CRRI

वार्षिक प्रतिवेदन

ANNUAL REPORT 2013-14

केंद्रीय चावल अनुसंधान संस्थान

भारतीय कृषि अनुसंधान परिषद

Central Rice Research Institute

(Indian Council of Agricultural Research)

CRRI

वार्षिक प्रतिवेदन
Annual Report
2013-14

केंद्रीय चावल अनुसंधान संस्थान

भारतीय कृषि अनुसंधान परिषद

कटक (ओडिशा) ७५३ ००६, भारत

Central Rice Research Institute

Indian Council of Agricultural Research

Cuttack (Odisha) 753 006, India

Correct Citation
CRRI Annual Report 2013-14
Central Rice Research Institute, Cuttack

ISBN : ISBN 81-88409-14-6

Published By
Dr Trilochan Mohapatra
Director, CRRI

Editorial Committee
Dr TK Dangar
Dr A Das
Dr SK Pradhan
Dr A Mukherjee
Dr R Raja
Dr GAK Kumar

Coordination
Dr BN Sadangi

Photography
Shri P Kar
Shri B Behera
CRRI Regional Station, Hazaribag
CRRI Regional Station, Gerua

Design and page layout
Shri Sunil Kumar Sinha

July 2014

Laser typeset at the Central Rice Research Institute, Indian Council of Agricultural Research, Cuttack (Odisha) 753006, India, and printed in India by the Print-Tech Offset Pvt. Ltd., Bhubaneswar (Odisha) 751024. Published by the Director, for the Central Rice Research Institute, ICAR, Cuttack (Odisha) 753006.

Contacts

Central Rice Research Institute
Indian Council of Agricultural Research
Cuttack (Odisha) 753 006
Phone : +91-671-2367768-83
Fax : +91-671-2367663
E-mail : crrictc@nic.in | directorcrricuttack@gmail.com

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

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

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

Contents


CRRI

Preface

Rice is the staple food for more than 50% world population and 85% Indian population. Concerted efforts of agricultural scientists and rice farmers supported by government policies ensured production of 105.2 million tons of milled rice during 2012-13. This enabled meeting the domestic demand and allowed export of rice to the tune of ten million tons. The estimate of rice production for 2013-14 is 106.29 million tons that makes the country's position very comfortable. However, to ensure food and nutrition for the ever-growing population in the face impending drought situation in 2014-15 and adversities due to climate change, the national efforts to increase rice production have to be sustained.

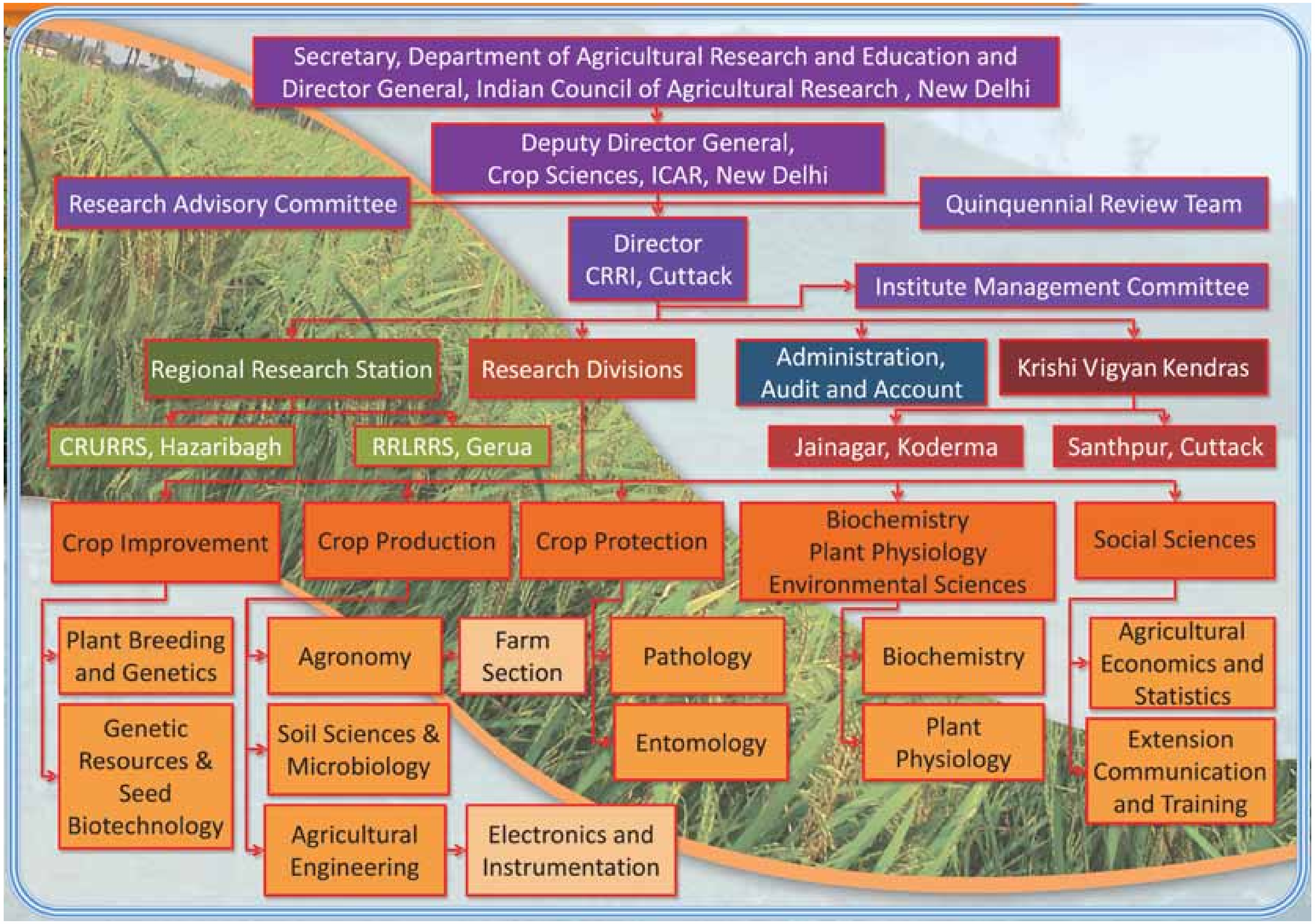
Central Rice Research Institute is devoted to rice research to improve production and productivity, particularly in difficult ecologies of the country often affected by a range of biotic and abiotic stresses, through development and dissemination of efficient rice varieties and production technologies. Research priorities of the institute are development of cost effective agricultural practices, optimization of resource management, mechanization and reduction of operational stress of the farm workers, eco-friendly crop protection systems, generation, dissemination and popularization of potent technologies, human resource development in-house and in collaboration with national and international organizations.

During the year under report, the scientists of the institute made dedicated efforts to develop varieties for different ecologies utilizing traditional and modern breeding tools, which led to release of eight and identification of three high yielding varieties including four for aerobic situations. Efforts were continued for developing genotypes/breeding lines with at least 20% yield advantage over popular varieties and minimization of the gap between potential and actual yield in farmers' field, dissemination of effective production technologies including farm mechanization, development and promotion of rice integrated crop management (RICM) systems, superior metabolically efficient and climate resilient rice genotypes and reduction of production cost of rice. The institute also developed and commercialized a leaf color chart (LCC) to ensure judicious application of nitrogenous fertilizer in rice. Use of herbicides to manage weeds and its dissemination among farmers has been taken up with renewed vigor to cut down the cost of controlling weeds manually. In keeping with the policy of the government for ensuring nutritional security, research on developing nutrient dense rice with special emphasis on protein, iron and zinc content were pursued, the benefits of which are likely to be available in near future. The institute strengthened research on low glycemic index rice with the approval of Institute Ethics Committee. It has developed collaboration with other research institutes and universities on the twin aspects of high protein rice and low-GI rice. The institute continued to monitor the BGREI program as the nodal agency to address the constraints to rice production in eastern India and endeavored hard to live up to its commitment to make innovations and achieve excellence in rice research to help the nation sustain productivity and prosperity.

I sincerely acknowledge the inspiring guidance of Dr. S. Ayyappan, Hon'ble Secretary, DARE and Director General, ICAR, New Delhi to sustain the activities of this institute. The valuable inputs, support and guidance provided by Dr. S. K. Datta, Deputy Director General (Crop Science), ICAR, New Delhi; Dr. E. A. Siddiq, Chairman, QRT; Dr. R. B. Singh, Chairman, RAC; the esteemed members of QRT, RAC and IRC are gratefully acknowledged. I express my sincere thanks to Dr. R.P. Dua, Assistant Director General (FFC), ICAR, New Delhi and other concerned officials of the council for their involved support. The efforts of Heads of Division, OICs of Regional Research Stations, Publication Committee, Administration, Finance and Publication Unit of the Institute for compiling, and editing the Annual Report are highly appreciated. My sincere thanks are due to all the staff of the institute for their whole-hearted support in carrying out institute's activities. I hope that this report will be useful for policy makers, researchers, development functionaries, farmers, farmwomen and students.

(T. Mohapatra)
Director

Organogram



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
CRRI, Cuttack
Institute Management Committee
Regional Research Station
Research Divisions
Administration,
Audit and Account
Krishi Vigyan Kendras
CRURRS, Hazaribagh
RRLRRS, Gerua
Jainagar, Koderma
Santhpur, Cuttack
Crop Improvement
Crop Production
Crop Protection
Biochemistry
Plant Physiology
Environmental Sciences
Social Sciences
Plant Breeding
and Genetics
Genetic
Resources &
Seed
Biotechnology
Agronomy
Farm
Section
Soil Sciences &
Microbiology
Agricultural
Engineering
Electronics and
Instrumentation
Pathology
Entomology
Biochemistry
Plant
Physiology
Agricultural
Economics and
Statistics
Extension
Communication
and Training

Executive Summary

As part of significant research outcomes during 2013-14, Central Rice Research Institute released eight rice varieties while variety identification committee identified another three rice varieties for release. Under rainfed shallow lowland ecology, CR Dhan 407 (IET 21974) was released for the states of Odisha and West Bengal. Three varieties namely CR Dhan 303, CR Dhan 304 and CR Dhan 305 were released for irrigated mid early group in the 68th meeting of Central sub-committee on Crop standards, Notification and Release of varieties for Agricultural Crops. CR Dhan 303 was notified for Madhya Pradesh, Uttar Pradesh and Odisha; CR Dhan 304 for Odisha and West Bengal while CR Dhan 305 was released for Jharkhand, Maharashtra and Andhra Pradesh. Two varieties CR Dhan 201 and CR Dhan 202 have been released for aerobic situation. CR Dhan 201 is recommended for Bihar and Chhattisgarh while CR Dhan 202 is for Jharkhand. Besides, CR Dhan 300, a fine grain rice variety is released for Maharashtra, Gujarat, Odisha and Bihar. Under deepwater ecology, CR Dhan 505 has been released for cultivation in Odisha and Assam. CR Dhan 205 has been identified for release in the states of Tamil Nadu, Gujarat, Odisha, Madhya Pradesh and Punjab under aerobic condition, while CR Dhan 204 has been identified for released in Jharkhand and Tamil Nadu. CR Dhan 306 is identified for Madhya Pradesh, Bihar and Puducherry for irrigated mid-early duration during the 49th annual rice group meeting. CRR 451-1-B-2-1 (IET 22020), an early culture of 68 days flowering duration with intermediate height (100 cm) and excellent grain quality was also identified for Jharkhand and Madhya Pradesh by Varietal Identification Committee during the last workshop.

During the year, exploration programme was conducted in North eastern state of Manipur for collection of rice germplasm in collaboration with NBPGR Regional Station, Shillong. Thirty accessions were collected. Besides, three accessions of *O. rufipogon* were also collected from Loktak Lake. About 2285 accessions were rejuvenated in the field for periodical maintenance of seed viability, seed increase and seed supply to different researchers. One thousand eight hundred twenty eight accessions of rice germplasm of both cultivated and wild species were supplied to the researchers all over the country for utilization in breeding programmes. Five thousand and thirteen germplasm lines were grown in the field for morpho-agronomical characterization. Molecular characterization of about 185 accessions of newly collected wild and weedy rice germplasm was also done. Besides, six hundred released rice varieties acquired / collected from different states of India were also characterized as per DUS descriptor. All these germplasm accessions were conserved as medium term storage in National Active Germplasm Site (NAGS) of CRRI. Data on 50% flowering, plant height and grain yield of 850 germplasms were recorded and seeds of 250 accessions were deposited in the gene bank.

Panicle progeny rows of 41 varieties were grown and evaluated in the field, as well as, laboratory for maintenance breeding. The selected progeny lines were bulked as nucleus seed and used for production of breeder seed. Though the breeder seed production was severely affected by the cyclonic storm Phailin, 483.12 quintals of breeder seed was produced comprising of 43 varieties and six parental lines during the year.

The *Oryza* wild species represent a potential source of new alleles for improving the yield, quality, abiotic and biotic stress. Introgression of BPH resistant gene utilizing two accessions of *O. rufipogon* (AC No. 100174, AC No.100444) and YSB tolerance traits of *O. brachyantha* (AC No.1086) with short stature, increased tiller number, reduced stem diameter (hardy stem) and narrow leaves into cultivated background were achieved. Development of co-dominant molecular markers distinguishing *Oryza sativa* c.v. CR1009 (AA) and *Oryza brachyantha* (AC No. 1086) (FF) genomes for further utilization in wide cross derivatives.

During evaluation of selected 58 genotypes for their reaction to salt stress (EC 6-8 dS / m) at flowering stage, Bhutia and Pokkali (AC 41585) with marginal reduction in grain yield under salt stress compared to the control were found most promising.A few lines, such as CR2815-4-23-7-S-2-1-1, CR2815-5-1-3-S-1-2-1 exceeded yield of Luna Sankhi in dry season under normal soil condition. Similarly, in wet season, a few lines such as CR2859-S-B-3-1-2B-1 (Varshadhan x FL496), CR2851-S-1-6-2B-1 (Gayatri x SR 26B) performed better than Luna Suvarna under coastal saline situation (EC= 6-7 dS / m) at Sundarban.

In super rice programme, potential donors *viz*., CR 3623-2-2-1, CR 3624-1 and CR 3724-1 were identified from the existing New Plant Types which had 8.0 -9.0 t / ha grain yield during *rabi* and 5.9- 6.7 t / ha in *kharif* even under natural calamity "Phailin". Similarly, IR 72158-148-4-2-6-2 was also found promising in bunded upland. Some of exotic and distant relatives of *indica* were identified in tropical japonica with '*wc*' genes producing high grain yield (EC 497016 with 1201 g / m^2) and better combining ability (EC 491313 and EC 491476). Few advanced generation fixed lines produced 8.01 t / ha grain in irrigated situation and 8.5 t / ha in shallow lowland with ideal plant type, possessing heavy panicle and good grain quality *vis-a-vis* field tolerance to major disease and pests.

To develop high yielding aromatic short grain rice promising lines were evaluated and IET 22649 (CR 2713-180), IET 22648 (CR 2713-179), IET 23189 (CR 2713- 35), IET 23203 (CR 2947-1) with good grain quality parameters were identified for final year of testing in AVT 2- ASG. In the trial IVT ASG, IET 23864 (CR 939-5-16-2-4-3-1-1) were found promising and promoted AVT 1 ASG. One long slender aromatic culture CR 3699-6-2 with more than 9 mm kernel length was identified and nominated to IVT-BT. Phenotyping of a backcross derived mapping population from Naveen and ARC10075, a donor for high GPC over two seasons revealed that the range of GPC was 5.06 to 14.24%.

The RIL mapping populations from the crosses CR 662-2211-2-1 / WAB 50-56 and PDKV Shriram / Heera were phenotyped for yield related traits for identification of QTLs associated with yield and its component traits. One hundred eighty five land races with different levels of resistance to blast were evaluated for SNP polymorphism at six major blast resistance genes, *Pi z, Piz-t, Pita/Pita-2, pita, Pi 9* and *Pi b* to identify QTLs / genes associated with blast resistance. Three hundred rice genotypes were screened for vegetative stage drought tolerance under field condition of CRRI, Cuttack for association analysis to identify QTLs / genes for drought tolerance. Two hundred rice genotypes were phenotyped for grain shape traits. Ninety six of these genotypes were amplified with primers specific for grain shape genes *GW2*, *GS3* and *GW5*. Polymorphisms were observed for each gene. The amplicon will be sequenced to find haplotypes and allelic variations. The genomes of 96 rice genotypes with different levels of drought tolerance were amplified with SNP primers in the WRKY family transcriptional factor (WRKY35 gene with LOC_Os04g39570) which will be sequenced to find haplo types and allelic variations.

Two hundred plants were generated from an elite rice hybrid, BS 6444 (G) through anther culture. The ploidy status of all the 200 plants was estimated morphologically to differentiate haploids, doubled haploids and polyploids. Simultaneously, 8 SSR markers were identified which could be able to discriminate diploid line (like the donor, BS644G) from all the DHs derived through anther culture. Besides, 158 DHs derived from eight elite hybrid rice varieties were selected for further agro-morphological evaluation at A_1 generation in the field.

Genetic constitution of upland rice varieties with respect to blast resistance probed with gene specific markers for nine major genes revealed the rare occurrence of *Pi 2* and *Pi ta2* which are effective against the prevalent population of *M. oryzae*. Several alleles of *Pi 2* and *Pi 9* were, however, detected in indigenous germplasm. Marker-assisted backcross breeding approach is being employed to further improve drought tolerance of popular upland variety CR Dan 40 in terms of grain yield under stress and blast resistance of Sahbhagidhan and Naveen. Backcross populations having drought QTLs and effective major genes for blast were generation advanced.

Elite rice cultures developed for DSR under unbunded (unfavorable) uplands were responsive up to moderate NPK levels (60:40:30) with no significant yield increase at higher level (90:60:45). The most promising among tested cultures were CRR-617-B-47-3 followed by CRR 616-B-66-2.

Spatial maps of soil DTPA extractable Fe and Zn for Nischintakoilli, Mahanga and Salipur block of Cuttack, Odisha and Nagpur, Parbhani and Wardha districts of Maharashtra were prepared using ordinary kriging interpolation technique with suitable variogram models.

Soil micronutrient maps of Rajnagar block in Kendrapada district for DTPA extractable Iron (Fe), Zinc (Zn), Manganese (Mn) and Copper (Cu) indicated that there is no Fe and Cu (>0.4 mg / kg) deficiency, about 6.3% area is Zn deficient to critically lower limit (<0.6 mg / kg) and 66.3% area had medium Zn content (0.8-1.2 mg / kg), and about 44% area is Mn deficient to critically lower limit (<3.5 mg / kg).

Application of rice husk biochar showed positive response on yield over control and recommended fertilizer dose (RFD). Biochar applied treatments recorded significantly higher soil pH vis-à-vis control and RFD indicating higher acid neutralizing capacity of biochar. Biochar treated soils also recorded higher microbial count and enzymatic activities at harvest over control.

Submergence tolerance of IR-64 and IR-64 *Sub1* at active tillering, panicle initiation and heading stage were compared with N and P application time. Post-submergence N with basal P application improved the survival (43%), reduced shoot elongation and significantly increased the yield (47%), with more pronounced effects in IR-64 *Sub1* over control and pre-submergence N application.

Elite rice cultures developed for DSR under unbunded (unfavorable) uplands were responsive up to moderate NPK levels (60:40:30) with no significant yield increase at higher level (90:60:45). The most promising among tested cultures were CRR-617-B-47-3 followed by CRR 616-B-66-2.

Integration of (i) arbuscular mycorrhiza (AM)-supportive crop rotation of maize relay cropped by horse gram in first year and rice in second year (ii) application of dual inoculums (AM + P-solubilizer) and (iii) P source of 50% P as DAP and 50% as PRP led to additive effect on AM-aided P acquisition and grain yield (2.65 t / ha) of upland rice cv. Vandana.

Among four advance breeding lines viz., CRR-616-B-66-2, CRR-455-109, CRR-676-1 (Vandana NIL) and CRR-596-8-1 tested, Vandana NIL showed highest AM-inoculation response and tended to at par with the high AM-responsive check Sathi 34-36.

Evaluation of crop establishment methods under post-flood situation in rainfed lowland ecosystem revealed that normal transplanting of Anjali, Luit, Abhishek and Naveen had significantly higher yield attributes and yield than double transplanting and wet direct seeding.

Performance evaluation of rice varieties Chandrama and Naveen under different dates of planting in *boro* season showed that 25th January transplanting recorded highest yield followed by 5th February while 5th January transplanting recorded the lowest yield in rainfed lowland ecosystem.

Cumulative effect of fertilizer treatments in a long-term fertilizer experiment of rice-rice sequence on weed composition and diversity revealed that sedges were dominant in all treatments followed by broad-leaves and grasses. High relative density of weeds was observed in control and FYM treated plots, whereas, low weed density was observed in N, NPK and NPK+FYM treatments.

Study on population dynamics of major rice weeds revealed that *Echinochloa colona* was the most predominant weed species (>50%) in both wet and dry direct-sown rice. *Leptochloa chinensis* was the most prevalent weed in rice-rice cropping sequence. Rice germplasms viz. IR 83929-B-B-291-2-1-1-2, IR 83750-B-B-145-4-174-3 and IR-84899-B-184-18-1-1-1 were found highly weed competitive in screening trial.

Application of Azimsulfuron provided broad spectrum of weed control of dry direct-sown rice with weed control efficiency (WCE) of 88%. Herbicide mixture of Azimsulfuron + Bispyribac sodium (22 + 25 g / ha) and sequential application of Flucetosulfuron followed by Bispyribac sodium (25 and 25 g / ha) showed excellent control of broad spectrum of weeds (WCE 91-92%) in wet direct-sown and transplanted rice.

