisory Committee
Quinquennial Review Team
Director NRRI, Cuttack
Institute Management Committee
Regional Research Stations
Research Divisions
Administration, Audit and Account
Krishi Vigyan Kendras
ICAR - NRRI Regional Station , Hazaribagh
ICAR - NRRI Regional Station , Gerua
Jainagar, Koderma
Santhapur, Cuttack
Crop Improvement
Crop Production
Crop Physiology and Biochemistry
Crop Protection
Social Sciences

Executive Summary

The National Rice Research Institute has developed a high yielding high protein rice variety CR Dhan 310 (IET 24780), which has been released and notified by Central Sub-committee on Crop Standard, Notification and Release of Varieties for the states of Odisha, Uttar Pradesh and Madhya Pradesh. This variety having 10.3% protein, 15 ppm zinc with average yield of 4.48 t/ha can solve the problem of malnourishment to a large extent. Three promising cultures were identified for release by Variety Identification Committee (VIC) in the 51st AICRIP group meeting held at Raipur. CR 2687-2-3-1-1-1 (IET 13053) was identified for release in semi-deep water ecology of Andhra Pradesh, Karnataka and Assam, while CR 3835-1-7-2-1-1 (IET 23601) was identified for deep water areas of Assam, West Bengal and Odisha. CR 2713-35 (IET 23189), an aromatic short grain rice culture was identified for release in West Bengal, Odisha and Uttar Pradesh. Proposals were submitted for release of eight cultures suitable for different ecologies by State Variety Release Committee (SVRC), Odisha. They are CR Dhan 409 for shallow low land, CR Dhan 207, CR Dhan 208 and CR Dhan 209 for aerobic, CR Dhan 507 and CR Dhan 509 for deep water, CR Dhan 800 for bacterial blight endemic areas and CR Dhan 311 for high protein content.

Three exploration programmes were conducted during this period in different parts of the country for collection of wild and weedy rice germplasm. Two were from mangrove deltas of Bhitarkanika and Andaman &Nicober Islands for collection of *Oryza coarctata* (*Porteresia coarctata)* and the third one was from coastal Odisha. Six thousand four hundred and six (6406) accessions of rice germplasm were characterized and rejuvenated for conservation. 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 screening, evaluation and utilization.

The wild rice accessions were screened against biotic (YSB, BPH & Sh.B) and abiotic (drought) stresses. Donors for YSB, BPH, Sh.B and drought were identified and have been used in hybridization programme. Comparative genome analysis using molecular markers revealed co-linearity in the genic region between *Oryza sativa* and *Oryza brachyantha*.

In Hybrid rice programme, hybrid combinations CRHR 102 (IET 25231) and CRHR 103 (IET 25278) were promoted to AVT 1-Late trial of AICRIP. A new CMS line, CRMS 52A having Kalinga I- CMS in the nuclear background of Sahabhagidhan was developed. Bacterial blight resistant genes (*Xa21, xa13, xa5 and Xa4*) were introgressed into CRMS 31A and CRMS 32A.

Two elite cultures IET 23934 (CR3838-1-2-1-4-2) and IET 23895 (CR2593-1-1-1-1) are in Advance variety trial-1 under rainfed shallow lowland. Another culture IET 24471 is in final year of testing for southern zone (zone VII) of the country. Eleven promising entries have been promoted to next level of testing under different trials conducted in semi-deep and deep water conditions during 2015.

Three breeding lines were promoted to final year of testing while ten lines were promoted to second year of testing year under CSTVT trial of AICRIP. Ninety six miRNAs were found to be differentially regulated between the control and salt-treated (at flowering stage) samples of salt tolerant variety Pokkali (AC 41585) at 1.5-fold change. Salt tolerant breeding line, CR2459-23-1-1-S-B1-2B-1 performed well at waterlogged situation (4184 kg/ha) in wet season.

Diversity analysis of promising high yielding new plant type selections, revealed that NPTs derived from *indica* and *tropical japonica*, still maintain sufficient genetic diversity from both of these races *vis-a-vis* from *temperate japonicas*, therefore could be potentially utilized further, in combination with different races. Physiological analysis, in super rice genotypes indicated that rate of partitioning to panicle was maximum in genotype showing highest grain yield. Two very high yielding genotypes CR3969-17-2-2-1-1 (9.03 t/ha) and CR3938-6-2-1-1-1 (8.90t/ha) were evaluated during wet season, 2015, where it was found that higher grain yield was attributed basically due to a balance of higher number of fertile grains, higher number of effective tillers and biomass.

Breeding materials for resistance to multiple insect-pests and diseases were generated in the background of Naveen and Pooja using donors for various biotic stresses.The composite interval mapping (ICIM) analysis identified one QTL qRTV1.1 with LOD score 3.23 explaining phenotypic variance (PV) of 18.57% towards resistance to RTD in the RIL mapping population of Tapaswini (susceptible) and IET 16952 (resistant). CR 2711-149, derived from a cross between Tapaswini/Dhobanumberi was found to be promising against multiple insect-pests (BPH, BPH+ WBPH, GM and SB) in Multiple Resistance Screening Trial (MRST) of AICRIP, 2015. Three cultures CR 3939-18 (IET 25318), CR 3981- 47-17-5 (IET 25266) and CR 3862-29-15-7 (IET 25244) were promoted to Advanced Variety Trial based on their superior performance.

In breeding for higher resource use efficiency, new source of phosphorus tolerance and early seedling vigour lines were identified. New methodologies were developed to estimate early seedling vigour by image analysis and strong culm by digital force gauge. Six aerobic, one early direct seeded and early transplanted culture developed under the Project were promoted to Advance Variety Trial-1 of AICRIP.

Two high protein lines in Naveen back ground were promoted for final year of testing and three promising lines in Swarna background were nominated for Biofortification trial. Effort was made to identify the protein fraction that increased the protein content in the high protein variety. A set of 129 genotypes were screened and two genotypes Dular and Madhukar were identified to have high iron and zinc content respectively in brown rice.

A method was standardized for development of green plants in an *indica* rice hybrid, 27P63 via androgenesis. The DH lines developed from non-aromatic rice hybrid BS6444G were found to be aromatic due to 8 bp deletion in the 2nd exon in the BADH2 gene. A total of 117 DHs derived from F_1s of Savitri and Pokkali were screened to find out the salinity tolerance during germination. A method was established for organogenesis followed by *Agrobacterium* mediated transformation in Swarna and Naveen.

Ten high yielding mega rice varieties of India namely, Swarna, Samba Mahsuri, MTU 1010, MTU 1001, PKM-HMT, PR 113, Pusa 1121, Pooja, Satabdi and Sahabhagidhan were re-sequenced using NGS technology. A large number of DNA polymorphisms were discovered between these varieties and both *indica* and *japonica* reference genomes, which will be useful for genomic studies and molecular breeding programs. The composite interval mapping (ICIM) analysis identified five QTLs, *QSN1.1, QPSY1.1, QPH9.1, QTN3.1* and *QTN6.1* controlling yield related traits in the RIL mapping population derived from the cross CR 662-2211-2-1/ WAB 50-56. Two QTLs, *Qbph4.3* and *Qbph4.4* were identified in resistant land race Salkathi, which explained phenotypic variance of 9.7% and 15.7%, respectively towards resistance to BPH. Candidate gene based association analysis for grain size indicated that two rice genotypes DBT1230 and AC522 contains novel gene(s)/QTLs for grain size, which can be utilized for suppression of negative function of *GS3*, a major gene explaining 97% of grain length variation in rice.

In upland breeding programme, two promising entries *viz.*, CRR-708-1-B-2-B-B and CRR-697-76-B-1-B-B identified in preliminary yield trial showed better vegetative stage drought tolerance than Sahbhagidhan. Introgression of grain yield under stress QTLs *DTY12.1* into moderately drought susceptible variety Anjali have resulted in significant yield improvement under severe moisture stress around flowering. Introgression lines also showed better tolerance to vegetative stage drought. Similarly, introgression of blast resistant gene *Pi2* along with QTLs *DTY12.1* into popular upland variety Vandana showed improved performance of the introgression lines against disease in the UBN nursery and also better grain yield under reproductive stage drought stress.

Long term fertilizer experiment demonstrated that addition of FYM alone or in combination with inorganic fertilizers increased the macro-aggregates and activities of N mineralization enzymes. Using semi-quantitative PCR, it was proved that denitrifying bacteria populations increased when FYM was applied along with fertilizer N.

Experiments on crop and varietal diversification revealed that yield of toria, green gram and black gram decreased up to 139, 116 and 95% when sown after Swarna-*Sub1* over sowing after Naveen and Sahbhagidhan, respectively. System productivity was maximum in rice cv., Naveen– black gram followed by Sahbhagidhan– black gram.

Arbuscular mycorrhizal fungi root colonization was higher with Zn at 5 kg/ha over other doses of Zn. Application of phosphorus decreased root colonization.

The N uptake of rice was significantly influenced by Si application. Partial factor productivity,agronomic N use efficiency, and N recovery efficiency ranged from 48.7-74.5 kg/kg, 19.6-30.8 kg/kg and 35.9-49.0 % with Si application.

Agglomerated urea briquettes were prepared using urea briquette machine. Urea briquette prepared by mixing urea with fly ash resulted in the highest N use efficiency. Urea briquette applicator could save time up to 82.8 % over hand application by using 3 row briquette applicator.

Photosynthetic rate, survival % and growth of all the cultivars tried decreased during submergence except in IR64 and Swarna. Application of Si as basal dose increased survival by 41.4%, irrespective of cultivars; additional 21.5% advantage in survival was recorded with N and Si.

Agronomic manipulations *viz.,* higher seed rate (60 kg/ha) and additional P application (20%) improved the allometric characters after germination and emergence. Application of 20% additional P along with recommended NPK produced more number of panicles, fertile grains per panicle and panicle weight.

Emission of CO_2 and N_2O increased by 12.9 - 23% and 22.1 - 23% respectively at soil moisture potential of -20 kPa and -30 kPa.A significant decrease in emissions of these gases were observed at higher SWP (-40 kPa and -60 kPa).

Rice plants under elevated CO_2 recorded increase in plant height, ear bearing tillers, grain and straw yield over ambient CO_2 under water deficit stress conditions suggesting that physiological changes occurring under elevate CO_2 helped the rice plant in mitigating the negative effects of water deficit stress.

Increase in application rates of rice husk biochar increased the soil β-glucosidase activity, fluorescein diacetate activity and dehydrogenase activity. The C-mineralization study revealed that the rate of release of CO_2 was lower in RFD till 15 days of soil incubation compared to biochar treated plots.

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 rice equivalent yield over other nutrient management treatments.

Application of 75 % of RDN applied through LCC was at par with 100% of RDN in rice but the yield of maize was higher when 100% RDN applied to rice compared to 75% RDN. The system REY with 100% RDN to rice was 7% higher than that obtained with 75% RDN applied through LCC.

Three management zones were delineated for Mahakalpada block of Kendrapara district, Odisha using nine soil attributes, including normalized difference vegetation index (NDVI) and enhanced vegetation index (EVI) images using principal component analysis and fuzzy c-means clustering algorithm. The three defined management zones provided valuable information for site-specific management in precision agriculture.

NRRI two row self-propelled weeder recorded higher field capacity was (0.052 ha/h) compared to Kalinga shakti power weeder (0.046 ha/h). The man power required for operation (333.5 man-h) was low with least cost of weeding (Rs 8337.5/ha) in NRRI two row self-propelled weeder.

Rice cv. Savitri recorded maximum ratoon yield (45% of the main crop). Sahbhagidhan, Swarna and Naveen showed weak ratooning ability. Sahbhagidhan produced only 17% yield as of main crop.

Application of paraquat recorded higher seedling death in ratoon compared to application of glyphosate in 15 cm stubble height. The seedling survival % of ratoon was marginally higher in 30 cm stubble with 9% and 31% respectively, in paraquat and glyphosate treatments.

In zero tillage rice, sequential application of bispyribac sodium and fenoxaprop-p-ethyl was found most effective in controlling the weeds. Among the pre-emergence herbicides, pendimethalin was most effective in restricting the weedy rice growth.

Biology based community level physiological profiling (CLPP) revealed that the microbial community diversity was significantly more in paddy soil of NRRI than Mangrove soils.

Under *in vitro* screening, three bacterial isolates showed strong insecticidal activity against both rice leaf folder and pink stem borer.

Among the sixteen P-solubilizing rice rhizospheric bacteria (*Firmicutes*) possessing 2-16% NaCl tolerance, all fixed nitrogen and solubilized phosphate; 75% and 50% organisms produced ammonia and siderophore, respectively.

Arbuscular mycorrhiza populationincreased over years (2013 to 2015) under conventional tillage (CT) as compared to deep tillage (DT). Higher native population in CT resulted in higher root colonization (AMF) (+29.9%), P uptake (+14.4%) and grain yield (+22.8%) over that of DT.

CR-1014 has been confirmed to have tolerance against sheath blight and it is being used for marker assisted selection and identification of genes for tolerance.

The isolation and mass production of false smut pathogen has been standardized and the pathogen has been identified using molecular diagnostics.

Ten RAPD marker analyses confirmed that the *Pyricularia oryzae* isolated form weed is different than that from rice. Conidia-packed bodies in *Pyricularia oryzae* culture originating from 'green island' producing rice blast lesions has been detected in highly virulent race.

Indigenous *Trichoderma* species are better candidate for biocontrol of rice diseases. Besides their growth promotion activity may be helpful for the farmers to reduce the application of chemical fertilizers.

Forty eight genotypes from NBPGR *viz.* B-127, B-129, B-134, B-136, B-150, B-180, B-189, B-220, B-221, B-231, B-235, B-242, B-246, B-360, B-369, B-382, B-383, B-389, B-395, B-396, B-400, B-401, B-406, B-408, B-409, B-412, B-414, B-416, B-427, B-429, B-430, B-431, B-433, B-447, B-497, B-606, B-613, B-617, B-654, B-660, B-726, B-733, B-742, B-849, B-864, B-876, B-888, B-1005., seven F3 lines from IRRI *viz.*, IR 113050-B-8, IR 113050-B-11, IR 113050-B-14, IR 113050-B-18, IR 113050-B-51, IR 113050-B-81, IR 113050-B-100 and one from PHS *viz.*, RP 2068-18-3-5 showed highly resistant reaction to brown plant hopper.

Field screening of breeding lines (CR 1009 x *Oryza brachyantha*), tropical japonica lines and double haploid lines with one hybrid CRHR 32 revealed that eight entries *viz.*, wild derivatives: B -8, B – 11 & B -16; tropical japonica lines: WC – 73, WC – 152, WC – 392; double haploid lines: SS-5, SS-19 showed zero damage score as against the susceptible check TN 1 with damage score of 7.

Rice stubbles analysis showed that three predominant stem borer larvae *viz.*, yellow stem borer, *Scirpophaga incertulus,* striped stem borer, *Chilo supressalis* and pink stem borer, *S. inference* harboring in the rice stubbles with the relative abundance of yellow stem borer (40.8%) was most predominant followed by striped stem borer species (36.2%) and pink stem borer (23%). The occurrence of stem borer species revealed that 60% of the total *S. inference* and 17.6% of the total *Chilo* sp recorded were concentrated to 9.8, 7.0 cm above the root zone respectively whereas 98% of the yellow stem borer larvae were concentrated to the base of rice stubbles.

Analysis of the bacterial association in mid gut region of cellulose degrading stem borer (CDSB) such as pink stem borer, white stem borer and yellow stem borer using Nutrient Agar (NA), King's B, Minimal medium and Nutrient Agar (NA) supplemented with Carboxy Methyl Cellulose (CMC) media revealed that the pink stem borer recorded higher bacterial population (1.51 x 10^4 larva^{-1}) followed by yellow stem borer (1.23 x 10^4 larva^{-1}) and striped stem borer (0.87 x 10^4 larva^{-1}) in Nutrient Agar medium.

Diversity indices computed for insect pests and natural enemies in irrigated ecosystem calculated as the Simpson's index [1/D] (10.48), Shannon-Wiener index [H'] (2.62), Margalef's index [M] (2.75) whereas in semi deep water ecologies the Simpson's index [1/D] (13.42), Shannon-Wiener index [H'] (2.78) and Margalef's index [M] (2.76) were computed to quantify diversity and understand community structure.

Consumption analysis of rice leaf folder, *Cnaphalocrocis medinalis* (Guenee) under elevated CO_2 concentration (CE) at CE (550 µmol mol^{-1}), ambient CO_2 concentration (~ 390 µmol mol^{-1}) and in open field condition showed that on the elevated CO_2 condition, the feeding activity of leaf folder decreased without affecting the feeding behavior. The percentage of leaf attacked was more in case of elevated condition (44.4%) as compared to ambient condition (34.8%) and field condition (38.5%). However, the average area of the leaf fed under elevated CO_2 was 7.6% where as the feeding in ambient CO_2 (15.8%) was more than double of the elevated CO_2.

Indigenous method was developed to bio-synthesize silver nanoparticles. Hot water extract of leaves of purple rice varieties were used at a ratio of plant extract with 1mM silver nitrate 1:9 (V/V) at 30-40°C temperature for 24 hours to synthesize silver nanoparticles. Purple rice varieties had high content of total phenols, flavonoids which might help in silver nanoparticles formation. The synthesized Ag-NPs were tested against *Xanthomonas oryzae* and *Rhizoctonia solani* and found to be effective @

4mL/100mL broth and @ 6mL/100mL broth, respectively.

Persistence of fipronil was more in soil amended with fly ash (@ 2.5 and 5%) and biochar (@2.5 and 5 %) compared to normal soil. Mechanism of degradation of imidacloprid revealed that microbial and photo degradation was the prominent routes of imidacloprid degradation compared to acid and alkali hydrolysis.

Studies on succession of stem borer revealed that 9.60 ± 3.57 per cent hills herboured stem borer larvae after harvest of the *wet season* rice crop. Use of pheromone traps recorded low incidence of dead heart (2.1%) as against 5.6% in control and white ear head (1.3%) as against 4.3% in control.

Cultivars IR 20, PTB 8, PTB 18, PTB 21, Shuli 2 and Utrirajapan showed resistant reaction against Gerua isolate of *tungro* disease. Of the 286 promising, recommended and indigenous rice genotypes and breeding lines screened against *tungro* under natural disease pressure, 12 showed resistant reaction while 33 exhibited moderate resistance. Gerua isolate of *Xanthomonas oryzae* pv. *oryzae* showed moderate to high virulence with location specific index of 4.8.

Glutelin was the most abundant protein fraction (76-83%) in the rice cultivars. Though the high protein donor rice ARC -10063 had only 78.97% glutelins, the breeding line CR2817-972 had the highest (82.93%) amount of it; while Swarna had the lowest (74.08%) amount of glutelins. The evaluation result of three high protein rice (Heera, PLN-100 and CR Dhan 310) along with check variety Naveen under three levels of nutrition reveled that Heera and newly released variety CR Dhan 310 have the inherent capability to accumulate more protein in their grains as compared to others. The result of eleven pigmented rice varieties grown both under *wet* and *dry season* showed that the antioxidant capacity (ABTS assay), anthocycnin content, flavonoids, phenolics and γ-oryzanol content of pigmented rice grain were significantly higher in *wet season* than those in the *dry season*. Iron and zinc are essential micronutrients for humans; their deficiency affects metabolism considerably with adverse effect on health. Rice does not provide these micronutrients adequately; the processing decreases their content in rice grains significantly. Not only this, presence of phytate in grain aggravates the problem as the interaction of phytic acid with proteins, vitamins and several minerals (Fe, Zn, Ca) further restricts their bioavailability. The analysis of 54 rice variety for phytic acid in brown rice revealed that the highest phytic acid content (2.83g/100g) was found in PB267 and lowest in Bindli (0.82 g/100g) among the non-pigmented rice. In case of colored rice, lowest phytic acid was found in Mornodoiga (0.34g/100g), while the highest amount was found in Manipuri Black rice (2.97g/100g) followed by Mamihungar. The result of total phenolic content of colored rice samples showed that maximum phenolic content was observed in in Lalbora (0.27mg/g GAE) and minimum in Mornodoiga (0.10mg/g GAE). The free radical scavenging activity (RSA) was found to be highest in the rice Saathi and was lowest in Mugai a colored rice.

Out of the 240 rice germplasms, the lines IC299929 and IC300131 were found to be tolerant to complete submergence for 14 days and were comparable to FR13A and found to be better than Swarna-Sub1. Among the 39 Pokkali accessions, AC 39417 was more tolerant to 12dS m^{-1} than the tolerant check FL478. The lines AC 39409, AC 39394 and AC 39411 were at par with FL 478 with respect to salinity tolerance, while AC 39365 and AC 39370 were more susceptible than the susceptible check IR 29. Considering various screening parameters the germplasm line AC39416A was found to be highly tolerant to multiple abiotic stresses

Out of the eight genotypes evaluated for water use efficiency the tolerant check CR 143-2-2 exhausted lowest amount of water (0.045 and 0.117 kg water/2 hrs) followed by EC 545088 and AC 43037 (0.115 and 0.121 kg water/2 hrs) under WW and AC 43012 and AC 42997 (0.046 and 0.049 kg water/2 hrs) under WS conditions.AC-43037, CR 143-2-2 and AC-42997 had lower stomatal density (258 - 352/mm^2) compared to other genotypes, where as IR 64 had maximum stomatal density (517/mm^2) depicting high transpiration rate. Among the twenty selected elite rice genotypes grown under three different moisture levels, EC 545088 had high grain yield under all three conditions with lower Relative yield reduction (RYR) and drought susceptibility index (DSI) under moderate stress, while IC 337606 had lowest RYR and DSI under both moderate stress and severe stress with highest yield even under SS indicating their stable tolerance under all the moisture regimes compared to other genotypes. In general, the rate coefficient (Y) of biomass partitioning to leaves was less than that 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 showed similar trend; however, variation was recorded in stems. The rate of partitioning to panicle was highest in CR 3856-44-22-2-1-7-1 (6.44 g/day/m^2), which was reflected in highest grain yield production

Out of thirteen species of the wild relatives of the genus *Oryza* were evaluated for their photosynthesis and chlorophyll fluorescence efficiency under normal and reduced light intensity (50% of normal light), Maximum photosynthesis (P_N)was recorded 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. echingeri.* Among the 15 genotypes, maximum yield was recorded in Sadamotasel (7.19 t/ha) followed by Pateni-23 (6.34 t/ha) and Salivahan (6.00 t/ha) under low light environment.

The approaches for developing rice based model village and enhancing rice productivity through participation of gender were implemented as for the plan set forth. Emphasis was laid on trying newly released rice varieties in meeting the drought situation and strengthening income of the farm families through vegetable production in kitchen gardens as well as in commercial scale. Interesting result on coping mechanisms of the farm families in drought situations and farmer perceptions on convergence were provided for drawing suitable inferences.

Participation of Gender in rice farming and needed technological support to the women farmer have been conceive as an approach to enhance and sustain rice productivity. Under the said approach capacity building of the farm women on rice production technology through training, demonstration, information and market support and value addition have been tried. Women preference for varieties and other production technologies and shortcomings have been brought out. Women have also showed their capacity in playing an effective role in rice value addition chain. The role of demonstration and feedback in harnessing the potential yield and refinement of technology were also stated for the uses of extension functionaries.

In case of NRRI implement manufacturing enterprise, the net profit increased by Rs. 5,05,181 from 2012-13 to 2015-16 because the total sales value of the implements proposed to be manufactured under this project increased by 56.63% (according to market price) from 2012-13 to 2015-16 and the cost of manufacturing all that proposed implement increased only 52.41%. In case of rice-fish farming system business plans for small, medium and commercial scales, increase in project cost by 13.48%, 12.40% and 13.25%, respectively was observed from 2012-13. In addition, due to increase in selling price the net profit also increased by 37.49%, 36.50% and 10.25% for small, medium and commercial rice-fish farming system, respectively.

Under the activity designing simulation model of adoption, the data collected from various secondary sources on correlation between dependent variables adoption of HYV of paddy and adoption of HYV paddy cultivation practices and independent variables were meta-analyzed using CMA software. The results showed that all these independent variables were positively significantly correlated with dependent variable adoption of HYV of paddy and adoption of HYV paddy cultivation practices.

It was estimated that NRRI varieties were grown to the extent of 14.42 lakh ha in West Bengal, 91600 ha in Jharkhand and 16900 ha in Andhra Pradesh.

Rice export analysis for the period 1990-91 to 2014-15 revealed that India has increased its export significantly during the post WTO period. The quantity of export has increased by 12 times and value by 10 times, when data for the quinquennium ending 1994-95 and 2014-15 was considered. The major destinations of basmati export were to West Asian region followed by Northern Europe, Northern America and Western Europe. West Asia alone imports 84% of total Indian Basmati. The non-basmati export was to West African region followed by South Asia, West Asia and Eastern Africa. West African region alone accounted for 43% of total non-basmati export and predominantly of parboiled grade.

कार्यकारी सारांश

राष्ट्रीय चावल अनुसंधान संस्थान ने अधिक उपज देने वाली उच्च प्रोटीनयुक्त चावल किस्म सीआर धान ३१० (आईईटी २४७८०) विकसित की है जिसे केंद्रीय फसल मानक, अधिसूचना किस्म विमोचन उप-समिति द्वारा ओडिशा, उत्तर प्रदेश तथा मध्य प्रदेश में खेती के लिए विमोचित एवं अधिसूचित किया जा चुका है। इस किस्म में १०.३ प्रतिशत प्रोटीन, १५ पीपीएम जस्ता है एवं इसकी औसत उपज क्षमता ४.४८ टन प्रति हैक्टर है। यह चावल बहुत हद तक कुपोषण की समस्या का समाधान कर सकता है। किस्म पहचान समिति द्वारा रायपुर में आयोजित ५१वें एआईसीआरआईपी की समूह बैठक में तीन आशाजनक किस्में विमोचित की गई। आंध्र प्रदेश, कर्नाटक तथा असम के अर्द्ध-गहरा पारिस्थितिकी में खेती के लिए सीआर २६८७-२-३-१-१-१ (आईईटी १३०५०) की पहचान एवं विमोचित की गई जबकि असम, पश्चिम बंगाल एवं ओडिशा के गहराजल क्षेत्रों में खेती के लिए सीआर ३८३५-१-७-२-१-१ (आईईटी २३६०१) की पहचान की गई। सीआर २७१३-३५ (आईईटी २३१८९) जो एक सुंगधित लघु दाना वाली चावल किस्म है, पश्चिम बंगाल, उत्तर प्रदेश एवं ओडिशा में खेती के लिए पहचान एवं विमोचित की गई। राज्य किस्म विमोचन समिति, ओडिशा द्वारा विभिन्न पारिस्थितिकियों के लिए उपयुक्त आठ किस्में विमोचन हेतु प्रस्ताव दिया गया। ये हैं-उथली निचली भूमि के लिए सीआर धान ४०६, ऐरोबिक के लिए सीआर धान २०७, सीआर धान २०८ तथा सीआर धान २०९, गहराजल के लिए सीआर धान ५०७ एवं सीआर धान ५०९, जीवाणुज अंगमारी आक्रांत क्षेत्रों के लिए सीआर धान ८०० तथा उच्च प्रोटीन मात्रा के लिए सीआरधान ३११।

खरपतवार एवं जंगली धान जननद्रव्य के संग्रहण के लिए देश के विभिन्न भागों में इस अवधि के दौरान तीन खोज कार्यक्रमों का आयोजन किया गया। ओरायजाकोराक्टा (पोर्टेरेसियाकोराक्टा) के लिए भीतरकनिका के सदाबहार डेल्टा तथा अंडमान एवं निकोबार द्वीप समूह से तथा ओडिशा के तटीय क्षेत्रों से तीसरी खोज की गई। धान जननद्रव्य के छह हजार चार सौ छह प्रविष्टियों को संरक्षेण हेतु लक्षणवर्णन एवं जीर्णोद्धार किया गया। इन ५५३२ प्रविष्टियों में मध्यम अवधि की भंडारण के लिए तथा डीयूएस परीक्षण के लिए ३५३, पश्चिम बंगाल के ६२० किसानों के किस्में तथा हाल में संग्रहित की गई खरपतवार एवं जंगली धान जननद्रव्य शामिल हैं। धान जननद्रव्य/श्रेष्ठ वंश/दाता किस्मों के पांच हजार दो सौ उन्नासी प्रविष्टियां देश के विभिन्न अनुसंधानकर्ताओं को आपूर्ति की गईं तथा संस्थान के वैज्ञानिकों को परीक्षण, मूल्यांकन तथा प्रयोग के लिए भी वितरित किया गया।

पीला तना छेदक, भूरा पौध माहू तथा आच्छद अंगमारी जैसे जैविक एवं सूखा जैसे अजैविक दवाबों के लिए जंगली धान जननद्रव्य प्रविष्टियों को परीक्षण किया गया। पीला तना छेदक, भूरा पौध माहू, आच्छद अंगमारी एवं सूखे के दाताओं की पहचान की गई तथा संकरीकरण कार्यक्रम में प्रयोग किया गया। आण्विक चिन्हक का प्रयोग करते हुए तुलनात्मक जीनोम विश्लेषण किया गया जिससे यह पता कि ओराइजासातिवा तथा ओराइजाब्रेकियांथा के बीच जीन क्षेत्र में सह-रैखिकता का संबंध है।

संकर धान कार्यक्रम में, सीआरएचआर १०२ (आईईटी २५२३१) तथा सीआरएचआर १०३ (आईईटी २५२७८) को संस्थान किस्म परीक्षण-विलंबित अवधि, एआईसीआरपी-२०१५ के तहत परीक्षण किया गया तथा विकसित किस्म परीक्षण-विलंबित अवधि कार्यक्रम में शामिल किया गया। एआईसीआरपी-२०१६ के तहत पांच विलंब अवधि वाले नए आशाजनक किस्मों जिनके दाने मोटे एव छोटे हैं, को बहुस्थानीय परीक्षण के लिए चुना गया।

लघु अवधि वाली एवु सूखा सहिष्णु कलिंग-१-सीएमएस सीआरएमएस ५२ए को सहभागीधान की पृष्ठभूमि में विकास किया गया। अच्छे मिश्रक, मध्यम से विलंब अवधि वाले चालीस पुनर्स्थापकों एवं २७ अनुरक्षकों की पहचान की गई। जीवाणुज आच्छद अंगमारी जीन (एक्सए २१, एक्सए १३, एक्सए ५ एवं एक्सए ४) को सीआरएमएस १३ए एवं सीआरएमएस ३२ए में अंतर्गमन किया गया।

दो श्रेष्ठ किस्में आईईटी २३९३४ (सीआर३८३८-१-२-१-४-२) तथा आईईटी २३८९५ (सीआर२५९३-१-१-१-१) वर्षाश्रित निचलीभूमि के तहत विकसित किस्म परीक्षण-१ में शामिल किया गया। देश के दक्षिण क्षेत्र के लिए (अंचल ७) आईईटी २४४७१ परीक्षण के अंतिम वर्ष में है। वर्ष २०१५ के दौरान अर्द्धगहरा एवं गहराजल परिस्थितियों में विभिन्न परीक्षण कार्यक्रमों के तहत परीक्षण के परवर्ती स्तर में ग्यारह आशाजनक प्रविष्टियों को शामिल किया गया। आर्द्र मौसम में, जलाक्रांत सहिष्णुता, प्रकाशसंवेदनशीलता, पौध ऊंचाई तथा अन्य पौध एवं बाली लक्षणों के आधार पर २५ संकर मिश्रणों में से ५२६ एकल पौध चयन किए गए।

एआईसीआरआईपी के सीएसटीवीटी परीक्षण के तहत तीन प्रजनक वंशों को परीक्षण के अंतिम वर्ष में जबकि १० वंशों को द्वितीय में आगे बढ़ाया गया। नियंत्रण तथा लवण सहिष्णु पोकाली (एसी ४१५८५) लवण उपचारित नमूनों (फूल लगने की अवस्था में) के १.५ मोड़ परिवर्तन के बीच छियानबे

एमआईआरएन में विभिन्नता देखने को मिला। जलाक्रांत परिस्थिति में आर्द्र मौसम के दौरान, लवण सहिष्णु प्रजनक वंश सीआर २४५९२३-३-१-१-एस-बी१-२बी-१ ४१८४ किलोग्राम प्रति हैक्टर की उपज मिली।

अधिक उपज देने वाली नई पौध प्रकारों के चयनों की विविधता विश्लेषण से पता चला कि टेंपरेट जापोनिका की तुलना में इंडिका तथा ट्रोपिकल जापोनिका से उत्पन्न इन प्रजातियों से पर्याप्त आनुवंशिक विविधता कायम रह सकता है और इसलिए इस आगे विभिन्न प्रजातियों के मिश्रण के लिए उपयोग किया जा सकता है। सुपर धान जीनप्ररूपों के पौधशरीरक्रियाविज्ञान के विश्लेषण से पता चला कि बालियों का विभाजन का दर सर्वाधिक जीनप्ररूप में है जिससे अधिक उपज मिली। २०१५ के आर्द्र मौसम के दौरान मूल्यांकन किया गया दो अधिक उपज देने वाली जीनप्ररूपों सीआर ३९६९-१७-२-२-१-१ से ९.०३ टन प्रति हैक्टर तथा सीआर ३९३८-६-२-१-१-१ से ८.९० टन प्रति हैक्टर की उपज प्राप्त हुई। अधिक बालियों एवं परिपूर्ण दानों, अधिक दौजियों एवं जैवपदार्थ के कारण यह अधिक उपज मिली।

नवीन एवं पूजा की पृष्ठभूमि में विभिन्न जैविक दबावों जैसे जीवाणुज अंगमारी, प्रध्वंस, भूरा पौध माहू, धान टुंग्रो रोग तथा आच्छद अंगमारी के लिए दाताओं का उपयोग करते हुए बहु-नाशककीटों तथा रोगों के प्रति प्रतिरोधिता हेतु प्रजनन सामग्रियां उत्पन्न की गईं। समग्र अंतराल मानचित्रण विश्लेषण में, तपस्विनी (ग्राह्यशील) तथा आईईटी १६९५२ (प्रतिरोधी) के वंशावलियों के आरआईएल चित्रण में धान टुंग्रो रोग प्रतिरोधी के प्रति एलओडी ३.२३ स्कोर सहित एक क्यूटीएल क्यूआरटीवी १.१ की पहचान की गई जिसमें फिनोटाइप विभिन्नता १८.५७ प्रतिशत था। तपस्विनी/धोबानंबरी (भूरा पौध माहू दाता) के संकर से उत्पन्न सीआर २७११-१४९ को २०१५ के एआईसीआरआईपी के बहुप्रतिरोधी स्क्रीनींग परीक्षण के तहत ३१ स्थानों पर १० नाशककीटों के विरुद्ध परीक्षण किया गया तथा भूरा पौध माहू, सफेदपीठवाला पौध माहू, गालमिज एवं तना छेदक जैसे नाशककीटों के विरुद्ध आशाजनक पाया गया। इस प्रविष्टि को लगातार दो वर्षों तक आशाजनक पाया गया। तीन संवर्द्धन सीआर ३९३९-१८ (आईईटी २५३१८), ३९८१-४७-१७-५ (आईईटी २५२६६) तथा सीआर ३८६२-२९-१५-७ (आईईटी २५२४४) को उनके बेहतर निष्पादन के लिए विकसित किस्म परीक्षण में शामिल किया गया।

अधिक संसाधन उपयोग क्षमता के लिए प्रजनन में, फोस्फोरस सहिष्णुता के नए स्रोत तथा शीघ्र ओज वाले पौदों की पहचान की गई। शीघ्र पौद ओज के आकलन के लिए ईमेज एनालिसिस तथा मजबूत कल्म हेतु डीजीटल फोर्स गेज जैसे नई प्रौद्योगिकियां विकसित की गईं। इस परियोजना के द्वारा, छह ऐरोबिक, एक शीघ्र सीधी बुआई तथा शीघ्र रोपित संवर्द्धन को एआईसीआरआईपी के मूल्यांकन के अगले स्तर में शामिल किया गया।

नवीन पृष्ठभूमि में दो उच्च प्रोटीनयुक्त वंशों को अंतिम वर्ष के परीक्षण के लिए आगे बढ़ाया गया तथा स्वर्णा पृष्ठभूमि में तीन आशाजनक वंशों को जैवसुदृढ़ीकरण परीक्षण के लिए चुना गया। उच्च प्रोटीनयुक्त किस्म में, प्रोटीन अंश जिससे प्रोटीन की मात्रा बढ़ जाता है, पहचानने के प्रयास किए गए। एक सौ नौ जीनप्ररूपों जिसमें चेक किस्में शामिल हैं, को छह एआईसीआरआईपी परीक्षणों में शामिल किया गया जहां उन्हें सुगंधित लघु दाना, मध्यम पतला दाना तथा जैवसुदृढ़ीकरण के लिए परीक्षण किया गया। १२९ जीनप्ररूपों का स्क्रीनींग किया गया तथा भूरा चावल के अंतर्गत दो जीनप्ररूप दुलार को उच्च लौह के लिए एवं मधुकर को जस्ता की अधिक मात्रा के लिए पहचान की गई।

इंडिका धान संकर २७पी६३ में हरा पौध के विकास हेतु एक विधि को एंड्रोजेनेसिस के माध्यम से मानकीकृत किया गया। गैर-सुगंधित धान संकर बीएस६४४४जी से विकसित डबल हाप्लाएड वंश बीएडीएच२ जीन में द्वितीय एक्सोन में ८ बीपी के कम होने पर सुगंधित पाए गए। सावित्री एवं पोकाली के एफ१ से उत्पन्न कुल ११७ डबल हाप्लाएडों को अंकुरण के समय लवणता सहिष्णुता के लिए परीक्षण किया गया। अर्गानोजेनेसिस के लिए एक विधि स्थापना की गई एवं इसके बाद स्वर्णा तथा नवीन में एग्रोबैक्टेरियम मध्यस्थ द्वारा परिवर्तन किया गया।

भारत के दस अधिक उपज देने वाले चावल किस्में जैसे स्वर्णा, सांबा महसूरी, एमटीयू १०१०, एमटीयू १००१, पीकेएम-एचएमटी, पीआर ११३, पूसा ११२१, पूजा, शताब्दी तथा सहभागीधान को एनएसजी प्रौद्योगिकी का उपयोग करते हुए रि-सिक्वेसिंग किया गया। इन किस्मों के बीच डीएनए का व्यापक बहुरूपता देखने को मिला तथा इंडिका एवं जापोनिका दोनों संदर्भ जीनोम जिससे जीनोमिक अध्ययन एवं आण्विक प्रजनन कार्यक्रम के लिए के मददगार साबित होगा। सभी किस्मों के जीनोम में एसएनपी तथा इनडेल क्षेत्रों में अनियमित वितरण दिखाई दिया। सीआर ६६२-२२११-२-१/डब्ल्यूएबी ५०-५६ संकर से उत्पन्न आरआईएल मैपिंग में नियंत्रण संबंधित लक्षणों के लिए समग्र अंतराल मैपिंग विश्लेषण से पांच क्यूटीएल जैसे क्यूएसएन१.१, क्यूपीएसवाई१.१, क्यूपीएच९.१, क्यूटीएन३.१ तथा क्यूटीएन६.१ की पहचान हुई। भूमिजाति किस्म सालकाथी में दो क्यूटीएल जैसे क्यूबीपीएच ४.३ एवं क्यूबीपीएच ४.४ की पहचान हुई जिससे भूरा पौध माहू के प्रति प्रतिरोधिता क्यूबीपीएच ४.३ की फिनोटाइप विभिन्नता ९.७ प्रतिशत एवं क्यूबीपीएच ४.४ की

फिनोटाइप विभिन्नता १५.७ प्रतिशत के बारे में पता चला। सिल्को विश्लेषण में क्यूबीपीएच ४.३ के लिए कैंडिडेट जीन के रूप में छह जीन तथा क्यूबीपीएच ४.४ के लिए कैंडिडेट जीन के रूप में २५ जीनों की पहचान की गई। दाना आकर के लिए कैंडिडेट जीन आधारित सहयोगी विश्लेषण से पता चला कि दो चावल जीनप्ररूपों डीबीटी१२३० तथा एसी५२२ में नया जीन/क्यूटीएल है जिसे जीएस३ के नकारातम्क कार्यवाही को दबाने में उपयोग किया जा सकता है जिससे धान के दाना की लंबाई की भिन्नता के ९७ प्रतिशत गठन की प्रक्रिया में सहायक होता है।

ऊपरीभूमि प्रजनन कार्यक्रम में दो आशाजनक प्रविष्टियां सीआरआर-७०८-१-बी-बी तथा सीआरआर-६९७-७६ (सीआरआर-४८४-२-१-१-१-१) को एआईसीआरआईपी के तहत परीक्षण के अंतिम वर्ष में शामिल किया गया। दबाव क्यूटीएल डीटीवाई१२.१ के तहत मध्यम सूखा ग्राह्यशील किस्म अंजलि में दाना उपज का अंतर्गमन से गंभीर सूखा नमी दबाव लगभग फूल लगने के समय में महत्वपूण रूप से उपज में सुधार हुआ। वृद्धि अवस्था में सुखा के दौरान अंतर्गमन वंशों में बेहतर सहिष्णुता देखने को मिला। उसी प्रकार, लोकप्रिय किस्म वंदना में क्यूटीएल डीटीवाई१२.१ वाली प्रध्वंस प्रतिरोधी जीन पीआई२ का अंतर्गमन से यूबीएन नर्सरी में रोग के विरुद्ध अंतर्गमन वंशों का बेहतर निष्पादन रहा तथा प्रजनन अवस्था सूखा दबाव के तहत बेहतर उपज निष्पादन रहा।

दीर्घावधि उर्वरक परीक्षण से पता चला कि केवल सड़ी हुई गोबर या अजैविक उर्वरकों के साथ मिश्रण करके प्रयोग करने पर नत्रजन के खनिज एंजाइमों के क्रियाकलापों तथा माक्रो-एग्रेगेट्स में वृद्धि हुई। अर्द्ध-परिमाणात्कम पीसीआर को प्रयोग करते हुए यह देखा गया कि नत्रजन के साथ सड़ी हुई गोबर प्रयोग करने पर नत्रजन को कम करने वाले जीवाणु संख्या में वृद्धि हुई।

फसल एवं किस्म विविधकरण के परीक्षणों से पता चला कि स्वर्णा-सब१ की बुआई बाद तोरिया की उपज १३९ प्रतिशत, नवीन की बुआई के बाद मूंग की उपज ११६ प्रतिशत तथा सहभागीधान की बुआई के बाद कुल्थी की उपज ९५ प्रतिशत घट गई।

आर्बूस्क्यूलार माइकोरजियाल कवक जड़ की संख्या जस्ता के साथ ५ किलोग्राम प्रति हैक्टर दर में प्रयोग करने पर बढ़ गई। फास्फोरस के प्रयोग से कवक जड़ की संख्या में कमी हुई।

एसआई के प्रयोग से धान में नत्रजन उद्ग्रहण महत्वपूर्ण रूप से प्रभावित हुई। आंशिक कारक उत्पादकता, नत्रजन प्रयोग के कार्यक्षमता तथा नत्रजन की प्राप्ति क्षमता एसआई के प्रयोग से ४८.७-७४.५ किलोग्राम प्रति किलोग्राम, १९.६-३०.८ किलोग्राम प्रति किलोग्राम तथा ३५.९-४९ प्रतिशत के बीच रहा।

यूरिया ब्रिकेट मशीन की सहायता से समुच्चयित यूरिया ब्रिकेटें तैयार की गईं। फ्लाई ऐश के साथ यूरिया मिलाकर तैयार किया गया यूरिया ब्रिकेट के प्रयोग से नत्रजन प्रयोग क्षमता में सर्वाधिक वृद्धि हुई। हस्तचालित तीन कतार वाला यूरिया ब्रिकेट एप्लिकेटर की अपेक्षा यांत्रिक यूरिया ब्रिकेट एप्लिकेटर के प्रयोग से ८२.८ प्रतिशत तक समय की बचत हो सकती है।

सिर्फ आईआर ६४ तथा स्वर्णा के सिवाय परीक्षण किया गया सभी किस्मों का प्रकाशसंश्लेषित दर, उत्तरजीवित्ता प्रतिशतता तथा वृद्धि जलनिमग्नता के दौरान घट गई। किसी भी किस्मों में, एसआइ के आधारी प्रयोग से ४१.४ प्रतिशत उत्तरजीवित्ता बढ़ गई, नत्रजन एवं एसआइ के प्रयोग से अतिरिक्त २१.५ प्रतिशत उत्तरजीवित्ता दर्ज की गई।

अधिक बीज दर (६० किलोग्राम प्रति हैक्टर) तथा अतिरिक्त फास्फोरस के प्रयोग (२० प्रतिशत) से अंकुरण एवं आविर्भाव के बाद एलोमेट्रिक लक्षण में सुधार हुआ। अतिरिक्त २० प्रतिशत फास्फोरस के साथ संस्तुत की गई नत्रजन, फास्फोरस एवं पोटाश मात्रा के प्रयोग से अधिक बालियां, परिपूर्ण दाना एवं बाली वजन बढ़ गई।

मृदा नमी में १२.९-२३ प्रतिशत कार्बन उत्सर्जन तथा नत्रजन उत्सर्जन २२.१-२३ प्रतिशत बढ़ गई। उच्च एसउब्ल्यूपी में इन गैसों के उत्सर्जन में भारी कमी देखने को मिला।

जलाभाव की स्थिति के तहत खुली खेत की अपेक्षा कार्बन की अधिक मात्रा में धान पौधों की उंचाई, दौजियां, दाने तथा पुआल उपज में बढ़ोतरी दर्ज हुई जिससे यह पता चलता है कि कार्बन की अधिक मात्रा में पौध के शरीर में परिवर्तन हुई जिससे जलाभाव की दबाव स्थिति को कम करने के लिए पौध को मदद मिली।

धान भूसी बायोचार के प्रयोग में अधिकता से मृदा में ग्लूकोसिडेस, फ्लोरोसिन डायसिटेट एवं डीहाइड्रोजेनेस क्रियाकला बढ़ गई। कार्बन-खनिजीकरण अध्ययन से पता चला कि बायोचार उपचारित खेतों की तुलना में १५ दिनों के मृदा इनक्यूबेशन संस्तुत उर्वरक मात्रा के तहत कार्बन उत्सर्जन कम रहा।

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 एवं लोबिया में प्रयोग करने से अन्य पोषकतत्वों प्रबंधन उपचारों की अपेक्षा चावल से सर्वाधिक उत्पादन हुआ।

ओडिशा के केंद्रापाड़ा जिले के महाकालपड़ा प्रखंड के लिए नौ मृदा लक्षणों, सामान्यीकृत अंतर वनस्पति सूचक तथा वद्धित वनस्पति सूचक, प्रधान घटक विश्लेषण के चित्रों तथा फजीसी-मीन्स क्लसटरिंग एलोगारिदम क उपयोग करते हुए तीन प्रबंधन क्षेत्रों को निरूपित किया गया। इन तीन परिभाषित प्रबंधन क्षेत्रों से परिशुद्धता खेती में स्थान-विशिष्ट प्रबंधन हेतु महत्वपूर्ण सूचना मिली।

एनआरआरआई विकसित दो कतार वाला स्वचालित वीडर ने ०.०५२ हैक्टर प्रति घंटा का खेत क्षमता दर्ज किया जबकि कलिंग शक्ति द्वारा निर्मित यंत्रचालित वीडर की खेत क्षमता ०.०४६ हैक्टर प्रति घंटा है। एनआरआरआई विकसित वीडर के संचालन हेतु कम श्रम (३३३.५ मानव घंटे) तथा कम लागत (८३३७.५ रुपये प्रति हैक्टर) की आवश्यकता होती है।

सावित्री चावल किस्म से सर्वाधिक रतून उपज (मुख्य फसल का ४५ प्रतिशत) मिली जबकि सहभागीधान, स्वर्णा तथा नवीन में रतून क्षमता कमजोर थी। सहभागीधान के मुख्य फसल से १७ प्रतिशत रतून उपज मिली।

१५ सेंटीमीटर डंठल ऊंचाई में ग्लाइफोसेट के प्रयोग की तुलना में पाराकुट के प्रयोग से रतून में अधिक संख्या के पौद नष्ट हो गए। ३० सेंटीमीटर डंठल ऊंचाई में पाराकुट के प्रयोग से रतून में पौद की उत्तरजीवित्ता ९ प्रतिशत था जबकि ग्लाइफोसेट के प्रयोग से रतून में पौद की उत्तरजीवित्ता ३१ प्रतिशत था।

जीरो टीलेज धान में, खरपतवार के नियंत्रण में बाइस्पिरिबैक सोडियम तथा फेनोजाप्रोप-पी-इथाइल के अनुक्रमिक प्रयोग असरदार पाया गया। आविर्भाव पूर्व शाकनाशियों में से पेंडिमेथालिन का प्रयोग खरपतवार नियंत्रण में सबसे अधिक प्रभावकारी रहा।

जीवविज्ञान आधारित समुदायिक स्तर शरीरक्रियाविज्ञान प्रोफाइलिंग से पता चला कि सदाबहार मृदाओं की अपेक्षा एनआरआरआई के धान खेतों में माइक्रोबॉयल समुदाय क्रियाकलाप विविधता अधिक है।

इन विट्रो स्क्रीनिंग में, पत्ता मोड़क तथा गुलाबी तना छेदक के विरुद्ध तीन जीवाणुज वियुक्तों में मजबूत कीटनाशक प्रतिक्रिया पाया गया।

सोलह फास्फोरस घुलनशील धान राइजोस्पेरिक जीवाणुज (फर्मीक्यूटस्) जिसमें २-१६ प्रतिशत तक लवणता सहिष्णुता है, सभी स्थायी नत्रजन तथा घुलनशील फास्फेट, ७५ प्रतिशत तथा ५० प्रतिशत जीव एमोनिया एवं सिडेरोफोर उत्पादन किए।

गहरी जुताई की अपेक्षा पांरपरिक जुताई के तहत आर्बूस्कूलार माइकोरहिजा की संख्या २०१३ से २०१५ की अवधि के दौरान बढ़ गई। गहरी जुताई की अपेक्षा पांरपरिक जुताई में देशी संख्या से २९.९ प्रतिशत अधिक जड़ कवक, १४.४ प्रतिशत फास्फोरस उदग्रहण तथा २२.८ प्रतिशत अधिक उपज हुई।

सीआर-१०१४ को आच्छद अंगमारी के विरुद्ध सहिष्णुता की पुष्टि की गई तथा इसे सहिष्णता के लिए जीनों की पहचान हेतु तथा चिन्हक सहायतित चयन के लिए उपयोग किया जा रहा है।

फल्स स्मट रोगजनक के सामूहिक उत्पादन एवं पृथककरण को मानकीकृत किया गया है तथ आण्विक निदान के रूप में उपयोग करते हुए रोगजनक की पहचान की गई।

दस आरएपीडी चिन्हक विश्लेषणों से पुष्टि हुई कि पाइराकुलारिया ओराइजा खरपतवार का पृथककरण रूप धान से भिन्न है। पाइराकुलारिया ओराइजा संवर्द्धन में कोनिडियायुक्त समुदायों को अत्यधिक विषालु जाति में धान प्रध्वंस घाव उत्पन्न करते पाए गए।

देशी ट्राइकोगामा प्रजातियां धान के रोगों के जैविक नियंत्रण में बेहतर पाए गए। इसके अतिरिक्त, उनकी वृद्धि होने से किसानों को रासायनिक उर्वरकों के कम प्रयोग करने में सहायक सिद्ध होगी।

एनबीपीजीआर से अड़तालिस जीनप्ररूपों जैसे बी-१२७, बी-१२९, बी-१३४, बी-१३६, बी-१५०, बी-१८०, बी-१८९, बी-२२०, बी-२२१, बी-२३१, बी-२३५, बी-२४२, बी-२४६, बी-३६०, बी-३६९, बी-३८२, बी-३८३, बी-३८९, बी-३९५, बी-३९६, बी-४००, बी-४०१, बी-४०६, बी-४०८, बी-४०९, बी-४१२, बी-४१४, बी-४१६, बी-४२७, बी-४२९, बी-४३०, बी-४३१, बी-४३२, बी-४४७, बी-४९७, बी-६०६, बी-६१३, बी-६१७, बी-६५४, बी-६६०, बी-७२६, बी-७३३, बी-७४२, बी-८४९, बी-८६४, बी-८७६, बी-८८८, बी-१००५, आईआरआरआई, फिलीपाइन्स से सात एफ३ वंश जैसै आईआर ११३०५०-बी-८, आईआर ११३०५०-बी-११, आईआर ११३०५०-बी-१४, आईआर ११३०५०-बी-१८, आईआर ११३०५०-बी-५१, आईआर ११३०५०-बी-८१, आईआर ११३०५०-बी-१०० तथा पीएचएस से एक जैसे आरपी २०६८-१८-३-५ ने भूरा पौध माहू के प्रति अत्यधिक प्रतिरोधी प्रतिक्रियायें जाहिर कीं।

सीआर १००९ एवं ओराइजा ब्रैकियांथा के संकर से उत्पन्न प्रजनन वंशों, उष्णकटिबंधीय जापोनिका वंशों तथा डबल हाप्लाएड वंशों के साथ एक संकर सीआरएचआर ३२ का प्रक्षेत्र परीक्षण से पता लगा कि आठ प्रविष्टियां जैसे जंगली उत्परिवर्तीः बी-८, बी-११ तथा बी-१६, उष्णकटिबंधीय

जापोनिका वंशोंःडब्ल्यूसी-७३, डब्ल्यूसी-१५२, डब्ल्यूसी-३९२, डबल हाप्लाएड वंशोंः एसएस-५, एसएस-१९ में शून्य क्षति स्कोर हुआ है जबकि ग्राह्यशील चेक टीएन १ (३२.१ प्रतिशत) की क्षति का स्कोर ७ था।

धान डंठलों के विश्लेषण से पता चला कि तीन प्रमुख तना छेदक जैसे पीला तना छेदक, स्कीरपोफागा, इंतरतुलास, धारीधार तना छेदक, चिलो सुप्रेसालिस तथा गुलाबी तना छेदक, एस.इनफेरेंस धान डंठलों में वास कर रहे हैं और इनमें से पीला तना छेदक की संख्या सर्वाधिक (४०.८ प्रतिशत), उसके बाद धारीधार तना छेदक की संख्या (३६.२ प्रतिशत) तथा गुलाबी तना छेदक की संख्या (२३ प्रतिशत) था। तना छेदक प्रजातियों के आक्रांत से पता चला कि धान पौध के जड़ के ९.८ सेंटीमीटर के ऊपर ६० प्रतिशत गुलाबी तना छेदक कीट एवं धारीदार छेदक कीट जड़ के ७.० सेंटीमीटर के ऊपर १७.६ प्रतिशत पाया गया जबकि पीला ९८ प्रतिशत तना छेदक के कीटें धान डंठलों के मूल में पाए गए।

सेलूलोज को विकृत करने वाले तना छेदक जैसे गुलाबी तना छेदक, सफेद तना छेदक तथा पीला तना छेदक का जीवाणुज के साथ संबंध का विश्लेषण पोषकतत्व अगार किंग्स बी, न्यूनतम मध्यम एवं पोषक अगार सहित कार्बोक्सी मिथाइल सेलूलोज मध्यम से पता चला कि गुलाबी तना छेदक मे जीवाणुज संख्या सर्वाििधक है, इससे कम पीला तना छेदक तथा इससे कम धारीदार तना छेदक।

सिंचित पारितंत्र में नाशककीटों एवं प्राकृतिक शत्रुओं के लिए विविधता सूचकांकों की गणना सिंपसन सूचक (१०.४८), शानन-वीनर सूचक (२.६२), मार्गालेफ सूचक (२.७५) के रूप में की गई जबकि अर्द्धगहरा जल पारिस्थितिकियों में सिंपसन सूचक (१३.४२), शानन-वीनर सूचक (२.७८), मार्गालेफ सूचक (२.७६) की गणना विविधता की विश्लेषण के लिए तथा समुदाय की बनावट को समझने के लिए की गई।

धान पत्ता मोड़क नाफालोक्रोसिस मेडिनालिस (गुएंस) का उच्च कार्बन सांद्रण, व्यापक कार्बन सांद्रण रूप में तथा खुली खेत परिस्थिति के तहत सेवन विश्लेषण से देखने को मिला कि उच्च कार्बन सांद्रण परिस्थिति में पत्ता मोड़क कीटों का खाने की क्रिया में बिना किसी परिवर्तन के कमी आई। व्यापक कार्बन सांद्रण परिस्थिति के तहत पत्ता मोड़क कीटों का प्रकोप ३४.८ प्रतिशत, उच्च कार्बन सांद्रण अवस्था में ४४.४ प्रतिशत तथा खुली खेत परिस्थिति में ३८.५ प्रतिशत पाया गया। किंतु, उच्च कार्बन सांद्रण अवस्था में कीटों द्वारा पत्ते खाने का औसत क्षेत्र ७.६ प्रतिशत, व्यापक कार्बन सांद्रण में १५.८ प्रतिशत था जोकि उच्च कार्बन सांद्रण से दुगुना था।

सिल्वर नैनोकणों को जैवसंश्लेषण करने के लिए देशी विधि विकसित किया गया। सिल्वर नैनोकणों को जैवसंश्लेषण करने के लिए ३०-४० डिग्री सेल्सियस तापमान में २४ घंटे के लिए १एमएम सिल्वर नाइट्रेट १:९ अनुपात में बैंगनी चाल किस्मों के पत्तों को गर्म पानी सहित पौध निचोड़ प्रयोग किया गया। बैंगनी चाल किस्मों में उच्च मात्रा में फेनोल, फ्लावोनाएड्स है जिससे सिल्वर नैनोकणों के गठन में सहायक सिद्ध होता है। संश्लेषित सिल्वर नैनोकणों को जांथोमोनास ओराइजा तथा राइजोक्टोनिया सोलानी के विरुद्ध परीक्षण किया गया तथा कम्रशः ४ मिलीलीटर प्रति १०० मिलीलीटर दर में तथा ६ मिलीलीटर प्रति १०० मिलीलीटर दर में प्रयोग करने में असरदार पाया गया।

फ्लाई ऐश (२.५ तथा ५ प्रतिशत) एवं बायोचार (२.५ तथा ५ प्रतिशत) के मिश्रण से साधारण मृदा की अपेक्षा संशोधित मृदा में फिप्रोनील की दृढ़ता अधिक पाई गई। इमिडाक्लोप्रिड के न्यूनीकरण की क्रियाविधि से पता चला कि अम्लीय तथा क्षारीय हाइड्रोलिसिस की तुलना में माइक्रोबॉयल एवं फोटोडिग्रेडेशन इमिडाक्लोप्रिड न्यूनीकरण के प्रमुख माध्यम थे।

इन चावल किस्मों में ग्लुटेलिन की प्रोटीन मात्रा सबसे अधिक भाग (२.७२-७.०५ प्रतिशत) था। किंतु उच्च प्रोटीन दाता एआरसी १००६३ में सिर्फ ४.९४ प्रतिशत ग्लुटेलिन है जबकि प्रजनन वंश ८८४ में यह सर्वाधिक ७.५ प्रतिशत था तथा स्वर्णा में सबसे कम २.७२ प्रतिशत था। तीन प्रोटीनयुक्त चावल किस्मों हीरा, पीएलएन-१०० तथा सीआर धान ३१० का चेक किस्म नवीन के साथ पोषकतत्व के तीन स्तरों में मूल्यांकन से पता चला कि दूसरों की तुलना में हीरा तथा हाल में विमोचित नई किस्म सीआर धान ३१० के दानों में अधिक प्रोटीन जमा करने की निहित क्षमता है। खरीफ एवं रबी में खेती की गई ग्यारह रंजक धान किस्मों के परिणाम से पता चला किइन रजंकयुक्त धान किस्मों में एंटिआक्सिडेंट क्षमता, एनथोसाइनिन मात्रा, फ्लावोनाएड्स, फिनोलिक्स् तथा ओराइनजल मात्रा रबी मौसम की अपेक्षा खरीफ में अधिक है। लौह एवं जस्ता मानव के लिए आवश्यक सूक्ष्मपोषकतत्व हैं, उनकी कमी से मेटाबालिज्म काफी प्रभावित होता जिससे स्वास्थ्य पर प्रतिकुल असर होता है। धान से इन सूक्ष्मपोषकतत्वों की उपलब्धता पर्याप्त मात्रा में नहीं होती है क्योंकि कुटाई के समय धान दानों में इनकी मात्रा घट जाती है। इसके अतिरिक्त, दाने में मौजूद फाइटेट के कारण प्रोटीन, विटामीन, खनिज एवं अन्य कई खनिज पदार्थों के साथ फाइटिक अम्ल का पारस्परिक अंतःक्रिया होता है जिससे जैवउपलब्धता मकी समस्या उत्पन्न होता है। भूरा चावल में फाइटिक अम्ल के लिए ५४ धान किस्मों के विश्लेषण से पता चला कि पीबी२६७ में सर्वाधिक अम्ल मात्रा (२.८३ ग्राम प्रति

१०० ग्राम) है तथा बिन-रंजक धान किस्मों के तहत बिंदली किस्म में सबसे न्यूनतम अम्ल मात्रा (०.८२ ग्राम प्रति १०० ग्राम) पाया गया। रंगीन धान किस्मों में, मोरनोडाएगा में सबसे न्यूनतम अम्ल मात्रा (०.३४ ग्राम प्रति १०० ग्राम) पाया गया जबकि मणिपुरी काला धान किस्म में सर्वाधिक अम्ल मात्रा (२.९७ ग्राम प्रति १०० ग्राम) देखा गया है। इससे कम मात्रा मामिहुंगार किस्म में है। रंगीन किस्मों के नमूनों के कुल फिनोलिक मात्रा से पता चला कि सर्वाधिक फिनोलिक मात्रा लालबोरा (०.२७ मिलीग्राम प्रति ग्राम जीएई) तथा सबसे न्यूनतम मोरनोडोएगा (०.१० मिलीग्राम प्रति ग्राम जीएई) है। मूल सफाई क्रियाकलाप साथी धान किस्म में सबसे अधिक पाया गया जबकि मुगई नामक एक रंगीन धान में सबसे कम देखा गया।

२४० धान जननद्रव्यों में से आईसी २९९९२९ तथा आईसी ३००१३१ वंश १४ दिनों की संपूर्ण जलनिमग्नता सहिष्णु पाए गए तथा एफआर१३ए के साथ तुलनात्मक था एवं स्वर्णा-सब१ से बेहतर था। ३९ पोकाली प्रविष्टियों में से सहिष्णु चेक एफएल४७८ की अपेक्षा १२ डीएस वर्गमीटर लवण स्तर में एसी ३९४१७ अधिक लवण सहिष्णु पाया गया। एसी ३९४०९, एसी ३९३९४ तथा एसी ३९४११ वंश लवण सहिष्णुता के मामले में एफएल४७८ के समान पाए गए जबकि एसी ३९३६५ तथा एसी ३९३७० ग्राह्यशील चेक आईआर २९ की अपेक्षा अधिक ग्राह्यशील थे। विभिन्न परीक्षण मानदंडों को विचार लेने पर, एसी ३९४१६ए जननद्रव्य वंश बहु-अजैविक दबावों के प्रति अधिक सहिष्णु पाया गया।

जल प्रयोग क्षमता के लिए मूल्यांकित किए गए आठ जीनप्ररूपों में से सहिष्णु चेक सीआर १४३-२-२ ने सबसे कम जल प्रयोग (०.०५ तथा ०.११७ किलोग्राम जल प्रति २ घंटे), ईसी ५४५०८८ एवं एसी ४३०३७ ने इससे कम जल प्रयोग (०.११५ तथा ०.१२१ किलोग्राम जल प्रति २ घंटे) किया तथा जलाभाव स्थिति में एसी ४३०१२ और एसी ४२९९७ ने कम जल प्रयोग (०.०४६ तथा ०.०४९ किलोग्राम जल प्रति २ घंटे) किया। अन्य जीनप्ररूपों की तूलना में, एसी ४३०३७, सीआर १४३-२-२ तथा एसी ४२९९७ में सबसे कम स्टोमाटल घनत्व देखा गया जबकि आईआर ६४ में सर्वाधिक स्टोमाटल घनत्व देखने को मिला जिससे उच्च स्वेद दर का पता चलता है। तीन विभिन्न नमी स्तरों में खेती की गई चयनित बीस श्रेष्ठ धान जीनप्ररूपों में से, सभी परिस्थितियों में, मध्यम दबाव के अंतर्गत, कम आपेक्षिक उपज कमी, सूखा ग्राह्यशीलता सूचक सहित ईसी ५४५०८८ से सर्वाधिक उपज प्राप्त हुई जबकि आईसी ३३७६०६ से आपेक्षिक उपज कमी तथा सूखा ग्राह्यशीलता सूचक सहित मध्यम दबाव एवं गंभीर दबाव दोनों के तहत यहां तक कि गंभीर दबाव में भी सर्वाधिक उपज प्राप्त हुई जिससे अन्य जीनप्ररूपों की तूलना में, सभी नमी परिस्थितियों में उनकी स्थायी सहिष्णुता का पता चलता है। सामान्य तौर पर, पत्तों के लिए जैवपदार्थ गुणक (वाई) विभाजन दर फसल की वृद्धि के दौरान तना की अपेक्षा कम था तथा बाली निकलने से लेकर पकने तक धीमी एवं कम प्रवृत्ति थी तथा पकने के समय लगभग नगण्य हो गया। सभी किस्मों में पत्तों के लिए जैवपदार्थ विभाजन दर इसी तरह की प्रवृत्ति देखने को मिला किंतु तनों में भिन्नता दिखाई दिया। बाली के लिए विभाजन दर सीआर ३८५६-४४-२२-२-१-७-१ (६.४४ ग्राम प्रति दिन प्रति वर्गमीटर) में सर्वाधिक पाया गया जो कि सर्वाधिक दाना उपज उत्पादन में दिखाई दिया। ओराइजा के जंगली सहयोगियों के तेरह प्रजातियों को सामान्य एवं कम प्रकाश तीव्रता के तहत (५० प्रतिशत सामान्य प्रकाश) उनके प्रकाश संश्लेषण एवं क्लोरोफिल प्रतिदीप्ती दक्षता के लिए मूल्यांकन किया गया। सामान्य प्रकाश परिस्थिति में सर्वाधिक प्रकाश संश्लेषण ओ.निवारा में देखा गया तथा इसके बाद ओ.अस्ट्रेलिनसिस एवं ओ.रुफिपोगन में किंतु कम प्रकाश स्थिति में सर्वाधिक प्रकाश संश्लेषण ओ.निवारा में देखा गया तथा इससे कम ओ.राइजोमेटिस एवं ओ.इच्छिनगिरि में देखा गया। १५ जीनप्ररूपों में से, कम प्रकाश परिस्थिति में, सदामोतासेल से ७.१९ टन प्रति हैक्टर की सर्वाधिक उपज मिली, इसके बाद पटनेई-२३ से ६.३४ टन प्रति हैक्टर तथा सालीवाहन से ६.०० टन प्रति हैक्टर की उपज मिली।

महिलाओं को शामिल करते हुए चावल उत्पादकता की वृद्धि हेतु तथा चावल आधारित नमूना गांव के विकास के प्रस्तावों को योजना के अनुसार कार्यान्वित किया गया। शाकवाटिका तथा व्यावसायिक स्तर पर सब्जी उत्पादन के माध्यम से किसान समुदाय के परिवारों की आय को सुदृढ़ करने तथा सूखा परिस्थिति का सामना करने के लिए हाल में विमोचित चाल किस्मों की खेती के लिए जोर दिया गया। किसान समुदाय के परिवारों द्वारा सूखा परिस्थितियों का मुकाबला करने तथा अन्य झुकाव की ओर किसानों की धारणाओं संबंधित उपयुक्त परामर्श प्रदान किए गए।

चावल की खेती में महिलाओं को शामिल करने तथा चावल उत्पादकता में वृद्धि हेतु तथा स्थिरता लाने के लिए उन्हें आवश्यकता अनुसार तकनीकी सहायता प्रदान के विचार पर निर्णय लिया गया। इसी निर्णय के तहत महिला किसानों को चावल उत्पादन प्रौद्योगिकी पर प्रशिक्षण, प्रदर्शन, सूचना तथा बाजार समर्थन तथा मूल्य वर्द्धन के माध्यम से उनकी क्षमता निर्माण किया गया। महिला किसानों द्वारा चावल किस्मों की पंसद तथा अन्य उत्पादन प्रौद्योगिकियों एवं खामियां सामने उभर कर आईं। चावल मूल्य वर्द्धित श्रृखंला में एक असरदार भूमिका निभाने में महिला किसानों ने अपनी क्षमताओं का

निष्पादन किया। संभावित उपज तथा प्रौद्योगिकी में हुए संशोधन को काम में प्रयोग करने एवं इससे संबंधित प्रतिपुष्टिओं के प्रदर्शन की भूमिका से विस्तार कार्मिकों के लिए उपयोगितायें भी सामने आईं।

एनआरआरआई उपकरण निर्माण उद्यम के मामले में, २०१२-१३ से २०१५-१६ तक का शुद्ध लाभ ५०५१८१ रुपये हुआ। इस अवधि अर्थात २०१२-१३ से २०१५-१६ के दौरान परियोजना के तहत प्रस्तावित उपकरणों के निर्माण का कुल बिक्री मूल्य बाजार मूल्य के अनुसार ५६.६३ प्रतिशत बढ़ गया तथा प्रस्तावित उपकरणों के निर्माण की लागत केवल ५२.४१ प्रतिशत बढ़ा। छोटे, मंझोले एवं व्यावसायिक स्तरों पर चावल-मछली खेती प्रणाली व्यापार योजनाओं के लिए परियोजना लागत वर्ष २०१२-१३ में क्रमशः १३.४८, १२.४० तथा १३.२५ प्रतिशत बढ़ा। इसके अतिरिक्त, बिक्री मूल्य में बढ़त से चावल-मछली खेती के छोटे, मंझोले एवं व्यावसायिक स्तरों पर शुद्ध लाभ क्रमशः ३७.४९, ३६.५० तथा १०.२५ प्रतिशत बढ़ा।

अभिग्रहण के अनुकरण मॉडल डिजाइनिंग कार्यकलाप के तहत, अधिक उपज देने वाली किस्मों के आश्रित परिवर्तियों अभिग्रहण तथा अधिक उपज देने वाली किस्मों की खेती पद्धतियों तथा स्वतंत्र परिवर्तियों के बीच सहसंबध पर सीएमए साफ्टवेयर करते हुए विभिन्न माध्यमिक स्रोतों एकत्र आंकड़ों का मेटा-विश्लेषित किया गया। परिणामों से पता चला कि अधिक उपज देने वाली किस्मों के आश्रित परिवर्तियां अभिग्रहण तथा अधिक उपज देने वाली किस्मों की खेती पद्धतियां के बीच सहसंबद्ध काफी सकारात्मक है।

यह अनुमान किया गया कि पश्चिम बंगाल में १४.४२ लाख हैक्टर भूमि में, झारखंड के ९१६०० हैक्टर भूमि में तथा आंध्र प्रदेश के १६९०० हैक्टर भूमि में एनआरआरआई के किस्मों की खेती की गई।

१९९०-९१ से २०१४-१५ की अवधि के दौरान चावल निर्यात विश्लेषण से पता चला कि भारत का डब्ल्यूटीओ पश्चात अवधि में चावल निर्यात महत्वपूर्ण रूप से बढ़ा है। निर्यात की मात्रा १२ गुना तथा मूल्य १० गुना बढ़ा है जबकि १९९४-९५ से २०१४-१५ की अवधि के आंकड़ों को विचार में लिया गया। पश्चिम एशिया क्षेत्र, उत्तर यूरोप, उत्तर अमेरिका तथा दक्षिण यूरोप में बासमती चावल निर्यात किया गया। पश्चिम एशिया क्षेत्र भारतीय बासमती के कुल ८४ प्रतिशत आयात करता है। पश्चिम अफ्रीका, दक्षिण एशिया तथा पूर्वी अफ्रीका के क्षेत्रों को गैर-बासमती चावल निर्यात किया गया। पश्चिम अफ्रीका को गैर-बासमती चावल के कुल ४३ प्रतिशत निर्यात किया गया तथा ये चावल मुख्यतः उसना ग्रेड के हैं।

Introduction

National Rice Research Institute (NRRI), formerly known as Central Rice Research Institute (CRRI), was established by the Government of India in 1946 at Cuttack, as an aftermath of the great Bengal famine in 1943, for a consolidated approach to rice research in India. The administrative control of the Institute was subsequently transferred to the Indian Council of Agricultural Research (ICAR) in 1966. The institute has two research stations, on at Hazaribag, in Jharkhand, and 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 Santhpur in Cuttack district of Odisha and the other Jainagar in Koderma district of Jharkhand. The research policies are guided by the recommendations of the research Advisory Committee (RAC), Quinquennial Review Team (QRT) and the institute Research Council (IRC). The NRRI also has an institute Management Committee (IMC) for formulating administrative policies.

Goal

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

Mission

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

Mandate

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

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

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

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

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

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

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

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

Thrust Areas

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

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

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

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

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

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

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

Research Achievements

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

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

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

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

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

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

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

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

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


Hansa Dubraj
2013/1507
Falodhan
2015/690
IC-517000
KH-07
BAN KENA
2014/1667
Phool Mecha
2013/1556
Kava Kor
2013/1546
Khutidhan-2
2014/1619
Godavari
2013/1552
Bohita
2015/168

PROGRAMME : 1

Genetic Improvement of Rice

The Crop Improvement Division is involved in genetic improvement of rice along with collection and conservation of rice genetic resources and basic studies in genetics, cytogenetics and molecular biology. The institute has developed a high yielding high protein rice variety CR Dhan 310 (IET 24780), which has been released and notified by Central Sub-committee on Crop Standard, Notification and Release of Varieties for the states of Odisha, Uttar Pradesh and Madhya Pradesh. This variety having 10.3% protein and 15 ppm zinc with an average yield of 4.48 t/ha, can solve the problem of malnourishment to a large extent. A total of 768.70 q of breeder seed was produced comprising 53 varieties and nine parental lines.

Three promising cultures were identified for release by Variety Identification Committee (VIC) in the 51st AICRIP group meeting held at Raipur. It includes CR 2687-2-3-1-1-1 (IET 13053) for release in semi-deep water ecology of Andhra Pradesh, Karnataka and Assam; CR 3835-1-7-2-1-1 (IET 23601) for deep water areas of Assam, West Bengal and Odisha and one aromatic short grain culture CR 2713-35 (IET 23189) for release in West Bengal, Odisha and Uttar Pradesh.

Proposals were submitted for release of nine cultures suitable for different ecologies to State Variety Release Committee (SVRC), Odisha. They are CR Dhan 409 for shallow low land, CR Dhan 207, CR Dhan 208 and CR Dhan 209 for aerobic, CR Dhan 507 and CR Dhan 509 for deep water, CR Dhan 800 for bacterial blight endemic areas CR Dhan 311 for high protein content and CR Sugandh Dhan 910 aromatic short grain

Exploration, characterization and conservation of rice genetic resources

Exploration and collection of rice germplasm

Three exploration programmes were conducted during the period in different parts of the country for collection of wild and weedy rice germplasm. They are listed below:

Exploration and collection of wild rice *Oryza coarctata* (*Porteresia coarctata)* germplasm from Bhitarkanika Mangrove National Park of coastal Odisha was conducted in collaboration with NBPGR Base Centre, Cuttack during 17-21 October, 2015.The wild rice *Oryza coarctata* is found along the Brahmani riverside estuaries/creeks where high tides are experienced twice a day. Eventually, they are tolerant to submergence and salinity. This species belongs to the tertiary gene pool of cultivated rice. The plant flowers twice a year i.e. during August and February with low seed setting and mostly sterile. They bear the recalcitrant seeds which upon drying desiccate. A total of 12 accessions from different estuaries of the mangrove areas were collected. The local name of the wild rice is Dhani dhan. It is found in abundance near Talchua and Dhamra area of the National park. The common associate of this wild rice in the mangrove region is Nalli grass (*Myriostachya wightiana*).

Another exploration was conducted during 5-12 November, 2015 in two districts of Andaman & Nicober islands in collaboration with the ICAR-Central Islands Agricultural Research Institute (CIARI), Port Blair. The region is having the highest range of mangrove forests where usually the wild rice *O. coarctata* is supposed to be found growing along the estuaries/creeks. But to our surprise, there was not a single plant found in the entire islands. However, as per the literature published by CIARI, there appears another new wild rice species called *O. indandamanica* in the high hills of Rutland Island of south Andaman and Saddle peak of north Andaman. This species later designated as *Oryza granulata* (as synonym) and thus *O. indandamanica* does not have a special entity. Because of the non-interference, the wild or weedy rices have also not reached the territory of the island from the south eastern Asian main lands where it is reported to occur profusely.

The third exploration and collection programme was conducted in coastal saline areas of Odisha and West Bengal for trait specific rice germplasm in collaboration with NBPGR Base centre, Cuttack during 18- 24, December, 2015 and a total of 37 accessions of saline tolerant farmers' varieties were collected from 27 sites covering three coastal districts namely Kendrapara (5), Bhadrak (9) and Balasore (11) of Odisha and east Midnapore district (12) of West

Bengal. Wide range of *in-situ* variability was recorded among collected landraces for various morpho-agronomic traits. Panicles and freshly harvested seeds were collected from the farmer's field, threshing yards and farm stores. Due attention was given to collect disease / pest free seeds with sufficient quantity (Gene Bank Standard). Information about genetic erosion of local primitive land races were also recorded during the exploration. The seeds of all the accessions will be deposited for conservation in NGB and MTS after proper processing (threshing/ cleaning/ drying). Some of the dominant primitive cultivars are Bhaluki, Bhundi, Rahaspanjar, Nona Bokra, Getu, Pateni etc. Dudsar, a fine grain local germplasm is grown in coastal saline areas of all these districts

Collection of wild rice (*Oryza coarctata*) from slushy areas of Bhitarkanika mangrove tidal creeks

Rejuvenation of the conserved germplasm and the new collections

The core set of 1055 accessions developed under National Rice Resources Database project were conserved in the gene bank for further evaluation against major biotic and abiotic stresses. One set was screened against vegetative stage drought stress in dry season and 132 accessions were found tolerant. 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 were received from NBPGR under CRP Agro biodiversity project and they were grown for characterization along with 580 newly acquired accessions. All the thirty morphological observations data on nineteen qualitative characters and eleven quantitative characters were recorded at appropriate stages of growth and maturity as per the descriptors. These material were harvested, processed, packed and stored in the gene bank for future use.

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

A total 5800 germplasm including wild and weedy rices were grown for characterization on agro-morphological traits of 30 DUS characters as per the descriptors.

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

A total of 17 landraces from North Eastern India along with 5 popular rice varieties of NRRI, Cuttack were characterized using STMS markers. A prescreening of 60 STMS markers was performed out of which only 16 STMS markers showed best amplification and reproducibility; these were selected for further analysis. Sixteen STMS markers produced a total of 53 bands out of which 47 bands (88.67%) were found polymorphic. The maximum number of total alleles (5) was amplified with RM10655, RM580, RM1 and RM3412; while RM10619 produced the lowest number (1) of total alleles. The amplicons were observed in the range of 30 to 450bp. The maximum PIC value (0.495) was observed with the marker RM23805 followed by 0.375 in RM10890 while RM10619 and RM13129 showed the minimum value of 0.086 and 0.138 respectively. The unique bands were observed in some of the markers (RM318, RM10655, RM580, RM 1 and RM13129) used for this study. For the genetic similarities analysis, 16 STMS markers data were used to construct a dendrogram by UPGMA to segregate 17 landraces and 5 popular rice varieties into two distinct groups (Fig.1.1).

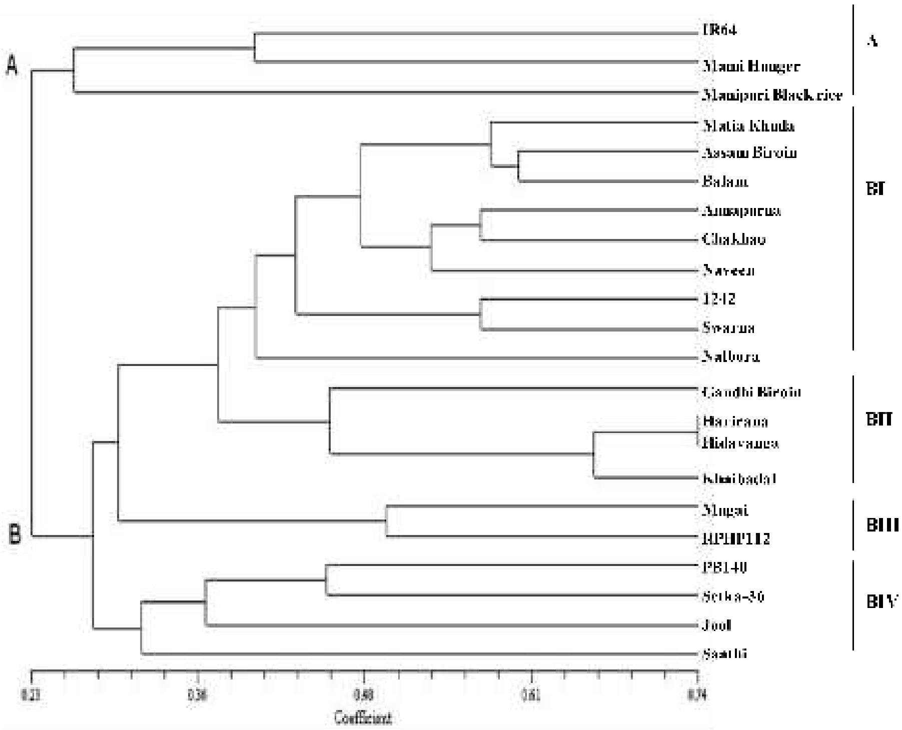


Fig.1.1. Dendrogram derived fromUPGMA cluster analysis using Jaccard's similarity coefficient based on 16 STMS markers showing the association among the 17 land races and five released varieties.

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

Germplasm conservation

Five thousand and eight hundred (5800) accessions of rice germplasm were characterized and rejuvenated for conservation. These material have been conserved in three layer aluminum pouches at national active gene bank at NRRI in Medium Term Storage (MTS) facility.

Seed Supply

Five thousand two hundred and seventy nine (5279) accessions of rice germplasm/elite lines/ donors/ released/notified varieties were supplied to different researchers all over the country and also to the research scientists for screening, evaluation and utilization. Out of these accessions, 188 were shared with different institutes/organizations through proper signing of Material Transfer Agreement (MTA).

Maintenance Breeding and Seed Quality Enhancement

Panicle progeny rows of 53 varieties were grown for maintenance breeding, during 2015-16. After thorough rouging of the border rows, rejection of the variant progeny lines and collection of true to the type panicles for growing in next year panicle progeny plot, the progeny lines were selected and harvested separately. The harvested lines were threshed separately and after table top examination the finally selected progeny lines were bulked as Nucleus seed. The Nucleus seeds are used for the production of breeder seed.

Keeping an eye on the DAC indent, breeder seed of 53 varieties and nine parental lines were grown. A total of 768.70 qtls of breeder seed were produced comprising of 53 varieties and 9 parental lines during the year.

Participatory Seed Production

Under National Seed Project, Farmer's Participatory Seed Production was taken up (under the supervision of NRRI Scientists) in two villages namely Goudagop, (Mahanga, Cuttack) and Bhandilo, (Kendrapara) in agreement with Mahanga Krushak Vikash Manch and Mahatma Gandhi Farmer's Club respectively. Seed production involved four popular varieties *viz.*;

Pooja, Sarala, Gayatri and Swarna sub 1.Time to time monitoring was conducted in the field and quality was checked after harvest. About 1005.751quintal seed, qualified for TL seed standard were procured back from the Mahanga Krushak Vikash Manch and Mahatma Gandhi Farmer's club which after processing were sold to the farmers as TL Seed.

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

Pre-breeding lines of wild rice sources: Wild rice accessions were screened against biotic and abiotic stresses and donors (YSB, BPH and drought) were identified and used in hybridization programme. The F_1s were further back crossed with recurrent cultivated parents and introgressive lines were generated employing embryo rescue technique. These lines were again screened and used as pre-breeding lines for varietal development. Five back crosses were made using Swarna Sub1, MTU1010 and APO as recurrent parents of *O. sativa* / *O. rufipogon* (AC105491) hybrids. Thirty three selections were made from fifty BC_2F_7 of Apo/*O. nivara* (AC 100476), CR143-2-2/ *O. nivara* (AC 100374), Lalat/ *O. nivara* (AC 100476) and IR64/ *O. nivara* (AC 100476) derivatives. Fifteen advance fertile disomic of *sativa*/*O. brachyantha*//*O. sativa* and eleven O. sativa/*O. nivara*/*O. sativa* (Apo and Lalat) lines were evaluated for yield and other traits. The promising entries significantly out yielded the checks. Among the entries CR 2873-51-3-7 (Lalat/*O. nivara* (AC100476), CR3426-1-5-1-5 (Apo/*O. nivara* (AC100476), CR3867-151-1-5-1-1(Apo/*O. nivara* (AC 100416)//Apo, CR3869-404-225 (Apo/*O. nivara* (AC100404)//Apo), CR3993-2-24 (CR1009/*O. brachyantha*//CR1009, CR3993-4-9-6(CR1009/*O. brachyantha*//CR1009) and CR3868-225-1-2-2-5 (Apo/*O. nivara* (AC100374)//Apo) gave yield >5.5 tons/ha. Tweleve new disomic fertile lines were selected from BC_2F_3 populations of CR1009/*O. brachyantha*//CR1009. Twenty three advanced generation lines (BC_2F_7) of CR1009/*O. brachyantha*//CR1009 were evaluated for yield and yield related traits along with three checks (Swarna and Savitri) in RCBD. Maintenance of sterile wide cross derivatives, accessions of wild species donor such as *O. nivara* (AC 100476, AC 100374) for drought, *O. brachyantha* (Acc. no. 1086) for YSB, *O. rufipogon* (AC 100174, AC100444) for BPH, *O. meridionalis* (AC 105290) for both yield under drought and *O. rufipogon* (IRGC105491) for yield in the net house. Three new BC_2F_1 hybrids (CR1009/*O. brachyantha*//CR1009) were produced and observation of morphological and cytological parameters were recorded.

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

African wild rice, *O. brachyantha*, is a distant relative of cultivated rice, *O. sativa*, which potentially carry useful genes to control imortant pests and diseases. From evolutionary perspective, *O. brachyantha* (FF) is considered to be one of the farthest relatives of *O. sativa*(AA) which are presumed to be diverged from each-other about 15 million years ago. Whole genome sequencing of *O. brachyantha* has revealed large variation in the non-genic region of these two genomes. A study was conducted to assess the cross-transferability of 15,837 *O. sativa* specific RM series Sequence Tagged Microsatellite (STMS) markers to *O. brachyantha* genome. Expectedly, the cross-transferability was very low (~0.79%) as most of the STMS sites were located at non-genic region. But importantly, most of the cross-transferability STMS markers (~75.20%) were found to be located at the genic region. Taking leads form this observation, some gene based Sequence Tagged Site (gSTS) and gene based Cleaved Amplified Polymorphic Sequence (gCAPS) markers were developed by exploiting the indels and SNP, respectively, present in some of the genes common to both these *Oryza* species. Taken together, the cross-transferability of these gSTS and gCAPS markers were found to be very high (~84.78%). Finally, 175 cross-transferable markers (STMS, gSTS and gCAPS) were mapped to the *O. sativa* and *O. brachyantha* genomes. It was found that, except few minor exceptions, the cross-transferable markers maintained co-linearity between these two *Oryza* genomes under study (Fig. 1.2). Hence, it was inferred that though the non-genic regions of these two *Oryza* species has gathered large extent of variation during the course of evolution, but the genic region of these two species remained largely conserved maintaining high level of co-linearity between them.

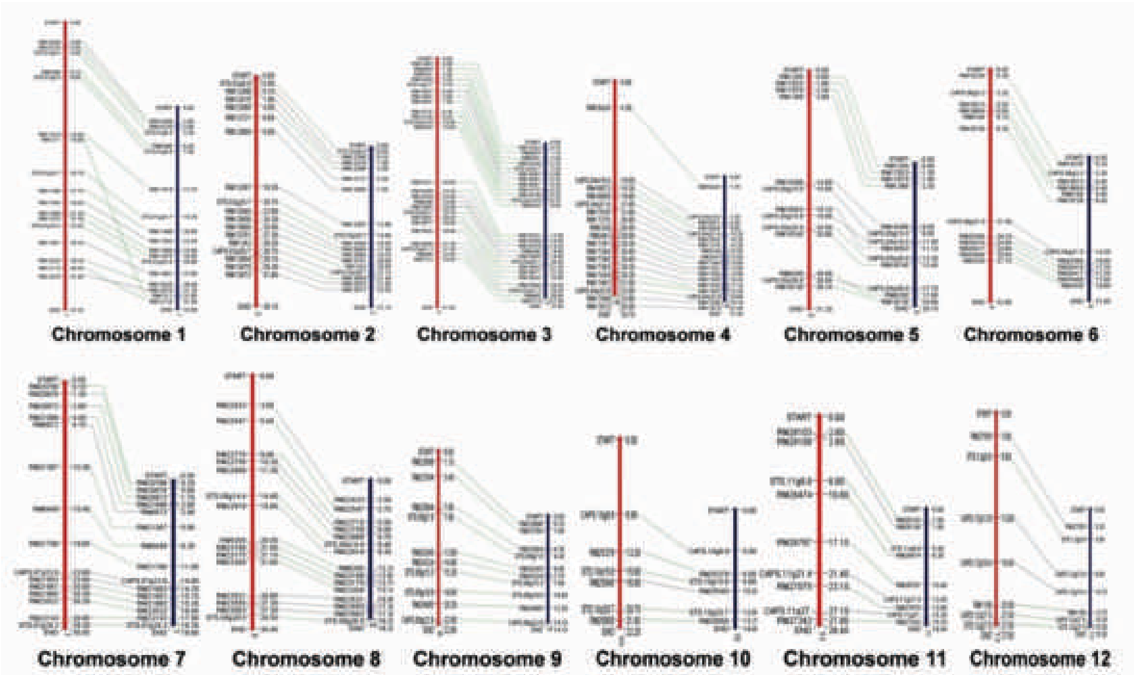


Fig. 1.2. Distribution of cross-transferable markers along the chromosomes of *O. sativa* (red)and *O. brachyantha* (blue).

Note: Markers polymorphic between *O. sativavar*. Savitri (CR1009) and *O. brachyantha* (AC100499) are marked by green dotted lines while the monomorphic markers are marked in black dotted lines.

Screening and generation advance for YSB tolerace

Field screening of 43 disomic fertile pre-breeding lines of CR 1009 / *Oryza brachyantha//CR1009* along with a susceptible check TN 1 was undertaken during *dry* 2016. At vegetative stage, twenty hills were randomly selected and total tillers and tillers with dead heart symptoms by yellow stem borer were counted from each entry planted in the field. Percent dead heart was calculated and damage scoring was assigned based on IRRI score (SES, 2002). The results revealed that three entries *viz*., B -8, B – 11 & B -16 showed zero damage score compared to susceptible check TN (1) (32.1%) with damage score of 7.

Screening and generation advance for Brown Plant Hopper resistance

The identified tolerant accessions of *Oryza rufipogon* (AC100444) and (AC 100005) were crossed with the susceptible variety Swarna to produce F_1. The F_1s were advanced to produce F_2s, and also backcrossed to Swarna for developing the backcross populations. The F_2 populations of the two crosses were screened for BPH tolerance to study the genetics of the trait in these populations. Approximately 300 seeds of each F_2 generation were sown in trays and twenty days old seedlings were subjected to BPH tolerance screening. The susceptible parent, Swarna, was raised in rows on both ends of the trays, and used as a susceptible check. In cross #86, out of the 82 seedlings, 55% seedlings were survived, whereas in the cross #89, only 27% of the total emerged seedlings survived. In the susceptible parent Swarna, 17 out of the 179 (<10% seedling survival) emerged seedlings were alive. ^{2} analyses were carried out to test whether the data fit in to a genetic hypothesis of a single gene for BPH tolerance segregating in the population. The chi-square value for the cross#86 cross indicates that this population does not fit in to the genetic hypothesis of a single gene segregating in the population for BPH tolerance. Whereas in the second cross (cross#89), the number of survived and dead seedlings were in the ratio of 1:3 (X^2= 0.05), indicating that a single recessive gene for BPH tolerance is segregating in the population. But the population size of Db-89 cross was less, hence the conclusion derived about the inheritance of the trait need to be further verified with a large segregating population. Further evaluations of F_2 population against BPH are in progress.

Screening for sheath blight resistance

Thirteen accessions of wild rice, *Oryza rufipogon* were raised in earthen pots under net house condition for second season i.e, during dry season 2015 which were artificially inoculated with the virulent isolate (ShbSL 4) of sheath blight pathogen, *Rhizoctonia solani* Kuhn by inserting five sclerotial bodies with bits of mycelia inside leaf sheaths. The susceptible check (Tapaswini) and resistant (CR 1014) were taken for comparison with different *O.rufipogon* accessions. The earthen pots were properly covered with large perforated polythene bags with regular watering for creating congenial condition for the sheath blight pathogen. The development of disease symptoms was critically recorded 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* within 4 to 7 days for producing sheath blight symptoms. *O. rufipogon* accessions namely, AC 100015, 100263,100444 along with check Tapaswini took minimum 3 days for sheath blight symptom expression; whereas, the accessions namely, AC 100034,100174 and 100493 took maximum 7 days for producing initial symptoms. Sheath blight incidence with least SES score of 2.5 (moderately resistance reaction) was found in case of accession AC 100444 and AC 100015, 100005, 100493 to be tolerant showing disease scores of 3.1,3.7,4.8 respectively. Maximum disease score of 6.8 was observed in accession AC 100033,AC100047 followed by AC 100493 showing 5.7 and 5.4 in AC 100019. The susceptible check, Tapaswini showed maximum disease score of 7.2 (highly susceptible reaction), whereas the resistant check, CR1014 recorded score of 2.9. The identified accessions will be retested for sheath blight resistance and used in breeding programme.

Screening of wide cross derivative lines against Sheath blight, Blast and Brown spot

A total number of 206 introgressed lines were screened against sheath blight disease under artificial inoculation with Annapurna as susceptible and CR 1014 as tolerant check. It was found that seven lines were showing high degrees of tolerance to Sheath blight and 36 lines are moderately tolerant and rest were highly susceptible.

Similarly 210 lines were screened for rice leaf blast disease in the uniform blast nursery taking HR12 and Karuna as susceptible checks. The result indicated that 33 are having resistance against leaf blast disease. The screening against brown spot under natural condition indicated that 78 lines are tolerant to brown spot disease. These data are based on a single year screening so, the selected lines needs further screening for confirmation.

Identification of *O.nivara* genome segments introgressed into Lalat cultivars related to drought tolerance

The wild relatives of rice have beenwidely used to transfer useful genes for biotic and abiotic stresses. It is worth to develop introgression lines (ILs) from various wild species and characterize for abiotic and biotic stresses. An accession of *O. nivara* (AC100476) with drought tolerant during the vegetative stage was crossed with recurrent parent Lalat, a drought susceptible cultivar to developed introgressed lines (ILs). A total of 100 ILs were developed through two times back-crossing with Lalat and then fixing themby selfing up to F_4 generation. To identify the introgressed genomic regions related to drought tolerant traits among the ILs, genome-wide simple sequence repeat (SSR) markers were used. For this, a total of 410 RM markers covering the entire chromosomes were used to survey the polymorphism between the Lalat and *Oryza nivara*. Out of which, 116 RM markers (28.9%) were found to be polymorphic between Lalat and *Oryza nivara*. These markers distributed uniformly throughout the twelve chromosomes except few gaps on chromosome 1, 7 and 10 (Figure 1.3). Identification of more polymorphic markers from these gaps will be carried out using more unused markers from the gap regions of chromosomes. During the dry season, these 100 lines were gown in the field in two replications. The drought treatment was given at 4 leaf stages by withholding the irrigation for 10 days. Leaf rolling parameter was adopted to measure the level of drought tolerance among the ILs which ranges from 1 (highly tolerant) to 9 (highly susceptible). The strategic identification of drought tolerant ILs coupled with genotyping using polymorphic markers will led to the identification of introgressed *nivara* genomic regions into Lalat which are valuable genetic resources not only for drought tolerance, but also for novel gene identification leading to cultivar development. Therefore, ten extreme tolerant ILs will be selected and genotyped using the whole polymorphic markers identified here.

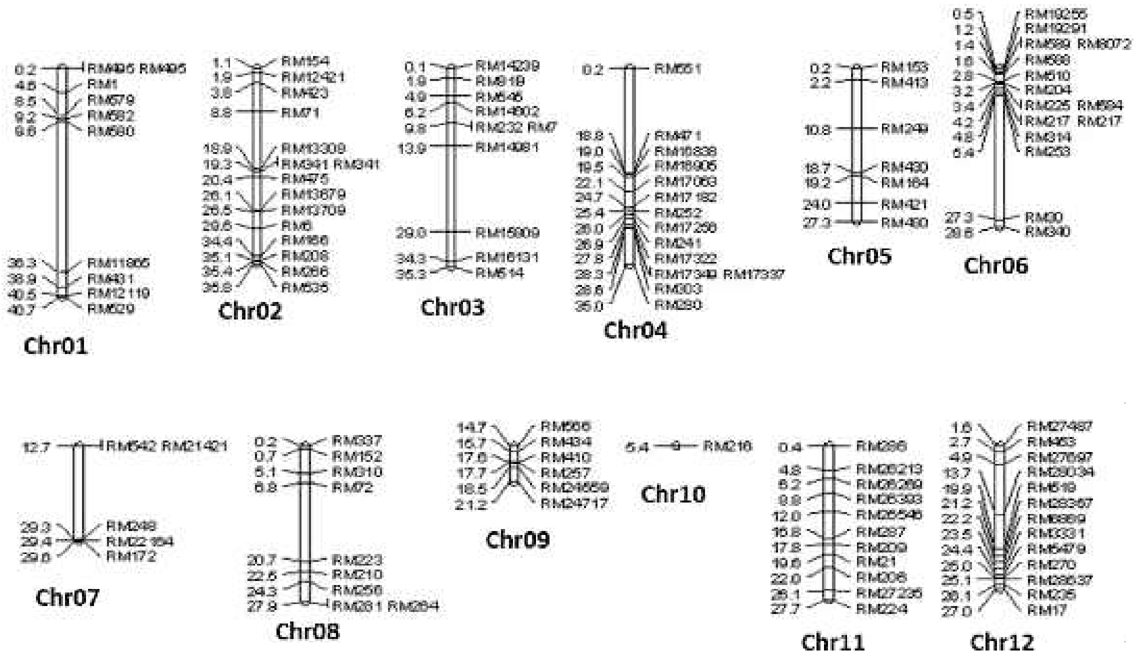


Fig.1.3. Distribution of polymorphic SSR markers between parents, Lalat and *Oryza nivara* (AC100476) on 12 chromosomes of rice. Numerical figure on the left side of the chromosomes is the physical position of markers in Mb unit.

Hybrid rice for different ecologies

Source nursery

NRRI has a total of 1107 diverse breeding lines/ varieties including male sterility sources in parental lines stock and maintained as source nursery. Six hundred and thirty four of these were screened for presence of restorer (*Rf*) genes where 322 lines were found with *Rf* positive (72 with *Rf*3 & *Rf*4, 116 with *Rf4* and 134 with *Rf* 3 only) which are being utilized in crossing programme.

Identification of new Cytoplasmic Male Sterility (CMS) source

To boost up further hybrid rice research and face the future challenges, identification of new CMS source is essential. In this regard, 50 new test crosses between 25 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. Notably, one sterile test cross from the previous crosses was found to be a new probable MS source which has been advanced in BC generation for further evaluation.

Identification of maintainer, restorer and new hybrid combinations

To test the combining, maintaining and restorer ability of promising genotypes, 1390 test crosses involving 7 CMS (CRMS31A, CRMS32A, CRMS51A, APMS6A, RTN 12A, PUSA 5A and PMS 17A) were evaluated. Result indicated that 27 lines/pollen parents were promising maintainers and 257 lines/pollen parents were effective restorers (restored > 85% fertility in respective F_1). Forty four, out of 257 identified restorers were found good combiners with CRMS 31A, CRMS 32A, RTN 12A, PMS 17A and were re-tested for validation (Table 1.1). A total of 847 new testcrosses involving seven CMS lines (CRMS31A, CRMS32A, RTN 12A, PUSA 5A, CRMS51A, PMS 17A & APMS 6A,) were generated during wet season, 2015.

Table 1.1: List of promising restorers

KPH 272 , CRL 353, TMRH 107, CRL 283, IET 24620, RP BIO 226, G 2434, HR 41126R, NPH 911, ATPDG 5 092, NP 256, NP 125, POORNABHOG,DGR 13	TK 53, DGR 014 , Moti Gold, GK 5017, CR 780 -1937-2R, CRL 20R, GK 155 , CRL 328, CRL 273, CRL 36, PA 147, CRL 103, DGR 12, DGR 10, CRL 354,	DGR 010 , CRRP 1 -12-18, CRL 27R, WGL 32, CR 8 -1-5, CRL 302, CRL 116, CRL 59 , INGER 318, CRL 110, NP 1 0001R, CRL 369, DRR 39, SYE-1, SASARSTAN,

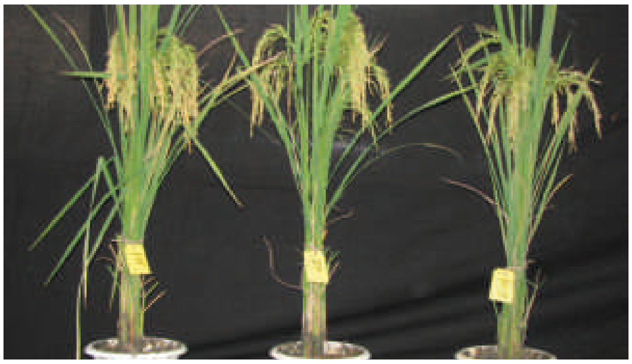


Fig. 1.4. Promising test cross evaluated during wet season, 2015

Development of new CMS lines

During wet season, 2015, 48 sterile backcrosses (BC_2-BC_8) and 27 new sterile test crosses were advanced in backcross generation. Three promising late duration sterile BC_1F_1's were advanced to BC_2F_1. Some of the promising lines with stable male sterility, good out crossing, good floret opening, along with considerable panicle and stigma exsertion are listed in Table 1.2.