The relationship between Block level rice productivity index (RPI) and Standardized Precipitation Index (SPI) of different wet season months (June-November) was studied using time series of rainfall data (1983-2008) from 168 rain gauge stations of Odisha. One month time scale SPI of July and October had significantly stronger relationship with RPI. Regression models were developed using 1-month SPI for forecasting rice productivity of blocks with varying proportion of rainfed area in Odisha.

System productivity and profitability of six different rice-based cropping systems were evaluated for crop / varietal diversification for climate change adaptation. Naveen and Swarna transplanted on 1st July gave 13.1% and 36.4% higher yield compared to that of transplanted on 1st August. System productivity was highest (5.49 t / ha) in the rice (Swarna)-toria-coriander system under prevailed weather conditions.

Best bet resource conservation technology involving i) Loosening of soil by mould board plough followed by Rotavator or cultivator; ii) Dry direct seeding of rice and dhaincha in paired row system by seed drill; iii) Incorporation of dhaincha at 25 DAS by Conoweeder if water is available; alternatively knock down of dhaincha by 2,4-D at 25 DAS if water is not available; iv) CLCC based real time N application in two splits and v) Harvesting through reaper / combined harvester was evaluated in farmers field. Adoption of RCT reduced cost of production saved energy and enhanced the rice yield over the farmers practice.

Small, medium and large size rice husk combustors having 1, 2 and 3 KW capacity were designed and fabricated. All three models were having thermal efficiency of 14-15% and suitable for thermal energy application depending up on the amount of heat required.

More than 1000 polyvalent plant growth promoting bacteria (PGPB) possessing various plant growth promotion (PGP) properties like P and N metabolism, plant growth regulaton, NH_3, toxin and inhibitor (siderophore, HCN, AHL lactonase etc.) production were characterized. One each of P-solubilizing, N_2-fixing and osmotolerant P-solubilizing polyvalent PGPB enhanced growth and production of rice in field condition.

Biopesticides like rhizospheric and phytonic Bt, oxic / anoxic and osmotic stress tolerant microbes, the diversity of the endophytic and epiphytic microbes of eight cultivated and four wild rice (*Oryza* spp.) genotypes have been assessed for their functionality and phenotypic diversityy. Six biocides of leaf folder i.e. *Beauveria bassiana, Metarhizium anisopliae* and four *Bacillus thuringiensis* strains have been formulated and processed for patent application.

Among biocides and fungicide treatments, *Trichoderma viride* of PCIL reduced sheath blight incidence by 53.82% followed *T. viride* of OUAT (45.8%) and Validamycin 3%L (43.66%) with highest grain yield (4.94t / ha) for the former.

Rice *tungro* disease (RTD) was recorded in thirteen districts of Assam on Mahsuri, Ranjit, Baismuthi, and Swarna *sub1*, Swarna, IR 64, China boro, Arize 6444, DRRH 2, JKRH 401, PAC 837 and Sahyadri 4. Sheath blight (6.26%) and sheath rot (6.94%) diseases occurred more on Swarna and Mahsuri, respectively.

Out of 1250 genotypes, 52 were highly susceptible, 1070 were moderately susceptible and 53 were moderately resistant against sheath blight. Out of 1670 lines, 2 lines were resistant against brown spot and out of 1685 lines, 118 lines were resistant but 1242 lines were moderate to highly susceptible to bacterial leaf blight.

Among 13 native *Trichoderma* spp., one isolate (T-2) effected 95% post emergence survival of seedling compared to 60% in control. Two bacterial bioagents, BC1 and BC2, could control seedling blight (*Sclerotium* sp.) of rice var. Satabdi and increased yield by 1.6 times and 1.4 times, respectively. Besides, seedling blight of Ketkijoha was also protected. Endophytic Acremonium sp. isolate from rice var. Karuna was effective against the blast pathogen in the laboratory.

Physicochemical analysis of the active principle of *O. sanctum* oil by ultraviolet (UV), infrared (IR), nuclear magnetic resonance (NMR), mass spectroscopy (MS) and elemental analysis identified the active constituent as eugenol.

Six fungicides and their mixture namely, Trifloxystrobin 25%+Tebuconazole 50% @ 0.8 g, Kresoxim methyl @ 2 ml, Azoxystrobin @ 2 ml, Tricylazole @ 1.2 g, Carbendazim @ 2 g and Propiconazole @ 2 ml could control sheath blight disease.

The endophytic *Dendryphiella* strain isolated from. Sarala and Savitri inhibit growth of *R. oryzae sativae* by 60% and sclerotia production by 90%. *Dendryphiella* strains (FV25 and FV16-II) were also effective against pathogenic *R. solani* and *Sclerotium rolfsi*. Foliar spray of cell free cultural filtrates of *Dendryphiella* strains FV9, FV 25, FV16-FV16-II and I were effective against gall midge, BPH and leaf folder.

Brown plant hopper (BPH) resistance was confirmed in 9 farmers' varieties, 1 CRRI (CR 3006-8-2), 14 IRRI lines and 2 wild accessions of *O. rufipogan* (AC 100174 and AC 100444). Among 14 BPH resistant genotypes, 9 genotypes i.e. SSTL No. 142, 227, 317, 395, 405, 490, 609, 680 and 691 scored 1. The wild rices viz. *O. rufipogon* accessions R-28, R-55, R-58, R-49, R-7, ND-44 (R), R-8 and R-48 recorded high resistance against BPH. The AICRP entries KAUM 166-2, KAUM 168-1, IR 65482-7-216-1-2-B, KAUM 179-1, KAUM 179-2, KAUM 179-4, TRG 167(BP 18) and TRG 170 (Bph 20 / 21) were highly resistant to BPH.

Out of 86 rice germplasms AC 42494 and AC 42518 showed moderate resistant (score 3) reaction against WBPH in net house

In greenhouse, out of 392 farmers' varieties, Reg. 907, 866, 1244, 513, 363, 635 and 743 were highly resistant to GM with score '0'. The entries of AICRIP-MRST showed susceptible reaction to CRRI gall midge (Biotype 2). Two NBPGR accessions (IC No. 298563, IC No. 2159) and four aerobic varieties (Solani, Sathia, Laxman sal and Mugi) were tolerant to rice root knot nematode.

Against YSB, among 60 CRRI accessions, AC 42494, AC 42499, AC 42513 and AC 42532 had damage score 2 at vegetative stage, while wild rice genotypes *viz.* ZA / BCP-17, ZA / BCP -18, ZA / BCP-27, PM-117, PM-125 rated stem borer damage score 1 at reproductive stage. Out of 150 breeding lines, C226-9-2-1-1, C226-10-3-2-1, C226-11-4-1-1 and C226-13-12-1-2 had no white ear head (WEH) formation with a damage score of 0 while C226-11-3-1-2 registered highest WEH (54.3%) followed by C226-12-4-1-1 (50%).

Assam collections viz. ZA / BCP-20, ZA / BCP-24, ZA / BCP-26, ZA / BCP-27, ZA / BCP-28, ZA / BCP-32 were not damaged by rice aphid, *Hysteroneura setariae*, whereas, ZA / BCP-08, ZA / BCP-13, ZA / BCP-14, ZA / BCP-18 showed heavy aphid infestation.

Two entries, IET 17886 and IET 20443 were moderately resistant while 3 entries, viz. IET 20755, ADT 39 and Mansarovar showed tolerance and 108 entries of AICRP were moderately resistance to sheath blight disease. Two resistant entries were recorded for RTD.

In long term pesticide trial during *Kharif*, Pretilachlor residue was reduced from 0.69 mg / kg soil on the day of application (DOA) to 0.05 mg / kg soil after 15 days and Chlorpyriphos was reduced from 0.25 mg / kg of soil on DOA to less than 0.01 mg / kg after 15 days.

High and prolonged YSB brood emergence was revealed during dry season by pheromone trap. Population increased from 2rd standard meteorological week (SMW), reached peak on 6th SMW and decreased towards 9 SMW.

The herbicide, azimsulfuron, highly reduced the spider population (1.5 spiders / sweep) followed by bispyribac sodium (2.6 spiders / sweep) and flucetosulfuron (3 spiders / sweep). Similarly odonate population was also reduced (0.5 insects / sweep) in azimsulfuron treated plots. IPM module evaluation in farmers' field in rainfed shallow land at Sankilo, Cuttack on Swarna and Pooja; Mahanga, Cuttack on multiple insect resistant line CR 2711-76; in upland of Chorkari and Manahari, Jharkhand on Kalamdani, in low land of Galdighala, Assam on Naveen and Abhisek and on farm trial on Swarna Sub-1 reduced respective pests among gandhi bug, stem borer, brown spot, neck blast, bakanae etc. infestation, increased average grain yield and natural enemies.

Out of 9 plant oils, castor, morchand, bael and crown oils reduced store pests below 50% level but none effected absolute control. Out of 9 new insecticides, Fipronil 5% @ 1000 ml / ha was best and was at par in grain yield (6.3 t / ha) with all other known insecticides. Among different treatments, RIL-IS-109 @ 1.75 ml / l + Baan @ 0.6 ml / l was best insecticide fungicide combination (5.4 t / ha) and effective against stem borer and leaf folder and leaf blight in varietyTN1. Rynaxypyr @ 30 ml a.i. / ha was more effective than triazophos, acephate, monocrotophos and sulfoxaflor. Acephate 75% SP @ 30 g a.i. / ha was effective to control BPH and dinetofuran 20% SG (500 g a.i. / ha) was effective against GM.

In controlled condition, 5th instar nymphs of BPH was 100% with (30 g a.i. / ha) immediately after tereatment with dinetofuran, imidacloprid 70 WG (20 g a.i. / ha) and thiamethoxam 25% EC (30 g a.i. / ha), whereas, effective persistent toxicity (above 50% mortality) up to 3 days was observed with acephate, dinetofuran, imidacloprid and thiamethoxam.

Tetep and monogenic differential with *Pi–z5* were resistant to *M. oryzae* at three locations of Jharkhand, whereas, the lines with *Pi 9, Pi ta2* (Reiho) and *Pi 5* showed resistance at two locations and restricted lesion development at the third location. In the process of development of NIL for *Pi9* and *PiZ-5* genes, 4 plants of BC1F1s of Poornima*2 / IRBL9-W was raised and being grown to confirm the presence of Piz-5 gene.

Native polyvalent *Pseudomonas fluorescence* isolates (SFA2 and SFA4) could control rice root-knot nematode, *Meloidogyne graminicola* under laboratory condition. The bio-control agent, *Trichoderma viride* reduced the sheath blight incidence by 53.82% in Assam.Rice *tungro* disease (RTD) was recorded in thirteen districts of Assam on Mahsuri, Ranjit, Baismuthi, Swarna*sub1*, Swarna, IR 64, China boro, Arize 6444, DRRH 2, JKRH 401, PAC 837, Sahyadri 4. The brown spot, sheath blight, sheath rot etc. were recorded from different placed of Assam from various rice varieties.

The rice sheath blight pathogen, *Rhizoctonia solani* has different weed hosts like yellow nut smudge (*Cyperus esculentus*), Bermuda grass (*Cynodon dactylon*), common crab grass (*Digitaria sanguinalis*), viper grass (*Dimbraretroflexa*), jungle rice (*Echinochloacolonum*), cockspur grass (*Echinochloa glabrescens*) and hoorah grass (*Fimbristylis miliacea*).

The glycemic index value of improved Lalat (MAS) appears to be low; further confirmation is under process. Unlike other two *'soak n eat rice'* cultivars, Aghoni maintained the soaking time, when grown at Gerua (Assam) or at Chinsurah (WB) in subsequent generation.

A pigmented rice cultivar was found to contain 13.2% crude protein (% Nx5.95). Backcross progenies (BC3F4) of Naveen with a high protein donor showed consistently higher grain protein content (GPC) in most of the high protein lines identified in BC3F3. GPC was higher in conventionally grown rice than organically grown samples. But amylose content, gel consistency and antioxidant activity were higher in the organically grown rice compared to the conventionally grown rice.

Out of 190 rice genotypes evaluated for grain micronutrient (iron / zinc) content, eight including Upahar, Saria, Kamesh, and IR 50 contained more than 6.0 ppm iron in the milled grains, while thirteen including Saria, Setka-36 and IR 50 had more than 20 ppm zinc. There was progressive loss of grain phytate during milling (22 to 31%) washing (55 to 70 %) and cooking (74 to 85%). Parboiling resulted in lesser loss of phytate. Genes encoding nicotianamine transporters viz. OsYSL4, OsYSL6, OsYSL9 and MA synthesis OsNAAT1 were highly expressed in the developing grain of Sharbati (high iron rice) as compared to Lalat (low iron rice).

As proper phenotyping is the key to success in identifying gene / qtl of interest as well in developing new varieties, chlorophyll a fluorescence based screening of rice germplasm tolerant to salinity was standardized, which distinguished between tolerant and susceptible genotypes and separated out best tolerant genotypes from the tolerant group. A genotype AC39416 was found to be tolerant to salinity, stagnant flooding with salinity, drought and anaerobic germination.

Looking to the climatic scenario and water scarcity, research efforts were made to identify and develop resistant / tolerant varieties, to understand their intrinsic behavior under moisture / high temperature stress and physiological basis of stress tolerance, with special emphasis on exploitation of genetic variability to identify genetic sources for component traits and superior alleles. Based on root traits, osmotic adjustment and survival, four cultivars AC 43020, AC 42994, AC 42997 and CR 143-2-2 were found tolerant to vegetative stage drought

Rice genotypes were evaluated for their physiological adaptation to low light stress and improvement of photosynthetic efficiency, light spectral analysis in relation to physiological changes & yield potential of rice and QTL analysis for some low light adapted traits of rice plant. The sterility % in the rice genotypes Lalitgiri under low light was the least (9.99%). In another project, NADP –Malic Enzyme gene was cloned and used to transform rice cv Naveen. Colony PCR result confirmed the cloning.

The results relating to returns from different cropping sequences introduced in the model village cluster indicated that recently introduced rice-onion crop sequence was more remunerative (Rs.92,065 / acre) in the rice-based cropping systems. The farmers, which produced higher yield (16 to 20 sq / acre), adopted the improved varieties namely, Sahabhagidhan, Swarna Sub-1, Pooja, Ketekijoha, Varshadhan and Naveen.

Among the various socio-economic characteristics, land holding size, non-farm income, labourer force participation rate, provision for irrigation etc. were important factors apart from the improved traits of rice varieties like high yielding potential, low disease infestation and better grain quality for their adoption, as well as, shifting of crop choices by the farmers.

In case of designing and testing of gender sensitive approaches in rice farming, the mean labourer used in mandays by different categories for half acre rice demonstrations revealed that the major labour intensive activities in descending order were harvesting and transportation, uprooting and transplanting, main field preparation and threshing and winnowing. Out of 36.58 mandays used for half acre rice cultivation and processing, women contributed 67.03% of total labour hours against 25.04% by men.

The technologies namely power tiller, line transplanting, thresher-cum-winnower, rice husk stove, mat type nursery and 2 and 4-row manual rice transplanter were found in the range satisfactory to highly satisfactory as perceived by the farmwomen.

The findings of feedback analysis indicated that the 'BGREI' and 'procurement of paddy at minimum support price (MSP)' schemes of the government had been great changers and boons for making rice cultivation a profit making enterprise as perceived by the beneficiary farmers. Feedback on the performance of CRRI paddy seeds revealed that majority of the farmers procured rice varieties like, Pooja, Sarala, Gayatri, Moti, CR-1014, Savitri, Durga and Varshadhan; and the major reason cited for procurement was all round performance like better seed quality, germination, tillering and after all more yield over any other source of seed.

CRRI varieties viz. Pooja, Sarala, Gayatri and CR 1009 (Sabitri) covered 25.74% (0.45 m ha) of 1.72 m ha rice area under study. Area under lowland and semi-deepwater is 40.42% (0.70 m ha). That means 64.28% of lowland and semi-deepwater rice area is under CRRI varieties. Whereas, in case of upland rice ecosystem, which is nearly 43% of total rice area, CRRI varieties have negligible presence. Besides, CRRI varieties are also not popular in deepwater rice ecosystem which covers 11.47% of the rice area under study. The regression analysis also shows that area under upland and deepwater had bearing on diffusion of CRRI varieties. This implies that efforts should be made to supply seeds of varieties suitable for upland and deepwater such as Sahbhagidhan, Satyabhama and Varshadhan for popularisation in northern Odisha (upland varieties) and Southern Odisha (deepwater varieties) so that CRRI HYVs will have greater presence.

It is estimated that CRRI varieties were grown to the extent of 698223 ha, 133607 ha and 22455 ha in the state of Odisha, Maharashtra and Madhya Pradesh, respectively. Pooja is extensively grown in all the districts of Odisha, while Ratna is grown in the Konkan region of Maharashtra.

The study on spread of rice transplanters in PPP mode in the state of Odisha revealed that the program is effective but not inclusive. Intensive training on raising mat type nursery and operation of the machine, execution of legal bond to cover more small farmers, prompt after sale service, cooperation with irrigation department, and designing of a new transplanter for older seedlings are suggested to make the program more effective and inclusive.

The impact assessment study on Swarna *Sub1* revealed that the variety has spread to 36% of rainfed shallow lowland in the project area within four years and the reduction in cost of production per quintal was Rs. 39 due to adoption of this variety.

Introduction

CRRI was established by the Government of India in 1946 at Cuttack, as an aftermath of the great Bengal famine in 1943, for a consolidated approach to rice research in India. The administrative control of the Institute was subsequently transferred to the Indian Council of Agricultural Research (ICAR) in 1966. The Institute has two research stations, one at Hazaribag, in Jharkhand, and the other at Gerua, in Assam. The CRRI regional substation, Hazaribag was established to tackle the problems of rainfed uplands, and the CRRI regional substation, Gerua for problems in rainfed lowlands and flood-prone ecologies. Two Krishi Vigyan Kendras (KVK) also function under the CRRI, one at Santhapur in Cuttack district of Odisha and the other at Jainagar in Koderma district of Jharkhand. The research policies are guided by the recommendations of the Research Advisory Committee (RAC), Quinquennial Review Team (QRT) and the Institute Research Council (IRC). The CRRI also has an Institute Management Committee (IMC), for formulating administrative policies.

Mandate

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

The Mandate of the institute are:

- Conduct basic, applied and adaptive research on crop improvement and resource management for increasing and stabilizing rice productivity in different rice ecosystems with special emphasis on rainfed ecosystems and the related abiotic stresses.
- Generation of appropriate technology through applied research for increasing and sustaining productivity and income from rice and rice-based cropping / farming systems in all the ecosystems in view of decline in per capita availability of land.
- Collection, evaluation, conservation and exchange of rice germplasm and distribution of improved plant materials to different national and regional research centres.
- Development of technology for integrated pest, disease and nutrient management for various farming situations.
- Characterization of rice environment in the country and evaluation of physical, biological, socio-economic and institutional constraints to rice production under different agro-ecological conditions and in farmers' situations and develop remedial measures for their amelioration.
- Maintain database on rice ecology, ecosystems, farming situations and comprehensive rice statistics for the country as a whole in relation to their potential productivity and profitability.
- Impart training to rice research workers, trainers and subject matter / extension specialists on improved rice production and rice-based cropping and farming systems.
- Collect and maintain information on all aspects of rice and rice-based cropping and farming systems in the country.

Thrust Areas

- Exploration of rice germplasm from unexplored areas and their characterization; trait-specific germplasm evaluation and their utilization for gene discovery, allele mining and genetic improvement
- Designing, developing and testing of new plant types, next generation rice and hybrid rice with enhanced yield potential.
- Identification and deployment of genes for input use efficiency, tolerance to multiple abiotic / biotic stresses and productivity traits.
- Intensification of research on molecular host parasite / pathogen interaction and understanding the pest genomes for biotype evolution, off-season survival and ontogeny for devising suitable control strategy.
- Developing nutritionally enhanced rice varieties with increased content of pro-vitamin A, vitamin E, iron, zinc and protein.
- Development of climate resilient production technologies for different rice ecologies; designing and commercialization of efficient farm machineries suitable for small farms
- Development of cost effective and environmentally sustainable rice-based integrated cropping / farming systems for raising farm productivity and farmers' income

Research Achievements

CRRI has released 106 rice varieties including three hybrids suitable for cultivation in upland, irrigated, rainfed lowland, medium-deep waterlogged, deepwater and coastal saline ecologies. Besides, 3 high yielding varieties and the varieties suitable for aerobic germination, low glycemic index, high protein, super rice etc. have been identified.

Maintains more than 30,000 accessions of rice germplasm including nearly 6,000 accessions of Assam Rice Collection (ARC) and 5,000 accessions from Odisha. Compiled Passport information on more than 30,000 germplasm.

Used marker-assisted selection for pyramiding BLB resistance genes and for developing BLB-resistant rice cultivars.

Used marker-assisted breeding for tolernace to biotic and abiotic stresses.

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

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

Evaluated, developed and tested several plant products with pesticide potential against field and storage insects and pathogens. Partially identified active principles of tulsi (*Ocimum sanctum*) oil.

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

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

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

Addressing rice production constrains in eastern India through BGREI programme.

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

Commercialized 3 hybrids, LCC and IPM for rice-based cropping system. Submitted one patent and developed agri-entrepreneurship.

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

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

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

Linkages

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

Location

The Institute is located at Cuttack about 35 km from Bhubaneswar airport and 7 km from the Cuttack railway station on the Cuttack-Paradeep State Highway. The institute lies approximately between 85°55'48" E to 85°56'48" E longitudes and 20°26'35" N to 20° 27' 20" N latitudes with the general elevation of the farm being 24 m above the MSL. The annual rainfall at Cuttack is 1,200 mm to 1,500 mm, received mostly during June to October (*kharif* or wet season) from the south-west monsoon. Minimal rainfall is received from November to May (*rabi* or dry season).

PROGRAMME 1

Genetic Improvement of Rice

The Crop Improvement Division is involved in collection, conservation and all round development of rice. The institute has developed eight rice varieties for various rice ecologies which were recommended for release by the Central Sub-committee on Crop Standard, Notification and Release of Varieties for various states of the country during year 2013-14. Elite rice culture CR Dhan 201 was recommended for the states of Bihar and Chhattisgarh, while CR Dhan 202 for Jharkhand and Odisha for aerobic cultivation. Three irrigated mid early cultures CR Dhan 303, CR Dhan 304 and CR Dhan 305 were released for cultivation. CR Dhan 303 is recommended for Madhya Pradesh, Uttar Pradesh and Odisha; CR Dhan 304 is recommended for Odisha and West Bengal while CR Dhan 305 is for Jharkhand, Maharastra and Andhra Pradesh. CR Dhan 300, a fine grain culture with 140 days duration was recommended for release for the irrigated ecology of Bihar, Odisha, Gujarat and Maharashtra. The institute has also developed lowland rice varieties CR Dhan 407 and CR Dhan 505. CR Dhan 407 is recommended for shallow lowlands of Odisha and West Bengal while CR Dhan 505 is for deep water ecologies of Assam and Odisha.

Three promising cultures were also identified for release in AICRIP group meeting held at DRR, Hyderabad. CR Dhan 205, a culture with 110 days maturity duration was found promising for Tamil Nadu, Gujarat, Odisha, Madhya Pradesh and Punjab. CR Dhan 306 is promising for Madhya Pradesh, Bihar and Puducherry for intermediate mid early ecology, while CRR 451-1-B-2-1(IET 22020) is suitable for upland ecology of the states Jharkhand and Madhya Pradesh. Besides, 20 cultures were promoted to 3rd year of testing under the AICRIP trials. Thirty hill rice germplasm lines from Manipur and Meghalaya were collected during last year. A total of 483.12 q of breeder seeds of 43 varieties and 6 parental lines were produced. Besides, various types of seeds were produced and distributed to fulfill the demands of the researchers, seed producers and the farmers of all over the country.

Exploration, characterization and conservation of rice genetic resources

Exploration and collection of rice germplasm from Manipur

An exploration and collection of rice germplasm programme was undertaken from 17-24 December, 2013 in collaboration with NBPGR Regional Station, Shillong. Thirty germplasms were collected from hill districts like Tamenglong and Ukhrul and valley districts like West Imphal, East Imphal, Bishnupur and Thoubal. Based on the available information, emphasis was given to collect from valley districts. The dominant accessions are Longphou, Giniphou, Namphaelong and Kumbhiphou. Few scented varieties namely Govindbhog and Chakhao were collected. Besides, three accessions of *O. rufipogon* were also collected from Loktak lake area.

Rejuvenation of the conserved germplasm and the new collections

Two sets of 2100 accessions of CRRI rice germplasm and another set of 1000 accessions of Assam Rice Collection (ARC) received from NBPGR were rejuvenated in the field for maintenance of seed viability, seed increase and seed supply to different researchers. Besides, a set of 60 *bao* rice germplasm collected from Assam and 125 accessions of submergence tolerant germplasm collected from coastal districts of Odisha were grown for maintenance of purity and viability.

Seed supply to researchers

Eighteen hundred twenty eight accessions of rice germplasm both cultivated and wild species were supplied to the researchers all over the country for screening, evaluation purposes leading to further utilization in breeding programmes.

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

Five thousand thirteen germplasm including 41 wild rice accessions collected from Assam and 139 wild and weedy rice accessions collected from Odisha during last *kharif* were sown and transplanted in augmented field layout along with check Swarna for characterization and seed multiplication. One hundred and eighty wild and weedy rice were grown for characterization on agro-morphological traits as per the descriptors.

In addition, one set of 124 accessions of submergence tolerant germplasm was sown in pots in two replications. The data on number of plants per pot and plant height were recorded before they were put in the deep water tank for evaluation against submergence tolerance. The plants were kept under complete submergence for 10 days and then taken out. The data on number of plants survived after submergence stress and their heights were recorded again.

Morphological characterization of released varieties

Six hundred rice varieties acquired / collected from different states of India were grown during *kharif* 2013 in an augmented design. The characters for both qualitative and quantitative characters as per DUS descriptor were recorded. Leaf length varied from 24.0 cm (Sneha) to 65.4 cm (Nalini). Leaf width varied from 0.65 cm (Sidhanta) to 1.9 cm (Luna Suvarna). The plant height ranged from 60.0 cm (Sattari) to 175.4 cm (Hanseswari). Days to fifty per cent flowering varied from 52 days (Vivekdhan-2) to 141 days (Nalini). Panicle length varied from 16.2 cm (VLdhan221) to 33.2 cm (Pantdhan-4). The varieties with long panicles (>30 cm) are Basmati 564, Pusa Sugandha-3, Ranbir Basmati, Pravathi, Rambha, Nuadhusara, Sonamani, Basmati 370 and Nuakalajeera. Single panicle weight varied from 1.0 g (Pantdhan-18) to 5.6 g (Padmanath). Heavy Panicle weight (>5.0 g) are observed in the varieties like Dandi, Pusa Sugandha-5, Mandakini, Mahalaxmi, Matangini, Golak, Jogen and Purnendu. The grain number was highest in Mahsuri (322) followed by Kanchan (315), Jajati (302), RTN-24 (299), Pavitra (298), WGL32100 (292). The 1000-grain weight was highest in Bhalum-2 (35.0 g) while the lowest was recorded in Palghar-2 (11.0 g).

Assessment of genetic variation in weedy rice (*Oryza sativa f. spontanea*) and wild rice (*O. rufipogon* Griff.) found in some parts of North-eastern India as revealed by SSR markers

Genetic variation of 27 weedy rice (*Oryza sativa f. spontanea*), 16 wild rice (*O. rufipogon*) and a deep water rice variety collected from 9 locations such as Sonitpur, North Lakhimpur, Dhemaji, Golaghat, Jorhat, Nagaon, Morigaon, Kamrup of Assam and Tripura of NE region were taken to assess the genetic variation using STMS markers. One hundred eighty four alleles with an average of 3.83 per locus ranging from 100 to 500 bp were generated by 48 SSR markers (*Fig 1*). This observation amply suggested that the genotypes selected for this study harbored enough genetic divergence. However, an UPGMA dendrogram based on the genetic relationships suggested a closer relationship of weedy and wild rice occurring within the same regions.

Documentation and conservation of the rice genetic resources

About four thousand three hundred and forty three (4343) accessions of rice germplasm were conserved in National Active Germplasm Site (NAGS) at CRRI, Cuttack for medium term storage during the period. Most of the wild species of genus *Oryza* collected and acquired from different sources are conserved *ex situ* in *Oryza* Garden, an isolated site of field gene bank to prevent spread of shattering seeds of wild rices.

Establishment of National Rice Resource Database

A core set of 1500 accessions was developed under the NRRDB project, of which 1055 accessions were multiplied for seed increase so that screening / evaluation could be taken up in subsequent seasons.

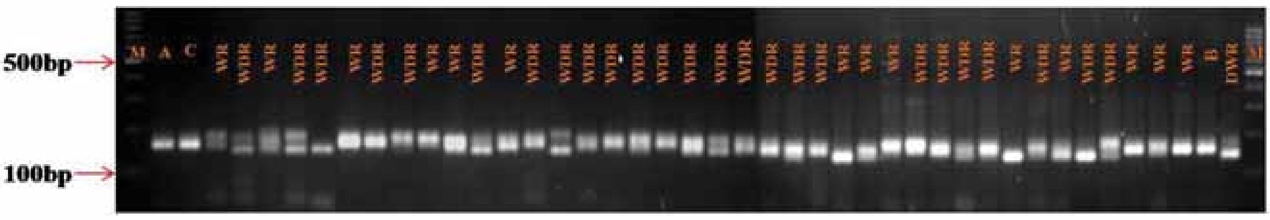


Fig 1. Allelic polymorphisms revealed by SSR markers (RM 18360). M: 100bp DNA lader; A-Swarna, B-Varshadhan, C-Sahabhagidhan, WR-Wild rice, WDR-Weedy rice, DWR-Deep water rice

Fresh seeds were harvested, processed and deposited back at NBPGR after regeneration and recording of morpho-agronomical characterization data as per the descriptor provided. One set is conserved in MTS for further evaluation against major biotic and abiotic stresses. The annual progress report and characterization data were submitted to the sponsoring agency through the coordinating centre.

DUS Testing and documentation

During *kharif* 2013, first year DUS testing of 11 candidate varieties against 25 reference varieties, second year testing for 18 candidate varieties against 31 reference varieties in addition to 8 VCKs against 23 reference varieties were conducted in two replications. Besides, DUS characterization of 16 farmers' varieties for generating one year data was also done. They were grown in specific ear-marked plots with all prescribed precautions. Later, the DUS testing plots were monitored by the members from PPV&FR Authority during 26-27 October, 2013.

Maintenance breeding and seed quality enhancement

Panicle progeny rows of 41 varieties were grown and evaluated in the field, as well as, laboratory for maintenance breeding during the year 2013 (*Table 1*). The selected progeny lines were bulked as nucleus seed and these nucleus seed were used for the production of breeder seed (*Table 2*). Though the breeder seed production was severely affected by the cyclonic storm "*Phailin*" that struck the Odisha coast during 12th October followed by torrential rain, 483.12 q of breeder seed was produced comprising of 43 varieties and 6 parental lines during the year.

Participatory seed production

Under National Seed Project, Participatory Seed Production of the variety Pooja had been taken up with an agreement with Mahanga *Krushak Vikash Manch* in an area of 50 acres at Goudagop, Mahanga, Odisha in the farmers' field with involvement of the farmers and under the supervision of CRRI scientists.

After checking the quality, 368.72 q seed that qualified for TL seed standard were procured back from the Mahanga *Krushak Vikash Munch*, and after processing 376.20 q seeds were sold to the farmers as TL seed.

Table 1. Panicle progeny rows evaluated and selected for nucleus seed during *kharif* 2013

Variety	Panicle progeny evaluated	No. of progeny lines selected
Pooja	485	405
Swarna *Sub 1*	475	385
Utkal Prabha	400	355
Varshadhan	400	345
Annada	400	358
CR 1014	450	387
Chandan (CR Boro dhan 2)	450	386
Dharitri (CR 1017)	400	345
Durga	400	355
Gayatri (CR 1018)	450	364
Geetanjali	450	367
Sarala	450	395
Satabdi	475	397
Savitri (CR 1009)	450	360
Satyakrishna (CR Dhan 10)	450	395
Naveen	450	398
Hanseswari (CR Dhan 70)	200	165
Pyari (CR Dhan 200)	200	156
CR Dhan 300	200	158
Hue (CR Dhan 301)	200	138
Reeta (CR Dhan 401)	200	146
Sumit (CR Dhan 404)	200	142
Luna Sankhi (CR Dhan 405	200	138
Luna Sampad	300	244
Luna Suvarna	300	235
Lunishree	400	297
CR Dhan 500	200	147
CR Dhan 601	250	168
Jaldidhan 6	250	376
Tapaswini	350	274
Ketkijhoha	400	365
Khitish	450	396
Moti	400	318
Nua Chinikamini	250	201
Nua Dhusara (CR Sugandh Dhan 3)	250	197
Nua Kalajeera	250	195
Padmini	400	364
Phalguni	250	168
Ranjeet	300	263
Ratna	400	310
Sahbhagidhan	250	145

Table 2. Breeder seed production of rice varieties during the year 2013

Vareity	Production during *rabi* 2012-13 (q)	Production during *kharif* 2013 (q)	Total production (q)
Pooja		114.15	114.15
Swarna *Sub 1*	-	52.65	52.65
Utkal Prabha	-	5.55	5.55
Varshadhan	-	16.50	16.50
Annada	1.70	-	1.70
CR 1014	-	15.15	15.15
Chandan (CR Boro dhan 2)	16.40	-	16.40
Dharitri (CR 1017)	-	1.65	1.65
Durga	-	1.05	1.05
Gayatri (CR 1018)	-	8.85	8.85
Geetanjali	-	2.10	2.10
Sarala	-	18.45	18.45
Satabdi	32.75		32.75
Savitri (CR 1009)	-	18.15	18.15
Satyakrishna (CR Dhan 10)	10.50	-	10.50
Naveen	63.00	-	63.00
Hanseswari (CR Dhan 70)	-	1.65	1.65
Pyari (CR Dhan 200)	1.60	0.45	2.05
CR Dhan 300	-	0.20	0.20
Hue (CR Dhan 301)	-	0.17	0.17
Reeta (CR Dhan 401)	-	0.75	0.75
Sumit (CR Dhan 404)	-	1.95	1.95
Luna Sankhi (CR Dhan 405)	1.60	-	1.60
Luna Sampad	-	1.35	1.35
Luna Suvarna	-	2.70	2.70
Lunishree	-	7.65	7.65
CR Dhan 500	-	0.45	0.45
CR Dhan 601	3.60	-	3.60
Jaldidhan 6	0.40	-	0.40
Tapaswini	-	0.75	0.75
Ketkijhoha	8.00	4.35	12.35
Khitish	6.00	3.15	9.15
Moti	-	2.55	2.55
Nua Chinikamini	-	2.25	2.25
Nua Dhusara (CR Sugandh Dhan 3)	-	1.35	1.35
Nua Kalajeera	-	1.65	1.65
Dhanrasi	-	0.90	0.90
Padmini	-	6.30	6.30
Phalguni	1.20	-	1.20
Ranjeet	-	0.45	0.45
Ratna	20.40	-	20.40
Sahbhagidhan	1.65	-	1.65
IR 20	4.80	-	4.80
CRMS 31 A	2.10	0.12	2.22
CRMS 31 B	2.00	1.50	3.50
CRMS 32 A	1.85	0.18	2.03
CRMS 32 B	1.50	1.00	2.50
IR 42266-29-3R	1.50	1.50	3.00
CRL-22R	0.50	0.50	1.00
Grand Total (in q)	183.05	300.07	483.12

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

Thirty collections of AA genome wild species along with identified donor from wild species of *O. nivara* (AC 100476, AC 100374), *O. brachyantha* (Acc. no. 1086) and *O. rufipogon* (AC 100174, AC100444) are being maintained in the net house for future utilization in breeding programme. The identified yellow stem borer donor *O. brachyantha* (Acc. No. 1086) has been effectively hybridized and one hundred ten wide cross derivatives has been generated for further use as pre-breeding lines for large panicle, high biomass (yield related traits), hardy stem, profuse tillering and narrow leaves (traits for YSB tolerance). Apart from this, ten MAAL lines has been produced and maintained in the net house for molecular identification. The seed set upon backcrossing the F_1 hybrid with the recurrent parent was quite low (0.22%). Eleven BC_1 plants were produced through embryo. The BC_1 plants were completely sterile and were pollinated with *O. sativa* cv. CR1009 pollen. Of the 7,294 spikelets of the BC_1 plants pollinated, only 112 (1.13%) rescue with 0.09 % crossability. Morphological characteristics of the BC_1 plants appeared to be like those of F_1 hybrids, but they were different in growth habit, height, length of leaves, size of spikelets. Sixteen BC_2 plants were obtained from 10 BC_1 plants. One BC_2 plant (#35-10) had the pollen fertility of 100% and produced a self seed-set. However, the pollen fertility of the other 15 BC_2 plants were very low (0.0 to 43.0%) and the seed set upon backcrossing varied from 0.0 to 15.56%. All of the 16 BC_2 plants were morphologically distinct, and they were quite different in growth habit, height, shape and length of leaves, presence or absence of awns, size of spikelet and panicle length. One BC_2 plant ($2n$=24) produced 22 BC_3 plants. Most of the BC_3 plants resembled *O. sativa*. Fertile disomic derivatives of *sativa/brachyantha//sativa* (photo-insensitive) were grown in field condition for further selection and evaluation for different traits like high tillering, hardy stem, purple base (leaf sheath), erect and narrow to wider leaves. The identified 32 derivatives (BC_2F_4) of *sativa/brachyantha//sativa* were screened against freshly hatched larvae of YSB and the #17, #15, #11, #10, #1, #2, #7, #36, #29, #28, #21, #23, #24, #25, #26 and #27 showed low dead heart formation ranging within 13.2 – 30%. The identified plants were selfed and seeds were harvested for further testing.

Another experiment was conducted to develop co-dominant molecular makers capable of distinguishing *Oryza sativa* c.v. CR1009 (AA) and *Oryza brachyantha* (Acc. no. 1086) (FF) genomes based on whole genome sequence information of both species available in the public domain (http://www.gramene.org). Twelve such gene based STS markers has been developed which can clearly distinguish both the genomes (*Fig 2*). The loci targeted by each of the markers in both the genomes are mentioned in *Table 3*.

Six accessions of *O. nivara* and 32 accessions of *O. rufipogon* were screened against BPH at vegetative stage (35 days old seedlings). None of *O. nivara* accessions showed resistant reaction to BPH. Seven accessions of *O. rufipogon* (AC 100493, AC 100168, AC 100014, AC 100174, AC 100444, AC 100173 and AC 100015) showed resistace to BPH with score '0'. Three accessions (AC 100174, AC 100005 and AC100444) were found resistant after screening twice and have been used in the hybridization programme with Swarna

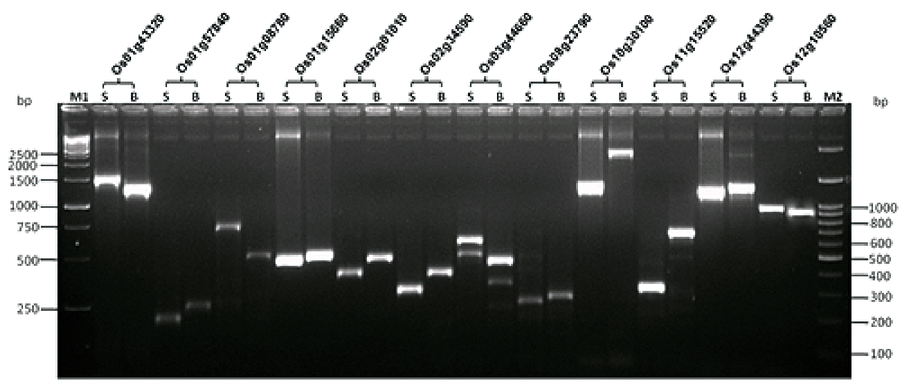


Fig 2. Gene based Sequence Tagged Site (STS) markers distinguishing Oryza sativa (savitri) and Oryza brachyantha genomes. The identifiers depicted at the top of each parenthesis are the part of MSU IDs (http://rice.plantbiology.msu.edu) of the genes for which the STS marker has been designed. The lanes designated as 'S' and 'B' depict O. sativa and O. brachyantha specific amplicons, respectively

Table 3. Target genes of the developed gene based STS markers and their locus in the genomes under study

		O. Sativa		*O. brachyantha*	
Marker IDs	Target genes (MSU ID)	Chromosome	Locus (Mb)	Chromosome	Locus (Mb)
Os01g43320	Loc_Os01g43320.1	1	26.4	1	18.3
Os01g57840	Loc_Os01g57840.1	1	35.2	1	25.8
Os01g08780	Loc_Os01g08780.1	1	4.4	1	3.2
Os01g15660	Loc_Os01g15660.1	1	8.8	1	7.0
Os02g01010	Loc_Os02g01010.1	2	0.1	2	0.02
Os02g34590	Loc_Os02g34590.1	2	21.6	2	14.8
Os03g44660	Loc_Os03g44660.1	3	25.9	3	20.2
Os08g23790	Loc_Os08g23790.1	8	14.5	8	8.4
Os10g30100	Loc_Os10g30100.1	10	16.1	10	8.8
Os11g15520	Loc_Os11g15520.1	11	8.7	11	5.4
Os12g44390	Loc_Os12g44390.1	12	5.6	12	3.9
Os12g10560	Loc_Os12g10560.1	12	27.7	12	15.3

Fig 3a. Resistant donor O. rufipogon (AC No.100005)

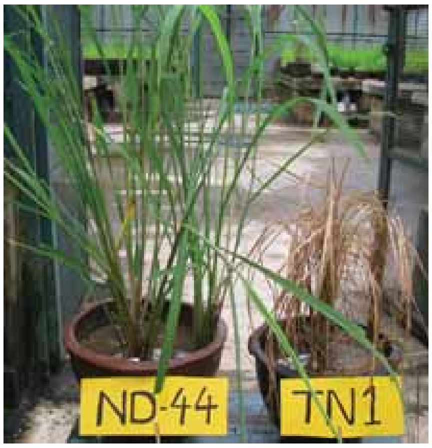


Fig 3b. Resistant donor O. rufipogon (AC No.100444)

Fig 4. Resistant donor O. rufipogon (AC 100005), F_1 (Swarna/O. rufipogon (AC No. 100005) and susceptible check TN1

background. All the F_1s were again screened against BPH along with parents (*Fig 3 a, b and 4*). The F_1 (Swarna / *O. rufipogon* (AC 100174) showed resistant reaction to BPH, whereas other F_1 (Swarna / *O. rufipogon* (AC 100444) was susceptible to BPH. These two F_1s were further back crossed to their respective recurrent parents for the generation of BC_1 progenies and will be tested against BPH.

O. rufipogon (IRGC 105491) was used as the donor of yield enhancing genes was crossed as the male parent to Swarna, MTU1010 and CR1009. The F_1 plants showed strong vegetative heterosis over recipient parents and will be backcrossed twice with recurrent parents. Use of wild species and effecting new crosses has been made for incorporation of drought tolerance traits are in progress. Generation advancement of backcross derivatives BC_2F_5 of Naveen / *O. nivara* (AC 100476) / / Naveen were grown in the field condition and three promising lines CR 2892-14-3, CR 2892-21-5, CR 2892-30-1-1 have been selected based on desirable plant type for next generation testing. Thirty five breeding lines of BC_2F_5 generation of Apo / *O. nivara* (AC 100476) / / Apo derivatives were screened for both vegetative and reproductive stage drought tolerance under rain out shelter. Three weeks old seedlings were exposed to stress for a period of 30 days and then stress was recovered. Again stress was imposed for another 30 days during the anthesis period. Seven lines did not flower under the stress treatment. However, four lines viz. KB 387-2 (N), KB 387-1 (N), KB 387 (N) and KB 225-1(N) had yield of >0.40 t / ha with lower sterility in the range of 27.5 to 49.8 %, while rest of the lines had > 60%. Highest yield of 0.70 t / ha was obtained in KB 225-1(N).