Table 1.2. Promising sterile backcross derived lines advanced during 2015

S. No.	BCN No.	Recurrent parent	Sourse of cytoplasm	Remarks
1	$BCN^8$199A	CR2234-1020 (WA)	WA	Good floret opening
2	$BCN^8$200A	CR2234-1020	Kalinga-I	Good floret opening
3	$BCN^6$99A	A-180-12-1(87)	WA	Short duration, drought tolerant
4	$BCN^8$180A	CR 2234-834(WA)	WA	Good floret opening and stigma exsertion
5	$BCN^6$140A	IR 68301-11-64-3-6-6	Kalinga-I	Complete panicle emergence
6	$BCN^5$853A	CR 25B-244B-440	WA	Good floret opening and purple stigma exsertion
7	$BCN^4$862A	31B-GP-18	WA	31B Gene pyramid with 4 BLB genes
8	$BCN^4$863A	32B-GP- 39	Kalinga-I	32B Gene pyramid with 4 BLB genes
9	$BCN^3$275A	CRMP1-07-1010	WA	Good floret opening, mid late
10	$BCN^3$276A	CRMP1-07-1010	Kalinga-I	Good floret opening, mid late
11	$BCN^3$278A	Kuderat-2	WA	Medium duration
12	$BCN^3$279A	Kuderat-2	Kalinga-I	Medium duration
13	$BCN^3$346A	CR-172	WA	Late duration
14	$BCN^2$121A	CRRP 1	WA	One time more floret opening
15	$BCN^2$118A	CRHR-330-1	WA	Complete panicle emergence

16	BCN^{2}582A	CR 25B-32B-337	WA	Mid-late duration, good floret opening and stigma exsertion
17	BCN^{2}583A	CR 25B-32B-337	Kalinga-I	Mid-late duration, good floret opening and stigma exsertion
18	BCN^{2}591A	CR 1071-C18-1840	WA	Mid-late duration, good floret opening and long stigma exsertion
19	BCN^{2}592A	CR 1071-C18-1840	Kalinga-I	Mid-late duration, good floret opening and long stigma exsertion
20	BCN^{1}252A	CR 31B-24B-79	WA	Good floret opening and long stigma exsertion
21	BCN^{1}253A	CR 31B-24B-79	Kalinga-I	Good floret opening and long stigma exsertion

Parental Line Improvement

Transfer of characters into CMS/restorer lines

In order to improve the parental lines with specific trait(s), MAS based introgression breeding approaches are being adopted. Parental lines of hybrids, Ajay and Rajalaxmi were introgressed with four bacterial blight (BB) resistant genes (*Xa 21, xa 13, xa 4 and Xa 5*). Introgression of four BB resistance genes in restorers, CRL 22R and in IR 42266-29-3R were advanced to BC_2F_2 generation. Respective CMS of these pyramided CRMS 31B and CRMS32B lines were also introgressed and being evaluated for their suitability. Additionally, introgression of five BLB resistance genes (*Xa 21, xa 13, Xa7, Xa 4 and xa 5*) were being done into a well combiner restorer Pusa 33-30-3R, advanced to BC_1F_1generation.Bio fortification of three hybrids, Ajay, Rajalaxmi and CR Dhan 701 with high Fe and Zn is being done. Enhanced out-crossing features like stigma and panicle exsertion in CMS, CRMS 31A and CRMS 32A are being introgressed from donors *O. longistaminata* and IR 71591B, respectively and are advanced to BC_1F_1 generation. Introgression of Rf3 and Rf4 genes (conferring complete fertility in CMS based hybrids) into four well combiner partial restorers, Akshaydhan, Azucena (BC_2F_1); INH 10001 and NP 801 are advanced to BC_1F_1.

Background selection of introgressed CRMS32B lines with *Saltol* and *Sub1* genes

CRMS32B, a maintainer line of hybrid rice, Rajalaxmi was introgressed to pyramid with the *Sub*-1 and *Saltol* genes from the donor parents, Swarna Sub-1 and FL478 lines respectively. Out of 26 BC_3F_2 lines, four lines which were phenotypically similar to the recurrent parent (CRMS32B) were selected for background analysis. Background selection of BC_3F_2 populations was carried out by using informative markers distributed throughout the genome. A total of 680 STMS markers, were used for identification of polymorphic markers between recurrent and donor parents. Out of 680 STMS markers, 68 (10%) markers were found to be polymorphic between FL478 and CRMS32B whereas 58 (8.5 %) markers were found to be polymorphic between Swarna Sub1 and CRMS32B. Genotyping was done using informative markers with recurrent parent, donor parents and BC3F2 lines (BC3F2-357-5, 358-2, 357-6, and 357-12). Out of them, only three lines *viz*. 358-2, 357-6, and 357-12, contain only target loci, *Saltol* and *Sub1* on the chromosome 1 and 9 respectively whereas remaining region is recovered from recurrent parent (Fig.1.5). Similarly, non carrier chromosome also recovered from recurrent parent. The average percentage of recurrent parent chromosome in 357-5 was 95% whereas remaining lines (358-2, 357-6, and 357-12) was 98%.

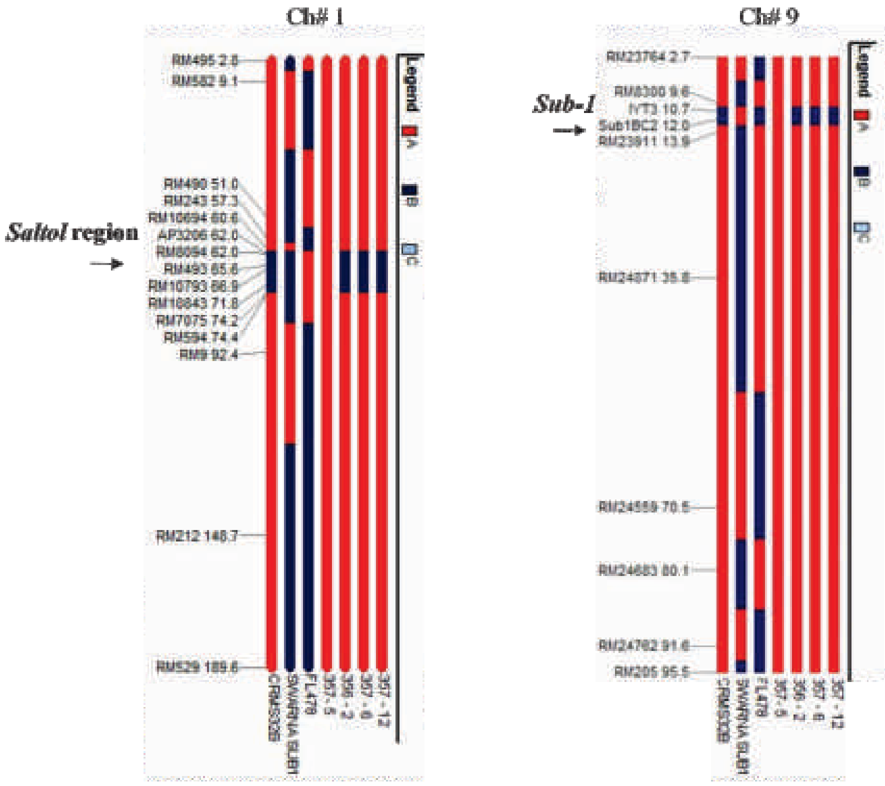


Fig.1.5. Background selection of five advanced backcrossed lines (BC3F2) of CRMS32B introgressed with *Saltol* genes (ch #1) and *Sub-1* gene (ch #9).

Phenotyping of introgressed CRMS32B with *Saltol* and *Sub1* genes

Submergence screening was performed in the concrete tank filled with turbid water up to 30 cm above the top of the plant canopy. A total of ten introgressed BC_3F_4 lines with *Saltol* and *Sub*-1 genes were screened for submergence with Swarna Sub1 (donor parent), CRMS32B (recipient parent). Twenty one days old seedlings were submerged for 14 days to confirm the introgression of the *Sub1* locus. The survival of plants was scored after 14 days of submergence. It was found that out of 10, 9 lines were survived like donor parent Swarna Sub1 whereas CRMS32B (recurrent parent) was completely died, which confirmed the introgression of the *Sub1* gene in introgressed CRMS32B lines.

The complete sequence of Kalinga mitochondrial genome causing cytoplasmic male sterility in rice (*Oryza sativa* L.)

Apart from WA-CMS, another CMS line named Kalinga, derived from *indica* cultivated rice variety Kalinga-I (CR126-42-2), was identified and used for developing popular rice hybrid named Rajalaxmi at NRRI, Cuttack. However, the molecular mechanism of male sterility of this CMS has not been characterized. Mitochondrial genome sequence of Kalinga CMS line was characterized and compared with the WA-CMS mitochondrial genome from the publicly available database to identify SNPs, InDels and DNA rearrangements between them. Since plant mitochondrial DNA contains highly repetitive sequences, which may be an obstacle for genome assembly, therefore two, paired-end libraries were prepared and sequenced on MiSeq and NextSeq sequencing systems, respectively (Illumina, San Diego, CA). The first paired-end library produced 10,605,764 paired-end reads and the second library produced 7,249,631 giving a total of 17,855,395 paired-end reads with 5.91 Gb of total sequencing data. The final resulted draft assembly with 6 gaps has an estimated size of 400,245 bp with 43.87% G+C content, covering 98.7% of the WA-CMS mitochondrial genome. Using Mitofy, BLAST searches performed against local protein and nucleotide database yielded 36 protein coding genes, 23 tRNAs and 6 rRNAs.

Distribution of both coding and non-coding genes is illustrated in Fig.1.6. The Kalinga genome (CRMS32A) when aligned with WA-CMS mitochondrial genome using MUMmer, identified 98 SNPs (55 transitions and 43 transversions) and 61 small insertions and deletions between two genomes. Out of these 34 SNPs and inDels are localized to protein coding regions.

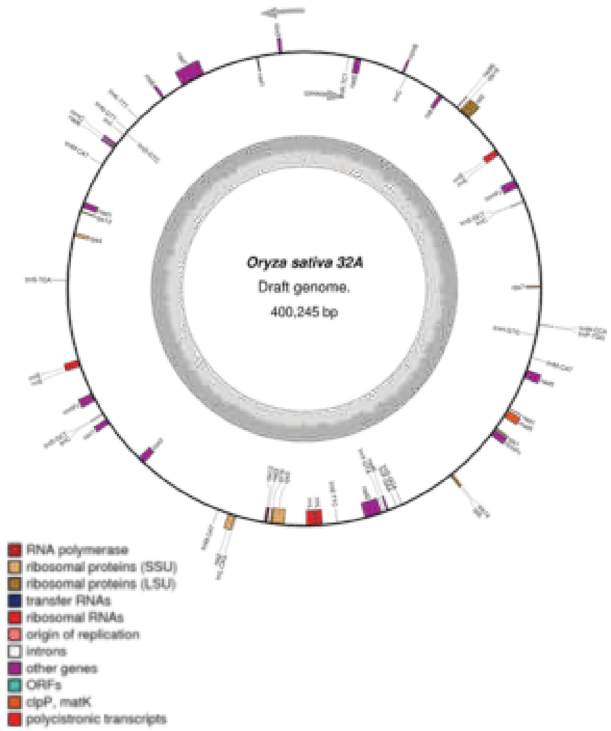


Fig.1.6. Distribution of genes in CRMS32A mitochondrial genome

Restorer and maintainer breeding

For diversification and improvement of parental line, a total 2028 single plant progenies (F_3 to F_{11} generations) generated through recombination breeding (From 72 crosses; AxR, RxR and BxB) were evaluated in pedigree nursery. Out of these, total sixteen desirable fixed lines (F_8-F_{10}) were selected and will be evaluated under station trials. In addition, 27 promising lines were used in crossing programme.

Diversifications of parental lines are also being taken up through genetic male sterility (GMS) based recurrent selection, a population improvement approach. In this fashion, four random mating maintainer populations (each population was constituted with 5 maintainers of specific trait) and two medium duration random mating restorer populations (each with 5 well combiner restorers) which were in 5^{th} random mating generation were grown during dry season 2014-15. During wet season, 2015, 6^{th} random mating generations of the same populations were grown and next random mating cycles were constituted for dry season-2015-16. During dry season 2014-15, one new restorer population was generated and evaluated; their population for next random mating cycle was constituted. During wet season, 2015, twenty eight new F_1 combinations of GMS with 6 promising restorers and 4 maintainers were generated and will be evaluated in dry season 2015.

Development of Iso-cytorestorer

Fifteen fertile iso-cytorestorers from DH derivatives BS 6444G were screened for presence of *Rf* gene (s) and used in test-cross (with 3 CMS, CRMS 31A, CRMS 32A and PMS 17A). Altogether, 45 test hybrids were generated and evaluated. Results of phenotyping revealed that all DHs except CR 6444G-66, CR 6444G-68 and CR 6444G-97 restored more than 85% spikelet fertility in the hybrids. Out of these CR 6444G-57 was recorded highest per plant yield (32 g) with CRMS 31A followed by CR 6444G-147 (29.5g with CRMS 31A) and CR 6444G-200 (27.2 g with CRMS 31A).

Seed production of hybrids

During the reporting period, truthfully labled seeds of twelve hybrid combinations, Rajalaxmi (CRHR-5) (263 kg.), Ajay (CRHR-7) (295 kg.), CR Dhan 701 (CRHR-32) (105 kg.), CRHR-100 (28 kg.), CRHR-101(12 kg.), CRHR-102 (21 kg.), CRHR-103 (9 kg.) CRHR-104 (16 kg.), CRHR-105 (16 kg.), CRHR-106 (8 kg.), CRHR-108 (19 kg.) and CRHR-109 (23 kg.) involving the CMS lines, CRMS 31A and CRMS 32A were produced and distributed to the farmers and research communities. In addition, breeder seeds of CMS, CRMS 31A (210 kg) and CRMS 32A (170 kg) were also produced and distributed.

New CMS line of Sahabhagidhan (CRMS 52A)

A short duration Kalinga-I-CMS, under nuclear background of Sahabhagi Dhan, has been developed from the recurrent backcrosses of CRMS 32A/Sahabhagi Dhan. It has plant height of 80-85cm and promising out crossing features like spikelets opening during flowering and dual stigma exertion with golden colour long bold (LB) grain. It has been observed as a very good combiner, having more than 25% out crossing ability. The new CMS line CRMS 52A will be of use in development of short duration drought and seedling stage cold tolerance hybrids.

New promising hybrid combinations

Ten promising test hybrid combinations with eight long duration (140-150 days) (CRHR-100, CRHR-101, CRHR-102, CRHR-103 and CRHR-104, CRHR 108, CRHR 109, CRHR 110) and two short duration (110-115 days) (CRHR-105 and CRHR-106) were found highly promising with an yield potential of 6.4-8.6 tonnes/ hectare under station trial. Among them, hybrid CRHR-102, CRHR 103 (AVT1-Late); CRHR 104, CRHR 105, CRHR 108, CRHR 109 and CRHR-110 are nominated under IVT-Late in AICRIP -2016.

Registration of hybrids/ parental lines

During 2015, Kalinga-1-CMS line, CRMS 32A (reg. No. 590) was registered with PPV& FR authority as extant variety.

Development of high yielding genotypes for rainfed shallow lowlands

An elite culture, CR2690-2-2-1-1-1(IET 23110) is proposed for release in the name of Pradhandhan (CR Dhan 409) for rainfed shallow lowlands of Odisha state (Fig.1.10). The proposed variety is a photosensitive genotype and flowers in 1st week of November. It takes around 160-165 days for maturity. The cultivar is a semi-tall, non-lodging plant type with a height of 120-130cm. It produces long slender grain, 350-400 panicles per m^2, high tillering (12-15) with a seed test weight of 22.5g. The cultivar can tolerate one week submergence tolerance and moderate waterlogging. The cultivar, CR Dhan 409 (Pradhandhan) possess desirable quality characters like high hulling (80%), milling (71.5%) and head rice (69%). The line exhibited moderately resistant to leaf blast, neck blast, sheath blight, sheath rot, stem borer (both dead heart and white ear heads) and leaf folder. The culture exhibited superior performance under farmers' fileld under short submergence and moderate waterlogging condition.

Five elite cultures observed to be suitable for rainfed lowland ecology on the basis of 2015 wet season trial were nominated for national testing under initial variety trial (IVT) and rainfed shallow lowland. IET 23934 (CR3838-1-2-1-4-2) and IET 23895 (CR2593-1-1-1-1) nominated during 2015 are promoted to advance variety trial-1(RSL). IET 24471 nominated to IVT-RSL during 2014 is promoted to 3rd year of testing for southern zone (zone VII) of the country. IET 24471 (CR2683-45-1-2-2-1) a derivative of CRLC899/Ac.38700 possess long bold grains and 118 days to 50% flowering recorded a mean yield of 4287 kg/ha with yield gain of 7% over best check in the region. It has good cooking quality characters like HRR (70 %), ASV (4.0), AC (23.08%) and GC (22 mm).

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

F_2 generations of ten three way crosses were raised in pedigree nursery with a population size of around 2000plants/cross. The progenies were transplanted along with three parents in a typical rainfed shallow lowland plot. 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 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, CR2682-2-3-1-1-1, CR2678-5-3-2-1-1, CR2683-15-5-2-1, CR 2683-45-1-2, CR 2683-28-12-1-4, CR 2687-2-3-5-2-1 and CR2683-15-5-2-1 which were used for their heavy panicle, high grain number, strong culm and for dark and upright top leaves characters. A total of 211 single plant progenies were selected from the segregating material of the ten crosses.

Observational yield trial for rainfed shallow lowland was conducted during wet season, 2015 to evaluate the elite lines developed for the ecology by comparing the performance with the three popular check varieties. A total of 35 promising single plant fixed progenies along with 3 checks were taken in randomized block design with two replications. The performances of 17 entries were observed to be better than the three check varieties.

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

F_1 seeds were generated using F_1 (Savitri Sub1/ CRMAS 2232-85) with Swarna line containing gene qDTY1.1, qDTY2.1 and qDTY3.1. 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, drought donor parent Swarna pyramid line containing yield QTLs under drought *i.e.,* qDTY1.1, qDTY2.1 and qDTY3.1.

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

The F_1 seeds collected from sterile plants during wet season, 2014 were raised to advance the generation for getting seeds of the next recombination phase. Variation was noticed during 2014 wet seasonfor grain yield traits like panicle/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 trait 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 (*qDTY1.1+qDTY2.1*) from IR64 NIL lines and yield from yield gene from two new plant type lines. The seeds collected from the advancement generation was bulked to raise the next recombination phase during wet season, 2016.

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

Seeds of 25 elite cultures and recently released varieties have been increased for various testing experiments like National, State, on station and international trials. The following evaluation trials of AICRIP and INGER were conducted at Cuttack during the season.

Trials under All India Coordinated Rice Improvement Programme (AICRIP)

1. Advanced variety trial 1-Late (AVT 1 Late): Advance variety trial 1 for late duration was conducted with 16 test entries including checks promoted from initial variety trial-late under zone 3. Highest grain yield of 6178 kg/ha was recorded from IET 24365 (PAN 828) followed by 6020 kg/ha and 5725 kg/ha from IET 23610 (NP 7061) and zonal check (NDR 8002) respectively from top three entries while highest grain yield of 5725 kg/ha was obtained from regional check amongst the check varieties.

2. Initial Variety trial-late (IVT-Late): Initial variety trial for for late duration was conducted with 61 test entries and three check varieties generated at different breeding centers of the country. Highest grain yield of 7761kg/ha was recorded from IET 25269 (MEPH 126) followed by 7701kg/ha and 7328 kg/ha from IET 25234 (KJT 4-12-10-3-14-12-7) and 25267(RP 5507 Bulk-3-1-4) respectively from top three entries while highest grain yield of 7194 kg/ha was obtained from local check (Sumit) amongst the check varieties.

3. Advance variety trial 1-rainfed shallow lowland (AVT1-RSL): Advance variety trial 1-rainfed shallow lowland was conducted with 13 test entries including checks promoted from initial variety trial-RSL Highest grain yield of 6762 kg/ha was recorded from IET 24474(OR 2330-1-1) followed by 6453 kg/ha and 6341 kg/ha from IET 24480 (CR 2681-2-3-1-1-1) and national check (Dhanrasi) respectively from top three entries while highest grain yield was obtained from national check amongst the check varieties.

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

1. **International Rainfed Lowland Observational Nursery (IRLON):** The 38th International rainfed lowland observational nursery comprised of 37 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 were HHZ 15-SAL-13-Y1, IR 11 A546, IR 11A 108, Maudamani and HHZ 26-SAL-12-Y1-Y1.

2. Green Super Rice for rainfed lowland yield trial (GSR-RFLL): The GSR-RFLL trial was conducted during wet season, 2015 to evaluate the promising GSR for Cuttack situation. Top four entries evaluated were HHZ 4-SAL5-L11-L11, Maudamani, HHZ 15-DT7-SAL2 and HHZ 26-SAL-12-Y1-Y1.

Development of improved genotypes for semi-deep and deep water ecologies

Identification of new sources of submergence tolerance

AC 20431B has been identified as submergence tolerant for 21 days. For identification of new locus for submergence tolerance other than the "*Sub1*", a mapping population was developed by crossing Swarna-Sub1 and AC 20431B. Twenty five days old F_2 seedlings were used for submergence screening. A total of 568 F_2 plants along with Swarna-Sub1 and AC 20431B were used for 21 days submergence. The survival of plants was scored at 3th, 7th and 15th days after de-submergence. It was found that AC 20431B was survived after 21 days submergence, whereas Swarna-Sub1 was totally killed. Out of 568 F_2 plants, 251 plants were survived. The phenotypic data of F_2 population will be used for identification of genomic region responsible for the submergence tolerance for 21 days period using bulk segregation analysis (BSA) or selective graphical genotyping.

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

Seven hundred and seventy four single plant progenies (F_3-F_7) from 48 cross combinations along with seven F_2 bulks were grown under semi-deep water conditions during wet season, 2015.At the time of maturity, five hundred and twenty six single plant selections were made from 25 cross combinations on the basis of tolerance to water logging, photo sensitivity, plant height, field tolerance to bacterial blight and stem borer and other plant and panicle characters.Besides, 50 uniform progenies were bulk harvested to see their yield performance in the next season.Further, seventeen F_1's made during last year using popular high yielding varieties and stress tolerant genotypes as parents have been generation advanced.

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

Evaluation of advance breeding lines under semi-deepwater conditions (Station trial)

Forty three advance breeding lines along with five check varieties were evaluated in a randomized block design with two replications under semi-deep water conditions during wet season, 2015. Among the 48 entries, CR 2459-23-1-1-S-B1-2B-1 performed best with an average yield of 4.18 t/ha followed by CR 3073-1-11-4-2 (4.07 t/ha) and IR 87146-CR 3-2-1-1-1-1(3.76 t/ha) against the best check variety Varshadhan (3.03 kg/ha).

Evaluation of advance breeding lines under deepwater conditions (Station trial)

Observational yield trial was conducted during wet season taking 28 elite fixed lines and 3 checks in randomized block design with two replications. The performance of 16 entries was observed to be better as compared to the three check varieties. CR 3836-1-7-4-1-1 recorded highest grain yield of 4.92t/ha followed by CR 3835-1-7-2-1-1(4.85 t/ha), CR 2687-3-3-1-1-3(4.62 t/ha) and CR 2304-5-7-2-3-1(4.74 t/ha) from the station trial.

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

National Semi-Deep Water Screening Nursery (NSDWSN)

Forty seven entries including three check varieties (Sabita, Purnendu and Varshadhan) were evaluated in a randomized block design with two replications under semi-deep water conditions. Among the different entries, Entry No. 611 (IET 25185; CR 3063-2-1-9-2) performed best with an average grain yield of 5.86 t/ha followed by Entry No. 635 (IET 25207; CR 2529-B-2-3-1-1-1) with 5.62 t/ha and Entry No. 630 (IET 25202)with 5.53 t/ha against the best check Varshadhan (4.81 t/ha).

Initial Variety Trial-Semi Deep Water (IVT-SDW)

Fourteen entries including three check varieties (Sabita, Purnendu and Varshadhan) were evaluated in a randomized block design with three replications under semi-deep water conditions. Among the different entries, Entry No. 503 (IET 24519; CR 2439-B-18-1-1-1-1) performed best (5.55 t/ha) followed by Entry No. 505 (IET 24495; MTU 1172)with 4.28 t/ha and Entry No. 514 (IET 24486; MTU 1184) with 4.02 t/ha against the best check Varshadhan (2.98 t/ha).

Advance Variety Trial 1-Semi Deep Water (AVT 1-SDW)

Fourteen entries including three check varieties (Sabita, Purnendu and Varshadhan) were evaluated in a randomized block design with four replications under semi-deep water conditions. Among the different entries, Entry No. 403 (IET 23906; CR 2789-9-2) performed best (4.25 t/ha) followed by Entry No. 407 (IET 23053; CR 2687-2-3-1-1-1)with 3.88 t/ha and Entry No. 411 (IET 23895; CR 2593-1-1-1-1) with 3.24 t/ha against the best check variety Varshadhan (2.93 t/ha).

Initial Variety Trial-Deep Water (IVT-DW)

Initial variety trial for deep water rice comprising eleven 1st year nominations and three 3rd year entries generated at different deep water breeding centers of the country were evaluated against 3 check varieties. Highest grain yield of 4.5.t/ha was recorded from test entry IET 23596 (CR 3836-1-7-4-1-1) followed by 4.4 t/ha and 4.2 t/ha from entry IET25219 (OR2423-1) and IET 25223(OR2420-3), respectively. The best check was local check variety, CR Dhan 500 which yielded 3.78 t/ha kg/ha.

Performance of entries nominated in AICRIP trials during 2015

Varieties identified for release during 51st annual rice group meeting held at IIRR, Hyderabad

CR Dhan 506 (IET 23053) was identified for release in the states of Assam, Andhra Pradesh and Karnataka for semi-deep water ecology. The genotype is a derivative of the cross CRLC 899 /Warda2. The mean yield in Assam, Karnataka and Andhra Pradesh were 4.7t/ha, 6.8t/ha and 3.4t/ha, respectively. The genotype is strongly photosensitive with average maturity duration of 160 days. It possesses long bold grain with a long heavy panicle having moderate seed test weight (23g). It is moderately resistant to leaf blast, neck blast, brown spot, sheath blight, sheath rot, tungro virus, stem borer (both dead heart and white ear heads), leaf folder and whorl maggot. CR Dhan 506 has good hulling, milling and head rice recovery as compared to check varieties. It possesses intermediate amylose content, long bold grain and other desirable grain quality parameters.

CR Dhan 507 (IET 22986) is proposed for release in the deepwater ecology of Odisha state. It was developed from the breeding material of cross Gayatri/Sudhir//Varshadhan. The mean yield of the variety in the state is 4.75t/ha. The genotype is strongly photosensitivewith average maturity duration of 160 days. It possesses short bold grain with a long heavy panicle having moderate seed test weight (25g). It is moderately resistant to neck blast, brown spot, sheath blight, sheath rot, stem borer (both dead heart and white ear heads), leaf folder and whorl maggot. IET 22986 has good hulling, milling and head rice recovery as compared to check and qualifying varieties. It possesses intermediate amylose content, short bold grain and other desirable grain quality parameters.

CR Dhan 508 (IET 23601) is identified for release in the states of Odisha, West Bengal and Assam states. The deep water elite line is a product of the crossCRLC 899/AC.38700. It has consistently out-performed the check varieties in the states of Assam, West Bengal and Odisha under national testing from 2013-2015. The mean yield in Odisha, Assam and West Bengal were 3.6t/ha, 3.4t/ha and 6.4t/ha, respectively. Maturity duration of the variety is 160 days. It possesses long bold grain and heavy panicle with high seed test weight (28g). It is moderately resistant to neck blast, brown spot and sheath rot, stem borer (both dead heart and white ear heads), leaf folder and whorl maggot. IET23601 has good hulling, milling and head rice recovery as compared to check varieties. It possesses intermediate amylose content, long bold grain and other desirable grain quality parameters.

Two entries *viz*., IET 23934(CR 3838-1-2-1-4-2) and IET 23895 (CR 2593-1-1-1-1) tested under AVT1-SDW have been promoted to AVT2-SDW based on yield superiority and other adaptability parameters. One entry IET 24519 (CR 2439-B-18-1-1-1-1) tested under IVT-SDW has been promoted to AVT1-SDW based on yield superiority and other adaptability parameters. Similarly, another eight entries viz., IET 25179(CR 2315-1-1-3-1-2), IET 25185(CR 3063-2-1-9-2), IET 25190(CR 3900-135-8-5-4), IET 25191(CR 2747-14-4-3), IET 25196(CR 3036-3-1-21-1), IET 25200(CR 3060-2-1-12-2), IET 25203(CR 3062-1-1-6-4), IET 25209(CR 3816-1-2-1-2-2) tested under NSDWSN have been promoted to IVT-SDW.

Breeding rice varieties for coastal saline areas

Hybridization programme

Twenty new crosses were made taking high yielding varieties/line *viz*., Luna Sankhi, Luna Barial, SR 48-2-1, TJ-12-2-2, TJ-115-3 with salt tolerant donors such as FL478, FL496, Binadhan 10, CSR 27, AC39416, AC39411, AC39417, Bhurarati, SR26B and CST-7-1. F_1 seeds have been harvested.

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

Under CSTVT in AICRIP, three entries, IET24430, IET 24434 and IET 24426 were promoted to the final year of testing (AVT 2). On overall mean basis IET 24430 (CR 2839-1-S-11-1-B2-B-46-2B) outperformed the best check (local) by 12.7%. IET 24430 derived from the cross Swarna/FL 496 was superior in overall mean yield (3411 kg/ha) with long bold grains. IET 24434 (IR 83421-6-B-3-1-1-CR 3364-S-2B-14-2B) from the cross IRRI 126/IRRI 135 was performed (3630 kg/ha) in Western zone. IET 24426 (CR 2218-41-2-1-1-S-B3-B) derived from the cross Savitri/Pateni was 2nd best in overall mean yield (5124 kg/ha) under moderate salinity stress. It possessed long bold grains with 122 days flowering duration. Apart from this 10 entries were promoted to the AVT-1 under CSTVT in 2015. They were IET 25049, IET25056, IET 25086, IET 25094, IET 25095, IET 25102, IET 25053, IET 25078, IET 25096 and IET 25101.

Evaluation of breeding lines for salt tolerance at seedling and flowering stages at simulation tank

A set of 165 salt tolerant genotypes along with three checks (Pokkali: AC41585, FL 478 and IR29) were sown for evaluation at simulation tank under control condition. Water EC at seedling stage was maintained at 12 dSm^{-1}. The stress was with drawl after 30 days. At reproductive stage again 30days were salinized with water EC 6-8 dSm^{-1}. Scoring was done at seedling stage and reproductive stage. CR3878-245-9-4-3 had highest plant yield (4.92 g) with 15.49 % of grain sterility. The plant yield of FL 478, Pokkali and IR 29 were 4.75 g, 4.87 g and nil, respectively. The best 20 lines par plant yield was given in histogram.

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

In dry season 45 breeding lines belonging to F_3 generation derived from 4 cross combinations have been raised at salinity microplot. When susceptible check, IR 29 showed susceptibility symptoms (SES score 9) then around 4300 tolerant and moderately tolerant single plants have been selected for salt tolerance at seedling stage (at EC=12 dSm-1) and planted to field. The cross combination are as follows.

a. CR2814-41-2-1-S-B1-B x Binadhan 10

b. CR2843-1-S-1-6-B-S-2B-1 x Binadhan 10

c. CR2838-1-6-3B-S-B-6-1-24-1-B (SR 12) x Binadhan 10

d. CR2838-1-6-3B-S-B-14-1-1-B (SR 27) x Binadhan 10

Development of mapping population for QTL analysis on salinity and waterlogging tolerance

RIL (F_4)populations from Savitri/Pokkali (AC39416) (tolerant to salinity, waterlogging and anaerobic germination) cross are being developed. Two RIL population (F2:7) for QTL analysis for salt tolerance from Swarna / Kamini and salt and waterlogging tolerance from Swarna/Rahspanjar have been developed. Two BC_2F_4 populations have been generated from Swarna/Chettivirippu (AC39389) and Naveen/Chettivirippu (AC39394).

Evaluation of mapping population for salt tolerance at seedling stage

A double haploid population derived from Savitri/Pokkali (AC39416A) was screened for salt tolerance at seedling stage at EC 12 dSm-1. Hundred and nineteen lines along with parents, susceptible check, IR 29 and tolerant check, FL478 with two replications were sown during February 2016 at simulation salinity tank. When the susceptible check attained SES score of 9, then scoring for all the genotypes were completed. Only two lines (DH-SP-30 and DH-SP-100) were found tolerant (SES score= 3) in all replications and another 15 lines were observed tolerant to moderately tolerant (SES score= 3-5) (Fig. 1.7). Around 1450 single plants from tolerant and moderately tolerant lines were selected, rescued and planted to the field.

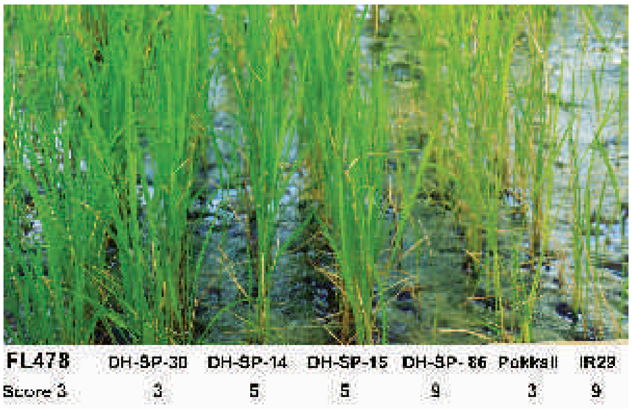


Fig. 1.7. Evaluation of double haploid population derived from Savitri/ Pokkali

Identification of differentially expressed miRNAs for salinity tolerance at reproductive stage

Pokkali (AC41585) was identified as one of the salt tolerant lines at flowering stage. The role of small RNA (miRNA) in gene regulation during salt stress at flowering stage has been studied. In this study, two small RNA libraries, one each from control (0 salt) and salt-treated (NaCl solution; 8 dsm^{-1}) leaves of Pokkali (AC 41585) were sequenced using next-generation sequencing technology (Ion Proton™ system) and generated a total of 43.55 and 40.22 million reads (Fig.1.8) with mean length of 19 and 20 respectively. Raw reads were preprocessed using Fastx toolkit and then aligned on to reference genome (Nipponbare) using Bowtie2 tool. Mapped reads were 92.20% and 93.59% in control and salt-treated samples respectively. A total of 1,596 matured miRNA have been detected in both the samples. Differential expression analysis were predicted using the R package DESeq2 tool. To detect differentially expressed miRNAs, we compared the level of expression of miRNAs between the control and salt-treated samples by using log2-ratios and Volcano plot. Based on this analysis, 96 miRNAs were found to be differentially regulated between the control and salt-treated samples of Pokkali at 1.5-fold change. Further analysis such as target identification, annotation and validation, up or down regulated miRNAs and its validation of expression pattern etc. are in progress.

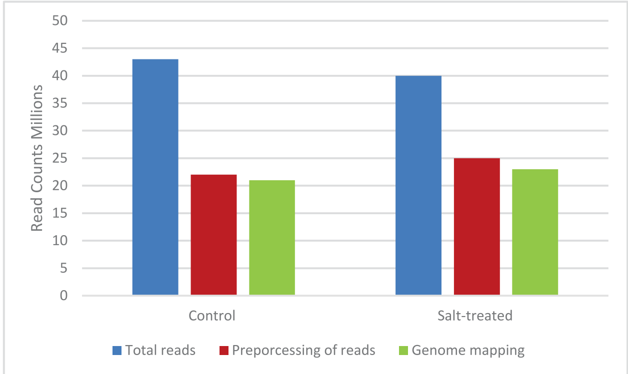


Fig.1.8. Graphical representation of number of read counts of small RNA sequencing results from Pokkali genotype. Totals reads, preprocessing of reads and genome mapping are denoted by different colors in the graph.

Evaluation of breeding materials during dry 2015 at target site

Nineteen short duration salt tolerant genotypes with two checks (Luna Sankhi and Naveen) were evaluated for salt stress and non- stress condition at farmer's field in replicated design. The water EC range varied from 4.6 to 8.9 dSm^{-1}throughout the growth period. The highest yield was recorded in CR 3881-M-3-1-5-1-1-1 (4.36 t/ha) followed by CR 3881-M-3-1-5-2-5-1 (4.09 t/ha) in saline condition. The saline tolerant check, Luna Sankhi yielded 3.15 t/ha. In non stress condition highest yield was recorded in CR 3881-M-3-1-5-2-5-1(7.51 t/ha) followed by CR 3881-4-1-3-7-2-3 (7 t/ha). Naveen yielded 6.3 t/ha (Fig.1.9).

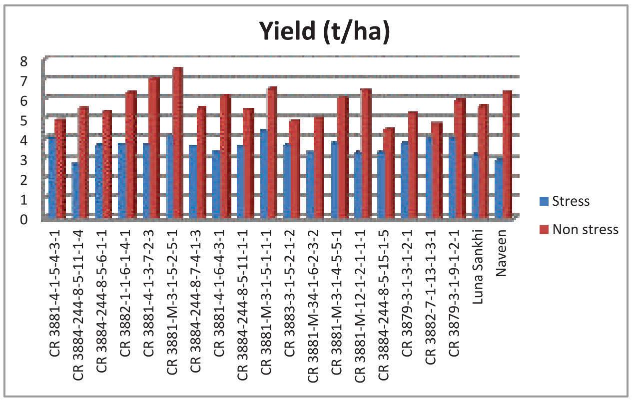


Fig.1.9. Yield comparison in salt stress and non-stress condition in dry season 2015

Evaluation of breeding material in wet season 2015 at target site

Twenty seven short duration salt tolerant genotypes with three checks (Luna Sankhi, Binadhan 8 and IR29) were evaluated at salt stress and non-stress condition at farmer's field in replicated design. The crop was subjected to high salinity stress (water EC range from 8.3 to 11.8 dSm^{-1})starting from planting to maturity. As a result all genotypes were completely damaged. However in non-stress condition the highest yield was recorded in CR 3881-M-3-1-1-3-1-1 (5.1 t/ha) followed by CR 3881-M-3-1-5-3-1-1 (4.81 t/ha) (Fig.1.10).

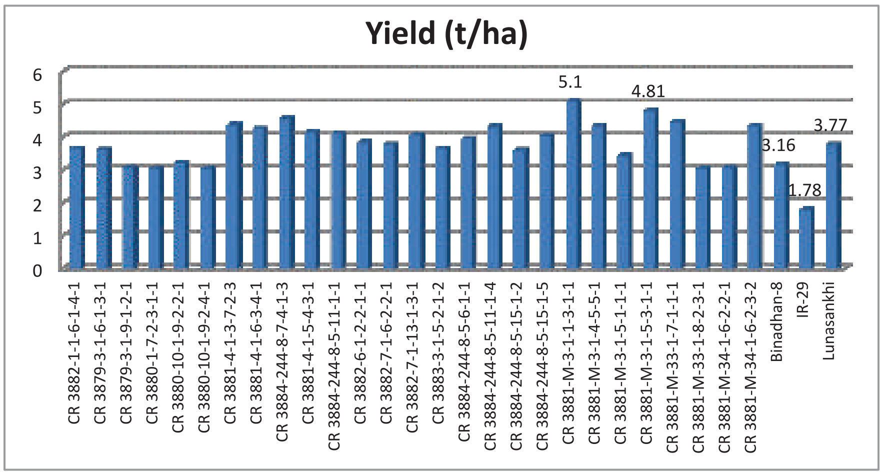


Fig.1.10. Yield of salt tolerant genotype in non stress condition in wet season 2015

Breeding rice varieties under salinity and waterlogging situation for wet season

F_3 seeds from four multiple crosses involving tolerant sources for salinity (Pokkali, Kamini, Ravana), waterlogging (AC39416, Varshadhan) have been harvested. Ten salt tolerant genotypes were evaluated at waterlogged situation with water depth upto 50 cm. CR 2459-23-1-1-S-B1-2B-1 (Gayatri/Rahspunjar) was found tolerant with estimated grain yield of 4184 kg/ha. This line also found promising under saline situation with estimated yield of 4250 kg/ha. Apart from this, another three lines, CR 2850-S-2-B-2-1-2-1 (Gayatri/FL496), IR 83425-B-AJY4-1-AJY2-CR 3382-S-1-1-4B-1 (IRRI 147/Pokkali), CR2814 (2843)-1-S-1-6-B-S-B-39-2B-1 (Naveen/FL 478) with estimated yield of 4500 to 4730 kg/ha were identified with higher yielding potentiality under coastal saline situation (EC= 2.5- 8.8 dSm-1). They were nominated for CSTVT trial.

Agronomic trial in coastal saline area

An experiment was conducted in the farmer field with moderate salinity of 3.2 to 8.6 dSm^{-1}at kujang, Ersama during dry season, 2015. Three salt tolerant rice varieties with one check (V_1: Bina Dhan 8, V_2: Bina Dhan 10, V_3: Luna Sankhi and V_4: Naveen(check)) were taken in the main plots and different planting density (S_1: 20 cm x 15 cm, S_2; 15 cm x 15 cm, S_3: 10 cm x 15 cm and S_4). Farmers practice(Random planting) were taken in the sub-plots with three replications. Results revealed that Bina Dhan 10 exhibited significantly maximum grain yield which was 27.9% higher than check and 14.7% higher over Luna Sankhi. Among the planting density, close planting 10 cm x 15 cm gave significantly higher grain yield (5.57 t/ha) over wider/normal spacing of 20 cm x 15 cm and farmers practice.

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 (from indigenous and exotic sources)

In dry season 2015, 80 elite lines basically derived from second generation NPTs 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) (Table 1.3). The entries were tested in Randomised Complete Block Design (RCBD) with two replications and with five checks *viz*., Naveen, Annada, IR-64, MTU-1010 and Swarna. Among the genotypes, CR 3624-1 recorded highest grain yield of 8.36 t/ha followed by CR3727-3, with 7.98 t/ha. There were yield advantages of 24.77%, 19.10%, 18.50%, 16.19%, 11.20% and 6.0% against best check MTU1010 (6.70 t/ha). Similarly, during wet season 2015, the same set of genotypes was planted under similar experimental conditions. Out of all the lines, CR2500-8 performed the best (6.1t/ha) followed by CR3978-3 (6.0 t/ha), CR2463-5-1 (5.68 t/ha), CR3980-5 (5.48t/ha) and CR3979-3-1 (5.35t/ha). There were yield advantages of 34.36 %, 32.15%, 25.11%, 20.86% and 17.62 % against best check Naveen (4.54 t/ha). It was analyzed that, there were appreciable number of ear bearing tillers, higher fertile grain number, along with higher 1000 grain weight that contributed to higher grain yield in comparison to checks.

Table 1.3: Performance of superior genotypes during dry season, 2015

Genotypes	Station code	GY	DFF	PH	PPM	FLL	FLW	NFG	NSP	TGW
CR 3624-1	N 306	8.36	109	101.4	227	35	1.39	123.0	13.1	23.38
CR 3727-3	N 370	7.98	101	106.5	259	36.8	1.21	102.0	12.8	25.49
CR2500-6	N 100	7.94	105	91.9	208.5	32.4	1.31	103.0	9.9	30.83
CR2463-5-1	N 336	7.45	109	96.4	247	34.8	1.37	113.6	12.7	23.48
CR2500-8	N 353	7.2	102.5	109.8	264.5	37	1.29	116.1	11.5	24.39
MTU 1010	-	6.7	98.5	99.2	244.5	35.8	1.40	111.5	9.9	21.52
LSD (5%)		0.71	3.3	2.94	20.76	5.6	0.34	8.7	3.6	2.92

GY: Gr. yield(t ha^{-1}), DFF: Days to 50% flowering, PH: Plant height (Cm), PPM: panicles/m^2, FLL: Flag leaf length (Cm), FLW: Flag leaf width (Cm), NFG: No. of Fertile grains/ panicle, NSP: No. of sterile grains/ panicle, TGW: Thousand grain weight.

Revealing contrasting genetic diversity in NPT selections using microsatellite markers

Forty eight breeding lines selected mostly from second generation NPT (top performers of Advanced Yield Trial) along with 12 checks (6 popular *indica* varieties, 3 *tropical japonica* and *temperate japonica* each). Sixty six, out of 160 markers were found to be polymorphic (distributed over 12 chromosomes) and were used to asses genetic diversity at molecular level. PCR amplification was done and the amplified products were separated on 2.5-3% agarose gels. The data was analyzed using, NTSYS-pc (Version 2.02). Further, the genetic diversity parameters were calculated by POPGENE as well as population structure analysis.

A total of 154 reproducible alleles were amplified, all being polymorphic with an average of 2.33 alleles per locus. Two unique alleles were identified which could be used as diagnostic marker in future. Two major clusters were observed at 54% of genetic similarity coefficient. PIC value for 66 SSR loci ranged from 0.516 (RM6266 and RM489) to 0.92 (RM204) with an average of 0.704.

Genetic diversity calculated by POPGENE, resulted expected homozygosity in the range of 0.262 (RM1132) to 0.967 (RM6266 and RM489) which is similar to Nei's genetic diversity. The expected homozygosity was negatively co-related to Nei's genetic diversity. The pair-wise genetic distance among the genotypes varied from 0.082 (lowest) between C-105A51 and Nipponbare to 1.006 (highest) between Samba mahsuri and IR73930-31-3-2-2-2 (N 65) with an average distance of 0.504 . No duplication among the accessions was recorded, which indicated that NPT lines were divergent. Moreover, the population STRUCTURE analysis revealed the existence of two optimum sub-populations with an allele frequency divergence of 0.1204. A total of 46.2% and 53.8% genotypes were present in sub-population POP1 and POP2 respectively, with average genetic distance of 0.2246 and 0.4339 in that order. However, 18 admixtures were detected which had a membership percentage of <80 for any inferred population. The neighbour-joining dendrogram constructed based on pair wise genetic distance in

MEGA6 was in line with the results of population structure (Fig. 1.11).

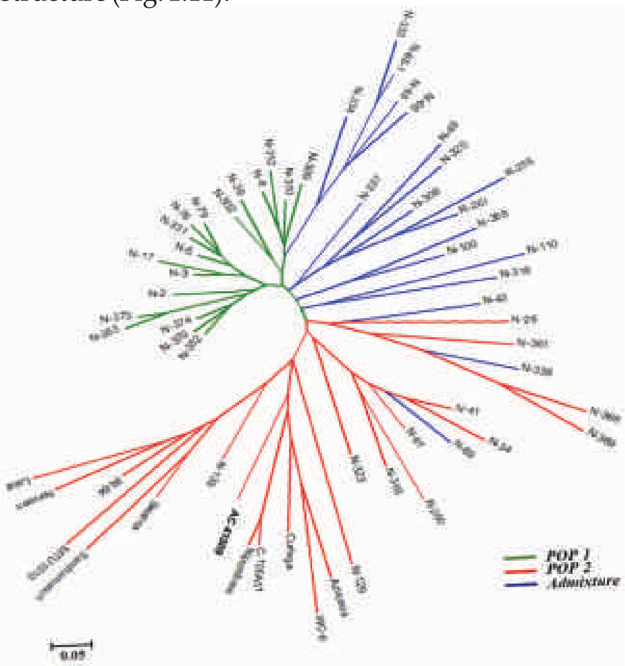


Fig.1.11. Genetic relationship between NPTs using popgene and their Segregation into populations

Analysis on sub-clustering pattern had correspondence to their sub-species classification *viz*., *indica*, *tropical japonica (TJ)* and *temperate japonica (TeJ)* etc. Moreover, the presence of significant diversity among NPT rice genotypes was clearly observed. Cluster I comprised all segregants from *Indica* and *TJ* derivatives(2nd generation NPTs and irrigated cultures). Second cluster consisted of different fixed lines basically derived from three major groups of *Oryzaviz*., *Indica,TJs and TeJs.* There was ample variation among NPT selection which could be effectively utilized for getting transgressive segregants upon hybridization.NPT selections although derived from *TJ* s and *indica* lines, still maintain sufficient genetic distance from *indica, TJ* s and *TeJs* and therefore, could be utilized for potential recombinants if crossed with genotypes of these sub clusters.

Genotypes are not clustered exactly according to their phylogeny. The cultures from different origin included in the same cluster, might be due to similar yield potential, morphology, segregation during selection, natural mutation and similarity at genome level. However, one NPT line comes in between *indica* and *temperate japonica* IR74714-141-3-3-2-4-3 (N 135), which is also close to popular mega variety Swarna, derived from Mashuri (product of *japonica* x *indica*). The information on genetic diversity could be very useful for selection of parents in biparental or multi parental mating to obtain potential transgressive segregants.

Identification of limitations in stable promising existing NPTs on the basis of morpho-physiological traits and biotic stress resistance :

Physiological efficiency of selected NPT lines for irrigated ecosystem

Six selected NPT lines along with high yielding checks MTU 1010 and Swarna were grown under field condition in a randomized block design with four replications during dry and wet seasons of 2015 with fertilizer dose of N:P:K@100:50:50 kg/ha in wet season and 120: 60: 60 kg/ha in DS.

Highest photosynthetic rate was observed in CR3856-44-22-2-1-10 (33.28 µmol CO_2 m^{-2} s^{-1}) in dry season and CR 3938-2-2-1-1-1-4 (36.07 µmol CO_2 m^{-2} s^{-1}) in wet season. CR 3938-2-2-1-1-1-4 and CR 3856-44-22-2-1-7-1 in dry season and CR 3856-44-22-2-1-7-1 and CR 3856-44-22-2-1-10-1 in wet season also recorded higher values for this trait compared to others. Grain yield was recorded highest in CR 3856-44-22-2-1-11-1 (6.82 t/ha) followed by CR3936-11-1-1-1-1 and CR 3856-44-22-2-1-10-1 (6.54 and 5.96 t/ha) during dry season and during wet season highest yield was obtained in CR 3856-44-22-2-1-7-1 (6.27 t/ha) followed by CR 3856-44-22-2-1-10-1 and CR 3936-11-1-1-1-1 (5.65 t/ha). Higher grain yield in these genotypes might have been contributed by high photosynthetic rate and higher biomass. Overall yield advantage in these NPT lines was 14.8 % and 16.5% over check variety MTU1010 in DS and WS respectively and highest yield advantage was obtained in CR 3856-44-22-2-1-11-1 in dry season and CR 3856-44-22-2-1-7-1 in wet season (>30.0%).

In general, the rate coefficient (ϒ) 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 (Fig.1.12). However, rate of partitioning to panicle was highest in CR 3856-44-22-2-1-7-1 (6.44 g/day/m2), which was being reflected in highest grain yield production.

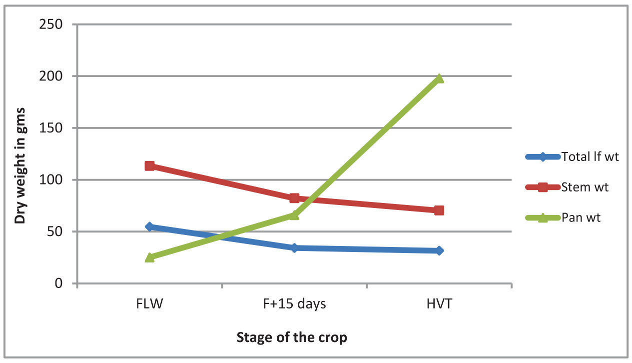


Fig.1.12. Biomass partitioning of different plant parts during flowering to maturity in selected NPT lines

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

Three hundred and sixty different genotypes including *tropical japonicas* (with wide compatibility 'wc' genes), their derivatives and other exotic lines along with four checks (IR 64, Gayatri, CR 1014 and Pooja) and screened in a Randomised Complete Block Design (RCBD) with two replications. Many key characters have been identified that could be useful if assembled in a particular fashion for deriving high productivity. Therefore, this set was screened for specific traits, for their suitability as parents for biparental/ multiparental mating for prospective hybridization in order to achieve transgressive segregants for development of super rice.

1. **Plant height:** Semi-dwarf height is ideal for an ultimate variety in farmers' field. In super rice however, 20% increase in height is recommended for higher biomass and ultimately, higher yield. Therefore, the following genotypes with semi-dwarf height and appreciable grain yield could be wise choice as diverse parents when selected for complementing parents in *indica cultures* (values in the parenthesis indicates grain yield/m^2).

   a. Height in the range of 100cm: EC497036 (515.82g), EC497023 (504.0g), EC497015 (495.6g) and EC496931 (423.4g)

   b. Height in the range of 110-120cm: EC491146 (618.8g), EC496927 (755.35g), EC496907 (528.0g)

2. **Number of effective tillers:** There should be 8-10 number of effective tillers to have optimum population. In this context, the following genotypes were identified as potential with high tillers as well as good yield.

   EC491203 (11.1), EC491172 (10.5), EC491221 (10.4), EC 496860 (10.4), EC497121 (9.6), EC 491288 (9.0) and EC 491466 (8.6).

3. **Number of fertile grains/panicle:** This is one of the important targeted traits for achieving higher grain yield. In this context, the following genotypes were recorded with high grain number at least to the tune of 20% superior than check varieties: EC491436 (227.6), EC496927 (193.6), EC491169 (192.3), EC 497036 (190.9), EC497180 (179.9) and EC 491146 (176.3). Out of these EC 491436, EC 491146 and EC 497180 were also found with high grain yield.

4. **1000 grain weight:** This is also one of the major character contributing grain yield. Higher grain weight might have significant contribution towards productivity, but it may not be accepted by the consumer, if the grain size is very bold. Therefore, there should be a limit for grain size. In this context, some of the exotic lines were found with high 1000 grain weight *viz*., WC 491379 (42.73g), EC 491385 (39.84g), EC 491313 (38.67g), EC491372 (37.92g), EC 491319 (36.82g) and WC 273 (36.32g).

5. **Top leaf length and width:** To achieve more grains per panicle more biomass is essential. To increase biomass one way is to increase plant height. However, if height is increased, then the chance of lodging increases, therefore, another way of increment of biomass is increasing in top three leaf length and breadth. In this context, genotypes with long and wide first two leaves vis-à-vis high grain yield were EC 491384 (first leaf length (FLL) 57.0cm, width (FLW) 2.04;2nd leaf length (SLL) 71.0cm and width (SLW) 1.6cm), EC 491379 (FLL 53.2cm, FLW 2.04cm; SLL 57.0cm, SLW1.8cm), EC491328 (FLL 56.0cm, FLW 2.22cm; SLL 76.2cm, SLW2.08), EC 491435 (FLL 53.8cm, FLW 1.6cm; SLL 64.6cm, SLW 1.5cm) and EC 491358 (FLL 49.6cm, FLW 2.3cm; SLL 70.0cm, SLW 2.0cm)

6. **Grain yield**: In this context some of the genotypes were found to be highly promising. Among the lines EC 496927, EC 491180, EC 491146, EC 491384 and EC 496983 were found to

have high grain yield with 755g, 625g, 618g, 608g and 580g per m^2, respectively. However, considering the specific requirements, other genotypes could also be chosen for prospective utilization in breeding programme.

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

Basically 2nd generation NPTs and some of the stable high yielding checks were supposed to be the potential candidates for development of super rice genotypes. In this context, 40 new crosses were attempted involving elite cultures (CR 3856-44-22-2-1, CR Dhan 307, Pusa 44, Tapaswini MAS, Swarna MAS, Wita-12, MTU-1010, IR 64 MAS etc.) along with *tropical japonicas* and aromatic derivatives and 40 F_1 were grown for developing Next Generation super rice (NGR). Some of the crosses with *tropical japonica* parent did not perform well, therefore the F_1 s of wide crosses were again backcrossed to *indica* elite lines for recovery of popular *indica* features along with introgression of super plant type traits.

Selection and generation advancement of segregating generations with super rice traits and biotic stress tolerance

Irrigated/ Shallow low land: Progeny row of Single Plant Selection in different generations *viz*., 286 F3, 110 F4, 63 F5, 44 F6, 21 F7, 6 F8, 8 F9 along with 54 F2 were grown for developing NGR .During development of super rice many heavy panicle type genotypes were identified. However, many of them were shy tillering type. Therefore, genotypes with moderately high tiller number, slightly less grain number as well as appreciable grain yield were selected and generation advancement was done using progeny row method.

Screening of super rice genotypes and NPT lines for resistance/tolerance against sheath blight pathogen, *Rhizoctoniasolani* Kuhn

A total of 91 super rice and NPT genotypes (87 super rice and 4 NPT lines) along with susceptible check, Tapaswini were taken up during wet season 2015 with a view to screen for resistance/tolerance against sheath blight pathogen, *Rhizoctonia solani* Kuhn. In the maximum tillering stage, the plants of each and every genotypes were artificially inoculated with the sheath blight pathogen, *Rhizoctonia solani* Kuhn by inserting its sclerotial bodies along with 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 by adopting 0-9 SES scale.

The results showed that out of 87 super rice genotypes, 11 showed tolerant reaction (disease score of 3.1-5) whereas, 61 were found to show susceptible reaction (disease score of 5.1-7) and 15 genotypes to be highly susceptible (disease score of 7.1-9) against sheath blight pathogen. Eleven super rice genotypes showing tolerant reaction were CR3938-1-2-1-2-4-1, CR3856-44-22-2-1-11-1, CR3936-1, CR3938-1-2-1-2-4-1, CR3967-8-3-2-2-1-1, CR3856-44-22-2-1-10-1, CR3856-29-2-1-1-2-1-1, CR3966-5-1, CR3856-44-22-2-1-14-1-2, CR3938-3-1 and CR3938-4-1.

In case of NPT lines, only one line, namely CR2324-1 showed tolerant reaction against sheath blight pathogen, whereas, 3 lines (CR3961-4, CR3624-2, IR 73963-86-1-5-2) were found to be susceptible. However, none of the genotypes and lines showed resistant reaction.

Field screening of breeding lines against yellow stem borer

Field screening of 14 *Tropical Japonica* lines along with one susceptible check TN 1 was undertaken during dry season 2016. At vegetative stage, twenty hills were randomly selected and total tillers and damaged tillers due to dead heart symptoms by yellow stem borer were counted from each entry planted in the field and replicated three times. Percent dead heart was calculated and damage scoring was done based on IRRI score (SES, 2002). The results revealed that three entries *viz*., EC491229, EC491322 and EC496970 showed zero damage score as against the susceptible check TN 1 (32.1%).

Introgression of BLB resistance through molecular approach:

In order to develop breeding material with super rice plant type and important 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, 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, back cross breeding programme was initiated along with marker assisted backcrossing. During 2014-15 fresh backcross was performed and during wet season $BC_1 F_1$ seeds have been made using heavy panicle genotype CR 3856-44-22-2-1-11-1 as recipient and IRBB-60 containing *Xa21*, *xa13* and *xa5* resistant genes as donor.

Preliminary yield trial for irrigated and shallow lowlands (PYT):

In the process of development of NGR the promising crosses were advanced in progeny row method with single plant selection from different cross combinations. Few fixed segregants were found promising because of super quantitative traits. In this context, 75 fixed lines were tested for their performance in Preliminary Yield Trial (PYT) for super rice traits that contributes towards higher grain yield. The experiment was laid out in RCBD with two replications and the popular varieties *viz.*, Annada, Naveen, MTU 1010 and Swarna were taken as checks. During dry season2015, highest yield was recorded in genotype, CR3856-44-22-2-1-11-1(7.67 t/ha) followed by CR3936-11-1-1-1-1-1 (7.28 t/ha), CR3856-44-22-2-1-10-5 (7.13 t/ha) , CR3938-2-2-1-1-1 (6.67t/ha) and CR3967-10-1-1-1-1(6.05 t/ha) having 48.93%, 41.35%, 38.44%, 29.51% and 17.47 % yield superiority over best check, respectively. Higher grain yield was attributed due to its component traits *viz.*, heavy panicles, higher number of fertile grains per panicle, less number of tillers (5-6 in high yielders) and higher biomass. The higher biomass resulted from slightly raised plant height due to long and wide leaves and higher culm diameter rather than higher plant height.

Similarly, during wet season 2015, the same set of genotypes was tested under similar experimental condition. Maximum grain yield was obtained in genotypes CR3969-17-2-2-1-1(9.5 t/ha), followed by CR3938-6-2-1-1-1(8.90t/ha), SR 3938-22-1-1-1-1(7.86 t/ha), CR3856-44-22-2-1-14-4 (7.23 t/ha) and CR3936-11-1-1-1-1-1-2 (7.16 t/ha) having 42.8%, 33.8%, 17.8%, 8.5% and 7.5%, respectively yield superiority over checks. Higher grain yield was attributed basically due to a balance of higher number of fertile grains and higher effective tillers and biomass. The higher biomass resulted due to long and wide leaves including strong culm. However, the height of the highest yielding culture (CR3969-17-2-2-1-1) was significantly less in comparison to the other top most yielders and best check which makes it more lodging tolerant (Table 1.4).

Table 1.4: Performance of promising super rice genotypes during wet season 2015

Genotypes	GY	DFF	PH	PPM	FLL	FLW	NFG	NSP	TGW
CR3969-17-2-2-1-1	9.03	112	110.8	221.5	40.4	1.44	160.8	14.6	21.6
CR3938-6-2-1-1-1	8.92	109	128.6	243.5	39.1	1.64	145.1	16.95	21.35
CR 3938-22-1-1-1-1	7.86	111	131.6	236.0	51.9	1.37	157.7	22.2	20.92
CR 3856-44-22-2-1-7-4	7.23	101.5	124.3	232.5	31.8	1.55	112.6	46.5	24.71
CR 3936-11-1-1-1-1-1-2	7.17	111	140.9	193.5	36.0	1.83	119.9	61.55	28.45
Swarna	6.67	121	105.8	281.0	33.3	1.52	104.8	25.8	18.24
C.D.(0.05)	0.84	2.40	5.1	19.5	4.8	0.32	10.2	4.6	2.36

GY: Gr. yield(t ha^{-1}), DFF: Days to 50% flowering, PH: Plant height (Cm), PPM: panicles/m^2, FLL: Flag leaf length (Cm), FLW: Flag leaf width (Cm), NFG: No. of Fertile grains/ panicle, NSP: No. of sterile grains/ panicle, TGW: Thousand grain weight.

Development of superior genotypes in favourable upland:

Generation advance of promising crosses

The F_3 generation of CR Dhan 40 / IR73963-86-1-5-2-2 was raised under transplanted condition during wetseason 2015 and 59 individual plants were selected based on traits like flag leaf angle, flag leaf length & breadth, panicle length, stay green character, grain yield and other yield attributing traits. Progeny row of 59 F4 plant were raised during dry season 2016 at NRRI Cuttack. Similarly, F_5 populations derived from 8 different crosses (Benibhog x CH 45, Sahbhagidhan x Naveen, Sahbhagidhan x Annada, Vandana x Naveen, Vandana x Swarna Sub-1, Anjali x NPT PSR 14, CR Dhan 40 x NPT PSR 14 and Sahbhagidhan x NPT PSR 18) were raised during dry seaso 2016. The population consisted of 197 F_5 plant progenies and selection would be made based on grain yield and super rice traits.

Development of superior genotypes in shallow lowland:

Variety CR Dhan 307 (Maudamani): It was recommended for notification, for favourable rainfed lowland / irrigated conditions of Odisha. It was progeny of cross Dandi/Naveen//Dandi with medium duration flowering (105 days), semi-dwarf, non-lodging with an average yield of 4.8 t/ha. It produces short bold grain, 278 panicles per m^2, good tillering with high grain number with desirable quality traits *viz*., high milling %, intermediate ASV, intermediate amylose and gel consistency. It exhibited moderate resistance reaction against the pests stem borer, leaf folder, rice whorl maggot, green leaf hopper, gall midge biotype 6, hispa and rice thrips; and diseases like leaf blast, neck blast and brown spot.

Phenotyping of a Recombinant Inbred Line (RIL) population derived from the cross CR 2324-1/ IR 73963-86-1-5-2 for yield attributing traits.

A $F_{9:10}$ mapping population consisting of 173 RILs derived from the cross CR 2324-1/ IR 73963-86-1-5-2 was utilized in the present study (Fig.1.13). The female parent CR 2324-1(P_1) is the superior parent having heavy panicle and higher grain number/ panicle. Whereas, the female parent IR 73963-86-1-5-2(P_2), which is a second generation-derived new plant type (NPT) line, has light panicle and less number of grains per panicle. The experiment was carried out in RCBD with two replications during the wet season (2015) in the experimental field of the National Rice Research Institute (NRRI), Cuttack. At maturity ten panicles were randomly collected from each line in the population and sun dried for reducing the moisture content. Individual RILs and parents harvested were subjected for phenotypic evaluation for four yield attributing traits *viz*., panicle weight, number of fertile grains/ panicle, number of chaffs/panicle and 1000 grain weight. Single panicle was threshed separately and the data on the above traits were recorded. The replicated data of the ten panicles, for the above traits, were subjected for statistical analysis *viz*., analysis of variance (ANOVA), mean, range, genetic variability components such as phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2) and genetic advance as per cent mean (GAM) and correlation analysis. A statistical software GraphPad Prism was used for the analysis. The number of lines that exceeded the performance of the better parent were noted as superior segregates for that particular trait and expressed as per cent of the total population.

Fig.1.13. RIL population of CR 3856 (CR 2324-1/ IR 73963-86-1-5-2)

The analysis of variance indicated significant variation for all the yield traits among the RILs, but the coefficient of variation (CV) was found to be high for all the traits, especially for the number of chaffs per panicle indicating that the effect of environment was high in conditioning these traits in the present study. Phenotypic data analysis for genetic variability components revealed higher magnitude of variation with high heritability and genetic advance for all the traits except No. of chaff/panicle.

Resistance breeding for multiple insect-pests and diseases

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

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

During dry season, 2015, forty five BC_2F_1(Naveen/ CRMAS 2231-37 // Naveen/ CRMAS 2620-1) plants along with recurrent and donor parents were grown. Using molecular markers, BC_2F_1plants were identified with all the five genes targeted (*xa5, xa13, Xa21, Pi2 and Pi9*). Selected plants were used for backcrossing with recurrent parent to get BC_3F_1seeds.During wet season, 2015, 26 selected BC_3F_1plantswere grown. From these 26 plants, 3 plants with all the five targeted genes were selected based on morphological characters and molecular analysis.

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

During dry season 2015, Sixty four BC_1F_1 plantsof cross (Pooja/*CRMAS 2232-71///* CRMAS 2619-9)were grown along with recurrent parent Pooja in the net house in a staggered manner. Selected plants with targeted genes having morphological characters of recurrent parent were used to backcross with the recurrent parent. Eighty four BC_2F_1seeds were harvested. During 2015 wet season season these BC_2F_1seedswere grown to get BC_2F_2plants. Only three plants with desired characters were selected for further analysis.

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

Twelve backcrosses were made taking elite varieties *viz*., Naveen, Pooja, Swana sub1, Tapaswini and promising donors for BPH, tungro and sheath blight disease. For tungro disease, IET 16952, Vikramarya and Kataribhog were taken as the resistant donors; for sheath blight CR 1014, Tetep, IET 19346, ADT; 39 and Jogen were used and for BPH resistance CR 3006-8-2 (derived from a cross combination of Pusa 44 / Salkathi), IR 65482-7-216-1-2 (Bph 18) and IR 71033-121-15-B (Bph 20 and Bph 21) were taken as donors.

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

Twelvegenotypes earlier found to be tolerant to sheath blight were again screened under artificial inoculation with *Rhizoctonia solani*virulent isolate ShbSL4 for revalidation. The genotypes were screened along with Tetep as tolerant check and Tapaswini, Annapurna, Swarna,Swarna sub 1 as susceptible checks.In the maximum tillering stage the plants of each genotype were artificially inoculated with the virulent isolate of the sheath blight pathogen, *R.solani* (Isolate ShbSL4) by inserting five sclerotial bodies alongwith bits of mycelia inside the leaf sheaths and sprayed with clean water regularly for creating favourable environment for the inoculums. The sheath blight disease incidences were recorded in the genotypes by adopting 0-9 scale of SES. CR 1014 was found to be moderately resistant (disease score of 2.8) and four genotypes i.e., Tetep, Manasarovar, IET 17886 and IET 20443 were found to be tolerant (disease score of 3.1-5).

One hundred F_3 lines derived from the cross MTU 1010 /IR 75870-8-1-2-B-6-1-1-B (derived from IR 64/ *O. glaberrima*) were screened against BPH and blast under artificial inoculation. Seventeen lines were found to be resistant to BPH (score 1-3) and 11 lines were found to be resistant to blast with score 3. Two lines showed resistant to both BPH and blast.

Identification of QTL for RTD resistance

Bulked segragnat analysis identified five out 84 polymorphic SSR markers putatively linked to QTL controlling RTD resistance in genotype IET 16952. One hundred and eighty seven RILs along with parents Tapaswini (susceptible) and IET 16952 (resistant) were genotyped with 5 putative SSR markers. The linkage map was constructed using integrated QTL IciMapping (v.4.0) software (*www.isbreeding.net*). The interval mapping (IM) analysis using integrated QTL IcMapping (v.4.0) software identified one QTL *qRTV1.1* on chromosome 1. The QTL *qRTV1.1* with LOD score 3.23 explained phenotypic variance (PV) of 18.57% towards resistance to RTD (Table 1.5 and Fig. 1.14). The region comprising RM 297 was further studied to explore the presence of resistance genes. *In sililico* analysis identified three candidate genes - AP003274 (coding for one unknown protein), AP003274(coding for a rhomboid protein) and AP003274(coding for a putative transcription factor) in the QTL region.

Table 1.5: Estimates of QTL position, effects (Interval Mapping) using QTL IciMapping Program

Trait Name	Chromosome No.	Position (cM)	Left marker	Right marker	LOD	PVE%	Add
RTD resistance	1	19	RM 297	RM 11701	3.23	18.57	-14.05

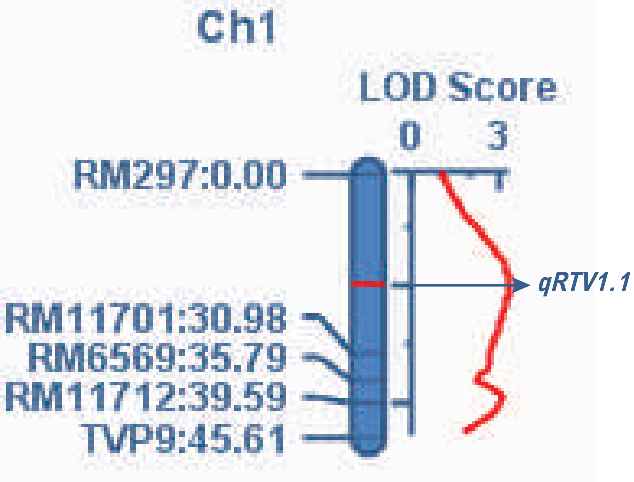


Fig.1.14. Location of QTL, *qRTV1.1* on rice chromosome 1 associated with RTV resistance using integrated QTL software IcMapping

Performance of entries in AICRIP trials during 2015

CR 2711-149, derived from a cross between Tapaswini / Dhobanumberi (BPH tolerant donor) was found to be promising against multiple insect-pests (BPH, BPH+ WBPH, GM and SB) while tested against 10 insect pests in 31 locations in Multiple Resistance Screening (MRST) Trial of AICRIP, 2015. This entry was found to be promising for two consecutive years.

CR 3939-18 (IET 25318), a selection from MTU 1001 / Pusa 44, which was tested under IVT-IM has been promoted to AVT 1-IM. Another culture CR 3981- 47-17-5 (IET 25266), a selection from Swarna / Salkathi, nominated under IVT-Late has also been promoted to AVT 1-L. CR 3862-29-15-7 (IET 25244), a selection from Swarna / Sarasa, which was tested under IVT-L has also been promoted to AVT I- L.

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

Fourteen entries include seven improved lines for bacterial blight and blast resistance and seven check varieties including four Donor Parents *viz.*, C101 LAC, C101 A51, Tetep and DHMASQ 164-2B and three recurrent Parents *viz.*, Swarna, Samba Mahsuri and Improved Samba Mahsuriwere evaluated in a randomized block design with three replications under irrigated conditions. Among the different entries, recurrent parent Swarna (Entry No. 3513) performed best with an average yield of 7.41 t/ha followed by Entry No.3501 (IET 25480)with 6.22 t/ha and Entry No. 3512 (IET 25484)with 6.18 t/ha and recurrent parent Samba Mahsuri (Entry No. 3504) with 5.38 t/ha).

New nominations for AICRIP trials

CR 3808-13 and CR 2711-76-13-1 for IVT-IM, CR 3808-57, CR 3941-14, CR 3943-6, CR 3942-2 and CR 3862-49-26-5 for IVT-L, CR 3939-4 and CR 3941-7 for IVT-MS were nominated for AICRIP trials of 2016.

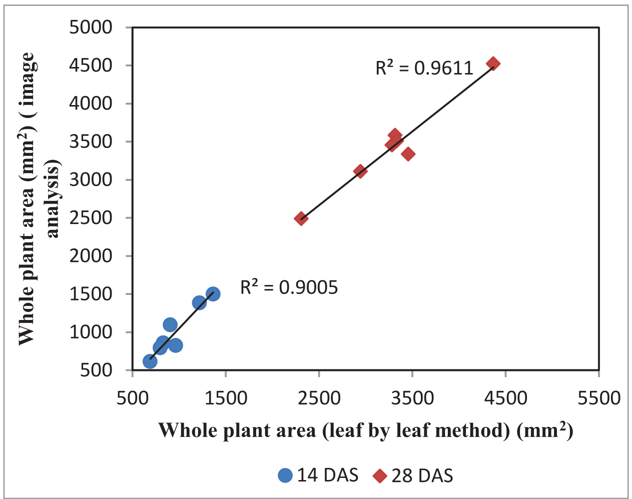
Breeding for Higher Resource Use Efficiency

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

A panel of 265 land races and improved lines were evaluated under direct seeded condition along with four checks (Dular, Shabhagidhan, Vandana and Varshadhan) during dry season 2016. Genotypes Sada Bahar and Sana Phou exhibited high absolute growth rate (AGR) than checks. Further, Chakhao Aubi, Hazzari Dhan, Sattari, Badsaria, Kabuk Phou, Bori and Vandana recorded higher AGR than the general mean of 0.483 cm day^{-1}. These selected genotypes should be tested for weed competitiveness ability to infuse them in future breeding program.

Novel methodology to assess early seedling vigour through image based phenotyping by non-destructive way

Early seedling vigour is the necessary trait to obtain rapid, uniform germination and the establishment of strong seedlings in direct seeded condition. The development of strong seedling vigour rice requires efficient and high-throughput screening techniques to identify promising lines for strategic breeding programme. Therefore, a non-destructive image based phenotyping protocol has been developed by assessing whole plant area by image analysis. Seven genotypes were studied to assess their growth over time on 14 and 28 days after sowing (DAS). The genotypes were first inducted for photograph, later the same plant was dissected into leaf and stem. Each leaf and stem was measured individually and whole plant area was calculated. The image taken as photograph was processed to calculate the whole plant area by using ImageJ software.To find the worthiness of image analysis, the whole plant area measured by leaf by leaf method and image analysis by photography of each genotype over the time was analysed (Figure 1.15) by regression. The linear regression and strong positive correlation coefficient (*r*) (r= 0.948 on 14 DAS and r=0.980 on 28 DAS) suggested that, image analysis has the potential to be used for high throughput screening procedures in the development of early seedling vigour genotypes in rice and useful tool for plant breeders and physiologists.



*DAS: days after sowing

Fig. 1.15. Relationship between sum of each leaf and whole plant area.

Workable and reliable method to determine culm strength in rice

Thirty three rice genotypes were tested for their culm strength, culm diameter and biochemical traits (hemicelluloses, celluloses and lignin). Twenty days after heading, strength of the culm was measured at fourth internode from the top of the individual culm by using digital force gauge. The peak breaking value was recorded in newton and further it has been converted into gram force to assess the culm strength. In addition, culm diameter, hemicellose, cellulose and lignin were estimated. Culm strength was positively correlated with culm diameter (r=0.518**) at 1% level of significance. To study the reliability of this method, individual culm was tested to estimate the strength and its biochemical factors. Since, the experiment has proved the higher level of significance between culm strength and diameter, the lodging resistance of a whole plant can be determined. The lodging resistance of a whole plant can be obtained by breaking the entire plant (all tillers together) at fourth internode and strength of an individual culm can be derived by dividing the total number of tillers per plant. Therefore, this methodology has proved the possibility and potentiality of the technique to screen large number of genotypes in short period of time in efficient way.

Incorporation of multiple abiotic (drought tolerant yield QTL), biotic (BB and Blast) resistance and strong culm QTL into a single genetic background

F_1 seeds were generated between Swarna Nil that possess DTY1.1+DTY2.1+DTY3.1+Sub1 QTL and CRMAS 2232-85 (*xa5+xa13+Xa21*) during wet season 2015. CRMAS 2232-85 is bacterial blight tolerant line possessing three resistant genes against bacterial leaf blight in the background of popular variety Swarna. Again, another cross was attempted between Swarna Nil and Vandana which has *Pi2* + *Pi9*. The third parent SR-1-1 which has strong culm was crossed with Swarna Nil with aim of developing an ideal variety for direct seeded situation with drought tolerance, submergence tolerance, strong culm, BB and blast resistance.

Development of mapping population for anaerobic germination tolerance

Two F_1s were generated between Swarna sub1 and anaerobic germination tolerant ARC 5848 and ARC 12172 during wet season, 2015 with the aim of developing backcross mapping population to identify novel QTLs related to anaerobic germination tolerance.

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

Fourteen entries of sub1 and DTY introgressed Swarna lines were tested under three replications with two checks *viz*., Swarna and Swarna Sub1 under transplanted and direct seeded condition. Grain yield was recorded significantly higher in three entries namely IR 96321-315-323-B-3-1-1, IR 96322-34-223-B-1-1-1 and IR 94391-131-152-3-B-3-1-1, compared to that of checks with the mean grain yield of 5.71 and 5.52 t ha^{-1} under transplanted and direct seeded condition respectively (Table 1.6). These three entries were selected for next stage of evaluation.

Table 1.6: Performance of sub1 and DTY introgressed Swarna entries during wet season 2015

	TPR		DSR	
Genotype	Days to 50% flowering	Grain Yield (t/ ha)	Days to 50% flowering	Grain Yield (t/ ha)
IR 96321-315-323-B-3-1-1	125	6.71	122	6.45
IR 96322-34-223-B-1-1-1	126	7.20	121	7.31
IR 94391-131-152-3-B-3-1-1	119	7.20	115	7.03
Swarna sub1	119	4.84	116	4.67
Swarna	125	7.04	121	6.89
Mean (n=14)	**121**	**5.71**	**115**	**5.52**
CD 5%	**1.81**	**0.99**	**1.78**	**0.95**

Evaluation of early seedling vigour genotypes for weed competitiveness under aerobic condition

Twenty seven early seedling vigour (ESV) genotypes were tested for their weed competitiveness during dry season 2016 in aerobic condition with three checks namely Vandana, CR Dhan 204 and CR Dhan 205 under weed free and weedy situation (Fig.1.16). Sixty days after sowing, morphological parameters such as plant height, tiller number, number of leaves and dry matter were recorded. Among them, five genotypes *viz*., AC 43917, AC 43696, AC 44025, AC 43884 and ARC 5906 exhibited superiority over the checks for dry matter weight. Further, these better performing genotypes would be tested against weed competitiveness for grain yield to be involved in future breeding program.

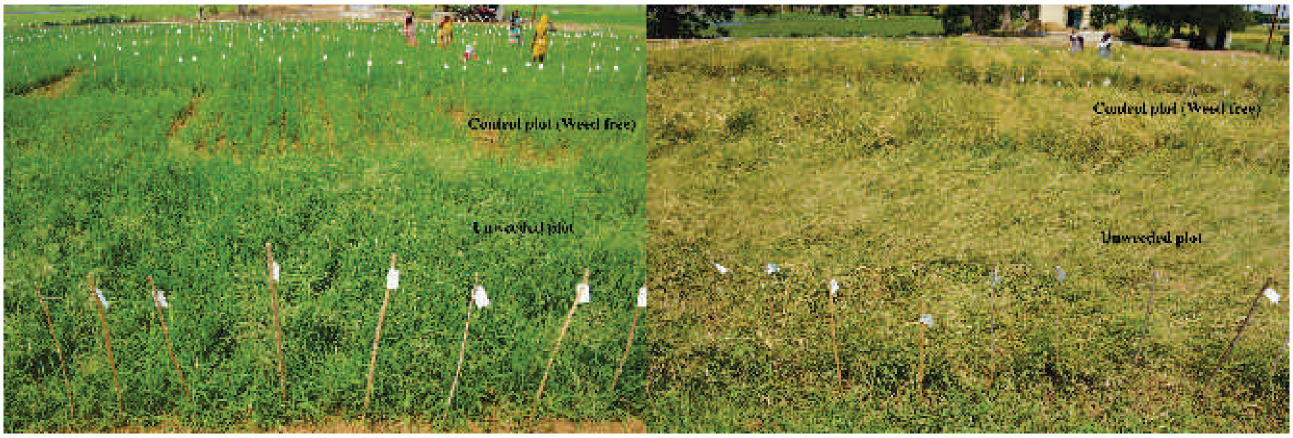


Fig.1.16. Field view of control (weed free) and unweeded plot at vegetative and maturity stage

Evaluation of advanced breeding lines under aerobic condition during dry season 2016.

Twenty six entries of advanced breeding lines, with five checks *viz*., Pyari, CR Dhan 202, CR Dhan 203, CR Dhan 204 and CR Dhan 205 were tested under aerobic condition with two replications. Grain yield was recorded significantly higher in five entries namely 1325-2-2-1, 1325-2-2-2, 37-3, 302-1-1 and 240-3-1 compared to that of checks with the mean grain yield of 3.63 t /ha under aerobic condition. These better performed five entries were forwarded for next stage of evaluation.

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

To target aerobic rice, 25 F_1s were obtained by cross combination of one upland drought tolerant parent with high yielding irrigated/low land variety with good grain quality during dry season, 2015. Further, in wet season, 2015, 15 new crosses were initiated between drought tolerant parent with high yielding irrigated/low land variety.

From the ongoing 75 lines of F_2 generation, single plant progenies were selected and 56 lines were advanced to F_3 generation. In another set, 112 F_3 lines were advanced based on single plant progenies to F_4 generation. Thirty one promising lines of F_8 generation were bulked for next season initial yield evaluation trial.

Development of genotypes with drought tolerance

To develop high yielding cultivars with drought tolerance for either of vegetative or reproductive stage or both. With this objective 21 F_1s were made for drought situation. Generation advancement of for 23 F_2, 9 F_3, 11 F_4, 1 F_5, were done for drought adaptation 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 are supposed to be taken up for drought screening after F_4. The crosses were made involving drought tolerant donors *viz*., Vandana, Satyabhama, CR 143-2-2, Sahabhagi Dhan, Vanaprabha, Salempikit, ZHU and BVD-9 with potential high yielding varieties.

Diversity and validation of microsatellite markers for grain yield under drought stress in upland cultures of rice

Thirty two upland rice genotype including tolerant checks (Sahabhagi Dhan and N22) and susceptible checks (IR 20 and IR 64) were studied. Fifteen days old seedlings were used for DNA isolation by adopting modified SDS lysis buffer method. The isolated DNA was amplified in PCR using 50 SSR markers tightly linked to 11 different qDTYs on both flanks under optimized conditions. Out of 50 SSR markers, only 17 markers linked to eight major and one minor qDTYs were found to be polymorphic with these genotypes. The entire set of 32 genotypes were also grown in control (irrigated) as well as under drought stress in the during wet season of 2015 and observations for biometric characters including number of fertile spikelets and grain yield were recorded.

The amplified PCR products were electrophoresed using 4% agarose gel at 110V for 3 hours against 50 bp ladder. The gels were visualized under UV gel documentation system and scored by 1 and 0 method for presence and absence of a particular allele. NTSYS was used for constructing phylogenetic tree to observe the genetic relatedness among these genotypes on the basis of their drought tolerance, percentage of spikelet fertility and relative yield reduction (RYR) percentage were calculated for control *vis-a-vis* stress.

Genotypic data showed the similar amplification pattern in Sahabhagi Dhan to that of positive checks, indicating the presence of four drought tolerance QTLs, *qDTY1.1*, *qDTY 2.1*, *qDTY6.2* and *qDTY12.1* (Table 1.7 and Fig. 1.17). Similarly, highly tolerant genotypes namely, Salempikit, Curinga and CR143-2-2, were found to be positive for four QTLs and Mahulata for three QTLs. The UPGMA dendrogram clearly differentiated all the 32 genotypes were grouped into two major clusters. Cluster I was found to be consisting of genotypes that shows varied level of tolerance starting from highly susceptible to moderately drought tolerance, while cluster II consisted of all the highly drought tolerant genotypes. Least RYR was observed in Mahulata (45.5%) followed by Salempikit (48.4%), CR143-2-2(49.52%), Sahabhagi Dhan and N 22 (52% both). Sahabhagi Dhan showed the highest spikelet fertility percentage (60%) under drought stress followed by Curinga (56%) and N 22 (53%). Whereas, IR 20 was observed to have lowest spikelet fertility of around 20%. Also, Sahabhagi Dhan showed least difference in spikelet fertility under control *vis-a-vis* stress.

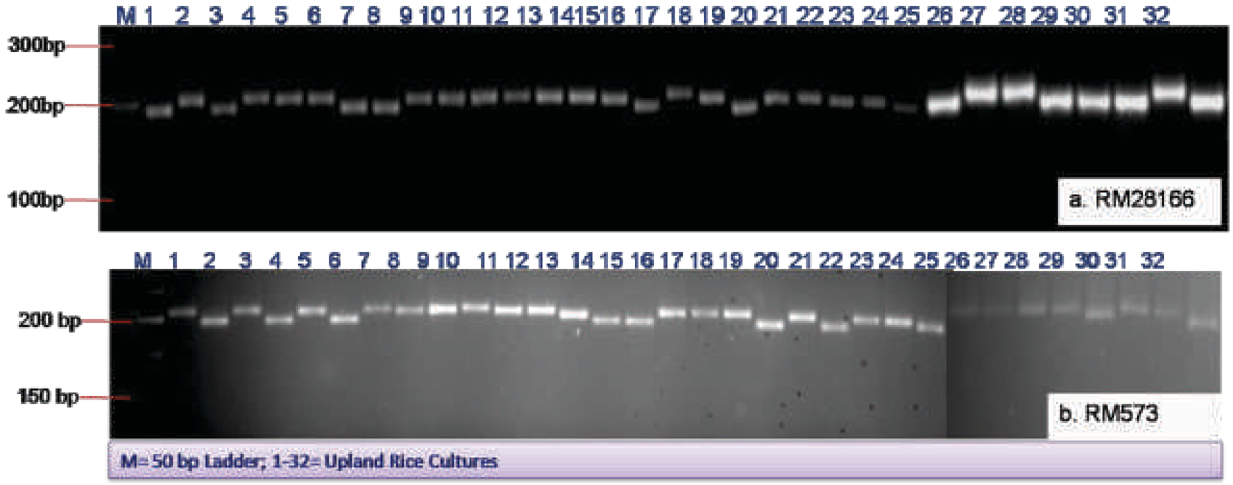


Fig.1.17. PCR amplification of a) RM28166 and b) RM573 under optimized conditions.

Table 1.7: List of upland rice cultures containing different combination of QTLs for grain yield under drought stress

Genotype	QTLs
Sahabhagi Dhan	*qDTY1.1, qDTY2.1, qDTY6.2, qDTY 12.1*
Salempikit	*qDTY1.1, qDTY3.1, qDTY2.3, qDTY3.2*
Curinga	*qDTY2.1, qDTY3.1, qDTY2.3, qDTY3.2*
Mahulata	*qDTY1.1, qDTY2.1, qDTY6.2*
CR-143-2-2	*qDTY1.1, qDTY2.1, qDTY3.1, qDTY6.2*
Azucena	*qDTY3.1, qDTY3.2, qDTY2.1*
CR 2702	*qDTY1.1, qDTY3.1*

The study could clearly differentiate upland genotypes into different groups, which could be utilized for choosing parents for biparental mating for exploiting transgressive segregants. Combination of QTLs of grain yield under stress and genetic distance could also be the guiding force for pinpointing parents for superior recombinants. In this context, promising genotypes such as Satyabhama and NDR 1045 could be the recipient parent in which traits/ genes could be transferred from highly drought tolerant genotypes such as Sahabhagi Dhan, Salempikit, Azuceana and N 22. Moreover, many *qDTYsviz*., *qDTY12.1*, *qDTY2.3*, *qDTY3.2* etc., have been reported to be similarly effective in lowland drought stress as in upland drought stress condition. Therefore, tolerant upland genotypes containing these QTLs can also be used as donors for conferring drought tolerance to popular lowland varieties that are susceptible to drought.

Evaluation of upland rice germplasm and wild species under low phosphorus condition during dry season 2016.

In order to identify new source and to validate phosphorus deficient tolerant lines, 70 upland rice genotypes and wild species (*O. nivara* and *O. rufipogon*) were raised under P deficient soil (6ppm/kg) during dry season 2016 with two tolerant checks (Kasalath and Dular) and one susceptible check (IR 36) . Among them, eight upland genotypes and four wild species exhibited superiority over positive checks for plant height, tiller numbers, number of leaves, leaf length and leaf width and on par for stem girth, root length and SPAD chlorophyll reading.

Table 1.8: List of upland and wild species of rice containing markers related to phosphorus uptake markers (*Pup1*).

Genotype	AC 100062	AC 100117	AC 100142	AC 100219	AC 100285	IR36	Brown gora	Sekri	Kasalath	Dular
K46-K1	*	*	*	*	*	N	*	*	*	*
K29-3	P	*	*	*	*	*	*	*	*	*
K20-2	P	P	*	*	*	*	*	*	*	*
K46	P	P	*	*	*	N	*	*	*	*

P.Polymorphic; N – Negative; * - Positive

Genotypes performed better under low P, positive and negative checks were analysed genotypically to assess the presence of *Pup1* allele with K46-K1, K46 (dominant, directly associated with PSTOL gene), K29-3 and K20-2 (co-dominant) markers. Genotypes AC100062 and AC100117 have exhibited polymorphism for the target Kasalath allele of K46, K29-3 and K20-2. Therefore, these genotypes might have new source of phosphorus tolerant gene and it would be used for advance studies and crop improvement program. On the other hand, Kasalath, Dular, Sekri, Brown gora and AC 100117 had similar amplification pattern (Table 1.8).

Trials under All India Coordinated Rice Improvement Programme (AICRIP)

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

Forty nine entries and five check varieties were evaluated in a randomized block design with three replications under direct seeded condition. Among the 46 entries, 12 entrieswere on par with the check Satyabhama with an average grain yield of 2.43 t/ha against.

Initial Variety Trial-Aerob (IVT aerob)

Sixty four entries including four checks (national, zonal, hybrid and local checks) were evaluated in a randomized block design with three replications under aerobic situation. Among the different entries, IET 25648 has performed on par against the best check Pyari (2.65 t/ha).

Advance Variety Trial 1 – Aerob (AVT 1-AEROB) (Zone 2, 3 & 5)

Six entries including checks were evaluated in a randomized block design with three replications under aerobic situation. Among the different entries, none of the entries performed better than the best check Pyari (3.17 t/ha).

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

Advance variety trial for aerobic situation was conducted with eight test entries generated at different breeding centers of the country including four check varieties. The experimental mean yield was 2.58 t/ha with 78.30 average days to 50% flowering and 302.5 panicles/m^2. The highest grain yield of 3.91 t/ha was recorded from 2910 followed by 3.84 t/ha, 2902.

Breeding for aromatic rice and grain quality improvement-

The objective of the project is to develop high yielding varieties with good grain quality, aroma and nutritional value. Segregating materials in different generations and fixed cultures were evaluated and two genotypes were selected with aroma and yield capacity more than 5.0 t/ha. A set of 129 genotypes were screened and two genotypes Dular and Madhukar were identified to have high iron and zinc content respectively in brown rice.The high protein rice variety CR Dhan 310with mean protein content of 10.3% in polished rice was released by CVRC for the statesof Odisha, UP and MP.Two high protein lines in Naveen back ground were promoted for final year of testing and three promising lines in Swarna background werenominated for Bio-fortification trial.Effort was made to identify the protein fraction that increased the protein content in the high protein variety. One hundred seventy nine genotypes including checks were evaluated in six AICRIP trials under Aromatic Short Grain,Medium Slender Grain and biofortification (Biofort).

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

In order to develop high yielding aromatic genotypes eight new crosses were made involving elite varieties NDR 359, Pusa 44, MTU 1071 and CR Dhan 300 with aromatic donors Gobindabhog, CR Sugandh Dhan 907, Geetanjali, Basmati 386. Three hundred nineteen lines belonging to 24 cross combinations in F_3 to F_7 generations were evaluated in irrigated condition and 490 single plant selections and 36 bulks were made based on their uniformity, agro-morphological characters and aroma. Further, eighteen F_1's made during last year using popular high yielding varieties and aromatic genotypes as parents have been generation advanced.In an advanced yield trial thirty two advance breeding lines along with two aromatic check varieties were evaluated in a randomized block design with two replications under irrigated conditions during wet season, 2015 at NRRI, Cuttack. Among the 34 entries, CR 2939-23-8-3 performed best with an average yield of 5.045 t/ha followed by CR 2613-2-1 (5.009 t/ha) against the best check variety Ketekijoha (3.558 t/ha).

Maintenance and collection of Aromatic Short Grain rice

One hundred twenty six aromatic short grain landrace collection of Odisha and two hundred twenty six aromatic short grain rice germplasm belonging to different states of India were evaluated for their uniformity and maintained for their use as donors.

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

Evaluation of rice germplasm for iron and zinc content

A set of 129 rice germplasm, breeding lines and released varieties of samples were analyzed for iron (Fe) and zinc (Zn) content in brown rice with X-ray fluorescence (XRF) machine. The range of iron and zinc content of brown rice was between 6.7 to 16.7 mg/kg and 14.7 to 36.5 mg/kg respectively. The genotype Dular was found to be the richest in iron (16.7mg/kg Fe and 28.8 mg/kg Zn) followed by Dehraduni sundari (16 mg/kg Fe and 19.7 mg/kg Zn) and Kalojeera (15.2 mg/kg Fe and 27.4 mg/kg Zn), the genotype Madukar was found to be rich in zinc (36.5 mg/kg Zn and 14.7 mg/kg Fe) followed by Lalmati (32.3 mg/kg Zn and 11.4 mg/kg Fe) and these can be utilized as donors for development of micronutrient rich rice varieties. Some of the rice genotypes with rich iron and zinc content are furnished below (Table 1.9).

In order to develop genotypes with higher level of micronutrient (Iron and Zinc) Two hundred thirty six lines belonging to fifteen cross combinations 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 one hundred forty two single plant selections and forty two bulks were made based on agro morphological characters and uniformity. F_1's made during last year using popular high yielding varieties and newly identified donors as parents have been generation advanced. Further generation advancement of eight new crosses of last year involving elite varieties and identified donors was made.

Evaluation of elite cultures in national trials at NRRI, Cuttack

a) AdvanceVarietyTrial1- Aromatic Short Grain (AVT 1- ASG)

Twenty one entries including three check varieties Sobhini (NC), Badshabhog and Dubraj (QC), CR Sugandh Dhan 907 (ZC) and Ketekijoha (LC) were evaluated in a randomized block design with three replications under irrigated conditions. The experimental mean yield was 3.88 t/ha with 107 average days to flowering, plant height 120 cm and 267 panicles/m^2. Among the different entries, the entry No. 2805, IET 24613 (ORJ-1135) performed best with an average grain yield of 5.05 t/ha, against the best check Badshabhog with 3.74 t/ha.

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

The trial was conducted with 25 test entries generated at different centers of the country along with three check varieties (Badshabhog (NC), Kalanamak (RC) and Ketekijoha (LC). The experimental mean yield was 3.88 t/ha with 128 average days to flowering, plant height 122 cm and 215 panicles/m^2. Highest grain yield of 6.6 t/ha was recorded from Entry No 2811 (CR 3660-22-9-4) followed by HUR 156with grain

Table1.9: Iron and zinc content in brown rice samples as measured with X-RF machine

S.N.	Genotypes	Iron (mg/kg)	Zinc (mg/kg)	S.N.	Genotypes	Iron (mg/kg)	Zinc (mg/kg)
1	Dehraduni sundari	16	19.7	17	Chak hao	13.5	23.1
2	Sadakajam	13.9	27.2	18	Assam birroin	12.4	21.5
3	WGL-44	12.6	21.2	19	Tulsi mukul	13.3	23.5
4	Dular	11.3	30.9	20	Kalo Bhutia	13.2	19.5
5	Lalat	10.7	26.1	21	Kalonunia	12.8	22.0
6	IR 29	12.7	28.5	22	Basumati Orissa	12.6	19.0
7	Abhimanyu	12.6	17.4	23	Pusa basmati-1	14.0	20.6
8	HMT	15.2	27.4	24	Lalmati	11.4	32.3
9	Patel 3	12.9	30.5	25	Madhukar	14.7	36.5
10	Taraori Basmati	13.1	24.1	26	Dular	16.7	28.8
11	N 22	12.7	27.0	27	Jasmine 85	11.7	24.6
12	Govind bhog	12.6	22.1	28	Norungan	7.8	18.6
13	Badasah bhog	11.4	31.3	29	Jyoti	13.1	21.0
14	CRMS 31 A	12.3	34.0	30	Annanda	12.7	25.9
15	CRMS 32 B	13.1	34.7	31	Kalinga III	11.5	26.4
16	Bindli	13.8	23.7	32	CR 2945-1-1-3-1-2	12.4	24.7

yield of 5.76 and 5.0 t/ha respectively in comparison to best check CR Sugandh Dhan 4.92 t/ha.

c) AdvanceVarietyTrial2- Rice Biofortification (AVT 2-Biofort)

Nine entries including checks Kalanamak, Chittimuthyalu, IR 64 and Samba Mahsuri were evaluated in a replicated trial under irrigated conditions. The mean yield was 3.04 t/ha and among the different entries, the entry No. 3209 (CR 2829-PLN-37) performed best with an average grain yield of 3.77 t/ha against the best check Samba Mahsuri (3.73 t/ha).

d)AdvanceVarietyTrial1- Rice Biofortification (AVT 1-Biofort)

Thirty entries including checks Kalanamak, Chittimuthyalu, DRRH 3 and Samba Mahsuri were evaluated in a replicated trial under irrigated conditions. The mean yield was 5.01 t/ha and among the different entries, the entry No. 3314 (RP 5898-138-14-9-8-4-2) performed best with an average grain yield of 6.52 t/ha against the best check Samba Mahsuri (6.16 t/ha).

e)Initial *Variety Trial*- Rice Bio-fortification (IVT -Biofort)

Forty five entries including checks Kalanamak, Chittimuthyalu, IR 64, Gontra Bidhan 3, DRRH 3 and Samba Mahsuri were evaluated in a replicated trial under irrigated conditions. The mean yield was 3.71 t/ha and among the different entries, the entry No. 3420 (NPH-8899) performed best with an average grain yield of 5.92 t/ha followed by 3417 R-RHZ-GI-56 (5.88 t/ha) against the best check hybrid DRRH 3 5.25 t/ha and variety Samba Mahsuri (3.52 t/ha).

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

Forty nine entries including checks WGL-14, Improved Samba Mahsuri, BPT 5204 and Pooja were evaluated in a replicated trial under irrigated conditions, the entry No. 3711 (MTU 1190) performed best with an average grain yield of 6.30 t/ha followed by3723; CB MAS 14065 (6.25 t/ha) against the best check WGL 14 (5.39 t/ha).

Performance of entries nominated in AICRIP trials during 2015

Two entries IET 25489 (CR 3511-3-2-2-5-1-1) and IET 25523 (CR 3505-7-1-1-1-2-1) tested under IVT MS grain were promoted to AVT 1-MSbased on yield superiority and grain quality.

New nominations for AICRIP trials

Three promising high yielding, semi dwarf aromatic cultures CR 2713-64, CR 2613-2-1, CR and CR 2982-6-2 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 CR 2830-PLS-156, CR 2830-PLS-17, CR2830-PLS-124 and CR 2830-PLS-30 with similar yield potential (5.4-5.6 t/ha) as Swarna (5.6 t/ha) were nominated to IVT –Biofortification.

Breeding for high protein rice

Performance of beeding lines in multilocational testing under biofortification trial

CR Dhan 310 (IET 24780) with mean grain yield of 4.48t/ha and mean protein content of 10.3% in polished rice was released by CVRC for Odisha, UP and MP. Nitrogen use efficieny of this variety was found high (1.28) in multolocational agronomic trials conducetd at AICRIP. In Biofortification trial, two high protein entries IET 24783 and IET 24772 were promoted to the final year of testing (AVT 2) based on yield advantage and zinc content. IET 24783 (CR 2829-PLN-32) derived from the cross HP-2/Naveen, possessed 9.5% protein. It had medium slender grains, 114 cm plant height, 96 days for 50% flowering and recorded overall mean yield of 4.488t/ha with 3.6% yield advantage over BPT 5204. It exhibited significant yield advantage in zone VII followed by zones III and V. In zone VII, it contains mean grain zinc content (21.6 ppm) in polished rice. IET 24772 (CR 2829-PLN-100) derived from the cross HP-2/Naveen, has 10.1% protein content in long bold grains. It has 115 cm plant height, 96 days of 50% flowering and recorded yield advantage in zone V and similar yield in zone VII. This entry promoted to AVT 2 based on zinc content above threshold level (21.2 ppm).

Hybridization programme

To improve high yielding varieties for protein and micronutrients (Zn) following three way crosses were made involving CR Dhan 310 and CR2829-PLN-116 with high protein (10%) and Kalinga III and Bindli with high protein (10%) and Zn (20 ppm) content and F1 seeds have been harvested.

a. BPT 5204 Sub1/ CR Dhan 310//Kalinga III
b. BPT 5204 Sub1/ CR Dhan 310//Bindli
c. CR2829-PLN-116/Kalinga III//Bindli

Evaluation and selection of breeding lines

From 750 breeding lines (F9), 118 lines were selected based on high protein content (>10%). Protein fractionation and SDS-PAGE revealed that the basic sub-unit, α-glutelin was found in an average 29 kD region while the average molecular weight of β-glutelin unit was 21 kD in all the genotypes. Another prolamin band was observed in all genotypes at 13-14 kD region. The differences were observed only in intensity of banding pattern. Higher expression in both α- and β-glutelin was observed in all high protein lines except CPL-A-F_8-1045 than the high yielding variety Swarna. This banding pattern was mostly correlated with the glutelin content observed through fractionation of soluble protein. The yield evaluation trial of these lines has been taken.