Hybrid rice for different ecologies

Development and evaluation of test cross/back cross hybrids

Two hundred and forty nine test crosses involving four CMS lines (CRMS31A, CRMS32A, CRMS8A and APMS6A) were evaluated during 2013. F_1 phenotyping results indicated that 21 lines were promising maintainers while 25 were effective restorers (*Table 4*). Four hundred ninety new test crosses (involving five CMS lines, CRMS31A, CRMS32A, CRMS 24A, CRMS51A and APMS 6A) were generated and being evaluated during *rabi* 2014 (*Table 5*).

Table 4. List of identified promising restorers and maintainers

Name of the promising restorer
MR219, 179-16-1, CR 2624-1, HUA 565, PK 38, CR-17-1703, CR 3725-4, CR 3727-1, HR 1064, IR 83140-B-36-B, HHZ 5-SAL10-DT-1DT 1, CR 39, CR 3624-3, CR 56, CR 302-, CR 318, IR 73931-40-1-2-3-2-2-1, HUANGHUNZHAN, CR 68R , CR 722R, CR 63, IR 73933-8-2-2-3-4, 73930-31-3-2-2-2-1, CR 52 and CR 61
Name of the promising maintainers
7302B-501, CR 11-100, CR 45, CR 56-1B, CRMP 1-03-1010, CR 34, CR 137, CR 50, CRGP-4, Khuderat 2, CRMP1-5(632), CR 123, CR 145, CR 263, CRMS31B- P-10, CRMP2-06-667, IR 71590-784, CR244-8B, IC 299554, IR 74401-215-13 and CRMP2-04-33

Table 5. Number of test crosses generated during *kharif* 2013

CMS lines	No. of Crosses
CRMS 31A	252
CRMS 32A	210
CRMS 24A	15
CRMS51A	10
APMS 6A	3
Total	490

Maintenance, evaluation and multiplication of CMS lines

Twelve CMS lines including six CRRI bred (CRMS 31A, CRMS 32A, CRMS 24A, CRMS 45A, CRMS 51A, APMS 6A, PMS 10A, PMS 17A, PUSA 6A, RTN 6A, RTN 10A and RTN 12A) were evaluated for agro-morphological and floral characteristics during *rabi* and *kharif* 2013 and were maintained through manual hand crossing. Two CMS lines namely, CRMS 31A and CRMS32A were multiplied in larger quantity (> 200 kg seeds of each). Six CMS lines were taken up for small scale multiplication for further utilization in dry and wet season of 2014. Short duration sterile backcrosses of Virendra and Satabdi were multiplied in small scale field production.

Nucleus seed production of parental lines

Fifty paired crosses for each parents (CRMS 31B, CRMS 32B, IR 42266-29-3R and CRL 22R with CRMS 31A & CRMS 32A) of CRRI bred rice hybrids, Ajay, Rajalaxmi and CR Dhan 701were made and evaluated during rabi 2014.

Transfer of characters into CMS lines

Introgression of BLB resistance genes (*Xa21, xa13, xa5 and Xa4*) into parental lines of Ajay, Rajalaxmi and CR Dhan 701 through MAS approach is under progress (now CRMS31B, CRMS32B in BC_3F_6; IR42266-29-3R in BC_3F_3 and CRL 22R in BC_2F_1 generation). To transfer the BLB resistance genes into CMS, backcrosses of CRMS31B-MAS and CRMS 32B-MAS (pyramided with 4 BLB resistance genes) with the respective CMS, CRMS31A and CRMS32A lines were advanced to BC_2F_1. CRMS 31B-MAS and CRMS 32B-MAS (pyramided with BLB resistance genes) are being introgressed with *saltol* and *Sub1* genes, separately and during *kharif* 2013 were advanced to BC_3F_3 and BC_3F_2 generation, respectively. To combine both genes *Saltol* and *Sub1* in same genetic background of CRMS31B and CRMS32B, intermating between BC_3F_1 *Saltol* of CRMS31B and BC_2F_1 *Sub1* of CRMS31B and in same way for CRMS32B were advanced to BC_2F_1 generation during wet season, 2013.

Status of back crossing to develop new CMS lines

A total of sixty five backcrosses were advanced with the generations ranging from BC2 to BC7 during *kharif* 2013. Twenty one new backcrosses were initiated involving the recurrent lines with earlyness, late, drought tolerant and MAS product (pyramided with BLB resistance genes, CRMS31B-MAS and CRMS 32B-MAS). In order to develop late duration CMS, four late duration anther culture derivatives of CRMS31B / CRMS24B and CRMS32B / CRMS24B were test crossed and evaluated for spikelets sterility, of which three crosses were found promising and advanced to BC1F1 generation. Some of the promising lines with stable male sterility and good out crossing traits are listed in *Table 6*.

New CMS line of Sahbhagidhan (CRMS 51A)

A short duration WA-CMS line, under nuclear background of Sahbhagidhan, has been developed from the recurrent backcrosses of CRMS31A / Sahbhagidhan. It has desirable plant height (85-90 cm) and a stable CMS lines with early duration (*Fig 5*). It is a well combiner CMS, having more than 20% out crossing ability, therefore, it can be used in development of short duration drought tolerance hybrids.

Fig 5. Flowering stage of early duration CMS line in the nuclear background of popular variety Sahbhagidhan

Table 6. Promising sterile backcross derived lines advanced during 2013

BCN No.	Recurrent parent	Source of cytoplasm	Remarks
BCN[7]12A	HR 26-73	WA	Medium duration
BCN[7]17A	HR 34-7	WA	Medium duration
BCN[7]39A	HR 2234-75	WA	Medium duration
BCN[6]52A	PS 92B(69) (Kalinga)	Kalinga-I	Purple leaf
BCN[6]71A	CRMP 2-1-614(79)	WA	Medium duration
BCN[7]166A	Satabdi	WA	Short duration
BCN[7]206A	Abhishek	WA	Short duration, drought tolerant
BCN[6]199A	CR2234-1020 (WA)	WA	Good floret opening
BCN[6]200A	CR2234-1020 (Kalinga)	Kalinga-I	Good floret opening
BCN[5]99A	A-180-12-1(87)	WA	Short duration, drought tolerant
BCN[6]187A	Sahbhagidhan	WA	Short duration, drought tolerant
BCN[6]180A	CR 2234-834(WA)	WA	Good floret opening and stigma exsertion
BCN[2]212A	31B-GP-39	WA	31B Gene pyramid with 4 BLB genes
BCN[2]213A	32B-GP- 62	Kalinga-I	32B Gene pyramid with 4 BLB genes
BCN[1]275A	CRMP1-07-1010	WA	Good floret opening, mid late
BCN[1]276A	CRMP1-07-1010	Kalinga-I	Good floret opening, mid late
BCN[1]278A	Khuderat-2	WA	Medium duration
BCN[1]279A	Khuderat-2	Kalinga-I	Medium duration
BCN[1]346A	CR172	WA	Late duration

Seed production of hybrids

Hybrid seeds of eight combinations, CRHR-5(125 kg), CRHR-7 (100 kg), CRHR-32 (65 kg), CRHR-100 (18 kg), CRHR-101 (15 kg), CRHR-102 (25 kg), CRHR-103 (15 kg) and CRHR-104 (15 kg) involving the CMS lines, CRMS 31A and CRMS 32A were produced during 2013.

Restorer and maintainer breeding

One thousand eight hundred fifteen single plant progenies from both population improvement and recombination breeding (62 crosses; AxR, RxR and BxB) were grown in pedigree nursery and 78 desirable lines were used in crossing programme. Three maintainer and 2 restorer populations were grown in *kharif* 2013 for constitution of next random mating cycles for *rabi* 2014. Five new restorers (Tulasimanjari, UPRI 93-133R, IR 48275R, Sambha Mahsuri and CRL 26R) and 10 maintainers (RTN-13B, IR70369B, IR 73327B, IR 80156B, IR 80155B, IR 6888B, RTN 10B, Mahasuri, IR 58025B and PMS 17B) population was developed and their next random mating cycle are constituted. Twelve new F_1 combinations of promising restorers and 16 of maintainers are generated and being evaluated in *rabi* 2014.

Development of Iso-cytorestorer

Ninety six promising iso-cytorestorers (62-CRMS31A / Hanseshwari, 19- CRMS32A / Hanseshwari, 6-CRMS31A / Purnendu, 5-CRMS32A / Rayada, 2-31A / CR664 and 2-IR62829A / Gayatri) with high fertility and different durations has been identified and being used for test crosses.

Maintainer (B line) development through *in vitro* approach

Anthers from two cross combinations of maintainer (BxB) were inoculated on N6 media for callus induction. Subsequently, the calli transferred into MS regeneration media supplemented with growth regulators showed 100% green shoot regeneration after 3 week of culture. Eighty two green shoots rooted in the MS media supplemented with growth regulators followed by acclimatization. Thereafter, all 82 plants were transferred to the net house which are under evaluation for ploidy status.

Evaluation of hybrids

National hybrid rice trial– MLT of hybrids (AICRIP Trial *kharif* 2013)

The MLT of released hybrids was conducted during wet season 2013 to identify suitable hybrids in mid-late duration. Tweenty one test entries including three checks (one hybrid and 2 varieties) were evaluated. In this trial Rajalaxmi was the top yielder.

Hybrid rice trial-Evaluation of rice hybrids/ varieties of private companies

During *kharif* 2013, a trial with twelve test entries (6 test hybrids and 2 varieties from private companies; 3 CRRI bred hybrids and one local variety) was evaluated. Among all entries tested, CR Dhan 701 recorded highest yield and total duration of maturity (*Table 7*).

Table 7. Evaluation of rice hybrids/varieties of private companies

Entry name	DFF	Plant height (cm)	Spi. Fert. (%)	EBT / m²	Grain yield (kg / ha)	Grain type	Purity score (UNI)	Incidence of diseases / pests DIS BB	SR	INS LF
US 312	108	123.1	84.59	399.6	6848.6	MS	1	3	0	1
US314	102	116.5	74.15	392.9	6519.7	MS	1	0	0	3
US382	110	121.6	71.78	361.2	6005.0	LB	2	1	0	3
BS6444G	108	118.8	81.64	416.2	6739.8	MS	1	0	0	3
BS110G	105	114.8	83.20	426.2	6622.8	LS	2	0	0	3
MTU 1001	108	115.0	93.93	349.6	5172.5	MB	2	0	0	7
MTU1010	101	95.8	86.71	428.7	4956.7	LS	1	0	0	5
Arize Prima	107	114.3	81.19	404.5	6274.4	LB	1	0	0	3
NAVEEN	102	116.0	73.34	421.1	5481.3	MB	1	0	0	5
Ajay	106	132.9	81.63	442.8	6979.8	LS	1	0	0	3
Rajalaxmi	108	131.4	82.98	380.2	7096.1	LS	2	0	0	3
CR Dhan 701	116	125.8	86.94	374.5	7336.4	MS	2	1	0	1
CD at 5%					183.8					
CD at 1%					259.0					
CV%					5.50					

Screening of released rice varieties and source nursery materials for the presence of *Rf4* and *Rf3* genes

Six hundred forty one released rice varieties were screened for the presence of *Rf4* and *Rf3* genes (fertility restorer genes) using functional markers RM6100 and DRRM Rf3-10, respectively (*Fig 6 and 7*). Out of them, 85 varieties showed the positive for both the genes, whereas, 329 varieties showed positive for only *Rf4* gene, 32 varieties were found positive to *Rf3* gene while both the genes were absence in 195 varieties. Similarly, 95 lines grown in hybrid rice source nursery were screened for both the genes, out of these 30 lines were found positive for both the genes. Additionally 34 lines showed presence of only *Rf4* gene while 10 lines had only *Rf3* gene. However, both the genes were absence in 21 lines.

DNA fingerprinting of commercially cultivated rice hybrids

DNA fingerprinting of 27 released rice hybrids of public and private organizations was done using 27 STMS markers. A STMS marker panel was developed in which 5 markers (RM336, RM3501, RM10167, RM228 and RM8213) could differentiate all 27 rice hybrids. Some unique markers were also identified that can give a unique pattern for a particular hybrid from rest of the hybrids. RM419 could distinguish and showed hybridity with TNRH 174 rice hybrid; however, none of the hybrid showed hybridity with RM419. Another marker RM1233 showed hybridity in Ajay and Rajalaxmi. RM8213 could distinguish DRRH3 from rest of the hybrids. RM250 can distinguish DRRH2 from rest of the hybrids. RM11278 and RM480 were able to distinguish US382 and INDAM 200-017, respectively from rest of the hybrids which also showed hybridity among 27 hybrids. Similarly, RM201 could distinguish Pusa RH10 from rest of the hybrids. Besides, RM206 distinguished Ajay and Rajalaxmi form rest of the hybrids whereas, RM336 could discriminate between Ajay and Rajalaxmi showing hybridity in both the hybrids.

MOU's/Consultancy services

MoUs were signed with six private seed companies during the year for production and marketing of the hybrids, Ajay, Rajalaxmi and CRDhan 701. In addition to this, consultancy services were extended to Bharat Nursery, Sai Shradha Agronomics, Nath Biogene (I) Ltd. and Sansar Agropol Pvt. Ltd. for hybrid seed production of Ajay, Rajalaxmi and CRDhan 701 as part of the MoU signed with these companies.

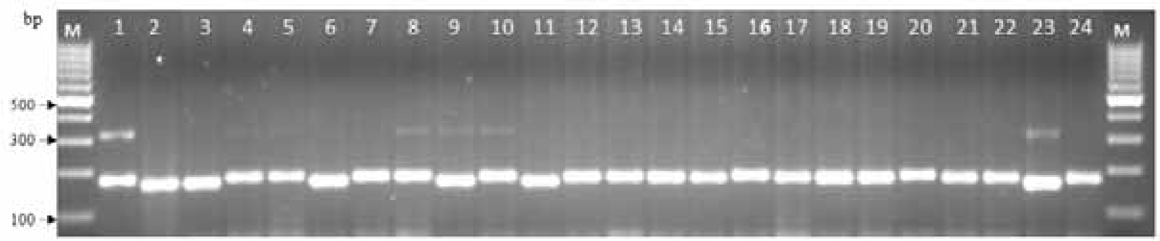


Fig 6. Presence of Rf4 *gene in selected released rice varieties using functional marker RM6100 on 4% metaphore agarose gel. M: 100 bp ladder, Lanes 1: +ve control, 2: -ve control, 3-24: selective released rice varieties*

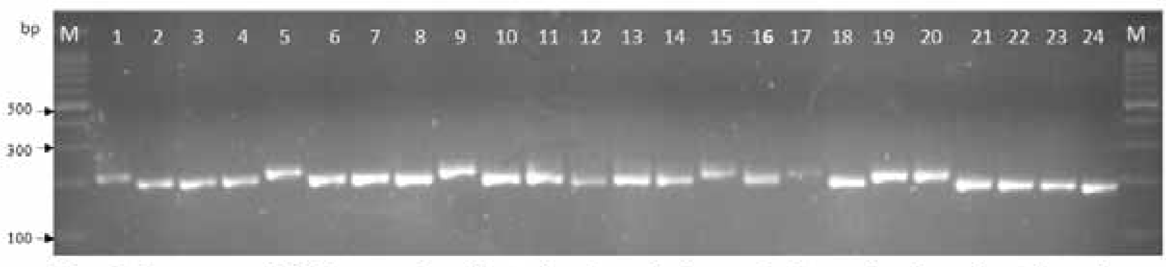


Fig 7. Presence of Rf3 *gene in selected released rice varieties using functional marker DRRM Rf3-10 on 4% metaphore agarose gel. M: 100 bp ladder, Lanes 1: +ve control, 2: -ve control, 3-24: selective released rice varieties*

Development of high yielding genotypes for rainfed shallow lowlands

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

Ten F_1s obtained with parental combination of one submergence tolerant parent with a tropical *japonica* derivatives were further utilized for hybridization with a third parent having a high yielding variety with good grain quality during *kharif* 2013. CR Dhan 300 was combined as third parent in a three way cross for good grain quality and better yield. Ten F_1s were generated using three parents in each cross (*Table 8*). From the ongoing 250 lines of F_3 generation, single plant progenies were selected and 145 lines were advanced to F_4 generation. Thirty promising lines in F_7 generation were bulked for next year initial yield evaluation trial.

Table 8. F_1s generated through three way cross combining high yielding parent, submergence tolerance and good grain quality

CR 2683-45-1-2 / Savitri *Sub1* / / CR Dhan 300
CR 2683-28-12-1-4 / Savitri *Sub1* / / CR Dhan 300
CR 2687-2-3-5-2-1 / Savitri *Sub1* / / CR Dhan 300
CR2682-2-3-1-1-1 / Savitri *Sub1* / / CR Dhan 300
CR2678-5-3-2-1-1 / Savitri *Sub1* / / CR Dhan 300
CR2683-15-5-2-1 / Ranjit / / CR Dhan 300
CR 2683-45-1-2 / Ranjit / / CR Dhan 300
CR 2683-28-12-1-4 / Ranjit / / CR Dhan 300
CR 2687-2-3-5-2-1 / Ranjit / / CR Dhan 300
CR2683-15-5-2-1 / Ranjit / / CR Dhan 300

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

The F_1 generation was advanced to raise the recombination phase for segregation of the assembled traits in the male sterile background. 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 from IR64 NIL lines and yield from yield gene from two new plant type lines.

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

Four hundred lines of recombinant inbred lines of the cross CR143-2-2 / Krishnahamsa were used for phenotyping for reproductive stage drought tolerance. The mapping population for reproductive stage drought tolerance was in F_7 generation. All the lines were observed to be highly variable with respect to the studied traits. There was wide variation for spikelet sterility, total dry matter at maturity, chlorophyll content of boot leaf at maturity and proline content.

Trials under All India Coordinated Rice Improvement Programme (AICRIP)

Initial variety trial for rainfed shallow lowlands was conducted with 46 test entries generated at different breeding centers of the country and three check varieties. The experimental mean yield was 4.778 t / ha with 112 average days to flowering and 238 panicles / m^2. Highest grain yield of 7.778 t / ha was recorded from IET 23557 followed by 7.367 t / ha and 7.298 t / ha from IET 23150 and IET 23538, respectively.

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

International Rainfed Lowland Observational Nursery (IRLON)

The 36^{th} International rainfed lowland Observational nursery (IRLON) comprised of 46 test entries and four international check varieties were grown for assessment of the entries based on flowering duration, overall phenotypic acceptability, grain yield and submergence tolerance. Top five entries evaluated were IR 10L185, IR10F577, IRRI163, IR10L357 and IR09L337.

Green Super Rice for Rainfed Lowland Yield Trial (GSR-RFLL)

The GSR-RFLL trial was conducted during wet season 2013 to evaluate the promising GSR for Cuttack situation. Top five entries evaluated were IIR119, HHZ 5-SAL1-Y1, IRRI 123, D4098 and HHZ 5-SAL12-Y2-DT1.

Variety released for rainfed shallow lowland situation

CR Dhan 407 (IET 21974) developed through pedigree breeding method using Swarna / IR64 was released by Central Sub-Committee on Crop Standard, Notification and release of variety for the states of Odisha and West Bengal (*Fig 8*). The variety possesses the characteristics of 150 days maturity duration, long bold grain,102 cm height, 63.6% head rice recovery, 23.5% amylose content, 22.8 g seed test weight and produces average grain yield of 5.2 t / ha.

Fig 8. Field view of CR Dhan 407 (IET 21974) at dough stage

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

Identification of new sources of submergence tolerance

Generation advancement of two new crosses viz. IR42 / AC 20431 and IR42 / IC 258990 using IR42 as recurrent parent and IC 258990 and AC 20431B as submergence tolerant donors has been taken up during the wet season 2013.

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

Eight hundred and forty eight single plant progenies (F_4-F_7) from 83 cross combinations were grown under semi-deep water conditions (*Table 9*). At the time of maturity, three hundred and sixty five single plant selections have been made from 64 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 during wet season 2013. Besides, 51 uniform progenies were bulk harvested to see their yield performance in the next season.

Table 9. List of breeding material grown and selections made during wet season 2013

Gen	Progenies / bulks gorwn	SPS	Bulks selected
F_3	186 (3)	100 (3)	-
F_4	79 (18)	60 (12)	-
F_5	272 (46)	179 (34)	-
F_6	305 (15)	26 (9)	49
F_7	6 (1)	0	2
Total	848 (83)	365 (58)	51

**Figures in parenthesis indicates no of crosses*

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

During 2013 wet season, selection and evaluation of segregating materials were taken up in F_5 - F_7 generations of deepwater rice breeding programme. Forty five promising single plants were selected from F_5 populations comprising of fourteen cross combinations on the basis of moderate elongation ability, good kneeing ability, high panicle and grain number, photo sensitiveness, plant height, field tolerance to bacterial blight disease and stem borer and leaf folder attack. Furthermore, eighty five F_6 progenies were grown under typical deepwater conditions and eighteen uniform progenies were bulk harvested for further evaluation.

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

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

Forty advance breeding lines along with eight check varieties were evaluated in a randomized block design with two replications under semi-deep water conditions during wet season 2013 at CRRI, Cuttack. None of the entries performed better than the best check variety Varshadhan. Among the different entries, CR 2583-1-1-1-20 performed best with an average yield of 4.11 t / ha followed by CR 2583-1-1-1-24 and CR 2582-1-1-1-2 with an average yield of 3.91 t / ha against the best check Varshadhan (4.29 t / ha).