Evaluation of another 15 introgression lines in Swarna background for grain yield revealed that CR 2830-PLS-156, CR 2830-PLS-17, CR2830-PLS-124 and CR 2830-PLS-30 had almost similar yield potentiality (5.4-5.6 t/ha) as Swarna (5.6 t/ha). They were nominated in Biofortification trial in 2016.

Genetic Improvement of rice through *in vitro* and transgenic approaches

Development of doubled haploids *via*. androgenesis from rice hybrid 27P63

Anthers containing the uninucleate stage in the pollen of rice hybrid, 27P63 responded 22.61 % to callus induction in N6 semi solid media supplemented with auxin-to-cytokinin ratio of 4:1 after 3-4 weeks of culture. Subsequently, the light brown calli turned into green colour which developed into green shoot buds in the MS media along with cytokinin -to- auxin ratio of 2:1 after 2-5 weeks of culture showing 75 % green shoot regeneration. The green shoots elongated after 4 weeks of culture. A total of micro shoots formed a high percentage (100%) of roots grown in MS media supplemented with auxin and cytokinin in 10:1 ratio (Fig. 1.18 A-E). Thereafter, more than 50 plants survived showing promising growth in the net house after acclimatization. All the plants attained flowering and produced filled grains.

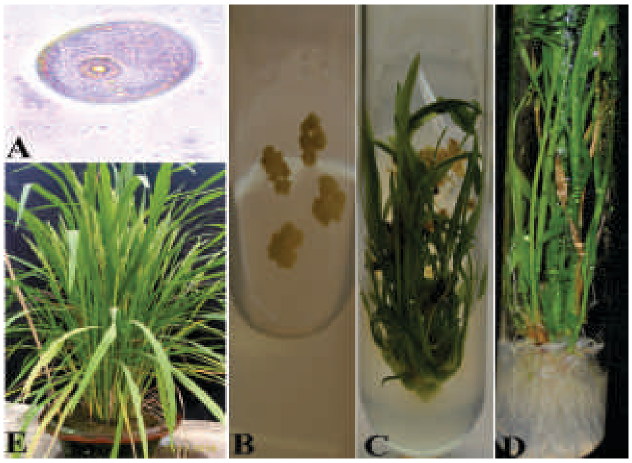


Fig. 1.18. Development of plants through androgenesis from rice hybrid, 27P63. A: Uninucleated stage of microspore, B: Callus induction from anther, C: Microshoots elongation, D: Rooting in microshoots, E: Acclimatization in pots.

Characterization of *Badh2* gene for rice grain aroma in the doubled haploid lines derived from rice hybrid BS6444G

Fragrance is considered as one of the most important grain quality trait in 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. The aroma of the rice grain is largely controlled by allelic variation of Badh2 gene. An 8 bp deletion in the exon 2 of this gene leads to fragrance in rice grain. Allele specific amplification (ASA) was conducted using four primers, two that anneal to sequences common without discriminating the fragrant and non-fragrant varieties, flanking to the deletion site designated as External Sense Primer (ESP; 5'-TTGTTTGGAGCTTGCTGATG-3') and External Antisense Primer (EAP; 5'-AGTGCTTTACAAAGTCCCGC-3'), and remaining other two that are Internal Fragrant Antisense Primer (IFAP; 5'-CATAGGAGCAGCTGAAATATATACC-3') and Internal Non-fragrant Sense Primer (INSP; 5'-CTGGTAAAAAGATTATGGCTTCA-3'), specific at the deletion site giving the two possible alleles designated as positive and negative. External primers generate a common fragment of approximately 580 bp size in all the sample as control. Using all the above four primers, a total of three different size of PCR fragments such as 580 bp, 355 bp and 257 bp are expected to be amplified. Amplification of either 257 bp or 355 bp fragment with 580 bp size indicated the presence of homozygous functional, positive (fragrant) and non-functional, negative (non-fragment) alleles respectively. Obtaining of all the three fragments in a particular DNA samples/ genotypes indicate heterozygosity with dominant non-fragrant traits (Fig.1.19). A total of 200 DH lines derived from non-aromatic rice hybrid, BS6444G developed through androgenesis were evaluated using all 4 markers. Of the 200 lines screened, 186 DH lines (93%) have been found to be positive allele (8 bp deletion) and remaining 4 DH lines (6%) are heterozygotes for the fragrance trait. To validate the allelic variation of the BADH2 gene, a total of six genotypes including parental hybrid, BS6444G and five DH lines (2 each carrying +ve and -ve allele and 1 heterozygote) were selected and sequenced using Big Dye Terminator reaction Kit on 3730xl DNA Analyzer (Applied Biosystems, USA) following manufacturer's protocol. Multiple sequence alignment has revealed the presence of 8 bp deletion in 7th exon in all the DH lines carrying with positive allele as reported earlier by different authors (Figure 1.20). Since, the hybrid BS6444G was non-aromatic and carry only homozygous negative allele (full length gene), obtaining of such DH lines with positive allele (8 bp deletion) was found to be unexpected which is very intriguing. To confirm and validate the heterozygosity of Badh2 gene in DH-2, one of the four heterozygote DH lines obtained, PCR amplification using ESP and EAP primers was conducted and produce a 580 bp amplicon. This PCR product was cloned using pGMTA vector. Around thirty five transformed white colonies were taken for colony-PCR using allele specific primers (IFAP and INSP) and found the presence of both the alleles. Further validation would be carried out by Sanger DNA sequencing method. Studies on the segregation pattern of the positive and negative allele of Badh2 gene using flanking markers among the DH lines would be useful to enlighten the molecular mechanism of spontaneous 8 bp deletion at the same position of the fragrance gene.

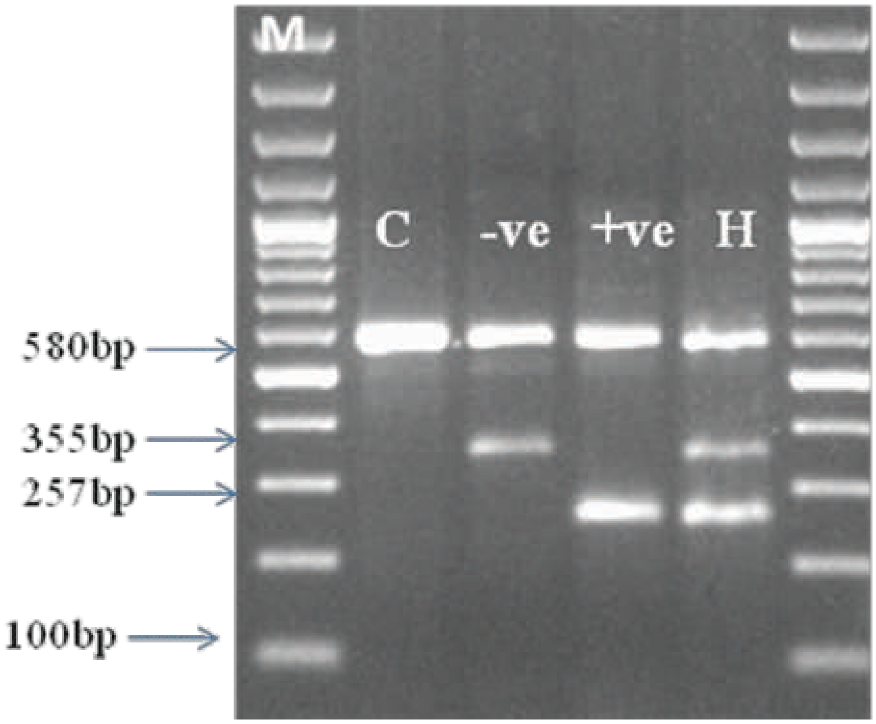


Fig.1.19. Gel based representation of allelic variation of Badh2 gene in rice. C: Control, -ve: Negative allele, +ve: Positive allele, H: heterozygote

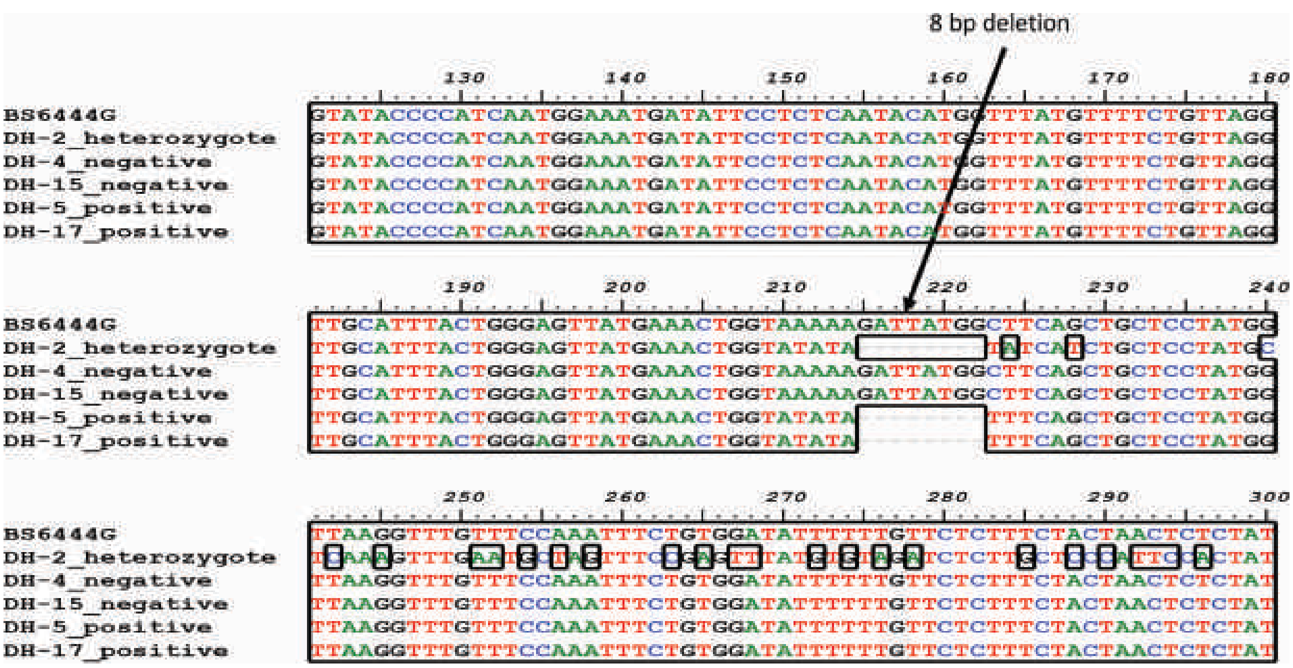


Fig.1.20. Representation of multiple alignment of Badh2 gene sequences in rice. Arrow indicates the location of 8 bp deletion in Badh2 gene. BS6444G: parental hybrid, DH-2: DH line carrying with heterozygote alleles, DH-4 & -15: DH lines carrying negative allele, DH-5 & -17: DH lines carrying with positive allele.

Screening of salinity tolerance during germination in the DH lines derived from F1s of Savitri x Pokkali cross

Seed germination, seedling emergence and their survival are particularly sensitive stage towards salinity. A systematic study was carried out to find out salinity tolerant lines during germination in different salinity levels for which 117 DHs derived from F1s of savitri (popular HY rice variety) and pokkali (salinity tolerant) were screened. Initially, a range of concentrations (0, 4, 8, 12, 16 and 20 dsm-1) of NaCl supplemented with Hoagland's solution were tested to observe the germination percentage of savitri and pokkali from which no significant differences were noticed in control. However, savitri and pokkali varied significantly not only for germination percentage ($p< 0.05$), but also for shoot length ($p< 0.05$) and root length ($p< 0.01$) at 16 dSm-1. Therefore, all the 117 DH lines were evaluated at 16 dSm-1 level of NaCl solution and the data of germination percentage, shoot and root length were recorded after 7 days of seeds sowing. Frequency distribution and linear correlation coefficient (r) for this three parameters were analysed. The germination percentage showed continuous variation with normal distribution whereas shoot and root length showed skewed distribution (Fig.1.21). The germination percentage ranged from 3.3 to 96% in 117 DH lines. The linear correlation coefficient (r) analyzed showed significant positive correlation (p = 0.01) among the above three parameters. In order to identify the genomic region responsible for germination percentage in salinity condition, further ten each extreme DH lines with germination percentage of <20% and >80% will be selected and used to conduct BSA (Bulked Segregant Analysis).

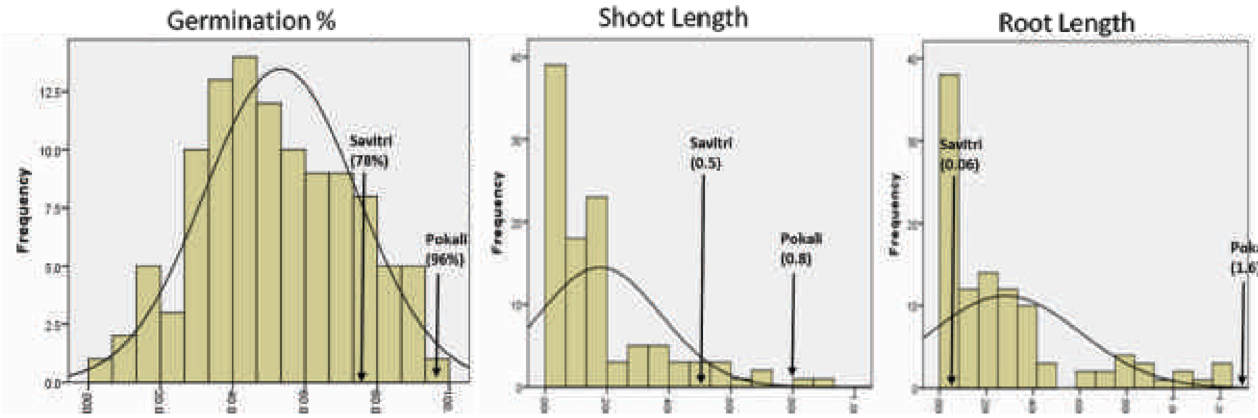


Fig.1.21. Frequency distribution of germination percentage, shoot length and root length after 7 days of sowing in 117 DH lines.

Grain quality characteristics of DH lines derived from CRHR 32 and BS6444G

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 parameters. An experiment was conducted to determine the biochemical composition of 20 and 13 selected anther derived DH lines in comparison with the donor CRHR 32 and BS6444G respectively.

The hulling percentage varied from 74 to 78% in 16 DH lines showing higher value than the donor (CRHR32). Similarly, 17 DH lines showed the milling percentage (%) higher as compared to their donor. The kernel length was found almost double in three DHs during elongation after cooking. The head rice recovery shows the range between 53-64%. The amylose content in DHs varied from 19.19% to 26.54%. Out of 20 DHs, 4 were found in grade 4 while rest showed grade 3 in the alkali spread value. The water uptake ranged from 90ml to 165ml. Out of 20 DH lines tested for physico-chemical parameters, CR 3-1, CR 7-4 and CR 7-7 showed superior quality over the donor taken for DH production. A total of 9 DHs derived from BS6444G showed higher hulling percentage as compared to their donor. Likewise, 11 and 13 DH lines showed a range of 62 to 79 % and 5.6 mm to 6.65mm for milling percentage and kernel length respectively which were found to be higher than donor. The head rice recovery varied from 46 to 70% in all 13 DHs. The amylose content in 8 DHs varied from 16.7% to 22.94% showing greater value than the parent as well. Out of 13 DHs, two were found in grade 4 while rest showed grade 3 in the alkali spread value. The water uptake ranged from 45ml to 160ml. Out of 13 DH lines tested for physico-chemical parameters, BS-48, BS-66 and BS-117 showed superior quality over the donor taken for DH production.

Yield evaluation of selected DHs derived from elite rice hybrids

A total of 13 DH lines of BS6444G and 24 of CRHR32 were selected for yield evaluation in dry and wet season, 2015 in replicated CRBD (Fig.1.22A). A comparison was made between the donor (CRHR32) and 24 selected DH lines in terms of the yield. While the parent showed 6.85 t/ha, the grain yield of 24 DHs lines varied from 5.41 – 7.02 t/ha. The highest grain yield was recorded as 7.02 t/ha followed by 6.96 t/ha, 6.73 t/ha and 6.69 t/ha. Besides, test weight of donor was noted as 23.1 gm and ranged from 21.12-25.1gm in the promising DH lines. The grain numbers in panicle of 5 DH lines were found to be more than the donor (Fig. 1.22B). Similarly, 13 DH lines of BS6444G were also assessed which were significantly different from the parents in terms of yield. The panicle length was significantly different among all the DH lines with a range of 19.6 to 33.8cm (Fig.1.22C). Grain yield showing an average maximum of 5.96 t/ha was significantly different from the parent hybrid. Out of 13 DHs tested, 6 DH lines could reach the heterotic level over-yielding (5.4%- 41.9%) the hybrid (BS6444G) and the checks (Naveen and Tapaswini).

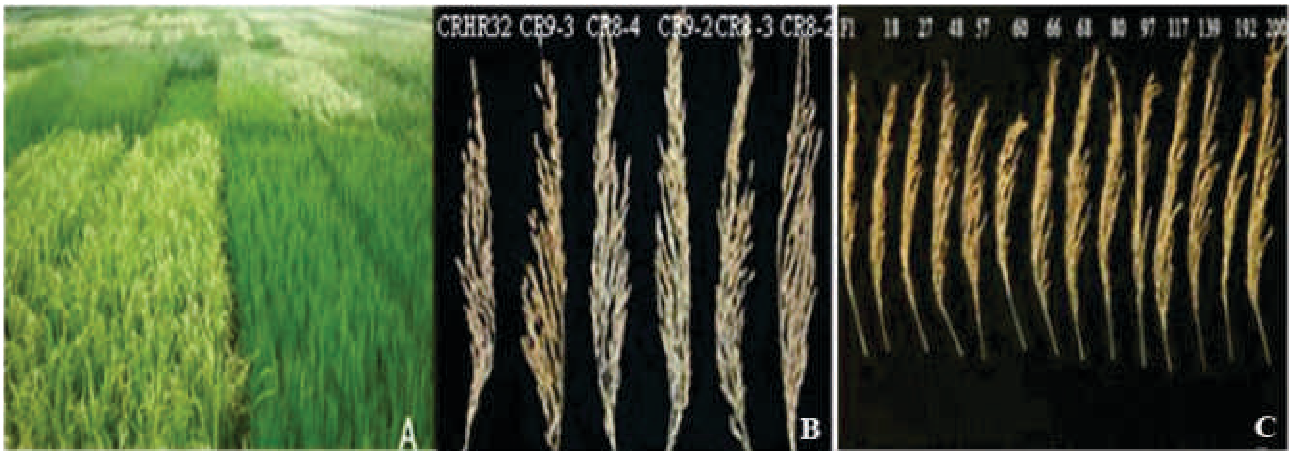


Fig.1.22. A: Selected DH lines showing variability in terms of maturity, plant height and yield in replicated trails. B: Panicles of DH lines of BS6444G. C: Promising DHs of CRHR32 having more (285-345) medium slender grains/panicle

Establishment of method for organogenesis and *Agrobacterium* mediated transformation in rice cultivars (Swarna and Naveen)

A successful method for organogenesis/somatic embryogenesis along with transformation system is required to establish for development of transgenic rice. Therefore, two popular rice cultivars *viz*. swarna and naveen were selected for organogenesis via callus culture for exploitation in transgenic rice production (Fig.1.23). Mature embryos were used as explants for the calli induction. Different devised media supplemented with various concentrations and combinations of PGRs were assessed for calli development efficiency from which basal MS media containing 2.5 mg/L 2, 4-dichlorophenoxyacetic acid (2,4-D), 30 g/L sucrose was found to be the best for callus induction in both the cultivars. Subsequently, transfer of primary and secondary calli showed highest shoot regeneration efficiency in MS media supplemented with 1 mg/L NAA and 2 mg/L Kinetin.

Secondary calli were used for *Agrobacterium* mediated transformation. A suspension of *Agrobacterium* strain LBA4404 harboring pCAMBIA1304 (with *gus* reporter gene) was coinfected with calli. Initially, different level of optical density (OD) of the suspension was tested and optimum level of OD was chosen. Calli was immersed with the bacterial suspension for 30 min, subsequently transferred on co-cultivation media (MS media + 100 mM Acetosyringone) and incubated in dark for 3 days. After washing once with antibiotic solution and thrice with sterile distilled water, calli were transferred to selection media (MS supplemented with 30 g/L sucrose, 2 mg/L 2, 4-D, 8 g/L agar and 50 mg/L hygromycin B solution). The surviving calli showed transient GUS expression which could be selected further in media containing hygromycin and subsequently tested for shoot regeneration (Fig.1.24).

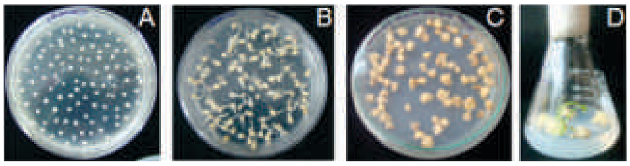


Fig.1.23. A-D. Representative image of different stages of embryo derived callus induction and shoot regeneration

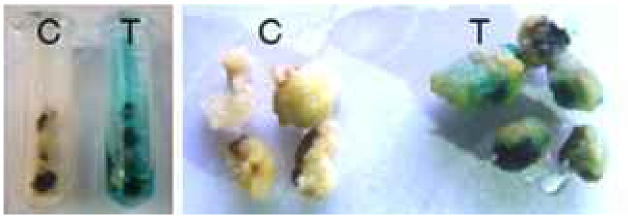


Fig. 1.24. Transient GUS expression analysis of the calli infected with Agrobacterium LBA4404 harbouring pCAMBIA1304-gus plasmid. C- Control non transformed and T- transformed calli. The GUS staining solution contained sodium phosphate (pH 7.0), chloramphenicol, Triton-X-100, methanol and 5-bromo-4-chloro-3-indolyl-β-D-glucuronide (X-gluc).

Development and use of genomic resources for genetic improvement of rice

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

Ten high yielding mega rice varieties of India namely, Swarna, Samba Mahsuri, MTU 1010, MTU 1001, PKM-HMT, PR 113, Pusa 1121, Pooja, Satabdi and Sahabhagidhan were re-sequenced with an average sequencing depths of 39.62X coverage of the uniquely mapped reads. More than 91% of the whole genome sequences of ten rice varieties were covered with either reference genomes. We discovered a large number of DNA polymorphisms between these varieties and both *indica* and *japonica* reference genomes, which will be useful for genomic studies and molecular breeding programs. We observed uneven distribution of SNP and InDel regions throughout the genome in all the varieties with respect to both the genomes. All the varieties showed presence of hot spots and high density SNP regions for all the chromosomes. All the varieties showed SNP and InDel desert regions in all the chromosomes with respect to *indica* genome while eight out of 10 varieties showed SNP desert regions in all the chromosomes with respect to *japonica* genome. Whole genome with approximate sequencing depth of 39.62X provided 100% coverage in an average of 78.51% of genes with 93-11 and 63.28% with Nipponbare genomes. 80% coding sequences (CDS) accounted 93.01% (Satabdi) to 97.13%(Samba Mahsuri) with an average of 94.83% of genes with respect to *indica* reference genome. Similarly, sequencing depth of 39.62X provided over 80% coding sequences in approximately 92.76% of genes with respect to *japonica* reference genome. Approximately, 0.82% and 0.72% of genes were not covered by any CDS with respect to *indica* and *japonica* genomes, respectively. The unavailable sequences corresponding to these CDSs were expected to present in the unmapped reads. The unmapped reads were assembled into contigs and re-mapped to *indica* and *japonica* reference genomes, which could increases the value of NGS short-reads and consequently coverage of previously unavailable sequences. The contigs with over 90% unique hit sequences were distributed unevenly across the chromosomes. These approaches facilitated the identification of 2070 new genes in coding sequences. The number of genes varied from 80 (Pusa1121) to 727 (Samba Mahsuri). The number of genes found to > 90% identity specific to cultivars of *indica* and *japonica* groups are 235 and 868, respectively. The number of genes found to be identical with *O. glaberrima*, *O. rufipogon*, *O. officinalis*, *O. brachyantha*, *O. ridleyi*, *O. longistaminata* are 2, 4, 6, 80, 1 and 1, respectively. Besides, few genes were found to be identical with *Zea mays*, *Sorghum bicolor*, *Triticum aestivum*, *Triticum urartu*, *Setaria italic*, *A. thaliana* and *A. lyrata.* MTU1010 and PR 113 showed least genomic difference while PKV-HMT and Pusa1121 showed highest difference with both *indica* and *japonica* reference genomes.

Identification of QTLs associated with yield related traits

The RIL mapping populations from the cross CR 662-2211-2-1/ WAB 50-56 was genotyped with SSR markers. The linkage map was constructed with 78 polymorphic markers using integrated QTL IcMapping (v.4.0) software (www.isbreeding.net). The composite interval mapping (ICIM) analysis identified five QTLs, *QSN1.1, QPSY1.1, QPH9.1, QTN3.1* and *QTN6.1* controlling spikelet number, *per se* yield, plant height and tiller number. *QSN1.1, QPSY1.1* explained phenotypic variance (PV) of 17.26% and 19.32%, respectively towards spikelet number (SN) and *per se* yield(PSY). *QPH9.1* explained phenotypic variance (PV) of 64.34% towards plant height (PH) while *QTN3.1* and *QTN6.1* explained phenotypic variance (PV) of 6.02% and 30.96%, respectively towards tiller number(TN)(Table 1.10, Fig. 1.25). RIL from Shriram/ Heera were grown in the field following Alpha Lattice design, each with two replications. Grain yield number and weight traits were recorded for identification of QTLs associated with high grain number and weight. The RIL population of the cross showed normal distribution for grain number and 100grain weight and showed transgressive segregation.

In silco analysis to identify candidate genes associated with BPH resistance in Salkathi

High throughput genotyping of RILs along parents TN1 and Salkathi with 40,894 SNP identified two QTLs, *Qbph4.3* and *Qbph4.4* on chromosome 4, which explained phenotypic variance of 9.7% and 15.7%, respectively towards resistance to BPH in Salkathi.. The physical position of *Qbph4.3* and *Qbph4.4* was found to be between 620000-1011000bp and 18001019-2200000bp, respectively. *Insilco* analysis identified 64 genes between 620000-1011000bp positions. Six genes were identified as candidate genes for *Qbph4.3* namely, LOC_Os04g02030(rp1), LOC_Os04g02040(NBS-LRR), LOC_Os04g02110(disease resistance protein RGA3), LOC_Os04g02280 (OsFBX114 - F-box domain containing protein) LOC_Os04g02480(NBS-LRR), LOC_Os04g02520(Leucine Rich Repeat family protein). 556 genes were identified between 18000000-22000000bp and 25 genes were identified as candidate genes for *Qbph4.4*. These genes belong to family protein like F-box/LRR-repeat protein, OsFBL - F-box domain, Leucine Rich Repeat family protein, OsFBL16 - F-box domain and LRR containing protein, OsFBLD2 - F-box, LRR and FBD domain containing protein, disease resistance protein RGA2, NBS type disease resistance protein, serine/threonine-protein kinase receptor precursor and domain receptor-like protein kinase.

Evaluation rice germplasm to identify QTLs/genes controlling blast tolerance using association analysis approach

Twenty nine accessions of wild species of rice consisting of *O. nivara* (12 accessions), *O. rufipogon* (7 accessions) and weedy rice (10 accessions) were evaluated for blast reaction in Uniform blast nursery during wet season 2015. The results showed that all the *O. rufipogon* accessions were resistant to leaf blast

Table 1.10: QTLs identified for yield related traits in the RIL population derived from the Cross CR 662-2211-2-1/WAB 50-56

Trait Name	QTL	LG	Chrom#	QTL Position (cM)	Marker interval	LOD	PVE(%)	Add
TN	*QTN3.1*	5	3	127	RM569-RM489	2.51	6.02	0.42
TN	*QTN6.1*	9	6	37	RM494-RM400	3.17	30.96	1.90
PH	*QPH9.1*	14	9	101	RM219-RM566	4.03	64.34	17.87
SN	*QSN1.1*	1	1	100	RM297-RM212	3.70	17.26	-15.94
PSY	*QPSY1.1*	1	1	108	RM297-RM212	7.78	19.32	-2.68

TN-Tiller number, SN-Spikelet number, PH-Plant height (cm), SN-Spikelet number, PSY-Perse yield(gm/plant)

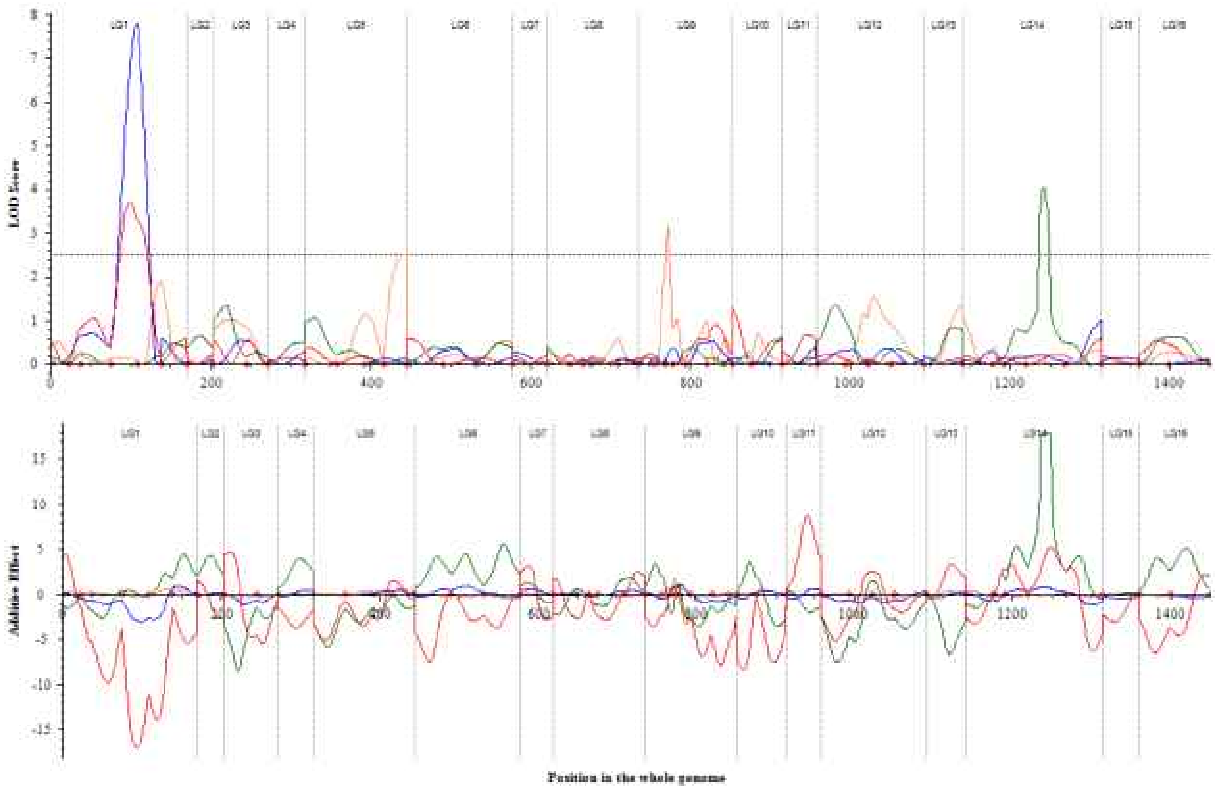
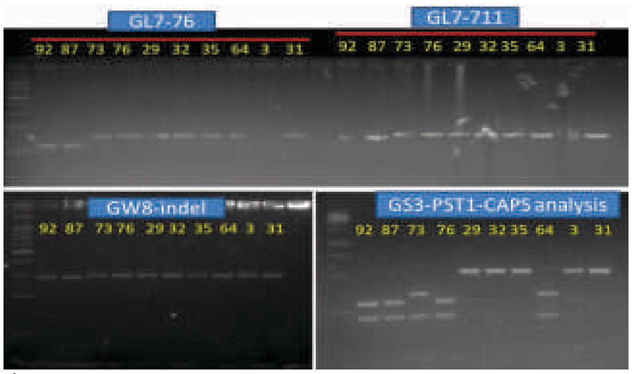


Fig. 1.25. One-dimensional scanning of whole genome for identification QTLs associated with yield related traits in the RIL mapping population derived from the cross CR 662-2211-2-1/ WAB 50-56 (Upper half shows position of QTLs with LOD score while lower half shows additive effects of QTLs)

disease with an average score of 3.0. In case of *O. nivara*, the average score of leaf blast resistance was 6.0 being susceptible. Most susceptible among the three category was weedy rice with a score of 7.2. These accessions will be used for association analysis to identify QTLs associated with blast tolerance.

Candidate gene based association analysis for grain size and identification of novel gene(s) donors superior to *GS3* gene for rice grain length

Grain size, one of the major components of rice yield is a complex trait governed by many QTLs. It is further determined by grain length, width and thickness. Previously, genetic association for grain size analysis using 12 markers from nine known genes in a selected 89 germplasm with diverse grain length has revealed the strong genetic association of *GS3* and *GL7* genes with the grain length trait. The *GS3* gene had been reported as major gene explaining 97% of grain length variation which encode a novel protein with several conserved domains including a phosphatidyl-ethanolamine-binding protein (PEBP)-like domain, a trans-membrane region, a putative tumor necrosis factor receptor/nerve growth factor receptor (TNFR/NGFR) family domain, and a von Willebrand factor type C(VWFC) domain. The functional SNP (recessive C165A mutation) in the second exon of *GS3* which determines the grain length was identified and converted as a CAPS marker using *Pst*I restriction enzyme. Digestion of PCR product revealed the presence of 'C' allele (positive allele;) for long grain phenotype and the presence of 'A' allele (negative allele) for short grain phenotype. Interestingly, two long grain genotypes DBT1685 and DBT2633 among the 89 rice genotypes in the previous study were found to carry negative allele (A) instead of the positive (C) allele (Fig. 1.26). Therefore, additional four each short grain genotypes DBT2405, DBT1697, DBT1230 and AC52292, and long grain genotypes DBT548, DBT1501, DBT1495, DBT840, two other genotypes DBT1685 and DBT2633 were furthered characterized using marker for major genes *GL7*, *GW8* and *GS3*. All the 10 genotypes except DBT1230 and AC522 showed positive correlation of *GL7* and *GW8* alleles with the grain length phenotype. In the case of *GS3*, all the four short grain genotypes DBT2405, DBT1697, DBT1230 and AC52292 and two long grain genotypes DBT1685 and DBT2633 were found to carry negative allele and remaining four long grain genotypes showed presence of positive allele. Therefore, these two long grain genotypes may be further utilized for identification of novel gene(s)/QTLs that can suppress the negative function of *GS3* protein in rice.



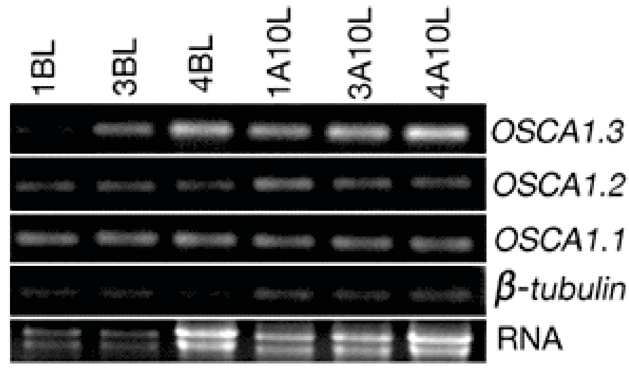
A.

Fig.1.26. Amplification with gene specific markers GL7-76 & GL7-711(*GL7*), GW8-indel (*GW8*) and *GS3-PstI* (GS) in selected 10 rice genotypes.
92: DBT2405; 87: DBT1697; 73: DBT1230; 76: AC522; 29: DBT548; 32: DBT1501; 35: DBT1495; 64: DBT1685; 3: DBT2633 & 31: DBT840

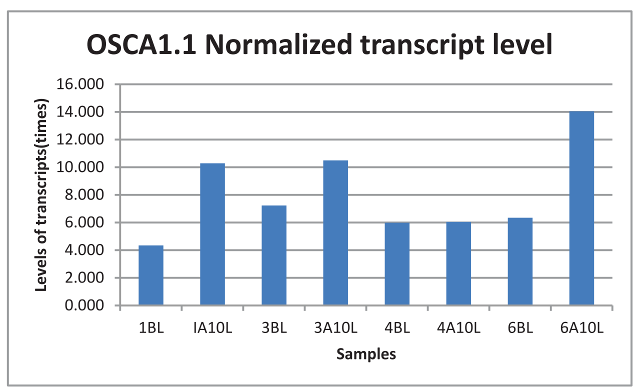
Functional validation of candidate genes for abiotic stress tolerance in rice

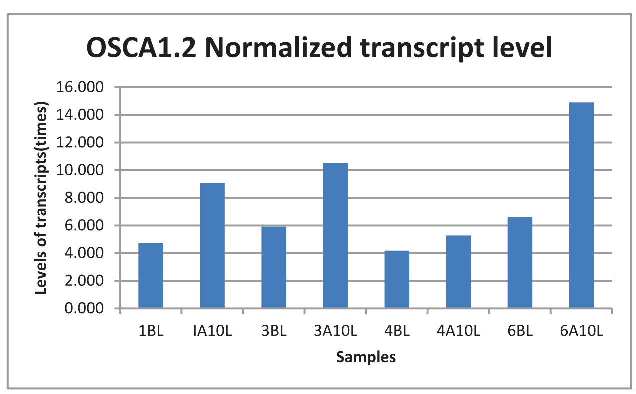
Analysis and expression studies of OSCA1 gene family in rice

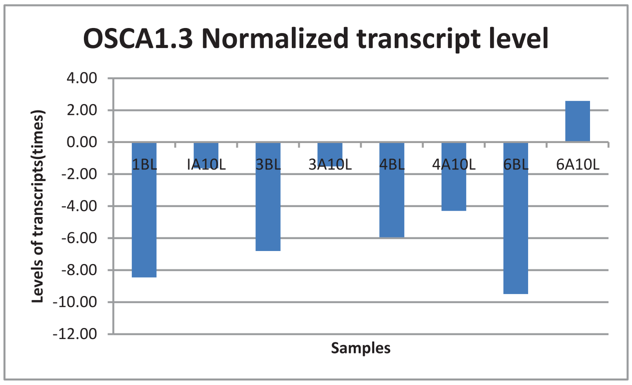
OSCA1 gene (*Reduced hyperosmolality-induced [Ca^{2+}]$_i$ increase 1*) is identified as a possible osmosensor in Adry season*dopsis* and plays important role in osmotic Ca^{2+} signalling in guard cells and root cells, in transpiration regulation and in root growth in response to osmotic stress. Osmotic stress unfavourably affect rice yield throughout the world. Therefore, analysis of *OSCA1* homologous genes in rice and expression of different members of the family in response to drought stress is necessary to find out the suitable gene for using in future drought tolerant breeding programme. *In silico* analysis was done to find homologous members in rice genome and the result revealed the presence of a total of 11 *OSCA* genes in rice *OSCA* family (Fig.1.27). All of them contain DUF221 as the conserved domain. All genes contained multiple exons (6-11) except the *OSCA4.1* containing single exon. In order to analyze the expression of all 11 *OSCA* genes in rice in response to artificial drought treatment, a total of six (3 drought susceptible and 3 drought tolerant) rice varieties were selected. The seedlings were treated with 20% PEG-6000 solution. RNA was isolated from leaf and root samples collected at different time points. Following DNaseI treatment cDNA was prepared and used as template for expression analysis of all 11 genes. Real time PCR has been performed to quantify the mRNA levels in leaf samples at different points. Rice tubulin gene was used to normalize all data. Quantitative analysis of mRNA levels in root samples through real time PCR is under progress.



A.







B.

Fig. 1.27. A) Agarose gel showing profile of RNA isolated and the real time PCR products

B) Bar diagram showing normalized transcript level of *OSCA1.1, OSCA1.2* and *OSCA1.3* before and after treatment with PEG. 1- drought sensitive variety, 3 & 4- drought tolerant varieties. BL- leaf collected before PEG treatment, A10L- Leaf collected at 10 minutes post PEG treatment.

Development of resilient rice varieties for rainfed direct seeded upland ecosystem

Hybridization, generation and evaluation of breeding lines

Five crosses were made for the development of resilient varieties for rainfed direct seeded uplands. These are mostly double crosses or three way crosses of the single crosses generated in the previous years. Thirty (30) F_3 bulk populations were grown during 2015 wet season season and 1520 single plant selections were made based on duration, plant type, panicle characters and reaction to abiotic and biotic stresses. Number of selections was less in most of the crosses because of severe drought stress during season. 150 F_4 progenies of the CR Dhan 40/ CG345 cross have been raised at NRRI, Cuttack during 2016 dry season season. 350 breeding lines of advance generation (F6) were grown under bunded upland during 2015 wet season season but because of delayed seeding and extreme moisture in the season only 50 entries performed moderately well and selected for further evaluation. Two hundred lines of the same population were generation advanced in transplanted condition to F_7 generation. Small scale seed increase and bulk multiplication of 20 elite lines was taken up during 2015 wet season.

Preliminary yield trial

Eight promising advance breeding lines along with three checks were evaluated under both direct seeding in bunded upland and transplanted conditions in randomized block design (RBD) with three replications. Recommend package of practices were followed. The entries were also screened for drought tolerance under rain-out shelter facility. As the sowing of the trial was delayed, the direct seeded trial underwent severe moisture stress from tillering stage onwards. Out of the eight lines, only three lines *viz*., CRR 693-28-B-1-B-B (Anjali / CR 2340-11), CRR 696-42-B-1-B-B (Vandana / CT 9993-5-10-1-M) and CRR 708-1-B-2-B-B (NDR 1045-2 / CR 2340-11) showed better vegetative stage drought tolerance as compared to checks both under direct seeded upland and managed stress (RoS) conditions. However, due to prolonged severe moisture stress none of the entries including checks gave any grain yield. In the transplanted condition, Sahbhagi dhan produced highest grain yield (5.67 t/ha) which is at par with the best entry CRR-708-1-B-2-B-B (5.48 t/ha). The maturity duration of Sahbhagi dhan is 13 days more than this culture. So, in terms of per day productivity CRR-708-1-B-2-B-B and CRR-697-76-B-1-B-B (5017 Kg/ha) will be superior to Sahbhagi dhan. Most of the test entries out yielded our early checks, Vandana and Anjali are at par with maturity duration. Based on the performance, four promising entries have been nominated for testing under AICRIP trial.

Entries promoted and new nominations in AICRIP trials

Considering yield advantage over best check, two entries namely, IET24053 (CRR 647-56-1) in AVT1E-TP and IET24334 (CRR 484-2-1-1-1-1) in AVT1-IM have been promoted for final year of testing under AICRIP trials. Besides this, 2 entries (IET 25115 & IET 25125) in IVT-E-DS and 3 entries (IET 25549, IET 25593 & IET 25603) in IVT-E-TP showed yield advantage of more than 5% over best check in respective trials and promoted for second year of testing under national coordinated trials. Eleven (11) promising entries developed at this station have been nominated for initial varietal testing under AICRIP trials during 2016 wet season.

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

Evaluation of Anjali drought NILs (q*DTY12.1*) under rainfed condition

Upland rice variety Anjali released for the states of Jharkhand, Bihar, Odisha, Assam and Tripura in the year 2002. This variety is well suited for cultivation under direct seeded favourable upland conditions but under severe drought this variety tends to suffer from moisture stress as it is moderately tolerant to drought. 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 q*DTY12.1* from Vandana /Way rarem population was introgressed into Anjali using linked SSR markers and introgression lines developed. During 2015 wet season seasonten introgression lines along with recurrent parent Anjali were evaluated under rainfed direct seeded condition and also screened for vegetative stage drought tolerance. Due to erratic monsoon during the cropping season the trial experienced severe moisture stress from booting stage to grain filling stage. As a result, the average yield of the trial was very low. Even at this low yield level 5 introgression lines gave significantly better yield than the recurrent parent Anjali by 31.4 to 88.63% (Table 1.11). These NILs have lower sterility% and also showed better vegetative stage drought tolerance score based on SES scale as compared to Anjali (Fig. 1.28). The best NIL gave a yield of 1222 kg/ha as compared to Anjali (648 kg/ha).

Evaluation of Vandana NILs with drought QTL and blast R gene (q*DTY12.1*+*Pi2*)

Popular upland rice variety Vandana is known for its high vegetative stage drought tolerance but it failed miserably if the stress is during reproductive stage. Introgression of q*DTY12.1* from Way Rarem into

Table 1.11: Performance of Anjali NILs (q*DTY12.1*) lines under rainfed during wet season 2015

Entries	Days to 50% flowering	Plant height (cm)	Grain yield (kg/ha)	Panicle length	Sterility (%)	Drought Score (SES)
ANIL-1/39	61	76.1	1222	20.2	25.4	3.0
ANIL-2/63	72	76.2	593	21.0	67.2	2.3
ANIL-3/225	69	74.1	1120	23.5	43.5	1.7
ANIL-4/256	67	72.8	769	21.2	63.6	4.3
ANIL-5/325	69	69.0	1111	22.0	45.1	1.7
ANIL-6/337	69	67.1	585	21.8	51.6	4.3
ANIL-7/342	69	76.0	963	21.6	42.9	2.3
ANIL-8/359	71	70.7	663	21.0	71.3	3.7
ANIL-9/365	69	76.8	570	21.1	65.1	3.0
ANIL-10/460	68	70.7	852	22.5	66.4	3.0
Anjali	67	69.9	648	20.7	52.1	6.3
LSD 5%	1.8	10.7	202.3	2.0	16.8	
CV (%)	1.5	8.6	14.4	5.4	18.3	

Fig.1.28. Anjali NIL (*qDTY12.1*) and Anjali under vegetative stage drought, wet season 2015

Vandana earlier led to marked improvement in its yield performance under reproductive stage stress. To improve it further for leaf blast tolerance broad-spectrum resistance gene *Pi 2*was introgressed using MAB. Ten introgression lines along with parent Vandana were evaluated under rainfed direct seeded conditions during wet season 2015. The same set was also screened for blast resistance in uniform blast nursery under artificial epiphytotics. This trial also faced severe drought stress from booting to grain filling stage and consequently gave very low yield. Only one NILs, CRR747-3-6-B gave significantly more yield than Vandana and 4 other NILs are just numerically better in terms of grain yield (Table 1.12). The introgression lines have same flowering duration and plant height as that of recurrent parent Vandana. In the uniform blast nursery the introgression lines did not take any infection and scored '0' for leaf blast disease (SES 2002), whereas the parent Vandana scored '4' (Fig.1.29). In the rainfed upland ecosystem where drought and blast are major problems these NILs might help in stabilizing the yield.

Table 1.12. Performance of Vandana NILs (q*DTY12.1*+*Pi2*) under rainfed condition wet season 2015

ENTNO	Days to 50% flowering	Plant height. (cm)	Grain yield (kg/ha)	Panicle length	Sterility (%)	Blast score
CRR747-3-6-B	65	80.5	1083	17.9	47.2	0
CRR747-3-7-B	67	81.9	1028	17.5	57.3	0
CRR747-3-8-B	66	79.4	778	17.7	65.6	0
CRR747-16-1-B	68	87.9	875	17.5	74.2	0
CRR747-16-2-B	66	78.1	736	18.0	62.4	0
CRR747-16-3-B	67	79.1	931	18.3	53.9	0
CRR747-12-1-B	67	80.4	736	17.3	69.2	0
CRR747-12-3-B	65	80.0	750	18.5	58.7	0
CRR747-12-4-B	65	78.3	1000	19.0	62.3	0
CRR747-16-5-B	68	77.3	708	17.0	60.6	0
Vandana	66	83.3	861	17.2	79.6	4
LSD 5 %	1.4	8.5	222	2.1	20.7	
CV (%)	1.3	6.2	14.9	7.0	19.4	

Fig. 1.29. Vandana NILs & Vandana under drought stress (A) and NILs in the uniform blast nursery

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

Twenty two (22) BPT 5204 NILs (*Pi9/Pib*) along with parent were evaluated for grain yield and other traits done under irrigated transplanted conditions during wet season 2015. The NILs 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 BPT 5204. Out of 22 lines, 4 NILs significantly out yielded the recurrent parent BPT 5204 with a yield advantage of 13.3 to 18.1 per cent. Three of these lines are similar to recurrent parent in flowering duration and one is about two week earlier than recurrent parent. Six NILs gave significantly lower yield than BPT 5204 and 12 NILs yielded at par with the recurrent parent. Screening in the uniform blast nursery showed that NILs introgressed with *Pib* were not effective at Hazaribag, though the gene is known to contribute to resistance in other localities. NILs carrying *Pi9* were however highly resistant in the nursery and had no disease in the field plots. Agronomically superior lines with *Pi9* and having duration, phenotype and grain quality characteristics similar to BPT 5204 will be seed increased for coordinated testing.

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-E-DS: Forty nine (49) entries including checks of early duration were evaluated in RBD under rainfed upland direct seeded condition. The trial was affected by severe prolonged drought from tillering stage onwards. The highest grain yield was obtained from the entry IET 25106 (190 kg/ha) followed by IET 25115 (160 kg/ha) as compared to national check Vandana (131 kg/ha).

AVT-2-IME: Altogether, 12 entries including four checks *viz.*, IR 64 (National check), Lalat (Regional check), US 312 (Hybrid check) and Abhishek (Local check) were tested during wet season, 2015. Among the test entries HRI 126 (7998 kg/ha) was found top yielder followed by XRA27936 (7681 kg/ha), XRA27935 (7555 kg/ha) and XRA27934 (7207 kg/ha) as compared to best hybrid check US312 (7910 kg/ha) and inbred check Abhishek (6552 kg/ha).

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

Two thousand one hundred and seventy six (2176) lines comprising indigenous germplasm (974) and entries of the national screening nurseries (NSN 1{341} and 2{686} and Donor Screening Nursery- 175) were screened for their reaction to leaf blast in a Uniform Blast Nursery at Hazaribag. Distribution of reaction types was bimodal with about 17% of the lines exhibiting highly resistant reaction and the rest showing a range of disease intensities. Land races were highly susceptible with only 2.0% of them showing highly resistant reaction. Selection efficiency of the breeding programmes was reflected in the progressive reduction of susceptible entries in NSN 2 and NSN 1 compared to the land races.

Development of rice genotypes for rainfed, flood-prone lowlands

Maintenance of rice germplasm: A total of 779 accessions of rice germplasm were maintained during wet season 2015. Observations on days to 50% flowering, plant height and grain yield were recorded.

Generation advancement of segregating material: Pedigree nursery of 124 F_5 progenies of four crosses was raised during *sali* season for development of rainfed lowland (semi-glutinous and soft) rice and F_6 seeds were bulked for further selection and evaluation. BC_1F_4 of 31 crosses were raised for improvement of rainfed shallow lowland rice and plants were bulked to BC_1F_5. For development of *boro* rice, 59 single plant progenies selected from 28 crosses were grown in F_6 nursery during dryseason 2015 and F_7 seeds were bulked for further evaluation and selection. For the development of pre-flood *ahu* rice, F_5 nursery of 5 crosses were raised during *ahu* 2015 and F_6 seeds were bulked for selection in the next generation.

Maintenance of elite breeding material: During *sali*/ wet season 2015, 27 Nos. of elite breeding lines for rainfed shallow lowlands were maintained, whereas during *boro* 2014-15, 4 Nos. of elite breeding lines were maintained.

Promising rice cultures for *boro* season in AICRIP trial: Three promising cultures were tested in AICRIP trial during *Dry season* 2014-15. Among the different entries tested CRL 193 (IET 24172), a selection from Huanghuazham, ranked fourth in *boro* 2015. It has long slender grains and takes 135 days for 50% flowering with a mean grain yield of 5480 kg/ha. It out yielded all the 4 checks national, regional, local and hybrid checks with a yield advantage of 12.80%, 22.76%, 10.71% and 1.44% respectively.

Evaluation of breeding materials in National (AICRIP) Trials: During wet season 2015, a total of 139 entries in different trails *viz*., IVT-RSL (58), AVT1-RSL (13), IVT-SDW (14), IVT-DW (16), AVT2-IME (12) and AVT1-NIL-Sub (26)

Performance of CR Dhan 909 in the Farmers' Field: CR Dhan 909 (IET 23193; CRL 74-89-2-4-1) from cross Pankaj/ Padumoni is a highly promising rice variety under aromatic short grain category developed at RRLRRS, NRRI, Gerua (Assam). The culture was approved by the Varietal Identification Committee, in the 50th Annual Rice Group Meeting, for release in the states of Odisha, Chhattisgarh, West Bengal and Assam. With the help of Krishi Vigyan Kendra, AAU, Darrang district, the variety was tested in a 0.8 ha MLT at farmers' field in Darrang district of Assam during *sali*/wet season2015. The location was Bamgaon (Mangaldoi). Aromatic rice variety 'Keteki joha' was used as the local check. CR Dhan 909 yielded 4.59 t/ha as against 3.24 t/ha of the local check.

PROGRAMME : 2

Enhancing Productivity, Sustainability and Resilience of Rice Based Production System

Efficient use of resources, *viz.,* nutrient, water and labour and managing the adverse biotic and abiotic stresses are keys to higher productivity and sustainability of the rice production systems. This programme was undertaken 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

Arbuscular mycorrhizal fungi colonization under phosphorus and zinc fertilization in aerobic rice

A field experiment was conducted during dry season, 2015 to study arbuscular mycorrhizal fungi (AMF) colonization under phosphorus and zinc fertilization in aerobic rice. The experiment comprised of twelve phosphatic and zinc fertilizer combinations *viz*., P_2O_5 at 0, 20 and 40 kg/ha; Zn at 0 and 5 kg/ha with two varieties CR Dhan 202 and CR Dhan 205 in a randomized complete block design with three replications. The results showed that root colonization was significantly higher in P_2O_5 at 0 level and Zn at 5 kg/ha over other nutrient treatments and maximum root colonization was recorded at panicle initiation stage. The number of AMF spores per gram soil also showed a similar trend. The mycorrhizal colonization and spore populations was also influenced by rice cv. CR Dhan 205.

Distribution of N mineralization enzymes in soil aggregates in a tropical rice-rice system

A study was conducted to evaluate the impact of long-term application of farm yard manure (FYM) and inorganic fertilizers in distribution pattern of enzymes, namely, urease, amidase and protease in different fractions of water stable soil aggregates. The treatments comprised of different combinations of inorganic fertilizers and farm yard manure (FYM) *viz.* control, N, NP, NK, NPK, FYM, FYM+N, FYM+NP, FYM+NK and FYM+NPK. The results showed that activities of urease and protease was least in control treatment and highest in FYM+NPK across aggregate fractions whereas highest amidase activity was recorded in FYM alone treatment. Urease activity in soil aggregates is shown in Fig 2.1. In contrast to urease and protease activity, amidase activity was highest in FYM alone treatment with 21.4-131.0% increase over control. Activities of all the enzymes reduced at 15-30 cm soil depth compared to surface soil in whole soil as well as in soil aggregate fractions. Activities of all the three enzymes were highest in aggregate faction of 5-2 mm. The results suggest that higher organic matter levels in FYM treatments provide a more favourable environment for the accumulation of enzymes in the soil matrix, since soil organic constituents are thought to be important in forming stable complexes with free enzymes. Thus, long term addition of FYM alone or in combination with inorganic fertilizer increases the macro-aggregates (5-2 mm) and overall activities of N mineralization enzymes.

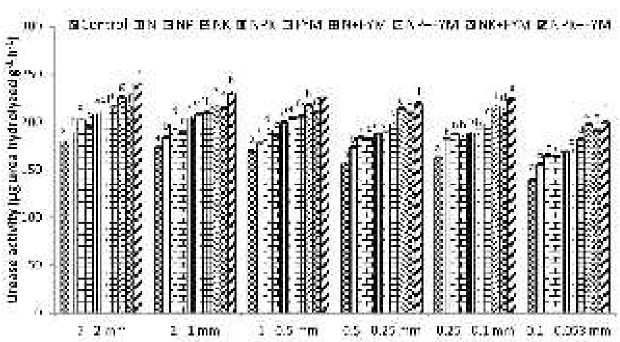


Fig. 2.1. Urease activity in different fractions of soil aggregates at 0-15 cm soil depth. (Different small letters indicate significant difference within the same aggregate class at $p \leq 0.05$; bars indicate standard errors).

Quantification of denitrifying bacteria in soil aggregates targeting nirS, nirK and nosZ genes using semi-quantitative PCR

This study was conducted to develop PCR assay targeting denitrification genes in order to assess the relative abundance in different treatments in long term fertilizer experiment. The treatments comprised of unfertilized control and different combinations of inorganic fertilizers and farm yard manure (FYM) *viz.* control, N, NP, NK, NPK, FYM, FYM+N, FYM+NP, FYM+NK and FYM+NPK. DNA was extracted from 500 mg of soil and PCR amplifications were done using 7 primers (2 for *nirS*, 2 for *nirK and* 3 for *nosZ genes*). Soil DNA was extracted from whole soil and 6 aggregates (5-2 mm, 2-1 mm, 1-0.5 mm, 0.5-0.25 mm, 0.25-0.1 mm, 0.1-0.053 mm) from different treatments. Amplification of DNA for three genes using seven primers was mostly detected in FYM+N and FYM+NP. Further, semi-quantitative PCR was used to determine genomic bacterial DNA concentration in a sample using two primer ***p1(***cd3aF (916-935); R3cd (1322-1341)) and ***p5*** (nosLb (1124-1144); nosRb (1405-1425)) specific to *nirS* and *nosZ* genes, respectively at 20, 27 and 35 cycles. Only the amplified PCR products were loaded onto 1.2% agarose gel stained with ethidium bromide and run on 0.5X TBE buffer with 100V in gel electrophoresis system. For this, Soil DNA samples from FYM+N, FYM+NP treatments from whole soil and FYM, FYM+N treatments of aggregate size 5-2 mm from soil aggregates which showed positive amplification for the above two primers were included. All the PCR reaction of 20 cycles condition failed to give detectable amplification in the gel. The amplification of PCR reaction started detection from 27 cycles with strong amplification at 35 cycle condition. The significant DNA amplification was detected at 35 cycles for both the primers. The amplification was strong for both the primer in whole soil as compared to soil aggregates. This result indicated that the denitrifying bacteria having *nirS* and *nosZ* genes are more in the whole soil as compared to soil aggregates. The amplification in FYM+N was stronger compared to FYM+NP for the whole soil hence it may be interpreted that populations were higher in FYM+N as compared to FYM+NP.

Investigating impact of silicon application on yield and N use efficiency of lowland rice

A field experiment was conducted during wet season, 2015 to investigate the impact of silicon application on yield and N use efficiency of lowland rice, Gayatri. The treatments consisted of two levels of Si (0, 200, kg SiO_2/ha) and 4 levels N (0, 80, 100, 120 kg N/ha) in randomized block design with three replications. The results revealed that application of Si increased the rice yield 12.2-16.9%. The N uptake was also significantly influenced by Si application. Partial factor productivity of N with Si application was 48.7-74.5 kg/kg; agronomic N use efficiency ranged from 19.6-30.8 kg/kg with Si and N recovery efficiency ranged from 35.9-49.0 % with Si.

Effect of integrated nutrient management options on yield, N use efficiency and N loss in transplanted rice

A field experiment was conducted during wet season, 2015 to study the effect of integrated nutrient management options on yield, N use efficiency and N loss in transplanted rice cv. Naveen. The experiment comprised of six treatments *viz.*, control (no N), 100% N as urea, 50% N as urea + 50% N as FYM, 50% N as urea + 50% N as poultry manure, 50% N as urea + 25% N as rice straw + 25% N as FYM, and 50% N as urea + 25%N as BGA + 25% N as FYM replicated four times in randomized block design. Organic manures were applied at the time of final land preparation. Manual closed chamber technique was used to measure NH_3 volatilization loss following acid trap method and to collect gas samples for analysis of N_2O using gas chromatograph (Table 2.1).

The results revealed that yields under 50% N as Urea + 50% as FYM, 50% N as Urea + 50% as poultry manure and 50% N as Urea+25% as BGA + 25% as FYM were statistically at par. The highest yield was recorded in 100% N as Urea (Table 2.3). Total N_2O-N emission under different treatments during the season followed the order T2>T3=T4=T5>T6>T1 and NH_3 volatilization loss was highest in 100% N as Urea followed by 50% N as Urea+50% as poultry manure.

Investigating effect of application of urea briquettes prepared by agglomerating urea with different amendments on yield and N use efficiency of transplanted rice

Agglomerated urea briquettes were prepared by mechanical compaction method using a urea briquette machine by mixing prilled urea, suitable amendments *viz.*, phosphogypsum, fly ash, silica powder, neem cake and rice husk as filling materials and biodegradable binding agents (Fig. 2.2). Characteristics of briquettes including their weight, urea content and time taken for dissolution are presented in Table 2.2.

Fig. 2.2. Urea briquette prepared with different filler material

A field experiment was conducted during wet season of 2015 with eight treatments *viz.*, control (No N), Urea granule, UPGB, UFAB, USPB, UNKB, URHB and UB replicated thrice in randomized block design with rice, Naveen. The highest grain yield was recorded in UFAB (5.2 t/ha). Agronomic N use efficiency, N recovery efficiency and partial factor productivity of N ranged from 19.0-28.7 kg/kg, 34.5-51.9 % and 42.7-52.0 kg/kg, respectively. Urea briquette prepared by mixing urea with fly ash (UFAB) resulted in the highest N use efficiency.

Mitigation of Greenhouse gas emission by scheduling irrigation based on soil water potential from direct seeded paddy fields

A field experiment was conducted during dry season, 2015 to evaluate suitable irrigation scheduling in rice for increasing water productivity and mitigating greenhouse gas (GHG) emissions with anticipation of water scarcity and global warming scenario. The experiment comprised of irrigation scheduling based on tensiometric measurement of soil water potential (SWP) in order to quantify temporal and seasonal variations in GHGs emissions and their trade off relationship at five levels of SWPs, *viz.*, SWP 1 (-20 kPa), SWP 2 (-30 kPa), SWP 3 (-40 kPa), SWP 4 (-50 kPa) and SWP 5 (-60 kPa), in addition to the traditional practice of flood irrigation (FI). Fluxes of CH_4 and N_2O during the growing period were measured using manual closed chamber-gas chromatograph and the CO_2 flux was measured using an infrared CO_2 analyzer. The experimental results showed a significant decrease in seasonal CH_4 emission (30-60.2%) at different SWPs as compared to CF. In contrast, emission of CO_2 and N_2O increased by 12.9 - 23% and 22.1-23%, respectively at SWPs 1 and 2; conversely, a significant decrease in emissions of these gases were observed at higher SWPs (SWPs 3 to 5). Among different SWP treatments, irrigation scheduling at SWP 2 maintained yield at par with CF

Table 2.1. Yield, agronomic N use efficiency (AE_N), N recovery efficiency (RE_N), and seasonal N_2O and NH_3 emission in transplanted rice under different integrated nutrient management options.

	Yield (t/ha)	AE_N (kg/kg)	RE_N (%)	N_2O emission (kg/ha)	NH_3 emission (kg/ha)
T1: 0 N	3.2d			0.34 d	2.3 d
T2: 100% N as Urea	5.1a	24.9 a	45.9 a	0.77 a	13.2 a
T3:50% N as Urea+50% as FYM	4.6b	18.8 b	31.8 b	0.67 b	9.0 c
T4: 50% N as Urea+50% as Poultry Manure	4.5b	18.2 b	33.1 b	0.68 b	10.6 b
T5: 50% N as Urea+25% as Rice Straw+25% as FYM	4.1c	13.9 c	28.3 b	0.67 b	8.7 c
T6: 50% N as Urea+25% as BGA+25% as FYM	4.5b	18.4 b	32.2 b	0.58 c	8.8 c
L.S.D. ($P \leq 0.05$)	0.34	3.4	9.8	0.086	1.5

Table 2.2. Weight, urea content and time taken for dissolution/disintegration of briquettes in distilled water

Amendments used	Product Code	Weight (g)	Urea content (g)	Time taken for dissolution/disintegration
	UB	1.42	0.71	10 minutes
Phosphogypsum	UPGB	1.41	0.71	3 minute 45 second
Fly ash	UFAB	1.08	0.54	24 hour
Silica powder	USPB	1.20	0.60	1 hour
Neem cake	UNKB	0.96	0.48	3 minute 5 seconds
Rice husk	URHB	0.98	0.49	2 minute 4 second

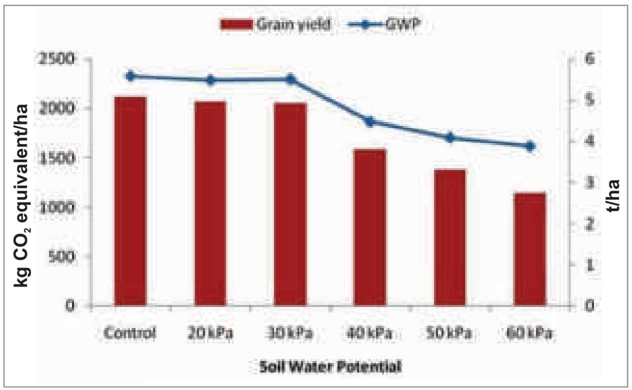


Fig. 2.3. Grain yield and global warming potential (GWP) at different soil water potentials

with water saving of 32.9% and reduced CH_4 emission (43%). However, due to increase in CO_2 & N_2O emission at SWP 2, there was no significant reduction in global warming potential (GWP) as compared with CF (Fig. 2.3). Among different rice growth stages, GHGs emissions were predominant during vegetative growth stage. Regression relationship of GHGs emission with key soil parameters was employed to predict seasonal emissions of GHGs from paddy field.

Water use efficiency of rice plants under elevated and ambient carbon dioxide conditions under different moisture regimes

A field study was conducted using Open Top Chambers (OTCs) during dry season, 2015 to elucidate the effects of ambient CO_2 (403.69 µmol/mol) and two levels of ECO_2 (550 µmol/mol and 700 µmol/mol) under two soil water levels (well watered and water stressed to -60 kPa) on water productivity (Wp) and physiological changes in rice. In water deficit treatments, measured amount of water was applied as surface irrigation, each time the soil water tension as measured by tensiometers, reached-60 kPa. There was an increase in plant height, ear bearing tillers, grain and straw yield over ambient CO_2 by 14, 28.9, 15.8 and 16%, respectively under well watered and ECO_2 conditions, whereas the increase over ambient CO_2 was 17, 22.5, 38.6 and 5.1% respectively under water deficit stress and ECO_2 conditions. ECO_2 decreased the irrigation water input by 10.8% under well watered condition, whereas the decrease under water deficit condition was approximately 4.7% over ambient CO_2 (Table 2.3). It suggests that irrigation water requirement for rice will be reduced under future ECO_2 environment. Wp increased with water deficit stress, particularly at ECO_2 (32.5% under well watered and 43% under water deficit stress). Water deficit stress coupled with ECO_2 induced changes in the response of antioxidant metabolites (proline, catalase and peroxidase) and plant water status like relative water content (RWC), electrolyte leakage (EL) and leaf water potential (LWP). This study suggests that physiological changes occurring under ECO_2 helped the rice plant in mitigating the negative effects of water deficit stress.

Agronomic manipulations in anaerobic germination to enhance rice crop establishment and productivity

A field experiment was undertaken to study the germination of rice cultivars under anaerobic conditions for better rice crop establishment. The results showed that IR64–AG had significantly higher germination % and plant population, which was 81.1 and 217.5% higher over IR64–*Sub1* and IR64. Agronomic manipulations *viz.,* higher seed rate (60 kg/ha) and additional P application (20%) improved the allometric characters after germination and emergence *i.e.* plant height, leaf area, number of tillers and biomass accumulation might be due to improved efficiency of the plant in the production and partitioning of photosynthates to the developing reproductive parts. More number of panicles was recorded at 60 kg seed rate. However, panicle weight was maximum under lower seed rate. Application of 20% additional P along with recommended NPK produced more number of panicles, fertile grains per panicle and panicle weight (Table 2.4). Regardless of the seed rate and nutrient application, IR64–AG cultivars resulted in highest grain yield, it was approximately 92.4 and 58.2% higher over IR64 and IR64-*Sub1*, respectively. Application of 20% additional phosphorus along with recommended dose of fertilizer resulted in 20.8, 15.8 and 18.9% higher grain yield in IR64–AG, IR64–*Sub1* and IR64 over control, respectively. The results suggest that physiological changes under anaerobic condition enhanced the starch hydrolysis and made more sugar available for embryo growth leading to higher germination, vigorous seedling production and later on improved allometric and yield attributes.

Effect of silica and nitrogen to improve submergence tolerance in rice

A field experiment was designed to study the effect of nitrogen (N) and silica (Si) application on submergence tolerance in rice cultivars *viz.*, IR 64, Swarna, IR64-*Sub1* and Swarna-*Sub1*. The results revealed that the photosynthetic rate, survival % and growth of all the cultivars decreased during submergence except in IR64 and Swarna. Application of Si as basal significantly reduced elongation (39.1%) and increased survival by 41.4%, irrespective of cultivars; additional 21.5% advantage in survival was recorded with N application with Si. IR64-*Sub1* recorded the highest survival and lowest elongation with the application of basal Si and N spray. The grain yield was 33.9 and 38.9% higher in Swarna-*Sub1* and IR64-*Sub1* over their recurrent parents, respectively. Interaction of basal Si and post-flood N spray was the most promising method of nutrient application which not only resisted the damage during submergence but also enhanced the survival, growth after recovery in terms of number of green leaves emergence, leaf area and photosynthetic rate. The interaction effect also revealed that basal application Si and post-flood N spray was a synergistic interaction, which resulted in 15.1 and 42.7% higher yield over N alone or Si alone, respectively. Basal Si application resists the damage of plant during submergence and helped in recovery after recedes of water, whereas, post-flood Si spray showed the negative effect on growth and yield (Fig. 2.4).

Table 2.3 Water productivity and harvest index of aboveground rice biomass under different CO_2 supply (ambient and elevated) and water regimes (well watered and water deficit).

Water status	**Water Productivity (kg/m ^{3})**		% CO_2 effect
	Ambient CO_2	Elevated CO_2	
Well watered	0.34 bB	0.47 aB	+38.2
Water deficit	0.44 bA	0.64 aA	+45.5
% water deficit effect	+29.4	+36.2	
Harvest Index			
	Ambient CO_2	Elevated CO_2	% CO_2 effect
Well watered	0.40 aA	0.42 aA	+5
Water deficit	0.35 bB	0.42 aA	+20
% water deficit effect	-12.5	-	

Different lower case letters indicate significant ($p < 0.05$) difference among treatments in a row, whereas different upper case letters indicate significant ($p < 0.05$) difference among the treatments in a column.

Table 2.4 Grain and straw yield (t/ha) of IR64, IR64 *Sub1*, IR-64AG-131 and IR-64AG-132 in experiment III as influenced by seed rate and nutrient application.

		Grain yield (t/ha)			Straw yield (t/ha)		
		Control	NPK	NPK+20%P	Control	NPK	NPK+20%P
40 kg/ha	IR64	1.84	1.98	2.22	2.54	2.73	3.07
	IR64-*Sub1*	2.29	2.47	2.58	3.05	3.25	3.71
	IR64 AG131	3.59	3.93	4.28	4.47	4.86	5.29
	IR64 AG132	3.64	3.97	4.32	4.53	4.89	5.33
50 kg/ha	IR64	1.91	2.06	2.30	2.82	3.05	3.39
	IR64-*Sub1*	2.41	2.57	2.85	3.18	3.46	3.77
	IR64 AG131	3.68	4.07	4.47	4.43	4.81	5.28
	IR64 AG132	3.75	4.11	4.59	4.50	4.91	5.23
60 kg/ha	IR64	2.09	2.19	2.44	2.99	3.13	3.49
	IR64-*Sub1*	2.49	2.68	2.91	3.32	3.55	3.84
	IR64 AG131	3.71	4.12	4.53	4.43	4.77	5.25
	IR64 AG132	3.80	4.17	4.64	4.47	4.89	5.26
$LSD_{P=0.05}$		**1.754**	**1.818**	**2.122**	**2.334**	**3.214**	**3.458**

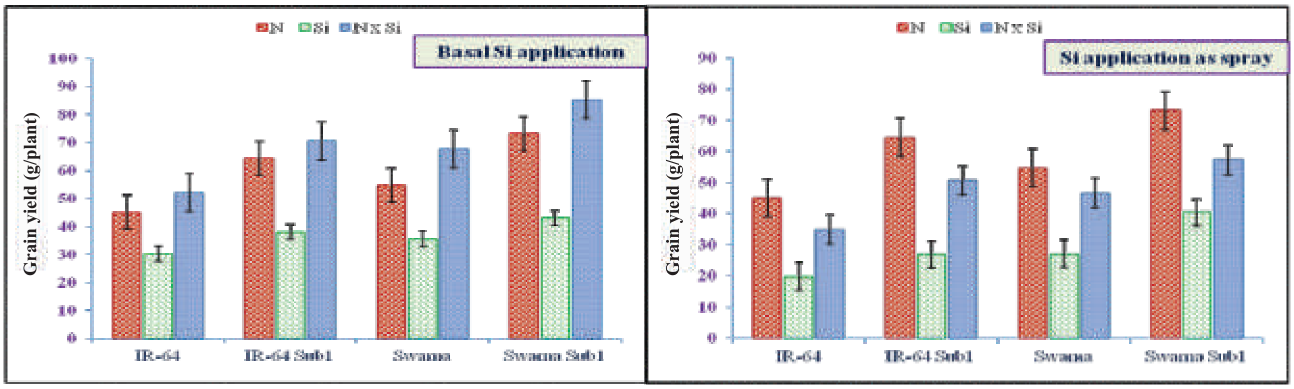


Fig. 2.4. Grain yield (g/plant) of rice cultivars as influenced by a) basal Si application b) Si spray with nitrogen interaction (vertical bars in each column represents standard error)

Effect of seedling age and nitrogen application in coping submergence stress of rice

The experiment was undertaken to understand the response of seedling age and nitrogen application on submergence tolerance in rice with *Sub1* and non-*Sub1* cultivars. The results showed that Swarna-Sub1 had the highest plant survival followed by IR64-*Sub1*. Across the cultivars, plant survival of 40 days old seedlings was 50-folds higher over 15 days old seedlings. Apart from seedling age, nitrogen application was also significantly influenced the plant survival. Post-flood N application contributed positively towards higher survival, basal N along with post-flood N showed a positive response on older seedlings but response was quite negative on younger seedlings. Plant survival was 58.1 and 53.8% higher with the application of post-flood N with basal N and without basal N, respectively, over no N application, irrespective of the cultivar and age of seedlings. Higher maintenance of sugar and starch (60.9% higher) in forty days old seedlings might be the reason for higher plant survival and lower mortality. Older seedlings (40 days old) of tolerant cultivars were also produced higher yield and it was 169 and 119% higher in IR64-*Sub1*, 167 and 129% higher in Swarna-*Sub1* over 15 and 20 days old seedlings. The crop fertilized with post-flood nitrogen resulted in substantially better survival, leaf and root growth, photosynthesis and yield, results were more positive in older seedlings of *Sub1* cultivars. These low input cost-effective approaches have been a good option for enhancing submergence tolerance and yield in stress-prone areas.

Yield and soil enzyme activities after two years of sequential biochar incorporation and C mineralization

The effect sequential application of rice husk biochar for two years at 0, 0.5, 1, 2, 4, 8 and 10 t/ha on yield and soil enzyme activities was studied in sandy clay loam soil in addition to recommended fertilizer dose (RFD) of 100:50:50 kg/ha NPK. The treatments were RFD (T1), RFD+0.5 t/ha (T2), RFD+1 t/ha (T3), RFD+2 t/ha (T4), RFD+4 t/ha (T5), RFD+8 t/ha (T6), and RFD+10 t/ha (T7). The results revealed that the grain yield ranged from 553 g/m^2 (control) to 685 g/m^2 (RFD+10 t/ha). At maximum tillering stage, the soil enzyme activities *viz.*, soil β-glucosidase activity, fluorescein diacetate activity and dehydrogenase activity increased with increase in application rates of rice husk biochar (Fig. 2.5).

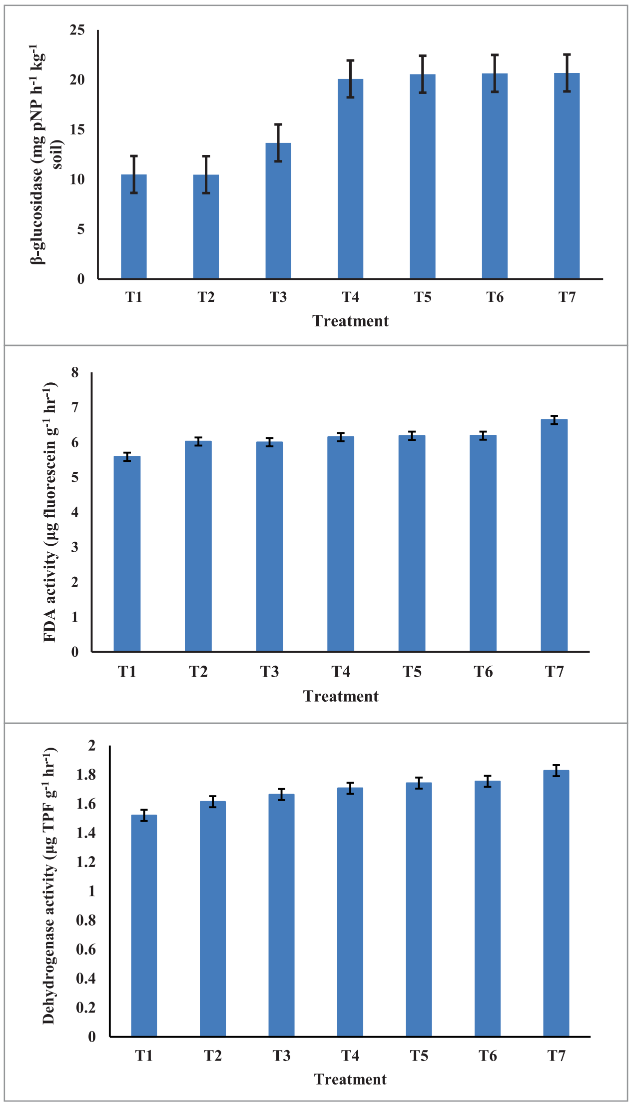


Fig 2.5. Soil β-glucosidase activity, fluorescein diacetate activity and dehydrogenase activity as influenced by rates of biochar application

With respect to above treatments, harvest soils were subjected to carbon mineralization study after two years of sequential biochar incorporation. The C-mineralization study revealed that the rate of release of CO_2 was lower in RFD (T1) till 15 days of soil incubation compared to biochar treated plots (Fig. 2.6). Beyond 15 days, there was non-significant difference in cumulative release of CO_2-C among the biochar treated plots. The study observed that an overall decrease in rate of release of CO_2-C over a period of time in all the treatments (Fig 2.7). This was due to faster degradation of loosely held organic material till 15 days. After 15 days, rate of release of CO_2-C was more stabilized in biochar treatments due to complex and aromatic structure of biochar.

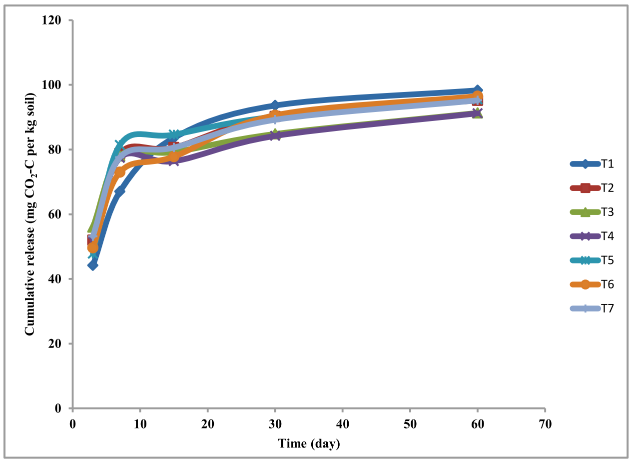


Fig. 2.6. Cumulative release of CO_2 as influenced by rates of biochar application

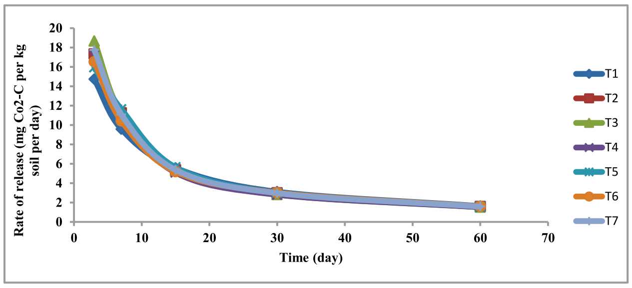


Fig 2.7. C-mineralization rates influenced by rates of biochar application

Performance evaluation of urea briquette applicators for transplanted rice

Field performances of five hand-operated applicators *viz.*, three basal applicators i.e. two row (UBA-I), three row (UBA-II) and four row (UBA-III) and two top dressing applicator i.e. UBA-IV and UBA-V were evaluated in Institutional farm as well as in farmers field for placement of circular shape urea briquettes in transplanted rice. Specifications of these applicators are given in Table 2.5.

Circular shaped urea briquettes having diameter 15 mm, thickness 8 mm and weight 1 g were used for evaluation of applicators. At average operating speed of 0.8, 0.92, 1.02, 1.4 and 0.78 the effective field capacity were found 0.070, 0.082, 0.06, 0.025 and 0.021 for UBA-I, II, II, IV and V, respectively. Urea briquette applicator could save time up to 78.5 %, 82.8 %, 78.5 %, 42.8 % and 31.4 % over hand application by using UBA-I, II, II, IV and V, respectively. For basal application UBA-II performed better in comparison to UBA-I in terms of UB missing percentage. Missing rate of UB was nil for UBA-V but the labour requirement was high.

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

A field experiment was conducted during dry season, 2015 to study the water use efficiency and water productivity in aerobic rice. The treatments consisted of two rice varieties, CR Dhan 200 and Shabhagidhan and 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. The results showed

Table 2.5 Brief specification of urea briquette applicators

Sl. No.	Particular	Applicator - I	Applicator - II	Applicator -III	Applicator - IV	Applicator - V
1	Overall dimensions, mm (L x W x H)	990 x 470 x 610	600 x 730 x 480	720 x 940 x 330	320x110x370	1200 x 150 x 1200
2	Ground wheel diameter, mm	300	480	500	--	--
3	Handle length, mm	900	870	870	1180	100
4	Float length, mm	1000	700	720	290	--
5	Weight without load, kg	14	20.5	14	9.3	1.66

consistently higher grain yield (3.85 t/ha) in CR Dhan 200 and 5-20% more grain yield with additional 20-30% irrigation at all three CGS i.e., tiller, panicle and grain development stage (S_2) over aerobic condition. Among different irrigation treatments, significantly higher grain yield (4.05 t/ha) was recorded with additional irrigation at all three CGS followed by at panicle/tiller and grain development stage that (3.86 and 3.75 t/ha, respectively). Irrigation requirement (IR) was lowest (950-965 mm) under aerobic condition accounting higher water productivity (0.35-0.38 g grain/ lit water applied) but with lower grain yield (3.47 t/ha).

Another experiment was conducted to study the interaction of irrigation interval with N management in aerobic rice. The treatments comprised of three irrigation intervals, I_1 : 4 days interval each at seedling, vegetative and reproductive stages; I_2 :6 days interval at seedling stage with 4 days interval each at vegetative and reproductive stages; and I_3 : 6 days interval each at seedling and vegetative with 4 days interval at reproductive stages with two levels of N i.e., N_1 : 100% of recommended dose (RFD) of N (120 kg/ha) and N_2 : 125% of RFD, and two application schedules, i.e., M_1 : 33% each at 10-12 days of emergence, active tillering and panicle initiation stage; and M_2 : 25% each at basal and panicle initiation with 50% at active tillering stage. The experimental results showed comparable grain yield (3.77 and 3.84 t/ha, respectively) in I_1 and I_2, significantly higher than that in I_3. Regarding N management, grain yield was comparable despite applying 25 % additional N, even with increasing N applications schedules.

Development of sustainable production technologies for rice based cropping systems

System based nutrient management in rice based cropping system

A field experiment was carried out to study the effect of system based nutrient management options on 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 5 system based nutrient management option i.e. control-control-control, RDF - RDF - RDF, RDF_{75} (75% of recommended dose of fertiliser) + Crop residue incorporation of previous crop (CRI) – RDF - RDF, RDF_{75}+CRI - RDF + Straw mulch (SM) - RDF and RDF_{75}+CRI-RDF+SM-RDF_{50} in subplots replicated thrice. The variety Naveen (Rice), Super 36 (Maize) and Banamali (Cowpea) were used in the experiment. Rice yield did not differ significantly with respect to different systems in wet season during third year. Among the nutrient management treatments, highest rice grain yield of 4.98 t/ha was recorded with RDF75+CRI - RDF + SM – RDF which was at par with that of RDF75+CRI- RDF+SM - RDF50. Significantly higher grain yield was recorded with RDF+ straw mulched plots compared to RDF applied plots in maize. The Rice equivalent yield (REY) of groundnut was significantly higher (10.0%) compared to maize in dry season. In summer season, similar yield of cowpea was recorded in both rice - maize -cowpea and rice - groundnut - cowpea systems. The total productivity of the rice-groundnut-cowpea system was comparable to that of rice - maize - cowpea system. Among the nutrient management options, the highest REY of 17.3 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 two cycles of the system, the organic carbon, available N content of the soil did not change with the cropping systems but higher available K was observed with rice - maize - cowpea cropping system. The organic carbon, available N, P and K of residue applied plots was though significantly higher than control but was at par with RDF applied plots. Thus, 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 that produced significantly highest REY may be practiced for sustainable production from irrigated medium land ecology (Table 2.6).

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

A field experiment was designed to examine the performance, system productivity and economics of different rice varieties and dry season crops under varying rice establishment methods *viz.*, dry direct-sown (D-DSR), wet direct-sown (W-DSR) and transplanted rice (TPR) under rainfed conditions. The experiment was laid out in a split plot design with rice

Table 2.6 Productivity of component crops and the system (REY) of RBCS under nutrient management options

Cropping system	Rice Equivalent Yield (t/ha)			
	Wet	Dry	Summer	System
Rice - Maize - Cowpea	4.54	6.78	2.63	13.94
Rice - Groundnut - Cowpea	4.25	7.47	2.66	14.38
CD (p =0.05)	NS	0.67	NS	NS
Nutrient management				
Control - Control - Control	3.33	2.50	0.53	6.36
RDF - RDF - RDF	4.46	8.10	2.92	15.48
RDF_{75} + CRI - RDF - RDF	4.40	7.87	2.56	14.83
RDF_{75} + CRI – RDF + SM - RDF	4.98	8.59	3.73	17.30
RDF_{75} + CRI - RDF + SM - RDF_{50}	4.79	8.56	3.47	16.82
CD (p =0.05)	0.31	0.45	0.21	0.57

establishment methods and rice variety in main and sub-plots, respectively and dry season crops in sub-sub plots. The results of the study revealed that establishment of rice crop by transplanting produced the highest yield, and it was around 27.8 and 8.5% higher over D-DSR and W-DSR, respectively, irrespective of the cultivars (Fig. 2.8).

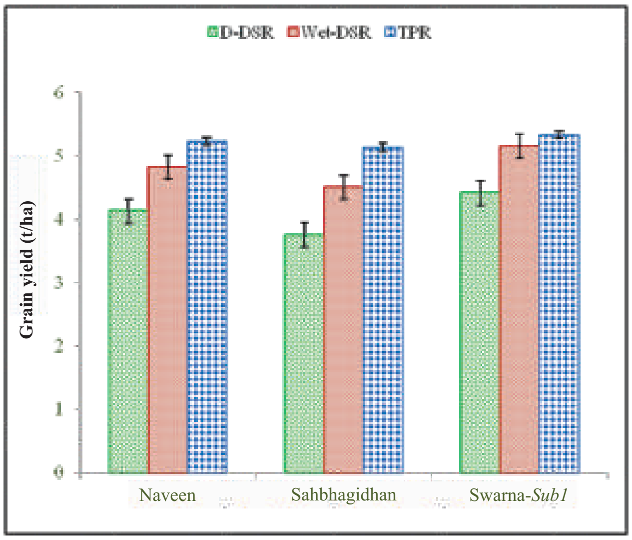


Fig 2.8. Grain yield of rice as influenced by different rice varieties and crop establishment methods

Among the cultivars, Naveen performed better followed by Sahbhagidhan. The yield of Swarna-*Sub1* was affected due to dry spells occurred at reproductive stage, however, it was at par with Naveen. Performance of dry season crops was severely affected when sown after Swarna-*Sub1* because of its late harvesting and non-availability of residual moisture for establishment and growth of succeeding crops. Yield of toria, green gram and black gram was decreased up to 139, 116 and 95% when sown after Swarna-*Sub1* over sowing after Naveen and Sahbhagidhan, respectively. In the dry season, black gram performed better when sown after Naveen and Sahabhagidhan. System productivity was maximum in rice cv., Naveen (TPR) – black gram followed by Sahbhagidhan (TPR) – black gram (Table 2.7). As per the benefit: cost ratio, Naveen (TPR) – black gram was most profitable (2.14) due to higher yield of both the crops followed by Sahbhagi dhan (TPR) – black gram (2.12), lowest net returns and B: C ratio was recorded for Swarna-*Sub1* in wet season and toria in rabi season because of their lower yield and high cost of cultivation.

Conservation Agriculture based resource management in rice – maize cropping system

A field experiment was carried out to study the effect of different nutrient management options on the rice-maize cropping system under conventional and zero/minimum tillage. The experiment was laid out in a split - split plot design with three replications. The treatments comprised of two tillage systems i.e.

Table 2.7 Rice equivalent yield of dry season crops and system productivity as influenced by different rice varieties and crop establishment methods under rainfed conditions

Establishment methods (M)	Variety (V)	REY (kg/ha)			System productivity (kg /ha)		
		Toria	Green gram	Blackgram	Toria	Green gram	Blackgram
Dry-DSR	Naveen	1116	1789	1968	5626	6299	6478
	Sahabhagidhan	1127	1809	1978	5957	6639	6808
	Swarna-Sub1	476	859	1059	5633	6016	6216
Wet-DSR	Naveen	1077	1709	1886	4833	5466	5643
	Sahabhagidhan	1088	1725	1907	5218	5855	6037
	Swarna-Sub1	448	799	980	4872	5222	5403
TPR	Naveen	1021	1632	1797	6155	6766	6931
	Sahabhagidhan	1030	1645	1810	6264	6878	7043
	Swarna-Sub1	430	725	876	5770	6065	6216
LSD $_{P=0.05}$		41.8			231.5		

conventional and zero/minimum tillage in main plots and three residue management system i.e. RDF + no residue, RDF + residue mulching (3 t/ha) and RDF + residue mulching (6 t/ha) to maize in subplots and two N levels to rice i.e. LCC based (75% RDN) and LCC based (100% RDN). The variety Pooja (Rice) and Super 36 (Maize) were used in the experiment. The experimental results indicated that significantly lower grain yield was recorded in maize when zero tillage was followed; however, yield difference was non-significant in rice where minimum tillage was followed compared to conventional tillage. The grain yield of maize was reduced by 8% in zero tillage compared to conventional tillage. The system productivity in terms of rice equivalent yield (REY) did not differ significantly in rice–maize cropping system in conservation tillage system compared to conventional tillage. The maize grain yield was increased with increase in residue of rice in maize up to 6 t/ha but the residual effect of residue management in maize is not significant on rice grain yield though numerically lower rice grain yield was observed in higher residue plots. Application of 100% of RDN did not showed significant difference with 75 % of RDN but the yield of maize was higher when 100% RDN applied to rice compared to 75% RDN. The system REY with 100% RDN to rice was 7 % higher than that obtained with 75% RDN applied through LCC (Table 2.8).

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

A field experiment was conducted to study the effect of rice canopy level radiation under different establishment methods and sowing time on grain yield. The treatments consisted of three methods of establishment (Wet-Direct seeding, W-DSR; transplanting, TPR and modified SRI), four dates of transplanting (1st week of June, 3rd week of June, 1st week of July and 3rd week of July in wet season and 1st week of December, 3rd week of December, 1st week of January and 3rd week of January in dry season) and two varieties (Pooja and Naveen during wet season and Rajalaxmi and Naveen during dry season). The experiment was laid out in split-split plot design keeping establishment methods in main plot, date of sowing and varieties in sub and sub-sub plots, respectively. The results revealed that fraction of radiation intercepted was significantly highest in W-DSR but RUE was higher in TPR during both the seasons. This might be due to higher grain yield in TPR with long duration varieties *viz.*, Pooja during wet season and Rajalaxmi during dry season as reflected in highesr PAR interception. But, RUE was higher in Naveen during wet season. The interaction effect was found significant.

Rice yield was affected by changing the ability of the canopies to intercept radiation and PAR utilization

Table 2.8 Productivity of rice – maize cropping system as influenced by tillage and nutrient management

Tillage in Maize/Rice	Maize Grain Yield (t/ha)	Rice Grain Yield (t/ha)	REY of Maize (t/ha)	System REY (t/ha)
Conventional Tillage	8.44	5.35	8.13	13.48
Zero/Minimum Tillage	7.76	5.31	7.47	12.78
CD (p =0.05)	0.63	NS	0.61	NS
Residue management in Maize				
RDF + No Residue	7.63	5.55	7.35	12.90
RDF + Residue Mulching (3 t/ha)	8.07	5.34	7.77	13.11
RDF + Residue Mulching (6 t/ha)	8.60	5.10	8.28	13.38
CD (p =0.05)	0.42	NS	0.40	NS
Nutrient management in Rice				
LCC based (75% RDN)	7.76	5.22	7.47	12.69
LCC based (100% RDN)	8.43	5.44	8.12	13.56
CD (p =0.05)	0.34	NS	0.33	0.71

efficiencies. Methods of rice establishment did not have any significant effect on yield. Among the date of sowing/transplanting, significantly highest yield was obtained under D_2 *i.e.* third week of June in wet season and third week of December during dry season, might be due to favorable crop growth conditions. Pooja sown during 3rd week of June gave the highest yield under TPR, similarly Rajalaxmi sown in 3rd week of December produced highest grain yield under TPR. Irrespective of the cultivar and methods of establishment, highest grain yield was obtained when sown during 3rd week of June. Due to late sowing/planting, grain yield was declined up to 9.4 and 18.9% in Naveen and Pooja, respectively.

Farm implements and post-harvest technology for rice

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

Modification and field performance evaluation of single row dry land weeder

Single row dry land weeder, developed earlier, was modified to get uniform depth of intercultural operation. A roller type depth control wheel with adjustable height was fitted in the front of machine and tested in direct sown rice with different row spacing at 1 to 5 cm depth with blades width of 12 and 18 cm and total weed biomass was 6.04 t/ha. The weeder performed well at 3 and 4 cm depth. It moved slowly at 1 to 2 cm depth due to poor thrust action of rotating blades. At greater depth of 5 cm, it stopped due to heavy load on engine. The maximum weed control efficiency was recorded when machines attached with 18 cm blade operated in 20 com row spacing.

Development of self-propelled single row wet land weeder

Fabrication of self-propelled single row wet land weeder with 1.03KW power engine was done during 2015. Power to lugged wheel was given to propel the machine forward and power from engine was transmitted to gearbox output shaft through clutch, bevel gear unit and gearbox assembly. Gearbox output shaft transmits power to rotor unit through chain and sprocket and to lugged wheel through belt and pulleys. Speed available at rotor unit and lugged wheel (transport wheel) was 492 rpm and 20 rpm at full throttle. The speed of the machine was 2.0 km/hr. Field evaluation and further modification is to be carried out during the next season.

Modification and evaluation of field performance of two row self propelled wet land weeder

The rear wheel of two row self-propelled wet land weeder, developed earlier, was modified to avoid sinking of rear depth controlled wheel in wet soil. A cylindrical hollow floating wheel of 10 cm width and 17 cm diameter was fixed and supported with U clamp to rotate free on its own axle. It was attached with the depth control lever shaft of weeder and its height with respect to ground position was made adjustable. The modified weeder with blades of different width was tested in direct-sown rice, Naveen established at three different row spacing viz., 20, 25 and 30 cm. Pad strips of 11 cm width in 20 cm and 14 cm width in 25 cm and 30 cm row spaced rice crop were used. There was no plant damage due to rear wheel and working blades. The performance details were cited in Table 2.9. However, further testing with different size of blades within same row spacing is to be carried out to examine its effect on plant damage and weed control.

Study of operational efficiency of rice planting and weeding implements in terms of productivity and economic returns

Study on openational efficiency of rice weeding impliments

Field testing of different types of weeders *viz*., finger weeder, cono weeder, NRRI developed two row self-propelled weeder, Kalinga Shakti power weeder was carried out in direct-sown rice, Pooja during wet season, 2015. Results revealed that highest field capacity was observed in NRRI two row self propelled weeder 0.052 ha/h), followed by Kalinga Shakti power weeder (0.046 ha/h). Total man-h required (333.5 man-h) for weed control was least for NRRI two row self-propelled weeder. Energy required for weeding was least for chemical weeding (700.5 MJ/ha). However, rice yield was at par among different treatments.

Study on operational efficiency of NRRI developed wet land seeders

Field evaluation of different NRRI developed wet land seeders viz., eight row power operated cylindrical, conical and cup type drum seeders, four row conical manual drum seeder, six row manual cylindrical drum seeder and two row manual cup type seeder was conducted during dry season, 2015 with rice cv. Naveen. The experimental results showed that eight row power operated seeder having cup type seed metering required least man hour (5.83 h/ha) for operation. The lowest cost for seeding (Rs 601/ha) was recorded by operating four row manual seeder having conical shape drum. Field efficiencies of seeder varied from 65.37% to 82.17%. No significant difference in rice yield was observed among different sowing machine treatments.

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

A light weight self-propelled eight row paddy seeder was developed. The shovel type furrow opener with adjustable depth was connected with cup type (10 mm) metering unit through seed delivery tube. Two depth control wheels were provided to control the operation depth and give smooth forward movement during field operation. The diameter of driving wheel

Table 2.9 Field performance of two row self-propelled wet land weeder with modified depth control wheel

Parameters	Row spacing (R) and blade width (W)		
	R =20cm W =6cm	R =25cm W =9cm	R =30cm W =12cm
Field capacity (ha/h)	0.054	0.064	0.078
Weeding control efficiency (%)	40.0	46.0	50.0
Real wheel sinkage (cm)	5	5	6.3
Working depth (cm)	8	7.5	7.3
Avg. speed of operation (km/h)	2.74	2.57	2.60

is 600 mm and width of wheel is 240 mm with 18 lugs giving 40 mm penetration in soil. Angle of lugs from horizontal plane is 75^0. MS Flate having thickness of 60 mm was used for making lugs. The field testing was done during wet season 2015 with rice, Naveen. It was found 1 to 3 seeds were fallen per hill. The field capacity, field efficiency and fuel consumption of the self-propelled dry direct seeder was 0.21 ha/h, 87% and 6.8 l/ha, respectively at the forward speed of 1.73 km/h and with seed rate of 28 kg/ha.

Resource Conservation Technologies (RCT) and Conservation Agriculture (CA) for sustainable rice production

Development of site specific RCT/ CA technologies

Field experiment was conducted with green gram during dry season, 2015. Six resource conservation technologies (RCTs) *viz*., T1: conventional practice as control; T2: brown manuring (*Sesbania aculeata*) dry direct seeded; T3: green manuring (*Sesbania aculeata*) dry direct seeded; T4: wet direct seeding of rice by drum seeder; T5: Zero tilled dry direct seeded rice; T6: Paired row dry direct seeded rice were implemented during preceding wet season with three replications in randomized block design. The green gram crop was raised with a fertilizer dose of 20-40-20 kg N, P_2O_5 and K_2O/ha. The seed yield varied from 0.72 to 1.07 Mg/ha and the highest yield was obtained in T6 followed by T3 treatment. The labile C and enzymatic actives were higher in T6 and T3 treatments. However no significant differences were observed in case of oxidizable carbon except zero tillage treatment.

Ratooning behavior of rice varieties under different management practices

A field experiment was conducted with ten rice varieties established under three different dates of planting in a factorial randomized block design with three replication to study the ratooning behaviour of different rice varieties. The results showed that ratoon crop took 50% less time to mature as of main crop. Short duration varieties *viz*., Naveen and Sahbhagidhan matured earlier than long duration varieties *viz*., Gayatri. The plant height of ratoon crop was 50-60% lower than the main crop. The panicle number was decreased in ratoon crop in all the tested varieties with maximum decrease in Sahbhagidhan (Table 2.10). Delayed planting reduced the fertile grains per panicle in both main and ratoon crop; reduction was around 27.3 and 31.8% in main and ratoon crop, respectively over timely planting. Ratoon crop contributed to the grain yield ranging from 17-45% to the main crop yield, total yield was highest in Rajalaxmi i.e. around 9 t/ha. Among the different cultivars, highest ratoon and main crop yield was obtained in hybrids, whereas, maximum ratoon yield after hybrids was obtained in Savitri which was 45% of the main crop. Varieties like Sahbhagidhan, Swarna and Naveen did not performed better in their ratooning ability. Sahbhagidhan produced only 17% yield as of main crop.

Comparative performance of manual transplanter and hand transplanting at farmers field

Transplanting by machine was not only economical but also reduced labour requirement and drudgery involved in manual operation. On-farm trial was conducted during wet season, 2015 in village Itukura of Mahanga block in Cuttack district to evaluate the performance of manual drawn paddy transplanter. Four row NRRI manual transplanter was operated by one person for transplanting rice, Pooja at 24 cm spacing. In manual planting, 23 days old seedlings were transplanted at 10-12 cm hill distance. The planting depth was 3 to 4.5 cm with missing hills of 9%. The actual field capacity was found 0.0239 ha/h with cost of operation Rs. 1560/ha. Grain yield in both manual and mechanical transplanting remained at par with mean grain yield of 4.52 and 4.38 t/ha, respectively.

Study on the efficacy of early and late post emergence herbicides and herbicide mixtures in zero tillage rice

Efficacy of early and late post emergence herbicides and herbicide mixtures was studied in zero tillage rice. The treatments comprised of sequential application of bispyribac sodium (30g/ha) followed by fenoxaprop-p-ethyl (50g/ha); fenoxaprop-p-ethyl + Ethoxysulfuron (50 g/ha + 20 g/ha) and Cyhalofop butyl at 50g/ha along with weed free and weedy check. The major weed flora in the weedy plots were grassy weeds *viz*., *Echinochloa colona* and *Leptochloa chinensis* sedges *viz*., *Scirpus incurvatus*, *Cyperus difformis* and *Fimbristylis miliacea* and broad-leaved weeds *viz*., *Sphenoclea zeylanica*. Sequential application of bispyribac sodium and fenoxaprop-p-ethyl was found most effective in controlling the weeds as reflected by

Table 2.10 Effect of planting time and varieties on grain yield of main and ratoon crop of rice

	Grain yield (t/ha)			
	Main crop	Ratoon crop	% of MC	Total (MC+RC)
Varieties (V)				
Gayatri	5.82	2.27	39.0	8.09
Pooja	5.60	2.09	37.3	7.69
Swarna-Sub1	5.03	1.88	37.4	6.91
Sahbhagi Dhan	4.09	0.71	17.4	4.80
Naveen	4.61	1.23	26.7	5.84
Savitri	5.27	2.38	45.2	7.65
Sarla	5.15	1.96	38.1	7.11
Swarna	5.11	1.72	33.7	6.83
Ajay	6.08	2.57	42.3	8.65
Rajalaxmi	6.31	2.73	43.3	9.04
$LSD_{P=0.05}$	0.627	0.246	-	0.976
Planting time (T)				
1st wk of July	5.68	2.25	39.6	7.93
3rd wk of July	5.33	1.98	36.5	7.31
1st wk of August	4.91	1.61	31.9	6.52
$LSD_{P=0.05}$	0.343	0.123	-	0.894
$LSD_{P=0.05}$ (VxT)	0.754	0.358	-	1.008

weed density (Fig.9) and weed biomass (Fig 2.10). Highest weed control efficiency was recorded in sequential application of bispyribac and fenoxaprop-p-ethyl (80%). Sequential application of bispyribac and fenoxaprop-p-ethyl recorded highest yield (5.2 t/ha).

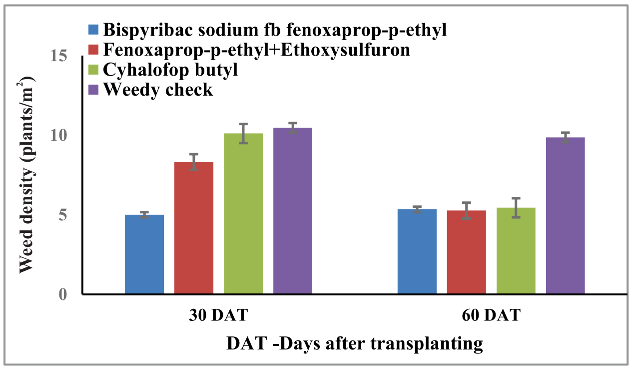


Fig 2.9. Total weed density (plants/m²) in different treatments at 30 and 60 DAS (calculated using transformed values)

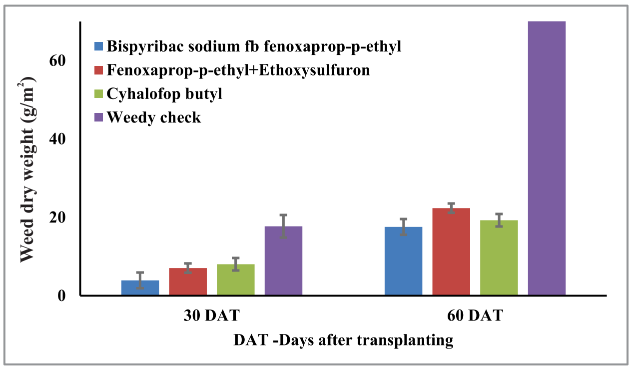


Fig 2.10. Weed dry matter (g/m²) under different treatments at 30 and 60 DAS

Ratoon suppression in conservation agriculture

A field experiment was conducted to evaluate the effect of herbicides on seedling survival of ratoon crop as influenced by date of harvesting of main crop and stubble height. The experimental results revealed that there was difference in seedling survival % of ratoon crop in response to date of harvesting of main crop but it was at par. Seedling survival % was significantly influenced by the stubble height and herbicide application. Application of paraquat recorded higher seedling death (5% survival) compared to application of glyphosate (25% survival) in 15 cm stubble height (Fig. 2.11). The seedling survival % was marginally higher in 30 cm stubble with 9% and 31 % respectively, in paraquat and glyphosate treated plots.

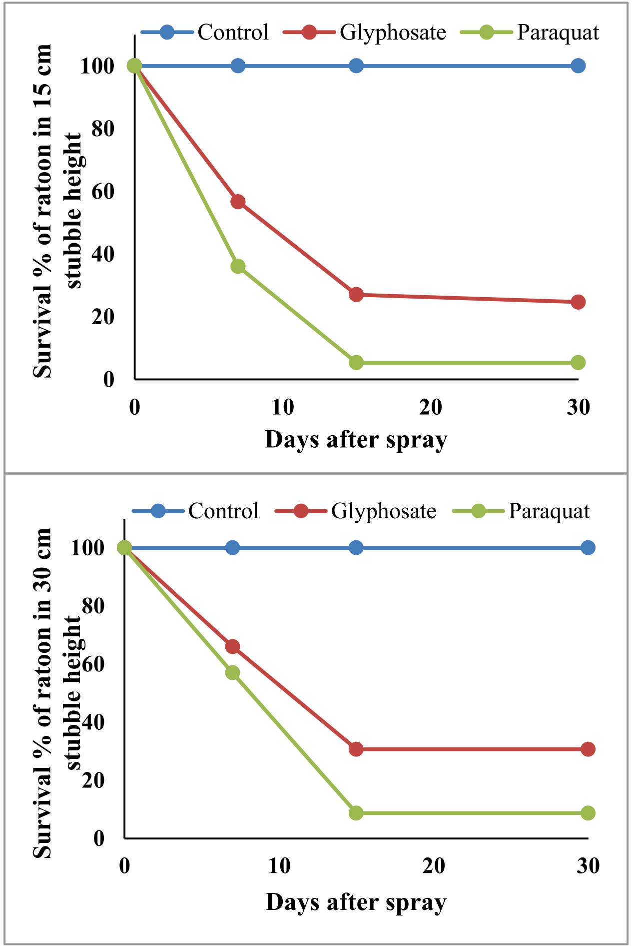


Fig 2.11. Seedling survival % of ratoon in 15 and 30 cm stubble height when treated with post emergence herbicides

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

Development of rice-based farming systems for upland ecologies

A rice-based farming system was initiated in rainfed upland of Krishi Vigyan Kendra, Santhapur for evaluating the performance of two rice varieties, Anjali (90 Days) and Sahbhagi dhan (100 days) and two pigeonpea varieties Maruti (125 days) and Asha (120 days) during wet season, 2015. Results showed that Shabhagi dhan yielded higher (2.85 t/ha) over Anjali (2.10 t/ha). Pegionpea varieties Maruti and Asha produced mean yield of 1.20 t/ha and 1.14 t/ha, respectively. Rice variety, Anjali recorded a net return of Rs. 16,500 with B:C ratio 0.26 whereas Sahbhagi dhan gave a net return of Rs. 17,750 with B:C ratio of 0.71. Pegionpea varieties Maruti and Asha gave a net return of Rs. 76,000 with B:C of 3.80 and Rs. 71,000 with B:C of 3.56, respectively. This exhibited that pigeonpea is more profitable in rainfed upland over rice.

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 deep water ecology. The grain yield of wet season rice Pooja, CR Dhan 500 and Durga, sown in Tier III were 5.95, 5.48 and 5.38 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 in Jalmani, CR Dhan 505 and Varshadhan were 3.70, 6.36 and 5.98 t/ha, respectively. Fresh spawns of Indian major carp were released in the water body during post-monsoon season. The graded harvested fish yielded 0.28 t/ha with an average weight of 0.5-0.9 kg. After the wet season rice, the performance of several crops viz., water melon, cucumber, okra, groundnut, green gram and rice *cv*. Naveen were evaluated during dry season with harvested rainwater. The highest yield was recorded with watermelon (11.8 t/ha) followed by cucumber (6.0 t/ha). The productivity of vegetable crops in raised land (Tier II) was in the range of 11.3-38.6 t/ha during dry season and 5.3-8.0 t/ha during wet seasons. Among vegetables, cowpea cv. Arka Suman (7.2 t/ha), okra cv. Arka Abhay (7.2 t/ha) and ridge gourd cv. Arka Sumeet (8.7 t/ha) were found remunerative during wet season. During dry season, bottle gourd on platform yielded highest (36.2 t/ha) followed by tomato (16.9 t/ha), french bean (8.0 t/ha), radish (10.8 t/ha) and leafy vegetables yielded 14.2-22.6 t/ha. Elephant foot yam (cv. Gajendra) grown as intercrop with guava yielded 6.7 t/ha whereas guava yield was 7.6-14.7 kg fruits/plant. Among the bird components, poultry birds (breed, Vanaraja) attained average weight of 2.1 kg in 90 days, while ducks (breed, Khaki Campbell) recorded an average weight of 1.6-1.9 kg in 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, *viz.*, 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 wet season rice *cv*. Durga and Varshadhan and during the dry season, Naveen and Maudamani were grown along with fish. Fingerling of rohu; catla; mrigal/mionor carp were released during wet season. Two rice crops together (Varshadhan/ Durga and Naveen/Maudamani) produced a total grain yield of 11.8 t/ha. On the bunds, winter leafy vegetables (amaranthus, spinach, fenugreek), coriander, french bean, tomato and radish performed well with an average productivity of 8.6 – 20.5 t/ha. The system could produce 12 q of food crops, 0.90 q of fish, 0.40 q of meat, 34 q of vegetables and 2.0 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 and agro forestry based integrated farming system

In Rice-fish-horticultural and livestock based integrated farming system model with water refuge area (approx. 15%), rice area (approx. 65%) and bunds on four side (approx. 20% area) was taken for experiment. The bund area used for horticultural crops (mango, Guava, coconuts, areca nuts, banana, pineapple, papaya etc.), and agro forestry plantation. Different types of vegetables were grown in bunds depending upon the season. Animal components viz., goat, duck, and poultry were reared by making suitable shed provisions for different animals. During dry season, rice cv. Naveen, CR dhan- 201, Pyari and Heera yielded 3.5, 3.2, 3.1 and 2.5 t/ha, respectively. During wet season rice cv. Varshadhan and Durga were yielded 3.4 and 3.1 t/ha, respectively. The poultry bird (Van raj variety) attains body wt. of 2.45 kg in 3 months. Among fishes, common carp attained higher growth followed by catla, rohu and mrigal. Ducks (Khaki ethoxysulfuron (5.15 t/ha) and cyhalofop butyl fb ethoxysulfuron (4.96 t/ha) treated plots. Sequential application of bispyribac sodium fb ethoxysulfuron showed 8 and 13% yield advantage over the recommended herbicides of azimsulfuron and bispyribac sodium, respectively.

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

Weed spectrum and efficacy of low dose herbicide mixtures for broad spectrum weed control was studied in transplanted rice with cv. Naveen. Total nine treatments including six herbicide mixtures *viz*., bispyribac sodium + ethoxysulfuron (25+15 g/ha), fenoxaprop-p-ethyl + ethoxysulfuron (50+15 g/ha), cyhalofop butyl + ethoxysulfuron (100+15 g/ha), bispyribac sodium + azimsulfuron (25+22 g/ha) and penoxsulam + cyhalofop butyl (120 g/ha) were compared with two recommended herbicide *viz*., bensulfuron methyl + pretilachlor (70+700 g/ha) and azimsulfuron (35 g/ha) along with weed free and weedy check. The experiment was laid out in randomized complete block design with three replications. Experimental results revealed that there was excellent control of complex weed flora in fenoxaprop-p-ethyl + ethoxysulfuron (50+15 g/ha) and bispyribac sodium + azimsulfuron (25+22 g/ha) treated plots applied at 15 days after transplanting (DAT) with weed control efficiency (WCE) of 88.0% and 87.1%, respectively. Among the herbicide treated plots, the highest yield was achieved in fenoxaprop-p-ethyl + ethoxysulfuron (50+15 g/ha) treatment (5.47 t/ha) and it was at par with weed free check (5.59 t/ha). There was 15% yield advantage in this treatment plots over recommended herbicide mixtures of bensulfuron methyl + pretilachlor. The yield reduction due to weed competition in weedy plots was more than 42%.

Response of weedy rice to seed burial and flooding depth

The experiment was carried out to determine the effect of seed burial depth on emergence of weedy rice accession collected from Kendrapara district (20˚72' N and 86˚64' E) of Odisha and to determine the effect of seed burial and flooding depth on emergence and growth of this accession. The results showed that the seed burial depth greatly affected the seedling emergence of weedy rice accession. The highest levels of emergence (>85%) was recorded when seeds are placed on the soil surface (1 cm depth). The emergence did not decrease significantly when seeds were buried at 2 cm. With further increase in burial depth to 4 cm, the seedling emergence decreased significantly. About 50% of the seedlings emerged from 4 cm burial depth and 6% from 8 cm depth. After 30 days of sowing, there was no significant difference in plant height of emerged seedlings among different treatments. It was also observed that the seedling emergence was influenced significantly under flooded condition. When seeds were sown on soil surface (1 cm depth), the seedling emergence with 2 cm standing water on surface was at par with un-flooded condition. Seeds buried in the soil at 2 cm recorded about 2% germination when flooded with 2 cm depth of water. Weedy rice seeds were unable to emerge when subjected to flooding depths of 4 cm or more.

Another experiment on the effect of different rates of residues (straw) on emergence and growth of weedy rice was carried out. The addition of residue increased the time required for seedling emergence. The seedlings emerged after 7 days when no residue was applied and it increased to 8 days when residue was applied at 4 and 6 t/ha. The seedling took 10 days when residue was applied at 10 t/ha. Plant height, root length and dry weight increased substantially with increase in rate of residue incorporation indicating that weedy rice growth is highly supported by plant (straw) residue. The maximum plant height (52.9 cm), root length (10.6 cm) and dry weight (3.3 g) at 30 days after emergence were recorded when residue was applied at 10 t/ha.

Effect of pre and early post emergence herbicides on seedling emergence and growth of weedy rice

The experiment was carried out to determine the effect of different rates of pre and early post-emergence herbicides on emergence and growth of the accession. Irrespective of rate of application, the application of pre-emergence herbicides (Pendimethalin, pretilachlor and butachlor) increased the time taken (8-11 days) for maximum seedling emergence. The seedling took 7 days to emerge in control plots and a height of 14.9 cm after 7 days of emergence. Among the pre-emergence herbicides, pendimethalin was most effective in restricting the weedy rice growth. At 7 days after emergence (DAE), weedy rice could achieve a plant height of 4.67 cm in pendamethalin treated pots. The total mortality of seedlings was recorded when oxadiargyl was applied at double the recommended dose. A plant height of 10.6 and 10.7 cm was observed with recommended dose of pretilachlor and butachlor, respectively.

Non-target effects of pretilachlor on soil microbial properties and primary metabolites of rice

Pretilachlor [2-chloro-2',6'-diethy1-N-(2-propoxyethyl)acetanilide], is a member of the acetanilide group of herbicides, widely used by farmers for the selective control of annual grassy weeds in rice fields. The persistence of pretilachlor and their effect on soil and plant (rice cv. Naveen) properties were studied in a pot experiment with three treatments *viz.*, pretilachlor at recommended dose (600 g/ha, RD), double the recommended dose (1200 g/ha, 2RD), ten times of the recommended dose (6000 g/ha, 10RD) with control, no herbicide application. The initial residues (after 2 hours of spray) in soil were 0.174 µg/g, 0.968 µg/g, 3.35 µg/g for recommended, double the recommended and 10 times of the recommended doses, respectively (Fig 2.12). After 45 days of spray, no residue was detected in RD treatment. The half life values were 16.90, 17.76 and 36.47 days for RD, 2RD and 10RD treatments, respectively. No residue of pretilachlor was detected from plant after 15 days for RD and after 20 days for 2RD (Table 2.11). But pretilachlor residue was obtained in the treatment of 10RD till 30 days of spray to the tune of 0.032 mg/kg. With little variations, 10RD treatment had shown drastic negative effects in soil microbial properties namely number of bacteria, actinomycetes, fungi, nitrogen fixers, microbial biomass carbon, dehydrogenase and other soil enzyme activities. Whereas, negative effects of pretilachlor at RD were not significant after 10-15 days of application. Percent germination, shoot and root length of the treated plant was lower compared to control. Total soluble sugar content was not affected by the RD treatment. Total free amino acid and protein content was less in plant samples treated with pretilachlor. More pronounced effect was observed in 10RD treatment. It has been observed that pretilachlor inhibits the synthesis of enzymes required for production of sugar, amino acids and protein. These phytotoxic effects are overcome by plants after 20-25 days of spray.

Table 2.11. Persistence of pretilachlor (µg/g) in plant samples

Time in days	RD	2RD	10RD
5	0.049	0.103	NP
10	0.039	0.085	0.287
15	0.034	0.043	0.156
20	ND	0.028	0.110
25	ND	ND	0.068
30	ND	ND	0.032
45	ND	ND	ND

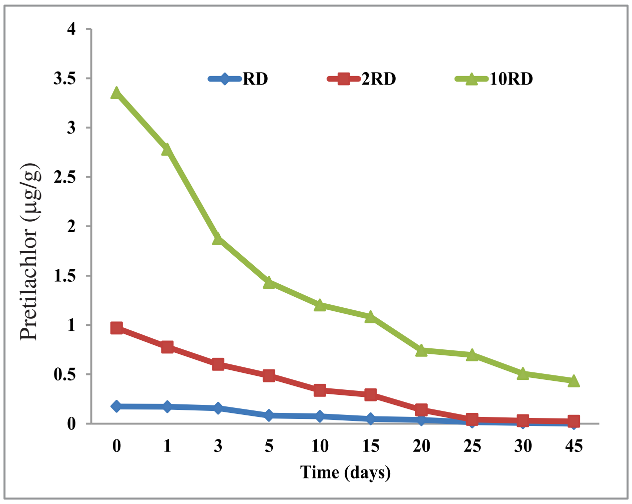


Fig 2.12. Persistence of pretilachlor (µg g^{-1}) in tropical rice soil

Effect of bispyribac sodium on Microbial Biomass Carbon (MBC) and Arbuscular Mycorrhizal (AM) fungi association in rice

The objective of this study is to identify eco-friendly herbicide molecule, which is harmless to AM fungal association in rice cultivation. Bispyribac sodium was evaluated in rice cv. Naveen under glass house condition to study its effect on AM fungal association. The results indicated that application of bispyribac sodium even at double dose (600 ml/ha) did not show any inhibitory effect to AM fungal root colonization and sporulation in rice, the same treatment which recorded 33.3 and 9.09% higher AM fungal colonization and sporulation respectively as compared to recommended dose (300 ml/ha). Similarly the AM fungi treated rice plants recorded significantly higher soil microbial biomass carbon (261.2 - 266.6 µg/g soil) after 30 days application of bispyribac sodium as compared uninoculated control.

Management of problem soils for enhancing the productivity of rice

Developing homogenous nutrient management zones for Mahakalpada block of eastern India

The approach of delineating management zones utilizing the spatial management tools of precision agriculture is a cost-effective approach to improve crop management. In precision agriculture, management zones are defined as regions representing homogenous characteristics. Besides representing areas of equal production potential, within-field management zones may also be used to develop nutrient maps for variable rate fertilizer application. In this study, nine soil attributes, including normalized difference vegetation index (NDVI) and enhanced vegetation index (EVI) images, soil electrical conductivity (EC), available nitrogen (AN), available phosphorus (AP), available potassium (AK), pH, soil electrical conductivity (EC), DTPA extractable iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn) acquired for Mahakalpada block were analyzed and selected as data sources. Subsequently, their spatial variability were analyzed and spatial distribution maps constructed with geostatistics technique.

Semi-variance calculations and semi-variogram model fitting were performed using the ArcGIS 10. The cross-validation analysis was conducted for evaluating kriging interpolation bias and accuracy. The best fitted models were then used in an ordinary kriging procedure to estimate different properties at non-measured points as interpolated values for mapping. Principal component analysis and fuzzy c-means clustering algorithm were then performed to delineate the management zones, fuzzy performance index (FPI) and normalized classification entropy

(NCE) was used to determine the optimal cluster number. In the present study, PCs with Eigen values ⩾1.0 were selected to develop the management zone classes. The fuzzy cluster analysis is performed to statistically minimize the within-group variability while maximizing the among-group variability based on two cluster validity functions FPI and (NCE) (Fig 2.13). The three defined management zones not only can direct soil sampling design, but also provide valuable information for site-specific management in precision agriculture (Fig 14).

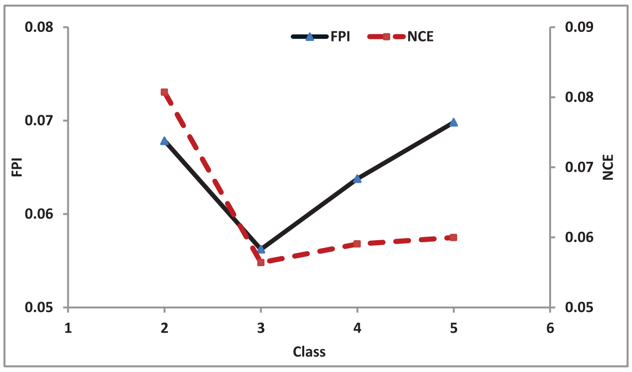


Fig 2.13. Optimum number of cluster classes selected on the basis of Fuzzy performance index (FPI) and normalized classification entropy (NCE).

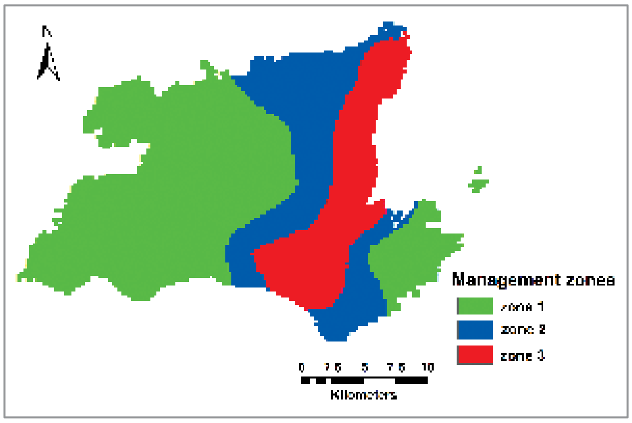


Fig 2.14. Three management zones developed for Mahakalpada block on the basis of fuzzy cluster algorithm

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

Plant-growth promoting bacteria associated with different species of *Azolla*

The present study was conducted to examine the abundance of plant-growth promoting bacteria from different species of *Azolla viz., A. microphylla, A. Mexicana, A. filiculoides, A. caroliniana, A. pinnata* and *A. rubra*. Among all selected isolates (n=120) from different *Azolla* species, nearly 70% of isolates showed plant-growth promoting traits. Among 120 isolates, 10%, 39.16%, 41.6%, 44.8%, 28.33% and 7.5% isolates were screened for nitrogen fixation, amylase production, ammonia production, siderophore, IAA and P-solubilising test, respectively. Based on *nifH* gene amplification, twelve isolates (AM1, AM2, AM3, AM4, AM5, AP1, AP2, AP3, AF1, AF2, AF3 and AC1) were found to be positive for nitrogen fixation. Biochemical characterization showed that two isolates (AM1 and AP1) were positive for indole, MR, VP, citrate, nitrate, gelatin, caesin, catalase, oxidase and tween 80. Moreover, three substrates (nitrate, gelatin, casein) were preferentially utilized by all nitrogen fixing bacteria.

Functional diversity of microbial community in paddy and mangrove soils

The present investigation was carried out to compare the changes of functional diversity of microbial community between paddy soil of Institute farm and Mangrove soils of Bhitarkanika (MB) and Sundarban (MS). Biology based community level physiological profiling (CLPP) revealed that the microbial community was observed significantly more in paddy soil of NRRI than Mangrove soils (NRRI > MS > MB) (Fig. 2.15). Moreover, Shannon–Weaver, average well color development (AWCD) and Mc-Intosh indices also revealed that the microbial community was significantly more in NRRI than MS and MB. Principal component analysis indicated the clear separation of the cluster comprising the NRRI paddy soils from the cluster of soils from MS and MB. Overall, the present study suggested that microbial community were comparatively superior in paddy soil of NRRI than mangrove soils of MS and MB.

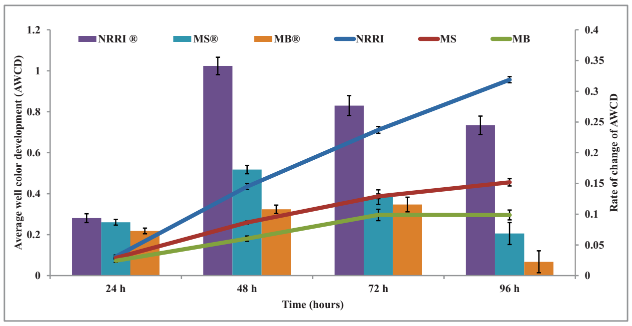


Fig 2.15. Comparative functional microbial community in terms of AWCD and rate of change in AWCD in soils of NRRI, Bhitarkanika and Sundarban

Association of entamopathogenic bacteria in rice pink stem borer larva and its insecticidal property

The experiment was conducted to identify efficient multifunctional entomopathogenic bacteria to manage both rice stem borer and leaf folder. Bacteria were isolated from dead/diseased rice pink stem borer larva collected from field and it was recorded in the range of 1.1-5.3 x 10^8 colony forming unit (CFU) bacteria per larva, of which *fluorescent pseudomonas* was recorded in the range of 4.5- 8.2 x10^3 CFU per larva. From the total bacterial population, five entomaopathogenic bacteria (RPSB 1 to RPSB5) were selected and assessed their insecticidal activity against rice leaf folder and pink stem borer larva. Out of five bacterial isolates, three isolates (RPSM 1, 3 and 5) had strong insecticidal activity against both rice leaf folder and pink stem borer under *in vitro* screening.

Plant growth promoting functions of the salt-tolerant phosphate solubilizing bacteria

Sixteen P-solubilizing rice rhizospheric bacteria (*Firmicutes*) possessing 2-16% NaCl tolerance were assessed for qualitative and quantitative P solubilization and some PGP activities viz. siderophore, ammonia and indole acetic acid production (Fig. 2.17). In soil, the organisms metabolize diverse residual macromolecules of plants and animals viz. protein, lipid, chitin, pectin and cellulose (Table 2.20) which, although varied among the organisms, they would recycle the macromolecules and maintain soil nutrition. Cellulase, amylase and protease producing microbes were 93.75, 75 and 75-81.25%, respectively but none produced cholesterol hydrolase, lecithinase and chitinase (Table 2.20). Among them, 100% organisms fixed nitrogen and solubilized phosphate; 75% and 50% organisms produced ammonia and siderophore, respectively (Table 2.21). Qualitatively, up to 15 days broth culture, the organisms metabolized 0.02-140.83 (µg/g dr. wt) P, and AP6 was highest and AP13 was least P solubilizing bacteria (Table 2.21). Phosphate (HAP) mineralization kinetics revealed that the organisms reached stationary phase of mineralization in liquid medium within 2d incubation (Fig. 2.16).

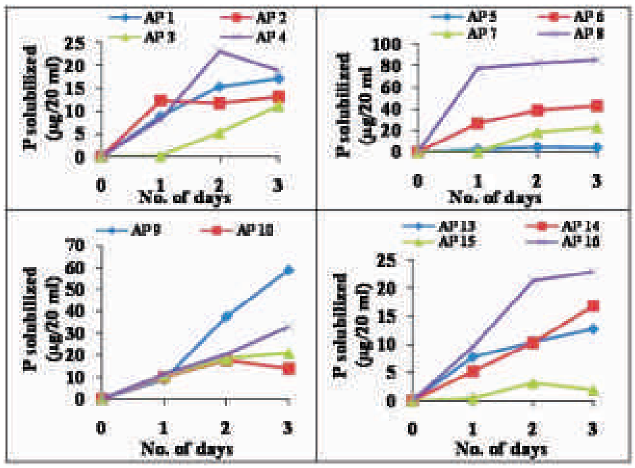


Fig 2.16. P solubilization kinetics of the isolates in NBRIP broth

Plant growth promotion (PGP) activity of the entomopathogenic fungi

Six effective entomofungal pathogens of LF *viz. Beauveria bassiana* (TF6, TF6-1A and TF6-1B) and *Metarhizium anisopliae* (TF19, TF19-3A and TF19-3B) were assessed for organic phosphate (phytate) and inorganic phosphate (tricalcium phosphate) solubilisation. They solubilized P on NBRIP agar containing tricalcium phosphate (Table 2.12). Solubilization efficiency of the isolates in NBRIP plates showed in the descending order of TF6-1B > TF6 > TF6-1A > TF19-3A > TF19-3B > TF19 i.e. 50.0, 28.6, 26.7, 21.4, 15.4, 11.8 %, respectively. In NBRIP broth, it was in the descending order of TF6-1A > TF6 > TF6-1B > TF19-3A > TF19 > TF19-3B i.e. 125.8, 75.8, 55.1, 44.6, 39.8, 28.6 mg/g dr. wt, respectively. TF6-1A solubilized maximum IP i.e. 125.8 mg/g dr. wt and the TF19-3B solubilized least phosphate (28.6 mg/g dr. wt). In phytate (organic phosphate) screening media (PSM), all the six isolates mineralized phytate, but the TF19-3A mineralized more phytate than the other pathogens (Table 2.13). The OP solubilization efficiency of the isolates in PSM was in the descending order of TF19-3A > TF6-1B > TF19-3B > TF6 > TF19 > TF6-1A i.e. 26.0, 17.3, 17.2, 15.3, 14.2, 12.3%, respectively. Change of methyl red to reddish-pink colour of the clear zone around the colony indicated acid production by the isolates. Some isolates which did not show any significant clear zone on NBRIP mineralized insoluble IP in liquid medium indicated uncertainty of the plate assay of P-solubilization. PGP trait assessment depicted that all the isolates produced ammonia, except for TF 19-3A, TF 19-3B produced maximum of ammonia but none produced indole and HCN.

Table 2.12. Phosphate solubilization by *Beauveria* and *Metarhizium* strains

Isolate No.	$Ca_3(PO_4)_2$ solubilization (mg/g dr. wt)	Phytate solubilization			HAP solubilization on NBRIP medium		
		Colony dia. (mm)	Halo zone dia. (mm)	Activity (%)	Colony dia. (mm)	Halo zone dia. (mm)	Activity (%)
Bb TF6	75.81	26.22	30.10	14.80	35.32	45.14	27.41
Bb TF6-1A	125.84	25.32	28.44	12.32	30.43	38.21	25.57
Bb TF6-1B	55.11	23.25	27.40	17.85	20.22	30.38	50.25
MaTF19	39.80	21.00	24.10	14.76	34.06	38.11	11.89
MaTF19-3A	44.60	23.12	29.23	26.43	28.24	34.32	21.53
MaTF19-3B	28.60	29.08	34.15	17.43	26.34	30.33	15.15

Bb = *B. bassiana*, Ma = *M. anisopliae*

Cellulose degradation by bacteria isolated from waste pit soils

From cellulose degradation enrichment culture of 4 waste pit soils of NRRI, 34 organisms i.e. C1-34 were isolated. Out of them only 7 organisms *viz*. C4, C5, C6, C12, C27, C29 and C30 degraded cellulose on CMC plate assay with activity efficiency 2.10-110.00% (Table 4). However, 12 isolates obtained from lignin degradation enrichment culture *viz*. C35-40 and L17-22 did not metabolize cellulose.

Soil and crop management for productivity enhancement in rainfed upland ecosystem

Integrated nutrient management in rainfed upland rice

Field experiment was conducted during wet season, 2015 to study the response of six early promising direct seeded rice cultures/varieties *viz*., CRR 455-109, CRR 363-136, CRR 616-B-88-2, CRR 617-B-47-3, Vandana & Anjali under different fertilizer regimes comprising various combinations of N, P and K alone as inorganic fertilizer or balancing N,P and K doses combining with two doses of FYM (2.5 t/ha & 5.0 t/ha) in red sandy soils in a split plot design with fertilizer treatments in main plots and rice cultures in sub-plots with three replication. Crop growth was good till it attained the panicle initiation stage but it suffered severe moisture stress immediately after flowering and yield levels became sarcastically low (0 - 0.4 t/ha) to infer any conclusions as treatment effects were masked by negligible differences in the yield.

Tillage effects on effectivity of native arbuscular mycorrhiza (AM)

The fixed plot experiment was initiated in 2013 and repeated during 2014 and 2015 in favorable (bunded) uplands under rainfed condition. Rice cv. CR Dhan 40 was grown (direct seeded) under both conventional and deep tillage (off-season tillage; OST).

Table 2.13. Cellulose digestion of bacteria of lignin degradation enrichment culture

Bacteria no.	Growth dia. (cm)	Halo zone (cm)	Activity efficiency (%)
C3	1.90	1.94	2.11
C4	1.44	1.81	25.69
C6	1.22	1.49	22.13
C12	1.20	1.45	22.13
C27	1.80	2.60	44.44
C29	2.00	4.20	110.00
C30	1.60	3.00	87.50

Recommended AM-supportive OST schedule of one post harvest tillage followed by one summer tillage was followed. Conventional tillage (CT) was done using tractor drawn cultivator and deep tillage (DT) using tractor drawn MB plough. As observed and reported in earlier studies, native population under both CT and DT crashed its lowest during June (off-season, October - June) and contrastingly reached its highest peak in October (during cropping season, July - Sept) (Fig 2.17). The extent of population decrease during off-season, however, was progressively reduced over years (2013 to 2015) under CT as compared to DT in the magnitude of 67.9 % increased population in June 2015 in CT over DT (Fig. 2.18). This resulted in concomitant higher increase (in CT over that of DT) in October. Higher initial native population in CT resulted in higher root colonization (AMF) (+29.9%), P uptake (+14.4%) and grain yield (+22.8%) over that of DT. Similar trends were observed during 2013 and 2014.

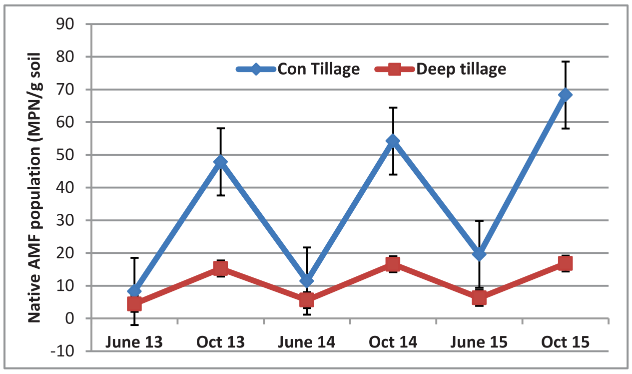


Fig. 2.17 Native AMF population dynamics under conventional and deep tillage in rainfed favorable (*bunded*) uplands

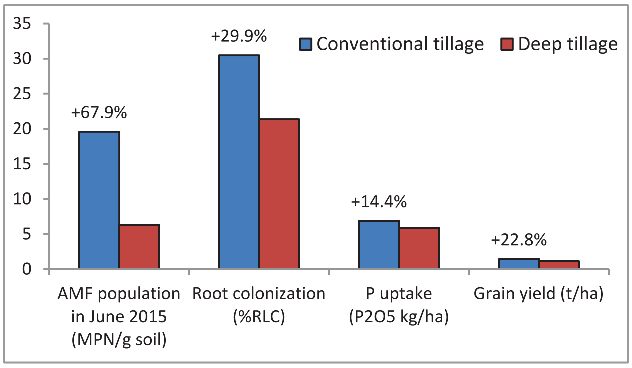


Fig. 2.18 Effects of conventional and deep tillage (off season tillage- twice) on native AMF population, rice root colonization, P uptake and grain yield

Varietal response to Arbuscular mycorrhiza

Two advance breeding lines viz., CRR- 617 and CRR 523 were evaluated in field for AM-responsiveness (% Mycorrhiza response; % MR) as compared to three checks known for their degree of response viz, Sathi 34-36 (highly responsive), Anjali (moderately responsive) and Jonga (poorly responsive) following the standard protocol. On-farm produced AM inoculum (native consortium) (Maiti et al, 2009) was used for the experiment. The results (Fig. 2.19) revealed that both the advance breeding lines are moderate to poor in responsiveness to AMF.

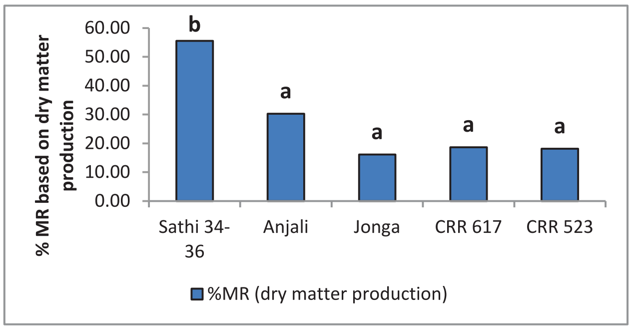


Fig. 2.19 Comparative arbuscular mycorrhiza-response (% MR) of advance breeding lines with check varieties (highly responsive – Sathi 34-36 and poorly responsive – Jonga).

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

Development of integrated rice-fish-horticulture farming system under flood-prone lowland ecosystem of Assam

The components of the integrated farming system were rice in main field; fish in refuge and trenches and rice field (at appropriate water level); and vegetables, fruits, ornamental crops and agro-forestry on pond dyke. A crop sequence of rice-*utera* linseed/latyuras-rice was followed in the main field. Rice variety Ranjit and Anjali were grown during wet and pre-wet season, respectively. Fingerlings of catla (*Catla catla*), rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigala*) and common carp (*Cyprinus carpio communis*) were released in the pond at 6000 fingerling/ha, 7 days after transplanting of wet season rice. Vegetable crops viz., lady's finger (cv. F_1 Durga), yard bean (cv. Reenu) during pre-wet season and wet season, green chilli (cv. Tejswini) were raised during wet and post-wet season. French bean, cauliflower, cabbage broccoli, radish and spinach were grown during dry season. Interventions made on the hanging platforms were of Pumpkin (cv. Arjun), ridge gourd (cv. Malika), bitter gourd (cv. Vivek), spine gourd (local) during wet season, bottle gourd and country bean during dry season. Well established fruit trees, *viz*., coconut, arecanut, Assam lemon, guava, mango and banana were on pond dyke. Altogether 650 plants of marigold were also grown on pond dyke with residual soil moisture and with supplemental irrigation during dry season. Twenty well-grown teak trees were on pond dyke in opposite side to pond refuge. Twenty five ducklings of 2 months old (breed, *Chara Chameli*) were released to the system in second week of August. The rice variety Ranjit and Anjali recorded grain yield of 5.6 t/ha and 3.86 t/ha, respectively. Composite fish yield of 656 kg/ha was recorded in two periodical netting in 10 months. Among the vegetables, elephant foot yam recorded tuber yield of 48.6 t/ha followed by cabbage (32 t/ha) and yard bean (22.5 t/ha). Besides these, the system produced a substantial amount of eggs, fodder, fuel wood, flower, seedlings and organic manures from 0.5 hectare farm. The system recorded the productivity of 19680 kg/ha of Rice Equivalent Yield per annum and employment generation was 204 man days from 0.5 ha of area.

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

A field experiment was conducted during wet season, 2015 in randomized block design with seven treatments comprising of control, NPK at 40:20:20 kg/ha, NPK at 50:25:25 kg/ha, NPK at 60:30:30 kg/ha, 40 kg N based on LCC along with PK at 20:20 kg/ha, 50 kg N based on LCC along with PK at 5:25 kg/ha, 60 kg N based on LCC along with PK at 30:30 kg/ha to standardize nutrient management in late-planted rice under post-flood situation. The crop was planted on the 10th September and harvested on the 1st 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 at 30:30 kg/ha recorded highest grain yield of 4.65 t/ha which was on par with the plots applied with 50 kg N based on LCC along with PK at 25:25 kg/ha which yielded 4.48 t/ha.

Sustainability of productivity in rice-rapeseed cropping system through Phosphorus and sulphur management in rainfed lowland ecosystem

A field experiment was carried out to assess the sustainability of rice-rapeseed cropping system through Phosphorus (P) and sulphur (S) management. Four doses of P (0, 20, 40 & 60 kg/ha P_2O_5) in main plots and three doses of S (0, 20 & 40 kg/ha S) in sub-plots were evaluated in split-plot design. The results showed that the maximum seed yield (4.58 t/ha) of rice was obtained with 60 kg P_2O_5/ha which was significantly higher over control and remained *on par* with 20 and 40 kg P_2O_5/ha. The carry over effect of P application on rapeseed crop was non-significant. Sulphur application of 20 and 40 kg/ha S significantly increased rice yield over control but remained on par with each other while rapeseed yield increased significantly up to 40 kg S/ha. The productivity of cropping system in terms of rice equivalent yield, gross return and net return under phosphorus levels of 40 and 60 kg/ha P_2O_5 was found significant over control but remained statistically *on par* with 20 kg/ha P_2O_5. The REY and gross return under sulphur application of 20 and 40 kg/ha S was found significant over control but remained *on par* with each other. It was found that the dose of 20 kg P_2O_5/ha and 20 kg S/ha was found to be sufficient for rice-rapeseed cropping system in shallow lowlands of Assam.

Standardization of integrated nutrient management practices in rice-based cropping system under rainfed flood-prone lowland ecosystem

Assessment of sustainability under green manuring, rice residue and fertilizer inputs

Profitability of rice based cropping system under green manuring, rice residue incorporation and fertility level in rainfed lowland conditions was evaluated. The treatment consisted of 8 treatment combinations, *viz*., green manuring and rice residue incorporation in main plots and four fertilizers inputs {control, 50, 75 & 100% recommended doses of fertilizer (RDF)} in sub plots for rice and two succeeding crops (lentil and linseed) in sub-sub plots. The maximum rice equivalent grain yield (5.19 t/ha), production efficiency (22.07 kg/day/ha), net return of Rs. 31072/ha and B:C ratio of 1.67 was recorded with green manuring which were significantly higher in comparison to rice residue incorporation. The fertility levels recorded significantly higher REY, production efficiency, B:C and net return over control but remained statistically *on par* with each other. Rice-linseed cropping system recorded maximum REY (5.23 t/ha) with net return of Rs. 29846/ha and B:C ratio of 1.62 while production efficiency (22.40 kg/day/ha) was the maximum with rice-lentil cropping system (Table 2.14).

Nitrogen management in rice-rice (ratoon) cropping system

A field experiment was conducted to evaluate the efficiency of rice cv. Naveen as ratoon crop under different planting dates of main crop, *viz.*, 5th, 15th and 25th February and application of different doses of N fertilizer in the ratoon crop, *viz.*, 0, 25% and 50% recommended doses of N. Results revealed that 15th February planting was optimum time for transplanting of the main crop to obtain maximum production efficiency in the ratoon. However, both 25% and 50% recommended doses of nitrogen provided significantly higher grain yield over control but it remained statistically *on par* with each other. Thus, 25% extra nitrogen application is sufficient to obtain significantly higher yield in ratoon (Table 2.15).

Table 2.14 Rice equivalent yield (REY) and economics of rice based cropping systems under different nutrient management practices

Treatment	REY (t/ha)	Production efficiency (kg/day/ha)	Net Return (Rs/ha)	B:C
Green manuring	5.19	22.07	31072	1.67
Rice residue incorporation	4.78	21.23	22892	1.47
CD ($P_{0.05}$)	**NS**	**NS**	**5764**	**0.12**
Fertility level				
Control	4.45	19.76	20874	1.46
50% RDF	5.02	22.31	27605	1.59
75% RDF	5.28	23.44	30681	1.65
100% RDF	5.20	23.08	28768	1.59
CD ($P_{0.05}$)	**0.31**	**1.37**	**4407**	**0.09**
Rabi crops				
Lentil	5.04	22.40	26989	1.56
Linseed	5.23	22.27	29846	1.62
Rape seed	4.68	21.77	24111	1.54
CD ($P_{0.05}$)	**0.12**	**0.52**	**1739**	**0.04**

Table 2.15: Productivity of rice-rice (ratoon) as influenced by date of planting and nitrogen

Treatment	Main Rice crop		Ratoon	
	Straw yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)	Grain yield (t/ha)
Date of planting				
5th Feb	5.48	4.94	2.46	1.90
15th Feb	6.06	5.46	2.63	2.18
25th Feb	6.26	5.90	3.03	2.07
CD ($P_{0.05}$)	0.66	0.82	0.48	0.23
Nitrogen management				
Control	5.71	5.24	2.53	1.81
25% N	5.92	5.40	2.70	2.11
50% N	6.17	5.67	2.89	2.22
CD ($P_{0.05}$)	0.89	0.81	0.32	0.25


SWARNA Sub-1

PROGRAMME : 3

Rice Pests and Diseases-Emerging Problems and Their Management

Insect pests and diseases play a pivotal role in dwindling the quality and yield of rice. There need to undertake basic and strategic research on important insect pests and diseases under changing climatic scenario and modern cultivation practices for developing holistic management strategies for the benefit of rice growers of the country. Hence, the present programme has been framed keeping in view of a holistic approach of increasing crop yield through proper crop protection strategies. The programme comprises of seven projects out of which five projects are being operational in main campus of the institute and two projects each in Regional Station of NRRI at Hazaribag and Gerua respectively. The programme is focused on the study of population dynamics of insect pests and pathogens in relation to climatic scenario, search for resistant donors, eco-friendly chemicals, biorational pesticides and biotic agents. The research finding of the projects are enumerated as follows

Management of Rice Diseases in Different Ecologies

Identification of donors for resistance to rice diseases

Rice Blast

A total of 62 previously identified resistant accession/varieties rescreened against seeding blast in the Uniform Blast Nursery (Fig 3.1) at Cuttack using standard protocol devised by IRRI (2002) during wet season 2015 revealed that 51.6% (32) were found resistant, 42% (26) moderately resistant. Highly resistant accession/varieties include; Dular, Savitri, AC-38662, AC-38642, AC-38546, AC-38541, AC-38472, AC-38436, AC-38435, AC-38410, AC-38406, AC-38404, Salumpikit and *Oryza minuta*. Similarly, out of 500 landraces from Odisha evaluated for their reaction to seeding blast, only 8% (40) were found to be resistant, showed (0-3) rating to leaf blast. Landraces showing 0-1 scores includes; Abhirman, Akula-s, Raigada-Baiganamanji, Bilei khuji, Bubaliachha, Chipti phal, Dal, Dengbari, Dhalajeera, Dhalashree-k, Dumerful-B, Balangir-gelheikanthi, Haladigundi-S, Haldisapura, Balangir-amapali-harisankar, Balangirthalbadh-harisankar, Jhumer, Blngr-kala krushan, Mayur kantha-ke, Parijat, Pustak, Putia china, Samudrabati, Saria-a, Saria-d, Saria-b, Saria-k, Saria-p, Taares, and Tulasi bas. These resistant landraces can be promising donors for breeding local rice varieties in the Eastern India particularly in Odisha.

Fig. 3.1 Reaction of rice genotypes to blast in uniform blast nursery at Cuttack

Sheath blight

A total of 1373 landraces/ varieties/ accessions from National Hybridization Nursery (NHN) entries were screened under field condition during wet season, 2015 against sheath blight, *Rhizoctonia solani* Kuhn. After every 10 entries, two rows of susceptible check Tapaswini were planted. Each rice plant was artificially inoculated with the sheath blight pathogen by inserting five sclerotial bodies along with bits of mycelia inside the leaf sheaths in the maximum tillering stage and clean water was sprayed regularly for creating favourable microclimate. The disease incidences were recorded by adopting 0-9 SES scale. Six land races, 10 varieties, 4 NHN genotypes were found moderately resistant, whereas, 11 landraces, 18 varieties, 6 NHN genotypes, 5 genotypes from earlier tolerant group and

71 genotypes of Assam Rice Collection (ARC) showed tolerant reaction. Out of a total of 1200 rice entries, 44 entries showed moderately resistant reaction and 76 being tolerant under NSN1 (National Screening Nursery); 28 entries were found to be moderately resistant and 150 entries were tolerant under NSN2 whereas in case of National Hybrid Screening Nursery (NHSN) entries, 5 entries showed moderately resistant reaction and 24 entries found tolerant.

Bacterial blight

Out of 137 rice genotypes from NRRI germplasm screened for Bacterial blight disease, only 10 genotypes showed resistance they are AC-39744, 36306, 35797, 36364, 35812, 35811, 36369, 36332, 36259, 36810

Brown spot

Out of 573 accessions of Assam Rice Collection screen during wet season 2015, only 22 accessions were found to be moderately resistant, showed (4-5) rating to brown spot. They were, namely, ARC – 5846, 5918, 5956, 5550, 6017, 6058, 6101, 6110, 6170, 6622, 7080, 7335, 10618, 10670, 10922, 10934, 11206, 11434, 11566, 11641, 11679 and 12006.

Sheath rot/ False Smut

Ninety nine entries received from AICRIP Coordination Unit under Donor Screening Nursery (DSN) trial, 130 in NHSN, 350 in NSN1 were screened against sheath rot pathogen under natural epiphytotic condition. Location severity index for sheath rot (ShR) disease incidence was very low in all three screening plot (ShR =1.7- 4.6). Altogether 61 of DSN, 25 of NHSN, 151 of NSN1 entries were totally free from sheath rot disease.

Out of 99 DSN entries screened under natural epiphytotic condition, 58 were totally free from false smut disease.

Standardization of false smut isolation and artificial culturing technique

False smut disease causing pathogen *Ustilaginoidea virens* in rice has been successfully isolated on potato sucrose agar (PSA) media and it took around 21 days to produce substantial growth and shape mimics in naturally infected grain at 26 ± 1^{0}C. *U. virens* pathogen was confirmed through colony morphology (Fig 3.2), microscopic examination and molecular diagnostic using interspecific transcribed spacer (ITS) primer (ITS1 and ITS4).

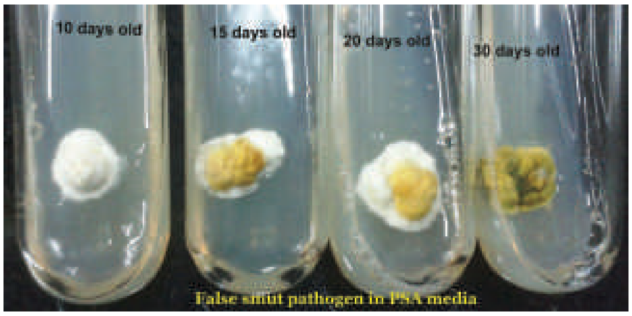


Fig. 3.2 False smut pathogen in PSA media

Artificial culture of false smut

False smut culture was transferred in Potato Sucrose broth and allowed to grow for 25 days at 26±1^{0}C with occasional shaking (Fig 3.3). Spore mass was dissolved in sterile distilled water and inoculated through injection of spore solution into rice plant at booting stage and kept the plant at 25±1^{0}C for 5 days. Another spraying of spore solution was done at heading stage. False smut balls appeared in those pots where both injection at booting stage (Fig 3.4) and spraying of spore at heading stage was done.

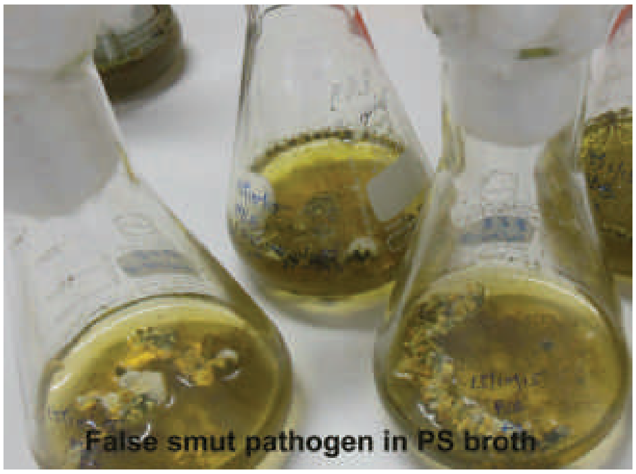


Fig. 3.3 False smut pathogen in PS broth media

Fig. 3.4 Inoculation at booting stage

Impact of false smut disease on seed health of rice

Seed from eight rice varieties were collected as diseased grains (from panicles having false smut ball) and healthy grains (from false smut ball free panicles) by random sampling. Per cent filled grain (%FG) was decreased from 3.0 - 71.8 *vis-à-vis* per cent chaffy grain (%CG) is increased alarmingly high (24.6 – 87.5) while 1000 grain weight (%GW) is increased by 1.2 – 10.8 in diseased panicle in compare to healthy panicle (Fig 3.5) Paired t-test indicated that grain weight diseased panicle significantly different ($p<0.05$) from healthy panicle. Statistical analysis proved that presence of false smut (Y) ball (0.9 - 12.4%) is negatively correlated with per cent filled grain (X_1) and grain weight (X_3) and positively correlated with per cent chaffy grain (X_2).

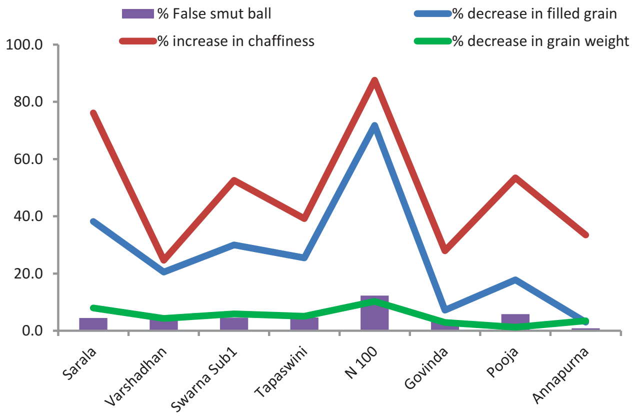


Fig. 3.5 Impact of False smut on paddy

Five months old stored grains were taken for the vigour study. Seedling vigour index (SVI) was lesser in diseased grain than healthy grain both in terms of root-shoot length (SVI-I: Fig 3.6) and dry weight of seedling (SVI-II: Fig 3.7). Per cent reduction of vigour in diseased grain in comparison to healthy grain was 6.8-38.5 (SVI-I) and 10.8-38.5 (SVI-II), respectively. Rudimentary and subnormal growth of the root hairs was observed in the seedlings emerged out of infected seeds may be one of the reasons behind low vigour of diseased grain.

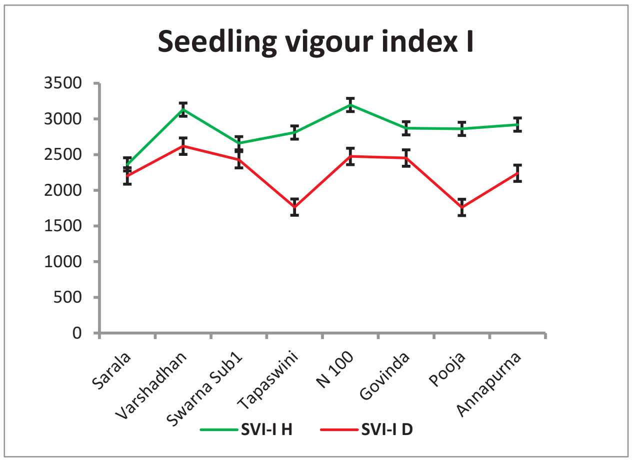


Fig. 3.6 Seedling vigour index I

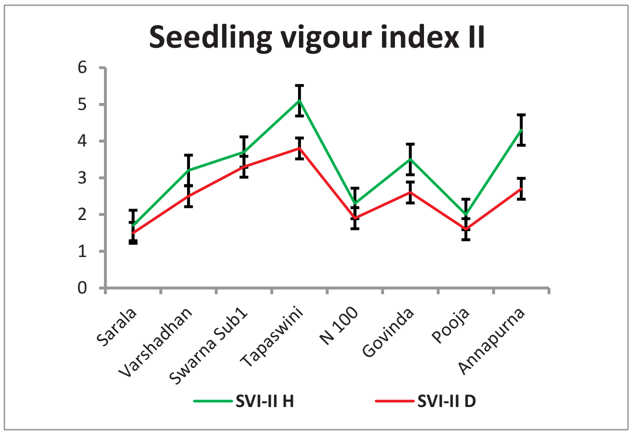


Fig. 3.7 Seedling vigour index II

Identification and genetic variability of major and emerging diseases of rice

Pyricularia isolates associated with the blast lesions produced on rice/ weeds

One hundred and twenty one *Pyricularia* isolates associated with the blast lesions produced on rice/ weeds were studied. About 30% cultures did not produce the typical blast conidia. The spore morphology and ITS ribosomal DNA sequences data suggested that conidial shape could be a primary character to differentiate the isolates. Spores of four isolates (from rice) had resemblance with the conidia of *Pyricularia kookikola.* The poor query coverage (18-64%) of their nucleotide sequences with sequences of data base (NCBI-BLAST) suggested that those four were probably new isolates.

RAPD analysis of *Pyricularia* isolates from rice and weed *Echinocloa colonum*

The genetic similarity and/or dissimilarity between blast isolates from weed host and rice were studied by Random Amplified Polymorphic DNA (RAPD) analysis. Fourteen isolates from rice host and six isolates i.e. B460- B465 from weed host *Echinocloa colonum* were subjected to PCR amplification by 10 RAPD primers *viz.,* PU-1, PU-2, OPB-10, OP219, R1, R2, R3, P-160, ap12h and 3B . A total of 72 fragments have been amplified out of which 51 fragments were found to be polymorphic, depicting a polymorphism of about 71%. Maximum 12 numbers of fragments have been amplified by primer R2 while only 3 fragments were obtained by primer 3B. Cluster analysis by SAHN program of NTSYS pc which delineated the blast isolates into 2 major groups (Fig. 3.8). These groups largely corresponded with the host specificity of the isolates where the six blast isolates from weed host were clearly placed in a separate group apart from the isolates of rice.

Several host specific markers were generated after PCR amplification of DNA of blast isolates. It was observed that the isolates from weed host were distinct from rice isolates by the presence or absence of unique banding patterns by RAPD primers. Amplified bands which were present only in weed isolates were observed at 400bp by primer R2, 1200bp by primer OPB10 where as such pattern was found at 1450bp and 290bp by primer R3. Similarly bands which were absent in weed isolates but present in rice isolates were observed at 1430bp by Ap12h, 1200bp by P160 where as by primer R3 this pattern was found at 1500bp and 280bp. Out of 10 RAPD primers used in the current study, R2, OPB10, AP12h, P160 and R3 have consistently placed weed and rice isolates in separate groups. Primer R3 was found to be the most useful primer to distinguish rice and weed isolates but the bands amplified at 1200bp by OPB10 was quite prominent and distinct among blast isolates from weed host . Hence, this can be used as a marker to distinguish the two groups.

Apart from the above amplification patterns some unique bands were also observed in some isolates. Unique bands were observed for B462 (from weed) at 2800bp and 1900bp by primer OPB10. Similarly PU1 amplified unique bands in isolate B460 (isolated from blast lesion on weed) at 2000bp.

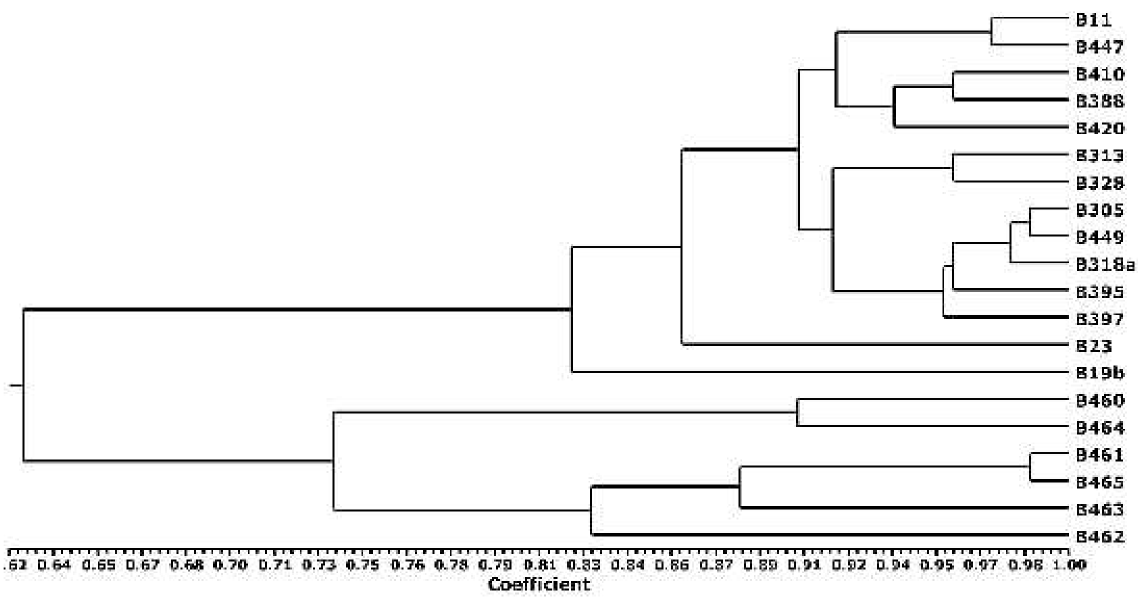


Fig. 3.8 UPGMA cluster analysis based dendrogram depicting genetic variability among Blast isolates from rice and weeds; Calculated from 72 bands generated by 10 RAPD primers

Conidia-packed bodies in *Pyricularia* culture originating from 'green island' producing rice blast lesions

The fifteen days old culture isolated from 'green island' producing blast lesion was black but aerial mycelium was grayish in color. Black sac like bodies of pin head size, covered with honey dew type drops were produced in the culture (Fig 3.9). This black structure was neither sclerotia nor perithecia. It contained plenty of *Pyricularia* conidia . On an average the conidia measured 25.4 to 27 X 9.5 to 10.2 µm. Two morphologically distinct spores were packed in each black body. About 75- 85 % spores present in it were typical pyriform , three celled *Pyricularia* conidia but 15-25% spores present in black bodies had big dark middle cell which had some resemblance with the conidia of *Pyricularia kookicola* Bussaban sp. nov. (Fig. 3.9, 3.10 & 3.11). Koch's postulates were proved. The sample was collected from a field where both mating types were present and the disease spread was very fast vertically as well as horizontally. The culture originated from the field had bamboo and weeds on the land of the field. The collateral host *i.e* weeds might seems to have played important role in the disease cycle of pathogen.

The organism was identified by molecular technique. DNA was extracted and the Internal Transcribed Spacer region was amplified. The nucleotide sequences were analyzed in NCBI-BLAST for identifying the organism. The sequences producing significant alignment with this isolate were searched in NCBI- BLAST. The E value was 1e-27and maximum score was 134 with all the sequences showing significant alignment. It had 81 % similarity and 38% query coverage with 13 *Magnaporthe oryzae* and seven *Magnaporthe grisea* isolates. The *Magnaporthe grisea* isolate F1175 had 87% similarity and 26% query coverage with query sequence. The query coverage and identity percentage (s) suggested that the nucleotide sequence of this isolate was not close to any isolate included in the analysis. The NCBI- GenBank accession number for this culture was KU870476.

Fig. 3.9 *Pyricularia* culture: Black structures

Fig. 3.10 *Pyricularia* conidia from crushed black body embedded in honey dew drops

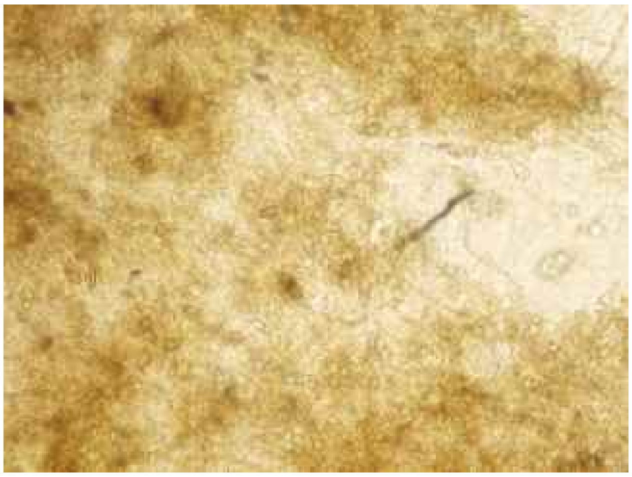


Fig. 3.11 Two type of *Pyricularia* spores present in black structure

Pathogenic and molecular identification of False smut and sheath rot pathogen

Two isolates (NRRI-Fs-1; NRRI-Fs-2) of *Ustilaginoidea virens* responsible for false smut disease in rice was isolated from naturally infected rice at NRRI, Cuttack and Gerua, Assam. Those isolates were tested by artificial inoculation in rice variety Pooja and found to be infectious. Pathogen also confirmed through molecular diagnostic using Internal transcribed Spacer (ITS) specific primer (ITS1 and ITS4) which amplified 650bp amplicon. Two isolates (NRRI-ShR-1; NRRI-ShR-2) of *Sarocladium oryzae* responsible for sheath rot disease in rice was isolated from naturally infected rice from NRRI farm and Pipili, Puri. Those isolates were tested by artificial inoculation in rice variety Tapaswini and found to be infectious. Pathogen also confirmed through molecular diagnostic using ITS region specific primer (ITS1 and ITS4) which amplified a fragment of 600bp (Fig 3.12). The sequences of the amplified product were matched with the sequences available in the public domain and confirmed the identity of the pathogens.

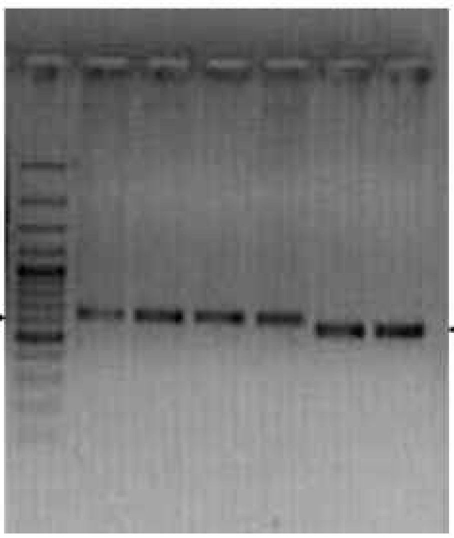


Fig. 3.12

Bioefficacy of fungicides against sheath blight *Rhizoctonia solani* Kuhn. in rice

Seven fungicides namely tricyclazole 45 + hexaconazole 10 WG (ICF-110) @ 1.0g/liter, tricyclazole 18 + mancozeb 62 WP @ 2.5g/lit, tricyclazole 75 WP @ 0.6g/lit, hexaconazole 5EC@ 2.0ml/ lit, mancozeb 75 WP @ 2.0g/lit, mancozeb 63 WP + carbendazim 12WP @1.5g/lit and carbendazim 50 WP 1.0g/lit were evaluated against sheath blight disease in rice under field condition through artificial inoculation for the second consecutive year i.e, wet season, 2015 with susceptible variety Tapaswini in randomized block design. The fungicide tricyclazole 18+ mancozeb 62WP @2.5g/lit caused 73.4% reduction of sheath blight disease severity and 65.8% reduction in sheath blight disease incidence over the untreated control followed by tricyclazole 45 + hexaconazole 10 WG and hexaconazole 5EC; the former reducing the disease severity by 70.3%, incidence by 62.2% and the later causing reduction in disease severity by 55.4% and incidence by 52.7%. Grain yield was highest (5.46t/ha) in tricyclazole 18+ mancozeb 62 WP treatment followed by tricyclazole 45 + hexaconazole 10 WG (5.35 t/ha) and 4.98 t/ha due to hexaconazole 5 EC (4.98 t/ha), while it was 3.47t/ha in untreated control.

Management of false smut disease of rice

For optimizing fungicide spray (as prophylactic measure) to manage false smut disease one experiment conducted by staggered planting of three different varieties (Pooja, Tapaswini and Ajay) done on 3rd August (TP1), 18th August (TP2) and 3rd September (TP3), 2015. No incidence of false smut was observed in Tapaswini and Ajay which are 1st planted (TP1) on 3rd Aug and matured during last week of October, whereas moderate incidence was observed in Pooja which is photosensitive and flower at the same time with second (TP2) and third transplanting (TP3). Moderate to high disease incidence was observed in TP2 and TP3 in all three varieties (Fig 3.13). Per cent hill infection (%HI), per cent tiller infection (%TI) and appearance of false smut ball (AFB) are significantly different (p<.01) w.r.t planting date (TP), variety and TP*Var interaction. Late planting is not ideal for managing false smut disease as it was evident from the graph that yield loss is positively correlated with %HI, %TI and appearance of AFB.

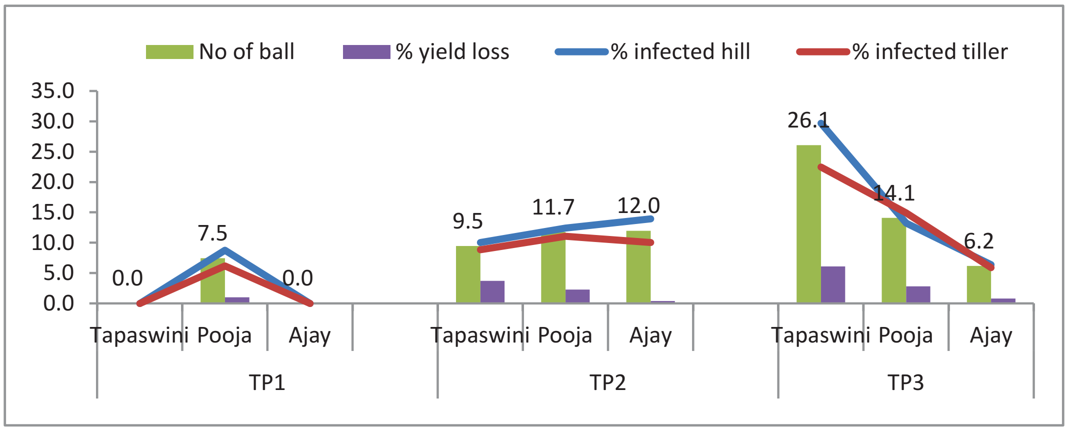


Fig. 3.13 Influence of planting date on false smut disease incidence

Effect of false smut on quality of grain

Some of the quality parameters of infected and healthy grain of 14 popular varieties like Pooja, Tapaswini, CR 1014, Dharitri, Gayatri, Ranjit, CR Dhan 500, Utkalprabha were tested to establish whether false smut disease has any effect on grain or not. The preliminary study revealed that head rice recovery (HRR) and per cent amylase content (AC) was significantly high ($p<0.01$) and water uptake capacity (WU) was significantly low ($p<0.01$) in infected grain than healthy grain attributed to negative cooking quality. Other quality parameters were non-significant (Table 3.1).

Table 3.1 Effect of false smut on some quality parameter of rice grain

Parameter	Healthy grain	Diseased grain	Per cent Change
Hulling (%)	77.64	76.62	1.3
Milling (%)	66.14	68.14	-3.0
HRR (%)	60.79	62.29	-2.5
KLAC	8.43	7.81	7.3
VER	4.03	3.94	2.3
ER	1.54	1.43	6.9
ASV	4.35	3.70	14.8
AC	23.20	23.98	-3.3
WU	131.96	76.17	42.3
GC	35.68	39.47	-10.6

Biocontrol of rice diseases

In vivo experiment was carried out for evaluation of growth promotion by taking seeds of two rice varieties (Sahabhagidhan and Karuna Dhan) treated with conidial suspension of the isolated *Trichoderma* species during wet season 2014 and dry season 2015. Plant defense enzymes were analyzed. The total Nitrogen, Phosphorous and Potassium available to plant was estimated. Isolated species were identified as T-1 *(T. harzianum)*, T-5 *(T. atroviride)*, T-9 (*T. atroviride)*, T-13 *(T. atroviride)*. All the species were found to be most effective biocontrol agent as indicated by percentage inhibition of pathogens. The expression of defense enzymes i.e. catalase, peroxidase and superoxide dismutase were notably enhanced (Table 3.2). All the isolated *Trichoderma* species shows the growth promotion as compared to control in both the varieties, whereas T-5 has shown the highest growth promotion activity among the treatments (Fig 3.14 and Table 3.2, 3.3). NPK content of plants treated with different species of *Trichoderma* showed that the nitrogen content was higher in treated plant than untreated but interestingly the %K was always higher in the treated plants in comparison to the untreated one. The higher nitrogen content in the treated plant was reflected in the greener appearance than the untreated (Fig 3.14)

From the present study it was evident that the indigenous *Trichoderma* species are better candidate for biocontrol of rice diseases. Besides their growth promotion activity may be helpful for the farmers to reduce the application of chemical fertilizers. However, they need further testing in larger area and different agro climatic zones.

Table 3.2 Expression of defense enzymes after *Trichoderma* treatment

Treatment	CAT activity of root (unit/min/g sample)		CAT activity of shoot (unit/min/g sample)		POD activity of root (unit/g sample)		POD activity of shoot (unit/g sample)		SOD activity of root (unit/g sample)		SOD activity of shoot (unit/g sample)	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
T0	1.28	0.83	1.3	1.27	0.57	0.77	0.46	0.48	157.75	57.21	111.5	121.05
T1	1.43	1.03	2.2	1.5	0.98	1.12	1.14	0.66	22.34	104.6	42.32	103.28
T5	0.87	1.4	1.34	1.17	0.87	1.58	1.1	0.69	44.98	143.13	22.41	133.26
T9	1.21	0.83	1.87	1.63	2	0.82	0.73	0.64	16.01	119.53	75.4	166.06
T13	1.07	1.04	1.5	1.5	1.01	1.12	1	0.6	41.39	101.9	90.86	124.89
Tukey HSD at 1%	0.699	NS	0.8811	NS	0.0096	0.0067	0.0043	0.0075	3.1207	3.4773	2.1536	1.6138

Table 3.3 Growth promotion analysis of rice (cv. Sahabhagi Dhan) with *Trichoderma* seed treatment

Treatment	Shoot length (in cm)	Root length (in cm)	Fresh shoot weight (in gm)	Dry shoot weight (gm)	Fresh root weight (gm)	Dry root weight (gm)	1000 grain weight (gm)	Yield/ hill (gm)	Yield/ $M^{2(gm)}$
T0	36.54^{B}	9.66	1.85^{C}	0.64^{C}	0.57^{C}	0.15^{C}	20.47^{C}	24.33^{B}	820.44^{B}
T1	42.78^{A}	11.43	3.83^{B}	1.31^{A}	0.94^{B}	0.27^{B}	20.61^{B}	40.06^{A}	095.24^{A}
T13	41.36^{A}	10.03	3.82^{B}	0.84^{B}	1.64^{A}	0.29^{AB}	20.57^{BC}	41.44^{A}	1004.67^{AB}
T5	42.17^{A}	10.42	5.06^{A}	1.17^{A}	1.64^{A}	0.34^{AB}	20.52^{BC}	43.23^{A}	1034.42^{AB}
T9	44.85^{A}	10.34	5.47^{A}	1.31^{A}	1.54^{A}	0.35^{A}	20.79^{A}	40.65^{A}	1060.44^{A}
Tukey HSD at 1%	3.8936	NS	0.548	0.15	0.2051	0.0732	0.1372	3.5953	233.38

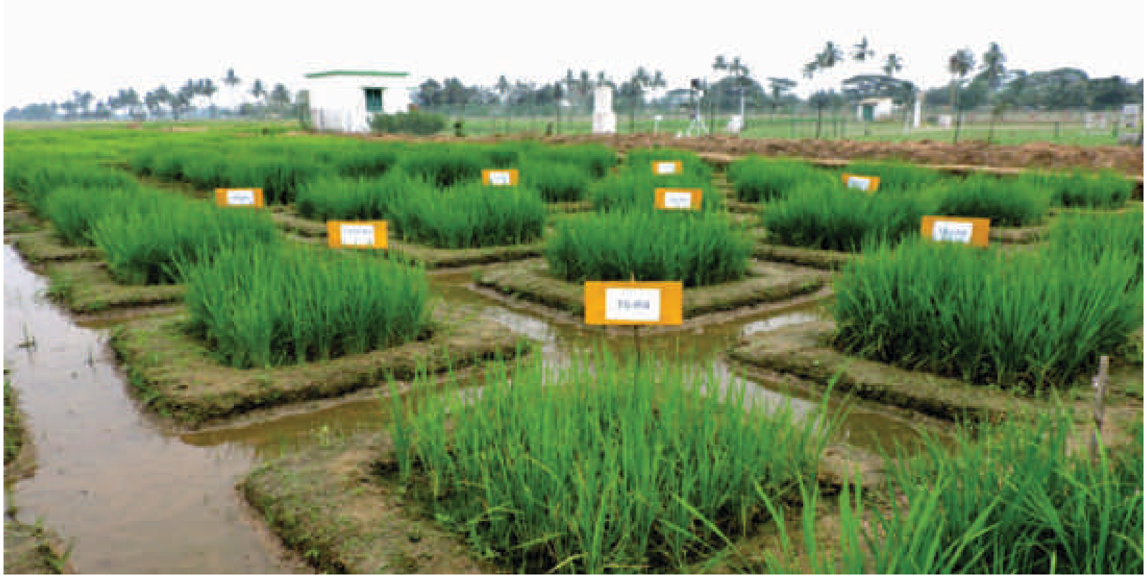
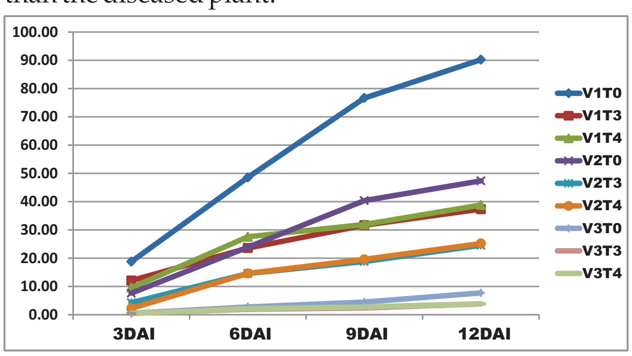


Fig. 3.14 Field experiment for growth promotion by *Trichoderma*

Management of Bacterial Blight, *Xanthomonas oryzae* pv. *oryzae* using Induced Systemic Resistance

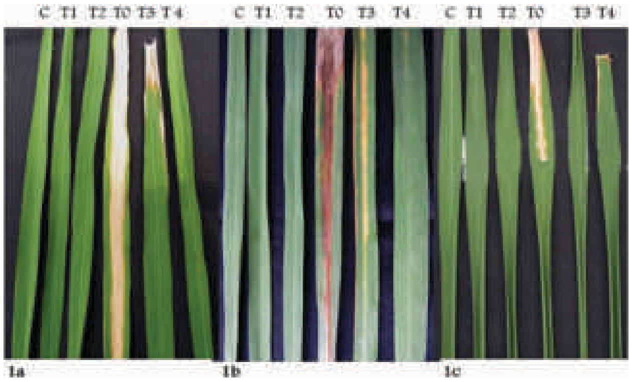
Among vitamins, riboflavin was known to be an effective vitamin in inducing resistance and maintaining PSII integrity against Bacterial blight (BB) in rice. The photosynthetic efficiencies of three varieties of rice i.e. TN-1 (highly susceptible to bacterial blight), IR-20 (moderately tolerant) and DV-85 (tolerant) infected with bacterial leaf blight was compared. After 45 days of germination plants were treated with riboflavin and then inoculated with *Xanthomonas oryzae* pv. *oryzae*. Disease percentage and chlorophyll fluorescence data has been taken at 0, 3, 6, 9 and 12 DAI (days after inoculation). Disease percentage data was compared by using the SAS software of IASRI, New Delhi Portal (www.iasri.res.in/sscnars/-). Disease controlled plants of susceptible variety (V1) showed highest percentage of disease progression (Fig. 3.15 and 3.16). Disease controlled as well as riboflavin treated plants of resistant variety V3 showed no significant changes in disease percentage (Fig. 3.16). Lowest yield was obtained in disease controlled plants of susceptible variety (V1). In all the three varieties plants treated with riboflavin showed higher yield (Fig. 3.15).

Plants treated with riboflavin showed higher photosynthetic efficiency, improved PSII activity, increased absorption and conversion efficiency of light energy and accelerated photosynthetic electron transport, less disease percentage and higher yield than the diseased plant.



(DAI- day after inoculation, T0- disease control (pathogen inoculation and without riboflavin treatment), T3- treatment 3 (riboflavin 1µM + pathogen inoculation), T4- treatment 4 (riboflavin 2 µM + pathogen inoculation), Trt- treatments, V1- variety 1 (TN-1, susceptible to BB disease), V2- variety 2 (IR-20, moderately resistant to BB disease), V3- variety 3 (DV-85, resistant to BB disease)

Fig. 3.15 Comparative analysis of disease progression in three rice varieties against bacterial blight disease after riboflavin treatment



{1a- variety 1 (TN-1, susceptible to BB disease), 1b- variety 2 (IR-20, moderately resistant to BB disease), 1c- variety 3 (DV-85, resistant to BB disease), C- control (no pathogen inoculation and no riboflavin treatment), T0- disease control (pathogen inoculation and without riboflavin treatment), T1- only riboflavin treatment (1 µM), T2- only riboflavin treatment (2µM), T3- treatment 3 (riboflavin 1µM + pathogen inoculation), T4- treatment 4 (riboflavin 2 µM + pathogen inoculation).}

Fig. 3.16 Disease reactions in response to different treatments against bacterial blight

Characterization of *Fusarium fujikuroi* species complex (FFSC) F-91 isolates causing bakanae/ foot rot disease in rice

Nine different solid and liquid media were evaluated for the growth and other morphological characteristics of F-91 isolate of *Fusarium fujikuroi* species complex (FFSC) causing bakanae/foot rot disease in rice under *In vitro* conditions. Among the different solid media tested, the maximum radial growth (90.00 mm) was observed in Potato Dextrose Agar (PDA), Carrot Agar, Host (Rice) leaf extract agar and Potato carrot agar (PCA) after seven days of inoculation at 27±1°C, whereas the least radial growth was observed in Elliet's agar medium (46.10 mm). Colony colour in all the media was grayish red to white cottony (Fig. 3.17). Maximum sporulation was observed in Fusarium specific (NSM) medium (Fig. 3.18). Among the nine different liquid media tested to evaluate their effect on growth of the pathogen, the maximum dry mycelial weight (418.33 mg) was recorded in potato dextrose broth (PDB) followed by Fusarium specific medium medium (381.67 mg) after 12 days of inoculation at 27±1°C, whereas the least dry mycelial weight (261.67 mg) was recorded in Elliet's broth medium.

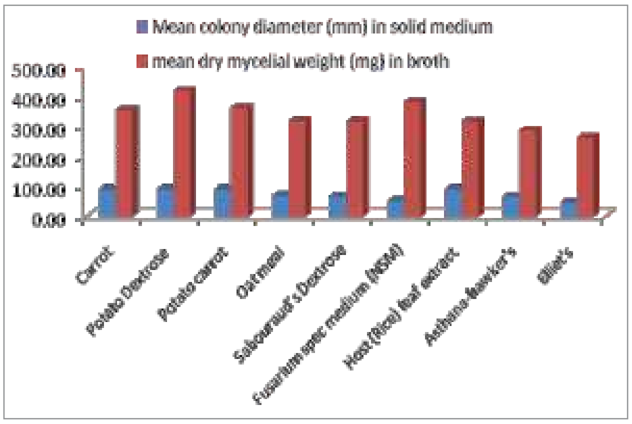


Fig. 3.17 Effect of different solid and liquid media on the growth characters of *Fusarium fujikuroi* species complex F-91 isolate.

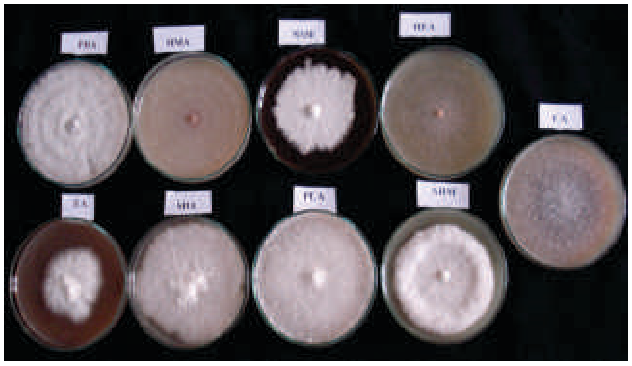


Fig. 3.18 Effect of different liquid media on the growth characters of *Fusarium fujikuroi* species complex F-91 isolate

Rice-endophyte Interaction With Pathogens In Response To Environment

Identification of endophytes isolated from rice seeds

Seven *Dendryphiella* isolates from rice seeds were identified by molecular techniques. Out of which four isolates i.e. crri.1, crri.2, crri.4 and crri.6 were from high yielding popular rice cultivars and their genBank accession numbers were KT582010, KT582011, KT582012 and KT582014 respectively. Other three *Dendryphiella* isolates were from rice landraces. *Dendryphiella* isolate. crri.33 (Acc. no. KT796364) was from land race Malabati. The *Dendryphiella* isolate. crri.34 (Acc. no. KT796365) was from land race Champa and *Dendryphiella* isolate. crri.36 (Acc. no. KT796367) was isolated from rice land race Rangiarai. The Evolutionary relationships of '*Dendryphiella*.crri.33' and nine Taxas showing significant alignment with it (Fig 3.19).

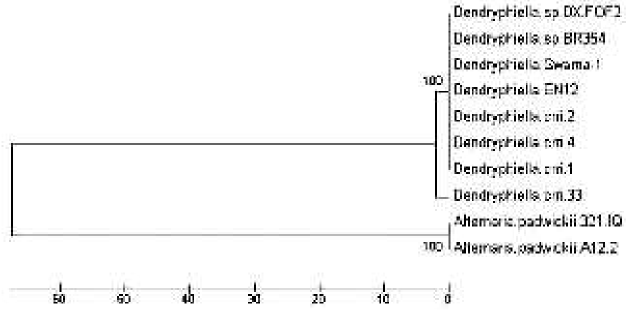


Fig. 3.19 Evolutionary relationships of '*Dendryphiella.crri.33*' and other nine Taxas

Seed borne endophytic *Pennicillium sp.*

The endophytic *Penicillium sp.* (GenBank accession no. KC515385) did not affect the germination percentage of host but significantly enhanced the growth and yield of rice plant (Table 3.4). The cell free cultural filtrates (CCF) of this endophyte inhibited the growth of rice pathogens *viz*., *Rhizoctonia solani, R.oryzae sativae, Bipolaris oryzae, B. sorokiniana, and Fusarium* isolate F55 *in vitro*. It was most effective against *R. solani* c.o. of sheath blight of rice. The growth curve analysis indicated that inhibitory effects of endophyte Cell free cultural filtrate on pathogen cultures were long lasting (Table 3.5).

Phylogeny analysis of *Dendryphiella*

The phylogeny of endophytic *Dendryphiella* fungi from rice seeds was analyzed to exploit their potential for raising healthy rice crop. *Magnaporthe grisea* (c.o. rice blast disease) is a seed borne pathogen. Sometimes the cultural characters i.e. color and mycelia growth of this fungi have some resemblance with the cultures of seed borne *Dendryphiella* spp. Hence, *Magnaporthe grisea* was included as an out group and phylogeny of *Dendryphiella* spp. was studied. The FASTA files of 31 nucleotide sequences of terrestrial (including 13 endophytic *Dendryphiella* isolated at NRRI, Cuttack) and marine *Dendryphiella* spp. retrieved from NCBI data base were analyzed in Phylogeny fr platform. There were two major clusters and six *Magnaporthe grisea* spp. clustered together in one group. All the *Dendryphiella* species clustering together in a different group justified the identity of *Dendryphiella* spp. included here (Fig 3.20). This group was further subdivided in to sub groups and one of the sub group was constituted of 10 marine *Dendryphiella* spp. along with two *Dendryphiella* spp. obtained from wheat / poppy fields. Another sub

Table 3.4 Effect of *Penicillium sp.* (GenBank accession no. KC515385) on rice var. Pooja

Treatment Name	Plant height(cm)	Fresh shoot weight(g)/ plant	Panicle weight (g)/ plant
*Penicillium sp.*E64	105.81^{A}	60.56^{A}	29.13^{A}
Control	93.06^{B}	35.88^{B}	20.81^{B}
SE(d)	1.991	2.906	1.297
LSD at 5%	4.2429	6.195	2.7635

Table 3.5 Regression analysis of mycelia growth of rice pathogens after treatment with Cell free cultural filtrate of *Penicillium sp.* (GenBank accession no. KC515385)

Test organism	Treatment	Growth in colony diameter (mm)	R^2
Rhizoctonia solani	Untreated control	$y = 64.55\ln(x) + 25.64$	0.939
	Treated	$y = 2.916e^{0.480x}$	0.991
R. oryzae sativae	Untreated control	$y = 30.68x$	0.987
	Treated	$y = 7.443x$	0.90
Bipolaris oryzae	Untreated control	$y = 5.277x$	0.929
	Treated	$y = 0.75x^2 - 2.267x + 1.36$	0.98
B. sorkiniana	Untreated control	$y = 25.30\ln(x) - 1.545$	0.991
	Treated	$y = 3.931x - 3.76$	0.989
Fusarium sp.	Untreated control	$y = 33.65\ln(x) - 0.942$	0.996
	Treated	$y = 8.9x - 6.54$	0.982

group consisting of 17 Texas had 16 *Dendryphiella* isolated from healthy rice seeds and one *Dendryphiella sp.* from a weed found in rice ecosystem. All non-spores producing, endophytic *Dendryphiella sp* isolated from rice seeds and *Dendryphiella* sp. NBRC 100153 (Patent No. JP8119817-A) present in irrigated rice area were clubbed together in one sub group irrespective of their geographic location.

Impact of endophyte *Dendryphiella* sp. FV39-II on rice plant

Dendryphiella sp.FV39-II significantly increased the fresh / dry weight of roots and shoots of 35 days old seedlings of sheath blight susceptible rice cultivar Annapurna. The fresh shoot weight increased 2.16 times and dry shoot weight was thrice than the untreated control. This endophyte increased the fresh root weight three times and dry root weight about 3.9 times more than the untreated control.

Effect of *Dendryphiella* spp. on rice variety Annapurna grown in soil infested with *Rhizoctonia solani*

Dendryphiella sp. FV16 and *Dendryphiella* sp.FV39-II both were found to be very effective as plant growth promoter. Both endophytes could mitigate the impact of sheath blight of rice in field (Table 3.6).

Impact of *Dendryphiella* sp. on soil borne rice pathogens *in vitro*

Effect of 'Cell free cultural filtrates' (CCF) of *Dendryphiella*. FV39-II and *Dendryphiella* sp. FV16 on soil borne rice pathogens *viz., Sclerotium* sp. c.o. of seedling blight of rice; *Rhizoctonia oryzae sativae* c.o.

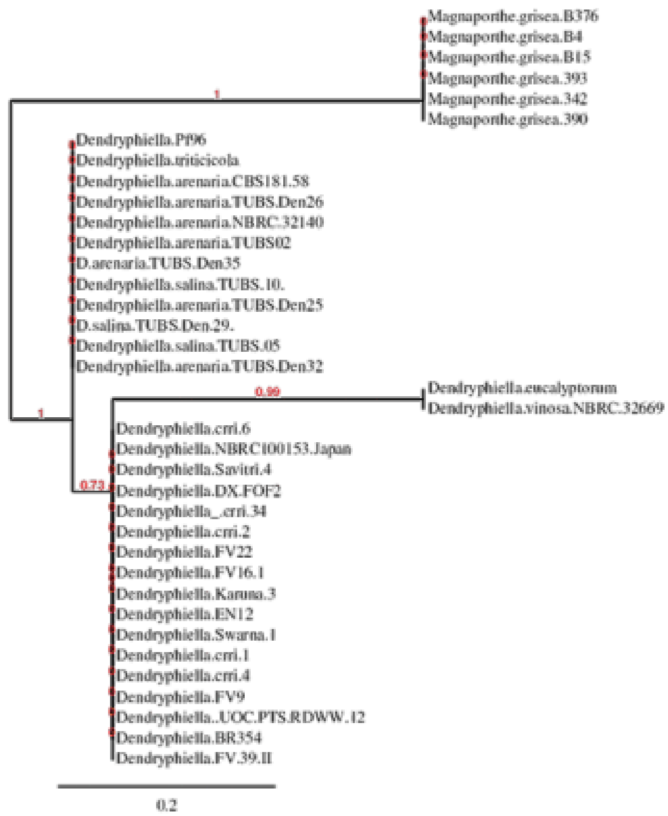


Fig. 3.20 Phylogenetic tree of *Dendryphiella spp.*

aggregate sheath spot of rice; *Rhizoctonia solani* c.o. sheath blight of rice was studied *in vitro*. Both endophytes were effective against three sclerotia producing soil borne rice pathogens. *Dendryphiella* sp.FV16 completely inhibited the sclerotia production in all the test organisms included The sclerotia initiation period, in cultures treated with CCF from *Dendryphiella* sp.FV39-II was almost 2.25 times more than the

Table 3.6 Effect of *Dendryphiella spp.* on yield attributes of rice variety Annapurna grown in soil infested with *Rhizoctonia solani*

Treatment Name	Filled grain %	Single spikelet wt(mg)	YR*
Rhizoctonia solani + *Dendryphiella* sp FV16	84.11^{C}	19.03^{C}	1612.94^{D}
Rhizoctonia solani + *Dendryphiella* sp FV39-II	84.63^{C}	19.44^{B}	1663.83^{C}
Rhizoctonia solani	76.56^{E}	17.30^{E}	1344.17^{F}
Dendryphiella sp. FV16	86.32^{B}	19.39^{B}	1684.80^{B}
Dendryphiella sp. FV39-II	89.06^{A}	20.17^{A}	1801.27^{A}
Untreated Control	82.72^{D}	18.64^{D}	1555.02^{E}
CV(%)	4.42	6.02	5.00
SE(d)	0.303	0.093	6.574
LSD at 5%	0.5935	0.183	12.896

YR* = Filled grain % X Single spikelet wt. (Dhua *et al.*, 2015; *J. Phytopathol.* 163:931–940) untreated control. The area of plates occupied by the sclerotia in untreated control was almost five times more than the endophyte treated plates (Table 3.7).

Identification and Utilization of Host Plant Resistance in Rice Against Major Insects and Nematode Pests

Identification of resistant donors

Brown Plant Hopper

A total of 695 genotypes, consisting of 450 genotypes received from NBPGR, 100 F_3 lines from IRRI and 145 genotypes from AICRIP Coordinating Unit, IIRR, Hyderabad under Planthopper Screening trial (PHS), Multiple pest resistance screening trial (MRST) and Planthopper Special Screening trial (PHSS) were screened against brown plant hopper (BPH) under greenhouse condition. Forty eight genotypes of NBPGR, 7 of IRRI and one of PHS were found highly resistant (Table 3.8).

Yellow Stem Borer

Field screening of 42 breeding lines (CR 1009 x *Oryza brachyantha*), 14 tropical japonica lines, 9 double haploid lines with one hybrid CRHR 32 revealed that eight entries *viz*., wild derivatives: B-8, B–11 & B-16; tropical japonica lines: WC – 73, WC – 152, WC – 392; double haploid lines: SS-5, SS-19 showed zero damage score as against the susceptible check TN 1 with damage score of 7.

Gall midge

A total of 1317 genotypes under biodiversity seed material (NBPGR) and Rice AICRIP, were screened under greenhouse condition. Forty genotypes showed high level of resistance against NRRI gall midge (Table 3.9)

Table 3.7 Effect of *Dendryphiella* FV39-II on soil borne rice pathogens

Treatment Name	Area of petri plate possessing sclerotia (mm^2)	Sclerotia initiation Time (days)
R.solani- Untreated control	34.60^C	4.00^C
R. - treated with CCF of endophyte	6.80^D	9.40^A
R. oryzae sativae - Untreated control	51.20^B	5.00^B
R. oryzae sativae - treated with CCF of endophyte	0.00^E	0.00^D
Sclerotium - Untreated control	90.00^A	5.00^B
Sclerotium - treated with CCF of endophyte	0.00^E	0.00^D
CV(%)	2.68	5.73
SE(d)	0.515	0.141
LSD at 5%	1.0745	0.295

Table 3.8 Resistant entries against Brown plant hopper

Seed source	Resistant with score 1
NBPGR, New Delhi	B-127, B -129, B -134, B -136, B -150, B -180, B -189, B -220, B -221, B -231, B -235, B -242, B -246, B -360, B -369, B -382, B -383, B -389, B -395, B -396, B -400, B-401, B-406, B-408, B-409, B-412, B-414, B-416, B-427, B-429, B-430, B-431, B-433, B-447, B-497, B-606, B-613, B-617, B-654, B-660, B-726, B-733, B-742, B-849, B-864, B-876, B-888, B-1005.
F_3 Lines (IRRI)	IR 113050-B-8, IR 113050-B-11, IR 113050-B-14, IR 113050-B-18, IR 113050-B-51, IR 113050-B-81, IR 113050-B-100.
AICRIP Coordinating Unit	RP 2068-18-3-5

Table 3.9 Resistant entries for Gall midge

Seed source	Resistant with SES Score 0
NBPGR, New Delhi	B-127, B-140, B-143, B181, B-182, B-184, B-322, B-454, B-920, B-804
AICRIP Coordinating Unit	IET 21842, IET 22698, ARC 14771, ASD7, Kakai (K 1417), Sina Sivappu, Sudu Hondarwals, Vellai, ARC 6248, RP 2068 -18-3-5, TH BR -68-72, T H BR -68-74, TH BR-68-79, Aganni, RMSG 7, RMSG 10, RMSG 11, RMSG 24, KNM 1623, KNM 1716, KNM 1717, KNM 1719, KNM 1720, RDR 1175, RDR 1176, WGL 667, WGL 764, WGL 767, NRC 3021.

Known gene differentials of gall midge resistant gene GM_1, GM_2, GM_3, GM_4, GM_5, GM_6, GM_7, GM_8, GM_9, GM_{10}, GM_{11} were screened against NRRI gall midge population (biotype 2) under green house condition. Only Aganni (GM_8) and INRC 3021 (unknown) were found resistant with score '0'.

White-backed planthopper (WBPH)

Out of 14 selected resistant lines *viz.*, AC34222, AC34264, AC34270, AC34273, AC34303, AC38468, AC38575, AC38609, AC42425, AC42465, AC42494, AC42499, AC42518 and AC42566 reported earlier were rescreened against WBPH. Only four lines i.e. AC34222, AC34264, AC38468 and AC42425 were reported to be resistant (Score1) and AC42494 was moderately resistant (Score 3).

Bioecology and Management of Pests Under Changing Climatic Scenario

Stem borer incidence in dry and wet season rice and its effective management

Monitoring of pests, particularly yellow stem borer (YSB) and brown plant hopper showed YSB as the common pest during both dry and wet season, 2015 (Fig 3.21). However, the population was 9.4 times more in *dry* than **wet season** which also prevailed for longer period (3^{rd} - 19^{th} SMW) than wet season (40^{th} - 51^{st} SMW). The early incidence of YSB in dry season was effectively managed by foliar spray of chlorantraniliprole 18.5SC (Coragen) @ 150ml/ha coinciding with high brood emergence. The grain yield was 9.6% more than the late application, *i.e.,* 10 days after the high brood emergence.

Shift of population towards 43 SMW increased insect infestation in long duration rice varieties like Varshadhan. In addition to YSB, infested tillers revealed the presence of pink stem borer (*Sesamia inference* Walker) and striped stem borer (*Chilo suppressalis* Walker) upto 21.93% and 13.9 % respectively, of the total population.

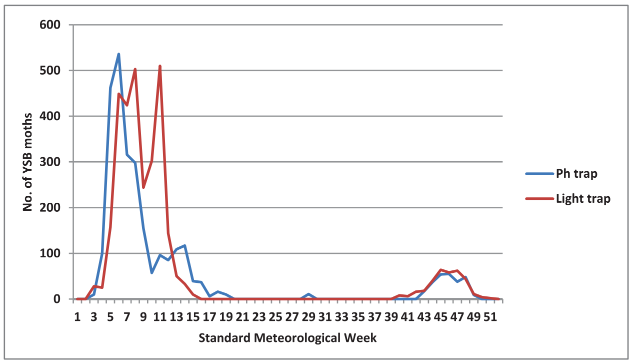


Fig. 3.21 YSB population monitored during wet season 2015

Incidence, diapause and carryover of the rice stem borer

The incidence of diapausing rice stem borer larvae in the rice crop residues (stalks and stubbles) were investigated during December 2015 to February 2016 just after harvest of wet season crop. The rice stubbles were uprooted and examined by dissecting stem on daily basis. The results revealed that three predominant stem borer larvae infesting rice were yellow stem borer, *Scirpophaga incertulus,* striped stem borer, *Chilo supressalis* and pink stem borer, *S. inferens sesamia* diapaused in the rice crop residues during the period of investigation. The relative abundance of three diapausing stem borers revealed that yellow stem borer (40.8%) was most predominant followed by striped stem borer (36.2%) and pink stem borer (23%). The occurrence of stem borer species was correlated with the height of the stubbles. The results revealed that 60% of the total *S. inferens* and 17.6% of the total *Chilo* sp recorded were concentrated to 9.8, 7.0 cm above the root zone, respectively, whereas 98% of the yellow stem borer larvae were concentrated to the base of rice stubbles. This low population mostly at the base of the stubbles appeared to be the source of infestation of the newly planted crop and may have the potential of causing heavy infestation. It is clear that destruction of diapausing above species of rice stem borer during land preparation would be an effective cultural control method to suppress the carry over population.