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

Station trial was conducted comprising 15 elite fixed lines and 3 checks in randomized block design with two replications. The Performance of 8 entries were promising as compared to the three check varieties CR Dhan 500 and Jalmagna. The promising genotypes were CR 3607-2-2-1-1, CR3604-5-2-1-1, CR3604-6-3-1-1-1, CR2679-4-2-1-1-1, CR2081-147-1-1, CR3835-1-7-2-1-1, CR2683-35-2-1-1 and CR3836-1-7-4-1-1.

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

National Semi-Deep Water Screening Nursery (NSDWSN)

Sixty two 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. 3943 (IET 23924: OR 2413-8) performed best with an average grain yield of 5.79 t / ha followed by Entry No. 3947 (IET 23928: OR 2427-3) with 4.22 t / ha and Entry No. 3951 (IET 23932: CR 3607-1-3-2-1-1) with 3.91 t / ha against the best check Varshadhan (3.43 t / ha). All these varieties had more than 95% survival.

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

Twenty 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. 616 (IET 23053; CR 2687-2-3-1-1-1) performed best (3.46 t / ha) followed by Entry No. 621 (IET 23066; CR 2683-45-2-2-3) with 3.06 t / ha and Entry No. 620 (IET 23063; CR 3606-16-1-3-1-1) with 3.01 t / ha against the best check Varshadhan (2.89 t / ha).

Initial Variety Trial-Deep water (IVT-DW)

Initial variety trial for deepwater rice was conducted with 17 test entries generated at different deepwater breeding centers of the country along with three check varieties. The experimental mean yield was 4.116 t / ha with 116 average days to flowering and 176 panicles / m^2. Highest grain yield of 4.784 t / ha was recorded from IET 23596 followed by 4.383 t / ha and 4.364 t / ha from local check CR Dhan 500 and IET 23599, respectively.

Advance Variety Trial-Deepwater rice (AVT I-DWR)

Advance variety trial for deepwater rice was conducted with nine test entries generated at different deepwater breeding centers of the country along with three check varieties. The experimental mean yield was 3.508 t / ha with 122 average days to flowering and 211 panicles / m^2. Highest grain yield of 4.797 t / ha was recorded from IET 222989 followed by 4.727 t / ha and 4.221 t / ha from IET22986 and IET 22302, respectively.

Performance of entries nominated in AICRIP trials during 2013

During the year, one high yielding rice variety CR Dhan 505 was released and notified for deepwater ecosystem of Odisha and Assam states. One entry CR 2593-1-1-1-1 (IET 23895) nominated under NSDWSN has been promoted to IVT-SDW and another entry CR 2437-B-2-1-1-1 (IET 23055), which was tested under IVT-SDW has been promoted to AVT1-SDW. Six deep water rice cultures viz., CR 2416-12-1-1, CR2681-147-1-1, CR2251-1-1-1-3, CR2679-4-2-1-1-1, CR3599-3-2-1-1-1 and CR3604-6-3-1-1-1, which were tested under AVT 1-DW have been promoted to AVT 2-DW.

Variety released for deepwater ecology

The promising breeding line CR2682-4-2-2-2-1 is developed from the breeding materials of cross CRLC 899 / Ac. 38606 (Pi Lam poon) and released as CR Dhan 505 (*Fig 9*). It has consistently out-performed the check varieties under national testing from 2010-2012. The promising line has exhibited stability for yield and other characters in region III exhibiting promising in the states of Odisha and Assam under waterlogged stress situation. Hence, the elite line has been identified for release in these two states by Central Variety Identification Committee held during 48th Annual Rice Workshop at Sri Nagar. The genotype showed promise in region III of the country exhibiting 55, 42 and 42% increase over national, regional and local checks, respectively. Maturity duration of the variety is 160 days with average yield of 4.3 t / ha. It showed increase over best inbred check in Odisha (31%) and Assam (40%) under water logged situation. It is moderately resistant to leaf blast, neck blast, sheath rot, sheath blight, rice tungro virus, stem borer, leaf folder, whorl maggot, GRH

Fig. 9 Field view of CR Dhan 505 (IET 21719) at dough stage

and rice thrips. It possesses intermediate amylose content (24.5%) and other desirable quality parameters for consumer's preferences.

Breeding rice varieties for coastal saline areas

Evaluation of rice germplasm for salinity tolerance at reproductive stage

A set of 58 rice germplasm lines was evaluated for salinity tolerance at reproductive stage under simulated condition at EC 6-8 dS / m during the wet season. The genotypes were divided into three different groups based on the maturity duration and grown in separate tanks. Bhutia and Pokkali (AC 41585) with marginal reduction in grain yield under salt stress compared to the control were found most promising followed by Chetivirippu (AC 39389), IRRI 147 and Agniban (AC 43219) (*Table 10*). Sterility (%) under salt-stress was the lowest in Chetivirippu (AC 39389) followed by Pokkali (AC 41585). The reduction in grain yield due to salt stress was between 40 and 50% in Bhundi, Patani, Dinkiasali, AC 35318, Canning 7 (AC 42447) and Rangi. The remaining 47 genotypes showed much higher yield reduction under salt stress compared to the control (data not given).

Evaluation of germplasms for salinity tolerance at seedling stage

Seventy germplasm lines were evaluated for their ability to tolerate salinity at seedling stage along with susceptible check, IR 29 and its tolerant counterpart, FL 478 (*saltol* introgressed line). Malbati, Mutra, Ratni, Lilabati (AC 35306), Raja Pateni, Gopal bhog and Dash are identified as moderately tolerant (SES score= 5) genotypes at EC 12 dS / m.

Development of elite lines tolerant to salinity

Development of salt tolerant lines with *Saltol* QTL introgression

FL 478 is a *Saltol* QTL introgression line and widely used for introgression of *Saltol* QTL into high yielding background. A breeding population of 93 lines (F_8) from IR 64 x FL 478 cross have been grown in salinity microplot with EC 12 dS / m in dry season 2013. Selected eight lines were taken in salinity microplot in two replications at EC= 12 dS / m. Except for the two lines, others viz., SR 12, SR-11, SR-27, SR-28, SR-40 and SR-89 along with FL 478 exhibited SES score 3 (*Fig. 10a & b*). SR-33 and SR-9 were moderately tolerant (SES score= 5). Eight F_8 tolerant and moderately tolerant lines along with their parents (FL 478 and IR 64) were subjected to analysis for validation of the microsatellite markers in the *Saltol* QTL region. Among the tested 12 primers

Table 10. Grain yield of selected rice genotypes in the control and salinity treatment, reduction in grain yield over the control and sterility (%) under the salt-stress (EC 6-8 dS/m) during reproductive stage

Genotype	Grain yield (g / plant)		Reducation (%) in grain yield over control	Sterility (%) salt-stress
	Control	Salinity		
Bhutia	2.35	2.11	10.2	33.0
Pokkali (AC 41585)	6.96	6.07	12.8	20.6
Chetivirippu (AC 39389)	11.39	8.41	26.2	13.6
IRRI 147	3.63	2.49	31.4	27.5
Agniban (AC 43219)	7.85	4.86	38.1	38.1
Bhundi	4.27	2.49	41.7	29.7
Patani	7.35	4.15	43.5	21.9
Dinkiasali	3.58	2.02	43.6	47.8
AC 35318	3.76	2.09	44.4	27.6
Canning 7 (AC 42447)	4.22	2.26	46.4	45.3
Rangi	3.69	1.87	49.3	39.1
LSD (P=0.05)	1.71	1.24	5.4	3.9

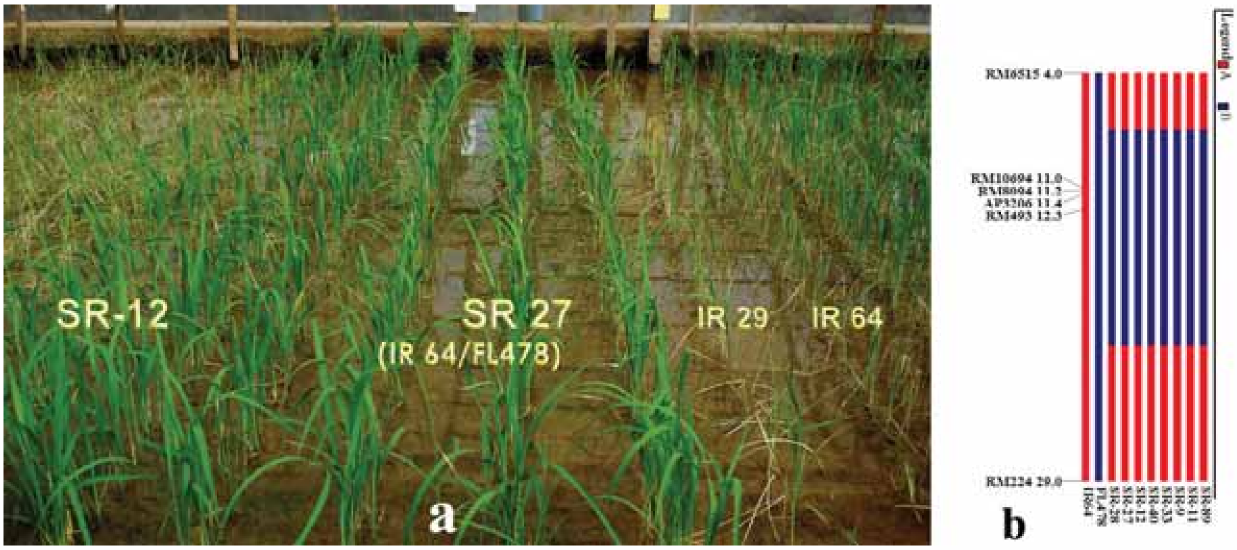


Fig 10. ***a.*** *Phenotyping of introgression lines in IR 64 background tolerant to salinity (EC= 12 dS/m) at seedling stage at salinity mocro-plot,* ***b.*** *Graphical genotyping of Saltol region of chromosome 1 in those Saltol introgression lines*

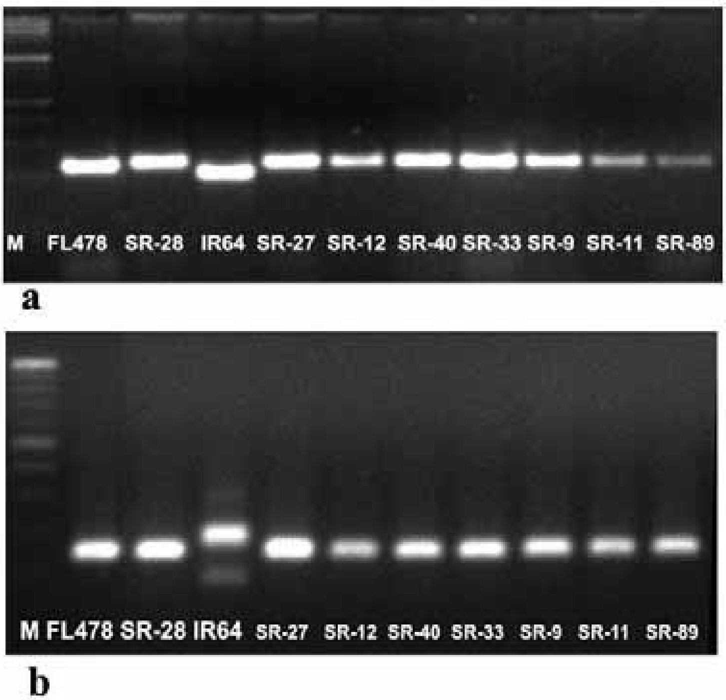


Fig 11. SSR polymorphism using Saltol markers, a. RM10694, b. RM8094 in parents and salt-tolerant introgression lines from IR64/FL478 cross

located at the *saltol* region, four primers (RM10694, RM8094, AP3206, RM493) (*Fig 11 a,b*) were found polymorphic between parents. FL478 specific marker alleles for different loci situated from 11 Mb to 12.4 Mb region in chromosome 1 were found in all the lines (*Fig 10b*). These tolerant and moderately tolerant lines sharing a common segment from the donor FL 478 might carry the *Saltol* QTL in this region.

Identification of salt tolerant lines at seedling stage

Six hundred twenty five F_5/BC_1F_5 lines from five cross combinations were evaluated for salinity tolerance at seedling stage under simulated condition at EC 10-12 dS / m during the dry season. One of the BC_1F_5 lines from Naveen x FL 496 cross was found tolerant while another 11 BC_1F_5 lines from the same cross were moderately tolerant.

Development of salt tolerant elite lines for wet season

Thirty cross combinations have been used to select high yielding lines with salt tolerance trait. A few lines derived from crosses involving indigenous salt tolerant donors, such as SR 26B, Pateni, Rahspunjar, Kamini were identified on the basis of performance both at normal and stressed (EC=5-8 dS / m) condition. F_1 seeds were generated during *kharif* season from the crosses using Pokkali (AC 39416A), tolerant to salinity, water-logging and anaerobic germination and popular high yielding varieties, Savitri, Gayatri and Varshadhan as the female parents. Around 800 single plants and 59 bulk population of F_5-F_8 were evaluated under saline and non-saline situation.

Development of lines tolerant to salinity and waterlogging for coastal saline areas

Using Triple cross, double cross method: F_1 and F_2 seeds were generated from three way and double crosses using Kamini and Ravana as salt tolerance donors, Gangasuili and Kalaputia for waterlogging while Savitri, Gayatri and Varshadhan for high grain yielding parent.

Through double haploid method: AC 39416 is tolerant to salinity at seedling stage, anaerobic germination and waterlogging was crossed with high yielding parents, Gayatri and Savitri. Around 230 F_1 plants have been raised so far and anthers are being taken for the production of double haploid lines.

Generation advancement of salt tolerant lines

Four hundred seventy F_5 progenies of multiple crosses for incorporating submergence and salinity tolerance in the derivatives and 545 F_{4-6} short duration saline tolerant lines were grown in normal soil and among these lines, 415 single plants were selected on the basis of plant type, duration, grain etc. from both duration group lines.

Evaluation of short duration saline tolerant lines at target environment

Thirteen salt tolerant short duration genotypes with two checks (Luna Sankhi and IR 29) were evaluated at target areas of coastal salinity and on farm normal soil during dry season 2013. The experiment design was RCBD with three replication. In saline soil the trial was completely failed due to non-availability of normal

Table 11: Evaluation of breeding lines for dry season in costal saline areas

Genotypes	Days to flowering	Plant height (cm)	Panicle length (cm)	EBT	Yield (t / ha)
CR2814-1-19-4-2-1-1	95	108.2	26.8	7.2	5.16
CR2814-2-4-3-1-1-1	92	101.6	22.8	5.4	2.49
CR2814-3-1-6-S-2-1-1	93	101.8	25.8	8.2	4.05
CR2815-4-23-7-S-2-1-1	64	102.0	27.8	9.2	5.95
CR2815-4-26-5-S-2-1-1	92	108.0	26.8	8.2	4.50
CR2815-4-23-5-S-2-1-1	92	104.0	27.4	8.4	5.07
CR2815-4-26-1-S-4-1-1	98	103.0	24.6	5.0	2.97
CR2815-5-6-1-S-1-1-1	98	103.8	20.0	6.2	2.96
CR2815-5-1-3-S-1-2-1	87	96.0	27.5	8.8	5.28
CR2815-2-4-2-1-1-1	90	109.0	24.4	5.2	2.50
CR2815-4-23-5-1-1-1	84	99.6	19.4	4.4	1.24
CR2814-2-4-3-2-1-1	92	99.6	25.0	7.4	4.54
CR2472-33-57-1	77	105.6	26.6	6.8	4.20
Luna Sankhi	83	106.2	24.4	7.2	4.20
IR29	89	110.0	23.2	6.4	2.32
LSD (P=0.05)					0.41
CV %					6.50

irrigation water and high soil and water ECs (15 dS / m) resulting complete damage of crop at vegetative stage. Under normal soil, highest grain yield was recorded from CR2815-4-23-7-S-2-1-1 (5.95 t / ha) followed by CR2815-5-1-3-S-1-2-1 (5.28 t / ha) (*Table 11*). Check variety Luna Sankhi yielded 4.2 t / ha, where as IR 29 yield was recorded 2.32 t / ha.

Evaluation of breeding lines at target environment during wet season

Eighteen lines derived from seven crosses involving salt tolerant donors SR 26B, FL 496, Pateni and FL 478 were evaluated along with Luna Suvarna, a released variety for coastal saline areas and CR 1017, a salt susceptible cultivar. They were planted on 7th August in replicated plots at Gosaba (Sundarban, West Bengal) under coastal saline areas. Throughout the crop season, salinity varied from 0.5-7 dS / m. Four lines exceeded Luna Suvarna for average plot yield. Among them two lines (CR 2839-1-1-S-1-2B-35-B, CR2859-S-B-3-1-2B-1) (*Table 12*) have been chosen by the farmers. Besides, CR 2218-41-2-1-1-S-B2-B also preferred by the farmers through participatory varietal selection. They have given estimated yield of around 3-3.5 t / ha with maturity duration of 145-155 days.

Development of mapping population for detection of salt-tolerant QTLs

Single seed descent method was followed for the development of RIL lines from Swarna / Kamini and Naveen / Chettivirippu (AC 39394) and 400 F_4 lines were advanced from each cross. Kamini and Chettivirippu (AC 39394) are tolerant to moderately tolerant to salinity at seedling and reproductive stages, respectively. Doubled haploids and BC_2F_2 populations are being developed using Pokkali (AC 39416), a variety tolerant to salinity, anaerobic germination and waterlogging.

Evaluation of mapping population for flowering stage salt-tolerance

One hundred eighty two $BC_3F_{3:5}$ introgression lines derived from cross involving flowering stage salt tolerant donor, Pokkali (AC 41585) and IR 64 along with their parents were taken for the study. Seedlings at the age of one month were planted in perforated pots filled up with fertilized soil. One set of potted seedlings was salinized and the other set was allowed to grow in normal condition in the net-house till maturity. Perforated pots were kept in water tank. Standard procedure with requisite modifications was followed to salinize potted plants. For salinization, NaCl was

Table 12. Performance of breeding lines under coastal saline environment during wet season

Lines	Parentage	Plot yiled (g / 5 m²)	Dayt to 50% flowing	Plant height (cm)	Water depth (cm)	Soil salinity level (EC)
CR2839-1-S-10-B2-B-43-B	Swarna / FL496	1100	116	107	5.0-54.0 cm Submerged for 10 days after 2-3 days of planting (40-60 days seedling- water depth varied from 16 to 54 cm)	0.5-7 dS / m at flowring time soil EC was 5-6 dS / m
CR2839-BC-1-1-S-1-2B-3-B	Swarna / FL496	1187.5	114	92		
CR2839-BC-1-1-S-1-2B-32-B	Swarna / FL496	1275	112	84		
CR2839-1*-1-S-1-2B-35-B	Swarna / FL496	1550	112	100		
CR2840-1-S-4B-31-B	IR 64 / FL496	1500	114	107		
CR2845-S-1-1-2B-1	Swarna Sub1 / SR 26B	1250	120	137		
CR2845-S-1-1-2B-5	Swarna Sub1 / SR 26B	925	113	147		
CR2851-S-B-1-2B-1	Gayatri / SR 26B	350	120	122		
CR2851-S-1-2-2B-1	Gayatri / SR 26B	675	115	145		
CR2851-S-1-6-2B-1	Gayatri / SR 26B	1475	115	107		
CR2851-S-B-3-2B-1	Gayatri / SR 26B	1200	120	130		
CR2851-S-1-5-2B-1	Gayatri / SR 26B	875	113	102		
CR2851-S-1-7-2B-1	Gayatri / SR 26B	1050	113	110		
CR2859-S-B-1-1-B-1	Varshadhan / FL496	950	113	160		
CR2859-S-B-3-1-2B-1	Varshadhan / FL496	1800	115	147		
CR2218-41-2-1-1-S-B1-B	Savitri / Pateni	1075	123	120		
CR2218-41-2-1-1-S-B2-B	Savitri / Pateni	1300	123	120		
Luna Suvarna	Released variety	1150	115	130		
CR 1017 (local)	Released variety	787.5	115	130		
Mean		1113.75	114.7	120.3		
SEM		116		10.5		
CD (5%)		215.3		7.3		

dissolved to tank water to make water EC 8 dS / m and salt-water was allowed to enter the porous pots to saturate soil. Salt stress was imposed on plants before booting. Data recorded on two years, 2012 and 2013, under saline and non-saline environment. Analysis of variances showed that population was significantly differ for most of the traits under both the conditions. A wide range of variation for tolerance was observed among the lines. Among yield attributing traits, plant height (cm) and panicle length (cm) were significantly reduced in salinized condition. A few genotypes (numbers 4, 5, 19, 66, 82, 100, 108, 123, 142, 186, 188, 192) were also identified with <25% yield reduction under stress. Yield and important yield attributing traits such as panicle length, straw weight, harvest index were revealing normal distribution (*Fig 12*) over the environments.

Combined analysis, AMMI model and identification of stable genotypes

Plant height, panicle length, plant yield and harvest index were significantly ($p<0.05$) different amongst genotypes (G), environments (E) and genotype x environment interaction (GEI) indicating the presence of genetic variation and possible selection of stable entries. For plant yield $IPCA_1$ could explain 61% variance of total GEI alone. Therefore, $IPCA_1$ value might be reliable determinant for stability of yield over environments. Genotype numbers 41, 45, 112, 171, 192 and Pokkali have low interaction PCA (near to 0) and same sign with genotypic variance were observed with significantly higher values than the mean. Therefore, they are stable under both the environment. On the other hand, genotype number 63, 114 have high IPCA (>1) and different sign with genotype variance showing specific adaptability to favourable (non-stress) environment. Similarly, due to different sign of genotypic variance and IPCA and higher yield than the mean, genotype number 174 and 175 and IR 64 could be specifically adaptable for favourable environment.