Effect of elevated CO_2 on feeding behavior of *Cnaphalocrocis medinalis* (Guenee)

The effect of elevated CO_2 concentration (CE) on leaf area consumption was evaluated during the vegetative stage of rice grown at CE (550 µmol mol^{-1}), open top chamber (OTC), ambient CO_2 concentration (~ 390 µmol mol^{-1}) in OTC and in open field. Pots having forty days old seedlings were transferred to OTCs and another set of pots were allowed to grow in open field condition till maturity. Five 4^{th} instar larvae of leaf folder were released on each caged pot. The larvae were allowed to feed on the leaves for 30 days. The feeding intensity of the leaf folder was estimated with the help of graph papers by plotting the damage along with the total leaf area on graph. Data on the effect of elevated CO_2 on the feeding behaviour of leaf folder indicated that the average tiller attacked per larva was 3.6, 3.7 and 3.8 cm^2 on elevated, ambient CO_2 and field, respectively. It was also observed that the percentage of leaf attacked was more in case of elevated condition (44.4%) as compared to ambient condition (34.8%) and field condition (38.5%). However, it was found that the average area of the leaf fed under elevated CO_2 was 7.6% where as the feeding in ambient CO_2 (15.8%) was more than double of the elevated CO_2.

Isolation and identification of bacteria associated with the midgut of different species of Rice Stem Borer

The bacterial association in mid gut region of different cellulose degrading stem borer (CDSB) larvae *viz.*, pink stem borer, white stem borer and yellow stem borer were analyzed by using different media *viz.*, Nutrient Agar (NA), King's B, Minimal medium and Nutrient Agar (NA) supplemented with Carboxy Methyl Cellulose (CMC). The results revealed that the pink stem borer recorded higher bacterial population (1.51×10^4 $larva^{-1}$) followed by yellow stem borer (1.23×10^4 $larva^{-1}$) and striped stem borer (0.87×10^4 $larva^{-1}$) in Nutrient Agar medium. The fluorescent *Pseudomonas* association in different stem borer larva indicated that there was higher population of pink stem borer (1.17×10^4 $larva^{-1}$) followed by yellow stem borer (1.10×10^4 $larva^{-1}$) and striped stem borer (0.84×10^4 $larva^{-1}$).

The cellulolytic bacterial association in different stem borer larvae showed that there was significantly higher population (8.21×10^4 $larva^{-1}$) in striped stem borer as compared to pink stem borer (1.29×10^4 $larva^{-1}$) and yellow stem borer (0.92×10^4 $larva^{-1}$) larvae. The above observation clearly indicates that the cellulolytic bacterial association was commonly present in three different rice stem borer species; however striped stem borer has higher bacterial population than other two species. For further confirmation of cellulolytic bacterial association in different stem borer species, in another experiment nutrient agar medium supplement with CMC was used. The result revealed that similar to CMC agar medium, cellulolytic bacterial population was found to be higher in striped stem borer (7.53×10^4 $larva^{-1}$) followed by pink stem borer (1.34×10^4 $larva^{-1}$) and yellow stem borer (1.02×10^4 $larva^{-1}$).

Ten different bacterial isolates were used to understand their cellulolytic activity. The cellulolytic activities of bacterial isolates were assessed in three different medium supplemented with CMC, xylan and crystalline cellulose. The results showed that none of the isolate showed xylanolytic activity except CDSB - 5 isolate. Out of 10 isolates, 9 isolates showed cellulolytic activity in CMC agar plate. The cellulolytic activity of bacterial isolates in crystalline cellulose supplement medium, eight isolates showed cellulolytic activity. The above information clearly proved that the majority of bacteria isolated from mid gut region of rice stem borer larva possess cellulolytic activity.

The rice stem borer bacterial isolates *viz.*, CDSB 3, 4, 5, 6 and 9 were selected for antibiotic sensitivity test by using different antibiotics *viz.*, ampicillin, tetracyclin, penicillin, streptomycin, chloramphenicol and erythromycin. The results indicated that all the bacterial isolates except CDSB 5 were found resistant to penicillin and ampicillin but susceptible to tetracycline, chloramphenicol and streptomycin (except CDSB 9). Out of five isolates, three isolates

(CDSB 3, 5 and 9) were susceptible to erythromycin. The present findings revealed that the following antibiotics *viz*., tetracyclin, chloramphenicol and streptomycin may be effective to suppress or kill the cellulolytic bacterial association in mid gut region of different rice stem borer larvae. Similarly the following different PGPR bacteria *viz*., *Pseudomonas*, *Streptomyces* spp (935, Act 1, 3 and 5) and one entomopathogenic bacterial isolate (RPSB 5) were tested their antagonistic potential against five stem borer mid gut associated cellulolytic bacteria (CDSB 3, 4, 5, 6 and 9). The results showed that none of the PGPR bacteria suppress the mid gut associated cellulolytic bacteria. Interestingly, *Pseudomonas* sp showed the antagonistic activity against CDSB 5 isolate. The present findings revealed that the following antibiotics *viz*., tetracycline, chloramphenicol and streptomycin can be used to suppress the cellulolytic bacterial association in mid gut region of different rice stem borer larva. The application of either individual or combination of the above said antibiotics may reduce the stem borer incidence in rice cultivation

Diversity of insect pests and natural enemies in lowland rice ecosystems

The study was conducted during wet season, 2015 and dry season, 2015 in semi-deep water and irrigated ecologies. The collection of insect pests and their natural enemies was mainly done through sweep net in the rice (cv. Lalat, an irrigated variety and Varshadhan, a semi-deep water variety). In semi deep water rice ecology, spiders (7.2/ sweep) outnumbered the other predatory groups and were widely distributed throughout the study area. The other major predatory arthropods include damsel fly (5.9/ sweep) and lady bird beetle (5.2/ sweep). Among the parasitoids, *Xanthopimpla* sp., *Carcelia* sp., *Stenobracon* sp. *Apanteles flavipes*, *Brachymeria* sp.,*Cardiochiles* sp.are the predominant one occurred in the study area (Fig 3.22). Although the same trend was observed in the irrigated ecology, the number was low compared to semi deep water ecology. There was no hispa recorded in the irrigated ecology.

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 computed in irrigated ecosystem Simpson's index [1/D] (10.48), Shannon-Wiener index [H'] (2.62), Margalef's index [M] (2.75) whereas in semi deep water ecologies the Simpson's index [1/D] (13.42), Shannon-Wiener index [H'] (2.78) and Margalef's index [M] (2.76) were computed to quantify diversity and understand community structure.

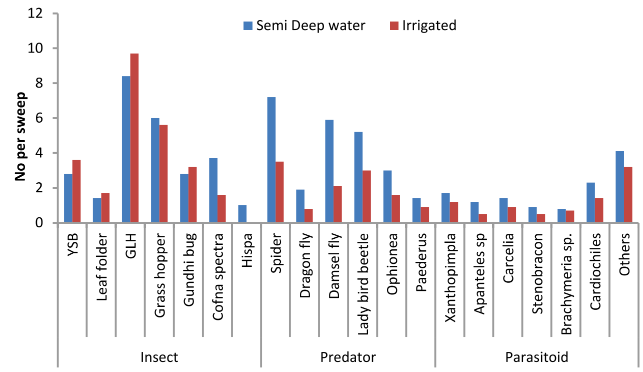
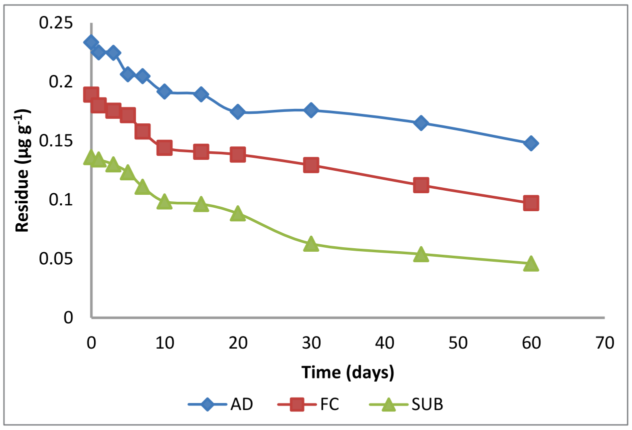


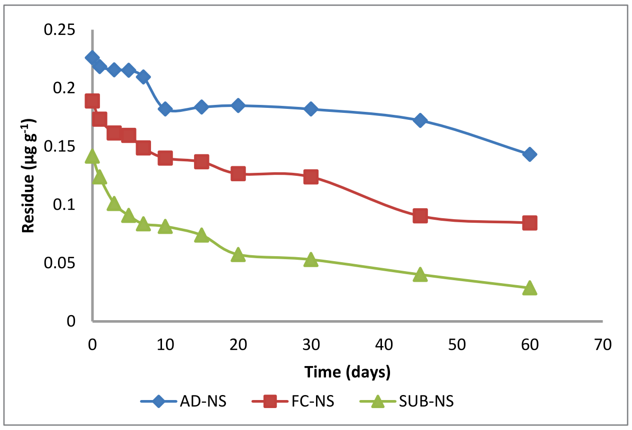
Fig. 3.22 Diversity of rice insect pests and natural enemies in irrigated and semi deep water ecosystem

Effect of abiotic factors in imidacloprid degradation

Pesticides undergo various dissipation processes like hydrolysis, photolysis, volatilization, leaching, surface runoff and microbial degradation after application in soil and plant canopy. The extent of their contribution towards total dissipation depends upon the nature of soil, pesticide chemistry and other environmental factors. Degradation of pesticides due to abiotic factors has been studied under laboratory in controlled conditions. To identify mechanisms and pathways of pesticide degradation, simplified matrices like pure light and moistures regimes were used. At different moisture regimes, the degradation of imidacloprid varied (Fig 3.23 a & b). It was found that with increase in moisture the rate of degradation is faster. Imidacloprid dissipated under controlled condition to the tune of 36.7 and 36.6% under air dried sterile and non sterile soil after 60 days of incubation, respectively. Similarly at field capacity, the dissipation was 48.7 and 55.3% in sterile and non sterile soil, respectively. Under field capacity moisture, the dissipation was 66.2 and 79.8% in sterile and non sterile soil, respectively. Microbial degradation is one of the prominent routes of imidacloprid degradation. In acidic and neutral water, imidacloprid is rather stable and hydrolyze slowly (Fig 3.24). The hydrolysis increases when the solution becomes alkaline. However, rate of hydrolysis of imidacloprid was not much faster at pH 9. Study revealed that photo degradation was one of the major routes of imidacloprid degradation (Fig 3.25). The half life of imidacloprid under sunlight was 16.12 and 13.59 hours under UV light. Imidacloprid dissipation in different matrices followed first order kinetics (Table 3.10).



a. Sterile soil



b. Non-sterile

Fig. 3.23 Persistence of imidacloprid at different moisture regimes (Where, AD-Air dried, FC-Field capacity, SUB-Submerged, NS- Non-merite.

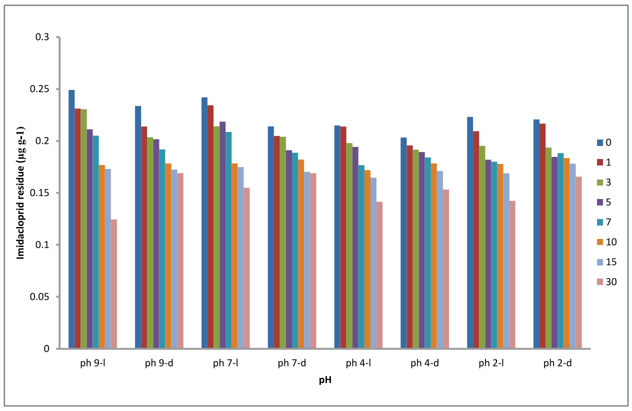


Fig. 3.24 Persistence of imidacloprid at different pH solution (Where, L-Light, D-dark

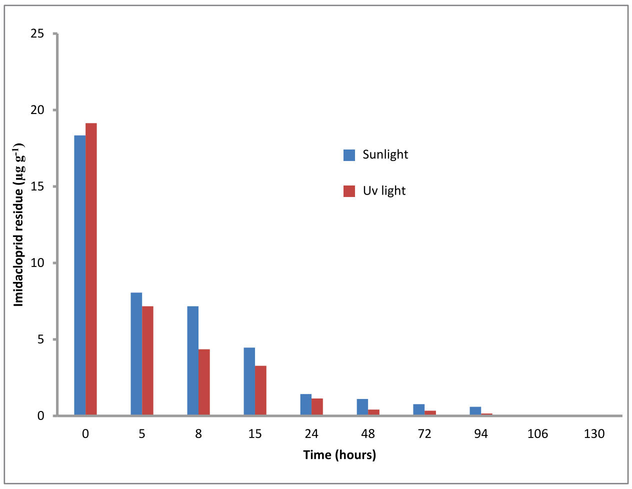
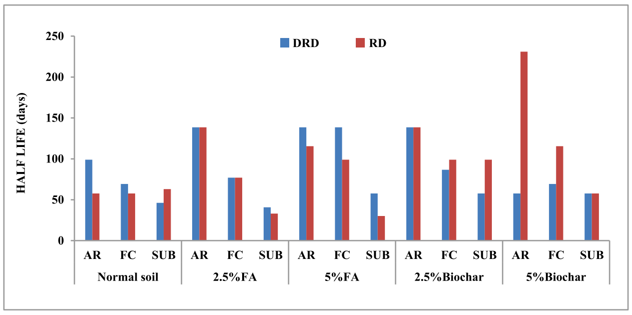


Fig. 3.25 Persistence of imidacloprid under UV light and sunlight

Persistence of fipronil under rice ecosystem in amended soil

Half life values of fipronil under submerged (SUB), field capacity (FC) and air dried (AR) soil ranged from 30-99, 57-115, 57-231 days for Recommended Dose (RD, 75g ai/ha) and 40-57, 69-138, 57-138 days for Double the Recommended Dose (DRD, 150g ai/ha) treatment, respectively. In amended soil half live values ranged from 33-138 days for 2.5% FA, 30-138 days for 5% FA, 57-138 days for 2.5% BC and 57-231 days for 5% BC treatment compared to 46-99 days in non-amended soil irrespective of water regimes (Fig.3.26).



FA: fly ash; BC: Bio-char

Fig. 3.26 Half-life of fipronil under different amended soils

Table 3.10 Linear regression equations and half-life of imidacloprid in different treatment conditions

Treatment	Regression equation	Regression coefficient	Half life (days)
Effect of moisture regime			
Sterile AD	y = -0.003x - 0.662	0.886	115.5
Sterile FC	y = -0.004x - 0.756	0.941	69.3
Sterile SUB	y = -0.008x - 0.886	0.963	36.5
Non- Sterile AD	y = -0.006x - 1.534	0.863	115.5
Non- Sterile FC	y = -0.012x - 1.774	0.948	57.7
Non- Sterile SUB	y = -0.023x - 2.206	0.935	30.1
Effect of pH solution			
ph 9-light	y = -0.022x - 1.43	0.972	31.50
ph 9-dark	y = -0.009x - 1.551	0.720	77.01
ph 7-light	y = -0.014x - 1.471	0.875	49.51
ph 7-dark	y = -0.007x - 1.592	0.779	99.02
ph 4-light	y = -0.013x - 1.575	0.920	53.32
ph 4-dark	y = -0.008x - 1.620	0.975	86.64
ph 2-light	y = -0.013x - 1.579	0.897	53.31
ph 2-dark	y = -0.008x - 1.583	0.730	86.64
Effect of light			
Sunlight	y = -0.043x + 2.323	R^2 = 0.908	16.12 hours
UV light	y = -0.051x + 2.102	R^2 = 0.920	13.59 hours

Formulation, Validation and Refinement of IPM Modules in Rice

Validation and Refinement of IPM module

Validation of IPM module in 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 Jhadeswarpur village of Mahanga block in Cuttack district during wet season, 2015 with varieties Swarna and Pooja under need based IPM, schedule based IPM and farmer practices. Survey for the incidence of major rice diseases and insect pests during wet season, 2015 in Jhadeswarpur village of Mahanga, Cuttack revealed that the dead heart due to stem borer was 3.5-6.0% and white ear head (3.5-5.7%), leaf folder (2.7-5.4%), gundhi bug (5.0-7.5%) during November 2015. Cartap @ 10 kg per acer against LF and YSB, chlorpyriphos @0.5kg a.i./ha against gundhibug and carbendazim @ 2g/lit against sheath blight, brown spot and sheath rot were effective against these pests.

Table 3.11 Effect of IPM on insect pest in shallow rainfed rice ecology during wet season 2015

SL No	Treatment	% DH	% WEH	% LFDL	% Gundhi bug	NE	Grain yield
1	Swarna IPM need based	3.5 (10.75b)	3.5 (10.75b)	2.65 (9. 22b)	5.0 (12.71b)	3.0b	6.25a
2	Swarna IPM schedule based	4.3 (11.95b)	3.7 (11.01b)	2.85 (9.57b)	5.25 (13.20b)	2.5b	4.75ab
3	Swarna farmer practice	5.75 (13.86a)	5.6 (13.67a)	5.1 (13.00a)	7.5 (15.85a)	5.12a	3.5b
4	Pooja IPM need based	3.8 (11. 8b)	3.9 (13.34b)	2.25 (8.45b)	5.0 (12. 81b)	3.25b	6.0a
5	Pooja IPM schedule based	4.35 (11.92b)	4.05 (11.47b)	2.5 (9. 05b)	5.5 (13.49b)	3.0b	5.0ab
6	Pooja farmer practice	5.95 (14.09a)	5.65 (13.72a)	5.4 (13.42a)	7.5 (15. 88a)	5.25a	3.25b
CD at 5%		1.85	1.92	2.44	2.15	1.64	2.08

Data in parenthesis are angular transformed values

In IPM practice, seed treatment was done with carbendazim 50WP @ 2.0g/kg seed before sowing in nursery bed with two popular varieties, Pooja and Swarna along with clean cultivation and line transplanting. Application of fertilizers was done at the dosage of 60:30:30 kg N:P:K/ha with basal dose of 30:30:15 kg N:P:K/ha in the main field before transplanting, top dressing with 15kg N:K/ha after 30days and 15kg N/ha after 60 days of transplanting. Need based application of pesticides were applied by the farmers in the affected areas only. The fungicide carbendazim 50WP@ 1.0g/lit against brown spot, sheath blight, sheath rot; the insecticide cartap hydrochloride @1kg a.i./ha against YSB, leaf folder, BPH and need based foliar application of chlorpyriphos 20 EC @ 0.5kg a.i./ha against gundhi bug were used. Pheromone traps for monitoring were installed. Farmers were trained to identify the harmful and beneficial insects in their fields. Disease and insect, pest infestation were regularly assessed.

In schedule based practice, farmers used pesticides in whole plot and in a schedule manner, irrespective of disease and pest incidences, at least 2-3 times in a season. In farmer practice there is no control measure against insect and diseases in the field. The dead heart, white ear head, leaf folder damage and gundhibug damage were significantly less and natural enemies population was significantly more in need based IPM practice in both the tested varieties (Table 3.11). Disease incidences were recorded both in IPM and non-IPM plots. From the experimental findings (Table 3.12), in case of Swarna IPM (Need based), 4.32% brown spot, 6.24% sheath blight, 3.82% sheath rot, 2.94% false smut incidences were recorded; in Swarna IPM (Scheduled based), 5.14% brown spot, 7.02% sheath blight, 4.5% sheath rot, 4.32% false smut incidences were observed; whereas, in case of Swarna non-IPM, 8.86% brown spot, 9.44% sheath blight, 7.22% sheath rot, 5.78% false smut incidences were recorded. In case of Pooja IPM (Need based), 2.76% brown spot, 5.82% sheath blight, 4.48% sheath rot, 4.33% false smut incidences were found; in Pooja IPM (Schedule based), 4.75% brown spot, 6.05% sheath blight, 5.65% sheath rot, 5.5% false smut incidences were recorded; while, in case of Pooja non-IPM, 8.1% brown spot, 7.68% sheath blight, 8.4% sheath rot, 7.36% false smut incidences were found.

Variety Swarna with need based IPM practice has

Table 3.12 Effect of IPM module on rice diseases in shallow rainfed rice ecology during wet season, 2015 (Jhadeswarpur, Cuttack)

Treatments	Brown spot (%)	Sheath blight (%)	Sheath rot (%)	False smut (%)	Grain yield (t/ha)
Swarna IPM(Need based)	4.32 (11.96b)	6.24 (14.43bc)	3.82 (11.17d)	2.94 (9.79c)	6.25a
Swarna IPM (Schedule based)	5.14 (13.06b)	7.02 (15.33bc)	4.50 (12.22cd)	4.32 (11.92bc)	4.75ab
Swarna (Farmer practice)	8.86 (17.29a)	9.44 (17.86a)	7.22 (15.56ab)	5.78 (13.86ab)	3.50b
Pooja IPM (Need based)	2.76 (9.49c)	5.82 (13.93c)	4.48 (12.19cd)	4.33 (11.98b)	6.00a
Pooja IPM(Schedule based)	4.75 (12.54b)	6.05 (14.19c)	5.65 (13.72bc)	5.50 (13.53b)	5.00ab
Pooja (Farmer practice)	8.10 (16.50)	7.68 (16.07)	8.40 (16.82a)	7.36 (15.71a)	3.25b
CD (at 5%)	1.81	1.86	1.92	2.14	2.08

Figures in parentheses represent the angular transformed values.

significantly higher yield (6.25 t/ha) compared to shedule based IPM (4.75 t/ha) and farmer's practice (3.5 t/ha). Significantly, higher straw yield of 5.5 t/ha were obtained from the variety Swarna with need based IPM practice, whereas, in case of Swarna schedule based IPM, straw yield of 4.5 t/ha were obtained and in farmer practice straw yield of 3.5 t/ha was obtained. Significantly, higher grain yield of 6.0 t/ha was obtained from the variety Pooja under need based IPM practice compare to grain yield of 5.0 t/ha in case of Pooja under schedule based IPM. In farmer practice the grain yield was 3.25 t/ha in Pooja.

On-Farm validation of IPM module in rainfed low land rice ecosystem

On-farm IPM trial on rice (cv. Pooja) was conducted in rainfed low land ecosystem in the Pipili block of Puri District in Odisha during wet season, 2015. The pest scenario and strategies were evaluated under two regimes *viz.*, 1. *Farmers' practice (FP):* (a) Direct seeding (b) Pest monitoring both in the nursery and main fields (c) Application of carbofuran in the nursery/ main field after seeing the damage 2. *IPM treatments:* (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) Chlorantraniliprole 0.4G @ 10kg ha^{-1} applied at 25 DAT (c) Need based application of foliar spray of flubendiamide 480SC @ 30g a.i. ha^{-1} and thiomethoxam 25WG @ 25g a.i. ha^{-1} (d) Need based application of fungicide plantomycin (Streptomycin sulphate + Tetracycline hydrochloride) @ 1g/lit of water against bacterial leaf blight. In case of IPM, 3.7% dead heart (DH), 1.8% white ear head (WEH) due to stem borer, 2.5% leaf folder damaged leaf, gundhi bug (1.4/ sweep) 4.5% sheath blight, 1.2% bacterial leaf blight infections, 1.8% balls due to false smut were recorded (Fig 3.27 & 3.28); whereas in case of Farmers Practice, 8.8% DH, 6.5% WEH, 8.4 BPH/ hill, 2.5 gundhi bug/ hill, 7.2% sheath blight, 4.5% bacterial leaf blight, 3.5% smut balls were found. In IPM plots, predator population was more (7.5 $sweep^{-1}$) compared to FP plots (4.2 $sweep^{-1}$) which includes spider, damsel fly, dragon fly, mirid bugs whereas parasitoid population was 5.6 $sweep^{-1}$ in IPM and 3.9 $sweep^{-1}$ in FP plots (Fig 3.29 & 3.30). The grain and straw yields in IPM treatments were 5.6, 9.8 t ha^{-1}, respectively compared to 4.2 and 9.5 t ha^{-1} in FP treatment. Farmers were trained for the identification of insect pests and their natural enemies to decide the timing of pest management practices.

Fig. 3.27 False smut in Farmers' practice plot

Fig. 3.28 Collection of insect pests and natural enemies in IPM plot at Arhua, Puri district

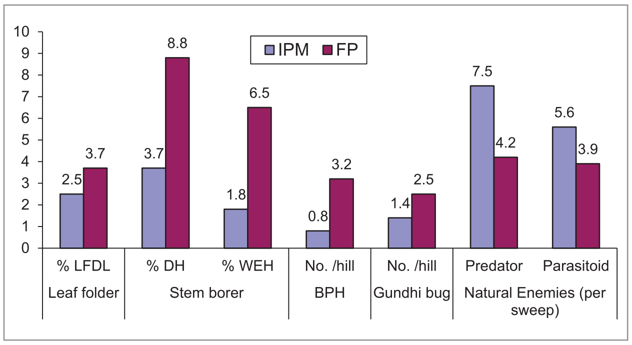


Fig. 3.29 Population dynamics of insect pests and natural enemies in rice

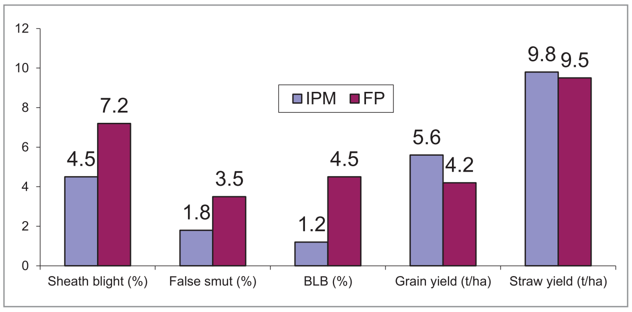


Fig. 3.30 Incidence of diseases, grain and straw yield in different pest management regime

Favourable Lowland ecology

IPM practice

In Mahanga block of Cuttack, 30 acres of rice field were under IPM with rice variety Pooja. The IPM practice included- (1) scheduled based seed treatment with carbendazim @ 2g/kg of seed. (2) Monitoring of pests and diseases visually or with insect specific interventions like pheromone trap. (3) Need based application of botanicals or pesticides. In farmers' practice, pesticide application was made at pest severity of crop stage.

Swarming caterpillar occurred as the major pest at nursery and at initial stage of transplanting. Though its common habitat is known to be the forest or bushy areas, the pest infestation was experienced during wet season 2015 in the irrigated rice areas of Mahanga and Nischitkoili block of Cuttack and vast area of Kendrapada district. Surveillance in the IPM plots in Mahanga block could help in detecting the pest at its initiation stage during 2nd week of August in about 1 acre of nursery beds and in 1.6 ha of transplanted paddy. Investigation on upsurge of the pest showed canal water as the madium. They were seen crawling at the side of the canal and most of the rice fields adjacent to the irrigation canal were affected more. Foliar spray of insecticides such as chlorpyrifos 20EC @ 1250ml/ha, imidacloprid 17.8SL @125ml/ha, thiamethoxam 25WG @ 100g/ha, triazophos 40EC @ 2.5 ml/liter and acephate 75SP @2gm/liter of water were applied immediately and the pest was under control. But it was again reported towards last week of September from non-IPM plots (In about 2.8 ha area) who had not taken any protection measures during the pest invasion. Larval population was on an average @ 10 larvae/m^2 and about 10 hills were infested to above 50% level. In addition, there was case worm infestation in about 10 acres, leaf folder in about 4 acres and sheath blight in about 5 acres. Immediate application of thiamethoxam for case worm and neem oil for leaf folder controlled the insect pests. Validamycin 3L@ 2ml/lit was applied as foliar spray for sheath blight treatment. The grain yield varied within 5.5-6.3 t/ha in IPM plots as compared to 4.4-4.8 t/ha in farmers' practices plots.

Bioefficacy of DPX-RAB55 10 SC (Triflumezopyrim) against sucking pests of rice

Field efficacy of DPX-RAB55 10 SC (Triflumezopyrim), an insecticidal product from E I DuPont India Pvt. Ltd.

was assessed on the basis of number of hoppers (Brown Plant Hopper, Green leaf hopper) per hill, changes in the population of natural enemies and the grain yield. At 3 days after spraying (DAS) the DPX-RAB55 10 SC at 35 and 25 g a.i./ha recorded lowest number of hoppers per hill followed by fipronil 5SC. Upto 15 days after spray DPX- RAB55 10SC at 35 and 25 g a.i./ha maintained the population of hoppers below economic threshold level. Population of hoppers considerably reduced after 3 days of spraying. Lowest hopper population was recorded in DPX- RAB55 10SC at 35 and 25 g a.i./ha which are statistically at par. DPX- RAB55 10SC at 25 and 35 g a.i./ha were recorded as the best treatments over other doses of DPX- RAB55 10 SC and fipronil 5SC. At 3 and 7 DAS, DPX- RAB55 10 SC @ 35 g a.i./ ha registered lowest no. of GLH/ hill, whereas at 7 DAS of DPX- RAB55 10 SC @ 35 g a.i./ ha to the rice crop recorded lowest no. of GLH/ hill. DPX RAB 55 10SC 35g a.i./ha recorded highest grain yield (4.6 t/ha) and was on par with DPX RAB 55 10SC @ 25 g a.i./ ha (4.25 t/ ha) which is significantly superior over untreated control (2.95 t/ ha). Population of mirid bug was found to be highly dependent on the availability of brown plant hopper for preying. Mean number of mirid bug per hill after 15 days of first spray was comparatively low in all insecticide treated plots than the untreated control. The predatory mirid bug population recorded at 3 and 14 days after insecticide application indicated significant variation among the treatments. Significantly higher mirid bug population was recorded in DPX- RAB55 treatments compared to fipronil 5SC in the present study. Although there was significant difference in natural enemies among treatments after 3 DAA, there was no significant difference among the population of mirid bugs and spiders after 14 DAS. Based on the above results it can be concluded that DPX- RAB55 10SC @ 25 g a.i./ha provided effective control of plant hoppers (BPH/WBPH and GLH). Further, DPX- RAB55 10 SC was safe to the predatory mirid bug, *Cyrtorhinus lividipennis* and spider, *Pardosa pseudoannulata*. Hence DPX- RAB55 10 SC @ 25 g a.i./ha can be recommended for the effective management of plant hoppers in rice for realizing higher grain yield.

Evaluation New Insecticide against insect pest of rice during dry season, 2015

Eight insecticides, fungicide and combination products were evaluated against insect pest of rice during dry season, 2015 out of which Coragen @ 0.3ml/lit + CM75 @ 2ml/lit was best combination for higher grain yield (5.76 t/ha) and was at par with other combination product (Coragen @ 0.3ml/lit + V3 @2.5ml/lit) (5.63t/ha), (Token @0.4ml/lit + CM75 @ 2ml/lit) (5.4t/ha), (Token @ 0.4ml/lit + V3 @ 2.5ml/lit) (5.2t/ha), Coragen @ 0.3ml/lit (5.7t/ha), Token @ 0.4ml/lit (5.0t/ha), CM75 @ 2ml/lit (4.93t/ha and V3@2.5ml/lit (4.6t/ha) (Table 3.14).

Evaluation of pesticide against rice pest during wet season, 2015

Eight insecticides, fungicide and combinations were evaluated against insect pest of rice during wet season 2015 out of which Coragen @ 0.3ml/lit + CM75 @2ml/lit was best combination for higher grain yield (5.66 t/ha) and was at par with other combination (Coragen @ 0.3ml/lit + V3 @ 2.5ml/lit) (5.53t/ha), (Token@ 0.4ml/lit + CM75 @ 2ml/lit) (5.3t/ha), (Token @ 0.4ml/lit + V3 @ 2.5ml/lit) (5.43t/ha), Coragen @ 0.3ml/lit (5.26t/ha), Token @ 0.4ml/lit (4.90t/ha), CM75 @ 2ml/lit (4.83t/ha and V3 @ 2.5ml/lit (4.5t/ha) (Table 3.15).

Management of rice weevil, *Sitophilus oryzae* by plant oil for safe storage of paddy

Laboratory studies were conducted to evaluate the contact and fumigant activities of some essential oils *viz.*, orange oil (*Citrus sinensis* L.), eucalyptus oil (*Eucalyptus obliqua* L'Her) and cinnamon oil (*Cinnamomum verum*) against rice weevil, *Sitophilus oryzae* L. In contact bioassay, at 24 h after treatment highest mortality (95.8 %) was recorded at 0.75 $\mu l/cm^2$ with Eucalyptus oil followed by orange oil (93.40 %) which was on par with eucalyptus oil (93.2 %) at 0.50 $\mu l/cm^2$. On the other hand, cinnamon oil at all the tested concentrations (0.75, 0.50 and 0.25 $\mu l/cm^2$) showed significantly less effect on *S. oryzae* by registering 16.63, 13.33 and 6.67 per cent mortality, respectively at 24 h after treatment. In fumigation assay also eucalyptus oil recorded highest mortality of 26.1 per cent followed by orange oil (13.3 %) and cinnamon oil (10.43 %) after 24 h exposure at the highest concentration used in the study (2 $\mu l/cm^2$). Fumigation toxicity trend remained same at different time intervals (48, 72, 96 and 120 h after treatment) for all the treatments, wherein increasing trend of mortality was observed as the time lapsed. Even after

Table 3.14 Efficacy of pesticides against insect and disease during dry season 2015

Treatment	Dose	%DH	%WEH	%LFDL	%Gbug	%blast	%blight	NE	Yield
Chlorantraniprole (Coragen)	0.3ml /lit	2.66 (9.41cd)	3.2 (10.26d)	2.2 (8.51d)	4.66 (12.50bc)	3.36 (10.40b)	3.66 (10.96ab)	2.33a	5.7a
Dinotefuran (Token)	0.4ml /lit	3.0 (9.99bcd)	3.33 (10.49cd)	2.66 (9.41bcd)	5.2 (13.13bc)	3.33 (10.34b)	4.0 (11.47ab)	2.66c	5.0a
Carbandazim + Mancozeb (CM75)	2ml /lit	3.73 (11.07b)	4.63 (12.41b)	3.53 (10.86b)	6.1 (14.29ab)	1.03 (5.83d)	3.0 (9.97bc)	4.33ab	4.93a
Validamycin (V3)	2.5ml /lit	3.6 (10.91b)	4.6 (12.37bc)	3.33 (10.51bc)	6.11 (14.38ab)	2.0 (7.94cd)	1.33 (6.53e)	4.33ab	4.60a
Chlorantraniprole + CM75	0.3+ 2ml/lit	2.3 (8.67d)	2.5 (9.06d)	2.31 (8.74cd)	4.2 (11.82c)	1.9 (7.21cd)	2.66 (9.26bcd)	3.0c	5.76a
Chlorantraniprole + V3	0.3+ 2.5ml /lit	3.5 (10.76bc)	3.0 (99.88d)	3.0 (9.97bcd)	4.2 (11.79c)	2.16 (8.45bc)	1.83 (7.65cde)	2.66c	5.63a
Dinotefuran + CM75	0.4+ 2ml /lit	3.2 (10.26bc)	3.33 (10.40d)	3.7 (11.01b)	4.32 (12.00c)	2.66 (9.36bc)	2.66 (9.36bcd)	3.0c	5.4a
Dinotefuran + V3	0.4+ 2.5ml/lit	3.3 (10.44bc)	3.4 (10.60bcd)	2.93 (9.88bcd)	4.32 (12.02c)	1.73 (7.51cd)	1.66 (7.33de)	3.33bc	5.2a
Control	500lit water/ha	5.47 (13.55a)	6.4 (14.64a)	5.33 (13.34a)	7.19 (15.45a)	5.66 (13.76a)	5.33 (13.34a)	5.33a	2.66b
CD at 5%		1.47	1.87	1.89	1.94	2.32	2.54	1.25	1.58

Data in parenthesis are angular transformed values

Table 3.15 Efficacy of pesticides against insect and disease during wet season 2015

Treatment	Dose	%DH	%WEH	%LFDL	%Gbug	%Blast	%Blight	NE	Yield
Chlorantraniprole (Coragen)	0.3ml /lit	2.5 (9.06bc)	2.66 (9.36d)	2.0 (7.94d)	4.8 (12.75cd)	2.66 (9.36bc)	2.83 (9.68bc)	2.6de	5.26a
Dinotefuran (Token)	0.4ml /lit	2.86 (9.74bc)	3.03 (9.93d)	2.16 (8.45cd)	5.46 (13.51bc)	3.0 (9.97b)	3.0 (9.97bc)	3.4b	4.90a
Carbandazim + Mancozeb (CM75)	2ml /lit	3.5 (10.76ab)	4.66 (12.46abc)	3.8 (11.12ab)	6.86 (15.17ab)	1.66 (7.33c)	3.33 (10.40ab)	4.4ab	4.83a
Validamycin (V3)	2.5ml /lit	3.53 (10.80ab)	5.0 (12.87ab)	3.86 (11.14ab)	6.30 (14.52ab)	3.1 (10.06b)	1.66 (7.33c)	4.43ab	4.5a
Chlorantraniprole + CM75	0.3+2ml /lit	2.2 (8.45c)	2.83 (9.51d)	1.9 (7.91d)	4.30 (11.88cd)	1.8 (7.68bc)	3.0 (9.72bc)	2.43e	5.66a
Chlorantraniprole + V3	0.3+2.5ml /lit	3.2 (1026bc)	3.03 (9.92d)	3.0 (9.97bcd)	4.10 (11.68d)	2.4 (8.87bc)	2.03 (8.01bc)	4.03bc	5.53a
Dinotefuran + CM75	0.4+2ml /lit	3.1 (10.04bc)	3.6 (10.91bcd)	3.3 (10.43cd)	4.2 (11.79cd)	2.0 (7.94bc)	3.0 (9.88bc)	3.73bc	5.3a
Dinotefuran + V3	0.4+2.5ml /lit	3.1 (9.92bc)	3.3 (10.43cd)	2.93 (9.86bcd)	4.3 (11.94cd)	2.3 (8.68bc)	2.0 (8.13bc)	3.43cd	5.43a
Control	500lit water /ha	5.1 (13.02a)	6.0 (14.17a)	4.96 (12.87a)	7.20 (15.55a)	4.26 (12.60a)	5.0 (12.87a)	5.06a	2.66b
CD at 5%		2.30	2.43	2.39	1.73	2.41	2.80	0.91	1.65

Data in parenthesis are angular transformed values

120 h after treatment only eucalyptus oil was able to kill more than 80 per cent of adult beetles in comparison to 65 and 50 per cent mortality respectively, for orange and cinnamon oil at the highest concentration tested (2 µl/cm^2). From this study it is evident that eucalyptus oil has the higher contact and fumigant toxicity potential, hence it can be included in the IPM programs for effective stored grain pest management.

Bio-synthesis of silver nanoparticles and its use as antimicrobial agents

Biosynthesis of silver nanoparticles (Ag-NPs) mediated by rice plant extracts has been undertaken with 1mM silver nitrate solution at different ratio of plant extract and at different temperature and duration. The reduction of silver was monitored by using the UV–Vis spectral analysis. The color of the mixture of plant extract turned light brown at 48 h and became dark brown after 72 h indicative of the formation of Ag-NPs. Strong surface plasmon resonance of Ag-NPs was centered at 420-480 nm (Fig 3.31). Strong signal at approximately 3 keV from Energy-dispersive spectroscopy (EDS) is due to surface plasma resonance of silver nanoparticles (Fig 3.32). The spectral signals for carbon, oxygen and chloride were also observed which indicated that the extracellular organic moieties from plant extracts. Particle sizes of synthesized Ag-NPs were ranged between 36-107 nm during different time intervals (Fig 3.33). The zeta potential was found to be ranged between -14.16 to -29.45 mV. The negative value of zeta potential shows repulsion among the particles and thus increasing the stability of nanoparticles. The spectra of synthesized nanoparticles showed distinct peaks at 3432, 2924, 2853, 1638, 1165 and 1037 cm^{-1} (Fig 3.34). The strong broad peak at 3432 cm^{-1} is characteristic of the N–H or O–H stretching vibration. The two bands observed at 1165 cm^{-1} and 1037 cm^{-1} can be assigned to the C–N stretching vibrations. Peak at 1638 cm^{-1} denotes presence of amide bond. The peak located at 1037 cm^{-1} can be assigned as the absorption peak of C-O stretching. Protein or amino acids may be acted as capping agent. Synthesis of silver nanoparticles was carried out with 12 rice germplasm. Among them, Kariglass 2014/1674 and Bygani Dhan found to be most effective in reducing $AgNO_3$ to silver nanoparticles. This is proved by high content of total phenols and total flavonoids in these plant extracts (Table 3.16). The synthesized Ag-NPs were used against *Xanthomonas oryzae* and *Rhizoctonia solani* and found to be effective @ 4mL/100mL broth and @ 6mL/100mL broth, respectively (Fig. 3.35).

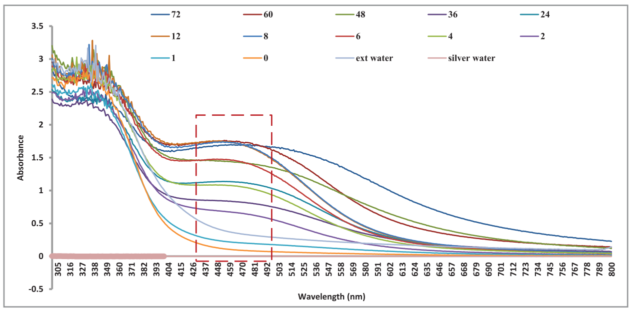


Fig. 3.31 Ultraviolet-visible spectra of synthesized nanoparticles at different time intervals

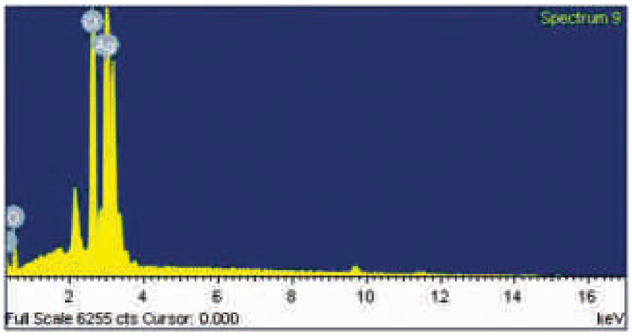


Fig. 3.32 EDS spectra of a representative Ag-NPs

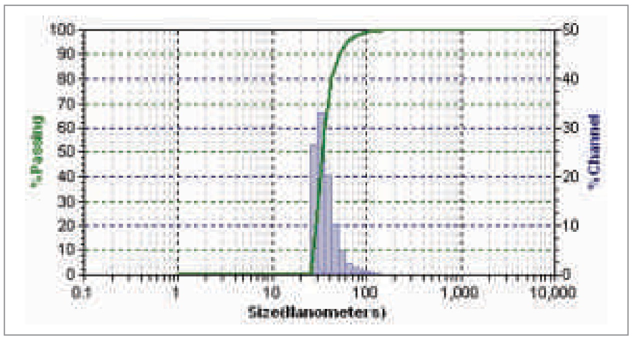


Fig. 3.33 Representative DLS spectrum of synthesized AG-NPs

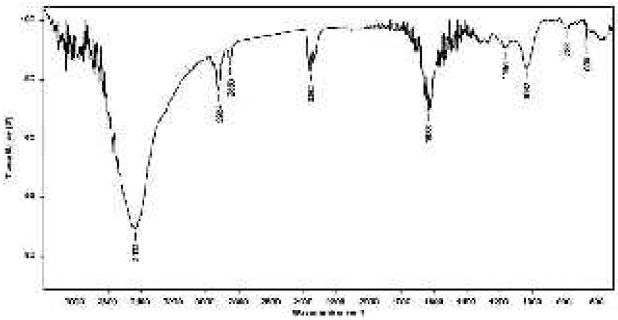


Fig. 3.34 Representative IR spectrum of Silver nanoparticles

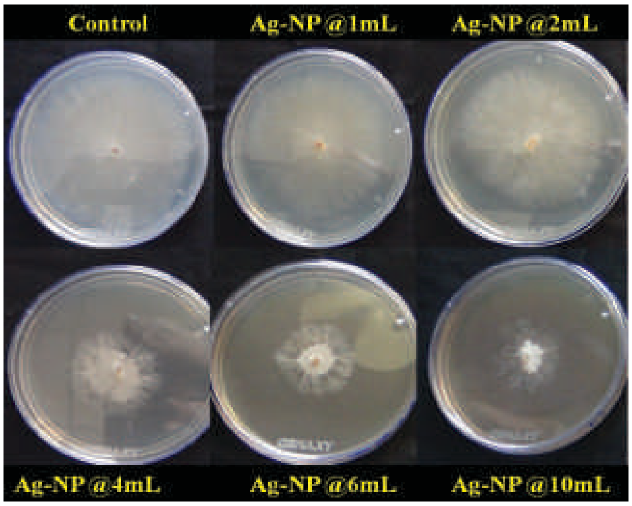


Fig. 3.35 Effectiveness of Silver nanoparticles against *Rhizoctonia solani*

Biotic Stress Management in Rainfed Upland Ecology

Evaluation of rice germplasm for leaf blast resistance

Among the 974 germplasm accessions (project on biodiversity sponsored by (ICAR-IIRR) - NBPGR) evaluated for leaf blast resistance at Hazaribag. Among them, 13 (1.33%) were highly resistant (SES scores 0 - 2) and 20 (4%) were moderately resistant (score 3 - 4). The rest showed varying degrees of susceptibility. About 16% of the entries were moderately susceptible (scores 5, 6) and the majority of entries (77%) were highly susceptible (scores 7 - 9). Since this set of entries is part of the core collection of national germplasm, it would be interesting to dissect the genetic constitution of the resistant entries *vis a vis* the known resistance genes to blast to find out existence of novel genes imparting resistance to the blast pathogen. It is already known that the pathogen population at Hazaribag is virulent on most of the resistant genes except *Pi 9*, *Pi 2* and *Pi ta2* and hence detection of novel R genes would be immensely useful for R gene deployment.

About 16% of the 354 accessions evaluated under NSN 1, and about 12 % of the 686 accessions under NSN 2 were resistant to leaf blast. About 45 entries (28%) of the 160 DSN and 20 entries (28%) of the IRBN entries were also resistant. The known, traditional blast resistant differentials Tetep, Tadukan, Raminad str 3 and derivative of *O minuta* continued to exhibit resistant reaction at Hazaribag. Among the new collections of *O. nivara*, *O. rufipogon* and weedy rice evaluated for resistance to blast, the *O. rufipogon* collections were relatively resistant to blast while the

Table 3.16 Total phenolics and flavonoids in plant extract (before and after formation of Ag-NPs)

Plant extract	Total phenolics (mg catechine equivalent per g dry weight)		Total phenolics (mg catechine equivalent per g dry weight)	
	Before	After	Before	After
Harekrishna	652.3	334.8	3070.2	367.9
Hempal	703.7	316.7	2951.2	362.2
Badamidhan	461.1	314.3	1686.3	288.1
Jalkeswar	677.1	321.7	2943.3	377.2
Kariglass 2014/1674	832.9	308.0	3123.0	477.0
Bygani Dhan	808.1	317.7	3298.0	479.1
Baithani dhan	500.0	308.4	2429.9	325.8
Dharshal	728.1	293.7	3249.6	322.3
Kamal luchai	746.2	291.5	3166.1	331.6
Dodana dhan	745.2	289.9	3433.5	482.7
Kariglass 2015/618	697.4	298.5	2937.6	366.5
Laal panna	675.6	363.7	3085.6	342.2

others were moderately to highly susceptible. Two accessions of *O rufipogon* exhibited high level of resistance (Fig 3.36). The accessions showing resistance to blast may be subjected to genetic analysis to detect the genes contributing resistance.

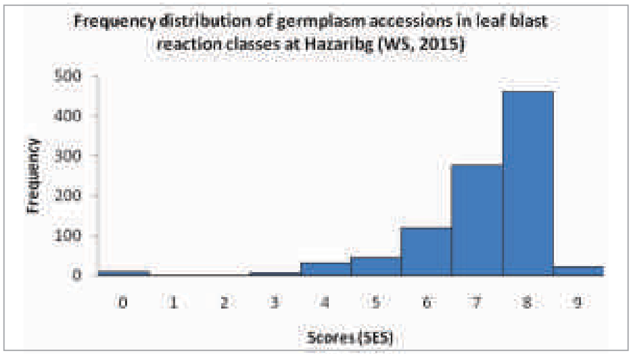


Fig. 3.36 Leaf blast reaction of germplasm accessions at Hazaribag (WS, 2015)

Integrated management of False smut of rice under rainfed ecology

The identified (best-bet) false smut management components (cultural management : date of transplanting and fertilizer level and chemical management : application of fungicide) were integrated and evaluated in field (under natural disease pressure) during wet season, 2015 using susceptible hybrid PHB 71 under transplanted condition. Under severe drought during flowering and grain filling stages, natural disease pressure was low. Lifesaving irrigations were also provided twice during flowering and grain filling stages. Among the three components (date of transplanting (DT), fertilizer dose (F) and chemical (C) spray at booting) tested, early transplanting (July 2nd week- 18th July) and application of hexaconazole significantly reduced disease incidence with concomitant increase in grain yield. Integration of the three management components revealed that early transplanting (July 2nd week) under higher fertilization (100:60:40; N:P:K) with prophylactic spray of hexaconazole @ 2 ml a.i./lit resulted maximum disease management and highest grain yield (Table 3.17).

Table 3.17 Interaction of Transplanting date (DT), Fertilizer dose (F) and chemical (fungicides) application on false smut incidence and grain yield of hybrid rice (PHB 71) under rainfed transplanted condition (WS, 2015)

Date of transplanting	NPK	False smut (% panicle infection)					Grain yield (t/ha)				
		Chemicals (Fungicides)			Mean (DT x F)	Mean (DT)	Chemicals (Fungicides)			Mean (DT x F)	Mean (DT)
		C 1	C 2	C 3 (control)			C 1	C 2	C 3 (control)		
DT 1	F1	0.00 a	0.00 a	1.03 abc	**0.34**	**0.51**	7.31 ab	7.84 bc	7.18 ab	**7.44**	**7.64**
	F2	0.00 a	1.11 abc	0.93 abc	**0.68**		8.39 c	7.89 bc	7.20 ab	**7.83**	
DT 2	F1	0.00	2.22 bc	2.34 bc	**1.52**	**1.59**	7.33 ab	7.21 ab	6.78 a	**7.59**	**7.35**
	F2	0.89 ab	0.89 ab	3.19 c	**1.66**		8.06 bc	7.33 ab	7.38 ab	**7.11**	
Mean (Fung.)		**0.22**	**1.06**	**1.87**			**7.78**	**7.56**	**7.13**		
LSD (5%) Fung.				**1.08**					**0.48**		
LSD (5%) DT						**0.89**					**0.39**
LSD (5%) F						NS					NS
LSD (5%) DT x F					**1.25**					**0.56**	
Mean DT x C	**DT 1**	0.00	0.55	0.98			7.85	7.87	7.19		
	DT 2	0.44	1.56	2.76			7.70	7.27	7.08		
LSD (5%) DT x C				**1.53**					**0.68**		
LSD (5%) F x C						NS					NS
LSD (5%) DT x F x C						**2.17**					**0.96**

DT (Date of transplanting): D/T 1= 18 July 2015, D/T 2= 27 July 2015
F (Fertilizer dose): F 1= 80:40:40 (NPK), F 2= 100:60:40 (NPK)
C (Chemicals (fungicides) application): C1= Hexaconazole (Contaf 5 EC) @ 2ml a.i./L, C2= Mancozeb (Indofil) @ 2.5 g a.i./L, C3 Control

Integrated Pest Management for direct seeded rice under favorable uplands

An attempt was initiated to work out IPM for direct seeded rice (DSR) under favorable (*bunded*) uplands. Weeds being major biotic stress under DSR, three IPM modules were formulated (Table 3.18) primarily based on different weed management strategies and compared with farmers' practice (FP) in field during wet season of 2015 using rice variety Sahabhagi Dhan under direct seeded and rainfed condition. Other IPM components like (i) mechanical seed treatment (mechanical seed separation (MSS) using 20% common salt solution) for seed borne diseases and (ii) N fertilizer schedules for diseases (like blast) which are aggravated under higher plant N level, were applied as blanket practice in all IPM modules for comparing with the FP. Blanket, need based application of plant protection chemicals (at action threshold level; already identified) were followed in all treatments including FP. Due to severe drought spells during the season, pests and diseases pressure (except *gandhi* bug and sheath rot) were low and only one need based blanket application of monocrotophos at milk stage was required for managing *gandhi* bug infestation.

Late hand weeding (at 35 DAG) in farmers' practice, imposed maximum weed competition during maximum tillering phase (20-30 DAG) of rice leading to poor growth of the crop as reflected in significantly lowest dry matter production of rice at maturity. Manual weeding in farmers' field is often delayed beyond ideal weeding time (20-25 DAG) under DSR, owing to shortage of labor as the time coincides with transplanting operation (in low lands). Timely application of weedicides (IPM modules 1, 2 & 3), on the other hand, reduced weed competition at critical crop growth stage (maximum tillering) and resulted in higher dry matter production of rice. All the IPM modules led to significant increase in rice dry matter production and grain yield over farmer's practice. On the other hand, combination of pre-emergence (Butachlore application at 2 DAG) and post-emergence (Bispyribac sodium application at 21 DAG) weedicide application (IPM module 1) significantly reduced weed biomass at 25 DAG over single applications of either pre-emergence or post emergence weedicides. But no significant difference in rice dry matter production and grain yield was observed among the three IPM modules. However, modules 1 and 3 increased grain yield respectively by

Table 3.18 Performance of IPM modules for direct seeded rice under favorable upland

Treatments	Avg. Disease score on SES scale*		Weed dry biomass at 25 DAE (g/m^2)*	Rice dry biomass at maturity (g/m^2)*	Rice grain yield (t/ha)*
	Br. spot	Sh. rot			
Control	5.79 b	8.34 b	76.89 d	500.00 a	1.57 a
IPM module 1	3.66 a	3.19 a	04.17 a	708.89 bc	2.43 b
IPM module 2	3.50 a	3.34 a	13.94 b	594.44 ab	2.09 b
IPM module 3	3.68 a	2.84 a	22.83 c	727.22 c	2.35 b
LSD (5%)	**0.74**	**1.11**	**5.51**	**117.45**	**0.51**

* Mean of five replications; SES -Standard Evaluation System for Rice (IRRI)

Blanket need based application of chemicals at action threshold (only Monocrotophos for G Bug at flowering was applied)

<u>Treatments details</u>

1. **Control:** No seed treatment + hand weeding (30-40 DAG: done on-35 DAG)+ N application = 20 (basal) : 40 (40 DAE) : 20 (65 DAE)+
2. **IPM module 1:** Seed treatment (MSS) + Pre-emergence weedicide (Butachlor at 2 DAG) application + Post-emergence weedicide application (Bispyribac Na: 21 DAG) + N application = 20 (basal) : 40 (25 DAE) : 10 (45 DAE) : 10 (65 DAE)
3. **IPM module 2:** Seed treatment (MSS) + Pre-emergence weedicide (Butachlor at 2 DAG) application + N application = 20 (basal) : 40 (25 DAE) : 10 (45 DAE) : 10 (65 DAE)

14.0% and 11.0 % over module 2. This revealed that at least one post-emergence application of Bispyribac sodium, in time (20-25 DAE) is essential for managing weeds under favorable uplands. MSS (IPM modules 1, 2 & 3), on the other hand, significantly reduced brown spot and sheath rot over non-MSS control (FP). The experiment will be repeated in 2016 for confirmation.

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

Survey was conducted for recording the incidence of insect-pests on rice in flood-prone lowlands of Darrang, Golaghat, Sivasagar and Kamrup districts of Assam during wet season, 2015. Rice leaf folder (*Cnaphalocrosis medinalis*), stem borers (*Scirpophaga incertulas* and *S. innotata*), gundhi bug (*Leptocorisa acuta*) were found to be the major insect pests and caseworm and rice hispa were recorded to be the minor pests in winter paddy. Mealy bug (*Brevennia rehi* Lindinger) infestation was observed on the variety Chandrama at tillering stage in the experimental farm of RRLRRS, Gerua. Mealy bug was observed on 4.33±2.35 number tillers of an infested hill. The number of mealy bug per tiller was found to vary from 1 to 10 bugs per hill with an average of 3.8±2.21 per tiller.

Succession of rice stem borer in rainfed lowland of Assam

An experiment was conducted at Gerua to study the succession of stem borer on rice variety Naveen during 2015-16. Paddy straw stubbles along with roots were excavated from one square meter area at five spots of the experimental plot for recovery of stem borer larvae after harvest of paddy in the month of December. Dissection of tillers revealed 1.95 ± 0.87 % tillers were infested with stem borer. It was observed that 9.60 ± 3.57 % hills harboured stem borer larvae after harvest of the crop and the number of larvae per hill varied from 1 to 3.

Diversity of insect-pests of rice at Gerua during *sali* 2015

A total of 5215 nos. of insect-pests of rice were captured installing two light traps at Gerua (Assam) during *sali*/ wet season 2015. Collected samples of insect-pests of rice comprised of stem borer, leaf folder, caseworm, green leafhopper, white back plant hopper and gundhi bug (Table 3.19). Besides these, spiders and ground beetle were also identified from the collected insect samples.

Moth activity of rice stem borer started at the end of September during *sali* 2015 and reached its first peak (173 nos. of moth/trap) on 07-10-2015 and then moth population gradually declined up to 9.5 nos. of moth/trap in the third week of October before reaching its second peak (118 nos. of moth/trap on 19-10-2015) (Fig. 3.37). Thereafter moth population declined gradually till the end of October and maintained a low population level up to the second week of December. No moth was captured from the third week of December.

Daily catch of yellow stem borer (YSB) in pheromone trap

Presence of YSB moth inside the pheromone trap was first noticed on 25-09-2015 during wet season, 2015-16. Thereafter, the number of moths trapped in the pheromone trap increased gradually and recorded the highest moth (3.75 /trap) on 12-10-2015 (Fig. 3.38). Thereafter the daily catch of moths inside the pheromone traps was found to decrease gradually and on 07-11-2015 no moth was trapped.

Table 3.19 Insect-pests of rice captured in light trap during *sali* 2015

Sl. No.	Species	Percentage of total captured
1.	Rice stem borer (*Scirpophaga incertulas*)	44.14
2.	Rice leaf folder (*Cnaphalocrosis medinalis*)	7.65
3.	Case worm (*Nymphula depunctalis*)	3.22
4.	Green leaf hopper (*Nephotettix virescens*)	37.43
5.	White back plant hopper (*Sogatella furcifera*)	6.77
6.	Gundhi bug (*Leptocorisa acuta*)	0.79

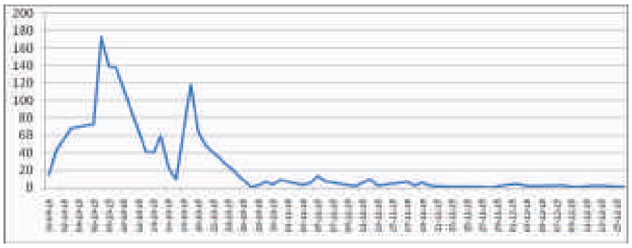


Fig. 3.37 Daily catch of yellow stem borer in the light trap

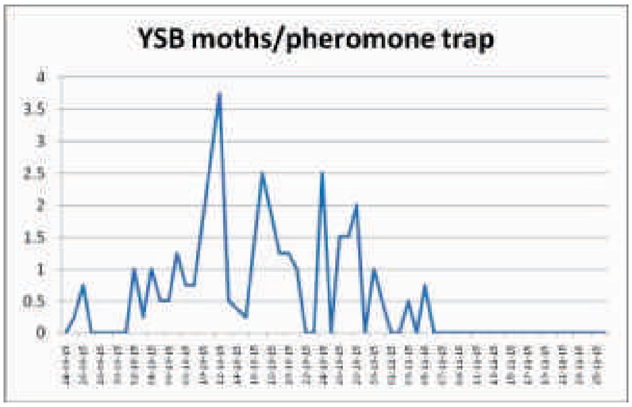


Fig. 3.38 Daily catch of Yellow Stem Borer (YSB) in the pheromone traps

Total number of moth catch per trap was found to vary from 13 to 38 during the crop period.

Insect-pests population on rice transplanted in different dates

Insect-pest population on rice variety Naveen was recorded at 15 days interval using insect sweep net in the crops transplanted on three different dates, *viz.*, 24.08.2015, 09.09.15 and 24.09.15. Population of stem borer was the highest (17 moths) in rice crop transplanted in the second fortnight of August as compared to first fortnight (12 moths) and second fortnight of September (10 moths). It was also observed that per cent dead heart was the lowest (0.54%) in rice crop transplanted in second fortnight of September as compared to the first fortnight of September (1.40%) and second fortnight of August (2.07%).

Population of rice leaf folder (11 moths), green leaf hopper (54 nos.), white-backed plant hopper (144 nos.) and gundhi bug (58 nos.) were the highest in crop transplanted on second fortnight of September as compared to that of second fortnight of August and first fortnight of September. Collection of ground beetle was the highest (2 nos.) and number of spider was the lowest (5 nos.) in crop transplanted on second fortnight of August.

Management of stem borer, leaf folder and gundhi bug in flood prone lowlands

An experiment was conducted at Gerua for the management of stem borer, leaf folder and gundhi bug in flood-prone lowland rice during wet season, 2015. Pheromone traps were installed in the experimental plot to ascertain the stem borer. Use of pheromone traps recorded low incidence of dead heart (2.06%) as against 5.63% in control and white ear head (1.31%) as against 4.32 % in control (Table 3.21). Percentage of leaf folder damaged leaves for all the treatments did not differ significantly from each other. However, application of coragen @ 50 g a.i./ha at 30 DAT recorded the lowest leaf folder damaged leaves (3.90%).

Evaluation of IPM module for rice in farmer's field

Evaluation of IPM module for rice comprising of seed treatment with carbendazim @ 2 g/kg seed, application of pretilachlor at 5-7 DAT, cartap hydrochloride @ 25 kg/ha at 30 DAT and need-based application of insecticide in the crops of 'Naveen' (10 ha) and 'Luit' (1 ha) was carried out at Village-Galdighala, District-Nalbari (Assam) during *boro*

Table 3.20 Population of insect-pests on rice crop transplanted in different dates

Date of planting	Total Nos. of insect caught in sweep net during the crop period							
	YSB	LF	GLH	WBPH	Gundhi bug	Grass hopper	Ground beetle	Spider
24-08-15	17	2	16	25	18	11	2	5
09-09-15	12	3	23	51	20	22	1	10
24-09-15	10	11	54	144	58	76	1	11

Table 3.21 Management of stem borer and leaf folder in flood prone lowlands

Treatment	Insect pests infestation			Yield (t/ha)
	DH %	WEH %	LF %	
Flubendiamide @ 50 ml/ha	2.10[b]	1.43[b]	3.92	4.57
Nursery application of carbofuran @ 33 kg/ha	2.23[b]	2.08[b]	4.02	4.48
Nursery application of carbofuran @ 33 kg/ha at nursery + spraying of cypermethrin 10% EC @1.5 ml/l at flowering stage	2.34[b]	1.99[b]	4.13	4.47
Chlorantriniliprole 18.5SC @ 50 g ai/ha	2.23[b]	1.46[b]	3.90	4.52
Pheromone trap @ 1 trap/15 sqm	2.06[b]	1.31[b]	4.46	4.23
Neem @ 3 ml/ha	3.03[b]	2.10[b]	4.32	4.28
Beauveria bassiana @ 3 ml/ha	3.09[b]	2.09[b]	4.40	4.23
Control	5.63[a]	4.32[a]	5.31	3.53
SE(d)	0.86	0.87	0.94	0.87
LSD ($P_{0.05}$)	1.79	1.82	NS	1.80

2014-15. Per cent dead heart in IPM plots under Naveen and Luit were 3.29% and 3.45%, respectively as compared to 7.60% and 7.85% in plots under farmer's practice. Application of IPM in Naveen variety recorded the lowest leaf folder folded leaves (1.24%). Under farmer's practices, the highest leaf folder damage (3.85%) was observed in variety Luit (Table 3.22). Implementation of IPM in Naveen yielded the highest grain yield (5.97 t/ha) as compared to farmer's practice (4.75 t/ha) and Luit under IPM yielded 3.90 t/ha against 2.90 t/ha under Farmer's practices.

Occurrence of rice tungro diseases in rainfed flood-prone lowland rice

Altogether six districts of Assam and four districts of Tripura were surveyed for the incidence of rice *tungro* disease (RTD) during 2015-16. In Assam, *sali*/ winter rice fields in Darrang, Golaghat and Sivasagar districts & summer rice fields in Golaghat, Jorhat, Nagaon and Nalbari districts were covered whereas in Tripura, *amon* rice fields in Sepahijala, Gomati, West and Khowai districts were covered. *Tungro* incidence was noticed in varieties Aathaisa and

Table 3.22 Evaluation of IPM module for rice in farmer's field

Treatment	% DH	% LFDL	Yield (t/ha)
IPM - Naveen	3.29[b]	1.24[b]	5.97[a]
Farmer's Practices- Naveen	7.60[a]	3.65[a]	4.75[b]
IPM-Luit	3.45[b]	2.52[ab]	3.90[ab]
Farmer's Practices-Luit	7.85[a]	3.85[a]	2.90[b]
SEd	1.04	0.90	0.84
CD (p=0.05)	2.54	2.20	2.05

Sahbhagidhan in summer rice and in Aizong, Baismuthi, Bismuthi, Ranjit, Rongadoria, Swarna, Swarna *sub1* and JKRH 401 in winter rice. RTD incidence up to an extent of 4.95% was observed in variety Athaisa in Nalbari district. In all other varieties, it ranged from traces to less than 2%. In Gomti district of Tripura, RTD incidence up to an extent of 1.8% was observed in variety 'Swarna (MTU 7029)'.

Identification of donor against rice *tungro* disease

Altogether 15 rice cultivars were used as differentials against Gerua isolate of *tungro* disease. Cultivars IR 20, PTB 8, PTB 18, PTB 21, Shuli 2 and Utrirajapan showed resistant reaction. While the cultivars Balimau Putih, Habigunj DW8, Utrimerah, and Pankhari 203 showed moderate resistance, Kataribhog, Nidhi, TKM 6, T(N) 1 and Vikramarya showed tolerant to susceptible reactions against the Gerua isolate.

Of the 1373 entries (NSN1 – 346 Nos.; NSN2 – 694 Nos.; NSN-H – 67 Nos.; NHSN – 101 Nos.; and DSN – 165 Nos.) tested in AICRIP national screening nurseries for their resistance against rice *tungro* disease. No entry showed resistant reaction. Fifty six entries (11 in NSN1, 42 in NSN2, 1 in NHSN and 2 in DSN) showed moderate resistance and the remaining 1317 entries showed tolerance to highly susceptible

PROGRAMME : 4

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

The programme-4 consists of four projects. The first project related to the Rice Grain and Nutritional quality-evaluation, improvement, mechanism and value addition. Protein fractionation from polished rice grains of high protein cultivars, Protein content (%) of polished rice grains as influenced by different doses of NPK fertilizers also identified. Evaluation of rice germplasm and advanced breeding lines for grain quality and aroma under AICRIP trial, Genotypic and environmental effect on physiological, physico-chemical and antioxidative properties of pigmented rice, Rice Grain and Nutritional Quality- Evaluation, Improvement, Mechanism and Value Addition, Phytic acid content of rice including pigmented rice in brown rice grains, Total phenolics and antioxidant potential of extracts of colored rice were undertaken

The second project deals with Phenomics of rice for tolerance to multiple abiotic stresses. Under this project work done to identify rice varieties for multiple abiotic stresses. Screening of rice germplasm for submergence tolerance, In order to identify new source salinity tolerance, Pokkali accessios collected from coastal saline areas were evaluated and Screening of rice germplasm for multiple abiotic stress tolerance such as submergence, anaerobic germination, salinity and drought were undertaken

In the third project identification of germplasm/ breeding lines tolerant to drought and high temperature stresses were undertaken including understanding the physiological mechanisms responsible for tolerance to moisture stress. Potential donors for vegetative stage and reproductive stage drought tolerance and rice varieties with higher productivity and higher level of drought tolerance were identified.

The fourth project relates to the evaluation and improvement of photosynthetic efficiency of rice. Screening of germplasm/breeding lines/elite rice genotypes with higher photosynthetic efficiency under low light stress were done. Photosynthesis and Chlorophyll fluorescence efficiency of wild relatives of genus *Oryza* under low light environment also a part of work under this project

Rice Grain and Nutritional quality-evaluation, improvement, mechanism and value addition

Protein fractionation from polished rice grains of high protein cultivars

In the present study, defatted polished rice grains of some high protein breeding lines/varieties were analyzed for protein fractions (albumins, globulins, glutelins and prolamins) to assess their nutritional quality. Rice seed storage proteins accumulate in two types of protein bodies (PB-I and PB-II) that are nutrient sources for animals. PB-I is indigestible and negatively affects rice protein quality. Prolamins, (seed proteins insoluble in water but soluble in water-ethanol mixtures) contain large amounts of the amino acids proline and glutamine (hence, the name), but only small amounts of arginine, lysine, and histidine. A considerable percentage of the rice prolamins (especially, the 13 kD prolamins) is not easily digestible by monogastric animals, thereby reducing the nutritional quality of the rice seed. Glutelins (water insoluble seed proteins but soluble in dilute acid/alkali) are reserve proteins; together with prolamins, they are found in the endosperm of seeds, but not in the embryo. Glutelins are rich in glutamic acid and lysine. Both prolamins and glutelins are mixtures of several similar proteins. Mean value showed that glutelin was the most abundant protein fraction (76-83%) in the rice cultivars. Though the rice ARC -10063 had only 78.97% glutelins, the breeding line CR2817-972 had the highest (82.93%) amount of it, while Swarna had the lowest (74.08%). SDS-PAGE of glutelin fraction showed similar result indicating that the line CR2817-972 had better nutritional quality than the high protein donor (Table1).

Table 1. Percent fraction (% of total protein) of defatted sample of protein from milled rice grain of different rice breeding lines/ cultivars

Breeding line	Albumins	Globulins	Prolamins	Glutelins
CR2818-1045	9.73C	3.95L	6.93GH	79.39K
CR2818-1049	9.47B	5.73H	7.09BC	77.72J
CR2818-1091	10.65A	5.61I	7.29CD	76.45L
CR2818-1031	7.98GH	6.92A	6.62EF	78.48H
CR2817-972	7.24I	3.35I	6.47A	82.93A
CR2817-966	7.92D	5.03C	6.21H	80.85C
CR2817-588	7.68FG	4.97D	6.61AB	80.74E
CR2822-824	7.18J	4.28G	6.49CDE	82.05D
CR2822-891	7.91E	6.18B	6.42FG	79.49F
CR2822-905	7.92GH	4.60K	6.75BC	80.73G
CR2822-884	7.99HI	5.41E	6.70CDE	79.89H
CR2822-887	7.13J	4.91C	6.44CD	81.52B
Swarna	10.86EF	7.62J	7.45I	74.08M
ARC 10063	8.63D	5.67F	6.73DE	78.97I
Mean	8.45	5.30	6.73	79.52
Tukey HSD at 5%	0.0068	0.0053	0.0267	0.0057

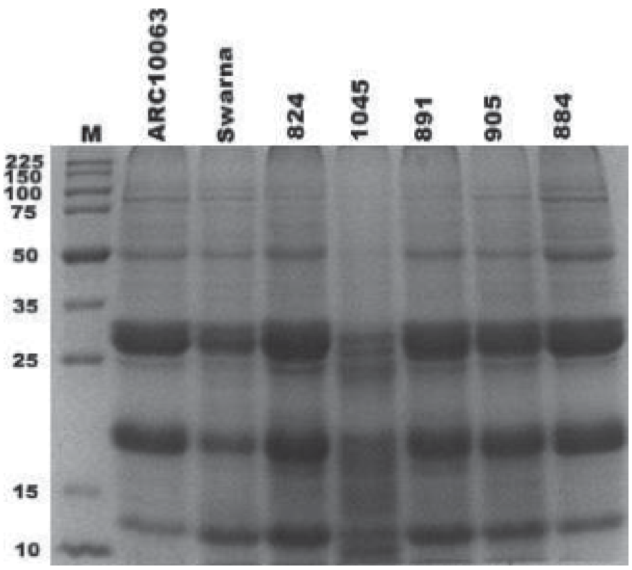


Fig.4.1. SDS-PAGE of Glutelin fraction of some high protein breeding lines / cultivars

Protein content (%) of polished rice grains as influenced by different doses of NPK fertilizers.

Three high protein rice (Heera, PLN-100 and CR Dhan 310) along with check variety Naveen were grown in pot culture under three levels of nutrition viz., no fertilizer (T1), 25% less than recommended dose of fertilizer (RFD) (T2) and the recommended dose (T3). The analysis of polished grains (10%) showed that there was no significant difference among T1 and T2, but grains under T3 (RFD, 100:80:80 NPK) showed higher protein content as compared to others. From the data (Table 2), it is evident that Heera and newly released variety CR Dhan 310 have the inherent capability to accumulate more protein in their grains as compared to others. The pot culture data were found to exhibit higher values of grain protein content compared to the field grown samples.

Table 2. Grain protein content (%) of polished rice grain from different level of fertilizer application.

	T1 (0 %)	T2 (75% RFD)	T3 (RFD)
Heera	9.815	9.980	10.793
PLN-100	7.057	8.255	8.218
Naveen	6.670	6.753	8.827
CR Dhan 310	8.533	9.700	11.407

Evaluation of rice germplasm and advanced breeding lines for grain quality and aroma under AICRIP (2015-16) trial

Twenty seven IVT-BT and eighteen AVT-1-BT cultures were analysed for grain quality under AICRIP trials (2015-16). Among IVT-BT samples, the entry 2610 was found to be the best followed by 2620, 2632, and 2623 on the basis of head rice recovery, kernel length, water uptake, amylose content, kernel length after cooking and alkali spreading value. Among AVT-BT samples, the culture 2503 was found to be the best in respect of aforementioned quality parameters.

Genotypic and environmental effect on physiological, physico-chemical and antioxidative properties of pigmented rice

Eleven pigmented rice varieties (Fig. 4.2) with wide adoptability were selected and planted in two consecutive seasons *viz.*, wet season (July to November) and dry season (December to March) to study the genotype X environment effects on physiological, physico-chemical and antioxidative properties of the grains. It was found that antioxidant capacity (ABTS assay), anthocycnin content, flavonoids, phenolics and γ-oryzanol content of pigmented rice grain were significantly higher in wet season than those in the dry season. Plant height, grain yield per plant and thousand grain weight were also found to be higher in wet season as compared to dry season. In fact, only the tillering capacity was recorded higher in dry season.

Fig.4.2. Pigmented brown rice and a white rice

Rice Grain and Nutritional Quality- Evaluation, Improvement, Mechanism and Value Addition

Iron and zinc are essential micronutrients for humans, their deficiency affects metabolism considerably with adverse effect on health. Rice does not provide these micronutrients adequately; the processing decreases their content in rice grains significantly. Not only this, presence of phytate in grain aggravates the problem as the interaction of phytic acid with proteins, vitamins and several minerals (Fe, Zn, Ca) further restricts their bioavailability.

Phytic acid content of rice including pigmented rice in brown rice grains

Phytic acid content was determined by an assay procedure specific for the measurement of phosphorus from phytic acid, myo-inositol (phosphate) and monophosphate esters by phytase and alkaline phosphatase using the phytic acid / total phosphorus assay kit (Megazyme International Ireland Limited). The 32 rice varieties already screened for Zn, Fe contents and the 22 colored rice varieties available in the institute were analyzed for phytic acid in the brown rice (Table 3 and Table 4). The highest phytic acid content (2.83 g/100 g) was found in PB267 and lowest in Bindli (0.82 g/100 g) among the non-pigmented rice . In case of colored rice, lowest phytic acid was found in Mornodoiga (0.34 g/100 g), while the highest amount was found in Manipuri Black rice (2.97 g/100 g) followed by Mamihungar.

Total phenolics and antioxidant potential of extracts of colored rice

The colored rice are expected to have high level of anthocyanins and consequently higher antioxidant potential. Considering this fact, total phenolic content from the extracts of colored rice samples was determined spectrophotometrically using Folin-Ciocalteau reagent. A calibration curve was prepared using gallic acid. Total phenolic content of the extracts was expressed as mg gallic acid equivalents (GAE) per

Table 3. Phytic acid content (g/100g dry weight) in brown rice of non pigmented rice

Sl. No.	Varieties	Phytic acid	Sl. No.	Varieties	Phytic acid
1	**Bindli**	**0.829**	17	Basmati - 370	1.315
2	Jaya	0.913	18	Vikash	1.337
3	IR64	0.968	19	Sneha	1.356
4	Indravati	0.989	20	PB-140	1.381
5	Swarna	1.046	21	Sudhir	1.409
6	Dhushara	1.055	22	Pusa Basmati	1.491
7	PB-177	1.070	23	Naveen	1.519
8	KetakiJoha	1.099	24	PB- 84	1.667
9	Vandana	1.168	25	Kalinga 3	1.686
10	Jool	1.177	26	Geetanjali	1.695
11	Sabita	1.180	27	Sharbati	1.893
12	Annada	1.180	28	Pb-312	1.930
13	Pooja	1.193	29	Taraori Basmati	1.949
14	Samlei	1.208	30	Tara	2.401
15	Heera	1.227	31	Kala Biroin	2.520
16	PB-58	1.234	32	PB-267	2.621

Table 4. Phytic acid content (g/100g dry weight) in brown rice of pigmented rice

Sl. No.	Varieties	Phytic Acid	Sl. No.	Varieties	Phytic Acid
1	Mornodoiga	0.345	12	Hidavanga	1.174
2	Mugai	0.364	13	Matiakhuda	1.256
3	PB-480	0.414	14	Harishankar	1.337
4	Setaka-36	0.540	15	Harirana	1.532
5	Khaibadal	0.609	16	Chakha	1.538
6	Nalbora	0.766	17	Gandhi biroin	1.563
7	Balam	0.829	18	RPHP-112	1.670
8	Annapurna	1.083	19	Jool	2.040
9	Saathi	1.161	20	Lalbora	2.492
10	T-1242	1.168	21	Mamihungar	2.834
11	Assam biroin	1.168	22	Manipuri black	2.976

gram of grain. The total phenolic content (Fig 3) was maximum in Lalbora (0.27mg/g GAE) and minimum in Mornodoiga (0.10mg/g GAE). The free radical scavenging activity (RSA) of colored rice extracts was determined by the DPPH method to assess the antioxidant activity. The RSA was found to be highest in the rice Saathi and was lowest in Mugai (Fig 4), a colored rice.

Phenomics of rice for tolerance to multiple abiotic stresses

Screening of rice germplasm for submergence tolerance

The experiment was conducted with 240 rice germplasm with three checks namely, Swarna, Swarna-*Sub1* and FR13A. The checks were repeated five times. The lines IC299929 and IC300131 among the newly tested materials were found to be tolerant to complete submergence for 14 days and were comparable to FR13A and found to be better than Swarna-*Sub1*. Two cultivars namely, IC456959 and IC459902 found to be tolerant last year also showed submergence tolerance at par with FR13A.

Identification of new donors for seedling stage salinity tolerance

Thirty nine Pokkali accessions collected from coastal saline areas for seedling stage salinity tolerance were evaluated in microplots at 12dS m^{-1}. AC 39417 was more tolerant than the tolerant check FL478. The lines AC 39409, AC 39394 and AC 39411 were at par with FL 478 with respect to salinity tolerance, while AC 39365 and AC 39370 were more susceptible than the susceptible check IR 29. These observations suggest for wide genetic diversity for seedling stage salinity tolerance among the Pokkali accessions.

Screening of rice germplasm for multiple abiotic stress tolerance

The experiment was conducted with 20 lines supplied by AICRIP centre, Hyderabad. IR29 was used as susceptible check in case of salinity trial, whereas IR20 was used as susceptible check for other experiments. Sahabhagidhan was used as tolerant check for drought tolerance, whereas AC39416A was used as tolerant check for anaerobic and salinity stress. The cultivars were tested for germination ability under one and two % mannitol induced drought condition, NaCl (12 ds m^{-1}) induced salinity condition and under complete submergence (anaerobic germination). Germination was found to be drastically reduced under submergence (anaerobic condition) compared to other stresses. In other stresses, except for a few lines, all others showed more than 80% germination. Under anaerobic conditions, seven lines did not germinate at all, whereas most of the lines showed less than 50% germination (Fig. 5). Three lines that showed

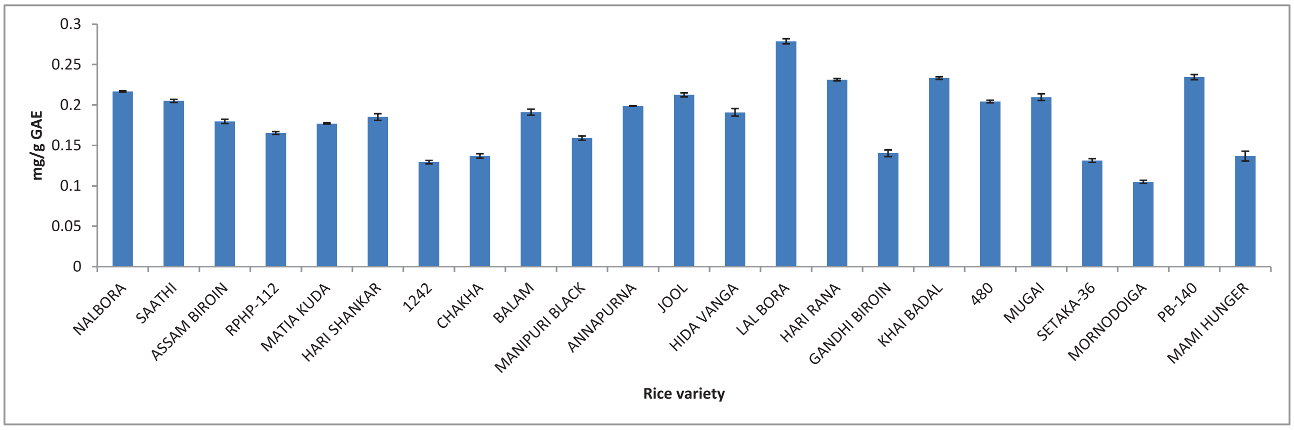


Fig. 3. Total phenolic content (mg gallic acid equivalents/g) of coloured rice varieties

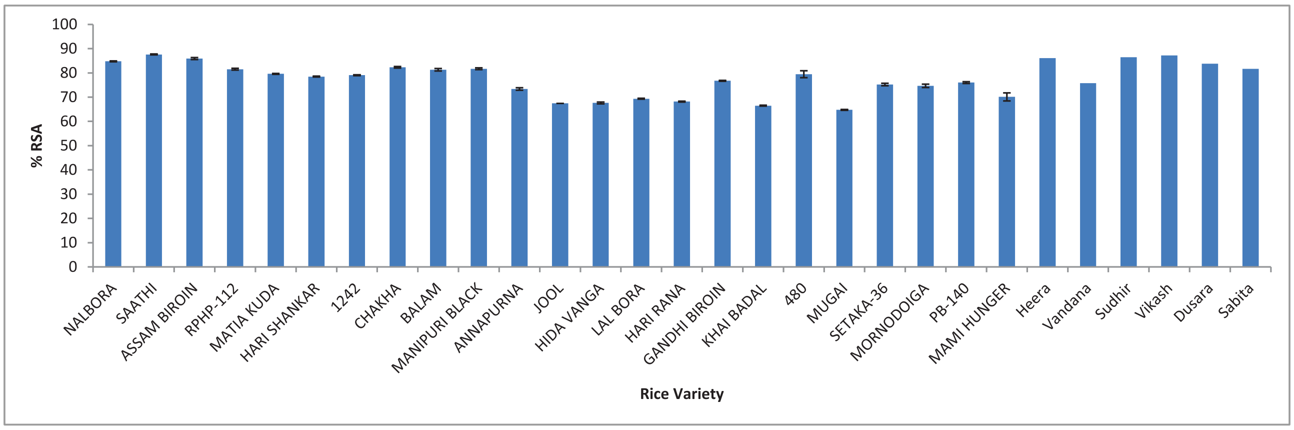


Fig. 4. Antioxidant capacity of colored rice varieties as radical scavenging activity (RSA)

more than 50% germination were AC39416A (72%), IET23246 (62%) and PHY4 (57%). Root and shoot length and dry weight drastically decreased under drought as well as salinity conditions, whereas under anaerobic condition, the cultivars that showed some degree of germination, the reduction in these parameters was not so drastic, though there were significant differences among the lines under all types of abiotic stresses. Considering all the parameters, the germplasm line AC39416A was found to be highly tolerant to different abiotic stresses (Fig.6).

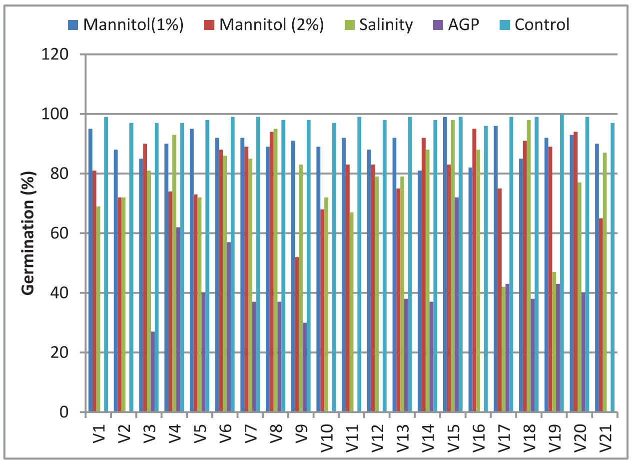


Fig. 5. Germination capability of different rice lines under multiple abiotic stresses.

(V1, IET23337; V2, IET24677; V3, IET24672; V4, IET23246; V5, PHY8; V6, PHY4; V7, IET 23335; V8, IET24687; V9, PHY2; V10, PHY7; V11, PHY6; V12, IET20924; V13, PHY1; V14, IET22116; V15, AC39416A; V16, PHY5; V17, Sahabhagidhan; V18, IR/20/29; V19, IET22747; V20, IET24674; V21, IET23223.)

Rice physiology under drought and high temperature stress

Evaluation of water use efficiency of selected genotypes under drought

Eight genotypes including two checks were selected depending on their performance in the field to evaluate water use efficiency. They were grown in pots containing 10 kg of finely ground soil with three

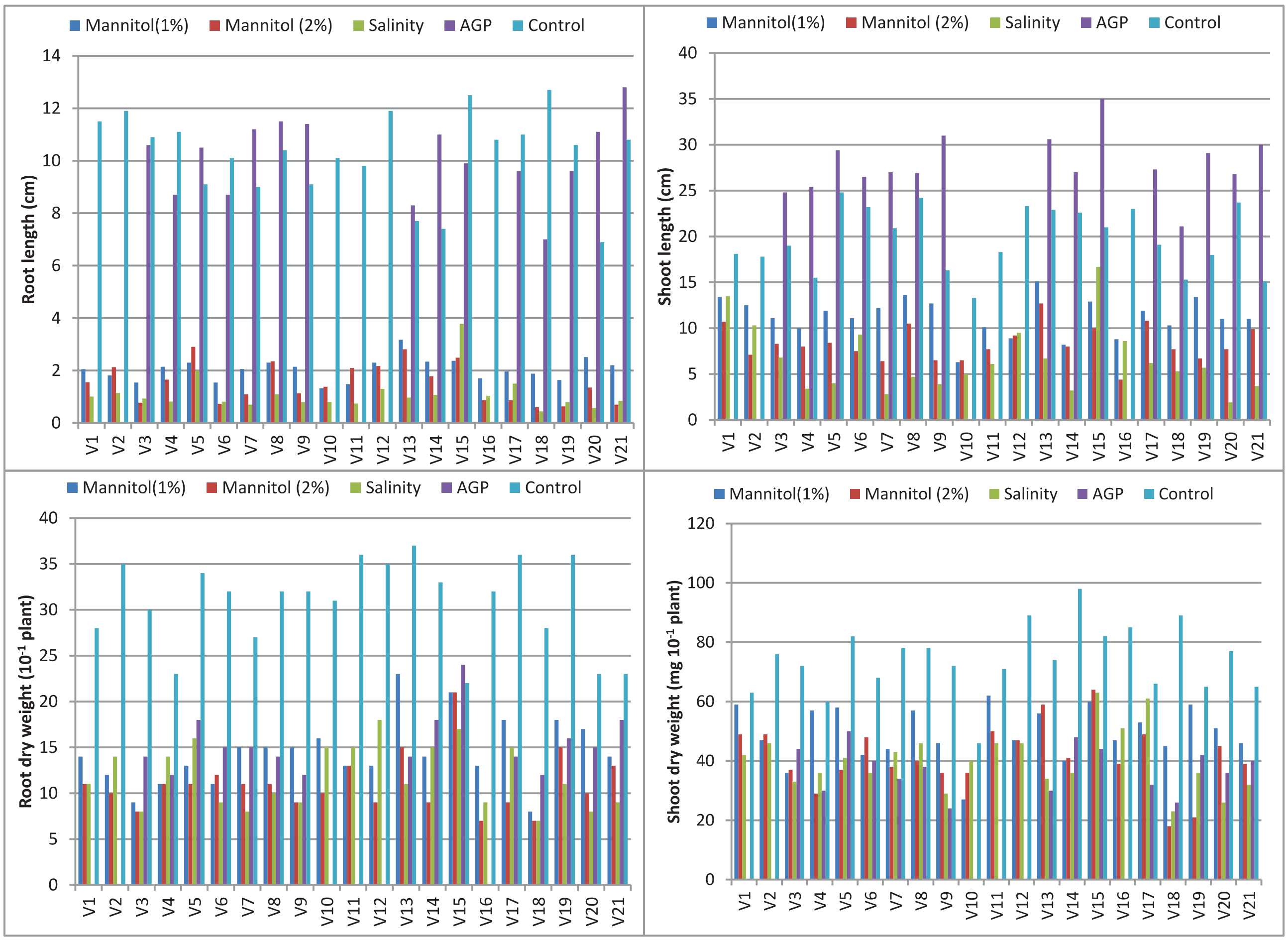


Fig. 6. Root and shoot length and dry weight of different rice lines under multiple abiotic stresses.
(V1, IET23337; V2, IET24677; V3, IET24672; V4, IET23246; V5, PHY8; V6, PHY4; V7, IET 23335; V8, IET24687; V9, PHY2; V10, PHY7; V11, PHY6; V12, IET20924; V13, PHY1; V14, IET22116; V15, AC39416A; V16, PHY5; V17, Sahabhagidhan; V18, IR/20/29; V19, IET22747; V20, IET24674; V21, IET23223.)

plants in each pot arranged in eight replications for each genotype in complete randomised block design. Plants were grown for up to 55 days under normal irrigation. Later, half of the pots of each genotype were maintained at 55% field capacity for water stress (WS) and the other half were maintained at 100% field capacity for well watered (WW) condition. The amount of water transpired was added back to maintain constant water content of the soil every day. Plant samples were taken before and after imposition of stress for recording biomass and leaf area .The stress was released when the transpiration of WS plants was less than 20% of WW plants. Water use efficiency (WUE)/ Transpiration efficiency (TE) was calculated based on amount of biomass produced per unit amount of water transpired. Transpiration efficiency was observed to be higher under stress than that under no stress.

Diurnal variation in transpiration rate was recorded from 9.00 hr to 17.00 hr at 2 hr interval. Maximum amount of water was exhausted at 13.00 hr. The susceptible line IR 64 exhausted maximum amount of water at 13.00 hr under both WW and WS (0.149 and 0.060 kg water/2 hrs, respectively) conditions. The tolerant check CR 143-2-2 exhausted lowest amount of water (0.045 and 0.117 kg water/2 hrs) followed by EC 545088 and AC 43037 (0.115 and 0.121 kg water/2 hrs) under WW and AC 43012 and AC 42997 (0.046 and 0.049 kg water/2 hrs) under WS conditions (Fig.7).

Observations on stomatal density and canopy temperature were also taken and the results revealed that AC-43037, CR 143-2-2 and AC-42997 had lower stomatal density (258 - 352/mm^2) compared to other

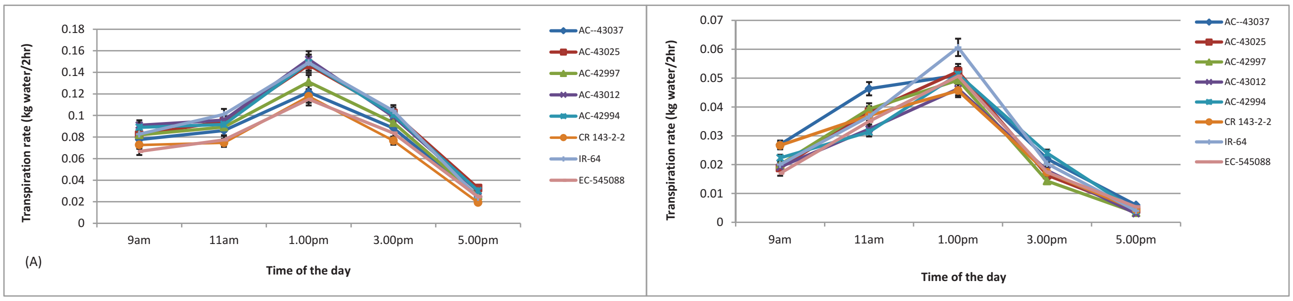


Fig. 7. Diurnal variation in transpiration rate (Kg water/2hrs) under well watered (WW) and water stress (WS) conditions during the course of a day.

genotypes, where as IR 64 had maximum stomatal density (517/mm^2) depicting high transpiration rate.

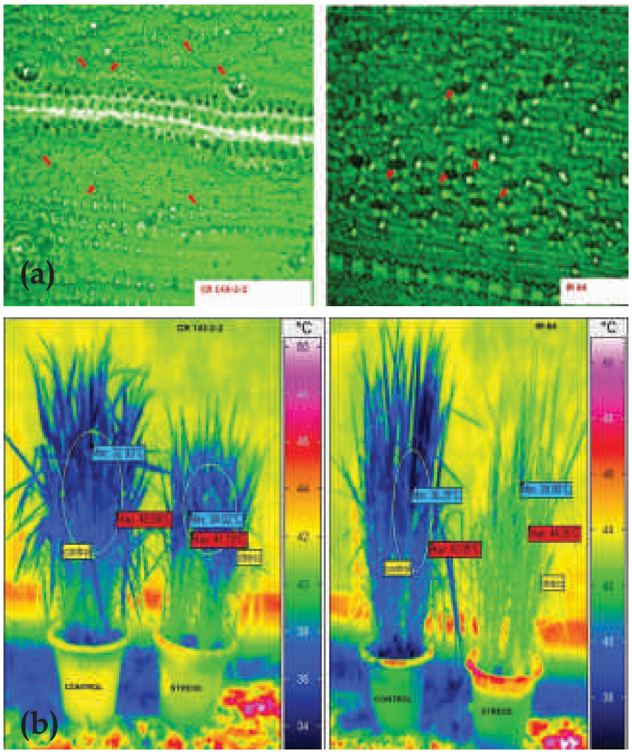


Fig. 8. Difference in stomatal density (a) and its effect on canopy temperature (b) between Tolerant (CR 143-2-2) and susceptible (IR 64) genotypes.

Lower stomatal density leads to low transpiration rate, thus maintained lower canopy temperature (34.02°C - 41.18°C) in CR 143-2-2 (tolerant check) whereas, high stomatal density in IR 64 (susceptible check) exhibited high transpiration rate and exhausted most of the water contained in the soil leading to high canopy temperature (39.90°C - 44.26°C) (Fig 8 a & b).

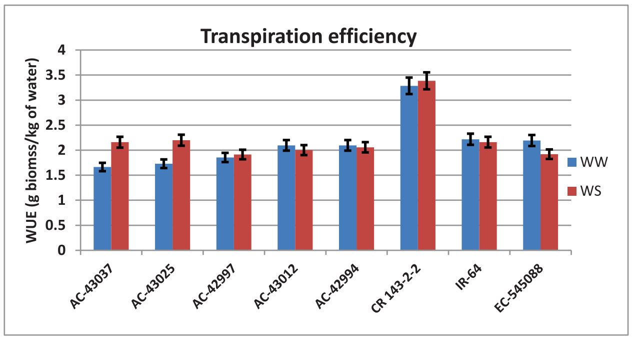


Fig. 9. Water use efficiency of genotypes under well watered and water stress conditions

Among eight genotypes tested, the tolerant check CR 143-2-2 (3.38 g/kg water) had highest WUE (Fig.9) under both WW and WS conditions. Though IR 64, EC 545088 had high WUE under WW condition, they had high transpiration and exhausted more water under WS. However, AC43037, AC 43025, AC 43012 and AC 42994 had better efficiency (2.0 to 219 g/kg water) compared to AC 42994, EC 545088 and IR 64 which had the lowest value (1.80g/kg water).

Evaluation of rice genotypes for drought tolerance under different moisture levels

Twenty selected elite rice genotypes were grown under three different moisture levels, control irrigated (C), moderate stress (MS) and severe stress (SS) to assess their yield performance. Stress levels were maintained MS: -32 to -45 kPa and SS: -55 to -67 kPa during panicle initiation (PI) to milky white stage. Highest grain yield was obtained in IC 311014 (4.27 t/ha) and EC 545088 (4.06 t/ha) under control; EC 545088 (2.32 t/ha) and IC 324171 (2.12 t/ha) under moderate stress and IC 337607 (1.76 t/ha) and EC 545088 (1.64 t/ha) under severe stress conditions. Relative yield reduction (RYR) was lowest in IC 337606 and EC 545088 (37.30% and 42.91%) in MS and

IC 337606 and IC 267416 (40.51% and 51.09%) in SS respectively. Seven genotypes had < 50% RYR in MS and seven genotypes had <60% RYR in SS. However, drought susceptibility index (DSI) was lower in these genotypes (<1.0) and lowest in IC 337606 (0.65) indicating their tolerance to stress level even up to -50 to -60 kPa (Table 5).

EC 545088 had high grain yield under all three conditions with lower RYR and DSI under MS, while IC 337606 had lowest RYR and DSI under both MS and SS with highest yield even under SS indicating their stable tolerance under all the moisture regimes compared to other genotypes.

Table 5: Grain yield and drought susceptibility index of elite rice varieties under different moisture levels

Sl No	VARIETY NAME	Grain Yield t/ha			Relative yield reduction (RYR %)		Drought susceptibility index (DSI)	
		C	MS	SS	MS	SS	MS	SS
1	IC-375769	3.61	1.59	1.52	55.95	58.02	0.97	0.92
2	IC-426044	3.71	1.91	1.38	48.56	62.68	0.85	1.00
3	IC-426060	3.95	1.73	1.45	56.22	63.39	0.98	1.01
4	IC-337576	2.95	1.32	0.96	55.23	67.65	0.96	1.07
5	IC-311022	3.07	1.73	1.47	43.67	52.15	0.76	0.83
6	IC-311024	3.75	1.50	1.41	60.02	62.46	1.04	0.99
7	IC-324171	3.85	2.12	1.49	44.82	61.21	0.78	0.97
8	IC-356432	3.89	1.47	1.35	62.20	65.41	1.08	1.04
9	IC-311014	4.27	1.53	1.37	64.27	67.98	1.12	1.08
10	IC-337574	1.85	1.01	0.78	45.21	57.67	0.79	0.92
11	IC-337606	2.96	1.86	1.76	37.30	40.51	0.65	0.64
12	IC-267416	2.24	1.26	1.09	43.86	51.09	0.76	0.81
13	IC-337596	2.16	0.82	0.90	61.82	58.11	1.08	0.92
14	EC-545077	4.05	1.03	1.00	74.58	75.24	1.30	1.19
15	EC-545088	4.06	2.32	1.64	42.91	59.68	0.75	0.95
16	EC-545075	4.23	1.62	1.30	61.68	69.17	1.07	1.10
17	IC-311021	4.03	1.23	1.08	69.52	73.25	1.21	1.16
18	IC-316312	3.71	1.65	1.48	55.70	60.23	0.97	0.96
19	IC-260964	4.11	1.68	1.62	59.20	60.58	1.03	0.96
20	IC-337571	3.37	1.23	1.14	63.60	66.17	1.11	1.05
21	Vandana	4.35	1.72	1.34	60.48	69.21	1.05	1.10
22	CR-143-2-2	3.26	1.50	1.06	53.92	67.54	0.94	1.07
23	IR-20	3.58	0.83	0.61	76.71	82.96	1.34	1.29
24	IR-64	3.22	1.20	0.88	62.81	72.67	1.09	1.13
	Average	**3.51**	**1.5**	**1.3**	**56.68**	**63.54**	**0.99**	**0.99**
	LSD 5%	**0.46**	**0.34**	**0.26**	-	-	-	-
	CV	**8.0**	**13.9**	**12.4**				

C - Control, MS – moderate stress, SS – severe stress

Segregation analysis of RILs (F8) derived from IR20 x Mahulata by using STMS markers

In order to map drought tolerance genes/QTLs a Recombinant Inbreeding Lines (RILs)population was developed from IR20 (susceptible parent) and Mahulata (tolerant to drought at vegetative and reproductive stage). The genetic segregation analysis of RILs was studied using STMS markers. A total of 45 STMS markers were used for parental phenotypic survey between the parents IR20 and Mahulata. Out of these, 20 showed polymorphism between parents. For QTL mapping, the RIL population should be ideally segregated in 1:1 ratio, therefore, a total of 282 lines were selected from 380 RILs and genotyped using 8 polymorphic markers localized on different chromosomes. Out of these, six STMS markers showed 1:1 allelic ratio of both the parents whereas two markers showed segregation distortion. Based on this marker data, RIL population showed nearly 1:1 ratio. This information indicated that this population is ideal for mapping of drought tolerant genes.