Development of super rice for different ecologies

Evaluation of new plant type (NPT)/ advance generation rice under irrigated condition

In *rabi* 2013, twenty three cultures were shortlisted from 76 elite lines and tested in AYT for evaluating their grain yield and morpho-physiological traits under higher fertilizer dose (120: 50: 50:: N :P_2O_5 :K_2O). The entries were tested in RCBD with two replication

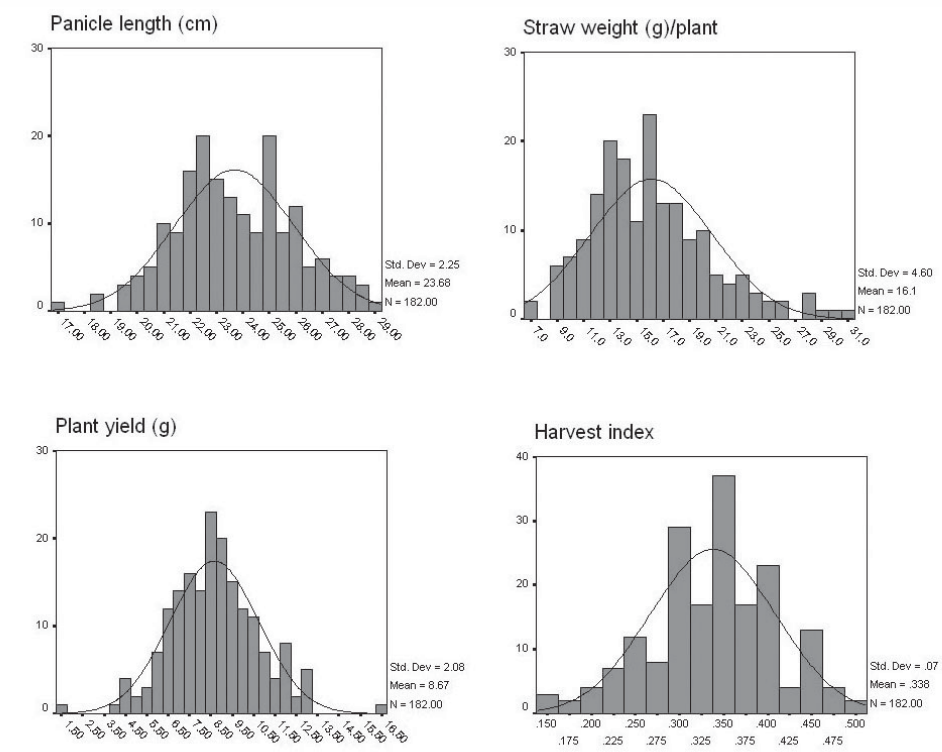


Fig 12. Histogram showing distribution of lines in mapping population derived from IR 64/Pokkali for yield and yield attributing traits related to salt tolerance at flowering stage

against four checks viz., Naveen, Annada, IR-64 and Swarna. Among the genotypes, CR 3624-1, CR 3721-11-1 and CR 3724-1 recorded highest grain yield of 9.15, 9.08 and 8.74 t/ha, respectively, in small plot experiments. There were yield advantages of 19.92%, 19% and 14.54% against best check Naveen (7.63 t/ha). Other two cultures viz., CR 3727-2-21 and CR 3623-2-2-1 also recorded yield advantage of 6.82% each in comparison to best check. It was analyzed that, there were appreciable number of ear bearing tillers, long panicles, marginally higher grain number, long and erect top three leaves contributed to higher grain yield in comparison to checks. In *kharif* 2013, 144 genotypes tested under OYT in Augmented Design and 80 genotypes under AYT in a experimental design of RCBD. In this season, the crop was affected by a natural calamity i.e., *Phailin* during October 2013 where very severe cyclonic storm struck the Odisha coast, bringing in its wake torrential rains and wind speeds of 110-120 kmph at the experimental site (CRRI, Cuttack) followed by heavy downpour of around 350 mm rainfall within a span of 3 days. Effective pollination was hampered (25-50%) in the genotypes at flowering stage. Some of the genotypes suffered from leaf splitting followed by secondary fungal infection. Under such circumstances, in AYT, highest grain yield was recorded in CR 3623-2-2-1 (6.67 t/ha) followed by CR 3624-1) (5.85 t/ha) and CR 3724-1 (5.20 t/ha). Significant yield advantages were recorded over best check (Swarna) i.e. 102%, 77.3%, and 57.6%, respectively. Similarly, in AYT2 (late planting), CR 3724-1 also performed best with a grain yield of 5.86 t/ha, followed by CR 3851-2-1 (5.11 t/ha) and CR 3726-1-1 with 4.78 t/ha, whereas checks viz. Naveen, IR-64 and Swarna recorded a grain yield of 3.53 t/ha, 2.6 t/ha and 3.26 t/ha, respectively. Thus, there were yield advantage of 65.72%, 44.75% and 35.41%, respectively, over the best check (Naveen). The high grain yield could be attributed to more tiller number (8-10), moderately long panicle (30-33 cm), and moderately long top three leaves. Similarly in AYT-3 (shallow lowland) maximum grain yield was obtained in culture ARC 4-2 (7.03 t/ha) followed by CR 3707-2-5-2-1(6.0 t/ha) and CR 3873 -1-3-1(5.78 t/ha) against grain yield of check variety Swarna (4.91 t/ha).

Standardization of agronomy for super rice

The objective of this study was to identify the best new plant type across nitrogen doses and spacing along with optimization of nitrogen doses. Here two genotypes viz. CR 3624-3-1-1, CR 3727-2-2-1 along with one high yielding super rice variety viz., CR Dhan 300 was taken as check. This experiment faced the severity of *Phailin*.

All the three varieties, CR 3624-3-1-1, CR 3727-2-2-1 and CR dhan-300 (check) recorded maximum yields when supplied with 120 kg N/ha. Higher N dose of 160 kg/ha was not found to have any positive effect on the yield. Across all N doses, CR 3727-2-2-1 and CR Dhan-300 recorded highest yields, 4.11 t/ha and 3.83 t/ha, respectively when grown under 15 cm X 15 cm spacing. However, CR 3624-3-1-1 recorded maximum yield (4.01 t/ha) under 20 cm X 15 cm spacing. As the super rice genotypes were having some sort of shy tillering, therefore, closer spacing was found to have high yield than wider one. However, it needs another season for confirmation.

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

In order to develop breeding materials with super rice plant type and super agronomic traits viz., heavy panicle , high fertile grain number, semi-dwarf height, strong culm, erect long and wide top three leaves along with field tolerance to major diseases and pests in the background of acceptable grain quality, twenty five three way crosses and fifteen new crosses were made involving tropical *japonica* and their derivatives in the back ground of elite varieties viz. CR 3856-44-22-2-1, PAU-201, Pusa-44, COR-50, Tapaswini MAS, Swarna MAS, Wita-12, MTU-1010, IR-64 MAS etc.

Generation advancement was carried out under pedigree method of selection. Progeny row was grown from single plant selections in different generations viz., 750 F_3, 46 F_4, 62 F_5, 68 F_6, 230 F_7 along with 40 F_2 populations. Ten F_2 (involving irrigated x tropical *japonica*) were grown and single plant selections were advanced to F_3. The plant type of tropical *japonica* lines was usually not very good. They also did not show good combining ability. However, some of the TJ lines viz., EC 491313 and EC 491476 were found to be very good combiners with heavy panicle and high fertile grain in the background of semi-dwarf plants.

In order to incorporate BLB resistance in super rice backcross BC_2F_1 was made using heavy panicle genotype CR 3856-44-22-2-1 as recipient and Swarna

MAS containing *Xa21*, *xa13* and *xa5* resistant genes as donor.

In F_7 generation, 230 lines were grown. Some of them were found highly promising viz., CR 3856-29-14-2-1-1-1, CR 3856-44-22-2-1-5 and CR 3856-76-11-2-2-1 were found with grain number as high as 427, 378 and 375 respectively with more than 85% spikelet fertility (*Table 13*). An ideal plant type CR 3856-44-22-2-1-11 was selected in F_7 with super rice traits viz. very strong culm, medium dwarf height (115 cm), erect long and wide top three leaves (37.8 cm flag leaf length, 48.6 cm second leaf with flag leaf width of 2.1 cm), 300-350 average grain number with 75% -90% fertility and 20.0 g thousand grain weight (*Fig 13*).

Fig 13. Single Plant view of CR 3856-44-22-2-1-11-1

In *rabi* 2014 preliminary yield trial (PYT) was conducted for the promising F_8 fixed materials with RCBD design with two replication taking medium sized plots (10 m^2) for each genotype. One of the promising selections CR 3856-44-22-2-1-11-1 performed well with 8.01 t/ha in a plot planted with single seedling at a spacing of 20 cm x 20 cm (*Fig 14*). The culture is having shy tillering, therefore, could not achieve the desired plant population per m^2 (250-300). In this context, agronomical study will be conducted in next generation for optimizing plant population.

Fig 14. Field view of CR 3856-44-22-2-1-11-1

Table 13. List of promising selections in F_6 showing high grain number

Genotype	No. of fertile grains (highest)	No. of sterile grains (highest)	Total no. grains (highest)	Tiller no. (effective)	Fertility (%)	Average no. of fertile grains	Average fertile fertility %
CR 3856-29-14-2-1-1-1	400	27	427	6	93.7	230	82.2
CR 3856-44-22-2-1-5	335	43	378	7	88.6	255	78.6
CR 3856-76-11-2-2-1	330	45	375	8	88.0	240	82.9
CR 3856-44-22-2-1-11	260	43	303	7	85.8	220	73.6
CR 3856-44-22-2-1-7	265	47	312	7	84.9	210	75.7
CR 3856-50-23-2-3-1	265	166	431	8	61.5	241	75.4
CR 3856-55-11-1-1-1	265	75	340	9	77.9	167	77.8
Swarna	135	25	155	9	82.0	115	82.1

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

Five hundred different genotypes including tropical *japonicas* (with wc genes), their derivatives, ARC and other exotic lines were collected and screened in a augmented block design with four checks (Annada, Naveen, IR-64 and Swarna) for potential morpho-physiological traits, for their prospective use as donor / parental lines.

- Most of the tropical *japonica* genotypes were with tall plant type, however, few were dwarf types with relatively high grain yield viz., EC-491156 (95.8 cm), EC 497134 (111.0 cm), EC-496935 (109.6 cm) and EC 491327(111.3 cm)
- High tiller number: High tiller is desirable in super rice along with heavy panicle and high grain yield. In this context, EC-497069 (14.6), EC-496897 (13.6), EC-491305 (11.6), and EC-491423 (11.6) registered higher tiller numbers along with appreciable grain yield.
- Number of fertile grains: One of the major bottleneck in *indica*, tropical *japonica* cross is grain sterility. Therefore, number of fertile grains should be taken care of during selection of potential donors. EC-491180 (165), EC-491480 (141), EC-497022 (137) were found with appreciable high grain along with standard grain yield.
- Leaf size: It has been reported that flag leaf and subsequent leaves were important for synthesis and translocation of assimilate for high grain number and weight. Moreover, the recent strategy for increasing biomass is long, wide and erect top three leaves, rather than tall height of plants. In view of this, EC 491157 (58.6 cm flag leaf; 69.6 cm 2nd leaf and 1.7 cm flag leaf width), EC- 491359 (48.0 cm; 58.6 cm and 2.06 cm), EC - 491379 (46.5 cm; 52.5 cm and 2.0 cm) and EC-491365 (54.6 cm; 65.3 cm and 2.2 cm) were recorded with long and broad leaf along with other standard features and could be the potential donors.
- Leaf erectness: EC-491234, EC-491327, EC-491393, EC-491402, EC-4911164, were registered with highly erect flag leaf architecture and could be useful parents for designing super rice.
- High culm diameter(a indicator for lodging resistance): The genotypes viz., EC-391239 recorded highest culm diameter (12.19 mm) followed by EC 491274 (11.81 mm), EC 491231 (11.31 mm), EC 491320 (11.10 mm) and EC 491335 (11.03 mm). However, grain is the product of several component characters. EC 497016 (1201 g / m^2) was found with highest grain yield followed by EC 497134 (998 g / m^2), EC 496929 (930 g / m^2) and EC 491156 (903 g / m^2) and could be utilized as donors for overall improvement of plant type including grain yield.

Photosynthetic efficiency of selected NPT lines

- Photosynthetic efficiency of eleven selected NPT lines and their parents were recorded at flowering during dry season 2013. Highest photosynthetic rate was observed in CR 3727-1 (30.88 µmol CO_2 / m^2 / s) followed by IR 78629-57-3-3-9-4, CR 3624-2 and CR 3623-2-2-1 (27 µmol CO_2 / m^2 / s), while stomatal conductance was highest in CR 3623-2-2-1 (1.79 mmol CO_2 / m^2 / s) followed by CR 3727-1 and CR 3624-2 (13.0 mmol CO_2 / m^2 / s). However, the efficiency of the parental line IR 73963-86-1-5-2-2 was at par with the CR 3727-1 for both the traits (*Fig 15 and 16*).

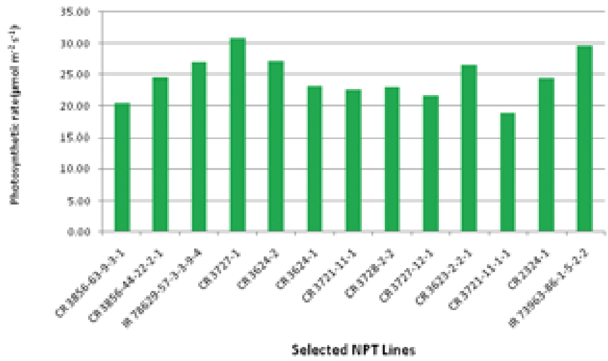


Fig 15. Photosynthetic rate (µmol $CO_2/m^2/s$) of selected NPT lines at flowering stage

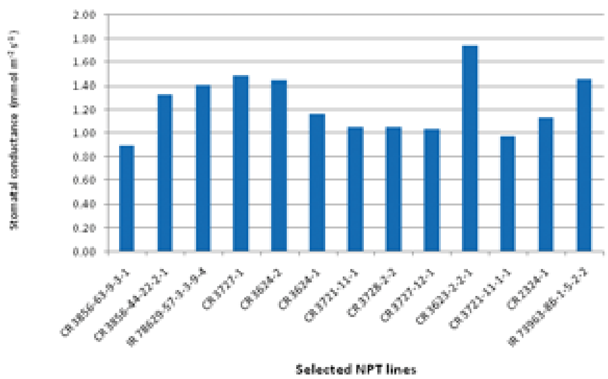


Fig 16. Stomatal conductance (mmol $CO_2/m^2/s$) of selected NPT lines at flowering stage

Total chlorophyll content was highest in CR 3856-44-22-2-1 (4.27 mg / g fresh weight (fr. wt.)) followed by CR 2324-1 and CR 3856-63-9-3-1, while CR 3727-1, CR 3624-1 and CR 3623-2-2-1 had higher range of chlorophyll content (3.38 to 3.53 mg / g fr. wt.) during flowering.

Among the 11 selected NPT lines tested NPT CR 3727-1 and CR 3623-2-2-1 had highest grain yield of 7.5 t / ha which might have been contributed by high photosynthetic rate of (30.0 µmol CO_2 / m^2 / s^1), high stomatal conductance (>1.5 mmol CO_2 / m^2 / s), high chlorophyll content (>3.5 mg / g fr. wt.).

Potential donors development possessing super traits for designing next generation rice for relatively less favourable ecology

Genotypes with high biomass (>20 t / ha) coupled with high harvest index (>0.5) supported by other superior features including strong culm are expected to break yield ceiling under good management practices. The targeted total biomass can be obtained with ideal plant architecture like super rice with modification in total productive tiller number / hill to 6-8 instead of 4-5. This type of rice can be described as "Next Generation Rice" which can further break the yield ceiling. In the present investigation, eleven possible donors of super traits (very heavy panicle, high spikelet number and very long panicle) were evaluated along with two popular check varieties for confirmation of the super traits. The experiment was carried out in RBD with three replications with addition of 80:40:40 kg NPK / ha with a need based plant protection measures during wet season 2013. During the pre-flowering period, the crop encourntered severe wind speed was due to the cyclone '*Phailin*' resulting in depression of yield and associated traits.

Significant differences were observed among genotypes for panicle weight, spikelets / panicle, panicle length, number of secondary and tertiary branches / panicle and grain yield / plot. The average panicle weight varied from 2.43 to 10.03 g amongst the genotypes. The highest average panicle weight was recorded for CR2683-7-1-2-2. Mean spikelets / panicle was observed to be highest in genotype CR2683-7-1-2-3 with a range of 139 to 339 amongst the genotypes. Number of secondary branches / panicle was highest (19.15) in CR2683-7-1-2-3 while tertiary branches / panicle showed maximum (77.1) in CR2682-3-1-1-1. With regard to panicle length, the genotype CR3697-3-2-3-1-1 exhibited a mean panicle length of 40.5 cm with a range of 24.5 cm to 40.5 cm. Genotype CR 2682-7-1-1-1 showed heavy panicle weight (8.13 g) with high spikelet number (276). CR2683-1-1-2-1-1 and CR 2682-7-1-1-1 exhibited high grain yield of 8.03 and 8.5 t / ha, respectively. These genotypes will be useful as donors of important yield contributing traits for developing next generation rice.

Potential donors development for favourable upland

Nineteen new plant type (NPT) lines along check were evaluated under both direct seeding and transplanted condition during *kharif* 2013. Under transplanted condition, moderate stress was observed during grain filling stage. Highest grain yield was recorded by IR 72158-148-4-2-6-2 (4.3 t / ha), followed by IR 73930-41-5-3-1 (4.185 t / ha) and IR 73907-753-2-3 (4.18 t / ha) (*Table 14*). Under favorable uplands and direct seeded condition, IR 73896-51-2-1-3 resulted in highest grain yield of 3.56 t / ha (*Table 15*) followed by IR 72158-148-4-2-6-2 (3.465 t / ha) and IR 73930-313-2-2 (3.38 t / ha) .

Table 14. Mean performance of top performing NPT lines for different biometrical characters and disease reaction under transplanted condition

Entry no.	Days to 50% flowering	Plant height	Tillers / plant	No. of Panicle / plant	Panicle length (cm)	Grain yield (kg / ha)	Blast score	Brown spot score
IR 72158-148-4-2-6-2	93	69.9	12.6	11.1	19.9	4300	4	5
IR 73930-41-5-3-1	90	69.9	12.4	10.7	24.4	4185	5	4
IR 73907-753-2-3	106	68.3	14.8	13.1	19.5	4180	5	4
IR 75282-58-1-2-3	97	66.0	11.2	9.8	18.4	4013	4	7
IR 73930-313-2-2	94	74.0	9.3	8.6	18.2	3980	3	6
Mean (all 20 entries)	94.3	68.4	12.0	10.5	20.3	2915.8	4.7	4.8

Table 15. Mean performance of 19 NPT lines for different biometrical characters under direct seeding condition.

Entry no.	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Grain yield (kg / ha)
IR 73896-51-2-1-3	94	64.2	19.6	3560
IR 72158-148-4-2-6-2	90	67.2	19.3	3465
IR 73930-313-2-2	88	71.5	17.8	3380
IR 75282-58-1-2-3	93	64.0	17.6	3275
Sahbhagidhan	81	74.3	20.6	3250
Mean (all 20 entries)	94.9	66.4	19.6	2532.8

Evaluation of genotypes for blast and brown spot

Nineteen NPT lines were evaluated for blast disease in uniform blast nursery during *kharif* 2013. The result revealed that many of the NPT lines were susceptible to leaf blast. Among the 19 lines tested, none were resistant, seven were moderately resistant and 12 moderately susceptible. Same lines were tested in brown spot nursery and many lines were found to be susceptible to brown spot also. Among 19 entries, none were resistant to brown spot, eight moderately resistant, 10 moderately susceptible and one was susceptible to brown spot (*Fig 17*).

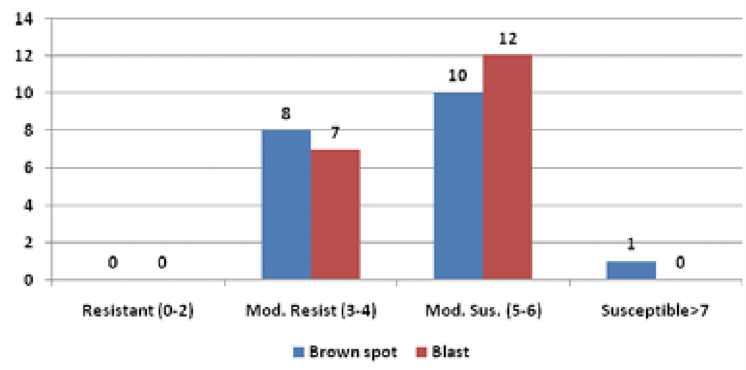


Fig 17. Reaction of 19 NPT lines to leaf blast and brown spot

Development of varieties for multiple biotic and abiotic stress tolerance

The F_2 populations derived from 11 different crosses (Benibhog / CH 45, Sahbhagidhan / Naveen, Sahbhagidhan, Annada, Vandana / Naveen, Vandana / Swarna *Sub-1*, Vandana / Annada, Anjali / IR 73907-753-2-3, CR Dhan 40 / IR 73907-753-2-3, Sahbhagidhan / IR 73893-71-2-6-3, Sadabahar / IR 72967-12-2-3 and Anjali / IR 72967-12-2-3) were raised at Hazaribag station. Both individual plant selection and bulk method was followed in F_2. Selected single plants in different crosses were harvested separately and their F_3 will be raised during *kharif* 2014. For bulk method, 2-3 seeds from each plant of a cross were bulked. F_3 from this bulk of all 11 crosses is raised at CRRI, Cuttack during summer 2014. Fresh crosses of Vandana x IR 73963-86-1-5-2-2, Vandana x IR 73930-41-5-3-1 and CR Dhan 40 x IR 73907-753-2-3 were attempted during *Kharif* 2013.

Resistance breeding for multiple insect-pests and diseases

Cultures notified by Central Variety Release Committee (CVRC)

CR Dhan 303 [CR 2649-7 (IET 21589)] derived from the cross between Udaya and IET 16611 was notified for release in irrigated areas of Madhya Pradesh, Uttar Pradesh and Odisha under mid-early duration in the 68th meeting of Central Sub-committee on Crop standards, Notification and Release of varieties for Agricultural Crops (*Fig 18*). In region III (Eastern India), it stood 1st among all the inbred lines tested for three years (2009-11) with over all yield advantage of 16.4%, 11.6% and 5.3% over National check (IR 64), regional check (Lalat) and Local check, respectively. Quality wise, it has 62.2% head rice recovery (HRR) with intermediate alkali spreading value (4.0) and amylose content (24.5%). This culture was also found to be promising for drought stress in AICRIP trial, 2010 for drought tolerance under rain out shelter at Coimbatore. The culture is moderately resistant to leaf blast, neck blast, sheath rot and rice tungro disease.

CR Dhan 304 [CR 2644-2-6-4-3-2 (IET 22117)] derived from the cross between

Fig 18. Field view of variety CR Dhan 303 (IET 21589)

Tapaswini and IET 16611 was notified for release in irrigated areas of Odisha and West Bengal under mid-early duration in the 68th meeting of Central sub-committee on Crop standards, Notification and Release of varieties for Agricultural Crops (*Fig 19*). In region III (Eastern India), it showed superiority in performance with yield advantage of 13.4%, 7.54% and 14.56% over National check (IR 64), Regional check (Lalat) and Local check respectively. This culture also stood 1st among all the inbreds and 2nd among all the hybrids and inbreds taken together in region III (Eastern India) in AVT 2-IME, AICRIP trial, *kharif* 2012. It stood 1st in Madhya Pradesh, 2nd in Andhra Pradesh and Odisha, 3rd in Bihar, 4th in Maharastra and 5th in Kerala among all the hybrids and inbreds taken in AVT 2-IME, kharif, 2012 of AICRIP. In AVT 1-IME trial, *kharif* 2011 of AICRIP, this culture stood 1st in West Bengal, 2nd in Rajasthan and 5th in Odisha among all the hybrids and inbreds taken together. This culture is moderately resistant to sheath blight, brown spot, rice tungro disease and gall midge biotype 1.

Fig 19. Field view of variety CR Dhan 304 (IET 22117)

Breeding materials found to be promising for various biotic stresses

CR 3006-8-2 derived from a cross combination of Pusa 44 / Salkathi recorded consistent resistance to BPH during second year of testing in Plant Hopper Screening (PHS) trial of AICRIP, 2013 which was conducted in 15 locations across the country against BPH, WBPH and mixed populations of plant hoppers under both field and green house condition. Earlier, it was also found to be resistant to BPH in AICRIP PHS trial, 2012. CR 2711-149 derived from a cross combination of Tapaswini / Dhobanumberi was found to be resistant to BPH in PHS trial of AICRIP, 2013. CR 2916-15 derived from a cross combination of Tapaswini / IET 16952 was found to be moderately resistant against sheath blight and sheath rot in Donor Screening Nursery (DSN) of AICRIP, 2013.

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

In order to develop breeding materials with resistance to multiple biotic stresses in high yielding background, twenty backcrosses, five three way crosses and eighteen new crosses were made involving elite varieties Naveen, Pooja and donors for resistance / tolerance to various biotic stresses such as IC 516210, BJ 1, IET 16952, Aguiha anarelo and Kataribhog for RTD ; CR 1014, Tetep, IET 20230, IET 20755, IET 19346, IET 17885 and Jogen for sheath blight; CR 2711- 76, CR 2711 - 114 , CR 2711- 149, CR 3005-230-5 and CR 3006-8-2 for BPH; CRMAS 2232-71 and CR 2231-37 for bacterial blight, CR 2619-9 and CR 2620-1 for blast; NDR 402 and Nalihazara for YSB; Mayurkantha for false smut; Kavya and Abhaya for gall midge.

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

Fifty-five cultures developed earlier involving improved varieties Naveen and Geetanjali and bacterial blight (CRMAS 2231-48, CRMAS 2232-85, IRBB 60) and blast (RIL 10, RIL 29 and RIL 249) resistant donors were evaluated for yield and other attributes during wet season, 2013. Among the different entries CR 3402-10-4-1-1-2 gave highest grain yield of 5.44 t / ha followed by CR 3404-48-1-1-1-1 (5.33 t / ha) and CR 3409-22-2-2-1-2 (5.16 t / ha) against the best check CRMAS 2232-85 (4.49 t / ha) and Naveen (3.61 t / ha). Besides this evaluation, fifty improved lines developed for bacterial blight and blast resistance using conventional and molecular techniques were also maintained during the season. Three hundred twelve multiple biotic (blast, BB, Gall midge) and abiotic (submergence and salt) stress tolerant lines of BC_3F_5 generation developed in the background of Tapaswini, Lalat, IR 64 and Swarna through marker assisted backcrossing were evaluated. Confirmation of the stable integration of resistant genes in these lines is in process. Ninety eight RTD resistant breeding lines were selected from segregating generations of crosses involving elite varieties Swarna, Gayatri, Satabdi, Tapaswini, Naveen and tungro resistant donors IET 16952, CB 98002, AC 6078, AC 290. One hundred forty three sheath blight tolerant breeding lines were selected from male sterility facilitated recurrent selection population of the crosses involving Genetic male sterile line and 13 sheath blight tolerant donors IET 17885, IET 17886, IET 19346, Jogen (AC 40922), Mansarovar (AC 40844), Manoharsali (AC 40509) and ASD 18 (AC 40865), IET 20755, IET 20737, IET 20443, IET 20553, IET 19140 and IET 20230.

New nominations for AICRIP trials

CR 3808-55 for IVT-RSL, CR 3808-60-13, CR 2647-5-2 and CR 3807-42 for IVT-IM, CR 3808-60-9, CR 3808-13 and CR 2919-12 for IVT-IME were nominated for AICRIP trials, 2014.

Breeding for higher resource use efficiency

Varieties released for aerobic adaption

CR Dhan 201(IET21924) is released for the states of Bihar and Chhattisgarh for aerobic cultivation in the states (*Fig 20*). It has consistently out-performed the check varieties under national testing from 2010-2012. The promising line has exhibited stability for yield and other characters in region III of the country. The average yield of the entry is 3.8 t / ha in overall AICRIP testing across 35 locations of the country. The frequency in top position for grain yield across locations was higher in the proposed variety as compared to national, regional and local check varieties. Maturity duration of the variety is 110-115 days with semi-dwarf plant type (100 cm). It possesses long slender grain, more panicles per m^2 (280) with 85-90 days to 50% floweirng, normal tillering (7-10), long and dense panicle with moderate test weight. It is moderately resistant to leaf blast, sheath rot, stem borer (both dead heart and white ear heads), leaf folder, whorl maggot and rice thrips. CR Dhan 201 has good hulling, milling and head rice recovery as compared to check varieties. It possesses intermediate amylose content and other desirable grain quality parameters.

Another variety CR Dhan 202 (IET 21917) is released for Jharkhand and Odisha states for aerobic situation. It has consistently out-performed the check varieties under national testing from 2010-2012. The promising line has exhibited stability for yield and other characters in region III of the country and was identified for release in these two states by Central Variety Identification Committee held during 48th Annual Rice Workshop at Sri Nagar from 13-16 April, 2013. The average yield of the entry is 3.7 t / ha in region III aerobic AICRIP testing across 18 locations of the country. Maturity duration of the variety is 110 days with semi-dwarf plant type (100 cm). The genotype is non-lodging type and is suitable for aerobic situation of Jharkhand and Odisha. It possesses short bold grain, more panicles per m^2 (285) with 85 days to 50% floweirng, normal tillering (7-10), medium and dense panicle with moderate test weight. It is moderately resistant to leaf blast, brown spot, sheath rot, stem borer (both dead heart and white ear heads), leaf folder, whorl maggot and rice thrips. CR Dhan 202 has good hulling, milling and head rice recovery as compared to check varieties. It possesses intermediate amylose content and other desirable grain quality parameters (*Fig 21*).

Fig 20. Field view of CR Dhan 201 at dough stage

***Fig. 21.** Field view of CR Dhan 202 at dough stage*

Promising genotypes identified for release

IET 22737 (CR Dhan 205) was recommended by Variety Identification Committee (VIC) for central release for the states of Tamil Nadu, Gujarat, Odisha, Madhya Pradesh and Punjab under aerobic condition. It has total duration of 110-115 days duration with semi-dwarf plant stature and short bold grains. IET 22084 (CR Dhan 306) has duration of 125-130 days, short bold grain with desirable quality parameters and identified for irrigated mid early areas of Madhya Pradesh, Bihar and Puducherry.

Generation of breeding materials

Seeds of F_6 generation of eight crosses involving parents ADRON 111 and ADRON 125 adapted to wetland direct seeded conditions along with Satabdi, Annada, Pusa Basmati 1 mutant and Lalat were grown and 146 single plants were selected for advancing the generation in the incoming *boro* season.

Backbross progenies were developed involving Naveen / CR260*[1]Naveen, Naveen / B6144FMR-6*[1]Naveen, Naveen / CR2921*[1]Naveen, Naveen / WITA8*[1]Naveen and Naveen / Sahbhagidhan*[1] Naveen for yield and quality attributes. Further, F_1 crosses were also attempted involving Naveen with purple base genotypes EC43, EC 40, EC77, and Chakaakhi for irrigated ecology. Crosses were attempted involving Geetanjali / MTU 1010 and Geetanjali / Sahbhagidhan for cold and heat stresses. Further, three way cross involving F_1 of Geetanjali / Sahbhagidhan with MTU 1010 had been completed. Evaluation and selection will be made in the segregating material in the subsequent generations. Selected genotypes of advanced lines were analyzed with known fine grain type for grain quality traits (*Table 16*). Out of the six long slender lines tested, CR 2349-2-3-1 had very high head rice recovery (64%) compared to others (49-56%), high grain length, right alkali spreading value and intermediate amylose per cent, and thus is fit for further promotion.

Breeding for water limited (aerobic) condition

During *kharif* 2013, one hundred and five lines of F_6 generation with less than 120 days duration were grown in pedigree nursery along with four checks viz. Swarna, MTU 1010, IR 64 and Pyari. Among them, 55 lines were forwarded for next generation based on their panicle and related traits.

Breeding for direct seeded condition

Selection for purple base in the segregating materials of crosses involving ADRON 125 / Satabdi and Naveen could identify eight purple base genotypes. After evaluating potential yield, these will be further selected. Anaerobic germination tolerant AC 34245 was crossed with recurrent parent Naveen with the objective of developing Naveen NILs for anaerobic germination tolerance.

Development of genotypes with drought tolerance

Forty five crosses have been made in the first year involving drought tolerant donors with irrigated high yielding varieties. The drought donors included were Vandana, Vanaprabha, Salempikit, CR 143-2-2, Sahbhagidhan, Brahmannaki and Mahulata. During *kharif*, ten F_1s developed using drought donors were again crossed with drought tolerant lines viz., Sahbhagidhan, CR 143-2-2, Satyabhama, Salempikit and BVD (drought tolerant line from Birsa Agriculture. University) with an objective of introgressing multiple tolerant genes in the background of high yielding varieties. Again, 10 new crosses were also made using

Table 16. Grain quality characteristics of some selected rice varieties and advanced lines

Variety	Moisture %	H %	M %	HRR %	Broken %	KL mm	KB mm	L / B	Grain type	ASV	VER	KLAC	ER	WU	AC %
CR 2349-2-3-1	12.30	80.0	69	64.0	5	6.64	1.66	4.00	LS	6.5	3.75	9.3	1.40	220	24.60
CPK-18	12.45	80.0	69	56.5	13	6.08	1.77	3.43	LS	4.0	3.75	9.5	1.56	95	20.25
OR2926-15-3-4-2	12.01	79.5	67	55.0	12	6.15	1.61	3.81	LS	7.0	4.25	9.6	1.56	145	24.26
WITA-8	12.53	80.0	69	49.0	20	6.69	1.59	4.20	LS	5.0	3.75	9.6	1.43	70	19.91
WITA-12	12.11	75.5	68	51.5	17	6.61	1.67	3.95	LS	4.0	3.75	9.8	1.48	85	19.95
Sankar (LS)	12.44	78.0	67	52.5	10.5	6.48	1.60	4.05	LS	4.0	4.0	9.7	1.49	100	23.44

diverse parents. The segregating materials are in different stages viz. F_1, F_2 and F_3. The new crosses have been advanced in irrigated situation with single plant selection. The objective is that the selections should perform better in irrigated situation would be tested finally for drought tolerance.

Evaluation of germplasm for yield and phenotypic acceptability

One hundred sixty elite cultures were evaluated for yield and related traits in F_5-F_7 generation under irrigated condition. Cultures of Birupa / Pusa 44PS-10-1-1-1-1, IET 40143 / AnnapurnaPS-2-1-1-1-1, Vijetha / N22 and IR36 / TapaswiniPS 1-2-3-2-1 were selected for further evaluation.

Breeding for aromatic rice and grain quality improvement

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

In order to develop high yielding aromatic genotypes eighteen new crosses were made involving elite varieties Naveen, Satabdi, Improved Lalat, Swarna, Tapaswini, Pooja and aromatic donors Kudrat, CR Sugandh Dhan 907, Pusa 1509 and Basmati 370. Eight hundred thirty four lines belonging to forty one cross combinations in F_3 to F_7 generations were evaluated in irrigated condition and five hundred forty five single plant selections were made and 215 bulks were harvested based on their agro-morphological characters and aroma.

In an un-replicated observational yield trial ninety-two uniform lines were evaluated and five promising genotypes (CR 2976-4-1, CR 3691-2-1, CR 2961-3, CR 2982-2-1 and CR 2982-4-2) were with more than 5.0 t / ha yield capacity with aroma which will be evaluated in replicated trial. In an advanced yield trial eleven aromatic, semi dwarf, high yielding promising breeding lines belonging to six cross combinations were evaluated in which three genotypes CR 3648-22-4 (5.453 t / ha), CR 3648-14-1 (4.694 t / ha), CR 3648-22-3 (4.025 t / ha) belonging to the cross Gayatri and Chinikamini were found promising in comparison to the aromatic check variety Ketekijoha (2.972 t / ha).

To develop aromatic breeding material with long slender grain segregating population belonging to cross combinations involving Taraori Basmati, Basmati 386 with CR 689-116, NLR 34449, Basmati 370, CRM 2203-4 were evaluated and 36 single plant selections were made. Five promising semi-dwarf lines belonging to the cross CR 3699 (PS 2 / Basmati-386) with uniform stand having more than nine mm kernel length were identified for further evaluation.

Evaluation of aromatic short grain collection

One hundred twenty six aromatic short grain landrace collection was evaluated for different agro-morphological characters following the guide lines of International Rice Research Institute (IRRI 1980) and wide variation was observed for 16 phenotypic traits among the genotypes (*Fig 22*). There was also good variation in morphological characters and the range plant height was from 93.1 cm to 172.3 cm, panicle length from 18 to

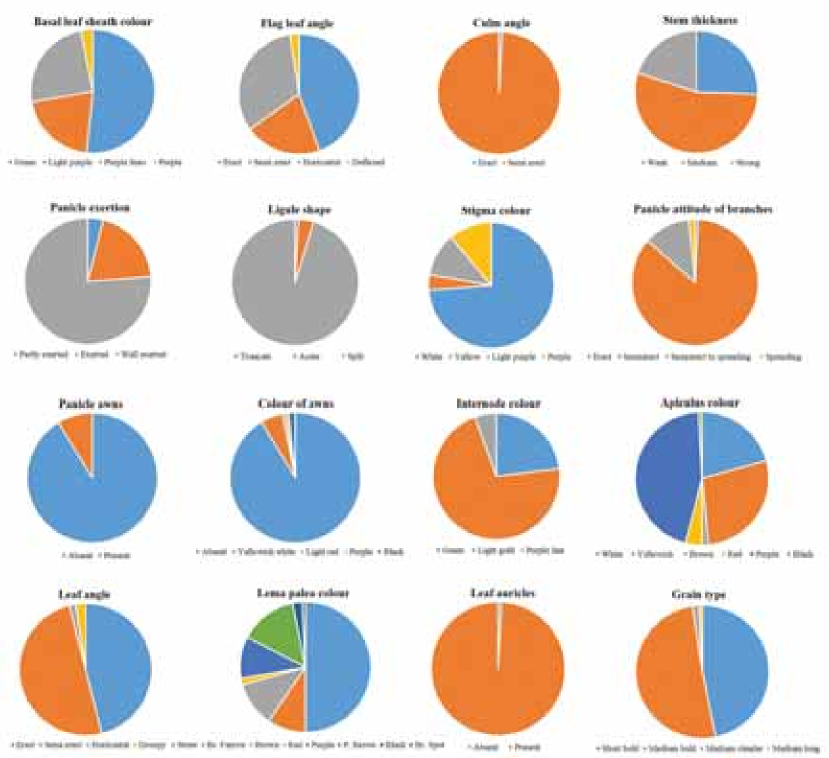


Fig 22. Variation for phenotypic characters among the aromatic short grain rice landraces

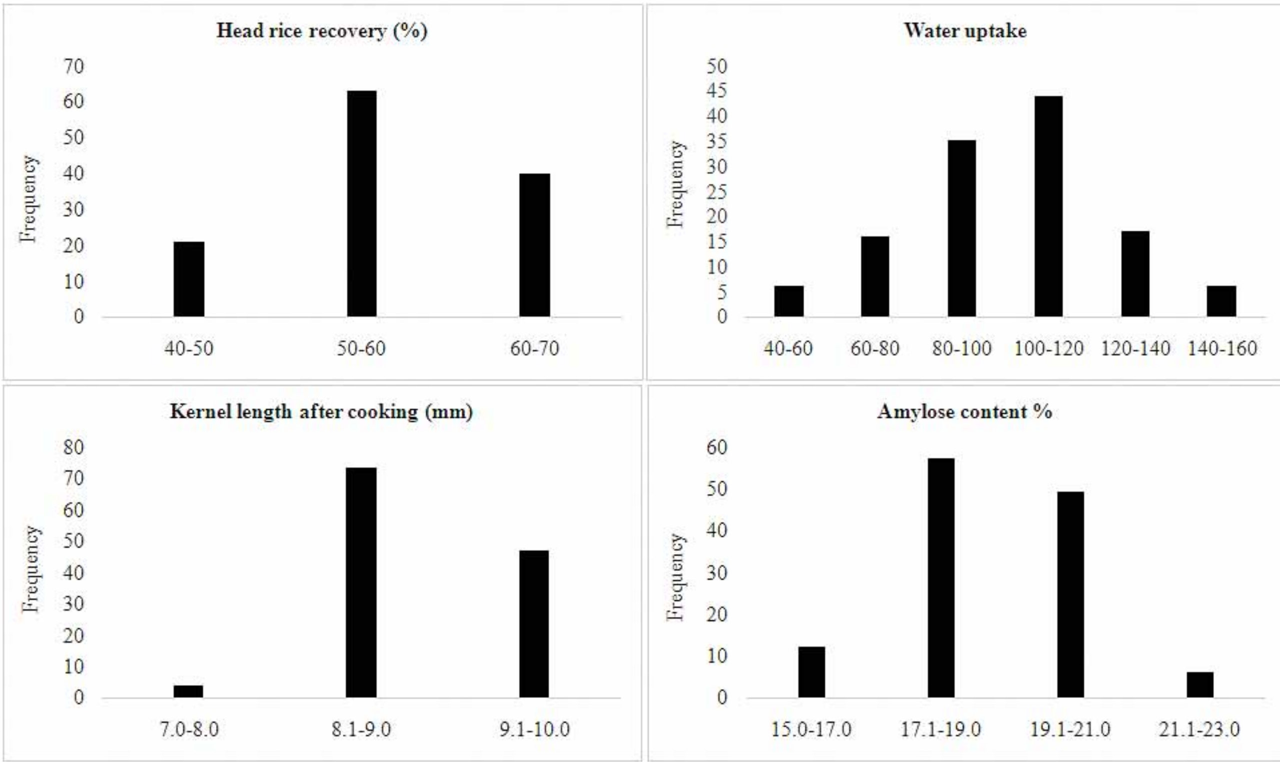


Fig 23. Frequency distribution of Kalanamak genotypes for different grain quality traits

31 cm and grain yield potential from 1.8 to 5.8 t/ha. One hundred twenty four Kalanamak genotypes collected from different regions of Uttar Pradesh were evaluated for their grain quality features. Wide variability was observed among the lines for important quality traits (*Fig 23*). Maximum number of genotypes was observed to be in the range of 50-60 for head rice recovery, 100-120 for water uptake, 8.1-9.0 for kernel length after cooking and 19.1-20.0 for their amylose content.

Evaluation of breeding material with slender grain and desirable grain quality

In order to develop high yielding genotypes with slender grain four hundred thirty two lines belonging to twenty-one cross combinations involving Samba Mahsuri, Padmakesari, HMT, Pooja, Swarna, Lalat, Katrani, Chinikamni, Kalajeera and Basmati 370 in F_3 to F_7 generations were evaluated in irrigated condition and three hundred sixty two single plant selections and 84 bulks were made based on their agro-morphological and grain characters. In an un-replicated observational yield trial ninety-two uniform lines were evaluated and five promising genotypes (CR 2976-4-1, CR 3691-2-1, CR 2961-3, CR 2982-2-1 and CR 2982-4-2) were with more than 5.0 t/ha yield capacity with slender grain.