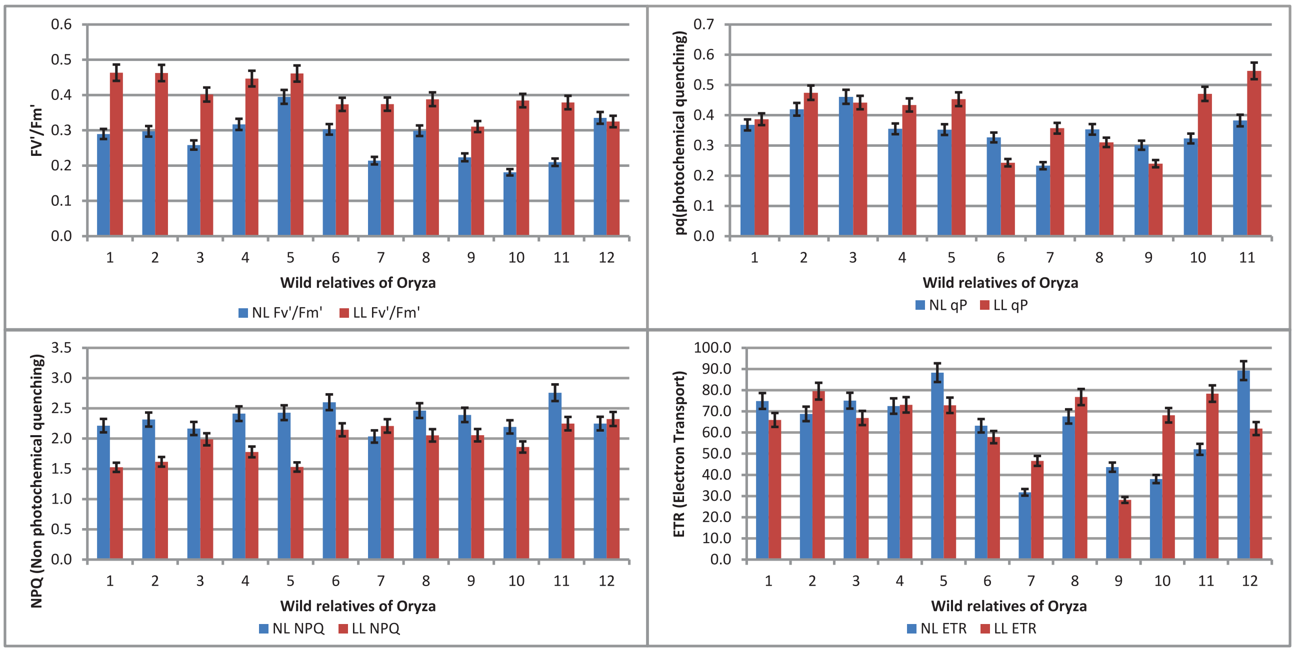
Improvement of Photosynthetic Efficiency of Rice

Photosynthesis and Chlorophyll fluorescence efficiency of wild relatives of genus Oryza under low light environment

Thirteen species of the wild relatives of the genus *Oryza* were evaluated for their photosynthesis and chlorophyll fluorescence efficiency under normal and reduced light intensity (50% of normal light). The stress here is defined as "how many oxidized / relaxed" photo system II reaction centers are found vs. the total Photo system II reaction centres, that can absorb light and perform photosynthesis-hence it is an indicator of quantum yield. When plants are subjected to less than ideal growing conditions, say low light intensity, they are under stress, which can affect growth, survival and crop yields. The Fv/Fm ratio tests whether or not plant stress affects photosystem II in a dark adapted state. In this study, the observations were recorded in *Fv'/Fm'*, Pq (Photochemical quenching), NPQ (Non-photochemical quenching and ETR (Electron transport ate) in all the 13 wild species of *Oryza*. The reversible enzymatic interconversion between the carotenoids violaxanthin and zeaxanthin (the xanthophyll cycle) regulates the induction of photoprotective NPQ in the thylakoid membranes of plants .The study confirmed that the photosynthetic organs which are subjected low integrated photon flux density (PFD) usually have small xanthophylls cycle pool strongly related to low NPQ in comparison to the normal light. The reduction in NPQ (Fig 10) under low light is coincident with decarboxylation of malic acid. This is reflected in depression of Fv'/Fm' (Fig) under low light environment. Maximum photosynthesis (P_N) was recorded 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. echingeri.*

Evaluation of rice genotypes for their adaptability to low light environment

One hundred sixty rice genotypes of 120-140 days duration group were evaluated for their adaptability to low light environment under two light regimes i.e. open (100%) and 75% light intensity under Agro shade nets. The experiment was laid out following the augmented statistical design by taking the tolerant check, Swarnaprabha by repeating it after 10 entries each. Among the 160 rice genotypes evaluated for their adaptability to low light environment, 15 genotypes were judged best performer in terms of yield, sterility percentage, specific leaf weight (SLW) and chlorophyll a/b ratio, the most prominent morpho-physiological markers considered for selecting varieties for low light environment (Table.6). Among the 15 genotypes, maximum yield was recorded in Sadamotasel (7.19 t/ha) followed by Pateni-23 (6.34 t/ha) and Salivahan (6.00 t/ha) under low light environment. All other parameters like sterility percentage, SLW and Chlorophyll a/b ratio also corresponds to the yield of these genotypes under low light environment. The mean data and the statistical data related to the parameters recorded under low light environment is depicted in Table-7.



1: O. nivara, 2: O.rufipogon, 3: O.officinalis, 4: O.punctata, 5: O.australiensis, 6: O.rhizomatis, 7: O.minuta, 8: O.baithii, 9: O.echingeri, 10: O.latifolia, 11: O.alta, 12: O.grandiglumis

Fig. 10. Chlorophyll fluorescence parameters in wild relatives of *Oryza* subjected to low light stress.

Table 6. Rice varieties grouped on different morpho-physiological parameters for low light stress

	Yield (g m^{-2})			Sterility (%)			SLW (mg cm^{-2})			Chl a/b ratio		
	NL	LL	% of loss over NL	NL	LL	% of loss over NL	NL	LL	% of loss over NL	NL	LL	% of loss over NL
Satyabhama	424.89	365.23	13.43	6.81	7.21	5.65	405.77	344.53	15.09	3.31	3.04	8.15
Pankaj	418.79	367.53	12.24	10.17	11.89	14.51	371.25	365.72	1.49	3.73	3.49	6.26
Pateni-23	763.59	633.74	17.01	16.86	17.65	4.52	516.00	403.38	21.83	3.74	3.28	12.38
Sadamotasel	734.63	719.56	2.05	22.10	44.56	50.42	436.78	394.35	9.71	3.40	3.30	2.88
Salivahan	661.40	600.34	9.23	6.52	8.40	22.40	458.90	425.80	7.30	3.15	2.90	7.82
Bardhan	427.06	342.10	19.89	29.69	59.61	50.19	371.74	338.76	8.87	3.45	2.97	13.90
BD-202	498.18	400.69	19.57	13.54	27.64	50.99	420.79	419.71	0.26	3.37	3.03	10.33
Sumit	328.73	319.33	2.86	26.20	38.59	32.13	420.44	370.93	11.78	3.33	2.89	13.34
Samalei	645.47	398.36	38.28	10.27	30.32	66.14	371.65	363.97	2.06	3.15	2.96	5.95
PR-120	665.32	391.83	41.11	13.58	19.33	29.75	422.24	394.97	6.46	3.44	3.35	2.53
GNR-3	485.95	366.76	24.53	19.80	30.01	34.01	480.63	331.76	30.97	3.05	2.96	2.71
Pabitra	601.47	422.66	29.73	16.06	66.41	75.82	348.88	326.70	6.36	3.66	3.14	14.10
GAR-2	401.76	310.14	22.81	20.57	38.89	47.10	381.11	362.44	4.90	3.60	3.52	2.01
Phondaghat-1	394.73	390.73	1.01	24.87	38.74	35.80	360.21	341.52	5.19	3.60	3.00	16.53
Bas-370	586.94	345.17	41.19	32.15	40.27	20.18	361.38	360.70	0.188	3.65	3.13	14.29
S.prabha	558.68	400.03	28.40	30.54	38.29	20.24	375.63	354.53	5.62	3.69	2.65	28.18

Table 7. Mean and statistical data of all the physiological parameters

Parameters	Mean		SD (Total SS)		SD (Residual SS)		CV		LSD 5%	
	NL	LL	NL	LL	NL	LL	NL	LL	NL	LL
Chl a	2.041	2.011	0.445	0.450	0.5113	0.518	25.08	25.8	1.541	1.563
Chl b	0.6343	0.633	0.202	0.226	0.152	0.195	24	30.8	0.459	0.587
Carotene	0.7142	0.711	0.170	0.171	0.181	0.174	25.3	24.5	0.545	0.524
Total Chl	2.675	2.643	0.617	0.611	0.655	0.654	24.5	24.7	1.974	1.970
Chl a/b	3.328	2.553	0.649	0.536	0.3559	3.416	10.7	8.23	0.073	100.43
SPAD	40.27	42.11	3.973	3.313	3.375	3.132	8.4	7.4	10.175	9.441
Tillers/m^2	252.5	202.0	59.871	45.93	53.56	75.49	21.2	37.4	161.44	274.22
Panicle/ m^2	241.2	189.8	56.61	47.25	51.733	83.605	21.4	44	155.94	303.70
DM/g/ m^2	1008	582.1	375.56	298.41	281.33	382.79	27.9	65.8	848.02	1390.51
HI	0.448	0.241	0.651	0.523	0.841	0.714	16.4	37.5	0.223	0.465
Grain: straw	1.556	1.077	0.531	0.457	0.657	0.792	42.2	73.5	1.981	2.877
100 grain wt	2.197	1.978	0.404	0.382	0.123	0.199	5.6	10.1	0.369	0.602
Sterility %	24.08	37.48	12.355	14.438	8.859	10.952	36.8	29.2	26.705	33.013
SLW (mg/cm^2)	377.1	351.7	45.55	47.04	21.02	51.019	5.6	14.5	63.35	254.75
SLA (c m^2/g)	269.1	289.4	33.48	38.41	13.93	34.639	5.2	12	41.99	105.06
Grain/g/ m^2	453.9	203.3	182.67	119.98	192.83	234.09	42.5	45.2	581.25	850.34

PROGRAMME : 5

Socio-economic Research and Extension for Rice in Developments

The socio-economic behaviour of rice growers, institutional arrangements to promote rice cultivation, feedback on rice production technologies, spread of NRRI varieties, business development around rice crop, trends in rice export, rice development model and capacity building of stake holders through extension approaches were taken up under programme 5.

The development of rice based model village under convergence mechanism in a rainfed cluster got a setback due to terminal drought during *kharif* 2015. Short duration rice varieties specially, CR Dhan 202, CR Dhan 204 and Hazaridhan produced a normal yield ranging from 3.5 to 3.24 t/ha. In medium and lowland ecology, the damage varied from 20% to total loss of crop. Farmers behaviour in the drought situation and their coping mechanism were studied. Convergence among departments of animal husbandry was found to be effective in deworming, vaxination, treatment of animals and demonstration. Villagers took up vegetable farming and got highest profit of Rs. 1400/-/acre from Okra. The data from the subproject i.e. gender sensitive approaches in rice farming brought out the preferences of women towards rice variety, production technologies, constraints and gender bias. One important approach namely, value addition to rice through group approach in form of *Mahila Bikash Samiti* was found to be successful. It generated feedback for the rice scientists to improve some of their recommended rice production technologies in gender perspective. Feedback analysis being routinely taken up brought out interesting findings on various aspects of sowing/planting and performance of major Govt. schemes on rice. Problems of rice farmers were also identified by interviewing 200 farmers across the states. The perception of the practicing farmers on Leaf Colour Chart (LCC) developed by the institute was studied by using some selected perception indicators. The other extension activities focusing the capacity building of the stake holders and the dissemination of rice production technology were trainers training programme, winter school, demonstration, publication, interface meeting, seed kit distribution, exhibition etc.

The project entitled "Characterization of Resources and Innovations to aid Rice Research and Develop Extension Models" reviewed the business plans for NRRI implements and rice fish farming systems on the basis of current data from agripreneurs and market. In its first step towards developing general simulation model of adoption of rice technologies in different rice ecologies, meta-analysis involving adoption of HYV of paddy and independent variables was undertaken to find out variables significantly correlated with adoption of high yielding variety.

The spread of NRRI varieties in West Bengal, Jharkhand and undivided Andhra Pradesh as wet and dry/summer crop was estimated by using certified seed distribution data for five years. It was found that the variety Shatabdi in West Bengal, Abhisek in Jharkhand and CR-1009 in Andhra Pradesh were most popular among the NRRI varieties grown in these states. Updation of rice export database of India for 2013-14 and 2014-15 was made and trend analysis on volume and value referring WTO period produced a global scenario and future trade policies. ARIMA model was employed to estimate the rice production of different varieties in Tamil Nadu and Karnataka state.

Development of rice-based Model Village, evaluation of interventions and recommendations

The Cluster Gurujang-Guali, Tangi-Choudwar Block covered under Rice-based Model Village faced drought during 2015-16. Rice grown under rainfed situation was most affected due to terminal drought and farmers income was affected. The Institute supplied newly released rice varieties for conducting result demonstrations (2) and minikit trial (34) as per the ecology besides holding method demonstrations in vegetable farming and livestock production. All the short duration rice varieties of 110 days duration grown in high and medium land escaped drought with minor loss. Short duration rice variety, CR Dhan-202 produced a highest yield of 3.5 t/ha. followed by CR Dhan-204 (3.35 t/ha.) and Hazaridhan 3.24 t/ha. Majority of rice land under medium and lowland ecology were badly damaged ranging from 20% to total loss of crop. Analysis of farmers behaviour brought out that farmers having pump set and physically alert could arrange critical irrigation to rice crop from nearby water sources like ponds, nala etc. and got relatively better yield than others who attempted later.

Interventions in livestock production and management were taken up under convergence mode with the involvement of SMS, KVK, Veterinary Assistant Surgeon (Tangi-Choudwar) and Mobile Veterinary unit, Department of Animal Husbandry, Govt. of Odisha. Interventions *viz.*, deworming, vaccination, treatment of animals, demonstration on duckery (Khaki Campbell-40 birds, White Pekin-20 birds) and health management in goats (30) were carried out. The above interventions resulted in four Tharparkar progenies through AI and greater participation of women in livestock production and management. The programme on Protein Supplementation in goats and their health management has boosted the confidence of goat keepers which resulted in body weight gain by an average of 25%. Farm women realized the benefits of supplementation of mineral mixture to improve production and reproduction traits and gained capacity to make adoption decisions.

Farmers and farm women during *wet* and dry season were given advisory services to grow vegetables for commercial and kitchen garden purposes. In wet season 35 families grew Okra, Ridge gourd, Bitter gourd and Cowpea. In dry season 10 families grew Bean, Cucumber, Okra and Pumpkin. Special drive was made to educate the farmers on hybrid vegetable seeds and its qualities. Farmers were not only supplied with quality vegetable seeds but also were linked to a credible vegetable seed dealer. The most promising vegetable crop was Okra variety (319F_1 hybrid) which produced an average yield of 30 qtl./ac. and gave a net profit of Rs. 14,000/- per acre.

A survey was conducted to assess the consequences of drought situation at the model village during 2015-16

Supplementing income through livestock production

and their coping strategies as well as the perceptions of beneficiaries on various efforts made by different organizations at the village to evaluate the scope for convergence of developmental activities for their all-round development.

Considering monthly rainfall data for seven years period (2009-15), standard precipitation index (SPI) was calculated for Tangi-Chowdhar block where the village is situated and the Cuttack district and monthly SPI was found to be negative for 36% of months. Though moderate intensity of drought was experienced during 2015, except September and December, all other months were deficient in rainfall. On an average 40% reduction of rice productivity was reported, however, it was indicated that the extent of losses were low compared to the similar kind of drought situations few years back which attributed to the adoption of drought resistant varieties of NRRI, Cuttack. Loss owing from reduction of crop productivity was higher compared to loss in milk and productivity from small animals (sheep/goat and poultry). The various coping mechanisms adopted by the farmers in the village as came out during survey indicated that small and marginal farmers adopted mainly three types of coping strategies like: resort to wage labour, lowering consumption and borrowing (mainly from non-formal sources) (Table 5.1). Other practices they followed were arranging critical irrigation, sale of livestock and other household assets, postponement of social activities like marriages, etc.

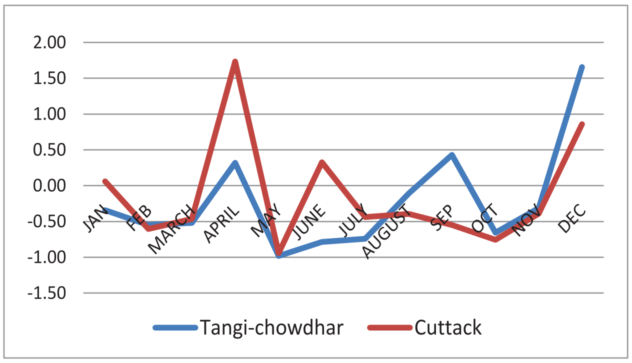


Fig. 5.1. Standardized preciptation index (SPI) for 2015 based on 7 years (2009-15) rainfall

Table 5.1. Coping strategies adopted during drought situations

Sl. No.	Coping strategies	Embraced by (% of respondents)
1.	Arranging critical irrigation	14
2.	Borrowing	36
3.	Maintaining buffer of grains and fodder	7
4.	Sale of livestock/other asset	21
5.	Lowering consumption	43
6.	Resort to wage labour	50
7.	Postponement of social activities	14

For efficient and effective extension services for upbringing social development, all the stakeholders must come under one roof through convergence mode along with active involvement of the clientele groups. During the process of model village development, efforts were made to bring together various government departments and developmental agencies. Enquiry was made to know the perceptions of respondents comprising non-beneficiaries (those who didn't received input support from NRRI, Cuttack/ KVK, Cuttack during last two years) as well as beneficiaries (those who received input support) on the issue of efforts/activities made by various organizations at the village. They were asked to assess subjectively and assign score on a scale of 10 and the analysis indicates that after ICAR-NRRI, Cuttack, Block Office/ Panchayat, Animal Husbandry and Horticulture department responded mostly to their needs and concern and least involvement of Forest department officials (Table 5.2). The Minor Irrigation department has assured to renovate the water harvesting structure in the cluster which has not yet been started. Similarly, the Forest department has never visited the village nor participated in any of the event conducted during the recent years for control of wild buffalos. The scores were subjected to Mann-Whitney 'U' test to show the un-anonymity between beneficiary and non-beneficiary groups and no significant difference in scores was observed.

Successful Kitchen gardening at Model Village

CR Dhan 202 performed well in drought situation

Table 5.2. Perception of farmers on convergence of activities

Organization	Average score *(on 10 point scale)*		
	Beneficiaries (n-10)	Non-beneficiaries (n-10)	Cumulative
1. NRRI, Cuttack/ KVK, Cuttack	8.17	7.40	7.89 (I)
2. Agriculture department	2.67	2.60	2.64 (VI)
3. Horticulture department	4.33	2.40	3.64 (V)
4. Animal Husbandry department	4.89	5.60	5.14 (III)
5. Minor irrigation department	1.89	3.00	2.29 (VII)
6. Forest department	0.11	0.20	0.14 (VIII)
7. Bank/ Cooperative Society	4.11	3.60	3.93 (IV)
8. Block Office/ Panchayat	5.78	5.60	5.71 (II)

Participatory Evaluation of interventions in Model Village

Designing and Testing of Gender Sensitive Approaches in Rice Farming

Under the project activity, 'Designing and Testing of Gender Sensitive Approaches in Rice Farming', technological and institutional interventions were continued and evaluated in Sankilo village of Cuttack district. During this year, demonstrations on seven NRRI rice varieties, *viz.*, Naveen, CR Dhan-303, CR Dhan-304, Swarna *Sub-1*, CR-1018 and Durga were conducted by forty adopted farmwomen in half-an-acre area by each during wet season 2015-16. Apart from varietal demonstrations, method demonstrations on raising of mat-type nursery, seed treatment, line transplanting, 4-row manual rice transplanter, 8-row power operated transplanter, 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, CRRI mini parboiling unit and rice husk combustor for meeting domestic fuel need from rice husk were also organized and their responses collected. A book on '*Traditional Rice Foods - The Rich Heritage of India*' has been brought out containing the process of making over hundred traditional rice-based value added products, primarily collected from the women group. A Rice value-chain has been established through a five-party MoU from seed breeder to seed miller wherein, the 'Ananya *Mahila Bikash Samiti*' is a signatory for producing paddy of the high value aromatic rice variety 'Geetanjali'. 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 performance of demonstrated technologies, perceived constraints and suggestions were analyzed. The summary of the findings is given below.

Signing of Five-Party "Rice Value Chain" Agreement where, 'Ananya Mahila Vikas Samiti is a Party/Signatory

Monitoring of Field Trials under Rice Value Chain Programme for Aromatic Rice variety 'Geetanjali'

Scientists interacting with the women rice farmers demonstrating NRRI rice varieties 'CR Dhan-304' and 'Swarna *Sub-1*'

During wet season-2015, seven NRRI varieties namely, Naveen (115-120 days), CR Dhan-303 (130-135 days), CR Dhan-304 (130-135 days), Swarna *Sub-1* (140-145 days), Pooja (150-155 days), CR-1018 (155-160 days) and Durga (155-160 days) were demonstrated as per pre-wet season plan meeting in ½ - 1 acre area with the participation of forty farmwomen in Sankilo village. Crop cutting data in Table-5.3 shows, CR Dhan-303 and CR Dhan-304 performed extremely well with average grain yield of 7.02 t/ha & 6.84 t/ha, respectively. All the practicing farmwomen also perceived these varieties as very good for favourable medium land situation. The variety Pooja has performed very well in shallow lowland situation with average grain yield of 5.76 t/ha, despite vagaries of nature and majority (90%) of the women rated as a very good performer, followed by Swarna *Sub-1*, a submergence tolerant variety (5.22 t/ha) and Naveen, a favourable medium land variety (5.04 t/ha).

Table 5.3. Performance of demonstrated rice varieties as perceived by farmwomen during wet season-2015 in respective ecologies (N=40)

Sl. No.	Technology (rice variety) used	Avg. grain yield (t/ha)	No. of technology users	Perceived levels of performance		
				Good (Score range 8-10)	Moderate (Score range 6-8)	Poor (Score 5 or less)
1.	Naveen	5.04	2 (100.0)	1 (50.0)	1 (50.0)	0 (00.0)
2.	CR Dhan-303	6.84	2 (100.0)	2 (100.0)	0 (00.0)	0 (00.0)
3.	CR Dhan-304	7.02	4 (100.0)	4 (100.0)	0 (00.0)	0 (00.0)
4.	Swarna *Sub-1*	5.22	12 (100.0)	9 (75.0)	3 (25.0)	0 (00.0)
5.	Pooja	5.76	20 (100.0)	18 (90.0)	2 (10.0)	0 (00.0)
6.	CR-1018	5.04	2 (100.0)	1 (50.0)	1 (50.0)	0 (00.0)
7.	Durga	4.68	3 (100.0)	2 (66.7)	1 (33.3)	0 (00.0)

(Figures in the parentheses indicate percentages)

Women farmers preparing mat nursery and operating 8-rows power operated rice transplanter

Apart from rice varieties, technologies relating to crop production, protection and farm implements were also demonstrated. Findings in the Table-5.4 depict that all the forty adopted farmwomen (100%) adopted 'seed treatment with Carbendazim', 'line transplanting' and 'application of recommended dose of fertilizers' and perceived these technologies as very good by 90, 92.5 and 100 per cent farmwomen, respectively. Similarly, 17 (94.4%) out of 18 practicing farmwomen, perceived 'application of need-based pesticides' as very good, while seven (100%) of them perceived 'rice husk combustor' as very good. All the four practicing women perceived both 4-row manual as well as 8-row power-operated transplanter as moderate performers, which might be due to first-time practitioners of heavy field implements. They expressed that transplanter should be designed to transplant in little standing water as it is difficult to manage rainwater during wet season. Value addition to paddy straw by using those as substratum for growing paddy straw mushroom and thereafter as compost was perceived as very good by seven (87.5%) out of eight practicing farmwomen.

Efforts were made to understand and prioritize the major constraints being faced by the farmwomen in rice production practices during wet season 2015. With the help of a 3-point continuum scale with score 1, 2 & 3, respectively based on the severity as responded by the farmwomen. Ranking was made as per the weighted cumulative score (WCS) of each constraint. It is seen from the Table-5.5 that 'seedling damage due to water logging in nursery as well as in main field before crop establishment due to heavy rainfall' with WCS of 101 was perceived as the major constraint followed by 'delayed planting due to late supply of canal water as well as late monsoon' (WCS of 98), 'No proper drainage facility' (WCS of 95), 'limitation of time availability to look after both farm and home activities' (WCS of 95), 'shortage of labour during peak season (WCS of 93), 'difficulty in application of fertilizers and spraying of pesticides by women (WCS of 93) and 'incompatibility of farm machineries to low lying farming situations during wet season' (WCS of 87). Since most of the constraints related to erratic rainfall, contingency planning is required to help the farm women to deal with such situation. Few women were constrained with limited household storage facility leading to untimely distress sale to middlemen. Therefore, government procurement policy should be suitably be modified to procure immediately after harvest season.

Demonstration of rice varieties 'CR Dhan-303' and 'CR-1018' in the gender project village

Table 5.4. Performance of rice production technologies and implements as perceived by farmwomen during wet season-*2015* (N=40)

S. No.	Rice production technology used	No. of technology users	Perceived levels of performance		
			Good (Score range 8-10)	Moderate (Score range 6-8)	Poor (Score 5 or less)
1.	Seed treatment with Carbendazim	40 (100.0)	36 (90.0)	4 (10.0)	0 (00.0)
2.	Raising of mat type seedlings	4 (100.0)	2 (50.0)	1 (25.0)	1 (25.0)
3.	Raised wet seed bed preparation	21 (100.0)	13 (61.9)	8 (38.1)	0 (00.0)
4.	Line transplanting	40 (100.0)	37 (92.5)	3 (7.5)	0 (00.0)
5.	Application of recommended dose of fertilizer (NPK @ 100:50:50)	40 (100.0)	40 (100.0)	0 (00.0)	0 (00.0)
6.	Application of need-based pesticide	18 (100.0)	17 (94.4)	1 (5.6)	0 (00.0)
7.	4-row manual transplanter	2 (100.0)	0 (00.0)	2 (100.0)	0 (00.0)
8.	8-row power operated transplanter	2 (100.0)	0 (00.0)	2 (100.0)	0 (00.0)
9.	Finger weeder	16 (100.0)	9 (56.3)	7 (43.7)	0 (00.0)
10.	Rice parboiling unit	4 (100.0)	1 (25.0)	2 (50.0)	1 (25.0)
11.	Rice husk combustor	7 (100.0)	7 (100.0)	0 (00.0)	0 (00.0)
12.	Paddy straw mushroom cultivation	8 (100.0)	7 (87.5)	1 (12.5)	0 (00.0)

(Figures in the parentheses indicate percentages)

Table 5.5. Constraints faced by farmwomen in the entire rice production process during wet season-*2015*

S. No.	Constraints faced in rice farming	Severity of Constraints			Weighted Cumulative Score	Rank
		High	Moderate	Low		
1.	Seedling damage due to water logging in nursery as well as in main field before crop establishment due to heavy rainfall	29	3	8	101	I
2.	Delayed planting due to late supply of canal water as well as late monsoon	23	12	5	98	II
3.	No proper drainage channels or facility in the entire area after heavy shower	23	9	8	95	III
4.	Limitation of time availability to look after both farm and home activities	22	11	7	95	III
5.	Shortage of labour during transplanting and harvesting	21	11	8	93	IV

6.	Difficulty in application of fertilizers and spraying of pesticides by women	16	21	3	93	IV
7.	Incompatibility of farm machineries to our low lying farming situations during *kharif* season	16	15	9	87	V
8.	Unavailability of sufficient quality seeds in time	14	13	13	81	VI
9.	Crop infestation by BPH, stem borer and case worm	15	8	17	78	VII
10.	Non availability of sufficient household storage facility leading to untimely distress sale to middlemen	9	18	13	76	VIII
11.	Problems in marketing of produce due to insufficient procurement by government forcing distress sale to middlemen	7	19	14	73	IX
12.	Insufficient as well as defunct irrigation infrastructure in the area	7	11	22	65	X

After over three years of technological interventions and capacity building, the adopted farmwomen were asked to prioritize various factors they perceive as important in bringing women equal to men in rice farming. As per the findings in Table 5.6, they perceived 'learning scientific rice cultivation practices' i.e., *Enhanced Knowledge*, as the most important factor (with WCS of 107) in brining women equal to men. Other important factor closely followed pertained to 'spending more time and working with male farmers in all farming activities' i.e., *Regular Practice* (WCS - 104), 'developing capacity through regular training' i.e., *Enhanced Skill* (WCS - 100) and 'a gender sensitive social environment' (WCS - 96). They also give due importance to 'joint family decision making' (WCS - 90), 'group mobilization by forming farmwomen interest groups' (WCS-87) and women-friendly government policies in farm sector (WCS - 85) to help bringing women equal to men in farming families. Many of the farmwomen perceived that by supplementing to family income, they can be equal partners with male members in rice production.

Table 5.6. Factors perceived as important by farmwomen in bringing women equal to men in rice farming (N=40)

S. No.	Important factors in bringing women equal to men in rice production	Degree of Importance			Weighted Cumulative Score	Rank
		High	Moderate	Low		
1.	By learning scientific rice cultivation practices from experienced members of the society, agricultural officers and scientists	27	13	0	107	I
2.	By spending more time and working with male farmers from nursery raising to harvesting in field as well as in post harvest processing and marketing	28	8	4	104	II
3.	By developing capacity of women farmers through regular training, awareness and farm exposure visit programmes	23	14	3	100	III
4.	Gender sensitive social environment with due recognition and modesty for women	21	14	5	96	IV
5.	By taking part in family decision making with regard to farming activities	19	12	9	90	V
6.	By forming farm women interest groups (FWIGs) and establishing linkages with other organizations for generating regular income	20	7	13	87	VI

7.	Women friendly government policies in farm sector with regard to easy access to inputs like land, loan, machineries and farm information	14	17	9	85	VII
8.	By supplementing family income through enterprises like preparation and marketing rice based VAPs leading to elevation of status of farm women in the society	17	9	14	83	VIII
9.	By adopting and practicing women friendly and drudgery reducing farm implements for enhancing work efficiency	8	19	13	75	IX
10.	Equal participation of both men and women in all farm and home activities without any gender discrimination	11	11	18	73	X
11.	By handling family finance and bank accounts jointly with male members	7	11	22	65	XI

Adopted women farmers doing crop cutting experiments in Sankilo village

As per the findings in the previous table, enhanced knowledge and enhanced skill play as important factors in brining women equal to men in farming. Hence, all the farmwomen were asked to give suggestions and prioritize them for enhancing their knowledge and skills. As per the findings in Table 5.7, 'attending training programmes' (WCS-113), 'learning from experts' (WCS-107), 'farm exposure visits' (WCS-105), 'adoption and practicing scientific technologies' (WCS-102) and 'group mobilization' (WCS-95) were perceived as major activities for enhancing their knowledge and skills. Other important factors included 'use of farm machineries' (WCS-89), 'regular interpersonal discussions and exchange of ideas' (WCS-87), watching TV, listening radio participating in workshops & meetings and reading farm literatures.

Feedback on Rice Production Technologies (RPTs) as perceived by the farmer stakeholders

During 2015-16, feedback on the performance of various rice production technologies (RPTs) and government sponsored programmes and schemes were collected randomly by accidental sampling from 200 visiting rice farmers from eight states namely, Bihar, Jharkhand, Madhya Pradesh, Chhattisgarh, West Bengal, Andhra Pradesh, Gujarat and Odisha, twenty five farmers from each state, through a structured interview schedule. The data on the performance of various methods of sowing and transplanting, perception on various government schemes & programmes and major problems faced in rice farming were analyzed in a five-point continuum scale and ranked as per the weighted cumulative score (WCS) and weighted unit score (WUS) of the practicing farmers.

Table 5.7. Suggestions given by farmwomen for improving their knowledge and skill in rice production (N=40)

S. No.	Suggestions for improving the knowledge and skill in rice production	Prioritization Categories			Weighted Cumulative Score	Rank
		High	Moderate	Low		
1.	Attending need-based and skill-oriented training programmes for capacity building of women farmers	33	7	0	113	I
2.	Learning improved package of practices of rice cultivation from progressive farmers, agricultural officers and experts	27	13	0	107	II
3.	Farm exposure visit to farmers' fairs and exhibitions to get idea and information about new technologies and enterprises	27	11	2	105	III
4.	Adopting and practicing scientific technologies in rice farming	24	14	2	102	IV
5.	Group mobilization through development of farm women interest groups (FWIGs) and linkages with other organizations	19	17	4	95	V
6.	Development and use of women friendly and drudgery reducing farm implements in rice cultivation.	18	13	9	89	VI
7.	Developing habit of regular interpersonal discussions and exchange of ideas with fellow farmers and farm women	14	19	7	87	VII
8.	Regular watching of TV programmes and listening to Radio programmes on agriculture	11	16	13	78	VIII
9.	Improving decision-making abilities through participating in different institutional workshops and meetings	9	17	14	75	IX
10.	Reading of farm extension literatures and journals available for farming communities	8	13	19	69	X

Table 5.8. Method of Sowing and Transplanting being practiced by farmers and perception about their performance (N=200)

Sowing / Transplanting practices	No of farmers* practiced	Rating of Performance (5/ 4/ 3/ 2/ 1)					WCS	WUS	Rank
		VG	G	Av	P	VP			
1. SRI method	68	58	7	3	0	0	327	4.81	I
2. Line transplanting	187	162	12	13	0	0	897	4.80	II
3. Machine transplanting	34	17	8	7	2	0	142	4.18	III
4. Wet direct sowing (W-DSR)	29	14	7	6	2	0	120	4.14	IV
5. Dry direct sowing (D-DSR)	26	9	8	4	3	2	97	3.73	V
6. Traditional random transplanting	108	27	31	39	11	0	398	3.69	VI
7. Broadcasting followed by beusaning	47	7	13	18	4	5	154	3.28	VII

(* Multiple responses were allowed; VG: Very Good, G: Good, Av: Average, P: Poor, VP: Very Poor; WCS: Weighted Cumulative Score; WUS: Weighted Unit Score)

The data analysis revealed that transplanting practices through SRI method (WUS of 4.81) was perceived as the best method closely followed by line transplanting (WUS-4.8), machine transplanting (WUS-4.18) and wet direct sowing (WUS-4.14), respectively over the traditional transplanting (WUS-3.69) and broadcasting practices (WUS-3.28). This clearly indicates that the farmers have now become aware about the comparative benefits of the scientific methods and practices.

Table 5.9. Perception about the performance of major Government programmes and schemes (N=200)

Major Schemes/ Programmes	No. of farmers responded	Rating of Performance (5/ 4/ 3/ 2/ 1)					Not Aware	WCS	WUS	Rank
		VG	G	Av	P	VP				
1. PMFBY	92	71	15	6	0	0	108	433	4.71	I
2. Soil Health Card	89	61	18	10	0	0	111	407	4.57	II
3. NFSM	66	41	21	4	0	0	134	301	4.56	III
4. ATMA	183	107	35	30	11	0	17	787	4.30	IV
5. BGREI	113	55	29	14	15	0	87	463	4.10	V
6. MSP	189	85	47	30	14	13	11	744	3.94	VI
7. KVK	137	57	41	16	6	17	63	526	3.84	VII
8. Seed sale though Govt. outlets	156	32	27	51	9	37	44	476	3.05	VIII

(WCS: Weighted Cumulative Score; WUS: Weighted Unit Score)

Table 5.10. Problems in rice production as perceived by the farmer stakeholders (N=200)

S. No.	Problems in Rice production	Severity of the Problem (5/ 4/ 3/ 2/ 1)					WCS	WUS	Rank
		Very Severe	Severe	Moderate	Mild	Very Mild			
1.	Unavailability of quality seeds in time	119	45	17	8	11	833	4.17	I
2.	Unavailability of labour during peak cropping season	101	58	18	14	9	828	4.14	II
3.	Lack of irrigation facility	71	57	49	19	4	772	3.86	III
4.	Crop damage due to drought and/or water scarcity	78	51	33	31	7	762	3.81	IV
5.	Erratic rainfall pattern in rainfed areas	78	49	24	30	19	737	3.69	V
6.	Distress sale of paddy below MSP	78	51	18	17	36	718	3.59	VI
7.	Infestation of diseases and pests	53	62	41	27	17	707	3.54	VII
8.	Poor farmers-officers interactions	59	31	57	37	16	680	3.40	VIII
9.	Crop damage due to flood and submergence after heavy rainfall	64	31	47	22	36	665	3.33	IX
10.	High costs of farm inputs	51	42	37	47	19	647	3.24	X
11.	Unavailability of sufficient numbers of farm implements/ machineries	41	33	53	51	22	620	3.10	XI
12.	Unavailability of sufficient pesticides and fertilizers	39	23	51	47	40	574	2.87	XII

(WCS: Weighted Cumulative Score; WUS: Weighted Unit Score)

Regarding the perception about the performance of various government schemes, the new schemes like Pradhan Mantri Fasal Bima Yojana (PMFBY) (WUS-4.71), Soil Health Card (WUS-4.57) and National Food Security Mission (NFSM) (WUS-4.56) have been well appreciated by the farmers' stakeholders, followed by the ongoing programmes like Agricultural Technology Management Agency (ATMA), Bringing Green Revolution to Eastern Indian (BGREI) and procurement through assured minimum support price (MSP), respectively.

From the analysis on various major problems encountered by the farmers, it can be seen from the table that unavailability of quality seeds in time (WUS-4.17), unavailability of labour during peak cropping season (WUS-4.14), lack of irrigation facility (WUS-3.86), crop damage due to drought and/or water scarcity (WUS-3.81) and erratic rainfall pattern in rainfed areas (WUS-3.69) were the major problems faced by the farmers in rice farming.

Apart from the above, data were collected from thirty leaf colour chart (LCC) practicing farmers of Cuttack and Kendrapada districts of Odisha to assess their perception about its benefits and constraints if any on the use of LCC. It can be inferred from that table that the practicing as well as neighbouring farmers were fully convinced with its efficiency and utility. According to them, it saves urea & reduces cost of cultivation (76.67% farmers agreed), easy to use and carry (93.33%), inexpensive & affordable (100%), and easy to know real time for application of urea though LCC (76.67%). More encouragingly, neighbouring farmers have borrowed from practicing farmers (60.0%) and 87.67 per cent farmers opined that neighbouring farmers have shown interest to purchase. However, all farmers viewed that the major problem was its unavailability in local market. All of them suggested that awareness programmes on its use should be organized and should be made easily available through local agricultural input traders.

Demonstration of NRRI rice varieties

Result of DS 2015-16

During DS 2015-16, it was observed that the rice hybrid Rajlaxmi gave the highest yield of 7.4 t/ha, while CR Dhan 101 gave the lowest yield of 3.8 t/ha. The yield data of other varieties have been given in the table no. 5.12 .

Further, during WS 2015-16, the same rice hybrid Rajlaxmi gave the highest yield of 7.3 t/ha, while CR Dhan 304 gave the lowest yield of 3.6 t/ha. The yield data of other varieties are as given in the table no. 5.12

Dissemination of rice production technology through KVK, Cuttack

OFTs (On Farm Trials)

On farm trials were conducted on "Assessment of real time nitrogen management by LCC in Rice" for scheduling of nitrogen in 15 farmers field of Mangarajpur (Badamba) Ganeshwarpur and Ucchapada (Tangi-Choudwar) and Sundarda (Niali). The average yield of 5.21 t/ha was recorded in OFT with an increase of 6.90 % in yield over control (4.85 t/ha). In another OFT on "Assessment of Zn @ 5 kg/ha ($ZnSO_4$ 25 kg/ha) and Borax (0.5%) as foliar spray on yield of rice" conducted at Mangarajpur (Badamba) and Sundarda (Niali) involving 13 farmers. On an average 5.27 t/ha yield was recorded which was 6.26% higher over farmers practice (4.94 t/ha). These two OFTs were conducted with variety Swarna which were grown by farmers in large area.

In the area of plant protection an OFT on "Assessment of IDM module against sheath blight in rice var. Swarna involving 15 farmers of Ucchapada village of Tangi-Choudwar Block. In recommended practice on an average 5.38 t/ha yield was recorded which was 14.6% higher over farmers practice (4.68 t/ha). Another OFT was on "Assessment of IPM module against Gundhy bug on rice was done at Ucchapada and Kadei (Tangi-Choudwar) involving 15 farmers. In recommended practice on an average 4.69 t/ha yield was observed which was 8.67% higher over farmers practice (4.31 t/ha).

Another OFT was on "Assessment of paddy straw of NRRI released rice varieties for mushroom cultivation" involving 15 farmwomen of Nrutanga (Mahanga) with three variety straws (Pooja, Sarala and Varshadhan) as substrate. The straw of variety Sarala fetched highest yield of 1.22 kg per bed followed by Pooja (0.95 kg per bed) and Varshadhan (0.85 kg per bed). As perception of the farmwomen quality of the mushroom was also good with variety Sarala followed by Pooja. This OFT was repeated as per the decision of the Scientific Advisory Committee Meeting and results are similar.

Table 5.11. Perception of practicing farmers about the use of Leaf Colour Chart (LCC) for fertilizer management in rice farming (N=30)

S. No.	Perception indicators	Agree	Disagree	Neutral	Total
1.	Saves urea (N-fertilizers) and reduces cost of cultivation	23 (76.67)	0 (0.00)	7 (23.33)	30 (100.0)
2.	Easy to know the real time for application of urea	23 (76.67)	3 (10.0)	4 (13.33)	30 (100.0)
3.	Easy to use and carry	28 (93.33)	2 (6.67)	0 (0.00)	30 (100.0)
4.	Inexpensive and affordable	30 (100.)	0 (0.00)	0 (0.00)	30 (100.0)
5.	Better crop growth and yield as compared to blanket recommendation of N-fertilizers	17 (56.67)	10 (33.33)	3 (10.0)	30 (100.0)
6.	Neighbouring farmers borrowed from me and used	18 (60.0)	0 (0.00)	12 (40.0)	30 (100.0)
7.	Neighbouring farmers showed interest in purchasing LCC	26 (86.67)	0 (0.00)	4 (13.33)	30 (100.0)
8.	Will persuade fellow farmers to purchase and use	30 (100.0)	0 (0.00)	0 (0.00)	30 (100.0)
9.	All rice growers must possess LCC for N-management	30 (100.0)	0 (0.00)	0 (0.00)	30 (100.0)
10.	LCC is good for soil health and environmental friendly	27 (90.00)	0 (0.00)	3 (10.00)	30 (100.0)
11.	All agricultural inputs traders should sell LCC	30 (100.0)	0 (0.00)	0 (0.00)	30 (100.0)
12.	Not available in local market	30 (100.0)	0 (0.00)	0 (0.00)	30 (100.0)
13.	No demonstration or awareness programme on use of LCC	30 (100.0)	0 (0.00)	0 (0.00)	30 (100.0)
14.	Cannot be used after one year due to expiry	22 (73.33)	8 (26.67)	0 (0.00)	30 (100.0)
15.	Use of LCC is better than visual assessment for N-fertilizer application	21 (70.00)	0 (0.00)	9 (3.00)	30 (100.0)

FLDs (Front Line Demonstrations)

Front Line Demonstrations on high yielding rice varieties Sahabhagidhan was done in 2.0 ha, Varshadhan (0.4 ha) and Poornabhog (0.4 ha) at Tentuliragadi, Indranipatna, Jodum, Andhoti and Haridapal villages involving 20 farmers. The average yield of variety Sahabhagidhan was 3.85 t/ha, Varshadhan was 4.8 t/ha and Poornabhog was 2.60 t/ha.

Collaborative Front Line Demonstrations with the scientists of CID, NRRI were done on the rice varieties CR Dhan 303 and and CR Dhan 304 at the villages Patrakana (Niali), Arada (Cuttack Sadar) and Indrani Patana (Tangi-Choudwar) involving 12 farmers. The average yield with variety CR Dhan 303 was 6.48 t/ha and with variety CR Dhan 304 was 6.32 t/ha which were 40.2 and 36.8 per cent higher, respectively over local check Naveen (4.62 t/ha).

Characterization of Resources and Innovations to aid Rice Research and Develop Extension Models

Develop Business Models of NRRI technologies for entrepreneurship development at community level

One of the focuses of this project is business plan

Table 5.12. The yield data of different varieties in *wet* and dry season

WS, 2015-16		DS, 2015-16	
Variety	**Yield (t/ha)**	**Variety**	**yield (t/ha)**
CR Dhan 304	3.6		
Lunasuvarna	4.1	CR Dhan 101	3.8
Lunasampad	4.2	CR Dhan 202	4.1
CR Dhan 300	4.2	Binadhan-8	4.1
Sumit	4.2	Hazaridhan	4.2
Satyabhama	4.5	Lunasanki	4.2
Lunasanki	4.5	CR Dhan 205	4.5
Poornobhog	4.6	CR Dhan 306	4.6
Pyari	4.6	Pyari	4.6
Lunabarial	4.7	CR Dhan 201	4.8
CR Dhan 205	4.7	Binadhan-10	4.8
Chakaakhi	4.8	Satyabhama	4.8
CR Dhan 202	4.8	Phalguni	4.9
CR Dhan 500	5.1	CR Dhan 303	5.1
CR Dhan305	5.1	Sahabhagidhan	5.1
CR Dhan 306	5.1	CR Dhan 203	5.2
CR Dhan 505	5.2	Naveen	5.2
CR Dhan 303	5.2	CR Dhan 304	5.3
CR Dhan 501	5.3	CR Dhan 305	5.4
Swarn *sub-1*	5.5	Satyakishna	5.8
Reeta	5.8	CR Dhan 701	6.8
CR Dhan 701	6.8	Ajaya	7.1
Ajaya	6.9	Rajlaxmi	7.4
Rajlaxmi	7.3		

development for NRRI technologies. In 2012-13 business plans were developed for NRRI implement manufacturing unit and three models of rice-fish farming systems on the basis of data collected from the agripreneurs. Meanwhile the market prices have increased; therefore, it was felt necessary to update the business plan as per the current market prices. Accordingly data was collected and analysed. The result is presented as follows in table no. 5.13.

In case of NRRI implement manufacturing, the net profit increased by Rs. 5,05,181 from 2012-13 to 2015-16 because the total sales value of the implements proposed to be manufactured under this project increased by 56.63% (according to market price) from 2012-13 to 2015-16 and the cost of manufacturing all that proposed implement increased only 52.41% which makes the project more profitable in 2015-16 than 2012-13.

In case of rice-fish farming system business plans for small, medium and commercial scales, increase in project cost by 13.48%, 12.40% and 13.25%, respectively was observed from 2012-13. However, due to increase in selling price the net profit also increased by 37.49%, 36.50% and 10.25% for small, medium and commercial rice-fish farming system, respectively. The details of the change in cost under different items is presented from table 5.14 to 5.16.

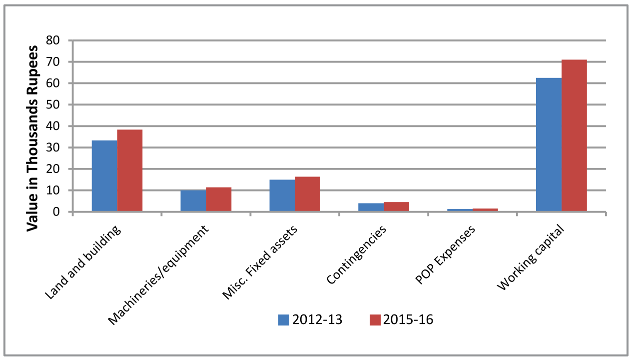


Fig. 5.3 Comparative Project cost of Rice-fish Farming System of Small size in 2012-13 and 2015-16

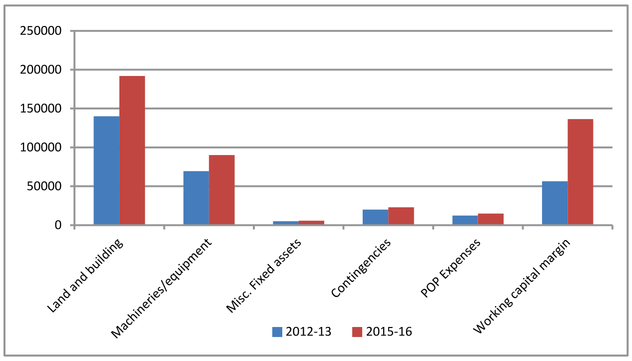


Fig. 5.2 Comparative Project cost of NRRI Implement Manufacturing in 2012-13 and 2015-16

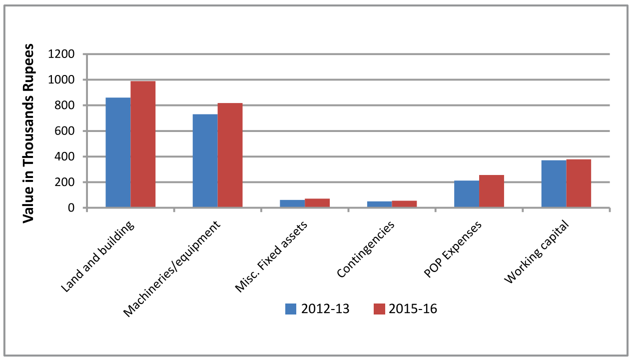


Fig. 5.4 Comparative Project cost of Rice-fish Farming System of medium size in 2012-13 and 2015-16

Table 5.13. Project cost of NRRI Implement Manufacturing Business

	2012-13 (Values in Rs.)	2015-16 (Values in Rs.)	Percentage increase
Land and building	140000	192000	37.14
Machineries/equipment	69500	90145	29.71
Misc. Fixed assets	5000	5750	15.00
Contingencies	20000	23000	15.00
POP Expenses	12365	14792	19.63
Working capital margin	56425	136549	142.00
TOTAL	**303290**	**462236**	**52.41**
Net Profit/Loss (Rs.)	487422	992603	103.64

Table 5.14. Project cost of Small Rice-fish Farming system Business plan

	2012-13 (Values in Rs.)	2015-16 (Values in Rs.)	Percentage increase
Land and building	33333	38333	15.00
Machineries/equipment	10000	11400	14.00
Misc. Fixed assets	15000	16400	9.33
Contingencies	4000	4500	12.50
POP Expenses	1320	1527	15.68
Working capital	62524	71020	13.59
TOTAL	**126177**	**143180**	**13.48**
Net Profit/Loss	164794	226568	37.49

Table 5.15. Project cost of Medium Rice-fish Farming system Business plan

	2012-13 (Values in Rs.)	2015-16 (Values in Rs.)	Percentage increase
Land and building	860000	989000	15.00
Machineries/equipment	730000	817500	11.99
Misc. Fixed assets	62000	72000	16.13
Contingencies	50000	56000	12.00
POP Expenses	212776	256331	20.47
Working capital	371745	379185	2.00
TOTAL	**2286521**	**2570016**	**12.40**
Net Profit/Loss	23519	32103	36.50

Table 5.16. Project cost of Commercial Rice-fish Farming system Business plan

	2012-13 (Values in Rs.)	2015-16 (Values in Rs.)	Percentage increase
Land and building	1752000	1906800	8.84
Machineries/equipment	546000	573960	5.12
Misc. Fixed assets	92000	98100	6.63
Contingencies	200000	230000	15.00
POP Expenses	250075	370529	48.17
Working capital	1045155	1220578	16.78
TOTAL	**3885230**	**4399967**	**13.25**
Net Profit/Loss	797966	879732	10.25

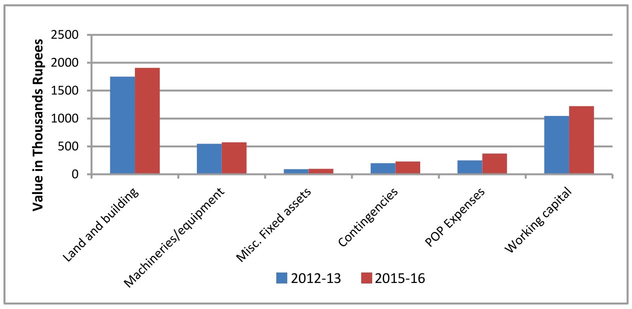


Fig. 5.5 Comparative Project cost of Commercial Rice-fish Farming System in 2012-13 and 2015-16

Designing general simulation model of adoption of rice technologies in different rice ecologies

Under the activity designing simulation model of adoption, the data collected from various secondary sources on correlation between dependent variable Adoption of HYV of Paddy and independent variables annual income, economic motivation, age, education, extension contact, family size, farming experience, risk orientation, scientific orientation, SES, social participation and attitude towards HYV of paddy were meta-analyzed using CMA software. The results showed that all these independent variables were positively significantly correlated with dependent variable adoption of HYV of paddy. Following table gives the details. Using these correlation coefficients modeling will be done which is supposed to be valid for the population.

Similarly, data was also collected from various secondary sources on correlation between dependent variable Adoption of HYV of Paddy and independent variables annual income, economic motivation, age, education, extension contact, family size, farming experience, risk orientation, scientific orientation, SES, social participation and attitude towards HYV of paddy and were meta-analyzed using CMA software. The results showed that all these independent variables were positively significantly correlated with dependent variable adoption of HYV of paddy. Following table 5.18 gives the details. Using these correlation coefficients modeling will be done which is supposed to be valid for the population.

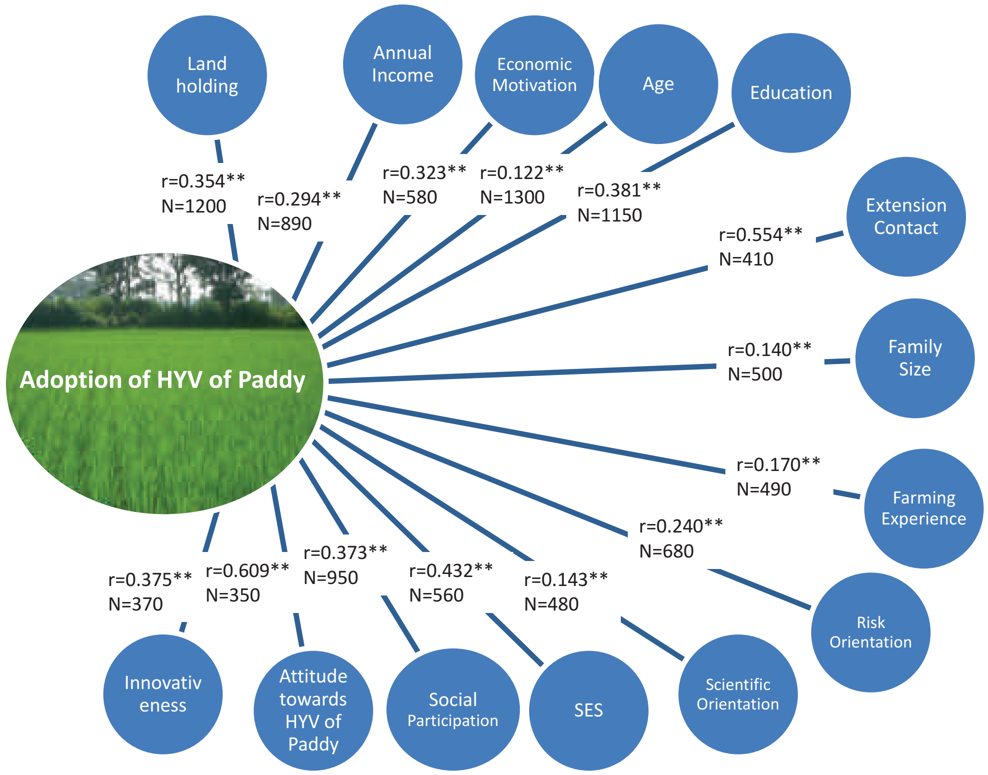


Fig. 5.6 Meta-analysed correlation coefficients between Adoption of HYV of Paddy and independent variables across studies

Table 5.17. Meta-analysed correlation coefficients between Adoption of HYV of Paddy and independent variables across studies

Dependent Variable	Independent Variable	Number of studies	Cumulative sample size	Cumulated correlation coefficient	P value
Adoption of HYV of Paddy	Annual Income	7	890	0.294**	0.000
	Economic Motivation	7	580	0.323**	0.000
	Age	15	1300	0.122**	0.000
	Education	12	1150	0.381**	0.000
	Extension Contact	6	410	0.554**	0.000
	Family size	3	500	0.140**	0.002
	Farming Experience	4	490	0.170**	0.000
	Risk Orientation	8	680	0.240**	0.000
	Scientific Orientation	5	480	0.143**	0.002
	SES	7	560	0.432**	0.000
	Social Participation	10	950	0.373**	0.000
	Attitude towards HYV of paddy	9	350	0.609**	0.000
	Innovativeness	3	370	0.375**	0.000
	Land Holding	12	1200	0.354**	0.000

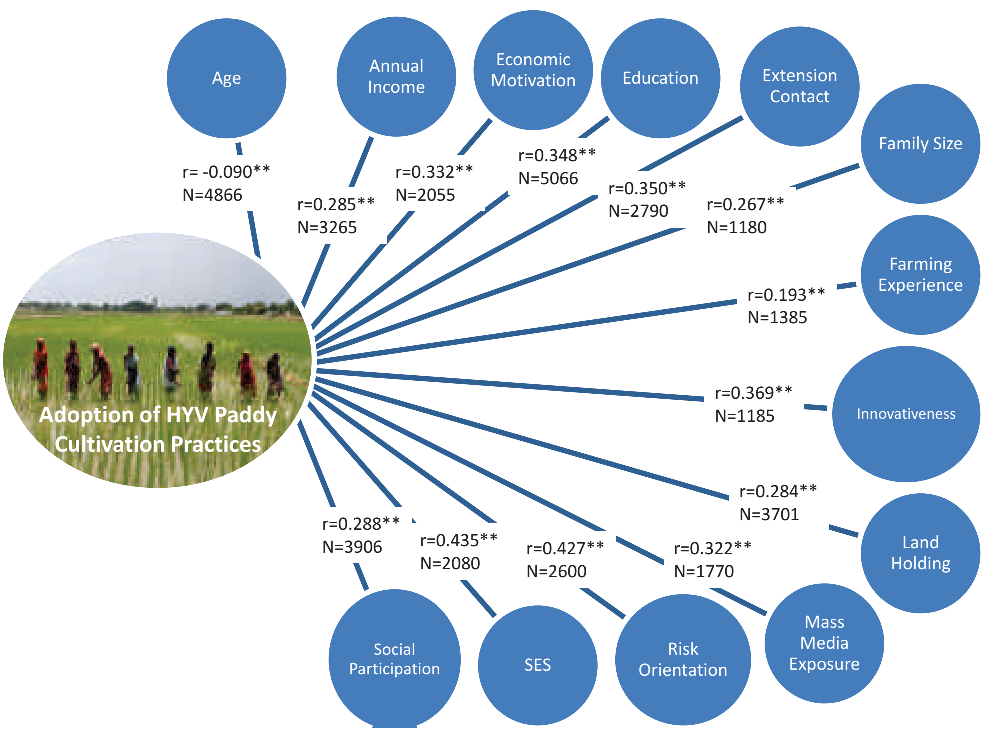


Fig. 5.7 Meta-analysed correlation coefficients between Adoption of HYV Paddy Cultivation Practices and independent variables across studies

Table 5.18 Meta-analysed correlation coefficients between Adoption of HYV Paddy Cultivation Practices and independent variables across studies

Dependent Variable	Independent Variable	Number of studies	Cumulative sample size	Cumulated correlation coefficient	P value
Adoption of HYV Paddy Cultivation Practices	Annual Income	32	3265	0.285**	0.000
	Economic Motivation	19	2055	0.332**	0.000
	Age	48	4866	-0.090**	0.000
	Education	50	5066	0.348**	0.000
	Extension Contact	28	2790	0.350**	0.000
	Family size	10	1180	0.267**	0.000
	Farming Experience	11	1385	0.193*	0.000
	Risk Orientation	23	2600	0.427**	0.000
	Innovativeness	11	1185	0.369**	0.000
	SES	27	2080	0.435**	0.000
	Social Participation	36	3906	0.288**	0.000
	Land Holding	35	3701	0.284**	0.000
	Mass Media Exposure	17	1770	0.322**	0.000

Develop pilot model for characterisation of resources and innovations for rice development in eastern region

In case of characterisation, grid based sampling (19 locations) was done earlier to predict the area under different NRRI varieties using GIS tools (Annual Report 2013-14). In order to confirm, if the predictions were accurate or not, this year data was collected from thirteen inter-grid points on area under Pooja, Gayatri, Sarala and Savitri (CR 1009). It was observed that out of 52 observations, 36 observations were having no deviations but nearly 30.77% data points showed variations ranging from 5 ha to more than 20 ha area under NRRI varieties. This difference could be due to restriction by state government on more than 10 years old varieties. This calls for measuring grid data and inter-grid data at the same time and compare. The table no 5.19 gives the details of the observations.

Table 5.19 Deviation between predicted and actual area under NRRI varieties

Deviation in ha	Pooja	Gayatri	Sarala	1009	Cumulative
0	5	11	8	12	36
0 to 5	2	0	1	1	4
5 to 10	3	2	2	0	7
10 to 15	0	0	1	0	1
15 to 20	1	0	1	0	2
More than 20	2	0	0	0	2
Total	**13**	**13**	**13**	**13**	**52**

Project No. 5.3 Impact analysis and database updation in relation to rice technologies, policy and programmes

The estimation of area coverage under NRRI varieties was done using certified seed distribution data of different rice varieties for five years and total modern varieties (MV) coverage in three states *viz.*, West Bengal, Jharkhand and undivided Andhra Pradesh.

The *wet* and *dry*/summer rice accounted for 77% and 23% of the total rice area respectively in the state of West Bengal. The mega varieties (area coverage > 1 lakh ha) of the state are MTU-7029, Shatabdi, IR-36, IR-64, Khitish, MTU-1010, Lalat, GB-1, Pratikshya, Annada, CR-1009 and MTU-1001. Among the MV, MTU-7029 covers maximum area and accounted for 26.8% of total MV area during wet season. Some varieties *viz.*, Shatabdi, IR-36, IR-64, Khitish, MTU-1010, Lalat, GB-1, Annada, Ratna and Parijat were grown during both wet and dry/summer season. Out of total 5.04 million ha of MV rice area in West Bengal, the coverage of NRRI varieties was 28.6%. The coverage of NRRI varieties during wet and dry/summer season was 23.8% (905,100 ha) and 43.1% (536,800 ha), respectively. The NRRI varieties covering maximum area in the state were Shatabdi (575,000 ha), Khitish (304,500 ha), Annada (123,700 ha), CR-1009 (115,800 ha), Ratna (87,300 ha), Gayatri (73,600 ha) and Dharitri (64,000 ha). The other NRRI varieties grown to a lesser extent in the state were Anjali, CR-1014, Sarala, Geetanjali, Lunisree, Pooja and Utkala Prabha.

Rice is mainly grown during wet season in Jharkhand to the extent of 1.38 million ha. The varieties with larger area coverage in the state were MTU-7029, Lalat, IR-64 and MTU-1010. Hybrid varieties were grown to the extent of 437,000 ha, which accounted for 37% of the total MV area. Among inbred varieties, MTU-7029 accounted for one-fifth of the total MV area. NRRI varieties were grown to the extent of 91,600 ha in the state, which accounted for 7.8% of the MV area. The NRRI variety like Abhisek, Rajalaxmi, Naveen and Sahbhagi was grown to the extent of 52,600 ha, 21,700 ha, 7,900 ha and 4,900 ha, respectively.

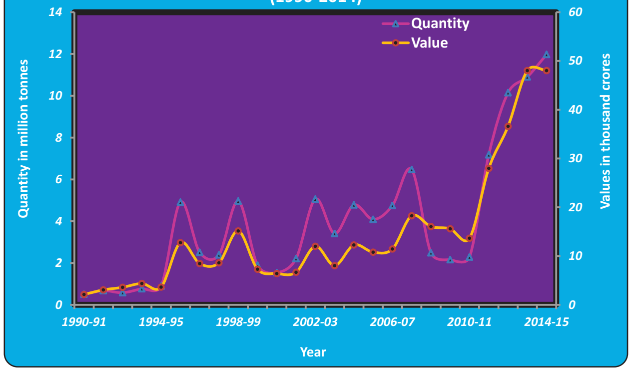
Rice is grown to the extent of 4.03 million ha in undivided Andhra Pradesh. wet season and *dry*/summer season rice accounted for 66% and 34% respectively of the total rice area. The mega varieties of the state were BPT-5204, MTU-1010, MTU-1001, BPT-3291, IR-64, MTU-1061 and MTU-7029. When both the season was considered, the first three varieties together accounted for 78.7% of the total MV area (4 million ha) in the state and BPT-5204 was the variety with highest area coverage (33.4%) followed by MTU-1010 (30.4%) in Andhra Pradesh. Season wise, BPT-5204 covered maximum area during *wet* (1,093,600 ha) and MTU-1010 maximum area (632,500 ha) during *dry*/summer. The NRRI variety CR-1009 was grown to the extent of 16,900 ha in the state.

Updation of rice export database and trend analysis

The country wise and grade wise export data (quantity and value) of rice from India was digitized for two years i.e. 2013-14 and 2014-15. Data was analyzed taking last 25 years (1990-91 to 2014-15) into consideration and by converting all the value data to constant 2014-15 price and comparison between pre (1990-94) and post (2010-2014) WTO period was made. Due to fluctuation in year to year values, quinquennium average were computed and compared. India exports seven grades of rice *viz.*, paddy of seed quality, paddy (others), brown rice, parboiled rice, basmati rice, white rice and broken rice. The export of basmati, parboiled and white grades together accounted for more than 90% of total volume and more than 95% of total value of rice exports and analyzed in more detail. The world has been divided into 19 regions as per FAO classification and these were used in this analysis. The trends in exports over years and regional destinations of Indian rice export were analyzed.

The global rice export has expanded by 3.5 times by volume during the last 25 years. India has emerged as the top exporter during the recent period (2012-2014) from a net importer during 1960s and 1970s. India's total rice export has increased more than 12 times by volume and 10 times by value, when data for the quinquennium ending 1994-95 and 2010-14 was considered. The volume of export has increased from 0.51 to 11.98 million tonnes and value has increased from Rs. 2125 to Rs 48026 crores at constant 2014-15 prices during 1990-91 to 2014-15 (Fig 5.8). The basmati export has increased by 907% and non-basmati by 1608% by volume during pre and post WTO period.

Fig 5.8 Trends in quantity & value of total rice exports (1990-2014)



The basmati export alone accounted for 38% of total volume and 63% of total value of Indian rice exports (Fig. 5.9 and 5.10). The export has increased from 0.23 million tonnes and Rs. 1365 crores during 1990-91 to 3.70 million tonnes and Rs. 27598 crores, respectively during 2014-15 (Fig. 5.11). West Asia region dominates other regions in basmati rice imports during the last 25 years. During the quinquennium ending 2014-15, the region alone imports 84% of total Indian basmati by volume. The other three important regions importing basmati rice are Northern Europe, Northern America and Western Europe (Fig. 5.12). These three regions accounted for 11% of total exports. Among the countries, Iran and Saudi Arabia together accounted for more than 50% of total Indian basmati exports by volume and value.

Fig 5.9 Average quantity share of different grades of rice (2010-2014)

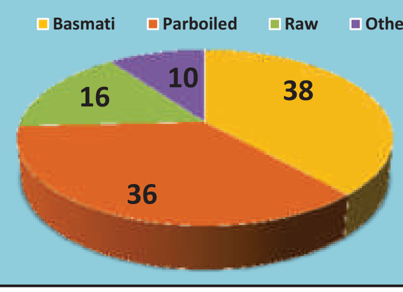


Fig 5.10 Average value share of different grades of rice (2010-2014)

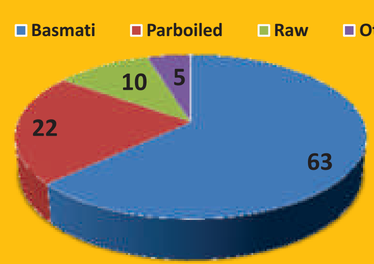


Fig 5.11 Trends in quantity & value of basmati rice exports (1990-2014)

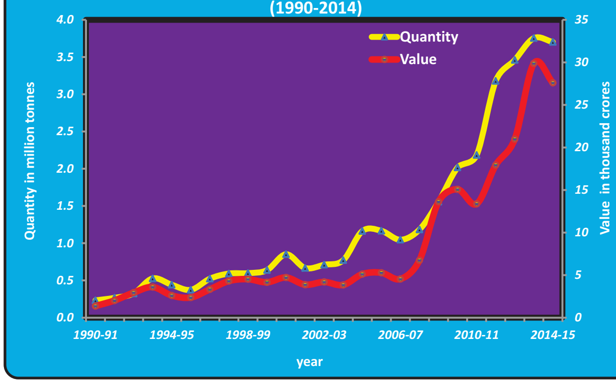
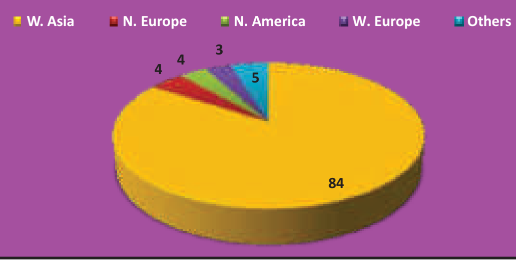


Fig 5.12 Average share (quantity) of different grades of basmati rice



The non-basmati export has increased from 0.27 million tonnes during 1990-91 to 8.27 million tonnes during 2014-15 (Fig 5.13). The non-basmati export has decreased significantly during 2008-11 due to export ban. Region wise, West African region leads the table in non-basmati imports from India during the recent past (2010-14) followed by South Asia, West Asia and East Africa (Table 5.20). West African region alone imports 43% of total non-basmati exports of India. India exported very less quantities of non-basmati during pre WTO period. However, the scenario has changed during post WTO period and export volume increased dramatically. During pre WTO period West Asia and East Europian regions were importing non-basmati rice in very small quantities and mainly of white grade. However, situation changed after WTO agreement came into existence. South Asia and West African regions emerged as major importers and West Asian region increased its import volume.

The volume and value of all the grades of rice has increased during the last two and half decades. The share of different grades of non-basmati rice has also changed during the post WTO period. Among non-basmati grades, parboiled and white rice accounted for major share. During pre WTO period, though white rice used to dominate the export volume, the parboiled rice dominated the export volume during post WTO period. The average export of parboiled rice has increased by 43 times by volume, when pre and post WTO period was compared (Fig 5.14). The major destinations of parboiled rice were to regions *viz.* West Africa, South Asia, West Asia, Northern Africa South East Asia and Eastern Africa (Fig 5.15). The white rice export has increased significantly also. Presently, the average export has reached 1.35 million tonnes from 0.26 million tonnes during pre WTO period (Fig 5.16). During 2010-14, the major export destinations of white rice were to the regions *viz.*, South Asia, West Asia, West Africa and East Africa (Fig 5.17).

Table 5.20 Average quantity (million tonnes) of non-basmati rice exports by regions (1990-2014)

S.I No.	Region	1990-94	Region	1995-99	Region	2000-04	Region	2005-09	Region	2010-14
1	W. Asia	0.12	S. Asia	1.03	S. Asia	0.83	S. Asia	0.90	W. Africa	2.27
2	E. Europe	0.06	W. Asia	0.36	W. Africa	0.41	W. Africa	0.78	S. Asia	0.91
3	S. Asia	0.04	S. Africa	0.31	SE. Asia	0.39	W. Asia	0.30	W. Asia	0.68
4	E. Africa	0.03	W. Africa	0.28	S. Africa	0.34	S. Africa	0.19	E. Africa	0.37
5	SE. Asia	0.03	SE. Asia	0.26	W. Asia	0.28	E. Africa	0.17	S. Africa	0.28
6	W. Africa	0.02	E. Africa	0.22	E. Africa	0.15	M. Africa	0.06	SE. Asia	0.27
7	M. Africa	0.01	E. Europe	0.19	E. Europe	0.04	N. Africa	0.04	M. Africa	0.17
8	N. America	0.01	N. Africa	0.03	M. Africa	0.03	E. Europe	0.04	N. Africa	0.11
9	N. Europe	0.01	N. America	0.03	N. America	0.02	SE. Asia	0.03	E. Europe	0.06
10	N. Africa	0.00*	E. Asia	0.02	N. Africa	0.02	N. America	0.02	W. Europe	0.02
11	S. America	0.00*	W. Europe	0.02	N. Europe	0.01	N. Europe	0.02	N. America	0.02
12	Oceania	0.00*	M. Africa	0.01	W. Europe	0.01	W. Europe	0.01	N. Europe	0.02
13	W. Europe	0.00*	S. America	0.01	Caribbean	0.01	S. Europe	0.01	S. Europe	0.02
14	S. Africa	0.00*	N. Europe	0.01	Oceania	0.01	Oceania	0.01	E. Asia	0.01
15	E. Asia	0.00*	Caribbean	0.00*	E. Asia	0.00*	Caribbean	0.01	Oceania	0.01
16	Caribbean	0.00*	S. Europe	0.00*	S. Europe	0.00*	E. Asia	0.00*	Caribbean	0.00*
17	S. Europe	0.00*	Oceania	0.00*	S. America	0.00*	C. Asia	0.00*	S. America	0.00*
18	C. America	0.00*	C. Asia	0.00*	C. America	0.00*	S. America	0.00*	C. Asia	0.00*
19	C. Asia	0.00*	C. America	0.00*	C. Asia	0.00*	C. America	0.00*	C. America	0.00*
	Total	**0.33**		**2.79**		**2.57**		**2.60**		**5.24**

* indicates negligible quantity.

Fig 5.13 Trends in quantity & value of non-basmati rice exports (1990-2014)

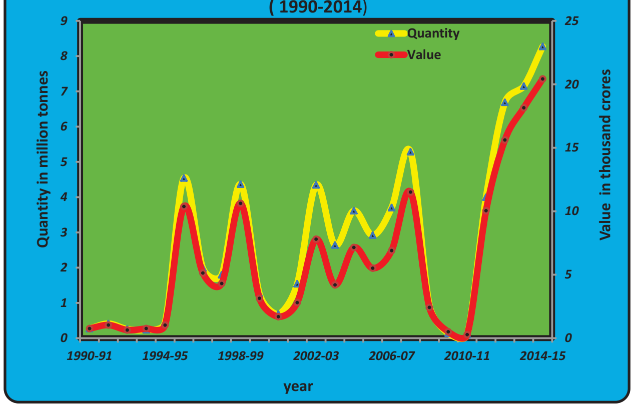


Fig 5.14 Average export of parboiled rice

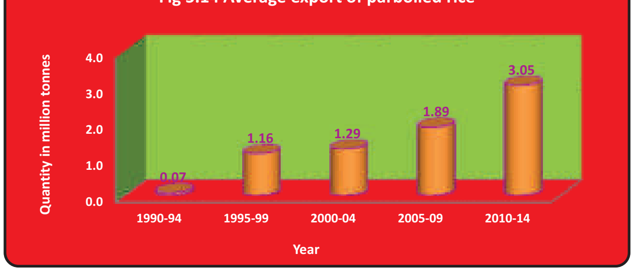


Fig 5.15 Increase in quantity of parboiled rice exports to major regions of world

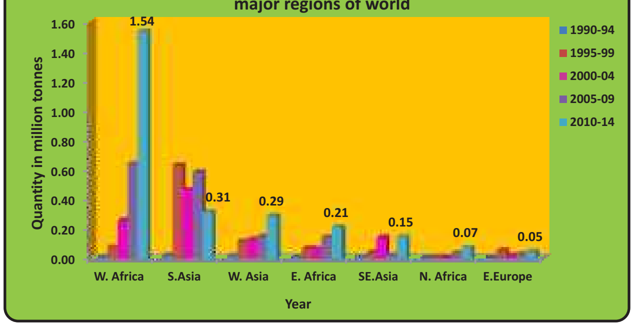
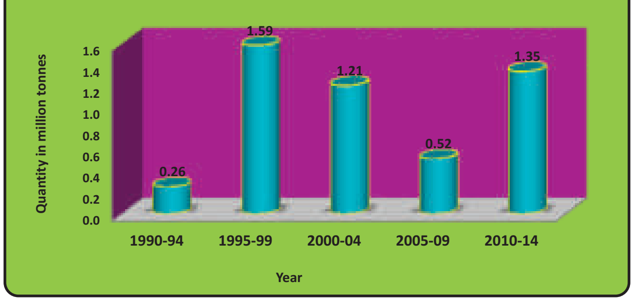
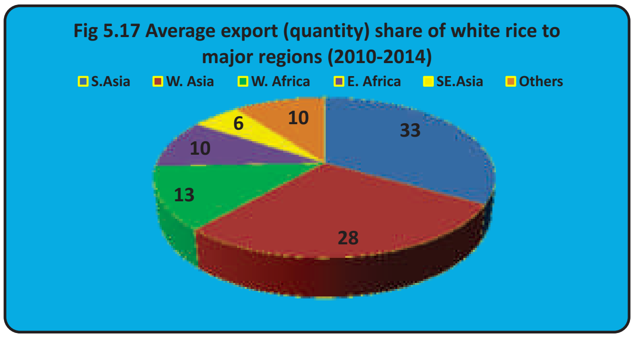


Fig 5.16 Average export of white rice (1990-2014)





Model Development

The model was developed for rice production data of Tamil Nadu and Karnataka using ARIMA. Fifty three years data from 1960-61 to 2012-13 was used for this purpose. The data was divided into two parts i.e. model estimation and model testing. The data from 1960-61 to 2003-04 was used for model estimation and data from 2004-05 to 2012-13 was used for model testing. Two statistics Akaike information criterion (AIC) and Bayesian information criterion (BIC) were used for best fitted model. For Tamil Nadu ARIMA (5, 1, 0) model was best fitted. The parameter estimated of MU; AR1,1; AR1,2; AR1,3; AR1,4 and AR1,5 are 49.85, -0.395, -0.165, -0.342, -0.548 and -0.638, respectively with their standard error 46.62, 0.151, 0.200, 0.208, 0.214 and 0.197, respectively. For Karnataka ARIMA (0, 1, 3) model was best fitted. The parameter estimates of MU; MA1,1; MA1,2; and MA1,3 are 47.26, 0.479, -0.067 and 0.588, respectively with the standard error of 9.096, 0.151, 0.170 and 0.164, respectively.

Publications

Research Papers

Adak T and Mukherjee I. 2016. Investigating role of abiotic factors on spinosad dissipation. *Bulletin of Environmental Contamination and Toxicology*. **96**(1): 125-129. DOI 10.1007/s00128-015-1644-z.

Adak T, Munda S, Kumar U, Berliner J, Pokhare SS, Jambhulkar NN, Jena M. 2016. Effect of elevated CO_2 on chlorpyriphos degradation and soil microbial activities in tropical rice soil. *Environmental Monitoring and Assessment*. **188**(2):105. DOI 10.1007/s10661-016-5119-4.

Alam S, Imam J, Mukesh N, Prasad C and Variar M. 2015. Molecular analysis of Blast resistance gene *Pi 2* in Indian rice landraces (*Oryza saliva* L.) and its verification by virulance analysis, *Proceedings of National Academy of Science, India Sect. B. Biological Science*. DOI: 10.1007/s40011-015-0548-3.

Anand ID, Ravikumar MR, Raghu S, Virupaksha Prabhu H and Ranganath Swamy M. 2015. Specific and quick detection of *Ralstonia solancearum* (E.F Smith) Yabuuchi *et. al*, from infected rhizomes causing Bacterial Wilt of ginger by using PCR based amplification of *fliC* gene coding for the Flagella Subunit, *Journal of Pure and Applied Microbiology*, Vol. **9** (Spl. Edn. 2).

Anandan A, Mahender A and Pradhan SK. 2015. Measuring whole plant area at seedling stage to assess the early seedling vigour by image analysis. CSIRO Press, *Ecological & Environmental Plant Physiology* (http://prometheuswiki.publish.csiro.au).

Anandan A, Mahender A, Sanghamitra P and Pradhan SK. 2016. Protocol for measuring grain colour intensity by digital image. CSIRO Press, *Ecological & Environmental Plant Physiology* (http://prometheuswiki.publish.csiro.au).

Anandan A, Mahender A, Pradhan SK and Jauhar Ali. 2016. Population Structure, Diversity and Trait Association Analysis in Rice (*Oryza sativa* L.) Germplasm for Early Seedling Vigor (ESV) Using Trait Linked SSR Markers. *PLOS ONE*. **11**(3): e0152406. DOI:10.1371/journal.pone.0152406.

Anantha MS, Patel D, Quintana M, Swain P, Dwivedi JL, Torres RO, Verulkar SB, Variar M, Mandal NP, Kumar A and Henry A. 2016. Trait combinations that improve rice yield under drought: Sahbhagidhan and new drought tolerant varieties in South Asia. *Crop Science*. **56**: 408–421. DOI:10.2135/ cropsci2015.06.0344 .

Bag MK, Yadav M, Mukherjee AK. 2016. Bioefficacy of Strobilurin based fungicides against rice Sheath Blight disease. *Transcriptomics*. **4**: 128. DOI : 10.4172/2329-8936.1000128.

Bagchi TB, Ghosh A, Kumar U, Chattopadhyay K, Sanghamitra P, Ray S, Adak T and Sharma SG. 2016. A comparison of nutritional and physicochemical quality of rice under organic and standard production system. *Cereal Chemistry*. DOI: org/10.1094/CCHEM-01-16-0001-R.

Bagyaraj DJ, Sharma MP and Maiti D. 2015. Phosphorus nutrition of crops through arbuscular mycorrhizal fungi. *Current Science*. **109**(7): 1288-1293.

Banik A, Mukherjee SK, Sahana A, Das D, Dangar TK. 2015. Fluorescence resonance energy transfer (FRET) based technique for intracellular tracking of endophytic bacteria in plant tissues. *Biology and Fertility of Soil*. DOI: 10.1007/ s00374-015-1064-6.

Banik A, Mukhopadhaya SK, Dangar TK. 2015. Characterization of N_2-fixing plant growth promoting endophytic and epiphytic bacterial community of Indian cultivated and wild rice (*Oryza* spp.) genotypes. *Planta*. DOI: 10.1007/s00425-015-2444-8.

Bhadana VP, Ansari MA, Punitha P, Prakash IM, Singh N, Sharma PK, Kumar S, Dutt S, Lal B and Ngachan SV. 2015. Participatory research for assessing the suitability of potential innovations: A case study on high-yielding varieties options for rice farmers in north east India. *Indian Journal of Agricultural Sciences*. **85**(7): 902-907.

Bharathkumar S, Jena PP, Kumar J, Baksh SKY, Samal R, Gouda G, Mukherjee M, Donde R, Vijayan J, Parida and M, Reddy JN. 2016. Identification of new alleles in salt tolerant rice germplasm lines through phenotypic and genotypic screening. *International Journal of Agriculture Biology*. **18**: 441-448.

Bharatkumar S, Jitendra K, Pragnya PJ, Gayatri G, Archana B., Saumya RB, Mitadru M, Ravindra D, Barada PP, Shakti PM and Reddy JN. 2015. A comparative study on flood tolerance of short and tall stature rice cultivars with *sub1* during seed germination and seedling stage. *International Journal of Agriculture Sciences*. **7**(7): 591-595.

Bharatkumar S, Pragnya PJ, Jitendra K, Ravindra D, Yashin B SK, Gayatri G, Madhuchhanda P, Mahender A, Soumya M and Reddy JN. 2015. Rice breeding lines developed with highly efficient submergence tolerance through advanced single seed descent method for semi-lowland and deep-lowland areas, *International Journal of Genetics*. **7**(1): 165-169.

Bhattacharyya P, Nayak AK, Shahid M, Tripathi R, Mohanty S, Kumar A, Raja R, Panda BB, Lal B, Gautam Priyanka, Swain CK, Roy KS, Dash PK. 2015. Effects of 42-year long-term fertilizer management on soil phosphorus availability, fractionation, and adsorption–desorption isotherm and plant uptake in flooded tropical rice. *The Crop Journal*. **3**:387–395.

Bhattacharyya P, Roy KS, Das M, Ray S, Balachandar D, Karthikeyan S, Nayak AK and Mohapatra T. 2015. Elucidation of rice rhizosphere metagenome in relation to methane and nitrogen metabolism under elevated carbon dioxide and temperature using whole genome metagenomic approach. *Science of The Total Environment*. **542**: 886-898.

Bihari P, Nayak AK, Gautam Priyanka, Lal B, Shahid M, Raja R, Tripathi R, Bhattacharyya P, Panda BB, Mohanty S and Rao KS. 2015. Long term effect of rice based farming systems on soil health. *Environmental Monitoring and Assessment* **187**: 296 (1–12) DOI: 10.1007/s 10661-015-4518-2.

Bose LK, Jambhulkar NN, Pande K and Singh ON. 2015. Genotype by environment interactions for grain yield in upland breeding lines of rice under direct seeded conditions across multi-environments. *Indian Journal of Genetics and Plant Breeding*. **75**(1): 117-120.

Bose LK, Jambhulkar NN, Pande K. 2015. Nonparametric statistics for evaluating yield of direct seeded rice genotypes in multi-environments. *Romanian Agricultural Research*, **32**:1-6.

Chakraborty K, Moitra MN, Sanyal AK and Rath PC. 2016. Important natural enemies of paddy insect pests in the upper gangetic plains of West Bengal, India. *International Journal of Plant, Animal and Environmental Science*. **6**(1): 35-40.

Chatterjee S, Azmi SA, Ghosh TS, Dangar TK. 2015. Characterization of the *Bacillus thuringiensis* isolates virulent against rice leaf folder, *Cnaphalocrocis medinalis* (Guenee). *Zoological Science*. DOI: 10.1007/s12595-015-0161-8.

Das Lipi and Mishra SK. 2015. Agricultural development through women empowerment in rice-based farming systems. *Journal of Extension Education*, **XX** (2): 159-165.

Dash SK, Meher J, Behera L, Anandan A, Azharudheen TPM, Barik M and Singh ON. 2015. Genetic diversity of New Plant Type rice selections with reference to *indica, tropical japonicas, temperate japonicas* and irrigated cultures. *Oryza*. **52**(4): 266-274.

Nayak DK, Pandit E, Mohanty S, Barik DP, Pradhan SK. 2015. Marker assisted selection in backcross progenies for transfer of bacterial leaf blight resistance genes into a popular lowland rice cultivar. *Oryza*. **52**(3): 163-168.

Ganeshmurthy AN, Kalaivanan D, Selvakumar,G. and Panneerselvam P. 2015. Nutrient Management in Horticultural Crops. *Indian Journal of Fertilizers*. **11**(12): 30- 42.

Gangopadhyay KK, Singh Ashish, Bag MK, Pragya Ranjan, Prasad TV, Roy Anirban, and Dutta M. 2016. Diversity analysis and evaluation of wild Abelmoschus species for agro-morphological traits and major biotic stresses under north western agro-climatic condition of India.

Genetic Resources and Crop Evolution. DOI 10.1007/s10722-016-0400-5.

Gautam NK, Bag MK, Prasad TV, Pandey Sushil, Roy Anirban, Singh Neeta, Ram Babu, Dutta M. 2015. IC0144901 (IC0144901; INGR 14056), a Black gram (*Vigna mungo* (L.) Hepper.) Germplasm Resistant to Mungbean Yellow Mosaic Virus (MYMV). *Indian Journal of Plant Genetic Resources*. **28**(3): 367.

Gautam P, Lal B, Raja R, Tripathi R, Shahid M, Baig MJ, Puree C, Mohanty S, Nayak AK. 2016. Effect of simulated flash flooding on rice and its recovery after flooding with nutrient management strategies. *Ecological Engineering*. **77**: 250-256.

Gautam P, Lal B, Nayak AK, Bhattacharyya P, Baig MJ, Raja R, Shahid M, Tripathi R, Mohanty S, Panda BB, Kumar A. 2015. Application time of nitrogen and phosphorus fertilization mitigates the adverse effect of submergence in rice (*Oryza sativa* L.). *Experimental Agriculture*. **51**: 522–539.

Gautam P, Lal B, Raja R, Baig MJ, Mohanty S, Tripathi R, Shahid M, Bhattacharyya P and Nayak AK. 2015. Effect of nutrient application and water turbidity on submergence tolerance of rice (*Oryza sativa* L.). *Annals of Applied Biology*. **166**: 90-104.

Gautam P, Lal B, Raja R, Panda BB, Tripathi R, Shahid M, Mohanty S, Maharana S, Nayak AK. 2015. Submergence induced tiller mortality and yield reduction in rice can be minimized through post-submergence nitrogen application. *Proceedings of National Academy of Sciences, India, Sect. B Biological Sciences*. DOI: 10.1007/s40011-015-0671-1.

Gautam P, Lal B, Tripathi R, Shahid M, Baig M J, Maharana S, Puree S, Nayak AK. 2016. Beneficial effects of potassium application in improving submergence tolerance of rice (*Oryza sativa* L.). *Environmental and Experimental Botany*. DOI: 10.1016/j.envexpbot.2016.04.005.

Gautam P, Lal B, Tripathi R, Shahid M, Baig M J, Raja R, Maharana S, Nayak AK. 2016. Role of silica and nitrogen interaction in submergence tolerance of rice. *Environmental and Experimental Botany*. **125**:98–109.

Henry Amelia, Swamy BPM, Dixit Shalabh, Torres Rolando D, Batoto Tristram C, Manalili Mervin, Anantha MS, Mandal NP and Kumar Arvind. 2015. Physiological mechanisms contributing to the QTL combination effects on improved performance of IR64 rice NILs under drought. *Journal of Experimental Botany*. DOI:10.1093/jxb/eru506.

Imam J, Alam S, Mandal NP, Maiti D, Variar M and Shukla P. 2015. Molecular diversity and mating type distribution of the rice blast pathogen *Magnaporthe oryzae* in North-East and Eastern India. *Indian Journal of Microbiology*. **55**(1):108–113.

Imam J, Alam S, Mandal NP, Shukla P, Sharma TR, Variar M. 2015. Molecular identification and virulence analysis of AVR genes in rice blast pathogen, *Magnaporthe oryzae* from Eastern India. *Euphytica*. DOI 10.1007/s10681-015-1465-5.

Jambhulkar NN, Bose LK, Pande K and Singh ON. 2015. Genotype by environment interaction and stability analysis in rice genotypes. *Ecology, Environment and Conservation*. **21**(3): 1427-1430.

Jambhulkar NN, Rath NC, Subudhi HN, Das Lipi and Kumar GAK. 2015. Rice yield performance stability in demonstrations conducted during *kharif* season. *Journal of Environment and Biosciences*. **29** (2): 519-522.

Jayalakshmi K, Lingaraju S, Bhat RS, Raju J, Naik ST, Raghu S, Bhagath YS, Madhu S Giri and Priti S. 2015. Biological Activity of Plant Tuber (RVL1) and Fungal Lectin (SRL1) Against *Sclerotium rolfsii*, *Journal of Pure and Applied Microbiology*. **9**(4): 3171-3177.

Jayalakshmi K, Nargund VB, Raju J, Benagi VI, Raghu S, Madhu S, Giri Basamma, Rajaput Rajani B, Priti S and Rajput Reena B. 2015. Pomegranate Anthracnose caused by *Colletotrichum gloeosporioides*: A menance in quality fruit production, *Journal of pure and applied microbiology*. **9**(4): 3093-3097.

Jena M, Panda RS, Sahu RK, Mukherjee AK and Dhua U. 2015. Evaluation of rice genotypes for rice brown plant hopper resistance through phenotypic reaction and genotypic analysis. *Crop Protection* **78**:119-126. ISI IF =1.493.

Lal B, Panda BB, Gautam P, Raja R, Singh T, Mohanty S, Shahid M, Tripathi R, Kumar A, Nayak AK. 2015. Input-output energy analysis of rainfed rice based cropping systems in Eastern India. *Agronomy Journal*. **107**(5): 1750–1756.

Lal B, Gautam P, Mohanty S, Raja R, Tripathi R, Shahid M, Panda BB, Baig MJ, Rath L, Bhattacharyya P, Nayak AK. 2015. Combined application of silica and nitrogen alleviates the damage of flooding stress in rice. *Crop and Pasture Science*. **66**: 679–688.

Lal B, Gautam P, Raja R, Tripathi R, Shahid M, Mohanty S, Panda BB, Bhattacharyya P, and Nayak AK. 2016. Weed seed bank diversity and community shift in a four-decade-old fertilization experiment in rice–rice system. *Ecological Engineering*. **86**: 135-145.

Lal B, Panda BB, Gautam P., Raja R, Singh T, Mohanty S, Shahid M, Tripathi R, Kumar A and Nayak AK. 2015. Input-output energy analysis of rainfed rice based cropping systems in Eastern India. *Agronomy Journal*. DOI:10.2134/agronj14.0313.

Lal B, Rana KS, Gautam P, Rana DS, Meena BP, Meena RK. 2016. Productivity of Ethiopian mustard+chickpea intercropping system influenced by moisture conservation practices and P and S fertilization. *National Academy Science Letters*. DOI: 10.1007/s40009-016-0481-x.

Layek J, Shivakumar BG, Rana DS, Munda S, Lakshman K, Panwar AS, Das A, Ramkrushna GI. 2015. Performance of soybean (*Glycine max*) intercropped with different cereals under varying levels of nitrogen. *Indian Journal of Agricultural Sciences*. **85**(12): 1571–7.

Layek J, Shivakumar BG, Rana DS, Munda S, Lakshman K. 2015. Effect of nitrogen fertilization on yield, intercropping indices and produce quality of different soybean (*Glycine max*) + cereal intercropping systems. *Indian Journal of Agronomy*. **60**(2): 230-235.

Lima JM, Nath M, Dokku P, Raman KV, Kulkarni KP, Chandrapal V, Sahoo S, Mohapatra UB, Amitha MSV, Chinnuswami V, Robin S, Sarla N, Seshashayee M, Singh K, Singh NK, Sharma RP and Mohapatra T. 2015. Physiological, anatomical and transcriptional alterations in a rice mutant leading to enhanced water stress tolerance. *AoB Plants*. DOI: 10.1093/ aobpla/plv023.

Mahender A, Dash GK, Swain P, Rao GJN. 2014. Physiological and molecular profiling of rice genotypes under drought stress. *Oryza*. **51**(1): 12-23.

Maiti D, Barnwal MK, Singh RK, Variar M. 2009. A new protocol for on-farm production method of arbuscular mycorrhizal fungal mass inoculum for rainfed upland rice. *Indian Phytopath Journal*. **62**(1): 31-36.

Maiti D. 2015. Improving Phosphorus Nutrition of Upland Rice through Native Arbuscular Mycorrhiza (AM) (Editorial), *Rice Research*: Open Access (Special Issue: Recent Advances in Rice Nutrition and Chemistry, **3**(3): e115 (On line), DOI: 10.4172/2375-4338.1000e115.

Mandal NP. 2015. Rice Breeding for Stress Environment of Upland Plateau in India. *SATSA Mukhapatra* - Annual Technical Issue. **19**: 59-68.

Manohara KK, Chattopadhyay K, Marndi BC, Singh ON and Singh NP. 2015. Korgut (IC0599689; INGR 14055), a Rice (*Oryza sativa* L.) germplasm tolerant (SES score 3) to salinity stress (EC=12 dS/m) at seedling stage. *Indian Journal of Plant Genetic Resources*. **28**(3): 356-370.

Meena BP, Kumar Ashok, Lal B, Sinha NK, Tiwari PK, Dotaniya ML, Jat NK, Meena VD. 2015. Soil microbial, chemical properties and crop productivity as affected by organic manure application in popcorn (*Zea mays* L. var. everta). *African Journal of Microbiology Research*. **9**(21): 1402-1408.

Mithra S VA, Kar MK, Mohapatra T, Robin S, Sarla N, Seshashayee, Singh K, Singh A K, Singh N K and Sharma R P. 2016. DBT propelled national effort in creating mutant resource for functional genomics in rice. *Current Science*. **110**(4): 543-548.

Mohanta RK, Garg AK, Dass RS and Behera SK. 2016. Effect of different sources of arsenic on intake and utilization of nutrients and growth performance in guinea pigs. *Indian Journal of Animal Nutrition*. **33** (1): 86-91.

Mondal B, Loganandhan N, Reddy KK and Channabasappa K. 2015. Decomposition analysis of output change under watershed management interventions in semi-arid regions. *Indian Journal of Soil Conservation*. **43**(1): 110-114.

Mondal B, Singh A, Sekar I, Sinha MK, Kumar S and Ramajayam D. 2015. Institutional arrangements for watershed development programmes in Bundelkhand region of Madhya Pradesh, India: an explorative study. *International Journal of Water Resources Development*. DOI:10.1080/ 07900627.2015.1060195.

Mukherjee AK, Mukherjee PK and Kranthi S. 2015. Identification of Sclerotium delphinii causing seedling rot in cotton. *Journal of Plant Pathology*. **97** (2):303-305 .

Munda S, Nayak AK, Mishra P, Bhattacharyya P, Mohanty S, Kumar A, Kumar U, Baig MJ, Tripathi R, Mohammad Shahid, Adak T and Thilagam K. 2015. Combined application of rice husk biochar and fly ash improved the yield of low land rice. *Soil Research*. **54** (4): 451-459.

Munda S, Shivakumar BG, Rana DS, Gangaiah B, Manjaiah KM, Dass A, Layak J, Lakshman K. 2016. Inorganic phosphorus along with biofertilizers improves profitability and sustainability in soybean (*Glycine max*)-potato (*Solanum tuberosum*) cropping system. *Journal of the Saudi Society of Agricultural Sciences*. DOI: 10.1016/j.jssas.2016.01.008.

Nair SA, Sangama, Raghupathi HB, Panneerselvam P. 2015. Influence of substrates and nutrient levels on production and quality of cut foliage in Leather Leaf Ferns (*Rumohra adiantiformis*). *Vegetos*. **28**(3): 20-26.

Narain A, Kar MK, Kalaiperumal V, Sen P. 2016. Development of monosomic alien addition lines from the wild rice (*Oryza brachyantha* A. Chev. etRoehr.) for introgression of yellow stem borer (*Scirpophagaincertulas* Walker.) resistance into cultivated rice (*Oryza sativa* L.). *Euphytica* Online publication.

Naskar B, Modak R, Sikdar Y, Maiti DK, Banik A, Dangar TK, Mukhopadhyay S, Mandal D, Goswami S. 2015. A simple Schiff base molecular logic gate for detection of Zn2+ in water and its bio-imaging application in plant system. *Journal of Photochemistry and Photobiology A: Chemistry*. DOI: org/10.1016/ j.jphotochem.2016.01.022

Panda BB, Badoghar AK, Das K, Panigrahi R, Kariali E, Das SR, Dash SK, Shaw BP, Mohapatra PK. 2015. Compact panicle architecture is detrimental for growth as well as sucrose synthase activity of developing rice kernels. *Functional Plant Biology*. **42**(9) 875-887. http://dx.doi.org/10.1071/FP14363.

Pandit E, Mohanty DP, Barik SR, Mohanty SP, Sikder N, Chakraborty S, Bhattacharya J, Ghosh SK, Singh ON and Pradhan SK. 2015. PCR-based diagnostic protocol for *orfB* gene containing transgenic nuclear male sterile rice lines. *Oryza*. **52**(4):248-252

Patnaik A, Roy PS, Rao GJN, Patnaik SSC and Sharma SG. 2015. Genetic enhancement of Dubraj, a specialty rice through pedigree approach employing marker based selection for plant stature, aroma and grain quality. *Euphytica* DOI: 10.1007/s10681-015-1382-7.

Patra BC, Jambhulkar NN and Mohapatra T. 2015. Development of a mini-core of rice germplasm. *Ecology, Environment and Conservation*. **21** (Suppl.) pp. S273 - S280.

Pokhare SS, Berliner J, Adak T, Kumar U, Mukherjee A. 2015. Entomopathogenic Nematodes: Insect biocontrol agents. *Indian Farming*. 65 **(9)**:20-23.

Prabhukarthikeyan SR and Raguchander T. 2016. Antifungal metabolites of *Pseudomonas fluorescens* against *Pythium aphanidermatum*. *Journal of Pure and Applied Microbiology*, **10**(1): 579-584.

Pradhan SK, Nayak DK, Guru M, Pandit E, Das Sujata, Barik SR, Mohanty SP, Anandan A. 2015. Screening and classification of genotypes for seedling stage chilling stress tolerance in rice and validation of the trait using SSR markers. *Plant genetic Resources; Characterization and utilization*. **15**:46 DOI: 10.1017/ S1479262115000192.

Pradhan SK, Nayak DK, Mohanty S, Behera L, Barik S, Pandit E, Lenka S and Anand A. 2015.

Pyramiding of three bacterial blight resistance in deep water rice variety Jalamanga. *Rice*. DOI: 10.1186/s 12289-015-8.

Pradhan SK, Nayak DK, Pandit E, Anandan A, Mukherjee AK, Lenka S, Behera, L and Barik DP. 2016. Incorporation of bacterial blight resistance genes into lowland rice cultivar through marker-assisted backcross breeding. *Phytopathology*. DOI: 10.1094/PHYTO-09-15-0226-R.

Pradhan, SK, Nayak DK, Pandit E, Barik SR, Mohanty SP, AnandanA and Reddy JN. 2015. Validation of bacterial blight resistance and characterization for morphological and quality traits of three gene pyramided rice genotypes. *Australian Journal of Crop Science*. **9**(2):127-134.

Prasanna R, Babu S, Bidyarani S, Kumar A, Triveni S, Monga D, Mukherjee AK, Kranthi S, Gokte-Narkhedkar N, Adak A, Yadav K, Nain L and Saxena AK. 2015. Prospecting cyanobacteria-fortified composts as plant growth promoting and biocontrol agents in cotton. *Experimental Agriculture*. **51**:42-65. DOI:10.1017/s0014479714000143.ISI IF=1.079.

Raghu S, Benagi VI and Nargund VB. 2016. Cultural, Morphological and pathogenic variability among the isolates of *Fusarium solani* causing wilt disease of chilli (*Capsicum annuum* L.) *Journal of Pure and Applied Microbiology*. **10** (1): 599-603

Raja R, Nayak AK, Shukla AK, Rao KS, Gautam P, Lal B, Tripathi R, Shahid M, Panda BB, Kumar A, Bhattacharyya P, Bardhan G, Gupta S, Patra DK. 2015. Impairment of soil health due to fly ash-fugitive dust deposition from coal fired thermal power plants. *Environmental Monitoring and Assessment*. **187**:679 (1–18). DOI: 10.1007/s10661-015-4902.

Rath PC, Chakraborty K, Nandi P and Moitra MN. 2015. Field efficacy of some new insecticides against rice stem borer and gundhi bug in irrigated rice ecology. *International Journal of Plant, Animal and Environmental Science*. **5**(2): 94-96.

Rath PC, Lenka S, Mohapatra SD and Jena M. 2014. Field evaluation of selected insecticides against insect pests of wet season transplanted rice. *Oryza*. **51**(4):324- 326.

Rautaray SK, Verma OP and Satapathy, BS 2015. Rice (*Oryza sativa*) - based system intensification in north-eastern India: Effect on yield, economics and soil properities. *Indian Journal of Agronomy*. **60**:20-24

Ray S, Bose LK, Ray J, Ngangkham U, Katara JL, Samantaray S, Behera L, Anumalla M, Singh ON, Chen M, Wing RA, Mohapatra T. 2016. Development and validation of cross-transferable and polymorphic DNA markers for detecting alien genome introgression in *Oryza sativa* from *Oryza brachyantha*. *Molecular Genetics and Genomics*. DOI: 10.1007/s00438-016-1214-z.

Ray S, Vijayan J and Sarkar RK. 2016. Germination Stage Oxygen Deficiency (GSOD): An emerging stress in the era of changing trends in climate and rice cultivation practice. *Frontier in. Plant Science*. **7**:671. DOI: 10.3389/fpls.2016.00671.

Rout M, Behera SK and Mohanta RK. 2014. Hypersensitivity reactions: the fulcrum of immunopathology. *Journal of Immunology and Immunopathology*. **16**: 20-32.

Roy Anirban, Bag Manas Kumar, Gautam NK. 2015. Blackgram germplasm resistant to Mungbean Yellow Mosaic Virus. *Virus Research News*. **4**(1): 1

Roy Pritesh S, Barada Baisakhi, Patnaik SSC, Rao GJN and Patnaik Ashok. 2015. Assessment of genetic diversity and DNA fingerprinting of aromatic rice varieties released by National Rice Research Institute (NRRI) IOSR *Journal of Agriculture and Veterinary Science*. **8**(12): 16-20

Roy PS, Patnaik SSC, Patnaik A, Rao GJN and Singh ON. 2015. CR Dhan 407, a high yielding rice cultivar released for the rainfed shallow lowland ecology of eastern India. *Crop Breeding and Applied Biotechnology*. **15**: 120-124.

Saha S, Munda S, Adak T. 2016. Efficacy of azimsulfuron against complex weed flora in transplanted rice (*Oryza sativa*) under rainfed shallow lowland. *Indian Journal of Agricultural Sciences*. **86**(2): 186-91.

Sahoo B, Dangar TK. 2015. Characterization and optimization of preservation of slant cultures of some entomopathogenic fungi of rice pests. *Biopesticides International*. **11**: 39-47.

Sahoo S, Adak T, Bagchi TB, Kumar U, Munda S, Saha S, Berliner J, Jena M, Mishra BB. 2016. Non-target effects of pretilachlor on microbial properties in tropical rice soil. *Environmental Science and Pollution Research*. DOI: 10.1007/s11356-015-6026-x.

Samal R, Roy PS, Dash AK, Rao Gundimeda Jwala Narsimha, Bharathkumar Srinivasan, Subudhi HN and Reddy JN. 2016. Genetic diversity in the rice landraces (*Oryza sativa* L.) of coastal Sundarbans (India) and their adaptation to the local saline condition investigated both at molecular and physiological level. *Acta Physiologia Plantarum*. **38**: 1-10.

Sarao PS, Sahi Gurpreet K, Neelam Kumari, Mangat Gurjit S, Patra BC and Singh Kuldeep. 2016. Donors for Resistance to Brown Planthopper *Nilaparvatalugens* (Stål) from Wild Rice Species. *Rice Science*, Elsevier. **23**(4): 1-6.

Sarkar RK, Ray A. 2016. Submergence-tolerant rice withstands complete submergence even in saline water: Probing through chlorophyll a fluorescence induction O-J-I-P transients. *Photosynthetica*. **54**: 275-287.

Satapathy BS, Singh T, Pun KB and Rautaray SK 2015. Evaluation of rice (*Oryza sativa*) under double transplanting in rainfed lowland rice ecosystem of Asom. *Indian Journal of Agronomy*. **60**: 245-248

Sethi AB, Dhua U, Dhua S, Mukherjee AK, Jena M, Gopalan S, Panda C. 2015. Molecular identification of seed borne non–sporulating endophytic mycobiota of rice landraces and its impact on soil borne rice pathogens. *Oryza*. **52**(3): 190-195.

Shahid M, Shukla AK, Bhattacharyya P, Tripathi R, Mohanty S, Kumar A, Lal B, Gautam P, Raja R, BB Panda, Das B, Nayak AK. 2016. Micronutrients (Fe, Mn, Zn and Cu) balance under long-term application of fertilizer and manure in a tropical rice-rice system. *Journal of Soils and Sediments*. **16**: 737-747.

Sharma SK, Vignesh Kumar P, Swapna Geetanjali A, Pun KB, Baranwal VK. 2015. Subpopulation level variation of banana streak viruses in India and common evolution of banana and sugarcane badnaviruses. *Virus Genes*. **50**: 450-465.

Singh BK, Chopra RC, Rai SN, Verma MP and Mohanta RK. 2015. Nutritional evaluation of seaweed on nutrient digestibility, nitrogen balance, milk production and composition in Sahiwal cows. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences*, 1-7. DOI: 10.1007/s40011-015-0616-8.

Singh BK, Chopra RC, Rai SN, Verma MP and Mohanta RK. 2016. Effect of feeding seaweed as mineral source on mineral metabolism, blood and milk mineral profile in cows. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences*. 86: 89-95.

Singh R, Singh Y, Xalaxo S, Verulkar S, Yadav N, Singh S, Singh N, Prasad KSN, Kondayya K, Rao PV Ramana, Girija Rani M, Anuradha T, Suraynarayana Y, Sharma PC, Krishnamurthy SL, Sharma SK, Dwivedi JL, Singh AK, Singh PK, Nilanjay, Singh NK, Kumar Rajesh, Chetia SK, Ahmad T, Rai M, Perraju P, Pande Anita, Singh DN, Mandal NP, Reddy JN, Singh ON, Katara JL, Marandi B, Swain P, Sarkar RK, Singh DP, Mohapatra T, Padmawathi G, Ram T, Kathiresan RM, Paramsivam K, Nadarajan S, Thirumeni S, Nagarajan M, Singh AK, Vikram Prashant, Kumar A, Septiningshih E, Singh US, Ismail AM, Mackill D and Singh NK. 2016. From QTL to variety-harnessing the benefits of QTLs for drought, flood and salt tolerance in mega rice varieties of India through a multi-institutional network. *Plant Science*. 242: 278–287.

Singh T, Pun KB, Satapathy BS, Saikia K and Lenka S. 2015. Incremental yield and returns from rice variety Naveen in front line demonstrations-an analysis. *Oryza*. **52** (1): 59-64.

Singh T, Soni RL, Singh R and Dave R 2016. Integrated farming system approach for tribal farmers of southern Rajasthan. *Indian Farming*. **65**(10): 20-23

Sreenivas AG, Nadagoud S, Hanchinal SG, Bheemanna M, Naganagoud N, Patil NB. 2015. Management of sucking insect pest complex of

Bt cotton by using dinotefuran – A 3rd generation neonicotinoid molecule. *Journal of Cotton Research and Development*. **29** (1): 90-93.

Swain P, Mall AK, Singh ON, and Baig MJ. 2014. Yield response of rice (*Oryza sativa* L.) genotypes to vegetative stage drought in dry season adapted to drought prone rainfed upland. *International Journal of Agricultural and Statistical Sciences*. **10** (1): 33-39.

Tarai RK, Behera SK, Beura JK, Sahoo TR and Mohapatra KC. 2014. Performance of tomato genotypes in the western undulating zone of India. *International Journal of Farm Sciences*. **4**(4): 83-90.

Tarai RK, Panda PK, Behera SK, Beura JK, Mohapatra KC and Sahoo TR. 2015. Varietal performance of onion in the western undulating zone of Odisha. *International Journal of Scientific Research and Engineering Studies*. **2**(1), January 2015.

Tarai RK, Sahoo TR and Behera SK. 2016. Integrated farming system for enhancing income, profitability and employment opportunities. *International Journal of Farm Sciences*. **6**(2): 231-239.

Toppo NN, Jambhulkar NN, Nitin M, Srivastava AK and Maiti D. 2016. On-farm production of vermiculite based indigenous AM fungus inoculum for improved Phosphorus nutrition in upland rice. *Ecology, Environment and Conservation*. **22**(1): 203-211.

Tripathi R, Nayak AK, Shahid M, Nayak D, Puree C, Mohanty S, Raja R, Lal B, Gautam P, Bhattacharyya P, Panda BB, Kumar A, Jambhulkar NN, Nayak AK. 2016. Soil quality in mangrove ecosystem deteriorates due to rice cultivation. *Ecological Engineering*. **90**: 163-169.

Tripathi R, Nayak AK, Shahid M, Lal B, Gautam Priyanka, Raja R, Mohanty S, Kumar A., Panda BB and Sahoo RN. 2015. Delineation of soil management zones for a rice cultivated area in eastern India using fuzzy clustering. *Catena*. **133**: 128–136.

Tripathi R, Nayak AK, Shahid M, Raja R, Panda BB, Mohanty S, Kumar A, Lal B, Gautam P and Sahoo RN. 2015. Characterizing spatial variability of soil properties in salt affected coastal India using geostatistics and kriging. *Arabian Journal of Geosciences*. DOI: 10.1007/s12517-015-2003-4.

Upreti, KK, Bhatt RM, Panneerselvam P, Varalakshmi LR. 2015. Morpho-physiological responses of grape rootstock 'Dogridge' to Arbuscular Mycorrhizal Fungi inoculation under salinity stress. *International Journal of Fruit Science*. **16**(2): 191-209.

Research Note

Dangar TK and Kumar U. 2015. Endophytic and epiphytic microbial community in phytonic parts of three cultivated (*Oryza sativa* L.) and one wild rice (*Oryza echengiri*). *NRRI Newsletter*. **36**(3): 13-14.

Dangar TK and Kumar U. 2015. Identification of cry genes of rhizoplanic *B. thuringiensis* by PCR amplification. *NRRI Newsletter*. **36**(2): 17.

Jambulkar NN, Rath PC, Jena M, Marandi BC, Subudhi HN, Pattnaik A. 2015. Database on WBPH Screening : A total of 1864 genotypes have been screened against WBPH in control condition during 2004-2013 and database has been developed. *NRRI News letter* July-Sept.36(3), pp17-18.

Kumar U and Dangar TK. 2015. Characterization of salt-tolerant diazotrophs from rhizosphere of diverse rice ecology. *NRRI Newsletter*. **36**(1): 17.

Lenka S, Bose LK, Mukherjee AK and Dhua U. 2015. Screening of accessions of wild rice, *Oryza rufipogon* for sheath blight resistance/tolerance. *CRRI Newsletter*. **36**(2):20.

Yadav MK, Aravindan S, Mukherjee AK and Bag MK. 2016. Validation of Previously Identified Resistance Accession/varieties for Leaf Blast Resistance in the Uniform Blast Nursery. *NRRI newsletter*. **36** (4): 13.

Popular Articles

Anandan A, Pradhan SK and Singh ON. 2015. Aerobic rice cultivation reduces water usage, *The Hindu*, Agri-Business, 14 September 2015.

Chourasia M, Prasad SM, Sarangi DR, Sethy S and Mohanta RK. 2015. Hanikarak Kharpatbar-gajarghasa (Harmful weeds: Parthenium). *Dhan*. **1**(2): 22.

Ghritlahre SK, Yadav MK and Aravindan S. 2015. Arsenic Biomagnifications in Rice Grain and Its Adverse Health Effect on Rice Consumers. Pop. *Kheti*. **3**(3): 157-161.

Jena M. 2015. ବର୍ଷାଦିନିଆ ଧାନ ଫସଲରେ ରୋଗ ପୋକ ନିୟନ୍ତ୍ରଣ (Insect pests and disease management in wet season rice), *The Samaj* (8 August 2015), Odia daily newspaper. **86**(216), pp. 18.

Kar MK. 2015. ଅଧିକ ଉତ୍ପାଦନକ୍ଷମ ଧାନ କିସମ ଓ ଏହାର ଗୁଣବତ୍ତା (The characteristics of high yielding varities of rice).*The Samaj*, 2 September 2015. p.18.

Kumar U. 2015. अजोला : एक अनोखा फर्न (Azolla: A wonderful fern). *Dhan*. **1**(1):14.

Kumar U. 2015. धान की ख़ेती में जैव उर्वरक का उपयोग (*Use of bio-fertilizer in rice farming*). *Dhan*. **1**(2): 30-31.

Lenka S, Pradhan SK, Rath PC and Dash SK. 2015. କୃଷି କ୍ଷେତ୍ରରେ ରାସାୟନିକ କୀଟନାଶକ ଔଷଧ ପ୍ରୟୋଗ ବେଳେ ସାବଧାନତା (Precautionary measures to be taken during application of pesticides in agriculture fields). *Krushak Sambad*. **2**: 7-8.

Lenka S. (2015). *"ଧାନ ଫସଲର କ୍ଷତିକାରୀ ରୋଗ ଓ ଏହାର ନିୟନ୍ତ୍ରଣ"* (Harm diseases of rice and their integrated management). *Krushak Sambad*. **10**: 1,12.

Mohanta RK and Behera SK. 2016. *"ଗୋପାଳନରେ ଥିବା ମୁଖ୍ୟ ସମସ୍ୟା ଓ ତାର ସମାଧାନ"* (Major problems of livestock rearing and their solutions). *Prani Bikas Dhara*. **1**(1): 17-18.

Mohanta RK and Sahoo B. 2015. " ସ୍ୱଚ୍ଛ ଦୁଗ୍ଧ ଉତ୍ପାଦନ କୌଶଳ" (Clean milk production technology). *Krushakbandhu Annapurna*. **XXIII** (12): 30-31.

Mohanta RK, Sarangi DR and Sethy S. 2015." ପାରିବାରିକ କୃଷି କ୍ଷେତ୍ରରେ କୃଷି ବିଜ୍ଞାନ କେନ୍ଦ୍ରର ଭୂମିକା" (Role of Krishi Vigyan Kendra in family farming). *Krushakbandhu Annapurna*. **XXIII**: 25.

Munda S, Saha S, Adak T and Kumar U. 2015. Prospects of Mycoherbicides. *Indian Farming*. **64** (11): 23- 24.

Pokhare SS, Berliner J, Adak T, Kumar U, Mukherjee A. 2015. Entomopathogenic Nematodes: Insect biocontrol agents. *Indian Farming*. **65** (9): 20-23.

Prasad SM, Chourasia M, Sarangi DR, Sethy S and Mohanta RK. 2015. जिवाणु खाद खेति के लिए जरूरी (Vermicompost: necessity for crop cultivation). *Dhan*. **1**(2): 25-26.

Rath PC. 2015. ପରଜୀବୀ ଦ୍ୱାରା ଖରିଫ୍ ଧାନ ଫସଲରେ ପୋକ ନିୟନ୍ତ୍ରଣ (Control of insect in *kharif* rice by insect parasite), *The Dhwani Pratidhwani* (26 August 2015), Odia daily news paper. **24** (221), pp. 4.

Roy Anirban, Bag MK, Gautam NK. 2015. Blackgram germplasm resistant to Mungbean Yellow Mosaic Virus. *Virus Research News*. **4**(1): 1.

Saha S and Ghosh D. 2015. Weedy rice – A serious threat for sustaining rice farming in India. *Indain Farming*. **64**(10): 16-19, 24.

Saha Sanjoy and Poonam A. 2016. Wet direct-sown rice: A viable and economic strategy for summer rice. *Indain Farming*. **65**(9): 15-19.

Sethy S, Prasad SM, Sarangi DR, Chourasia M and Mohanta RK. 2015. तुडाइ उपरान्त सब्जीयोंका प्रबंधन (Postharvest processing of vegetables). *Dhan* **1**(2): 25-26.

Sethy S. 2016. Food fortification: a novel attempt to combat micronutrient deficiency. *Science Horizon*. **6** (1): 30-33.

Singh ON and Samal P. 2015. National Rice Research Institute in the service of mankind *in* Handbook of 5th Global Economic Summit, pp. 36-40.

Singh T, 2015. Mridaurvaratakotikaubanayerakhne men sahayakharikhad. *KisanKheti*. **2** (1): 72-76.

Swain P, Samantaray S, Kar MK, Das L, Bag MK and Shahid Md. 2016. Agriculture: The Cutting Edge of Innovations and Developments. Popular Article published on the eve of Agriculture Education Day (18 January, 2016) by the Director, ICAR-NRRI, Cuttack.

Yadav MK, Aravindan S, Ghritlahre SK, Adak T and Berliner J. 2015. Induced systemic resistance and plant responses to fungal biocontrol agents. *Kheti*. **3**(2): 63-67.

Yadav MK, Aravindan S, Lal B, Gautam P and Ghritlahre SK. 2015. Mycoviruses: An introduction to potential biocontrol agents. *Kheti*. **3**(2): 68-70.

Yadav MK, Aravindan S, Mukherjee AK, Bag MK and

Lenka S. 2015. Sheath rot:emerging threat to rice production. Published in *Every man's Science*. 286-288.

Yadav MK, Aravindan S, Mukherjee AK, Bag MK and Lenka S. 2015. Viral diseases of soybean. *Kheti*. **3**(3): 138-143.

Papers presented in Workshop/ Seminars/ Symposia/ Conferences

Anandan A. 2015. Genetic diversity and maternal lineage among early maturing genotypes of *Indica* and *Japonica*. In: International Rice Symposium 2015 on Rice Science for global food and nutritional security, Hyderabad, India, 18-20 November, 2015, p. 235.

Anandan A. 2015. Image based phenotyping for early seedling vigour in rice by non-destructive method. In: International symposium on Biodiversity, Agriculture, Environment and Forestry, Tamil Nadu, India, 11-12 December, 2015, p. 43.

Anandan A. 2016. Differential responses of rice genotypes and physiological mechanism under different level of water. In: National Symposium on Innovations in Coastal Agriculture – Current Status and Potential under Changing Environment, Bhubaneswar, Odisha, 14-17 January, 2016, p. 143.

Anandan A. 2016. Genetic diversity, population structure and trait association analysis in rice germplasm for early seedling vigour using trait linked SSR markers. In: National Seminar on Plant Genomics and Biotechnology: Challenges and Opportunities in 21st Century, Bhubaneswar, India, 23-24 January, 2016, p. 92.

Anantha MS, Kumar Yogesh, Mandal NP, Dash SK and Variar M. 2015. Performance of new plant type rice genotypes under drought prone shallow lowlands in Jharkhand and their reaction to leaf blast and brown spot diseases. In: International Rice Symposium 2015, “Rice Science for Global Food and Nutritional Security”, Hyderabad, India, 18-20 November, 2015.

Bag M, Prasad TV, Singh R, Roy Anirban. 2016. Evaluation of Rapeseed-Mustard germplasm provide evidences of specific adaptation of Croton Yellow Vein Mosaic Virus in new host: A new threats to oilseed production. In: National Seminar on 'Plant Genomics and Biotechnology: Challenges and Opportunities in 21st Century', OUAT, Bhubaneswar, India, 23-24 January, 2015.

Bag MK, Mukherjee A, Yadav M. 2015. Post flowering diseases of rice: potential threat to rice production. In: International Rice Symposium on 'Rice Science for Global Food and Nutritional Security', Hyderabad, India, 18-20 November, p.575.

Bag MK, Mukherjee AK, Jena M. 2016. Impact of false smut [*Ustilaginoidea virens* (Cooke.) Tak.] disease on rice seed health. In: 6th International Conference on 'Plant, Pathogens and People', NAAS Complex, New Delhi, India, 23-27 February, 2016. P.61.

Bag MK, Mukherjee AK. 2016. Pathogenic diversity of post flowering diseases of rice and its impact on the product: A case study on false smut. In: National Symposium on 'Microbial Diversity and Its Impact', Kolkata, India, 18-19 February, p.35.

Bag MK, Prasad TV, Goutam NK, Ray A. 2016. Evaluation of Plant Genetic Resources: Identification of resistant black gram germplasm. In National Symposium on 'Microbial Diversity and Its Impact', Kolkata, India, 18-19 February.

Bag MK, Yadav M, Mukherjee AK, Jena M. 2016. Changing rice disease scenario: impact of post flowering diseases and its management. In: 11th National Symposium on 'Innovations in Coastal Agriculture – Current Status and Potentials under Changing Environment', Bhubaneswar, India, 14-17 January, p. 121.

Bagchi TB, Sanghamitra P and Sharma S G. 2015. Seasonal variations of pigmented rice in terms of pigmentation, nutrition and agronomic characters. International Rice Symposium, Hyderabad. p. 656.

Behera SP, Swain H, Bagchi TB, and Mukherjee AK 2015. Evaluation of *Trichoderma spp*. isolated from rice rhizosphere for management of rice

diseases and growth promotion. International Rice Symposium-2015, Hyderabad, India, 18-20 November.

Bose LK, Jambhulkar NN, Jena M, Mohapatra SD, Roy S and Singh ON. 2015. Broadening genetic base of rice against major pest through wide hybridization. In: International Rice Symposium on 'Rice Science for Global Food and Nutritional Security' Hyderabad, India, 18-20 November, p. 190.

Dash GK, Debata AK, Baig MJ and Swain P. 2015. Differential response of rice genotypes towards transpiration efficiency under drought. In: International Rice Symposium on "Rice Science for Global Food and Nutritional Security". Hyderabad, India,18-20 November, p. 238.

Gitishree Das, Rao GJN, Kar MK, Prasad D, Das, KM, Reddy JN, Marndi BC, Variar M and Prakash A. 2015. Marker assisted genetic stacking in Lalat to confer resistance/tolerance against different biotic and abiotic stresses. In: International Rice Symposium on "Rice Science for Global Food and Nutritional Security", Hyderabad, India, 18-20 November, p.32.

Jambhulkar NN. 2015. Modeling and Forecasting of Rice Production in Punjab' in an International Rice Symposium 2015 on 'Rice Science for Global Food and Nutritional Security' organized by DRR, Hyderabad from 18-20th November.

Kar MK, Bal A, Swain A, Mishra R, Mahender A, Mohanty SK, Mukherjee A, Behera L and Rao GJN. 2015. Molecular and *insilico* approaches for mapping of resistance to Rice Tungro Disease. Page 52. In Compendium of Abstracts, International Rice Symposium on "Rice Science for Global Food and Nutritional Security" held at Hyderabad, India during November 18-20, 2015.

Katara JL, Verma RL, Nayek D, Parida M, Ngangkham U, Ray S, Behera L, Samantaray S, Rao RN, Singh ON, Mohapatra T. 2015. "Parental line improvement of hybrid rice: Integration of sub1 andsaltol genes into maintainer line (CRMS 32B)". In: International Rice symposium, Hyderabad, India, 18-20 November, 2015.

Lenka S, Bose LK and Mukherjee AK. 2015. Screening of wild rice accessions of *Oryza rufipogon* for resistance against sheath blight pathogen, *Rhizoctonia solani* Kuhn. In: International Rice Symposium, 2015 held in ICAR-IIRR, Rajendranagar, Hyderabad from 18-20 November, 2015

Lenka S. 2015. Field efficacy of bio-control agents for eco-friendly management of sheath blight in rice caused by *Rhizoctonia solani* Kuhn. In the 6th IPS International Conference held in NASC complex (ICAR), New Delhi from 23-27 February, 2016.

Maiti D, Toppo NN, Kumar B, Singh CV & Variar M. 2015. Amending phosphorus nutrition of rainfed rice by exploiting ecosystem services of native *arbuscular mycorrhizal* fungi: a climate resilient technology, pp. 63, In: Compendium of Abstracts: International Rice Symposium – 2015, Hyderabad, India, 18-20 November, p. 641.

Maiti D, Toppo NN, Nitin M & Kumar B. 2016. Native Arbuscular Mycorrhizal fungi: a boon for direct seeded rice (DSR) under rainfed ecology, pp. 175-176, In: Proc. 6th Inter. Conf. "Plant, Pathoged and People: Challenges in Pl Pathology to benefit Humankind", 23-27 Feb., New Delhi, 621 p.

Mandal NP, Imam Jahangir, Anupam Alpana and Variar Mukund. 2015. Multiple introgression of a major QTL/gene for improvement of drought and blast resistance in upland rice variety Vandana. In Proc. Int. Rice Symposium 2015, "Rice Science for Global Food and Nutritional Security" held at IIRR, Hyderabad, 18-20 Nov.

Mohapatra S, Pokhare SS, Berliner J, Adak T, Kumar U, Mukherjee AK and Jena M. 2016. Valuation of fluorescent pseudomands for biocontrol potential against rice nematodes and pathogens and their plant growth promotion. National seminar on "Plant Genomics and biotechnology: challenges and opportunities in 21st century" Bhubaneswar, Odisha on 23-24 January. p. 132

Mukherjee AK, Swain H, Behera SP, Adak T, Bagchi TB, Bhattachrayya P, Jena M, Dhua U. 2015.

Utilization of *Trichoderma* diversity isolated from above ground sources for rice health management. In: International Symposium of Biodiversity, Agriculture, Environment and Forestry, Tamil Nadu, India, 11-12 December, 2015, p. 61.

Mukherjee AK. 2015. Polymerase chain reaction based molecular markers for assessment of genetic diversity in forest trees and horticultural crops. In: International Symposium on Biodiversity, Agriculture, Environment and Forestry, Tamil Nadu, India, 11- 12 December.

Mukherjee AK. 2016. Application of polymerase chain reaction based molecular diagnosis for identification of disease free plants. In: National seminar on plant genomics and biotechnology, Challenges and Opportunity in 21st Century, Bhubaneswar, India, 23-24 January, 2016.

Munda S, Saha S and Adak T. 2016. Grain characteristics and yield performance of rice in response to rice-weedy rice competition. *In:* Proceedings of National symposium of Indian Society of Coastal Agricultural Research on"Innovations in Coastal Agriculture-Current Status and Potentials under Changing Environment", Bhubaneswar, Odisha, 14-17 January: 106-107.

Nayak N, Rout PT, Verma RL, Ngangkham U, Ray S, Behera L, Singh ON, Samantaray S. 2015. "Generation of doubled haploids from an elite rice hybrid (BS6444G): Characterization for BLB resistance and aroma". In: International Rice symposium, Hyderabad, India, 18-20 November.

Patra BC, Saha S and Singh ON. 2015. Weedy rice – a natural process of germplasm enhancement. Abstract in International Rice Symposium, Hyderabad, India, 18-20 November: 388.

Patra BC. 2015. Promoting indigenous and climate resilient varieties for sustaining productivity in rice. Invited talk at 2nd Odisha Biodiversity Congress-2015 held at Saraswati SishuVidyamandir, Paradeep on 27 December.

Ray S, Ray V, Bose LK, Singh ON and Mohapatra T. 2015. Development and validation of cross-transferable and polymorphic DNA markers for detecting alien genome introgression in *Oryza asativa* from *Oryza brachyantha*. In: National Seminar on Resource Based Inclusive Agriculture and Rural Development: Opportunities and Challenges. Kolakata, India, 15-17 January, 2015.

Saha S, Munda S, Patra BC, Adak T and Singh S. 2015. Management of weeds in dry-seeded and aerobic rice systems. In: 25th Asian-Pacific Weed Science Society Conference on "Weed Science for Sustainable Agriculture, Environment and Biodiversity", Hyderabad, India, 13-16 October, p. 52.

Samal P. 2015. Global Rice Trade: Policies and Perspectives. In: International Rice Symposium 2015, Hyderabad, India, 18-20 November.

Samal P. 2015. National Rice Research Institute in the service of mankind. In: 5th Global Economic Summit, Mumbai, India, 21 November.

Sarkar RK, Roy A, Chattopadhyay K, Gayen S. 2016. Genetic diversity and climate resilient rice. In: National seminar on 'Resource based inclusive agriculture & rural development: Opportunities & challenges. Kolkata, India, 15-16 January.

Singh T, Pun KB, Satapathy BS, Saikia K and Lenka S. 2015. Economics and gap analysis of rice variety Naveen in front line demonstrations under shallow lowland of Assam. In: International Rice Symposium 2015 on 'Rice Science for Global Food and Nutritional Security', Hyderabad, India, 18-20 November: 610-611.

Swain H, Behera SP, Adak T, Dhua U, Jena M, Bagchi TB, Bhattachrayya P, Mukherjee AK. 2015. Identification and characterization of Trichoderma species as biocontrol agent in effective management of rice diseases. In: National seminar on "Plant Genomics and biotechnology: challenges and opportunities in 21st century", Bhubaneswar, Odisha 23-24 January: 115.

Swain P, Baig MJ, Barik M, Dash GK and Debata, AK. 2015. Effect of different levels of moisture regimes on phenology, growth and yield parameters of rice genotypes. In: International

Rice Symposium on "Rice Science for Global Food and Nutritional Security", Hyderabad, India, 18-20 November: 17.

Training Compendium

Das Lipi, Mishra SK and Sadangi BN. 2014. *Dhan Utpadan ebam Utpadakata ki brudhhi hetu Unnatshil Kheti Prathaen* published during the Trainers' Training Programme organized at ICAR-NRRI, Cuttack during 14-18 May, 2015 sponsored by ATMA, Umaria, Madhya Pradesh, pp. 116.

Das Lipi, Mishra SK and Sadangi BN. 2014. '*Rashtriya Khadya Surakshya ki sthayitwa ke liye Chawal Utpadan Takniki*' published during the Trainers' Training Programme organized at ICAR-NRRI, Cuttack during 3-7 July, 2015 sponsored by ATMA, Valsad, Gujarat, pp. 116.

Das, Lipi, Mishra, SK and Sadangi, BN. 2014. '*Utpadakata main brudhhi ke liye Sydharit Chawal Utpadan Takniki*' published during the Trainers' Training Programme organized at ICAR-NRRI, Cuttack during 13-17 July, 2015 sponsored by ATMA, Patna, Bihar, p.116.

Das Lipi, Mishra SK and Sadangi BN. 2015. *Chawal se Utpadan ebam Aya badhane ki Baigyanik Bidhiyan* published during the Trainers' Training Programme organized at ICAR-NRRI, Cuttack during 5-9 October, 2015 sponsored by ATMA, Katihar, Bihar, p. 105.

Das Lipi, Mishra SK and Sadangi BN. 2015. '*Chawal Utpadan ki Bikshit Taknikon dwara Ajibika main Sudhar*' published during the Trainers' Training Programme organized at ICAR-NRRI, Cuttack during 6-10 September, 2015 sponsored by ATMA, Valsad, Gujarat, p.105.

Das Lipi, Mishra SK and Sadangi BN. 2015. '*Chawal Utpadan tatha Utpadakta Badhane ke liye Kheti Pranaliyan*' published during the Trainers' Training Programme organized at ICAR-NRRI, Cuttack during 15-20 April, 2015 sponsored by ATMA, Bhagalpur, Bihar, p.116.

Das Lipi, Mishra SK and Sadangi BN. 2015. 'Improved Rice Production Technology for sustaining National Food Security' published during the National Level Senior Officers' Training organized at ICAR-NRRI, Cuttack during 30-31 October, 2015 sponsored by DRD, Patna, Bihar under NFSM, p.105.

Das Lipi, Mishra SK and Sadangi BN. 2015. 'Skill Development in Improved Rice Cultivation Practices' published during the Trainers' Training Programme organized at ICAR-NRRI, Cuttack during 25-28 August, 2015 sponsored by ATMA, Kendrapara, Odisha, p.146.

Das Lipi, Mishra SK and Sadangi BN. 2016. '*Adhik Utpadakata ebam Kisano ki Aya mein brudhhi hetu Unnat Chawal Utpadan Pranaliyan*' published during the Trainers' Training Programme organized at ICAR-NRRI, Cuttack during 10-14 March, 2016 sponsored by ATMA, Koderma, Jharkhand, p.105.

Das Lipi, Mishra SK and Sadangi BN. 2016. 'Improved Rice Production Technology for increasing Productivity and Income of Farmers' published during the Trainers' Training Programme organized at ICAR-NRRI, Cuttack during 1-5 March, 2016 sponsored by ATMA, Mayurbhanj, Odisha, p.146.

Das Lipi, Mishra SK and Sadangi BN. 2016. 'Skill Development in Improved Rice Cultivation Practices' published during the Trainers' Training Programme organized at ICAR-NRRI, Cuttack during 25-29 January, 2016 sponsored by ATMA, Mayurbhanj, Odisha, p.146.

Kumar GAK, Sadangi BN, Mondal B and Jambhulkar NN. 2016. Changing methodological paradigm in Extension Research. ICAR-National Rice Research Institute, Cuttack, Odisha, India, p. 262.

Book and Book Chapter

Dash SK, Sahoo KK, Chattopadhyay K, Behera L, Pradhan SK, Molla KA. and Mohapatra, SD. 2016. High Beta-Carotene Rice in Asia: Techniques and Implications. In U. Singh et al. (eds.), *Biofortification of Food Crops*, Springer India, pp. 359-374., DOI 10.1007/978-81-322-2716-8-26.

Imam J, Mandal NP, Variar M and Shukla P. 2016. Advances in molecular mechanism toward understanding plant-microbe interaction: A Study of *M. oryzae* versus rice. In: Pratyoosh

Shukla (ed.) *Frontier Discoveries and Innovations in Interdisciplinary Microbiology*. Springer India, New Delhi. pp. 79-96.

Jambhulkar NN, Lal Krishan, Parsad R and Gupta VK. 2016. Minimum Aberration Fractional Factorial Plans for Multi-Level Experiments. In: Ed. Neeraj Tiwari. *Statistical and Mathematical Sciences and their Applications*. Narosa Publishing House, New Delhi p. 41-73.

Mondal B, Patil SL, Loganandhan N, Reddy KK and Channabasappa K. 2015. Priorities and rationalities in watershed governance: A study of watersheds of the semiarid tropics. In: Raizada *et. al* (Eds.) *Managing Natural Resource in the Dry lands*, Satish Serial Publishing House, Delhi, p. 355-361.

Mondal B, Patil SL, Loganandhan N, Reddy KK and Channabasappa K. 2015. Priorities and rationalities in watershed governance: A study of watersheds of the semi-arid tropics. In: Raizada *et. al*. (Eds.) *ManagingNatural Resource in the Drylands*, Satish Serial Publishing House, Delhi, p. 355-361.

Nayak S and Mukherjee AK. 2015. Management of agricultural wastes using microbial agents. In: RP Singh and A. Sarkar (eds) *Waste Management: Challenges, Threats and Opportunities* (ISBN: 978-1-63482-195-7) Publisher Nova Scientific, USA. Pages: 7x10 - (NBC-C).

Patra BC, Umakant N, Roy S and Mohapatra T. 2015. Rice. In: Mohar Singh and Hari D. Upadhyaya (eds.) *Genetic and Genomic Resources for Grain Cereals Improvement*, Oxford: Academic Press; 2015, p. 1-80.

Singh SK, Mohapatra SD and Duraimurugan P. 2016. Pulses In: C. Shivaraju Mani (ed), *Mealybugs and their Management in Agricultural and Horticultural crops*. DOI 10.1007/978-81-322-2677-2_24

Singh T, Pun KB, Bhagat K, Lal B, Satapathy BS, Sadawarthi MJ, Katara JL, Lenka S and Gautam P.2015. Abiotic stress in rice :mechanism and adaptation. In R.K Pasalu , K.Bhagat and Y. Singh (Eds.) *Challenges and prospectives of plant abiotic stress*, Vol.I, National Institute of Abiotic Stress Management, Baramati, Pune, Maharashtra".

Singh T, Pun KB, Saikia K, Satapathy BS, Bhagat K, Das A and Lal B 2015.Abiotic stress management in rice. In: Rajkhowa DJ, Das A, Ngachan SV, Sikka AK and Lyngdoh M, (Eds.) *Integrated Soil and Water Resource Management for Livelihood and Environmental Security*. Published by ICAR Research Complex for NEH Region, Umiam (Meghalaya), pp. 219-258.

Thirugnakumar S, Anandan A, Ushakumari R and Senthilkumar N. 2015. Objective Genetics. New India publishing agency, New Delhi (ISBN: 9789383305605, 9383305606).

Report

Mohanta RK, Sadangi BN, Sarangi DR and Prasad SM. 2015. Krishi Vigyan Kendra Cuttack. Performance-cum-Impact 2010-15. ICAR-National Rice Research Institute, Cuttack, pp. 1-164.

Technology Bulletin

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 (Odia), *NRRI Technology Bulletin No.108*, Cuttack, India.

Pradhan SK, Barik SR, Meher J, Anandan A, Sadangi BN, Singh ON and Mohapatra T. 2015. Satyabhama-A high yielding drought tolerant upland rice variety, *NRRI Technology Bulletin No.109*, Cuttack, India.

Pradhan SK, Nayak DK, Behera L, Mishra JR, Sadangi BN and Singh ON. 2015. Satyabhama-A high yielding drought tolerant upland rice variety (Odia), *NRRI Technology Bulletin No.110*, Cuttack, India.

Jena M, Adak T, Sahu RK, Pokhare SS and Berliner J. 2015. Integrated management of Brown Plant Hopper (BPH), *NRRI Technology Bulletin No.111*, Cuttack, India.

Jena M, Adak T, Sahu RK, Pokhare SS and Berliner J. 2015. Integrated management of Brown Plant Hopper (Hindi), *NRRI Technology Bulletin No.112*, Cuttack, India.

Jena M, Adak T, Sahu RK, Pokhare SS and Berliner J. 2015. Integrated management of Brown Plant Hopper (Odia), *NRRI Technology Bulletin No.113*, Cuttack, India.

Verma RL, Katara JL, Samantaray Sanghamitra, Patra BC, Sahu RK, Pattnaik SSC, Singh SP, Poonam Annie, Hembram Baidnath, Rao RN, Singh ON and Mohapatra T. 2015. A practical guide for successful hybrid seed production in rice: A profitable venture. *NRRI Technology Bulletin No. 114.* Cuttack, India.

Mukherjee AK, Jena M., Gayen S., Chattopadhya K, Dhua U. and Sarkar RK. 2015. Dhaner mukhya rog-poka daman (Bengali). *NRRI Technology Bulletin No. 115*. Cuttack, India.

Sethy S, Prasad SM, Sarangi DR, Chourasia M, Mohanta RK, Patra BC and Sadangi BN. 2015. ଉଦ୍ଭିଦ କିସମ ଏବଂ କୃଷକ ଅଧିକାର ସଂରକ୍ଷଣ ପ୍ରାଧିକରଣ (Protection of Plant Variety and Farmers' Rights Act). *Technical Bulletin No. 6.* Krishi Vigyan Kendra Cuttack, Santhapur.

Prasad SM, Sethy S, Dash SK, Pradhan SK, Sarangi DR, Chourasia M, Sahoo TR and Mohanta RK. 2015. ଧାନ ଭିତ୍ତିକ ଫସଲ ପର୍ଯ୍ୟାୟରେ ଉନ୍ନତ ପ୍ରଣାଳୀରେ ମୁଗ ଚାଷ (Improved Production Technology of Greengram in Rice based Cropping System) (Odia), *NRRI Technology Bulletin no. 116*, Cuttack, India.

Prasad SM, Sethy S, Dash SK, Pradhan SK, Sarangi DR, Chourasia M, Sahoo TR and Mohanta RK. 2015. ଧାନ ଭିତ୍ତିକ ଫସଲ ପର୍ଯ୍ୟାରେ ଉନ୍ନତ ପ୍ରଣାଳୀରେ ବିରି ଚାଷ (Improved Production Technology of Blackgram in Rice based Cropping System) (Odia), *NRRI Technology Bulletin no 117*. Cuttack, India.

Patnaik A, Rao GJN, Patnaik SSC, Rao KS, Das KM and Jena M. 2016. Geetanjali- A high yielding basmati type aromatic rice variety package of practices. (Odia), *NRRI Technology Bulletin no 118*. Cuttack, India.

Marndi BC, Chattopadhyay K, Singh DP, Saha S, Sen P, Mahato KR, Nayak AK, Kumar Prem Pal and Singh ON. 2016. Luna Sankhi (CR Dhan 405)-A high yielding rice variety for coastal saline areas of Odisha for dry season: package of practices. *NRRI Technology Bulletin no 119*. Cuttack, India.

Swain P, Mohanty S, Bhattacharya P, Baig MJ, Chattopadhyay K, Singh ON and Sarkar RK. 2016. Rice cultivation in rainfed upland and drought prone areas under changed climate. (Hindi), *NRRI Technology Bulletin no 120*. Cuttack, India.

Satapathy BS , Singh T, Pun KB, Saikia K and Lenka S. 2015. Diversified rice-fish horticulture farming system for low land rice ecosystem of North Eastern India. RRLRRS *Technical Bulletin No.6*. Gerua, India.

Extension Bulletin

Chourasia M, Behera KS, Das KM, Prasad SM, Sahoo TR, Sarangi DR and Sethy S. 2015. ଧାନର ପୋକ ଓ ରୋଗ ନିୟନ୍ତ୍ରଣ (Management of rice pests and diseases). *CRRI Extension Bulletin No. 5*, Cuttack, India, p 76.

Extension leaflet/ Technical Bulletin

➢ Mohanta RK, Prasad SM, Sethy S, Sarangi DR, Sahoo TR, and Chourasia M. 2016. ଘର ଅଗଣାରେ ବତକ ପାଳନ *(Backyard duck rearing)*. Technical Bulletin no. 7. Krishi Vigyan Kendra Cuttack, Santhapur.

➢ Sarangi DR, Mohanta RK, Sethy S, Prasad SM, Chourasia M and Nayak AK. 2015.ଅନ୍ତର୍ଜାତୀୟ ମୃତ୍ତିକା ବର୍ଷର ଅନୁଚିନ୍ତା *(Theme of International Year of Soil)*. Krishi Vigyan Kendra Cuttack, Santhapur.

Other Publications

Das Lipi. 2015. Traditional Rice Foods: The Rich Heritage of India. CRRI , Cuttack, India, p 122.

Television and Radio Talks

➢ Dr. PC Rath delivered a radio talk on “ଜୈବିକ ଉପାୟରେ ଧାନ ଫସଲରେ ପୋକ ଦମନ” (Biological control of insect pest of rice) in Pallimancha which was broadcasted by AIR Cuttack on 19 June 2015 at 7.30 PM.

➢ Dr. SD Mohapatra delivered a radio talk on “ଖରିଫ୍ ଧାନ ଫସଲରେ ଜୈବିକ ଉପାୟରେ ପୋକ ଦମନ”

(Biological control of insect pets kharif rice) in Krishi Sansar programme of All India Radio, Cuttack broadcasted on 22 July 2015.

- Dr. RK Mohanta, delivered a talk on "ପରିଷ୍କାର ଦୁଗ୍ଧ ଉତ୍ପାଦନ ପାଇଁ ସାବଧାନତା" on AIR Cuttack broadcasted in Krishi Sansar programme on 16 September 2015.
- Dr. RK Mohanta delivered a talk on "ନିଜ ଅଞ୍ଚଳରେ ମିଳୁଥିବା ଉତ୍ପାଦାନକୁ ନେଇ ସୁଷମ ଖାଦ୍ୟ ପ୍ରସ୍ତୁତି" on AIR Cuttack recorded on 15 December 2015 for Krishi Sansar programme.
- Dr. Yogesh Kumar delivered two radio talks on धान की फसल कटने के बाद पबी दलहनो की वेज्ञानिक खती तथा झारखण्ड में चना एवं मसूर फसलों का उपादन बढाने के तरीके व लगने बाले रोगों व कीटों का निवारण in All India Radio Jharkhand (AIR-102.1 Mhz) broadcasted on 19 October 2015 (5.40 pm) and 04 December 2015 (5.40 pm).
- Smt. S Sethy delivered a talk on "ବାଡ଼ି ବଗିଚାରେ ଋତୁ କାଳୀନ ଶାଗ ଚାଷ" (Seasonal cultivation of green leafy vegetables in kitchen garden) which was broadcasted by AIR, Cuttack on 1 January 2016.
- Dr. Lipi Das delivered a talk on "ଧାନ ଚାଷ ଓ ମହିଳା ସଶକ୍ତିକରଣ" (Empowerment of women in rice cultivation) recorded and broadcasted by AIR, Cuttack on 21 January 2016 for Krushi Sansar programme.
- Dr. RK Mohanta delivered a radio talk on "ଗୋପାଳନରେ ଥିବା ମୂଖ୍ୟ ସମସ୍ୟା ଓ ତାର ସମାଧାନ" (Major problems of livestock rearing and their solutions which was broadcasted by AIR Cuttack on 2 February 2016.
- Dr. DR Sarangi delivered a talk on "ପନିପରିବା ଚାଷରେ ଅଣୁସାରର ସମନ୍ୱିତ ପରିଚ୍ଳନା" (Balanced micronutrient management in vegetable cultivation) recorded and broadcasted in Krishi Sansar programme of AIR Cuttack on 5 February 2016.
- Dr. SK Dash delivered a radio talk on aerobic rice "ସ୍ୱଳ୍ପ ବୃଷ୍ଟିପାତ ଅଞ୍ଚଳ ପାଇଁ ଚାଷ କୌଶଳ" recorded and broadcasted by AIR, Cuttack on 11 February 2016.
- Six TV talks were delivered as follows on transfer of technology through Prasar Bharti, Bhartiy Prasharan Nigam Ranchi during October-December 2015.
- Mr. Bhoopendra Singh 'Protected cultivation of vegetable and off session vegetable cultivation'
- Mr. Bhoopendra Singh 'Scientific cultivation of potato in Jharkhand'
- Mrs. Chanchila Kumari 'Nutritional kitchen gardening'
- Mrs. Chanchila Kumari 'Scientific cultivation of mushroom production in Jharkhand'
- Mr. Manish Kumar 'Scientific cultivation of mustard in Jharkhand'
- Mr. Manish Kumar 'Insect pest control in the oil seed and pulses crops'

Events and Activities

IJSC, IMC, IRC, RAC and SAC Meetings

Institute Joint Staff Council

The Institute Joint Staff Council meeting was held on 21 March 2016 at NRRI, Cuttack under the chairmanship of Dr. AK Nayak, Director (Acting). The members present during the meeting were Drs ON Singh, Head, Crop Improvement Division, Mrs. S Samantary, PS, Crop Improvement Division, SD Mohapatra, Sr. Scientist, Crop Protection Division, Shri SR Khuntia, CF&AO, Shri BK Sinha, SAO, Shri DK Mohanty, AAO (Technical & Secretary official side), Shri RC Pradhan, CJSC Member, Shri SK Sahoo, Secretary staff side, Shri B Pradhan, Technician, Shri DR Sahoo, STA, Shri P Moharana, STA, Shri KC Ram, SSS, Shri Meru Sahoo, SSS and Shri MC Nayak, SSS. Various administrative and financial matters were discussed and finalized.

Institute Management Committee

The XXVIIIth Institute Management Committee (IMC) meeting of the NRRI was held on 11 December 2015 at Cuttack under the chairmanship of Dr. AK Nayak, Director (Acting), NRRI. The members present were Dr. (Mrs.) Mayabini Jena, Head Crop Protection Division, NRRI, Dr. CS Kar, PS, CRIJAF, Barrackpore, Shri SK Pathak, Dy. Director (F)-III, ICAR, New Delhi, Shri UK Parida and Shri Kulamani Rout, Ex-MLA, Bari-Derabish, Kendrapara. Dr. ON Singh, Head, Crop Improvement Division, NRRI, Dr. BN Sadangi, Head, Social Science Division, NRRI, Dr. (Mrs) Padmini Swain, Principal Scientist, Crop Physiology & Biochemistry Division, NRRI, Dr. SP Patel, PS & I/c Head Crop Production Division, NRRI, Shri SR Khuntia, CF&AO, NRRI as invitee and Shri BK Sinha, SAO, NRRI as Member Secretary also attended the meeting. Matters related to infrastructure development and budgetary provisions for construction works and purchase of equipments were discussed.

Research Advisory Committee

The XXIth Meeting of the Research Advisory Committee (RAC) of NRRI was held at NRRI, Cuttack from 26 to 27 October 2015. Dr. VL Chopra, Ex-Secretary, DARE & Director General, ICAR, Chairman, RAC and members Dr. AK Singh, Principal Scientist, Division of Genetics, (IARI),New Delhi, Dr. VK Dadhwal, Director, National Remote Sensing Centre, Balanagar, Hyderabad, Dr. (Mrs) Krishna Srinath, Emeritus Scientist, Directorate of Extension Education, TANUVAS, Chennai, Dr. BV David, Chairman, International Institute of Biotechnology & Toxicology, Chennai, Dr. IS Solanki, ADG (FFC), Shri Kulamani Rout, Ex-MLA, Bari Derabish, Kendrapara, Odisha and Shri Utkal Keshari Parida, Derabish, Kendrapara, Odisha were present during the meeting. Dr. V Ravindra Babu, Director, IIRR attended the meeting as a special invitee. The Chairman along with the members conducted a premeeting briefing with the Director followed by an open session. Dr. ON Singh, Director (Acting), NRRI presented the highlights of the research achievements and infrastructural developments since the last RAC meeting. Dr. JN Reddy, Member Secretary presented the details of the action taken report (ATR) on the recommendations of the XXth RAC followed by presentations of the Programme/Co-Programme Leaders (Dr. JN Reddy, Dr. AK Nayak, Dr. (Mrs.) Mayabini Jena, Dr. SG Sharma and Dr. BN Sadangi) on research and extension achievements made between November 2014 and September 2015. During the meeting, one technology bulletin on "A practical guide for successful hybrid seed production in rice: A Profitable Venture" authored by Dr. Ramlakhan Verma and his colleagues was released by the Chairman and members of the RAC. The RAC Members also visited different experimental fields and facilities in the divisions and had discussion with the scientists of concerned disciplines.

Visit of the RAC Members to Experimental fields

Institute Research Council

The 34th meeting of the Institute Research Council (IRC) was held from 22 to 26 June and 4 July 2015 for presentation of results of 2014 -15 and work plan for 2015-16 under the chairmanship of Dr. T Mohapatra, Director and chairman, IRC. The secretary, IRC, Dr. (Mrs.) Mayabini Jena welcome the Director and the chairman, IRC and other members of the house. Project wise presentation of results of all 41 projects for the year 2014-15 was 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. NK Dhala and Dr. RC Dani

Programme 4 (Crop physiology & biochemistry) -
Dr. PK Mahapatra and Dr. SK Nayak

Programme 5 (Social Science) -
Dr. C Satpathy and Dr. D Naik

SAC meeting of Krishi Vigyan Kendra

KVK, Santhapur

The 17th Scientific Advisory Committee meeting of Krishi Vigyan Kendra Cuttack was held on 29 March 2016 at Santhapur under the chairmanship of Dr. AK Nayak, Director (Acting), ICAR-NRRI, Cuttack and several SAC members namely Shri SC Sahu, Dy. Director of Agriculture, Cuttack, Dr. B Mallick, CDVO Cuttack representative, Project Director, Watershed, Cuttack, Shri Durga Manjhi, FRO, Akashwani, Cuttack, Shri Dharanidhar Nayak, Farmers' Representative, Shri Chaitanya Muduli, Farmers' Representative, Smt. Mamata Baral, Farmwomen Representative, Smt. Banaja Parida, Farmwomen Representative, Dr. SM Prasad, Senior Scientist and OIC, KVK Cuttack & Member Secretary with the Heads of the Division of ICAR-NRRI, Cuttack and many officers from line department and progressive farmers also attended the SAC meeting as special invitees.

Dr. SM Prasad, Sr. Scientist & OIC, KVK Cuttack welcomed the Chairman and other members. Dr. Prasad presented the overall achievements of KVK Cuttack for the period from April 2015 to March 2016 and action taken report. It was followed by discussion related to the presentation. After that all Subject Matter Specialists presented their brief achievements of 2015-16 and Annual Action Plan for April 2016 to March 2017. In course of presentation, the Chairman and other members provided their valuable suggestions.

In the concluding part of the meeting the overall suggestions of the Chairman, Nodal Officer and other members were recorded for taking appropriate actions. At the end of the meeting a progressive farmer of KVK operational area, Shri Sudhansu Shekhar Nayak, was felicitated by Director, NRRI, Cuttack. Dr. DR Sarangi, SMS (Soil Science) proposed the vote of thanks.

KVK, Koderma

Scientific Advisory Committee meeting of Krishi Vigyan Kendra (Koderma), Jainagar, was held on 19 February 2016 under the chairmanship of Dr. Dipankar Maiti, OIC (Acting), CRURRS, Hazaribagh. Shri G. Hansada, DAO, Koderma, Mr. Bhaskar Mridha, DDM, NABARD, Koderma, Dr. A. Choudhary, All India Radio and farmers representatives Mr. Bundak Yadav, village Veko, Mr. Baijnath Rai, Babandi, Mrs. Archana Devi, Chopnadih and Mrs. Rajiya Khatoon Santh, Jainagar attended the meeting. The meeting was conducted by Mrs. Chanchila Kumari (SMS) and attended by the scientists of CRURRS, Hazaribag, staff members of KVK Koderma. Dr. Yogesh Kumar Senior Scientist cum In-charge KVK Koderma presented overview of ongoing activities of KVK, achievements in 2015-16 and proposed the work plan for 2016-17.

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

Attended in Farmers' Day and Stakeholders meeting organized by Ramie Research Station, CRIJAF, Sorbhog, Assam on 6 April 2015	Dr. T Singh and Mr. BS Satapathy
Attended annual workshop KVK from 8 to 9 April 2015 at Deoghar, Jharkhand and presented annual action plan for 2015-16 and annual progress report of 2014-15	Dr. VK Singh
Attended attended a meeting on "Rice strategy for India" at Hyderabad on 14 April 2015	Dr. P Samal
Attended 50th Annual Rice Group Meeting at IIRR, Hyderabad from 11 to 15 April 2015	Drs. Mayabini Jena, Padmini Swain, M Variar, CV Singh, KB Pun, T Singh, SSC Patnaik and SK Lenka
Attended Annual Review and Planning Workshop of STRASA Project (EAP_126) at NAAS Complex, New Delhi on 18 April 2015 and presented the result of trials conducted under Drought Breeding Network	Dr. Padmini Swain
Attended inspected in collaboration with DDA, Cuttack and Seed Certification Officer, Cuttack for verification of hybrid paddy seed production at Banki and Athagarh blocks on 20 April 2015	Dr. SM Prasad
Attended in STRSA Workshop organized by IRRI at NASC Complex, IARI, New Delhi from 19 to 22 April 2015	Drs. M Variar, NP Mandal and Y Kumar
Attended Workshop on 'Multiplication & Dissemination; Characterization of Stress Prone Areas; Impact Assessment and Gender Issues' organized by IRRI-NFSM (STRASA) at NASC Complex, New Delhi from 19 to 22 April 2015	Drs. M Variar and AK Mukherjee
Attended Zonal workshop at Zonal Project Directorate, Kolkata from 23 to 24 April 2015 and presented annual action plan 2015-16 and annual progress report 2014-15 of NICRA project	Mr. B Singh
Attended in the Brain Storming Session on "Photosynthetic enhancement to boost yield" (IRRI) at Hotel Lemon Tree premier, New Delhi on 25 April 2015	Dr. T Mohapatra
Attended "World Veterinary Day Celebration" at CDVO Office, Cuttack on 25 April 2015	Dr. RK Mohanta
Attended the District Level Technical Committee meeting at ATMA Koderma on 27 April 2015 and discussed about fixing limit of cost of cultivation for purposes of grant of crop loan	Mr. B Singh
Attended the training programme 'Crawford Fund Master Class in Communicating with Stakeholders' which was jointly organized by The Crawford Fund, IRRI and E-connect at Srinagar, Jammu & Kashmir from 26 April to 2 May 2015	Dr. Y Kumar
Attended 32nd Research Advisory Committee Meeting at Central Sericultural Germplasm Resources Centre, Hosur, Tamil Nadu on 5 May 2015	Dr. T Mohapatra
Attended 9th Research Council Meeting of Bihar Agricultural University, Sabour, Bhagalpur, Bihar from 6 to 7 May 2015	Dr. T Mohapatra
Attended Directors' Conference at NASC Complex, Pusa, New Delhi from 15 to 16 May 2015	Dr. T Mohapatra
Attended the Annual Action Plan Workshop of KVKs of Odisha at OUAT, BBSR from 18 to 19 May 2015	Dr. SM Prasad

Attended the Review meeting in KVK, at Birsa Agriculture University Ranchi on 20 May 2015 and presented achievement of KVK	Mr. B Singh
Attended invited by the Regional Plant Resource Centre and Odisha State Biodiversity Board, Bhubaneswar to make an oral presentation on "Weedy Rices-enriching biodiversity through rapid evolution in Nature" on the occasion of Celebration of International Day for biological diversity at Hotel New Marrion, Bhubaneswar on 22 May 2015	Dr. BC Patra
Attended in the XXII Meeting of the ICAR Regional Committee (Zone III) at Agartala, Tripura from 22 to 23 May 2015	Dr. KB Pun
Attended attended in Annual Zonal Workshop of KVKs of Zone II at CIFRI, Barrackpore, Kolkata from 26 to 27 May 2015 and presented achievement of KVK (K)	Mr. B Singh
Attended IMC meeting of IIRR, Hyderabad on 27 May 2015 as a member of IMC	Dr. Mayabini Jena
Attended as resource person in Kisan Mela-Cum-Kisan Gosthi' organized by Department of Agriculture, Government of Jharkhand at Hazaribag, Jharkhand on 28 May 2015	Dr Y Kumar
Attended the Field Day programme under BGREI demonstration at Indranipatna village, Tangi-Choudwar organized by DDA, Cuttack on 28 May 2015	Dr. SM Prasad
Attended meeting for implementation of Seed Bill 2004 at ICAR, Krishi Bhawan, New Delhi on 29 May 2015	Dr. T Mohapatra
Attended lecturer in Krishak Mahotsav/Krishi Rath at Koderma on 29 May 2015	Mr. M Kumar
Attended lecture in Krishak Mahotsav/Krishi Rath at Chandwara Block on 2 June 2015	Mr. B Singh
Attended 22nd Annual General Body Meeting of NAAS, New Delhi from 3 to 5 June 2015	Dr. T Mohapatra
Attended in the seminar jointly organized by Orissa Environmental Society and Indian Science Congress Association (ISCA), Bhubaneswar at RPRC, Bhubaneswar on the occasion of celebration of World Environment Day on 5 June 2015	Dr. BC Patra
Attended Planning and Review Meeting of XII Plan Scheme on Incentivizing Research in Agriculture at NBPGR, New Delhi on 6 June 2015	Dr. T Mohapatra
Attended attended meeting related to project entitled "Incentivizing Research in Agriculture: Genetic modifications to improve biological nitrogen fixation for augmenting cereals" at NBPGR, New Delhi on 6 June 2015	Dr. U Kumar
Delivered lecture in Krishak Mahotsav/Krishi Rath at Domchanch, Koderma on 8 June 2015	Mr. M Kumar
Attended the Block Level Training programme for 50 progressive farmers as resource person at ATMA Training Hall on 4 June 2015 and RPSC meeting of AIR, Cuttack on 12 June 2015	Dr. M Chourasia
Represented CRURRS as resource person in the Regional Advisory Group meeting of NABARD at NABARD Regional Office, Ranchi on 12 June 2015. Promotion of DSR with proper weed management was traced upon by Dr. Maiti to be incorporated in the Agril. road map of Jharkhand	Dr. D Maiti
Attended in the training programme on "Integrated pest management of selected field and horticultural crops" at BCKV, Kalyani, WB from 16 to 18 June 2015 which was organized by NCIPM New Delhi	Mr. B Singh

Attended in the meeting on contingency plan of Koderma district, Jharkhand-2015 at office of secretary of Agriculture Ranchi on 22 June 2015	Mr. M Kumar
Attended District Level Monitoring Team meeting of BGREI at DDA office on 23 June 2015	Dr. SM Prasad and Dr. M Chourasia
Attended meeting on 'Finalization of Krishi Darshan programme' organized by Doordarshan Kendra Ranchi at Doordarshan Kendra Ranchi, Jharkhand on 24 June 2015	Dr. Y Kumar
Attended as resource person in Kisan Mela-Cum-Kisan Gosthi' jointly organized by Central Government, State Government and ICAR at Barhi, Hazaribag, Jharkhand on 27 June 2015	Dr Y Kumar
Attended as resource person in the "kisan gosthi" organized By IFFCO at village Gargai on 30 June 2015.	Mr. B Singh
Attended the Selection Committee Meeting at ASRB, New Delhi on 1July 2015	Dr. T Mohapatra
Attended a training programme as resource persons organized by Sri Satya Sai Seva Samitee, Cuttack at Manibada (42-Mauza), Cuttack Sadar on 5 July 2015	Drs. SM Prasad and M Chourasia
Attended as resource persons for two days in the skill development training programme for 34 rural youth on "Soil Health and Fertility Management" from 5 July to 4 August 2015 at KVK Barchana, Jajpur on ring concept of KVK	Mr. DR Sarangi
Attended Summer school on Aquaculture Diversification towards Boosting Pond Productivity and Farm Income, ICAR-CIFA, Bhubaneswar from 8 to 28 July 2015	Dr. Annie Poonam
Attended Scientific Advisory Committee meeting at KVK Barchana, Jajpur on 14 July 2015	Mr. DR Sarangi
Attended in ATMA GB meeting at ATMA, Koderma, Jharkhand on 17 July 2015	Mrs. Chanchila Kumari
Attended 'Workshop-cum-Training Programme' under Tribal-Subplan Programme held at Kalinga nagar, Jajpur on 14 July 2015	Dr. Lipi Das
Attended as an expert to evaluate M.Sc. (Microbiology) thesis (Viva-voce) at OUAT, Bhubaneswar on 22 July 2015	Dr. U Kumar
Attended the 87th Foundation Day of ICAR and 9th National Conference of KVKs organized at S.K. Memorial Hall, Patna from 25 to 26 July 2015	Dr. T Mohapatra, Dr. SM Prasad, Smt. S Sethy, Shri DR Sarangi and Mrs. Chanchila Kumari
Attended the Sectional Committee meeting of INSA at New Delhi from 27 to 28 July 2015	Dr. T Mohapatra
Attended a Short Course on "Promoting Occupational Safety and Drudgery Reduction among Farm Women" at ICAR-CIWA, Bhubaneswar from 1 to 10 August 2015	Smt. Sujata Sethy
Attended workshop on 'KRISHI: Knowledge Based Resources Information Systems Hub for Innovations in Agriculture (ICAR Research Data Repository for Knowledge Management)' at NASC Complex, New Delhi from 4 to 5 August 2015	Dr. NN Jambhulkar
Participated in integrated development programme for schedule tribe organized by NABARD at Katio, Domchanch, Koderma on 8 August 2015	Mrs. Chanchila Kumari and Mr. R Ranjan

Attended the National Symposium on "Germplasm to Genes: Harnessing Biotechnology for Food Security and Health" at NRCPB, Pusa Campus, IARI, New Delhi from 9 to 11 August 2015	Dr. T Mohapatra
Attended the Programme Advisory Committee (PAC) meeting at NABI, Mohali, Chandigarh on 12 August 2015	Dr. T Mohapatra
Attended the HRDcum-Review Programme for Execution of XII th Plan Proposal and New Projects of KVKs of Odisha at Directorate of Extension Education, OUAT, BBSR from 13 to 14 August 2015	Drs. SM Prasad and M Chourasia
Attended monitoring visits to Districts Motihari and Madhubani of Bihar from 17 to 19 August 2015	Dr. D Maiti
Participated as a Coordinator for the Kisan Gosthies in Agriculture Exhibition at Motihari, Bihar from 19 to 21 August 2015	Dr. T Mohapatra
Attended the meeting on Comprehensive District Agriculture Action Plan Development for Cuttack district at ATMA conference hall Cuttack on 20 August 2015	Dr. SM Prasad and Dr. Manish Chourasia
Participated in two days Agriculture Exhibition and Kisan Sangosthies on 'Rice, Pulses, Sugarcane, Oilseed and Crop Production & Management' at Pipra Kothi, Motihari, Bihar from 20 to 21 August 2015	Drs. D Maiti, NP Mandal and CV Singh
Attended the Foundation day programme of OUAT, BBSR on 24 August 2015 with a progressive mushroom entrepreneur Sri Chandrasekhar Ray of Cuttack who was felicitated on the occasion	Dr. SM Prasad
Attended a training programme on 'Developing Winning Research Proposals in Agricultural Research' at ICAR-National Academy of Agricultural Research Management (NAARM), Hyderabad from 25 to 29 August 2015	Dr. B Mondal
Attended the "Krishak Gosthi" organised by OCTMP at Tentuliragadi, Tigiria on 27 August 2015.	Drs. SM Prasad and M Chourasia
Attended and presented report in the review meeting of KVK at BAU, Ranchi from 26 to 27 August 2015	Mrs. Chanchila Kumari
Attended two days training programme "Comprehensive District Agriculture Action Plan at OUAT, BBSR from 29 to 30 August 2015	Dr. SM Prasad
Attended Nadia and North 24-Paraganas districts of West Bengal from 29 August to 2 September 2015 for monitoring BGREI Program	Dr. Sanjoy Saha
Attended the training programme as resource person at ATMA, Cuttack on "Agronomical practices in Integrated farming system" on 2 September 2015	Dr. SM Prasad
Completed Three Months Professional Attachment Training (PAT) At ICAR- NBAIR, Bengaluru From 1 September to 30 November 2015	Drs. NK Patil and Raghu S
Attended the training programme as resource person on "Inclusion of animal component and their management in IFS" at ATMA, Cuttack on 2 September 2015	Dr. RK Mohanta
Attended the training programme as resource person on "Integrated Pest Management in Integrated farming system" at ATMA, Cuttack on 3 September 2015	Dr. M Chourasia
Attended monitoring visits to Districts Ranchi and Hazaribag of Jharkhand from 1 to 3 September 2015	Dr. Y Kumar
Attended attended the meeting on 'Rice-fallow' program organized by CGIAR at New Delhi to develop new project on the aspect with ICAR, IRRI, ICARDA and ICRISAT. Dr. Kumar presented proposal for rice-fallow under raifed uplands	Dr. Y Kumar

Attended the DLMT meeting of BGREI of *kharif* 2015 at O/o DDA, Cuttack on 4 September 2015	Drs. SM Prasad and M Chourasia
Visited jute growing border areas in Murshidabad district of West Bengal as member of ICAR Team from 6 to 8 September 2015 to review the issues as raised by Home Ministry for imposition of restriction of cultivation of high standing crops in the Indo-Bangladesh border passing through Murshidabad district of West Bengal	Dr. S Saha
Attended Zonal Workshop of KVKs of Zone VII at Ujjain from 9 to 11 September 2015	Drs. SM Prasad and M Chourasia
Attended RPSC meeting of All India Radio, Cuttack at ICAR-CIWA, Bhubaneswar on 11 September 2015	Smt. Sujata Sethy
Participated in GB meeting ATMA and BGREI, Koderma on 14 September 2015	Mrs. Chanchila Kumari
Attended Agriculture Technology Management Agency G.B. Meeting at ATMA Office Koderma on 9 September 2015	Mr. B Singh
Attended two days orientation workshop for State Govt. Officers of Odisha on latest ICT initiatives under NEGP at Hotel Sandy's Tower, Bhubaneswar from 15 to 16 September 2015	Dr. SM Prasad
Attended the Mid-Term Review meeting of Regional committee II at CIFRI, Barrackpore on 19 September 2015	Dr. ON Singh
Attended a training programme on 'Capacity Building Program on Methodologies in Agriculture Extension Research' at NASC Complex, Pusa New Delhi from 21 to 24 September 2015	Dr. B Mondal
Attended 21 days CAFT training on "Nutritional intervention for sustainable livestock production under impending climate change scenario" at Indian Veterinary Research Institute, Izatnagar from 17 September to 7 October 2015	Dr. RK Mohanta
Attended for monitoring of early trials at BHU, Varanasi, NDUAT, Faizabad, BAU, Ranchi and ZDRPRS, Hathwara from 26 September to 1 October 2015	Dr. NP Mandal
Attended Group meeting-cumorientation workshop on Cluster demonstration of Oilseed and Pulses at OUAT, Bhubaneswar under the Chairmanship of Director, ATARI, Zone-VII, Jabalpur on 6 October 2015	Dr. SM Prasad
Participated in the 'Workshop for identifying the production and technological gaps in Middle Gangetic Plains Region' Chaired by Dr. JS Sandhu, DDG (CS) at ICAR Research Complex for Eastern Region, Patna on 7 October 2015	Dr. NP Mandal
Attended National Seminar by Orissa Chapter, ISA on Emerging weed problems and their management in major crops, Bhubaneswar, Odisha from 8 to 9 October 2015	Dr. S Saha
Attended 25th Asian-Pacific Weed Science Society Conference on Weed Science for Sustainable Agriculture, Environment and Biodiversity, Hyderabad from 13 to 16 October 2015	Drs. S Saha and A Poonam
Attended the International conference on "Research Interface Promoting Exportable Rice Varieties and Evolving a Sustainable Development Model" at IARI, New Delhi from 16 to 18 October 2015	Shri SSC Patnaik
Visited field programme of BGREI at Kasuambi and Sonbharda, Uttar Pradesh on 17 October 2015	Dr. ON Singh
Attended the workshop on 'Combating Desertification, Land Degradation and Drought' at Biswanahakani College, Tangi, Cuttack 29 October 2015	Dr. SM Prasad

Attended the Selection Committee meeting(s) at ASRB, New Delhi on 29 October 2015	Dr. ON Singh
Attended the Review meeting on Soil Health Card preparation by KVKs of Odisha at OUAT, Bhubaneswar 30 October 2015	Dr. SM Prasad and Shri DR Sarangi
Attended the third "IIRR-Industry Meet 2015" at IIRR, Hyderabad on 31 October 2015	Dr. ON Singh
Attended the National seminar on "Contextual Relevance of ITKs in Plant Protection" at Pusa Campus, New Delhi from 28 to 29 October 2015 and presented a lead lecture on "Prospect of rice pest management in eastern India through Indigenous Technical knowledge (ITK) – A tribal farming system approach"	Dr. (Mrs.) Mayabini Jena
Participated in the 26th All India Congress of Zoology & International Symposium on Innovation in Animal Sciences for Food Security, Health Security and Livelihood-2015 at Babasaheb Bhimrao Ambedkar University from 29 to 31 October 2015	Mrs. Chanchila Kumari and Mr. R Ranjan
Attended the 'Field Day and Press Meet' under BGREI program on 2 November 2015 at Khuniapukur village of Kharibari block in Darjeeling district and visited the demonstration plots under BGREI program in different blocks of Malda and Darjeeling district from 2 to 5 November 2015	Dr. S Saha
Attended the ASRB Foundation Day at New Delhi on 3 November 2015	Dr. ON Singh
Participated as team member with Deputy Director, Horticulture, Cuttack for verification of organic farming at Banki block on 14 November 2015	Shri DR Sarangi
Attended Model training course on Livelihood Improvement of Farm Families through Integrated Farming System, ICAR-CIWA, Bhubaneswar from 17 to 24 November 2015	Dr. A Poonam
Attended International Rice Symposium on Rice Science for Global Food and Nutritional Security, Hyderabad, Telangana from 18 to 20 November 2015	Drs. PK Nayak, CV Singh, D Maity, S Mohanty
Attended the 2nd meeting of the Indian Grain storage Working Group (IGSWG) and presented on "Storage and pest harvest issues in Rice" at NASC, New Delhi on 21 November 2015	Dr. (Mrs.) Mayabini Jena
Attended XXIII International Grassland Congress – IGC, Delhi NCR from 20 to 24 November 2015	Dr. U Kumar
Attended the Annual Shuttle Breeding Selection Activity and EIRLSBN Workshop at OUAT, Bhubaneswar from 23 to 24 November 2015	Shri SSC Patnaik
Attended the 'Review meeting' under BGREI & NFSM Program of West Bengal at Kolkata on 24 November 2015	Dr. Sanjoy Saha
Attended the "Golden Jubilee of Green Revolution in India on 27 November 2015 at A.P. Sinde Symposium Hall, NASC, New Delhi and received the prestigious recognition award for NRRI for its significant contribution to Green Revolution from Hon'ble Union Minister of Agriculture & Farmers Welfare	Dr. AK Nayak
Attended and delivered a lecture on the topic "Career Guidance for the Agriculture Students" in the programme "Alumini Association" at College of Agriculture, OUAT, Bhubaneswar on 4 December 2015	Dr. AK Nayak
Attended the IMC meeting of IIRR, Hyderabad on 4 December 2015	Dr. (Mrs.) Mayabini Jena
Participated as resource persons in one day training programme organised by NABARD (trainees- Field/ Project Officers of different state Govt. organizations) at CRURRS, Hazaribag on 4 December 2015	Drs. D Maiti, NP Mandal, CV Singh and Y Kumar

Participated in the event of 'World Soil Heath Day' jointly organised by the State Government of Jharkhand and Birsa Agricultural University, Ranchi, Jharkhand at Ranchi on 5 December 2015	Dr. D Maiti
Delivered lecture on different topics in the kisan gosthi organized by KVK Koderma on 5 December 2015	Drs. NP Mandal, CV Singh and Y Kumar
Attended the Selection Committee Meeting on 9 December 2015 at ASRB, New Delhi	Dr. AK Nayak
Attended the Selection Committee Meeting on 15 December 2015 at ASRB, New Delhi	Dr. AK Nayak
Attended Management Development Programme on "Leadership Development (a Pre-RMP Programme)" at NAARM, Hyderabad from 30 November to 11 December 2015	Dr. KB Pun
Attended the International Symposium on "Biodiversity, Agriculture, Environment and Forestry" organized by the Association for the Advancement of Biodiversity Science, Ooty, Tamil Nadu form 11 to 12 December 2015 and delivered a lecture	Drs. AK Mukherjee and A Anandan
Deliver an oral presentation at Young Scientists conference as a part of India International Science Festival at IIT Delhi from 4 to 8 December 2015	Mr. A Kumar
Attended National Symposium on Integrated Farming systems for Sustainable agriculture and Enhancement of Rural livelihoods, NAARM, Hyderabad, from 13 to 14 December 2015	Dr. Annie Poonam
Attended Competency Enhancement Programme for the Technical Officers of ICAR at ICARNAARM, Hyderabad from14 to 23 December 2015	Mr. KK Suman
Attended Scientific Advisory Committee meeting at KVK Jajpur, Barchana on 18 December 2015	Mr. DR Sarangi
Attended one day sensitization programme on 'Biological Diversity Acts, 2002 and Rules, 2004 of India' organized by State Biodiversity Board, Odisha at Hotel Suryansh, Bhubaneswar on 19 December 2015	Dr. BC Patra
Attended Advisory Committee meeting of Doordarshan Kendra Ranchi, Jharkhand as an expert on 21 December 2015	Dr Y Kumar
Attended National Seminar on Microbial Technology: Prospects and Applications, OUAT, Bhubaneswar from 25 to 26 December	Drs. P Panneerselvam, R Tripathi and U Kumar
Attended the second Odisha Biodiversity congress-2015 at Paradeep on 27 December 2015 and presented an invited talk on Promoting indigenous and climate resilient varieties for sustaining rice productivity	Dr. BC Patra
Participated in district level *rabi* workshop organised by ATMA Koderma on 22 December 2015 at ATMA Koderma, 28 December 2015 at Chandwara block, 29 December 2015 at Markacho block, 30 December 2015 at Domchanch block	Mr. B Singh
Participated in block level *rabi* workshop organised by ATMA Koderma on 28 December 2015 at Koderma block, Jainagar block and Sadganvan block	Mr. M Kumar
Attended Zonal Workshop on oilseed and pulses organized by ATARI, Zone-VII at OUAT, Bhubaneswar from 5 to 6 January 2016	Dr. SM Prasad
Attended Lunching Workshop of N 22 Mutant Project at TNAU, Coimbatore, Tamilnadu from 7 to 10 January 2016	Dr. Padmini Swain

Attended the "International Workshop on Soil Health" at Birsa Agricultural University, Ranchi and organized jointly by Birsa Agricultural University, Ranchi and Cornell University, Ithaca, USA from 12 to 13 January 2016	Dr. CV Singh
Attended the ISCAR Symposium and presented a paper entitled "Rice based cropping in changing the livelihood of farming communities in coastal areas: initiatives from NRRI" under the theme I: Innovations in soil, water and crop management for enhancing production in coastal region at ICAR-IIWM, Bhubaneswar on 15 January 2016	Dr. AK Nayak
Attended the National Seminar on 'Resource based inclusive agriculture & rural development: opportunities & challenges' at RKMVU, Narendrapur, Kolkata from 15 to 16 January 2016	Dr. RK Sarkar
Attended 11th National Symposium on Innovations in Coastal Agriculture - Current Status and Potential under Changing Environment, at ICAR-Indian Institute of Water Management, Bhubanrswar, India, from 14 to 17 January 2016	Drs. PK Nayak, S Saha, A Poonam, BB Panda, S Munda, MK Bag and A Anandan
Attended 50th annual convention of Indian Society of Agricultural Engineers (ISAE) and Symposium on Agricultural Engineering in Nation Building: Contributions and Challenges held at College of Agricultural Engineering and Technology, OUAT, Bhubaneswar from 19 to 21 January 2016	Dr. SP Patel and Er. PK Guru
Attended Directors' Conference at NASC, Pusa, New Delhi from 23 to 24 January 2016	Dr. AK Nayak
Attended the National Seminar on Plant Genomics and Biotechnology: Challenges and Opportunities in 21st Century organized by Dept. of Agricultural Biotechnology, College of Agriculture, OUAT, Bhubaneswar from 23 to 24 January 2016	Drs. BC Patra, AK Mukherjee and A Anandan
Attended the 4th ICAR-Institutes-SAU-State Departments Interface Meet at OUAT, Bhubaneswar from 27 to 28 January 2016	Dr. AK Nayak
Participated in interaction meeting cum training programme for partners of Consortia Research Project on Conservation Agriculture at CIAE, Bhopal from 29 to 30 January 2016	Dr. BB Panda and Er. PK Guru
Attended BGREI Program reviewed the progress of BGREI activities in Darjeeling, Jalpaiguri and Uttar Dinajpur districts of West Bengal from 2 to 7 February 2016	Dr. S Saha
Attended Rabi Farmers' Fair 2016 organized by Krishi Vigyan Kendra, Jagatsinghpur in collaboration with District Agricultural Department, Jagatsinghpur at Bagoi village (adopted village of Hon'ble MP (Loksabha), Jagatsinghpur) of Kujang block on 3 February 2016	Dr. SD Mohapatra
Attended the meeting of Pradhan Mantri Krishi Sinchayee Yojana at Project Director, DRDA, Cuttack on 4 February 2016	Dr. SM Prasad
Attended the XVI Biennial Conference of Animal Nutrition Society of India organised by Animal Nutrition Society of India at ICAR-NDRI, Karnal from 4 to 10 February 2016	Dr. RK Mohanta
Attended XIX workshop of ICAR, all India co-ordinate research project on energy in agriculture and agro based industries at Indian Institute of Horticultural Research, Hessergutta, Bengaluru from 8 to 10 February 2016	Dr. SP Patel
Attended the 40th Annual Conference of Orissa Botanical Society and National Conference on Marine Bioresources of East Coast of India and their bioprospecting at Fakir Mohan University, Balasore from 10 to 12 February 2016 and made a presentation on 'Geographical Indication (GI) of IPR enabling Trade in Rice'	Dr. BC Patra

Attended training workshop on Competency Development for Human Resource Development Nodal Officers of ICAR organized by ICAR- National Academy of Agricultural Research Management (NAARM), Hyderabad from 10 to 12 February 2016	Dr. SD Mohapatra
Attended National Symposium on 'Microbial Diversity and Its Impact', in the session of 'Host-Pathogen interaction' of Indian Mycological Society held at Kolkata, West Bengal from 18 to 19 February 2016	Dr. MK Bag
Attended the Inter-State Agri-Horti Fair and Farmers-Scientists Interaction Meet during Prime Minister's visit at Bargarh, Odisha from 18 to 21 February 2016	Dr. AK Nayak
Attended the International Conference on 'Climate Change and Food Security: Ethical Perspective' at Agri Biotech Foundation, Hyderabad from 11 to 13 February 2016	Dr. RK Sarkar
Attended the National seminar on 'Technological Options for Bringing Second Green Revolution in North East' and Assam Krishi Unnayan Mela 2016 at Regional Centre of CPCRI, Guwahati, Assam from 13 to 14 February 2016	Drs. KB Pun, T Singh, BS Satapathy and K Saikia
Participated in the Exhibition-cum-workshop of PPV & FRA at Jabalpur from 12 to 13 February 2016	Drs. SM Prasad and M Chourasia
Attended the National Seminar on 'Integrated Development of Horticulture in Sub-Tropical & Hill Region' at HRS, Guwahati, Assam from 17 to 19 February 2016	Drs. KB Pun, T Singh and K Saikia and BS Satapathy
Attended the Winter School on "Changing Methodological paradigm on Extension Research" at ICAR-NRRI, Cuttack from 2 to 22 February 2016	Mrs. Sujata Sethy
Attended the 6th International Conference on "Plant, Pathogens and People: Challenges in Plant Pathology to benefit Humankind" organized by Indian Phytopathological Society at NASC Complex, New Delhi from 23 to 27 February 2016	Drs. KB Pun, D Maiti and Mr. B Kumar (SRF, CRURRS, Hazaribagh)
Participated in the Institute Management Committee meeting of National Centre for Integrated Pest Management, New Delhi on 24 February 2016	Dr. KB Pun
Attended National Conference (AgRiCon 2016) on Balanced Fertilization: A Key to Food Security & Environmental Sustainability, Amity University, Uttar Pradesh, India, from 24 to 25 February 2016	Drs. CV Singh, D Maiti
Attended the 6th International Conference on "Plant, Pathogen and People: Challenges in Pl Pathology to benefit Humankind" at New Delhi from 23 to 27 February 2016	Drs. D Maiti, MK Bag and SK Lenka
Attended the review meeting of the project on 'Development and dissemination of climate-resilient rice varieties for water-short areas of South and Southeast Asia' at ICRISAT, Hyderabad from 25 to 26 February 2016	Dr. P Samal
Participated in National Conference on "Hill Agriculture in Perspective HAP-2016" on addressing weaknesses, creating, opportunities, harnessing potential and developing strategies for nutrition and environmental security in posterity at GBPUA&T, Pantnagar from 26 to 28 February 2016	Mr. B Singh
Attended the Conference on National Priorities in Plant Health Management at Tirupati from 4 to 5 February2016	Dr. PC Rath
Attended refresher course on Agricultural Research Management at ICAR-NAARM, Hyderabad from 23 February to 5 March 2016	Dr. SM Prasad
Attended Group Meet and Discussion on the ISRO EOAM project entitled "Satellite-based Value-added Agro-Met Products for Early Warning to Farmers" organized by ISRO- Space Application centre, Ahmadabad from 8 to 9 March 2016	Dr. SD Mohapatra

Attended a workshop on "Climate resilient cropping systems in East India Plateau" at Birsa Agricultural University, Ranchi from 10 to 11 March 2016	Dr. CV Singh
Attended Eight days training programme on "Pest Surviellance" at National Institute of Plant Health Management (NIPHM), Hyderabad, Telangana, India from 10 to 17 March 2016	Dr. Raghu S
Deliver a lecture on "Awareness generation on IPR" at Odisha Bigyan Academy, Bhubaneswar on 11 March 2016	Dr. BC Patra
Attended Rashtriya Krishi Unnati Mela at IARI, New Delhi from 19 to 21 March 2016	Drs. SM Prasad and Lipi Das
Attended CGIAR Site Integration India Consultation Meeting at NASC Complex, New Delhi on 22 March 2016	Shri SSC Patnaik
Attended workshop on 'User's Training Workshop on ICAR KRISHI Geoportal' at NBSS & LUP, Nagpur from 28 to 30 March 2016 and made presentation on 'Database on Rice, their formats and standards'	Dr. NN Jambhulkar
Attended as an expert member in the field of domesticated biodiversity by the Odisha Biodiversity Board to attend a meeting and select books and audiovisual materials related to domesticated biodiversity for Odisha Biodiversity Resource Centre at Regional Plant Resource Centre, Bhubaneswar on 30 March 2016	Dr. BC Patra

Participation in Exhibitions

The institute participated in the following exhibitions for showcasing the CRRI technologies:

- "World Food Day-2015" celebrated by the Orissa Krushak Samaj (OKS) at Bhubaneswar on 16 October 2015.
- "International Rice Symposium-2015" at ICAR-Indian Institute of Rice Research (IIRR), Hyderabad from 18 to 20 November 2015.
- "Women in Agriculture Day-2015" at ICAR-Central Institute for Women in Agriculture (CIWA), Bhubaneswar on 4 December 2015.
- "11th National Symposium of ISCAR" (Indian Society of Coastal Agricultural Research) at ICAR – IIWM, Bhubaneswar from 14 to 17 January 2016.
- "Agriculture Education day 2015" at NRRI, Cuttack on 18 January 2016.
- 4th "ICAR Institutes–SAU–State Departments Interface Meet" at OUAT, Bhubaneswar from 27 to 28 January 2016.
- "Agri–Horti Exhibition and Farmers Scientists Interaction Meet" at Bargarh, Odisha from 20 to 22 February 2016.
- "Odisha Krushi Mahotsav–2016" at Bhubaneswar from 11 to 14 March 2016.
- "Krishi Unnati Mela– 2016" at IARI, New Delhi from 19 to 21 March 2016.

Secretary, DARE & DG, ICAR Dr. T Mohapatra visiting NRRI exhibition stall at Krishi Unnati Mela– 2016" at IARI, New Delhi

Organization of Events, Workshops, Seminars and Farmers' Day

Inspection by the Sub-Committee of Committee of Parliament on Official Language

The second sub-committee of the Parliamentary Committee inspected the official language activities of eight central government offices including NRRI, Cuttack on 13 April 2015 at Puri. Dr. T Mohapatra, Director, NRRI, Cuttack extended a warm welcome to the Honorable members of the Committee during the inspection program of NRRI. Dr. T Mohapatra at first apprised the Hon'ble members about the mandate of NRRI and also its achievements. The Director provided information about the use of Official Language Hindi at the Institute and the related activities. The meeting was attended by NRRI Director Dr. T Mohapatra, Dr. IS Solanki, Assistant Director General (FFC) and Shri Harish Chandra Joshi, Director (OL) as representatives from Indian Council of Agricultural Research, New Delhi and other officials of NRRI. Committee convener Dr. Prasanna Kumar Patsani, Hon'ble Member of Parliament (Lok Sabha) appreciated NRRI for the efforts done regarding the use of OL by the institute. Dr. Prasanna Kumar Patsani, Hon'ble Member of Parliament and Convenor chaired the meeting. The other Hon'ble Members of Parliament who attended the inspection program were Shri Lakshmi Narayan Yadav, Hon'ble MP (Lok Sabha), Shri Vasishta Narayan Singh, Hon'ble MP (Rajya Sabha), Dr. Mahendra Nath Pandey, Hon'ble MP (Lok Sabha) and Dr Sunil Gaikwad Baliram, Hon'ble MP (Lok Sabha). In addition to these, Shri Suraj Bhan, Secretary, Committee of Parliament on Official Language, Ms. Abhilasha Mishra, Hindi Officer and Mr. Rajesh Jha, Committee Assistant were present during the meeting.

The Sub-Committee of Committee of Parliament on Official Language in progress

69th Foundation Day and Dhan Diwas

The ICAR-National Rice Research Institute (NRRI), Cuttack observed its "69th Foundation Day and Dhan Diwas" on 23 April 2015. Shri Debi Prasad Mishra, Hon'ble Minister, Departments of Industries and School & Mass Education, Govt. of Odisha graced the function as Chief Guest. In his address he appreciated the efforts made by NRRI in developing about 114 varieties of rice for the farming community during last 69 years. He also emphasized on optimum use of water and fertilizers in rice cultivation, conservation of soil fertility and rice germplasm, expansion of area under aromatic rice for higher return and increasing average rice yield up to 4-5 t/ha. Shri Pravat Ranjan Biswal, MLA, Choudwar- Cuttack attended the function as Guest of Honour. In his address he highlighted on how the farmers are getting immense benefit from this Institute. Prof. PP Mathur, Vice Chancellor, KIIT University, Bhubaneswar and the Guest of Honour of the function highlighted on the use of NRRI rice varieties in India and also outside India. Prof. Manoranjan Kar, Vice Chancellor, OUAT, Bhubaneswar, attending the function as the Guest of Honour, spoke on the complementary role NRRI and OUAT are playing in rice research and development for the benefit of rice farmers. In the beginning, Dr. T Mohapatra, Director highlighted the significant achievements of the Institute during past one year, especially the recently released varieties and their suitability for different ecologies. He also stated the thrust areas of research for getting higher yield and climate resilience in the coming years. On this occasion, the chief guest inaugurated an exhibition showcasing technologies of NRRI and other ICAR Institutes located at Bhubaneswar. He also felicitated six retired scientists, the best workers of the institute from different categories and twelve rice farmers and farmwomen from Assam, Jharkhand and Odisha for their innovative practices in rice farming. One book and eight technology bulletins were released by the dignitaries. Dr. BN Sadangi, Head, SSD and Co-chairman welcomed the guests, dignitaries and invited guests and Dr. NC Rath, Organizing Secretary offered vote of thanks at the end of the program. Special programs like field visit for the farmers, scientists-farmers interaction, interface meet involving scientific staff and retired scientists and cultural events were organized for the benefit of the farmers and the staff of the institute.

Chief Guest Shri Debi Prasad Mishra, Hon'ble Minister, Department of Industries and School & Mass Education, Govt. of Odisha addressing the gathering

Foundation Day Lecture

On the occasion of the 69th foundation day of the NRRI, Prof. PP Mathur, Vice Chancellor, Kalinga Institute of Industrial Technology (KIIT) University (Bhubaneswar) and former Senior Professor of Biochemistry and Molecular Biology, Pondicherry University delivered the foundation day lecture on the topic, "Bioinformatics: Scope and Applications". His inspiring lecture covered the chronology of the evolution of sequencing methods, initial establishment of open-source bioinformatics resources on the global stage, landmark projects including the very first human genome, plant genomes such as rice and the 1000-genomes project in human and its implications to personalized medicine. He highlighted various bioinformatics resources available in the public domain. He passionately appealed to scientists and young graduate students of NRRI to effectively utilize bioinformatics tools to understand the mechanisms underlying biological processes. Dr. Mohapatra, Director, ICAR-NRRI presided over the function and felicitated Prof. PP Mathur on the occasion.

World Soil Day

ICAR-National Rice Research Institute, Cuttack celebrated the "World Soil Day" on 5 December 2015 in collaboration with Krishi Vigyan Kendra, Cuttack. Shri Bhartruhari Mahtab, Hon'ble Member of Parliament, Cuttack was the Chief Guest and Shri Pravat Ranjan Biswal, Hon'ble Member of Legislative Assembly, Cuttack-Choudwar was Guest of Honour on this occasion. Dr. AK Nayak, Director (Acting), NRRI, presided over the function. Farmers from Salepur, Mahanga, Nischintakoilli, Tigiria, Badamba, Tangi-Chaudhwar, Niali and Cuttack-Sadar blocks of Cuttack district attended the function. Dr. BN Sadangi, Head, Social Science Division welcomed the guests and farmers. Soil Health Card was distributed to 130 farmers on this occasion. Shri Biswal, Guest of Honour, drew the attention of farmers towards maintaining the soil fertility for future generations. Chief Guest while speaking on the importance of soil health card inspired the farmers to apply balanced fertilizer on the basis of soil testing. Director, NRRI informed the gathering about the soil degradation and challenges ahead for increasing the productivity. He informed that soil health card will play a major role in increasing the productivity of crops. Dr. SM Prasad and Dr. Lipi Das facilitated the program while, Dr. Rahul Tripathi proposed the vote of thanks.

Jai Kisan Jai Vigyan

ICAR-National Rice Research Institute, Cuttack observed 'Jai Kisan Jai Vigyan' Week from 23 to 29 December 2015 on the birth anniversary of former Prime Ministers Shri Atal Bihari Vajpayee and Late Shri Chaudhary Charan Singh. A Krishak Goshthi was organized on this occasion at the Sansad Adarsh Gram "Urali", Cuttack on 23 December 2015 in the presence of Officials from agriculture department, local panchayat and KVK, Cuttack and about 70 farmers, farmwomen and extension functionaries attended the programme. Scientists from the institute and KVK visited three villages on 28 December 2015 and organized awareness meeting on 'Jai Kisan Jai Vigyan' week and three farmers were chosen for their opinion leadership using sociometry method. A celebration was also organized at the institute on 29 December 2015 and thirty two farmers and farmwomen from above three villages participated on the programme and the leaders so selected were felicitated. The programme was presided over by Dr. AK Nayak, Director (Acting), ICAR-NRRI, Cuttack. Scientific, technical, administrative staff, research fellows and students attended the programmes. Dr. BN Sadangi, Head, Social Science Division spoke on importance of the Jai Kisan Jai Vigyan Week. Dr. SG Sharma, Head, Crop Physiology & Biochemistry Division narrated the contribution of Late Shri Ch. Charan Singh and Shri Atal Bihari Vajpayee in agriculture and science and Dr. Mayabini Jena, Head, Crop Protection Division recounted the role of ICAR-NRRI towards betterment of farmer's community. In an open session, farmers as well as other participants discussed the issues relating to quality seeds, changing climate affecting farm production etc. Dr. AK Nayak, Director (Acting) in his presidential address indicated that livelihood security of the farmers and income generation is possible through science-base agriculture. He further indicated that policy on minimum support prices, input management and creation of buffer stock are the result of scientific and policy researches. Dr. Biswajit Mondal, Senior Scientist, Social Science Division coordinated the programme and proposed vote of thanks.

Heads along with director on the dais

International Day of Yoga

The International Day of Yoga (IDY) was observed at ICAR-NRRI on 21 June 2015 with the participation of staff members which was coordinated by Institute Swachh Bharat Mission Committee. Dr. T Mohapatra, Director of the institute highlighted about the importance of yoga for maintaining a healthy life free from stress also advised all the staff to practice yoga every day. Dr. AK Nayak, Chairman, Institute Swachh Bharat Mission Committee elaborated on benefits of yoga. The various types of yogasans were demonstrated by two trained Yogacharyas from Regional Centers of Art of Living Organization, Cuttack and Patanjali Yogpeeth, Cuttack. The staff thoroughly enjoyed the programme and suggested regular practice camps at the institute for the benefits of the staff.

A view of International Day of Yoga Celebration

Foundation Stone of Social Science Division Building, ICAR-NRRI laid by Additional Secretary, DARE and Secretary, ICAR

Shri Chhabilendra Roul, IAS, Additional Secretary, DARE, Govt. of India and Secretary, ICAR laid the foundation stone of Social Science Division Building of ICAR-NRRI, Cuttack, Odisha on 27 February 2016 in presence of Dr. JS Sandhu, Deputy Director General (Crop Science) and Dr. AK Nayak, Director (Acting), ICAR-NRRI and staff of the Institute. Shri RK Shami, Chief Engineer, CPWD along with his staff graced the occasion. Thereafter, the dignitaries visited NRRI experimental farm and reviewed the ongoing research followed by visit to *Oryza* Museum. Later, Shri Roul addressed the gathering of scientists and other staff. He emphasized rice as a strategic crop and in its socio-economic and cultural perspectives. He further stressed that the history and culture of this Institute should be well documented as well as exhibited in the museum. He advised the social scientists to undertake socio-economic evaluation of different rice production systems.

Dignitaries at the proposed site of Social Science Division New Building

Union Agriculture Minister Inaugurated "Agri-Horti Fair" at Bargarh

A three-day "Interstate Agri-Horti Fair" and "Farmers-Scientists Interaction Meet" was organized jointly by the Indian Council of Agriculture Research (ICAR), New Delhi and the National Horticulture Board" (NHB), New Delhi at Bargarh, Odisha from 20 to 22 February 2016. Inaugurating the fair on the first day, Hon'ble Union Minister of Agriculture & Farmers Welfare and Chief Guest of the function Shri Radha Mohan Singh urged the farmers to diversify their farming and take up cash crops and horticultural crops along with traditional crops, pisciculture and organic farming for getting more profit from unit investment. He advised them to visit all the exhibition stalls and interact with experts to enrich their knowledge and clear all doubts. He spoke on various centrally sponsored welfare schemes like National Food Security Mission (MFSM), Pradhan Mantri Fasal Bima Yojana, Pradhan Mantri Sichhai Yojana and distribution of Soil Health Cards to all farmers of the country. Hon'ble Union Minister of Tribal Affairs Shri Jual Oram and Hon'ble Union Minister of State (Independent Charges) of Petroleum and Natural Gas, Shri Dharmendra Pradhan also attended the function as Guests of Honour and addressed the gathering on various issues concerning farmers and farm activities. In the inaugural session, Dr. AK Singh, Managing Director of the NHB welcomed the guests and dignitaries, and Dr. AK Nayak, Director (Acting), ICAR-NRRI & Nodal Officer of the event proposed vote of thanks.

Union Ministers inaugurating the "Inter-state Agri-Horti Fair"

Workshop on "Legal Awareness for Women Workers"

A workshop on "Legal Awareness for Women Workers of CRRI" was jointly organized by ICAR-National Rice Research Institute, Nari Surakshaya, Odisha and State Legal Service Authority, Cuttack on 30 June 2015 at NRRI, Cuttack. Nearly, one hundred women and men attended the workshop. At the outset, Ms. Bidyut Kumari Lala, Vice President of Nari Surakshaya, Odisha introduced the dignitaries on the dais and briefed on the importance of the workshop followed by the welcome address by Dr. (Mrs.) Sanghamitra Samantaray, Chairperson, Women Cell, NRRI. Ms. Lalita Satpathy, President, Nari Surakshaya, Odisha described about the activities of Nari Surakshaya and elaborated the relevance of legal awareness in the context of women suffering from domestic violence. The programme was inaugurated by lighting the lamp which was followed by the inaugural speech on "Protection of women at work places and domestic harmony of the women" by Mr. Sashikant Mishra, Member Secretary, State Legal Authority, Cuttack. Mr. Manas Ranjan Tripathy, Advocate, Odisha High Court, spoke about the awareness of women workers on legal issues for women protection. The chief speaker, Mr. Hrudaya Ballav Das, Legal Advisor, Directorate of State Jail talked about the domestic violence act, welfare and protection of women, Visakha guidelines and physical and mental equality of women. The chief guest, Smt. Jayanti Manjaree Rath, Ex-Director, Odisha Tele-communication Centre, presented her thoughts regarding harmony of women at work places. On his presidential address, Dr. T Mohapatra, Director, NRRI appreciated the efforts of the Nari Surakashya team and the Women Cell, NRRI in organizing such legal awareness programme at NRRI. He also expressed his views on the relevance of women empowerment through legal awareness at work places. At the end of the workshop, Ms. Priyanka Gautam, Member Secretary, NRRI, Women Cell extended a formal vote of thanks.

Inaugurating the workshop by lighting the lamp

Institutional Biosafety Committee Meeting

The 5th Institutional Biosafety Committee (IBSC) meeting was held on 30 June 2015 under the chairmanship of Dr. ON Singh, Head, Crop Improvement Division & Chairman, IBSC. Prof. R Srinivasan, New Delhi attended the meeting as DBT nominee. Director, NRRI also attended the meeting as an invitee. As this was the last meeting since the IBSC is going to complete its three years term on 8 August 2015, the committee reviewed the progress of the work done during its term. As per the recommendations of IBSC 13 proposals were submitted to RCGM, DBT along with the relevant documents and the same were approved during the tenure of IBSC and work is continuing on these aspects. The house acknowledged the contribution of all members of IBSC more specifically the contribution of Dr. R Srinivasan, DBT nominee and three external members during their three years term.

Central Workshop of BGREI Programme

Central Workshop on the "Bringing Green Revolution to Eastern India (BGREI)" program was organized on 11 June 2015 at the ICAR-Central Rice Research Institute, Cuttack, Odisha under the Chairmanship of Dr. JS Sandhu, DDG (Crop Science), ICAR and Agricultural Commissioner (In-Charge), DAC, Government of India, New Delhi. Shri Sanjay Lohiya, IAS, Joint Secretary (Crops), DAC, Government of India, New Delhi, Co-Chaired the workshop. Dr. T Mohapatra, Director, NRRI and member, Central Steering Committee, BGREI programme welcomed everyone, briefed about the background and genesis of this program, and outlined the objectives of the Central Workshop. Sri Lohiya spoke about the new guidelines, and fund allocation pattern during 2015-16. He suggested State Department and SAUs to arrange similar Workshop in respective states before mid July this year. While appreciating the impact of this program, particularly in case of rice, Dr. Sandhu emphasized on greater involvement of the SAUs in this program for improving the overall output. He urged the States to send their officers and farmers to NRRI for exposure to advance knowledge and skill on various aspects of rice production technologies. In the technical session, achievements during 2014-15 and the Action Plan for 2015-16 were presented by the participating states which were reviewed by the Chairman and Co-chairman. State specific recommendations were made after each presentation. This was followed by an interaction meet involving the scientists of NRRI and SAUs, and officers of the state departments in the afternoon on technical issues pertaining to rice production and marketing. On this occasion, a rainout shelter facility for drought tolerance screening of rice germplasam was inaugurated and seed packets of recently released rice varieties from this Institute were distributed among the participants from different states and among the Deputy Directors (Agriculture) of Odisha. The workshop was attended by Dr. PK Meherda, Commissioner cum Director, Department of Agriculture, Odisha, representatives of agriculture departments and SAUs of Assam, Chhattisgarh, Jharkhand, Odisha, UP and WB, Heads of Divisions of NRRI, DDAs of 22 districts of Odisha, seven scientists of NRRI involved in the SLMT for monitoring of seven states, 16 NRRI scientists involved in monitoring of BGREI as DLMT members in Odisha. Dr. A Ghosh, Co-Coordinator and Organizing Secretary of the program offered vote of thanks.

Dr. Sandhu giving his remarks on the action plan for the year 2015-16

Interface Meet

The 4th "ICAR Institutes–SAU–State Departments Interface Meet" for the year 2015-16 for Odisha was organized by ICAR-NRRI, Cuttack at OUAT, Bhubaneswar from 27 to 28 January 2016. The Chief Guest of the function Shri Manoj Ahuja, IAS & Principal Secretary of Agriculture, Govt. of Odisha inaugurated and complemented the efforts of ICAR and OUAT to hold this meet to bring all stakeholders of agricultural development of the state to a single platform for four consecutive years. He emphasized on the generation, assimilation and transfer of the new knowledge among the farming community for overall development of agriculture in the state of Odisha. He asserted that the KVKs need to play a major role in dissemination of new technologies, and the technology should be developed on the basis of farmer's conditions, ecosystems and available market situations. He also highlighted about the special provisions of the state government for rapid sectoral growth in the form of a separate agricultural budget. Chairing the two-day meet, Prof (Dr.) Manoranjan Kar, Vice-Chancellor, OUAT, Bhubaneswar remarked that ICAR Institutes-SAU-State line Departments are complementary to each other and should work hand-in-hand in a coordinated manner to address the problems of the farming communities and transfer technologies more efficiently.

Dr. AK Nayak, Director (Acting), NRRI & Convener briefed about the objectives of holding the Meet and presented the ATR in the beginning of the programme. He highlighted some important points and drew attention to seed production by the farmers themselves at their doorstep for self-sufficiency, proper government policy for production and promotion of low cost small and drudgery reducing farm machineries available with research institutes, developing irrigation infrastructure in the state, creation of awareness for long-slender grain, high value aromatic and hybrid rice among the farmers, food processing and value addition. He also indicated about the research breakthrough of the institute on high protein rice lines for eradicating malnutrition problem of the country.

Chief Guest Shri Manoj Ahuja, IAS addressing the participants

The two days meet was attended by above two hundred participants including representatives of the state line departments, Directors and Heads of ICAR institutes/Regional Stations/KVKs, all Deans/ Directors of OUAT, progressive farmers/farm leaders, NABARD, leading NGOs and agro-based industries. An exhibition was also arranged on this occasion, where all institutes and organizations showcased their models and technologies. Further, a Press Meet was also arranged on the occasion on the second day, in which both Chairman and Convener of the meet apprised the media personnel about the outcomes of the Interface Meet for a greater benefit of the farming community. At the outset of the meet, Dr. BN Sadangi, Head, Social Sciences Division welcomed the guests and delegates while, Dr. SK Mishra, Principal Scientist & Coordinator of the meet offered vote of thanks in the concluding session.

Agriculture Education Day

The institute celebrated its "4th Agriculture Education Day" on 18 January 2016 in its premises with the participation of above 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 Dr. T Mohapatra, Director and Vice-Chancellor, ICAR-IARI, New Delhi inaugurated the programme with lighting of lamp as well as the *Agricultural Science Exhibition* showcasing the projects developed by the students of all participating schools and colleges on the theme *"Energy Efficient Rural Agricultural Production Systems"*. Speaking on the occasion, he stressed about the importance and relevance of various horizons of agricultural sciences namely, education, research and extension. He emphasized that a career in agricultural science would be equally challenging and intellectually satisfying as any other science discipline. He encouraged the students and advised them to keep agriculture and allied subjects in mind, while choosing a career in future. Shri AK Panigrahi, IPS, IG of Police, CID, CB, Odisha, Cuttack and the Guest of Honour in his inspirational speech advised students to overcome from family welfare and should broaden their horizon for greater welfare of the nation. He also encouraged that each student must have a dream and achieve this through sincerity, hard work and dedication for the betterment of our society as well as of our country.

The Chairman of the inaugural function Dr. AK Nayak, Director (Acting), NRRI sensitized the students about the scope and advantages of agriculture education and advised them to be a part of agricultural science. On this occasion the Chief Guest released one educational bulletin entitled *"Agriculture: The Cutting Edge of Innovations and Developments"* for the benefit of the students.

The day-long celebration was highly exciting with special events for the participating students like Debate competition on *"Transforming Farming into Commercial Ventures-Possibilities and Barriers"*; Quiz competition on *"General Agriculture"* and Group Song competition, apart from the Exhibition which showcased the innovative ideas of the students in the form of models, charts, graphs and live materials. Through an outlet on Career Counseling in Agriculture, the students were sensitized and provided counseling on the scope and opportunity in the discipline. Trophies and certificates were presented to the winners of the competitions and exhibition, and also to all the participating students by the Chief Guest. At the outset, Dr. BN Sadangi, Co-chairman and Head, Social Science Division welcomed the guests, dignitaries, teachers and students and at the end, Dr. (Mrs.) Lipi Das, Senior Scientist, Social Science Division and Organizing Secretary proposed vote of thanks.

Release of an educational bulletin during the occasion

24th Dr. Gopinath Sahu Memorial Lecture

The 24th Dr. Gopinath Sahu Memorial Lecture was jointly organized by Association of Rice Research Workers (ARRW), Dr. Gopinath Sahu Memorial Trust and National Rice Research Institute, Cuttack on 9 November 2015. Dr. Trilichan Mohapatra, Director & Vice Chancellor, Indian Agricultural Research Institute, New Delhi was the Guest Speaker and Dr. Pramod Kumar Mohapatra, President, Dr. Gopinath Sahu Memorial Trust and Executive Editor of the popular Odia daily, The Samaj was the Guest of Honor. Dr. Trilochan Mohapatra delivered the memorial lecture on "Rice Genomics: Past, Present and Future". Before starting his deliberation, he remembered the work of Dr. Gopinath Sahu and paid rich tribute to him. He reviewed the past, present and future of rice genomics. Rice genome has been the focus of many mapping experiments associated with QTL localization. These genetic maps now serve as a background for physical mapping, genome sequencing and gene discovery. He also reviewed recent progress on the rice functional genomics with the function of different genes. The Guest of Honor Dr. Pramod Kumar Mohapatra described the water and soil scarcity and it may affect two-thirds of the world's population by 2050 and will strongly impact on the food security of various regions of the planet. Dr. JN Reddy, President, ARRW gave the stature's of the guest. Dr. ON Singh, Director (Acting), NRRI presided over the function and Dr. MJ Baig, Treasurer, ARRW offered vote of thanks.

Dr. T Mahapatra delivering the memorial lecture

9th Dr. TD Biswas Memorial Lecture

The Cuttack Chapter of Indian Society of Soil Science, NRRI, Cuttack organized "9th Dr. TD Biswas Memorial Lecture-2015" on 17 August 2015 at NRRI, Cuttack. Prof. BS Das, IIT, Kharagpur delivered the memorial lecture on "Digital Soil Mapping: Future in India". He emphasized on opportunities and challenges for rapid soil assessment in India through Digital Soil Mapping. Currently, most of soil analyses have been done through chemical analysis. There are about 1049 soil testing labs operating in our country with an annual analyzing capacity of 10.7 million samples. However, there are approximately 138 million agricultural fields and the capacity of soil testing labs simply lags far behind the requirement. Under such conditions, very high spectral, spatial and temporal resolutions of diffuse reflectance spectroscopy (DRS) and hyper spectral remote sensing (HRS) technology offer attractive alternative to do soil testing in a rapid and non-invasive fashion. With the help of DRS and HRS technologies, digital soil mapping could be done more efficiently. Earlier, Dr. AK Nayak, President, Cuttack chapter of ISSS welcomed and introduced the speaker. Dr. ON Singh, I/c, Director NRRI, presided over the meeting and addressed the gathering by emphasizing the importance of modern soil science to cope up with climate change and natural resource management. Dr. P Bhattacharyya, Secretary, Cuttack chapter of ISSS delivered the vote of thanks. More than 80 scientists and researchers from NRRI and OUAT, Bhubaneswar participated in the event.

Workshop on "Rice Value Chain"

A "Rice Value Chain" (RVC) workshop was organized by the ICAR-NRRI, Cuttack on 12 October 2015 in the institute with the participation of over fifty participants from five partners of the RVC, namely, (i) ICAR-NRRI, Cuttack; (ii) M/s Sansar Agropol Pvt. Ltd, Bhubaneswar; (iii) Ananya Mahila Vikas Samiti, Nischintakoili; (iv) Mahanga Krushak Vikas Mancha, Mahanga; and (v) M/s Sabitri Industries, Pvt. Ltd., Jajpur including HODs and associated scientists of the institute. Inaugurating the workshop, Chief Guest of the function Dr. T Mohapatra, Director & Vice Chancellor, ICAR-IARI, New Delhi spoke on the strategy for successful implementation of the RVC starting from production & supply of breeder seed of the long slender aromatic rice variety 'Geetanjali' and field level monitoring by the 1st party; certified/ truthfully-labeled (TL) seed production & distribution by the 2nd party; paddy production by the 3rd & 4th party (farmers' organizations) and finally, procurement, processing & marketing by the 5th party as per the RVC agreement. He advised proper monitoring support by ICAR-NRRI and holding a second workshop before *rabi* season to discuss technical matters with the participating farmers. He added that a crop calendar/plan may be finalized through the workshop with details of action points to be undertaken by various stakeholders at opportune time. Dr. Mohapatra also advised to undertake an impact study on the socioeconomic implications of the RVC after one year of implementation to suggest future course of action. Prior to that, Dr. ON Singh, Director (Acting) of the institute presented a brief achievement report of the RVC till date and made aware that 6.5 qtls. of breeder seed of Geetanjali had been supplied by the National Seed Project (NSP) of the institute to M/s Sansar Agropol Pvt. Ltd. for multiplication of sufficient quantity of TL seed during the ongoing *kharif* season to cover about 5000 acres area in the coming *rabi* 2015-16 season. During the opening session, Dr. BN Sadangi, Head, Social Science & Chairman, RCV Monitoring Committee apprised the participants about the objectives of the workshop and the expected benefits for all the stakeholders of the RVC. Based on the suggestions and interactive discussions of the all stakeholders, an action plan was developed. At the outset, Dr. BC Patra, Principal Scientist & In-Charge, ITMU welcomed the guests and participants, and at the end, Dr. Lipi Das, Senior Scientist & Member Secretary, RCV Monitoring Committee proposed vote of thanks.

Dr. T Mohapatra addressing the participants

Awareness Programme

An Awareness Programme on 'IPR Issues in Agriculture' was organized at ICAR-National Rice Research Institute (NRRI), Cuttack on 17 March 2016 under the auspices of Institute Technology Management Unit (ITMU) and Agribusiness Incubation (ABI) Centre. All the Scientists, Research scholars, Technical Officers, C&FAO, SAO, F&AO, AOs and AAOs of the Institute took part in this programme. Dr. AK Nayak, Director (Acting), NRRI inaugurated the programme. In his inaugural address, he highlighted the importance of protecting the intellectual property in the present regime. He encouraged the scientists to orient their thinking towards the development of patentable and commercializable designs, methods, processes and technologies.

Prof. Baburam Singh, College of Forestry, OUAT, Bhubaneswar was the Chief Speaker. In the present context of competitive scientific research and innovations in the field of modern agricultural science, he stressed upon filing the patent applications at the earliest on the inventions made so that the prior art remains with the inventor. Two other invited speakers namely Dr. SR Dhua and Dr. TK Dangar also gave special emphasis on patent filing and obtaining trademark/registration for commercialization of technologies and products. In the beginning Dr. BC Patra, Principal Scientist and Member Secretary, ITMC, NRRI welcomed the Scientists, scholars and other participants. Dr. GAK Kumar, Principal Investigator of the ABI Project proposed vote of thanks.

Awareness-cum-training programme on 'Quality Seed Production'

An awareness-cum-training programme on 'Quality Seed Production' was held at Bada-adampur village of Jajpur District under 'Mera Gaon Mera Gaurav' initiative on 18 March 2016. About 150 farmers from a cluster of five villages participated and received first-hand knowledge about the high yielding rice varieties suitable for different ecologies as well as package of practices for quality seed production. Importance of insect-pest management in rice for quality seed production was discussed and a demonstration on use of customized leaf colour chart (CLCC) for enhancing nitrogen use efficiency in rice through real time nitrogen management also conducted. Leaflets on quality seed production in local language was distributed among the farmers.

Vigilance Awareness Week

The Vigilance Awareness Week 2015 was observed from 26 to 31 October 2015. On this occasion a debate competition on 'Preventive Vigilance as a Tool of Good Governance' in Hindi and English was conducted for staff of NRRI. Dr. ON Singh, Director (Acting), NRRI gave away certificates to the winner of debate competition. He spoke on the different dimensions of corruption and the different means to reduce it.

Hindi Workshops

A one day Hindi Workshop on titled “Compliance of Section 3 (3) of the Official Language Act” was organized at National Rice Research Institute, Cuttack on 27 August 2015 for the Assistant Administrative Officers of the Institute. Dr. T Mohapatra, Director, NRRI inaugurated the workshop and presided over it. Shri Surendranath Samal, Assistant Director, (OL) All India Radio Prasar Bharati, Cuttack was invited as the speaker for the workshop. All AAOs of the institute participated in the one day workshop.

A one day Hindi Workshop on “Noting & Drafting” was organized at National Rice Research Institute, Cuttack on 30 December 2015 for Assistants of the Institute. Dr. AK Nayak, Director (Acting), NRRI inaugurated the workshop and presided over it. Shri Surendranath Samal, Assistant Director, (OL) All India Radio Prasar Bharati, Cuttack was invited as the speaker for the workshop. A total seven Assistants of the Institute participated in this workshop.

A one day Hindi Workshop on “Unicode system & Hindi typing in computer” was organized at National Rice Research Institute, Cuttack on 10 March 2016 for the staff of the institute. Dr. AK Nayak, Director (Acting), NRRI inaugurated the workshop. Shri Bana Bihari Sahu, Deputy Manager (OL), State Bank of India, Administrative Office, Sambalpur Circle was invited as the speaker for the workshop. A total of ten senior scientists, scientists and assistants participated in this workshop.

Hindi Workshop in progress

Hindi Fortnight

The Hindi Fortnight-2015 was celebrated at the institute from 14 to 29 September 2015. During this period five Hindi Competitions i.e. Correct & Speed Hindi Writing, Hindi Reading, Hindi Word Translation, Hindi Shabdantakshari, and General Knowledge Competitions were organized on 16th, 18th, 19th, 21st and 23rd of September, respectively for the officers/ employees of the Institute. A total of 72 staff members enthusiastically participated in the above competitions. The closing ceremony of Hindi Fortnight-2015 was organized on 30 September 2015 in the auditorium of the institute. On this occasion Shri Tapas Ranjan Ray, Station Manager, Air India, Bhubaneswar was the Chief Guest of the function. The winners of the various Hindi Competitions were honored with prizes and certificates were distributed by the Chief Guest. Dr. ON Singh, Director (Acting), NRRI expressed his satisfaction for organizing successfully the Hindi Fortnight and appreciated the members of the organizing Committee. Dr. MJ Baig, Dr. GAK Kumar, Dr. Rahul Tripathi and Shri BK Mohanty coordinated all the activities related to the Hindi fortnight celebration.

Annual Workshop

One day Annual Workshop of NRRI-NCIPM Collaborative Project on 'Development and Validation of IPM module for Rice' was organized at NRRI, Cuttack on 24 September 2015. The workshop was chaired by Dr. AK Nayak, Director (Acting) of the institute. Dr. C Chattopadhyay, Director, NCIPM, New Delhi, Dr. (Mrs.) Mayabini Jena, Head, Crop Protection Division, Dr. KB Pun, Head, RRLRRS, Gerua along with collaborative scientists of the project and scientists of Crop Protection Division participated the workshop. Dr. SD Mohapatra, PI of the project presented the research findings of the project for NRRI main centre and Dr. K Saikia presented report for Gerua centre. Based on the research finding, the technical programme for the next season was finalized in the workshop. Dr. M Jena in her welcome address highlighted the importance of the IPM in rice pest management and emphasized the location specific IPM module as a key to successful pest management. The chairman appreciated the effort made by Director, NCIPM for this collaborative research project and emphasized on the development of holistic IPM module to tackle the insect pests and diseases problems in rice. Director, NCIPM appreciated the nicely conducted experiment on IPM in rice at both Cuttack and Gerua and expressed that the data generated from the experiment is of very high importance. Dr. S Lenka, Co-PI of the project proposed the vote of thanks.

Tribal Sub-Plan (TSP)

The institute is implementing Tribal Sub Plan (TSP) in three tribal blocks in Mayurbhanj, Balasore and Jajpur districts of Odisha during *kharif* 2015 with the major objective of bridging the gap between Scheduled Tribe (ST) population and others by accelerating their development through rice-based technological interventions. Rice demonstration with HYV/ rice hybrids of the institute namely, Sahbhagidhan, Naveen, CR Dhan 303, CR Dhan 304, Pooja, Ajay and Rajlaxmi in about 180 acres area have been conducted including some method demonstrations like mechanized line transplanting and drum seeding adopted by over 180 tribal farmers. The beneficiaries were provided with free seeds and other critical inputs like need-based pesticides. Three training programmes on "Improved Rice Production Technology" were conducted in these locations during July-August 2015 with the participation of all the adopted farmers. In addition, an exposure visit to the institute was organized for them on 10 July 2015.

Farmers' Exposure Visit to the institute under TSP on 10 July 2015

World Food Day

Krishi Vigyan Kendra, Cuttack observed the "World Food Day" on 16 October 2015 at Mangarajpur village of Baramba block on the theme "Social Protection and

Agriculture: breaking the cycle of rural poverty". A "Kissan Gosthi" was organized discussing different issues faced by the farmers and farmwomen on the above theme. More than 100 farmwomen, rural youths and farmers from different villages like Gamei, Mangarajpur and Deuli of Baramba block attended the programme. SMSs of Krishi Vigyan Kendra, Cuttack Mrs. Sujata Sethy, Mr. DR Sarangi, Dr. M Chourasia, and Dr. RK Mohanta took part in the discussion and provided valuable suggestions and suitable solutions regarding social and economic security of the farm families. Sri Chaitanya Muduli, a progressive farmer of the village Mangarajpur proposed the vote of thanks.

Women in Agriculture Day

Krishi Vigyan Kendra Cuttack observed the "Women in Agriculture Day" on 4 December 2015 under the Chairmanship of Dr. SM Prasad, Head, KVK Cuttack at Paramhansa village of Cuttack Sadar block. More than 150 farmwomen, rural youths and farmers from Paramhansa and Rajhansha village of Cuttack-Sadar block attended the function. Farmwomen were made aware of different issues like Safe grain storage, seed treatment, benefits of cleanliness, group management etc. The programme was facilitated by Mrs Sujata Sethy, SMS (Home Science) of KVK, Cuttack. Sri Laxmidhar Rout, Krishak Sathi of the village Paramhansa proposed the vote of thanks.

Welfare Activities

A Corporate Eye Screening Programme was organized by ICAR-NRRI, Cuttack in association with Lawrence & Mayo Pvt. Ltd., Bhubaneswar, a pioneer company established in 1877. Apart from this, a general health check up camp was also organized as a part of observance of "27th National Road Safety Week", where 137 staff members/pensioners of the institute availed the opportunity. A complete health check up camp was organized on 18 March 2016 in companion with AEGON Life Insurance Company Ltd., Mumbai. The health check up covered BP, blood sugar, nutritional, dental and orthopedic test, where 120 staff members/pensioners including their family members availed the facility.

Another eye screening camp was organized on 19 March 2016 in association with JPM Rotary Club of Cuttack Eye Hospital & Research Institute, CDA, Cuttack. Dr. AK Nayak Director (Acting), NRRI, Cuttack inaugurated the programme. Dr. PK Agrawal, ADG, ICAR, New Delhi was the Chief Guest of the programme. Almost 100 staff members/ pensioners including their family members availed the facility.

All the medical activities were coordinated and managed by Dr. J Pani, Medical Officer and Shri BK Sahoo, AO & Welfare Officer, NRRI, Cuttack.

Health Awareness Camp

Moon Hospital Private Limited, Mahanadi Vihar, Cuttack conducted a Health Awareness Camp at NRRI, Cuttack on 2 May 2015. Dr. T Mohapatra, Director, NRRI inaugurated the camp. Specialists such as Dr. PC Mohanty, M.D. (Medicine), Dr. Atanu Sahu, M.S. (Ortho), Dr. Ashok Padhi, M.D. (O&G) and Dr. T Barik, M.D. (Pulmonary Medicine) provided free consultation. Tests for fasting blood sugar was done by the para-medical staff of Moon Hospital. More than 200 staff and their family members availed the facility. Free medicines were also distributed. Dr. PC Mohanty, M.D. (Medicine) gave a brief presentation on modification of life styles and adopting healthy practices to avoid life style related diseases.

Exposure Visits

Five thousand eight hundred sixty four (5864) visitors including farmers, farmwomen, students, agriculture officers and scientists from United Kingdom, Philippines, Bangladesh, Nepal, Odisha, Jharkhand, Bihar, Chhatishgarh, West Bengal, Gujarat, Punjab, Madhya Pradesh, Andhra Pradesh, Tripura and Tamil Nadu 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

Hon'ble Union Minister of State for Agriculture and Farmers Welfare

Shri Mohanbhai Kalyanjibhai Kundariya, Hon'ble Union Minister of State for Agriculture and Farmers Welfare paid a visit to this institute on 11 February 2016 and chaired the Review Meeting on BGREI. Scientists, senior level state govt. officers, farmers and farmwomen participated in the meeting and raised many issues for development of agriculture in the eastern region.

Hon'ble Minister addressing the gathering

Deputy Director General (Crop Science)

Dr. JS Sandhu, Hon'ble Deputy Director General (Crop Science) visited ICAR-NRRI, Cuttack on 18 April 2015. Dr. Sandhu addressed the scientists, research scholars and students on rice production scenario in general and potential of Eastern India in particular. He advised the scientists to work more on abiotic stresses towards meeting the challenges by adopting right kind of strategies and take leads. To improve quickly the productivity of rice in eastern India, he laid emphasis on yield gap analysis and technological backstopping methods. He urged the scientists to significantly contribute to sustainable flow of technology to the end users through demonstrations in farmers' field. He along with the Director and scientists visited the experimental plots to assess the performance of the newly released varieties and breeding lines and made critical observations on important yield parameters, doubled haploid breeding for stress tolerance and nitrogen use efficiency.

Dr. JS Sandhu having a critical look at next generation rice

Additional Secretary, DARE, Govt. of India and Secretary, ICAR

Shri Chhabilendra Roul, IAS, Additional Secretary, DARE, Govt. of India and Secretary, ICAR and Dr. JS Sandhu, Deputy Director General (Crop Science) paid a visit to this institute on 27 February 2016

ICAR, Governing Body Member

Mr. Sudhir Bhargava, ICAR, Governing Body Member visited NRRI on 29 April 2014. Mr. Bhargava interacted with the scientists of the institute. He advised the scientists to improve quality research to compete with other National and International research organizations. He along with the Director and scientists visited the experimental plots to assess the performance of the newly released varieties and breeding lines and made critical observations on important yield parameters, doubled haploid breeding for stress tolerance and nitrogen use efficiency.

Mr. Bhargava visiting the experimental plots

Hon'able Union Minister of Agriculture Visited CRURRS, Hazaribag

Hon'able Union Minister of Agriculture Shri Radha Mohan Singh visited NRRI Regional Station (CRURRS), Hazaribag on 22 June 2015, accompanied by Dr. S Ayyappan, Secretary DARE and DG, ICAR and Shri R Rajagopal, Secretary, ICAR and Addl.

Release of Research Bulletin by the Hon'able Union Minister of Agriculture in presence of the DG, ICAR, Secretary, ICAR, DC, Hazaribag and OIC, CRURRS

Secretary, DARE and held discussion with the scientists on research activities of the station and monsoon preparedness.

Director General (Designate), IRRI

Dr. Mathew Morell, Deputy Director General (Research) and Director General (Designate), International Rice Research Institute, Philippines along with Dr. Abdulbagi Ismail, Coordinator, STRASA, Dr. US Singh, Country Representative India & Nepal, Dr. Sudhansu Singh and Dr. Manjoor Dar visited ICAR-National Rice Research Institute, Cuttack, Odisha on 2 October 2015. Being the Birth Centenary of Mahatma Gandhi, Dr. Morell offered floral tribute to the Father of Nation. Dr. ON Singh, Director (Acting), NRRI welcomed and introduced Dr. Mathew Morell and praised his contribution to rice. Subsequently, Dr. Morell interacted with the Director, Head of Divisions and other scientists of the institute to understand the progress made in collaborative projects and bottlenecks, if any. The major areas of discussion were i) stress tolerant rice, ii) aerobic rice, iii) anaerobic germination, iv) new plant type, v) weed management, vi) low light, vii) C4 rice and viii) seed production of stress tolerant rice. Dr. Morell emphasized on strengthening the collaboration between IRRI and NRRI and identifying new areas of collaboration. Dr. AK Nayak proposed vote of thanks.

Dr. Morell visiting the experimental plots at NRRI

Bangladesh Delegates

A mixed group of scientists and policy makers from Bangladesh visited NRRI, Cuttack from 17 to 18 December 2015 under the Capacity Building Program on "Technological advances in rice cultivation particularly in the context of adverse ecological condition" sponsored by Training and Technology Transfer (TTT), New Zealand. During their stay they were apprised of the Institute's mandates and achievements, advanced methodologies being applied in rice research and the rice environment in this region through highly focused talks and discussions. They also got an exposure to lab facilities and technologies developed by the Institute. Dr. AK Nayak, Director (Acting) welcomed the delegates and spoke about the Institute and the ICAR. Dr. Lipi Das, Senior Scientist coordinated the programme

A 15 member delegations from Philippines Rice Achievers Awardees visited NRRI on 24 June 2015 and interacted with the Director and scientists of the institute on various issues affecting rice productivity of India in general and Eastern India in particular.

Group photograph of Delegates with the Director

Mr. Bheem Sen Yadav, Samaj Chairman visited NRRI on 27 May 2015.

Dr. Samarthia Thankapan and Dr. Patrik Bucker, Environment Department, University of York, United Kingdom visited NRRI on 16 June 2015.

Dr. Ravinder Kaur, Director, IARI, Dr. RK Jain, Joint Director, Education and other officials from IARI and ICAR visited CRURRS Hazaribagh from 25 to 26 June 2015 and held discussion with scientists of the station on upcoming post graduate programmes of IARI Jharkhand and the research activities to be carried out by students in collaboration with the station.

Dr. T Mohapatra, Director, NRRI, visited Hazaribagh and interacted with scientists and staff of the research station on research activities, infrastructural and human resource needs of the centre from 27 to 29 June 2015.

ADG (Seeds) accompanied by the Director NRRI visiting exhibition stall at village Rasoia Dhamna, Barhi, Hazaribag on 27 June 2015

Seminar

- Dr. KK Jena, Principal Scientist, IRRI, Philippines delivered a lecture on 'New paradigm towards increasing yield potential and biotic stress resistance of rice' on 2 June 2015.
- Dr. DT Singh, Founder & President, Cloud Seq Prt Ltd, Singapore delivered a lecture on 'Rice Genome Informatics with Cloud Seq' on 13 July 2015.
- Dr. DT Singh, Founder & President, Cloud Seq Pvt. Ltd, Singapore delivered a lecture on 'Rice Genome Informatics with Cloud Seq' on 13 July 2015.
- Dr. BB Panda delivered a lecture on 'Crop Cutting Experiment for Yield Estimation' on 17 July 2015.
- Dr. NN Jambhulkar delivered a lecture on 'KRISHI: Knowledge Based Resources Information Systems Hub for Innovations in Agriculture (ICAR Research Data Repository for Knowledge Management) on 22 August 2015.
- Prof.(Dr.) JS Nanda, Former Consultant Food & Agriculture Organization delivered a lecture on 'Experience in Rice Research' on 13 November 2015.
- Dr. Tomasz Czechowski, Research Team Leader, Centre for Novel Agril. Products, Dept. of Biology, University of York, U.K. delivered a lecture on 'Metabolomics - theory & application' on 16 March 2016.

Awards/Recognition

NRRI Recognized for its Contribution to Green Revolution

ICAR-National Rice Research Institute was recognized and felicitated by National Academy of Agricultural Sciences, New Delhi in the Golden Jubilee of Green Revolution - 2015 function for the leadership role played by in Green Revolution along with IARI, New Delhi and five State Agricultural Universities organized by NAAS in collaboration with ICAR and IARI on 27 November 2015 at AP Sindhe Auditorium, NASC Complex, New Delhi. Hon'ble Union Minister of Agriculture and Farmers Welfare Shri Radha Mohan Singh was the Chief Guest of the function. Dr. AK Nayak, Director (Acting) of ICAR-NRRI received the memento and plaque from Hon'ble Minister for commendable contribution of the institute in Green Revolution making the country self-sufficient in food grain production. Prof. MS Swaminathan, Dr. MV Rao, Dr. MJP Rao and other scientists were also felicitated by the Academy for their leading role in individual capacity for the success of Green Revolution. The function was presided over by the Dr. S Ayyappan, President, NAAS.

Dr. AK Nayak, Director, NRRI receiving the award

ICAR-NRRI conferred with Lokmat National Education Leadership Award

ICAR-National Rice Research Institute, Cuttack was honoured with the Lokmat National Education Leadership Award in recognition of significant contribution in the area of leadership development in rice farming in the country. On behalf of the Institute, Dr. T Mohapatra, Director received the award during the World Education Congress on 24 July 2015 at Taj Lands End, Mumbai. The programme was organized by Mohan Group, India.

ICAR-NRRI adjudged the Best Performing Institute under NICRA

The NRRI was judged as one of the best performing institutes at the NICRA annual workshop at CMFRI, Cochin, Kerala during 13- 14 August 2015. The DG, along with Dr. Virmani, DDG, Crop Science, Director CRIDA, CMFRI congratulated the NICRA team and felicitated them.

Individual Awards

Dr. AK Mukherjee was awarded with 2015 Distinguished Achievement Award for the innovative research at the frontier of Plant pathology and for exceptional potential to shape the future through intellectual and inspired leadership in Plant Biotechnology contribution which was conferred by the Association for the Advancement of Biodiversity science. Dr. AK Mukherjee was selected as Fellow of the Association for the Advancement of Biodiversity Science 2015. Dr. AK Mukherjee has been elected as Fellow of Scientific Society of Advanced Research and Social Change, 2015.

Shri BS Satapathy received the Best Poster Award under the sub-theme 'Resource Management' for his poster presentation entitled 'Diversified rice-fish-horticulture farming system for enhancing productivity and sustainability of lowland rice ecosystem of Assam' in International Rice Symposium 2015 held at IIRR, Hyderabad.

Dr. BC Patra received the Dr. M. Brahmam Memorial Award with a citation, memento, shawl and cash award for significant contribution in Plant Diversity Conservation during 40th Annual Conference of Orissa Botanical Society at Fakir Mohan University, Balasore on 7 February 2016.

Dr. SK Pradhan was selected as the Fellow-2015 by Indian society of genetics and plant breeding in 2015.

Dr. SK Pradhan was awarded the Indira Gandhi Gold Medal Award presented by Global Economic Progress & Research Association on 19 November

2015 at Bengaluru.

Dr. A Anandan was awarded for Excellence in Research, for significant contribution in the field of agricultural research by Research & Branding Company, Science & Technology Awards 2015.

Dr. A Anandan was selected as Fellow of the Association for the Advancement of Biodiversity Science 2015.

Dr. Kanchan Saikia was conferred upon Fellow of Applied Zoologists Research Association (AZRA) in XV AZRA International Conference on 'Recent Advances in Life Sciences' at Ethiraj College for Women, Chennai, Tamil Nadu from 11 to 13 February 2016.

Best Workers of NRRI-2015

Best Worker	Category
Dr. SK Pradhan	Principal Scientist
Dr. R Raja	Senior Scientist
Dr. M Shahid	Scientist/ Scientist (SS)
Smt. Sujata Sethy, ACTO, SMS (Home Science)	Technical (T6 – T9)
Shri Sesadev Pradhan, Sr. Technician (Field Asst.)	Technical (T1 – T3)
Shri Narayan Mahavoi, Private Secretary	Administrative-I (above UDCs including PS)
Shri Sanjeeb Kumar Sahoo, UDC	Administrative-II (upto UDCs including Stenos)
Shri Sudhakar Parida, SSS	SS Grade

Sports Activities

Zonal Sports Tournament

The ICAR-NRRI Sports contingent participated in the ICAR-East Zone Sports Tournament held at ICAR-IVRI, Izatnagar from 28 to 31 October 2015. The NRRI won the first position in kabaddi, foot ball and 4 x 100 m relay race and second position in volley ball shooting and badminton (men). In individual events the first position was secured by Shri PK Parida in 100 m race (men), 200 m race (men), 400 m race (men) and 800 m race (men). Shri AK Parida secured first position in carom (men) and Ms. Sabita Sahoo secured first position in high jump (women), second position in long jump (women) and third position in javelin throw (women). Mrs. Rosalia Kido secured second position in javelin throw (women) and discus throw (women). Mrs. Rosalia Kido and Ms. Sabita Sahoo secured second position in badminton doubles (women). Shri B Pradhan secured second position in high jump (men), third position in 100 m race (men) and long jump (men). Shri S Pradhan secured second position in 400 m race (men). Shri D Behera secured third position in shotput throw (men) and Shri PK Jena secured third position in cycle race. NRRI, Cuttack was awarded the Overall Championship Trophy and Shri PK Parida was adjudged the Best Athlete (men). Shri RK Sahu was the Chief-de-Mission, Shri SK Mathur was the Manager and Shri DK Mohanty was the Asst. Manager.

Sports Activities

Shri PK Jena, Captain of NRRI kabaddi team and Shri PK Parida, outstanding kabaddi player of NRRI, Cuttack were nominated for participation in the selection trial for 1st Odisha Kabaddi Premier League (OKPL), organized by Odisha Kabaddi Association, Cuttack on 26 February 2016. Shri PK Parida was selected player and captain of Suredra Sai Tigers Team. The extraordinary performance and outstanding captaincy of Shri Parida was gloriously appreciated by the viewers. Shri Parida was awarded Best Player of the match and his team won the 1st Odisha Kabaddi Premier League Championship.

Commercialization of Hybrid Rice and Other Technologies

MoUs Signed

One MoU was signed for developing Rice Value Chain by commercializing the premium rices developed by the institute. Geetanjali is such a variety having aroma and superfine long slender grains, which is preferred by consumers. The MoU was signed on 69th Foundation day and Dhan diwas celebration of the Institute on 23 April 2015 aiming to establish a value chain that will promote cultivation of this high quality rice, its processing and trade so that the consumers have access to its premium quality, and all the parties involved in the value chain are benefitted. This multi-partite agreement was signed among ICAR-NRRI, two Companies namely, M/s Sansar Agropol Pvt. Ltd. and M/s Sabitri Industries Pvt. Ltd. and two farmer groups namely, M/s Ananya Mahila Bikash Samiti and M/s Mahanga Krushak Vikas Manch in presence of Hon'ble Minister, Industries, School & Mass Education, Government of Odisha, Shri Debi Prasad Mishra and the Hon'ble MLA, Shri Pravat Ranjan Biswal. The copies of MoUs were handed over to concerned parties by the Hon'ble Minister in presence of Vice-Chancellor, Orissa University of Agriculture & Technology, Bhubaneswar Prof. M Kar and Vice-Chancellor, KIIT University, Bhubaneswar, Prof. PP Mathur.

The second one was signed on 11 May 2015 with Bhartiya Beej Nigam Ltd., Rudrapur, Uttarakhand for seed production and commercialization of NRRI hybrid CRHR 5 (Rajalaxmi).

The third MoU was signed on 15 September 2015 with a Multinational company E.I. DuPont India Pvt. Ltd. for contract research. The purpose of this MoU is to facilitate productive, contract scientific research on "Multilocation monitoring of Rynaxypyr™ 20SC against *Scirpophaga incertulas* in rice and Rice hopper susceptibility survey in India for DPX-RAB55 106SC against *Scirpophaga incertulas* & *Sogatella furcifera*.

The fourth MoU was signed with Delta Agrigenetics Pvt. Ltd. Hyderabad on 19 March 2016 for seed production and commercialization of NRRI hybrid CRHR 32 (CR Dhan 701). All these activities will support spread of the NRRI technologies in coming years in the country.

Hon'ble Minister with the signed MoU in the company of the Partners involved in rice value chain

MoU signed with Bhartiya Beej Nigam Ltd., Rudrapur, Uttarakhand

Patents Filed

During this year two patent applications were filed with the Intellectual Property Office (IPO) at Kolkata.

The details are as follows:

1. A composition of novel *Trichoderma* strain (*T. erinaceum)* having the potentiality of increasing the yield besides managing seed borne pathogens in rice when used as seed treatment has been patented. The number assigned for the said application is **1240/KOL/2015 dt. 2.12.2015**. This strain has been isolated from the bark of *Cassia tora* plant and there is no earlier report on using this species for growth enhancement and biocontrol of soil borne pathogens particularly in upland rice.
2. Method for Albino free shoot regeneration in rice through anther culture (Application No.-**1355/KOL/2015 DT. 31.12.2015.**

Variety Registration with PPV&FRA

One application for registration as new variety developed at ICAR-NRRI was submitted to the PPV&FR Authority in the year 2015-16. The required characterization data for filling up the application form for CR Dhan 40 were collected from the field as well as from the laboratories. It is now under examination by the PPV&FR Authority, New Delhi.

Training and Capacity Building

A. Physical targets and achievements

S. No.	Category	Total No. of employees	No of training planned for 2015-16 as per Annual Training Plan	No of employees undergone training during 2015-16	% realization of trainings planned during 2015-16
1	Scientist	85	12	12	100.0
2	Technical	84	8	4	50.0
3	Administrative & Finance	69	5	1	20.0
4	SSS	28	Nil	Nil	Nil

B. Category-wise trainings attended by employees

Category: Scientific

(i) Professional attachment training

Sl. No.	Name & Designation	Period	Place
1.	Dr. Mohammed Azharudeen T.P.	10.08. 15 to 9.10.15	RRS, Vyttila, Kerala
2.	Dr. Naveenkumara B. Patil	01.09. 15 to 30.11. 15	ICAR-NBAIR, Bengaluru
3.	Mr. Prabhat Kumar Guru	01.09. 15 to 30.11. 15	PAU, Ludhiana.
4.	Dr. Raghu S	29.08. 15 to 28.10.15	UHS, GKVK Post, Bengaluru
5.	Mr. Parameswaran. C	19.11. 15. to 18.1.16	ICAR-NRCPB, New Delhi
6.	Mrs. Nabaneeta Basak	19.11. 15 to 18.1.16	ICAR-NRCPB, New Delhi
7.	Dr. Prabhukarthikeyan, S.R	21.11. 15. to 20.1.16	ICAR-IARI, New Delhi
8.	Dr. Guru Pirasanna Pandi, G.	21.11. 15. to 20.1.16	ICAR-IARI, New Delhi
9.	Dr. Basana Gowda, G,	01.1215 to 29.2.16	ICRISAT, Hyderabad
10.	Dr.Sutapa Sarkar,	29.7.15 to 28.10.15	NIPGR, New Delhi.
11.	Sh. Surendra Kumar Ghritlahre	01.09.15 to 10.09.15	IIRR, Hyderabad

(ii) National Training

10.	Sh. Aravindan.S,	02.01.16 to 22.01.16	Functional Analysis of Pathogenicity Genes of Plant Pathogens	ICAR-IARI, New Delhi

(iii) International Training

Sl. No.	Name of the Scientist	Period	Training Title	Institution
1	Dr. Lotan Kumar Bose	07.03.2016 to 18.03.2016	Rice Breeding	IRRI, Philippines
2	Dr. Sushmita Munda	2.11.2015 to 13.11.2015	Ecological Management of rodents, insects and weeds, in rice agro-ecosystems	IRRI, Philippines
3	Dr. S.K.Pradhan,	28.09.15 to 09.10.15	Molecular Breeding Course	IRRI, Philippines

Category: Technical

S. No.	Name of Employee	Period	Name of Training Programme	Institution
1	Dr. R. Chandra	19.08.15 to 28.08.15	Competency Enhancement Training programme of Technical Officers	ICAR-NAARM, Hyderabad
2	Sri Aparti Sahoo			
3	Sri K. K. Suman	14.12.15 to 23.12.15		
4	Sri Srikrishna Pradhan	01.03.16 to 10.03.16		

Category: Administrative

S.No.	Name of Employee	Period	Name of Training Programme	Institution
1	Sri S.R. Khuntia	17.08.15 to 22.08.15	Public Procurement	NIFM, Faridabad
2.	Sri N Mahavoi	18.05.15 to 19.05.15	Communication Skill	ISTM, New Delhi

Category: Progressive Farmers and Govt. Officials

The following State and National level training programmes were organized by NRRI, Cuttack during 2015-16

Sl. No.	Title of the training	Period	Sponsored by	Target group with number
1.	Package of Practice for enhancing Rice Production and Productivity	15 to 20 April 2015	ATMA, Bhagalpur, Bihar	Kisan Mitras (19)
2.	Package of Practice for increasing Rice Production and Productivity	14 to 18 May 2015	ATMA, Umaria, MP	AEOs, SMSs, BTMs and Kisan Mitras (25)
3.	Rice Production Technology for Sustaining National Food Security	3 to 7 July 2015	ATMA, Valsad, Gujarat	Kisan Saathis and Block Technology Managers (23)
4.	Improved Rice Production Technology for enhancing Productivity	13 to 17 July 2015	ATMA, Patna	Kisan Mitras (26)
5.	Skill Development in Improved Rice Cultivation Practices	25 to 28 August 2015	ATMA, Kendrapara	Kisan Sathis/ Kisan Mitras (25)

6.	Improving Livelihood through Technological Advances in Rice Production	6 to 10 September 2015	ATMA, Valsad	Kisan Saathis and ATMA officials (23)
7.	Scientific Skills for Increasing Production and Income from Rice	5 to 9 October 2015	ATMA, Katihar	Kisan Sathis/ Kisan Mitras/BTMs (25)
8.	Improved Rice Production Technology for Sustaining National Food Security	30 to 31 October 2015	DRD, Patna	JDAs, DDAs, DAOs, PDs of ATMA and senior officers (19)
9.	Skill Development in Improved Rice Cultivation Practices	25 to 29 January 2016	ATMA, Mayurbhanj, Odisha	*Kisan Saathis* and ATMA officials (30)
10.	Improved Rice Production Technology for increasing Productivity and Income of Farmers	1 to 5 March 2016	ATMA, Mayurbhanj, Odisha	*Kisan Saathis* and Elite farmers (30)
11.	Improved Rice Production Technology for increasing Productivity and Income of Farmers	10 to 14 March 2016	ATMA, Koderma, Jharkhand	Farmers (27)
12.	Improved Rice Production Technology (Exposure-cum-Farmers' Training programmes)	28 to 29 October 2015	IFFCO, Raipur	Farmers and officers from (34)
13.	Improved Rice Production Technology (Exposure-cum-Farmers' Training programmes)	14 to 16 December 2015	FAIC, Kandhamal, Odisha	Farmers and one officer (10)
14.	General Awareness of proper selection of rice varieties under changing climatic scenario	2 December 2014	NICRA	Farmers (70) at chhoto sehera (Block-Sandesh khali-1) West Bengal

C. Financial targets and achievements for 2015-16 of all NRRI employees

S. No.	RE 2015-16 for HRD			Actual Expenditure 2015-16 for HRD	% Utilization
	Plan	Non plan	Total		
	(Lakh Rs.)			(Lakh Rs.)	2015-16
1.	4.00	-	4.00	4.00	100%

In-Charge and Members of Different Cells

Research Advisory Committee

Prof. VL Chopra, Ex-Secretary, DARE & Director General, ICAR, New Delhi, Chairman

Dr. AK Singh, Principal Scientist, Division of Genetics, (IARI), New Delhi, Member

Dr. VK Dadhwal, Director, National Remote Sensing Centre, Balanagar, Hyderabad, Member

Dr. BV David, Chairman, International Institute of Biotechnology & Toxicology, Chennai, Member

Dr. (Ms.) Krishna Srinath, Emeritus Scientist, Directorate of Extension Education, TANUVAS, Chennai, Member

Director, NRRI, Cuttack, Member

Assistant Director General (FFC), ICAR, New Delhi, Member

Shri Kulamani Rout, Ex-MLA, Bari Derabish, Kendrapara, Odisha, Member

Shri Utkal Keshari Parida, Derabish, Kendrapara, Odisha, Member

Dr. JN Reddy, Principal Scientist, NRRI, Cuttack, Member Secretary

Institute Management Committee

Director, NRRI, Cuttack, Chairman

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

Director of Agriculture, Jharkhand, Ranchi, Member

Dr. PC Das, Dean of Research, OUAT, Bhubaneswar, Member

Dr. SG Sharma, Head, NRRI, Cuttack, Member

Dr. (Ms.) M Jena, NRRI, Cuttack, Member

Dr. Shiv Sewak, Principal Scientist, IIPR, Kanpur, Member

Dr. CS Kar, Principal Scientist, CRIJAF, Barrackpore, Kolkata, Member

Dr. IS Solanki, ADG (FC), ICAR, New Delhi, Member

Shri SK Pathak, DD(F)-III, ICAR, New Delhi, Member

Shri BK Sinha, SAO, NRRI, Cuttack, Member Secretary

Shri Kulamani Rout, Ex-MLA, Bari Derabish, Kendrapara, Odisha, Member

Shri Utkal Keshari Parida, Derabish, Kendrapara, Odisha, Member

Institute Technology Management Committee (ITMC)

Director, NRRI, Cuttack, Chairman

Dr. P Swain, CIFA, External Member

Dr. ON Singh, Member

Dr. SG Sharma, Member

Dr.(Ms.) M Jena, Member

Dr. GAK Kumar, Member

Dr. BC Patra, Member Secretary

Institute Joint Staff Council (IJSC)

Director, NRRI, Cuttack, Chairman

Dr. ON Singh, Member

Dr. (Ms.) S Samantaray, Member

Dr. SD Mohapatra, Member

Shri BK Sinha, Member

Shri SR Khuntia, Member

Asstt. Administrative Officer (Technical Section), Secretary (Official side)

Shri Sanjaya Kumar Sahoo, (Administrative Staff Side), Member & Secretary (Staff side)

Shri Rama Chandra Pradhan, (Administrative Staff Side), Member

Shri Dipti Ranjan Sahoo, (Technical Staff Side), Member

Shri Prahallad Moharana, (Technical Staff Side), Member

Shri Bhagyadhar Pradhan, (Technical Staff Side), Member

Shri KC Ram, (Supporting Staff side), Member

Shri Meru Sahoo, (Supporting Staff Side), Member

Shri Markand Charan Nayak, (Supporting Staff side), Member

Central Public Information Officer

Shri BK Sahoo

PME Cell

Dr. (Ms.) M Jena

Dr. TK Dangar

Shri SSC Patnaik

Dr. JN Reddy

Dr. AK Nayak

Dr. GAK Kumar

Dr. (Ms.) MK Kar

Dr. NN Jambhulkar

Shri SK Sinha

Dr. R Chandra

Shri J Sethi

Human Resource Development (HRD) Committee

Nodal Officer- Dr. (Mrs.) S Samantaray

Co-Nodal Officer- Dr. SD Mohapatra

Women Cell

Dr. (Ms.) S.Samantray, Chair person

Ms. Pravasini Sarangi, 3rd Party Member

President, Odisha Women Housing Development Cooperative Society,Bhubaneswar

Dr. (Ms.) MK Kar, Member

Dr. MJ Baig, Member

Dr.(Ms.) A Poonam, Member

Ms. Manasi Das, Member

Ms. Chandmoni Tudu, Member

Ms. Surubali Hembram, Member

Ms. Priyanka Gautam, Member Secretary

Institute Grievance Cell

Director, NRRI, Cuttack, Chairman

Dr. (Ms.) Mayabini Jena, Member

Shri BK Sinha, Member

Shri SR Khuntia, Member

Dr. AK Mukherjee, Member

Shri Santosh Kr. Ojha, Member

Shri CP Murmu, Member

Shri Ganesh Chandra Sahoo, Member

Asstt.Administrative Officer (Tech), Member Secretary

Institutional Bio-Safety Committee

Director, NRRI, Cuttack Chairman

Dr. BP Shaw, Scientist-F, Institute of Life Sciences (ILS), Bhubaneswar, DBT Nominee

Dr. MJ Baig, Member Secretary

Dr. PK Chand, Professor (Botany), Dept. of Botany, Utkal University, Bhubaneswar, Outside Experts

Dr. Kishore CS Panigrahi, Reader-F, NISER, Bhubaneswar, Outside Experts

Dr. Luna Samanta, Professor & Head, Dept. of Zoology, Ravenshaw University, Cuttack, Outside Experts

Dr. Jogeswar Pani, Medical Officer, NRRI, Cuttack, Biosafety Officer

Dr. ON Singh, Member

Dr. SG Sharma, Member

Dr. (Ms.) S Samantaray, Member

Personnel

(as on 31.03.2016)

1. Dr.Trilochan Mohapatra, Director : 01.04.2015 to 27.08.2015
2. Dr.Onkar Nath Singh, Director (Acting) : 28.08.2015 to 17.11.2015 (F.N)
3. Dr.Amaresh Kumar Nayak, Director (Acting) : 17.11.2015 (A.N) to 31.03.2016

Crop Improvement Division

Name of the Scientist	Designation
Dr. Onkar Nath Singh	**Head**
Dr. J.N. Reddy	Pr.Scientist
Dr. (Ms.) S. Samantaray	Pr.Scientist
Dr. B. C. Patra	Pr.Scientist
Dr. (Ms.) Meera Kumari Kar	Pr.Scientist
Dr. Sarat Ku. Pradhan	Pr.Scientist
Dr. Lambodar Behera	Pr.Scientist
Dr. Hatanath Subudhi	Pr.Scientist
Dr. Lotan Kumar Bose	Pr.Scientist
Dr. K. Chattopadhyay	Pr.Scientist
Dr. Sushant Kumar Dash	Sr.Scientist
Dr. A. Anandan	Sr.Scientist
Sri R. K. Sahu	Scientist
Sri S. S. C. Pattanaik	Scientist
Sri B. C. Marndi	Scientist
Dr. J. Meher	Scientist
Dr. Jawahar Lal Katara	Scientist
Dr. Ramlakhan Verma	Scientist
Dr. Soham Ray	Scientist
Dr. (Ms.) P. Sanghamitra	Scientist
Dr. N. Umakanta	Scientist
Sri Surendra Kumar Ghritlahre	Scientist
Dr. (Ms.) Sutapa Sarkar	Scientist
Sri Muhammed Azharudeen T.P.	Scientist
Dr. Kutubuddin Ali Molla	Scientist
Sri Parameswaran, C	Scientist

Crop Production Division

Name of the Scientist	Designation
Dr. A. K. Nayak	**Head**
Dr. S. P. Patel	Pr.Scientist
Dr. T. K. Dangar	Pr.Scientist
Dr. P. K. Nayak	Pr.Scientist
Dr. Amal Ghosh	Pr.Scientist
Dr. Sanjoy Saha	Pr.Scientist
Dr. P. Bhattacharyya	Pr.Scientist (upto 2.12.2015)
Dr. R. Raja	Sr.Scientist (upto 15.04.2015)
Dr. (Ms.) Annie Poonam	Sr.Scientist
Dr. B. B.Panda	Sr.Scientist
Dr. P. Paneerselvam	Sr.Scientist
Dr. Rahul Tripathi	Scientist
Dr. (Ms.) Sangita Mohanty	Scientist
Dr. Mohammad Shahid	Scientist
Sri Anjani Kumar	Scientist
Dr. Upendra Kumar	Scientist
Dr. Banwari Lal	Scientist
Dr. (Ms.) Sushmita Munda	Scientist
Ms. Priyanka Gautam	Scientist
Sri Prabhat Kumar Guru	Scientist
Dr. Dibyendu Chatterjee	Scientist

Crop Protection Division

Name of the Scientist	Designation
Dr. (Ms.) M.Jena	**Head**
Dr. (Ms.) Urmila Dhua	Pr.Scientist
Dr. P.C.Rath	Pr.Scientist
Dr. S.D. Mohapatra	Pr.Scientist
Dr. A.K. Mukherjee	Sr.Scientist
Dr. Srikanta Lenka	Sr.Scientist
Dr. Manas Kumar Bag	Sr.Scientist
Dr. Totan Adak	Scientist
Sri Berliner J	Scientist (upto 21.11.2015)
Sri Somnath Suresh Pokhare	Scientist (Study Leave)
Sri Manoj Kumar Yadav	Scientist
Sri Aravindan S.	Scientist
Dr. Naveenkumara Basavanagowda Patil	Scientist
Dr. Raghu S	Scientist
Dr. Basana Gowda, G	Scientist
Dr. Guruprasanna Pandi, G	Scientist
Dr. Prabhukarthikeyan, SR	Scientist

Crop Physiology and Biochemistry Division

Name of the Scientist — **Designation**

Dr. S.G. Sharma .... **Head**
Dr. R.K. Sarkar .... Pr.Scientist
Dr. (Ms.) P.Swain .... Pr.Scientist
Dr. M.J. Baig .... Pr.Scientist
Dr. Awadhesh Kumar .... Scientist
Sri Torit Baran Bagchi .... Scientist
Ms. Nabaneeta Basak .... Scientist

Social Science

Name of the Scientist — **Designation**

Dr. B.N. Sadangi .... **Head**
Dr. P. Samal .... Pr.Scientist
Dr. N.C. Rath .... Pr.Scientist
Dr. G.A.K. Kumar .... Pr.Scientist
Dr. S.K. Mishra .... Pr.Scientist
Dr. (Ms.) Lipi Das .... Sr.Scientist
Dr. Biswajit Mandal .... Sr.Scientist
Sri Nitiprasad Jambhulkar .... Scientist

Central Rainfed Upland Rice Research Station, Hazaribagh

Name of the Scientist — **Designation**

Dr. M. Variar .... O.I.C (From 01.04.2015 to 30.11.2015)
Dr. D. Maiti .... I/c OIC (From 01.12.2015 to 31.12.2016)
Dr. N.P. Mandal .... Pr.Scientist
Dr. C.V. Singh .... Sr. Scientist
Dr. Yogesh Kumar .... Sr.Scientist
Dr. Anantha M.S. .... Scientist

Resional Rainfed Low Land Rice Research Station, Gerua, Assam

Name of the Scientist — **Designation**

Dr.Khem Bahadur Pun .... O.I.C
(From 01.04.2015 to 01.02.2016)
I/c O.I.C.
(From 02.02.2016 to 31.12.2016)
Dr. Kanchan Saikia .... Sr.Scientist
Dr. Teekam Singh .... Sr.Scientist
Sri B.S. Satapathy .... Scientist

Krishi Vigyan Kendra, Cuttack (Santhpur)

Name of the Scientist — **Designation**

Dr. Shiv Mangal Prasad .... Sr.Scientist

Administrative Staff as on 31.03.2016

Name — **Designation**

Sri S.R. Khuntia .... Chief Finance & Accounts Officer
Sri B.K. Sinha .... Senior Administrative Officer
Sri Sunil Kumar Das .... Finance & Accounts Officer
Sri S.K. Mathur .... Administrative Officer
Sri Basanta Kumar Sahoo .... Administrative Officer
Sri Bahudi Bhoi .... Assistant 'Administrative Officer
Sri B.K. Moharana .... Assistant Administrative Officer
Sri Sunil Kumar Sahoo .... Assistant Administrative Officer
Sri D.K.Mohanty .... Assistant Administrative Officer
Sri S.K.Jena .... Assistant Administrative Officer
Sri Nabakishore Das .... Security Officer
Sri Narayan Mahavoi .... Private Secretary
Sri G.K. Sahoo .... Private Secretary
Sri N.N. Mohanty .... Private Secretary
Sri Janardan Nayak .... Private Secretary
Sri Trilochan Ram .... Personal Assistant
Sri A. Kullu .... Personal Assistant
Ms. Belarani Mahana .... Personal Assistant
Sri Daniel Khuntia .... Personal Assistant
Ms. Nirmala Jena .... Personal Assistant
Sri Manas Ballav Swain .... Personal Assistant
Ms. Snehaprava Sahoo .... Personal Assistant
Miss Sabita Sahoo .... Personal Assistant
Arabinda Jena .... Canteen Manager
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
Ms. Rosalia Kido .... Assistant
Sri Narayan Prasad Behura .... Assistant
Sri Sanjaya Kumar Sahoo .... Assistant
Sri Munael Mohanty .... Assistant
Sri Saroj Kumar Nayak .... Assistant
Sri Dillip Kumar Parida .... Assistant
Sri Santosh Kumar Satapathy .... Assistant
Sri Manoj Kumar Sethi .... Assistant
Sri Kailash Chandra Behera .... Assistant
Sri Pravat Chandra Das .... Assistant
Sri Abhaya Kumar Pradhan .... Assistant
Sri Rama Chandra Pradhan .... Assistant
Sri Vishal Kumar .... Assistant
Sm. 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.

Crurrs, Hazaribag (Jharkhand)

Name **Designation**

Sri Sudhakar Das .... Assistant 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.

RRLRRS, Gerua (Assam)

Name **Designation**

Sri N.C.Parija .... Assistant Administrative Officer
Ms. Jali Das .... U.D.C.

K.V.K., Santhpur, Cuttack

Name **Designation**

Sri Bibhuti Bhushan Polai .... Stenographer, Grade III

Technical Staff as on 31.03.2016

NRRI, Cuttack

Category-I

Name **Grade**

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 Pramod Kumar 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 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)
Ms. Chintamani Majhi .... Sr.Technical Asst. (Field Asst.)
Sri Bansidhar Ojha .... Sr.Technical Assistant (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 Assistant (Fitter)
Ms. 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 Assistance)
Sri K. K. Suman .... Technical Officer (Field Assistance)
Sri Aparti Sahoo .... Technical Officer (Field Assistance)
Sri J.C.Hansda .... Technical Officer (Field Assistance)
Sri Srikrishna Pradhan .... Technical Officer (Field Assistance)
Sri K. C. Bhoi .... Technical Officer (Blacksmith)
Sri Bhagaban Behera .... Technical Officer (Photography)
Sri Ramsingh Jamuda .... Technical Officer (Field Assistance)

Category-II

Name **Grade**

Ms. Chandamuni Tudu .... Sr.Technical Asst. (Farm Asst.)
Ms. R. Gayatri Kumari .... Sr.Technical Asst. (Farm Asst.)

Ms. Baijayanti Nayak ....Sr.Technical Asst. (Farm Asst.)
Ms. Rosalin Swain ....Sr.Technical Asst. (Farm Asst.)
Ms. Sandhyarani 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... Asst. Chief Technical Officer (Technical)
Dr. Pradeep Kumar Sahoo..Asst. Chief Technical Officer (Fishery)
Sri P. Jana ....Asst. Chief Technical Officer (Rice Production Training)
Sri Prakash Kar ....Chief Technical Officer (Photography)

Category-III

Name	Grade
Sri K. K. Swain	Chief Technical Officer (Mechanical)
Dr.Jogeswar Pani	Medical Officer (On deputation)

Crurrs, Hazaribag (Jharkhand)

Category-I

Name	Grade
Sri Ugan Saw	Technical Assistant (Driver)
Sri Sawan Oran	Sr.Technical Assistant (Field Asst.)
Sri A. N. Singh	Technical Officer (Field Assistance)
Sri Ranjit Tirky	Technical Officer (Field Assistance)
Sri Jitendra Prasad	Technician (Extension Asst.)

Category-II

Name	Grade
Sri R. P. Sah	Technical Officer (Mechanic)
Sri D. Singh	Technical Officer (Electrical)

RRLRRS, Gerua (Assam)

Category-I

Name	Grade
Sri Haladhar Thakuria	Technical Officer (Field Assistance)
Sri Bhupen Kalita	Technician (Field Asst.)

Category-II

Name	Grade
Sri Bibhash Medhi	Sr.Technical Assistant (Farm Asst.)

K.V.K., Santhpur, Cuttack

Category-I

Name	Grade
Sri Makardhar Behera	Technical Asst. (Tractor Driver)
Sri Arabinda Bisoi	Technician (Driver)

Category-III

Name	Grade
Ms. Sujata Sethy	Asst. Chief Technical Officer, SMS (Home Sci.)
Sri Dillip Ranjan Sarangi	Sr.Technical Officer, SMS (Soil Science)
Sri Tusar Ranjan Sahoo	Sr.Technical Officer, SMS (Horticulture)
Dr. Manish Chourasia	Sr.Technical Officer, SMS (Plant Protection)
Dr. Ranjan Kumar Mahanta	Sr.Technical Officer, SMS (Animal Science)

K.V.K., Jainagar, Koderma

Category-I

Name	Grade
Sri Sanjay Kumar	Sr.Technician (Driver Vehicle)

Category-II

Name	Grade
Sri Rupesh Ranjan	Sr.Technical Asst., Trg. Asst. (A.F)
Sri Manish Kumar	Sr.Technical Asst., Trg. Asst.(Agril.)

Category-III

Name	Grade
Mrs. Chanchila Kumari	Asst. Chief Technical Officer, STA (H.S)
Dr. Shudhanshu Sekhar	Asst. Chief Technical Officer, STA (V.Sc.)
Sri Bhoopendra Singh	Sr.Technical Officer, SMS (Horticulture)

Skilled Support Staff as on 31.03.2016

NRRI, Cuttack

Name	Designation
Sri Sahadev Naik	Skilled Support Staff
Sri Rtnakar Das	Skilled Support Staff
Sri Suresh Chandr Mohanty	Skilled Support Staff
Sri Sankhai Soren	Skilled Support Staff
Sri Sundara Marandi	Skilled Support Staff
Smt. Gurubari Dei	Skilled Support Staff
Sri Purna Chandra Sahu	Skilled Support Staff
Sri Dambarudhar Das	Skilled Support Staff

Sri Fakira Charan Sahu .... Skilled Support Staff
Sri Jogendra Biswal .... Skilled Support Staff
Ms. Snehalata Biswal .... Skilled Support Staff
Ms. Namasi Singh .... Skilled Support Staff
Sri Lawa Murmu .... Skilled Support Staff
Sri Prafulla Bhoi .... Skilled Support Staff
Ms. Surubali Hembram .... Skilled Support Staff
Ms. Mukta Hembram .... Skilled Support Staff
Ms. Basanti Marandi .... Skilled Support Staff
Sri Kailash Chandra Ram .... Skilled Support Staff
Sri Dasia Naik .... Skilled Support Staff
Sri Krushna Naik .... Skilled Support Staff
Sri Duryodhan Naik .... Skilled Support Staff
Sri Ganesh Chandra Sahoo .... Skilled Support Staff
Sri Bichitrananda Khatua .... Skilled Support Staff
Sri Rabindra Dalai .... Skilled Support Staff
Sri Laxmidhar Maharana .... Skilled Support Staff
(From 28.02.2016 to 31.03.2016)
Sri Basudev Behera .... Skilled Support Staff
Ms. Santi Dei .... Skilled Support Staff
Sri Nityananda Bhoi .... Skilled Support Staff
Ms. Sara Dei (S) B .... Skilled Support Staff
Ms. Chanda Dei (Bijuli Maa) .... Skilled Support Staff
Ms. Malati Singh .... Skilled Support Staff
Ms. Pramila Dei (Laxmi Maa) .... Skilled Support Staff
Ms. Hadi Dei .... Skilled Support Staff
Ms. Deba Dei .... Skilled Support Staff
Sri Dharmananda Bhoi .... Skilled Support Staff
Sri Kirtan Das .... Skilled Support Staff
Sri Sarat Chandra Das .... Skilled Support Staff
Sri Narayan Das (B) .... Skilled Support Staff
Sri Sudhir Kuamar Bhoi .... Skilled Support Staff
Sri Gokuli Majhi .... Skilled Support Staff
Ms. Mini .... Skilled Support Staff
Ms. Kuni Dei .... Skilled Support Staff
Sri Duruja Naik .... Skilled Support Staff
Ms. Pramila Dei .... Skilled Support Staff
Ms. Ramani Dei .... Skilled Support Staff
Sri Biranchi Bhoi .... Skilled Support Staff
Sri Pradeep Kumar Das .... Skilled Support Staff
Sri Sadananda Naik .... Skilled Support Staff
Sri Jagu Marandi .... Skilled Support Staff
Ms. Jayanti Dei .... Skilled Support Staff
Sri Rabi Naik .... Skilled Support Staff
Sri Bijay Naik .... Skilled Support Staff
Sri Pandab Naik .... Skilled Support Staff
Sri Debaraj Naik .... Skilled Support Staff
Sri Bansidhar Naik .... Skilled Support Staff
(From 28.02.2016 to 31.03.2016)

CRURRS, Hazaribag, Jharkhand

Name — **Designation**

Sri Rameswar Ram .... Skilled Support Staff
Sri Liladhar Mahato .... Skilled Support Staff
Ms. Sita Devi .... Skilled Support Staff
Ms. Nagiya Devi .... Skilled Support Staff
(From 28.02.2016 to 31.03.2016)
Sri Bhuneswar Oran .... Skilled Support Staff
Ms. Panwa Devi .... Skilled Support Staff
Ms. Karmi Devi .... Skilled Support Staff
Ms. Dhanwa Devi .... Skilled Support Staff
Sri Tirath Ram .... Skilled Support Staff
Sri Shambhu Gope .... Skilled Support Staff
Sri Gopal Gope .... Skilled Support Staff
Sri Megh Narayan Prasad .... Skilled Support Staff
Sri Harish Chandra Bando .... Skilled Support Staff
(From 28.02.2016 to 31.03.2016)

RRLRRS, Gerua, Assam

Name — **Designation**

Sri Manoranjan Das .... Skilled Support Staff

KVK, Santhpur, Cuttack

Name — **Designation**

Sri Rama Pradhan .... Skilled Support Staff

KVK, Koderma, Jharkhand

Name — **Designation**

Sri Mukesh Ram .... Skilled Support Staff

Financial Statement for 2015-16

(As on 31 March 2016)

Plan 2015-16 *(Rs. in Lakh)*

Head of Accouant	RE	Expenditure
TA	27	27
HRD	4	4
Contigency	362	362
Capital	540	540
TOTAL	933	933
Non-Plan		
Establishment Charges	2230.00	2230.00
Wages	168.35	168.35
OTA	0.50	0.34
TA	13.00	13.00
Pension	3100.00	2937.98
Repair & Maintenance		
Equipment	18.00	18.00
Office Building	45.00	45.00
Residential Building	20.00	20.00
Minor Worsk	10.00	9.96
Contigency	424.69	424.69
Capital		
Equipment	6.00	5.97
Library Books	2.00	1.99
Furniture	4.00	3.82
TOTAL	**6041.54**	**5879.10**

Work Plan 2015-16

Programme 1: Genetic improvement of rice: ON Singh/JN Reddy

Exploration, characterization and conservation of rice genetic resources

Principal Investigator: BC Patra

Co- Principal Investigator (Co-PI): BC Marndi, HN Subudhi, S Samantray, JL Katara, LK Bose, N Mandal, P Sanghamitra, N Umakanta and Muhammed Azharudheen TP

Maintenance breeding and seed quality enhancement

Principal Investigator: RK Sahu

Co- Principal Investigator (Co-PI): ON Singh, RL Verma, SSC Patnaik, L Behera, SK Pradhan, U Dhua, M Jena, T Bagchi, A Poonam, CV Singh, NP Mandal, BC Marndi, P Sanghamitra, MK Bag 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, Soham Ray and Muhammed Azharudheen TP

Hybrid rice for different ecologies

Principal Investigator: ON Singh

Co- Principal Investigator (Co-PI): RL Verma, JL Katara, S Samantaray, RK Sahu, BC Patra, MS Ananta, NP Mandal, D Maiti, SP Singh, TB Bagchi, AK Mukherjee and Sutapa Sarkar

Development of high yielding genotypes for rainfed shallow lowlands

Principal Investigator: SK Pradhan

Co- Principal Investigator (Co-PI): ON Singh, SSC Pattanaik, JN Reddy, SK Dash, MK Kar, L Behera, S Samantray, P Swain, J Meher, A Anandan and Sutapa Sarkar

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, A Anandan and Muhammed Azharudheen TP

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, SK Ghritlahre, Sutapa Sarkar and A Kumar

Improvement of rice through in vitro and transgenic approaches

Principal Investigator: S Samantaray

Co- Principal Investigator (Co-PI): LK Bose, RL Verma, Kutabuddin A Molla and A Kumar

Development and use of genomic resources for genetic improvement of rice

Principal Investigator: L Behera

Co- Principal Investigator (Co-PI): M Variar, SK Pradhan, RK Sahu, M Jena, NP Mandal, SK Dash, BC Marndi, J Meher, K Chattopadhay, P Swain, S Samantray, MS Anantha, HN Subudhi, NN Jambhulkar, N Umakanta and Kutabuddin A Molla

Development of resilient rice varieties for rainfed direct seeded upland ecosystem

Principal Investigator: NP Mandal

Co- Principal Investigator (Co-PI): MS Anantha, Y Kumar, M Variar, D Maiti, SK Dash, P Swain and CV Singh

Development of rice genotypes for rainfed flood-prone lowlands

Principal Investigator: JN Reddy

Co- Principal Investigator (Co-PI): KB Pun, SK Pradhan, L Behera and S Lenka

Programme 2: Enhancing the productivity, sustainability and resilience of rice based production system: AK Nayak/S Saha

Enhancing nutrient use efficiency and productivity in rice based system

Principal Investigator: AK Nayak

Co- Principal Investigator (Co-PI): S Mohanty, Md. Shahid, P Bhattacharya, R Tripathi, U Kumar, R Raja, BB Panda, A Ghosh, Priyanka Gautam, Banwari Lal, S Munda, SS Pokhare, D Chatterjee, P Panneerselvam and A Anandan

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

Principal Investigator: A Ghosh

Co- Principal Investigator (Co-PI): P Swain, CV Singh, BB Panda, A Poonam, R Tripathy, J Berliner and Priyanka Gautam

Development of sustainable production technologies for rice based cropping systems

Principal Investigator: BB Panda

Co- Principal Investigator (Co-PI): R Raja, AK Nayak, A Gosh, Teekam Singh, B Lal, R Tripathy, SD Mohapatra, Md. 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, D Chatterjee, S Mohanty, Md. 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): Md. 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, S Munda and P Panneerselvam

Management of problem soils for enhancing the productivity of rice

Principal Investigator: R Tripathi

Co- Principal Investigator (Co-PI): Md. Shahid, AK Nayak, A Kumar, S Mohanty, R Raja and D Chatterjee

Bio-prospecting and use of microbial resources for soil, pest and residue management

Principal Investigator: U Kumar

Co- Principal Investigator (Co-PI): TK Dangar and P Panneerselvam

Soil and crop management for productivity enhancement in rainfed upland ecosystem

Principal Investigator: CV Singh

Co- Principal Investigator (Co-PI): MS Anantha, Y Kumar, M Variar, D Maiti, SK Dash, P Swain and VK Singh

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

Principal Investigator: BS Satapathy

Co- Principal Investigator (Co-PI): S Saha, T Singh, A Kumar, KB Pun and NN Jambhulkar

Programme 3: Rice pests and diseases-emerging problems and their management: U Dhua/ M Jena

Management of rice diseases in different ecologies

Principal Investigator: AK Mukherjee

Co- Principal Investigator (Co-PI): U Dhua, SD Mohapatra, S Lenka, T Adak, J Berliner, SS Pokhare, MK Bag and Raghu S

Rice endophyte interaction with pathogens and pests in relation to environment

Principal Investigator: U Dhua

Co- Principal Investigator (Co-PI): M Jena, AK Mukherjee, MK Bag and Raghu S

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

Principal Investigator: M Jena

Co- Principal Investigator (Co-PI): PC Rath, SD Mohapatra, J Berliner, SS Pokhare, RK Sahu, SK Pradhan and Naveenkumar B Patil

Bio-ecology and management of pests under changing climatic scenario

Principal Investigator: SD Mohapatra

Co- Principal Investigator (Co-PI): M Jena, PC Rath, J Berliner, SS Pokhare, S Saha, U Kumar, AK Nayak, NN Jambhulkar, T Adak, Raghu S and Naveenkumar B Patil

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, T Adak, Raghu S, Naveenkumar B Patil and P Panneerselvam

Biotic stress management in rainfed upland rice ecology

Principal Investigator: D Maiti

Co- Principal Investigator (Co-PI): M Variar, CV Singh, NP Mandal and Yogesh Kumar

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

Principal Investigator: K Saikia

Co- Principal Investigator (Co-PI): KB Pun, MK Kar, AK Mukherjee, S Lenka, T Singh and BS Satapathy

Programme 4 : Biochemistry and physiology of rice in relation to grain and nutritional quality, photosynthetic efficiency and abiotic stress tolerance: SG Sharma/ P Swain

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

Principal Investigator: SG Sharma

Co- Principal Investigator (Co-PI): TB Bagchi, BC Marandi, A Ghosh, U Kumar, Md. Shahid, Totan Adak, P Sanghamitra and A Kumar

Phenomics of rice for tolerance to multiple abiotic stresses

Principal Investigator: RK Sarkar

Co- Principal Investigator (Co-PI): P Swain, MJ Baig 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, JL Katara and A Kumar

Evaluation and improvement of photosynthetic efficiency of rice

Principal Investigator: MJ Baig

Co- Principal Investigator (Co-PI): P Swain, R Raja and SK Pradhan

Programme 5 : Socio economic research and extension for rice in development: BN Sadangi/ P Samal

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

Principal Investigator: L Das

Co- Principal Investigator (Co-PI): BN Sadangi, P Samal, NC Rath, SK Mishra, GAK Kumar, SSC Pattnaik, S Saha, M Din, M Jena, RK Sahu, HN Subudhi, PC Rath, NN Jambhulkar, SP Patel, MK Kar, B Mondal, SM Prasad and VK Singh

Characterization of resources and innovations to aid rice research and develop extension models

Principal Investigator: GAK Kumar

Co- Principal Investigator (Co-PI): BN Sadangi, L Das, NN Jambhulkar, M Din, SG Sharma, M Jena, RL Verma, SK Mishra and B Mondal

Impact analysis and database updation in relation to rice technologies, policy and programmes

Principal Investigator: P Samal

Co- Principal Investigator (Co-PI): NN Jambhulkar, BN Sadangi, GAK Kumar, L Das, ON Singh, SK Pradhan, M Din and B Mondal

Ongoing Externally Aided Projects (EAPs)

Project No.	Title of the Project	Principal Investigator	Source of Funding
EAP 12	Multilocation evaluation of rice germplasm	HN Subudhi	NBPGR
EAP 15	Multilocation evaluation of rice germplasm	A Mukherjee	NBPGR
EAP 27	Revolving fund scheme for seed production of upland rice varieties at CRURRS, Hazaribagh	NP Mandal	AP Cess
EAP 36	National Seed Project (Crops)	RK Sahu 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 Trangenics in Crops	S Samataray	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 areas- CRRI Centre	ON Singh P Swain	ICAR - IRRI-(B&MGF)
EAP 127	Stress tolerant rice for poor farmers of Africa and South Asia - Submergence and Flood prone areas (STRASA)	JN Reddy SSC Patnaik RK Sarkar	ICAR-IRRI (B&MGF)
EAP 128	Stress tolerant rice for poor farmers of Africa and South Asia – Salt affected areas (STRASA)	B Marandi A Nayak A Poonam 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 U Dhua	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 AK Nayak P Swain S Mohanty SK Mishra K Chattopadhyay SD Mohapatra AK Mukherjee A Anandan D Chatterjee K Pun BS Sathpathy	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 (CRRI, 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)	M Jena T Adak	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 Dash 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)	ICAR-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	ICAR-IRRI STRASSA
EAP 186	Use of microbes for management of abiotic stresses in rice	AK Mukherjee	ICAR-IRRI
EAP 187	Low carbon resource conservation technologies for sustainable rice production in low land ecology	P Bhattacharyya	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- NFSM
EAP 189	Front Line Demonstrations	NC Rath	DAC – DRR (NFSM)
EAP 190	Multi location evaluation of rice germplasm	M Variar	DRR
EAP 191	CRRI-NCIPM collaborative project on development and validation of IPM module for rice	SD Mohapatra S Lenka J Berliner K Saikia KB Pun T Singh T Adak U Kumar	CRRI/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 M Sahid R Tripathy	STRASSA South Asia
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 A kumar	ICAR Plan-CRP
EAP 198	Incentivizing Research in Agriculture: Study of rice yield under low light intensity using genomic approaches	L Behera A Kumar SK Pradhan SK Das S Samantaray	ICAR Plan

EAP 199	Incentivizing Research in Agriculture: Towards understanding the C3-C4 intermediate pathway in Poaceae and functionality of C4 genes in rice	MJ Baig P Swain L Behera SK Pradhan S Ray A Kumar K Alimolla	ICAR Plan
EAP 200	Incentivizing Research in Agriculture: Genetic modifications to improve biological nitrogen fixation for augmenting nitrogen needs of cereals	TK Dangar U Kumar	ICAR Plan
EAP 201	Incentivizing Research in Agriculture: Molecular genetic analysis of resistance/tolerance to different stresses in rice, wheat, chickpea and mustard including sheath blight complex genomics	M Kar L Behera A Mukherjee S Aravindan NP Mandal S Samantaray S Ray	ICAR Plan
EAP202	Associated mapping of genes/QTLs for yield under reproductive stage drought stress in rice (*Oryza sativa* l.)	L Behera P Swain SK dash SK Pradhan BC Patra	BIRAC
EAP 203	Strategic development of water utilization in rice production system for higher crop and water productivity and profitability	A Ghosh P Swain SK Pradhan L Behera BB Panda R Tripathy	ICAR (CRP – water)
EAP 204	Germplasm characterization and multiplication	BC Patra	ICAR (CRP – Agrobiodiversity)
EAP 205	Nutrient cycle in agricultural system at field and regional scales	AK Nayak S Mohanty P Bhattacharyya R Tripathy M Sahid A Kumar P Goutam	ISRO – EOAM
EAP 206	Eliciting soil microbiome responses of rice for enhanced water and nutrient use efficiency under anticipated climate changes	P Bhattacharyya AK Nayak MJ Baig Md. Sahid S Raj A Kumar T Adak	ICAR-NASF

EAP 207	Conservation agriculture for enhancing the productivity of rice based cropping system in Eastern India	AK Nayak P Bhattacharyya R Tripathy B Lal BB Panda M Sahid S Munda S Saha SK Mishra SD Mohapatra P Guru	ICAR-CAP
EAP 208	Evaluation of efficiency of zinc metalosate and boron metalosate foliar supplements for maximizing yield through balanced nutrition of important crops grown in India	M Sahid AK Nayak A Kumar	AICRP
EAP 209	CRP on hybrid technology	RL Verma	ICAR-CRP
EAP 210	Fine mapping and identification of candidate gene/QTL for brown plant hopper resistance in rice cultivar, Salkathi	P Pattnaik (L Behera)	DST INSPIRE
EAP 211	CRP on molecular breeding	M Kar L Behera M Jena A Mukherjee S Ray N Umakanta S Aravindan	ICAR-CRP
EAP 212	Multilocational monitoring of Rynaxypyr 20SC against *Scirpophaga incertulas* in rice and rice hopper susceptibility survey in India for DPH-RAB55 106SC against *Nilaparvata lugens* and *Sogatella furcifera*	SD Mohapatra M Jena	Du Pont
EAP213	Maintenance, characterization and use of EMS of upland variety Nagina 22 for functional genomics in rice – Phase II	M Kar P Swain AK Mukherjee S Ray	DBT
EAP214	Energy and mass exchange in tropical rice system	D Chatterjee R Tripathy AK Nayak	ISRO
EAP215	Agri-Business incubator centre	GAK Kumar M Jena SG Sharma NC Rath S Saha RK Sahu BB Panda B Mondal AK Mukherjee PK Guru	NAIF, IP&TM, ICAR

EAP216	Evaluating performance of polymer coated urea in terms of enhancing yield and nitrogen use efficiency of rice under different growing contion	S Mohanty AK Nayak A Kumar	Gujarat State Fert & Chem Ltd.
EAP217	Development of high yielding, water and labor saving rice varieties for dry direct seeded aerobic conditions utilizing recent discoveries on traits, QTLs, genes and genomic technologies	ON Singh A Anandan S Sarkar SK dash MS Ramesh	DBT
EAP218	Evaluation of XR-848 benzyl ester alone; XR-848 Benzy ester + cyhalofop-butyl and penoxulam + cyhalofop-butyl for broad-spectrum weed control in wet direct-sown rice under shallow lowland and irrigated ecology	S Saha S Munda	Dow agro sciences india pvt. Ltd.
EAP219	Genetic enhancement of rice for low moisture stress tolerance	NP Mandal	ICAR
EAP220	Delivering food security on limited land (DEVIL)	AK Nayak SD Mohapatra M Sahid R Tripathy B Mondal	Min. Earth Science, GOI
EAP221	IT enabled self-sufficient seed system for rice (4S4R)	GAK Kumar	ICAR
EAP222	Earth observation application mission	AK Nayak S Mohanty P Bhattacharyya R Tripathy M Sahid A Kumar P Goutam	ISRO
EAP223	Marker-assisted introgression of yield-enhancing genes to increase yield potential in rice	L Behera M Kar SK Dash SK Pradhan N Umakanta	DBT
EAP224	Understanding mechanism of tolerance to low light intensity in rice	MJ Baig	NASF

Results-Framework Document (RFD) 2014-15

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

Functions

- 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	Genetic enhancement and development of improved cultivars	62	Evaluation of genetic material	Breeding and germplasm lines evaluated	Number	17	672	560	448	336	224
				Lines identified for unique traits	Number	5	6	5	4	3	2
			Development of improved cultivars	Entries contributed for AICRIP multi-location trial	Number	15	110	92	74	56	38
				Varieties identified for release	Number	5	4	3	2	1	0
			Seed production programme	Breeder seed produced	Weight MT	15	54	45	36	27	18
				Truthfully labeled seed produced	Weight MT	5	66	55	44	33	22
2	Development and identification of appropriate crop production & protection technologies	10	Development and testing of new technologies	New technologies identified & tested	Number	10	6$	5	4	3	2
3	Technology dissemination and capacity building	8	Demonstrations conducted	Front line demonstrations conducted	Number	4	22	18	14	10	6
			Farmers/ Extension officials training programmes organized	Trainings organized	Number	4	12	10	8	6	4
*	Publication/Document ation	5	Publication of the research articles in the journals having the NAAS rating of 6.0 and above	Research articles published	No.	3	42	35	28	21	14
			Timely publication of the Institute Annual Report (2013-2014)	Annual Report published	Date	2	30.06. 2014	02.07. 2014	04.07. 2014	07.07. 2014	09.07. 2014
*	Fiscal resource management	2	Utilization of released plan fund	Plan fund utilized	%	2	98	96	94	92	90
*	Efficient Functioning of the RFD System	3	Timely submission of Draft RFD for 2014-2015 for Approval	On-time submission	Date	2	May 15, 2014	May 16, 2014	May 19, 2014	May 20, 2014	May 21, 2014
			Timely submission of Results for 2013-2014	On-time submission	Date	1	May 1 2014	May 2 2014	May 5 2014	May 6 2014	May 7 2014

*	Enhanced Transparency / Improved Service delivery of Ministry/Department	3	Rating from Independent Audit of implementation of Citizens' / Clients' Charter (CCC)	Degree of implementation of commitments in CCC	%	2	100	95	90	85	80
			Independent Audit of implementation of Grievance Redress Management (GRM) system	Degree of success in implementing GRM	%	1	100	95	90	85	80
*	Administrative Reforms	7	Update organizational strategy to align with revised priorities	Date	Date	2	Nov.1 2014	Nov.2 2014	Nov.3 2014	Nov.4 2014	Nov.5 2014
			Implementation of agreed milestones of approved Mitigating Strategies for Reduction of potential risk of corruption (MSC)	% of implementation	%	1	100	90	80	70	60
			Implementation of agreed milestones for ISO 9001	% of implementation	%	2	100	95	90	85	80
			Implementation of milestones of approved Innovation Action Plans (IAPs)	% of implementation	%	2	100	90	80	70	60

As per the DAC indent received

$ Reduction in target due to depleting scientific and technical manpower

† As per sponsorship received

Section 3: Trend Values of the Success Indicators

Sl. No.	Objectives	Actions	Success indicators	Unit	Actual Value for FY 2012-2013	Actual Value for FY 2013-2014	Target value for FY2014-2015	Projected Values for FY2015-2016	Projected Values for FY 2016-2017
1	Genetic enhancement and development of improved cultivars	Evaluation of genetic material	Breeding and germplasm lines evaluated	Number	2470*	873	560	600	650
			Lines identified for unique traits	Number	5	6	5	7	8
		Development of improved cultivars	Entries contributed for AICRIP multi-location trial	Number	225	118	92	94	100
			Varieties identified for release	Number	2	7	3	2	2
		Seed production programme	Breeder seed produced	Weight MT	45	60.3	45	47	50
			Truthfully labeled seed produced	Weight MT	42.8	70$	55	59	62
2	Development and identification of appropriate crop production & protection technologies	Development and testing of new technologies	New technologies identified & tested	Number	8	10	5	5	6
3	Technology dissemination and capacity building	Demonstrations conducted	Front line demonstrations conducted	Number	19	30	18	20	21
		Farmers/ Extension officials training programmes organized	Trainings organized	Number	9	18	10	11	12
*	Publication/Documentation	Publication of the research articles in the journals having the NAAS rating of 6.0 and above	Research articles published	No.	34	59	35	40	44
		Timely publication of the Institute Annual Report (2013-2014)	Annual Report published	Date	-	-	02.07.2014	-	-
*	Fiscal resource management	Utilization of released plan fund	Plan fund utilized	%	100	100	96	96	96

*	Efficient Functioning of the RFD System	Timely submission of Draft RFD for 2014-2015 for Approval	On-time submission	Date	-	-	May 16, 2014	-	-
		Timely submission of Results for 2013-2014	On-time submission	Date	-	-	May 2, 2014	-	-
*	Enhanced Transparency / Improved Service delivery of Ministry/Department	Rating from Independent Audit of implementation of Citizens' / Clients' Charter (CCC)	Degree of implementation of commitments in CCC	%	-	-	95	-	-
		Independent Audit of implementation of Grievance Redress Management (GRM) system	Degree of success in implementing GRM	%	-	-	95	-	-
*	Administrative Reforms	Update organizational strategy to align with revised priorities	Date	Date	-	-	Nov.2, 2014	-	-
		Implementation of agreed milestones of approved Mitigating Strategies for Reduction of potential risk of corruption (MSC)	% of implementation	%	-	-	90	-	-
		Implementation of agreed milestones for ISO 9001	% of implementation	%	-	-	95	-	-
		Implementation of milestones of approved Innovation Action Plans (IAPs)	% of implementation	%	-	-	90	-	-

* Higher achievement due to evaluation of more number of germplasms under the project EAP 172 in collaboration with NBPGR and NICRA project
$ Higher production due to participatory seed production in farmers' fields

Section 4(a): Acronyms

S. No.	Acronym	Description
1	AICRIP	All India Coordinated Rice Improvement Project
2	DAC	Department of Agriculture and Cooperation
3	MT	Metric Tonne
4	NGO	Non Government Organization
5	CRRI	Central Rice Research Institute
6	ICAR	Indian Council of Agricultural Research

Section 4(b): Description and definition of success indicators and proposed measurement methodology

S. 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	Lines identified for unique traits	Lines with unique traits to be identified from the germplasm	Germplasm lines with very specific characteristics are to be identified	Number	This will help in identification of lines useful for improving specific economic traits
3	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
4	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
5	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
6	Truthfully labeled seed produced	Truthfully labeled seed is produced at the Institute for supplying quality seeds of popular varieties to farmers	Truthfully labeled seed is the progeny of foundation, certified or labeled seed	Quantity produced (MT)	Quantity will depend on farmers' demand for quality seed

7	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	
8	Front line demonstrations conducted	Front line demonstrations are conducted for technology testing in the farmers conditions	Frontline demonstration is the field demonstration conducted on farmers field under the close supervision of scientists	Number	
9	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 that are critical for delivering agreed results

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	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	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	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	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 activities of Department / Ministry

S. No.	Outcome/Impact	Jointly responsible for influencing this outcome/ impact with the following organization(s)/ department(s)/ ministry(ies)	Success indicator(s)	Unit	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
1	Acceptance and popularity of CRRI varieties as evidenced by sale of quality seeds	DAC, State Agriculture Departments, NGOs and farmers	Demand for breeder & TL seeds	MT	87.8	130.3	110.0	115.0	120.0
2	Enhanced rice productivity	DAC, Ministry of Rural Development, State Agriculture Departments and NGOs	Increase in productivity	Percent	1.8	2.0	2.25	2.5	2.5
3	Enhancement in export of rice	Ministry of Commerce and Export houses	Increase in export #	Percent	41.4*	7.33	7.0	8.0	8.0

Calculation based on data available in APEDA website.

* Higher value in 2012-13 is due to more increase in export of non-basmati rice over the previous year. Earlier in 2010-11, there was a ban on non-basmati rice export and non-basmati export picked up slowly in 2011-12.

NRRI RFD 2014-15 Approved Annual Achievement

Annual (April 1, 2014 to March 31, 2015) Performance Evaluation Report in respect of RFD 2014-2015 of ICAR-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.	Objectives	Weight	Actions	Success Indicators	Unit	Weight	Target / Criteria Value					Achievements	Performance		Percent achievements against Target values of 90% column	Reasons for shortfalls or excessive achievement, if applicable
							100%	90%	80%	70%	60%		Raw Score	Weighted Score		
1	Genetic enhancement and development of improved cultivars	62	Evaluation of genetic material	Breeding and germplasm lines evaluated	Number	17	672	560	448	336	224	1146	100	17	204.6	Received new germplasm lines for evaluation than usual material
				Lines identified for unique traits	Number	5	6	5	4	3	2	6	100	5	120.0	
			Development of improved cultivars	Entries contributed for AICRIP multi-location trial	Number	15	110	92	74	56	38	122	100	15	132.6	
				Varieties identified for release	Number	5	4	3	2	1	0	8	100	5	266.7	Due to identification of more no. of promising entries in AICRIP trials
			Seed production programme	Breeder seed produced	Weight MT	15	54	45	36	27	18	80.4	100	15	178.7	
				Truthfully labelled seed produced	Weight MT	5	66	55	44	33	22	70	100	5	127.3	
2	Development and identification of appropriate crop production & protection technologies	10	Development and testing of new technologies	New technologies identified & tested	Number	10	6$	5	4	3	2	6	100	10	120.0	

3	Technology dissemination and capacity building	8	Demonstrations conducted	Front line demonstrations conducted	Number	4	22	18	14	10	6	28	100	4	155.6	
			Farmers/ Extension officials training programmes organized	Trainings organized	Number	4	12	10	8	6	4	22	100	4	220.0	Due to more no. of sponsorships received
*	Publication/Documentation	5	Publication of the research articles in the journals having the NAAS rating of 6.0 and above	Research articles published	No.	3	42	35	28	21	14	48	100	3	137.1	
			Timely publication of the Institute Annual Report (2013-2014)	Annual Report published	Date	2	30.06. 2014	02.07. 2014	04.07. 2014	07.07. 2014	09.07. 2014	09.07. 2014	60	1.2		
*	Fiscal resource management	2	Utilization of released plan fund	Plan fund utilized	%	2	98	96	94	92	90	100	100	2		
*	Efficient Functioning of the RFD System	3	Timely submission of Draft RFD for 2014-2015 for Approval	On-time submission	Date	2	May 15, 2014	May 16, 2014	May 19, 2014	May 20, 2014	May 21, 2014	May 13, 2014	100	2		
			Timely submission of Results for 2013-2014	On-time submission	Date	1	May 1, 2014	May 2, 2014	May 5, 2014	May 6, 2014	May 7, 2014	April 25, 2014	100	1		
*	Enhanced Transparency / Improved Service delivery of Ministry/Department	3	Rating from Independent Audit of implementation of Citizens' / Clients' Charter (CCC)	Degree of implementation of commitments in CCC	%	2	100	95	90	85	80	100	100	2		
			Independent Audit of implementation of Grievance Redress Management (GRM) system	Degree of success in implementing GRM	%	1	100	95	90	85	80	100	100	1		

*	Administrative Reforms	7	Update organizational strategy to align with revised priorities	Date	Date	2	Nov. 1, 2014	Nov. 2, 2014	Nov. 3, 2014	Nov. 4, 2014	Nov. 5, 2014	Nov. 1, 2014	100	2		
			Implementation of agreed milestones of approved Mitigating Strategies for Reduction of potential risk of corruption (MSC).	% of Implementation	%	1	100	90	80	70	60	100	100	1		
			Implementation of agreed milestones for ISO 9001	% of implementation	%	2	100	95	90	85	80	100	100	2		
			Implementation of milestones of approved Innovation Action Plans (IAPs).	% of implementation	%	2	100	90	80	70	60	100	100	2		

Total Composite Score: 99.20
Rating: Excellent

ANNEXURE-I

Actual Scientific Staff in position in the Institute and their research articles publications published in International and National Journals having NAAS rating 6.00 or more during April 1, 2014-March 31, 2015

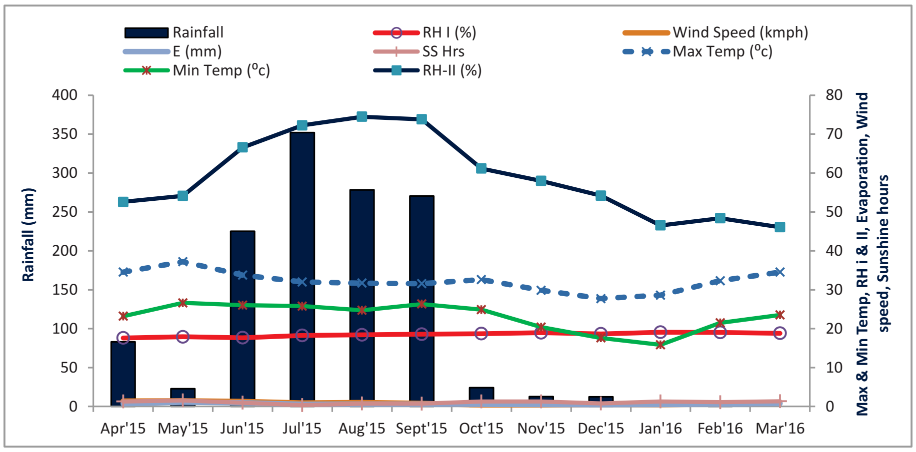
Name of the Division: Crop Science

Name of the Institute: ICAR- Central Rice Research Institute

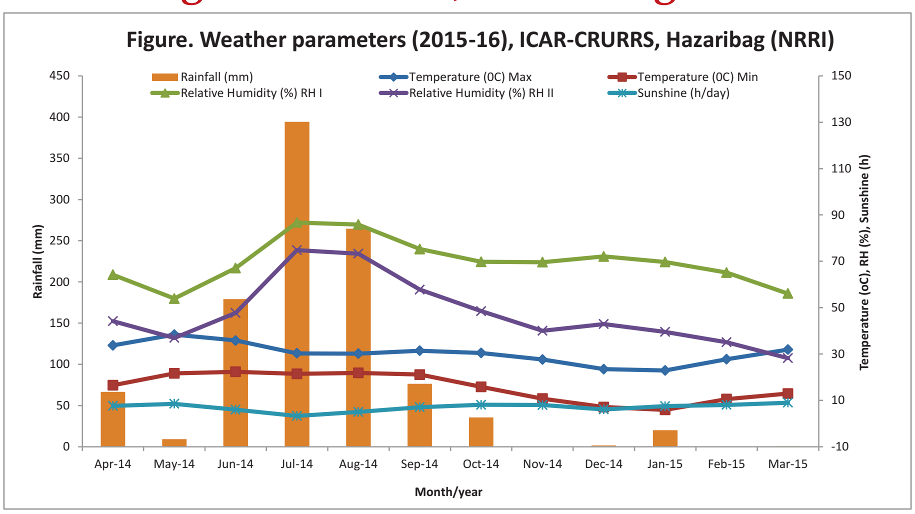
S. No.	Category of Scientific Staff	Actual Scientific Staff in position (Nos.)	Research articles publications as first /corresponding author (Nos.)	Publication productivity (Number of research articles publications divided by number of Scientists)
1.	Principal Scientist	29	05	0.17
2.	Senior Scientist	21	16	0.76
3.	Scientist	27	10	0.37
Total		77	31	0.40

Weather

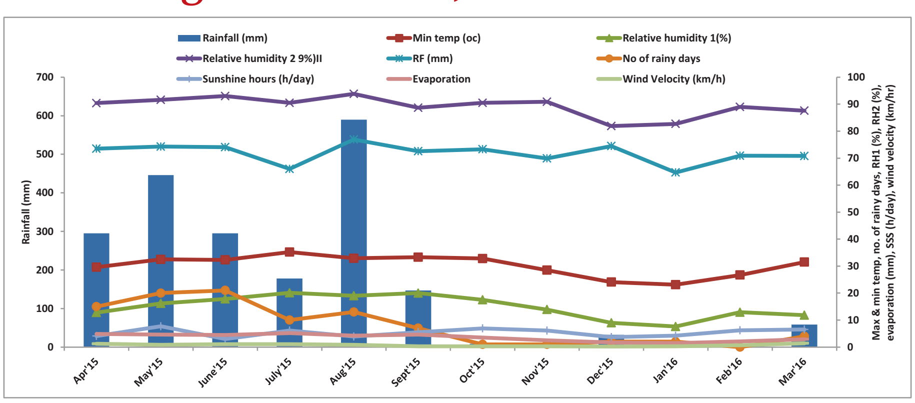
NRRI, Cuttack



NRRI Regional Station, Hazaribag



NRRI Regional Station, Gerua



Acronyms

AAU : Assam Agricultural University
ADG : Assistant Director-General
AICRIP : All India Coordinated Rice Improve-ment Project
AIR : All India Radio
AMAAS : Application of Microorganisms in Agriculture and Allied Sectors
ANGRAU : Acharya N.G. Ranga Agricultural University, Hyderabad
ARIS : Agricultural Research Information Service
ASG : Aromatic-Short Grain
ASGON : Aromatic Short Grain Observation Nursery
ASRB : Agricultural Scientists Recruitment Board, New Delhi
ASV : Alkali Spreading Value
ATMA : Agricultural Technology Management Agency
AVT : Advanced Varietal Trial
AWD : Alternate Wetting and Drying
AYT : Advance Yield Trial
BB/BLB : Bacterial Leaf Blight
BMGF : Belinda and Bill Gates Foundation
BPH : Brown Planthopper
Bt : Bacillus thuringiensis
CAC : Consortium Advisory Committee
CIAE : Central Institute of Agricultural Engineering, Bhopal
CIC : Consortium Implementation Committee
CIFA : Central Institute of Freshwater Aquaculture, Bhubaneswar
CMS : Cytoplasmic Male Sterile/Sterility
CRIDA : Central Research Institute for Dryland Agriculture, Hyderabad
CRIJAF : Central Research Institute for Jute and Allied Fibres, Barrackpore
CRRI : Central Rice Research Institute, Cuttack
CRRURS : Central Rainfed Upland Rice Research Station, Hazaribag
CSIR : Council of Scientific and Industrial Research
CURE : Consortium for Unfavourable Rice Environment
DAC : Department of Agriculture and Cooperation
DAF : Days after Flowering
DAH : Days after Harvest
DAO : District Agricultural Officer
DARE : Department of Agriculture Research and Education, Government of India
DAS : Days after Sowing
DBN : Drought Breeding Network
DBT : Department of Biotechnology, New Delhi
DFF : Days to 50 % Flowering
DH : Dead Hearts
DNA : Deoxyribonucleic Acid
DRR : Directorate of Rice Research, Hyderabad
DRWA : Directorate of Research for Women in Agriculture
DS : Dry Season
DSN : Dry Season Nursery
DSR : Directorate of Seed Research, Mau
DST : Department of Science and Techno-logy, New Delhi
EAP : Externally Aided Projects
EC/ECe : Electrical Conductivity
EIRLSBN : Eastern India Rainfed Lowland Shuttle Breeding Network
FLD : Frontline Demonstration
FYM : Farmyard Manure
g : Gram
GLH : Green Leafhopper
GM : Green Manuring / Gall Midge
h : Hour
ha : Hectare
HI : Harvest Index
HRR : Head Rice Recovery
HYV : High-yielding variety
IARI : Indian Agricultural Research Institute, New Delhi
IASRI : Indian Agricultural Statistics Research Institute, New Delhi
ICAR : Indian Council of Agricultural Research
ICRISAT : International Crops Research Institute for the Semi-Arid Tropics
IDM : Integrated Disease Management
IET : Initial Evaluation Trial
IFAD : International Fund for Agricultural Development
IGAU : Indira Gandhi Agricultural University, Raipur
IGKVV : Indira Gandhi Krishi Vishwavidyalaya
IINRG : Indian Institute of Natural Resins and Gums, Ranchi
IISS : Indian Institute of Soil Science, Bhopal
IIVR : Indian Institute of Vegetable Research, Varanasi
IJSC : Institute Joint Staff Council
IMC : Institute Management Committee
INGER : International Network for Genetic Evaluation of Rice

INM	:	Integrated Nutrient Management
INSA	:	Indian National Science Academy
IPM	:	Integrated Pest Management
IPR	:	Intellectual Property Rights
IPS	:	Indian Police Service
IRRI	:	International Rice Research Institute, Philippines
IVRI	:	Indian Veterinary Research Institute, Izatnagar
IVT	:	Initial Varietal Trial
Kg	:	Kilogram
KVK	:	Krishi Vigyan Kendra
L	:	Litre
LB	:	Long-bold
LCC	:	Leaf Colour Chart
LF	:	Leaf Folder
LS	:	Long-slender
LSI	:	Location Severity Index
MAS	:	Marker-assisted Selection
MB	:	Medium Bold
MLT	:	Multilocation Trial
MS	:	Medium-slender
NAARM	:	National Academy of Agricultural Research Management, Hyderabad
NAAS	:	National Academy of Agricultural Sciences
NAIP	:	National Agricultural Innovation Project
NARES	:	National Agricultural Research and Extension Research
NARS	:	National Agricultural Research System
NASC	:	National Agricultural Science Complex, New Delhi
NBAIM	:	National Bureau of Agriculturally Important Microorganisms
NBPGR	:	National Bureau of Plant Genetic Resources, New Delhi
NDRI	:	National Diary Research Institute, Karnal
NDUAT	:	Narendra Dev University of Agriculture And Technology
NFSM	:	National Food Security Mission
NGO	:	Non-governmental Organization
NHSN	:	National Hybrid Screening Nursery
NIL	:	Near-isogenic Lines
NIPGR	:	National Institute for Plant Genome Research, New Delhi
NIWS	:	National Invasive Weed Surveillance
NPK	:	Nitrogen, Phosphorous, Potassium
NPT	:	New Plant Type
NRC	:	National Research Centre
NRCPB	:	National Research Centre for Plant Biotechnology, New Delhi
NSN	:	National Screening Nursery
NSP	:	National Seed Project
OFT	:	On-farm Trials

ISBN 81-88409-00-6

ICAR-National Rice Research Institute
(Formerly Central Rice Research Institute)
An ISO 9001:2008 Certified Institute
Cuttack-753 006, Odisha, India
Phone: 0671-2367757, Fax: 91-671-2367663
Email: director.nrri@icar.gov.in, directorcrricuttack@gmail.com
Website: http://www.crri.nic.in