Identification and mapping of genes/QTLs associated with grain aroma

Six hundred forty two single plant selections of F_6 generation mapping population belonging to two cross combinations Pusa 44/Kalajeera and Gayatri/ Kalajeera were collected to raise the F_7 population for phenotyping.

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

In order to develop genotypes with higher level of micronutrient (iron and zinc) five hundred six hundred eight lines belonging to 30 crosses involving Pusa 44, Gayatri, NDR 359, PR 118, PR 111, BPT 5204, Savitri, Sarala, Swarna and MTU 1071, Azucena, Jalamagna, Basmati-370, Dhusara and Chinikamini were advanced and four hundred sixty two single plant selections and seventy five bulks were made based on agro morphological characters and uniformity. Eleven new cross combinations were attempted involving elite varieties Naveen, Swarna, Upahar and newly identified donors Bhabani, Khira, Samlei, Gandhibiron and Setka-36.

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

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

The IVT- ASG trial was conducted with 31 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 2.6 t ha^{-1} with 96 average days to flowering and 216 panicles / m^2. The flowering duration was reduced due to the late sowing of the trial in the month of July. Highest grain yield of 3.9 t/ha was recorded from NDR 9720 followed by PAB 9527 and CRL 74-89-24-2 with grain yield of 3.71 and 3.72 t/ha, respectively, in comparison to local check 2.58 t/ha.

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

Ten entries including three check varieties (Badshabhog (NC), Kalanamak (RC) and Ketekijoha (LC) were evaluated in a randomized block design with three replication under irrigated conditions. The experimental mean yield was 3.21 t/ha with 109 average days to flowering and 224.8 panicles/ m^2. Among the different entries, the entry No. 2602 (CR 2713-35) performed best with an average grain yield of 4.0 t/ha, followed by entry No. 2604 (CR 2713-179) with 3.8 t/ha and entry No. 2609 (CSAR 10210) with 3.6 t/ha against the best check Badshabhog with 2.8 t/ha.

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

Eleven entries including three check varieties were evaluated in a replicated trial where the experimental mean yield was observed to be 2.61 t/ha with 104 average days to flowering and 268 panicles m^{-2}. Among the different entries, the entry No. 2503 (CR 2713-11) performed best with an average grain yield of 3.09 t/ha against the best check Ketekijoha (3.1 t/ha).

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

Twenty nine entries including checks Kalanamak, Chittimuthyalu and BPT 5204 were evaluated in a replicated trial under irrigated conditions. The experimental mean yield was 2.6 t/ha and among the different entries, the entry No. 4009 (NP 9381) performed best with an average grain yield of 4.4 t/ha against the best check Samba Mahsuri (3.5 t/ha).

Performance of entries nominated in AICRIP trials during 2013

During the year in AVT-1 ASG, IET 22649 (CR 2713-180), with yield of 3.99 t/ha and 111 days to 50% flowering, selection from (Swarna / Geetanjali) gave higher yield of 56.33%, 56.7% and 24.57% over Badshabhog, Kalanamak and local, respectively. Other promising entries include IET 22648 (CR 2713-179), IET 23189 (CR 2713- 35), IET 23203 (CR 2947-1) which showed improved yield over the best check on overall basis and also good in quality parameters. All the entries were semi dwarf and promoted to final year of testing in AVT 2- ASG. In the trial IVT ASG, IET 23864 (CR 939-5-16-2-4-3-1-1) was found promising in Region 3 and was promoted to second year of testing under AVT 1-ASG.

New nominations for AICRIP trials

Four promising high yielding, semi dwarf aromatic cultures CR 3648-22-3, CR 3648-22-4, CR 2939-3 and CR 2713-9-6, having grain yield potential of more than 4.5 t/ha were nominated for AICRIP trial IVT-ASG and one long slender aromatic culture CR 3699-6-2 was nominated to IVT-BT.

Breeding for high protein rice

More than 1000 single plants from high GPC lines (F_7-F_8) belonging to 10 cross combination involving donor for high GPC were selected in *kharif* 2013 and planted in *rabi* 2014. Seven advanced breeding lines were found promising with high GPC (11-12%) and high yielding ability (3.5-5 t/ha).

High grain protein content donor, ARC 10075 was crossed with a high yielding popular variety, Naveen. A mapping population (BC_3F_4) from this cross was developed by three consecutive backcrossing with recurrent parent Naveen, followed by single seed descent. Two hundred lines (PLN-1 – PLN-200) from this population along with parents were planted and evaluated for yield, yield attributing traits and grain protein content for consecutive two seasons (*kharif* 2012 and *rabi* 2013). Normal distribution in the mapping population was observed for all traits such as maturity duration (109-139 days), plant height (61-187 cm), number of panicles / plant (3-18), panicle length (19-33 cm), spikelets / panicle (27.5-189.5), seed yield / plant (7.1-39.7 g), GPC (5.06-14.24%) and single grain protein (0.76 to 3.07 mg). GPC (%) and single grain protein content did not show any significant correlation with grain yield.

Promising lines with high yield and GPC and phenotypically similar to Naveen were evaluated in randomized block design. Apart from grain protein content another 20 parameters including yield and yield attributing traits, grain quality were recorded. All parameters except water uptake (WU) and valume expansion ratio (VER) were significantly differ among the entries (*Table 17*). Most of the entries were detected with at per grain yield with Naveen and at per GPC with the donor ARC10075.

Ten lines were detected from the backcross derived population based on phenotypic similarity with cv. 'Swarna'. GPC in brown rice of some of the lines such as PLS-17, PLS-156 (*Fig 24*), PLS-3, PLS-114 and PLS-133 were higher both in percent basis and single grain basis (11-13% and 1.55-1.82 mg) as compared to Swarna.

Fig 24. Introgression lines for GPC in Swarna background along with high GPC donor (ARC10075)

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

Development of doubled haploids via callusing from anthers of BS 6444 (G)

The anthers containing the uninucleate stages of the pollen of hybrid rice variety, BS 6444 (G), responded 22-24% to callus induction in N6 semi-solid media after 3-4 weeks of culture. Subsequently, the light yellowish calli turned in to green colour which developed in to green shoot buds in the MS media along with growth regulator supplements after 7-12 days of culture showing 55 - 60% shoot regeneration; no calli produced albinos. The green shoots elongated after 4-week of culture (*Fig 25*). A total of 200 micro green shoots formed a high percentage (100%) of roots grown in MS media supplemented with growth regulators (*Fig 26*). Thereafter, all the 200 plants survived showing promising growth in the net house after acclimatization.

Evaluation of ploidy status of DHs derived from BS 6444G

A total of 200 green plants developed through anther culture were evaluated after seed set from which two were found to be polyploids.; no haploids were observed. However, remaining plants (198) were observed to be DHs. Different variants of DHs are being recorded for morpho-agronomic characters like days to 50% flowering, plant height, effective tiller number, panicle length, spikelet fertility, grain yield / plant and test weight. A total of 36 SSR markers were used for distinction of diploids (donor like) and DH lines of which 8 markers were identified to be useful for this. These 8 markers could be able to identify diploid line (like the donor, BS644G) from all the DHs derived through anther culture (*Fig 27*); no markers were found suitable to identify polyploids from the DHs.

Evaluation of DHs derived from elite hybrid rice varieties

From the morphological evaluation of the doubled haploids generated earlier from eight elite hybrid rice varieties, 158 DHs were selected for further agro-

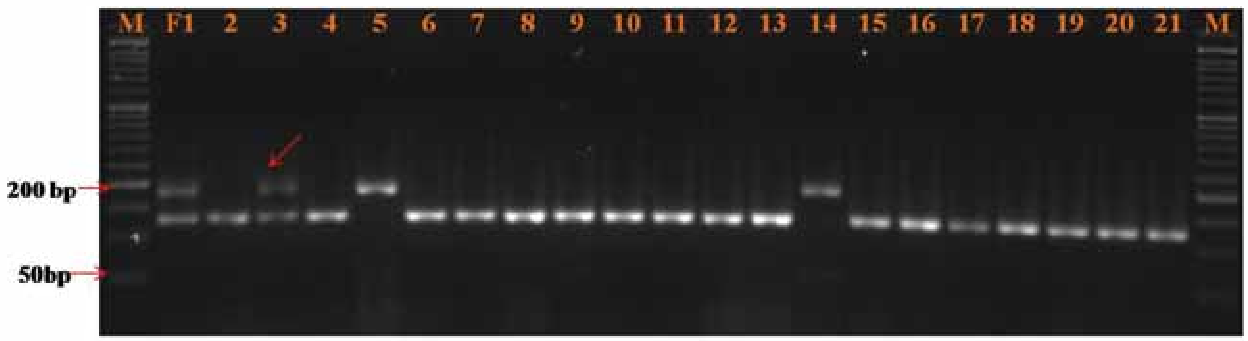


Fig 25. Identification of diploids (like donor) from doubled haploids using STMS marker. M:50bp DNA ladder,1:BS6444G(F1), 2-21: Anther derived green plants, Arrow: diploid(Like donor)

Table 17. Yield, quality and grain protein content of introgression lines for high GPC in Naveen background

	Dur	PH	PL	SPP	PY	Hull	Mill	HRR	KL	KB	LB	ASV	WU	VER	KLC	ER	AC	GPC	SGPC
PLN-23	125.00	121.93	26.02	119.97	17.41	75.04	62.89	56.83	5.45	1.56	3.49	3.00	70.00	3.58	10.13	1.86	23.06	11.44	2.16
PLN-31	127.33	122.21	23.71	107.13	18.67	76.84	66.17	62.94	6.13	1.65	3.73	4.67	94.44	3.67	10.53	1.72	24.40	11.01	2.15
PLN-32	126.00	127.13	25.18	110.43	20.37	78.68	68.56	66.78	6.01	1.57	3.83	4.72	76.11	3.67	10.97	1.84	23.87	11.14	2.00
PLN-36	122.33	109.37	25.10	115.60	20.74	78.10	66.72	62.22	5.80	1.50	3.88	4.00	65.00	3.50	10.23	1.77	21.36	12.36	2.07
PLN-37	126.00	121.13	26.51	101.67	20.97	77.17	65.94	61.06	5.83	1.58	3.68	3.67	93.33	3.67	10.53	1.81	22.89	11.52	2.07
PLN-58	124.33	121.00	23.16	100.97	15.87	77.54	67.11	64.78	5.77	1.57	3.67	4.33	78.89	3.67	10.72	1.86	22.93	11.95	2.27
PLN-63	120.33	126.87	27.84	101.20	22.31	75.53	63.22	52.06	6.38	1.63	3.91	4.67	101.67	3.75	10.94	1.72	23.25	11.50	2.43
PLN-97	121.00	119.67	24.93	125.33	21.59	78.22	68.50	63.28	6.00	1.49	4.02	3.33	68.89	3.50	10.26	1.71	22.65	11.77	1.96
PLN-98	120.67	116.13	23.82	121.20	14.10	76.52	66.22	61.78	5.55	1.51	3.67	3.33	60.56	3.75	10.62	1.91	23.48	12.29	2.08
PLN-99	120.33	119.13	24.11	112.70	16.07	74.50	64.78	60.28	5.43	1.50	3.62	3.67	87.22	3.58	10.01	1.84	21.55	12.06	2.14
PLN-100	123.00	116.13	24.04	111.27	17.98	79.00	68.72	65.44	6.17	1.55	3.98	4.00	84.44	3.67	11.06	1.79	23.61	11.14	2.10
PLN-108	119.33	121.67	24.25	109.70	16.08	77.17	67.22	62.61	5.49	1.56	3.54	3.67	93.56	3.75	10.42	1.90	22.53	11.43	2.08
PLN-114	119.00	119.67	25.51	111.90	17.21	78.88	67.44	62.39	5.47	1.48	3.70	3.00	92.22	3.58	10.07	1.84	22.05	12.55	2.11
PLN-116	119.00	112.37	23.66	108.16	16.80	78.44	67.78	64.11	5.33	1.48	3.61	3.67	71.67	3.75	10.29	1.93	22.73	12.27	2.14
ARC10075	128.33	140.67	24.89	94.72	12.43	74.51	65.22	61.56	5.43	1.63	3.36	7.00	116.67	3.50	10.00	1.84	24.35	12.52	2.58
Naveen	121.33	123.00	25.82	124.06	21.21	78.38	68.39	66.67	5.05	1.46	3.45	4.00	76.67	3.67	10.00	1.98	22.51	9.57	1.60
Mean	122.71	121.13	24.91	111.00	18.10	77.16	66.56	62.17	5.71	1.55	3.70	4.05	83.21	3.64	10.42	1.83	22.95	11.66	2.12
C.V.	1.25	3.45	4.13	9.23	17.31	1.93	2.74	4.41	4.35	2.92	4.93	16.26	24.25	3.52	2.29	4.88	0.90	5.37	6.09
S.E.	0.89	2.41	0.59	5.92	1.78	0.86	1.05	1.58	0.14	0.03	0.11	0.38	11.65	0.07	0.14	0.05	0.12	0.36	0.07
C.D. 5%	2.56	6.96	1.72	17.09	4.13	2.48	3.04	4.58	0.41	0.08	0.30	1.10	-	-	0.40	0.15	0.35	1.04	0.22

Note: Dur: Duration, PH: Plant height (cm), PL: Panicle length (cm), SPP: Spikelet / panicle, PY: Plant yield (g), Hull: Hulling (%), Mill: Milling (%), HRR: Head rice recovery (%), KL: kernel length (mm), KB: kernel breadth (mm), LB: length- breadth ratio, ASV: Alkali spreading value, WU: water uptake (ml / g), VER: volume expansion ratio, KLAC: kernel length after cooking, ER: elongation ratio, AC: amylase content (%), GPC: grain protein content (%), SGPC: single grain protein content (mg)

Fig 26. Green shoots and roots after four weeks of culture

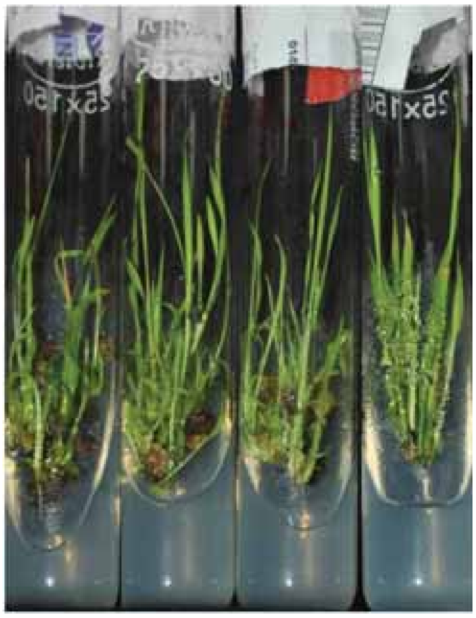


Fig 27. Green shoot regenerated from anther derived calli of BS6444G after 2-3 weeks of culture

morphological evaluation at A_1 generation in the field. These include forty nine from CRHR 32, ten from PA 6201, two from DRRH 1, five from Pusa RH 10, five from PHB 71, six from KRH 2, twenty five from CRHR 7 and fifty six from CRHR 5.

Development of doubled haploid mapping population for salt tolerance

Anthers from a cross combination of Savitri x Pokkali were inoculated on N6 media for callus induction. The calli induced from the anthers were transferred in to MS regeneration media from which green shoots regenerated after 3-weeks of culture showing 100% regeneration. The green shoots rooted in the MS media followed by acclimatization. Subsequently, 80 plants were transferred to the net houses which are under evaluation for ploidy status.

Development and use of genomic resources for genetic improvement of rice

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

The RIL mapping populations from the crosses CR 662-2211-2-1 / WAB 50-56 and PDKV Shriram / Heera were grown in the field following Alpha Lattice design, each with two replication. Different agro-morphological, yield related traits were recorded for identification of QTLs associated with yield and its component traits. Further, RIL(F_6) mapping populations from the cross AC 38562 / Pimpudibasa for 1000-grain weight, TN1 / Dhobanmbari for BPH resistance were grown in the field during *kharif* for further generation advancement and phenotyping.

Evaluation of rice germplasm for association analysis to identify QTLs/genes associated with major biotic and abiotic stress tolerance

Identification of useful alleles of rice genes would give breeders direct access to key alleles conferring, among others, tolerance to major biotic and abiotic stresses. Genetic diversity in 185 land races obtained from NBPGR was evaluated for blast resistance using gene based markers at six major genes. The land races were selected based on their reaction to blast in the UBN and comprised 65 resistant, 71 moderately resistant and 49 susceptible accessions. The genomes of these land races were amplified with SNP markers, z 56592, zt 56591, YL155 / 87, YL183 / 87 (*pita)*, 195R-1 and Pb 28, respectively for six major genes, *Pi z, Piz-t, Pita/Pita-2, pita, Pi 9 and Pi b*. The germplasm carried one to five alleles at the six genes. Alleles of *Pi b* were present in all the germplam, while *Pi ta/Pi ta-2* was detected in 60% of the germplasm. *Pi zt* and *Pi 9* were less frequently detected with 7% and 18%, respectively in the 185 accessions (*Fig 28a, b*). Presence of alleles of *Pi 9, Pi zt* and *Pi ta-2* did not appear to contribute to resistance in

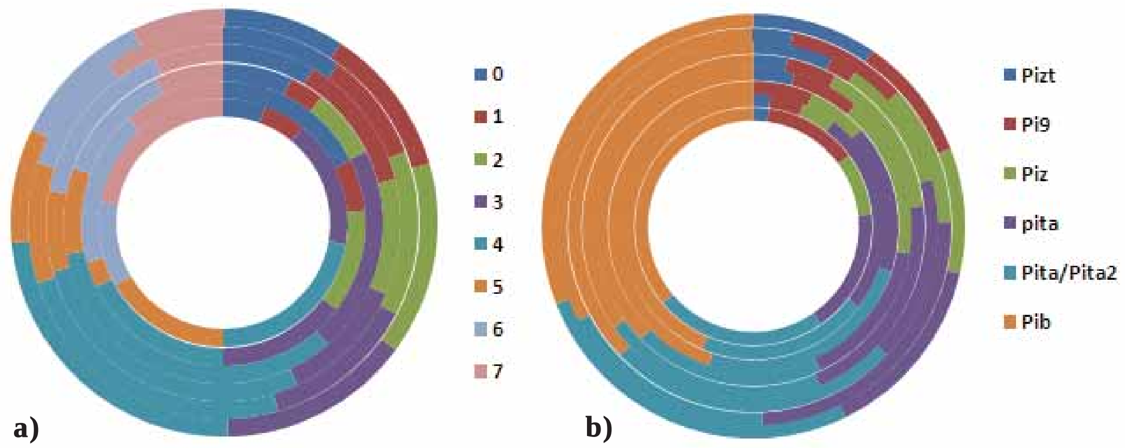


Fig 28. Frequency distribution of different blast resistance genes with PCR based SNPs and STS markers for 65 resistant (scores: 0-2), 71 moderately resistant (scores: 3-4) and 49 blast susceptible (scores: 5-7) rice germplasm

several accessions as the germplasm carrying these genes had a range of reaction in the blast nursery. High density SNP genotyping of a core set of the germplam will reveal the allelic variation in the functional genes.

Three hundred diverse genotypes grown under field condition of CRRI, Cuttack were exposed to vegetative stage drought stress. 80 genotypes had SES '1" followed by 126 of SES "3", 55 of SES "5", 4 of SES "7" and 29 were drought escaping type as flowered at the onset of drought. Genotypes with SES "1" had higher RWC of 65.0 to 80.0%. These genotypes will be used for genotyping and association analysis for identification of QTLs / genes associated with drought tolerance.

Fifty upland rice genotypes were screened for drought tolerance under rain-out shelter facility during 2013 *kharif* season at Hazaribagh. Stress was imposed at booting to pre-flowering stage by withholding irrigation for 15 days. Observations were recorded on days to flower, plant height, biomass, grain yield, panicle length, number of filled grains and unfilled grains per panicle. Genotypes were also scored for drought tolerance at the peak moisture stress following SES. Among the genotypes, days to flower ranged from 62 to 97 days, plant height from 51-98 cm, biomass from 69-481 g / plot, grain yield 0.9-795 kg / ha, number of filled grain from 10-56 per panicle and sterility from 36-86 %. Distribution of the genotypes for grain yield under stress followed a normal distribution (*Fig 29*). Based on leaf rolling and drying score (SES), the genotypes were grouped for drought tolerance. Drought tolerance score ranged from 3 to 9. Only 8 genotypes found to have good drought tolerance with a score of '3' (*Fig 30*). Majority of the genotypes (30) were moderately drought tolerant with score '5'. Nine

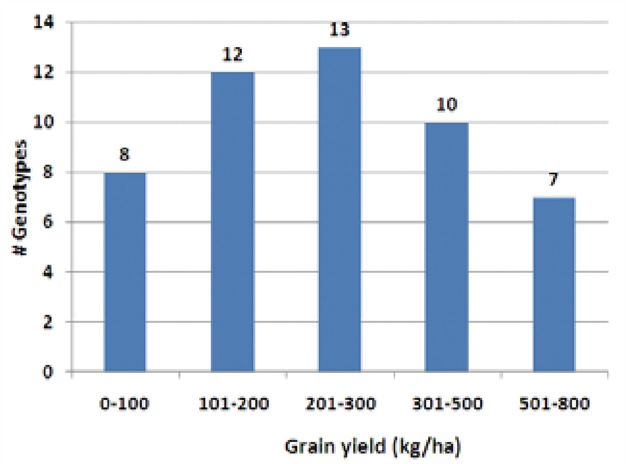


Fig 29. Distribution of 50 genotypes for grain yield (kg/ha)

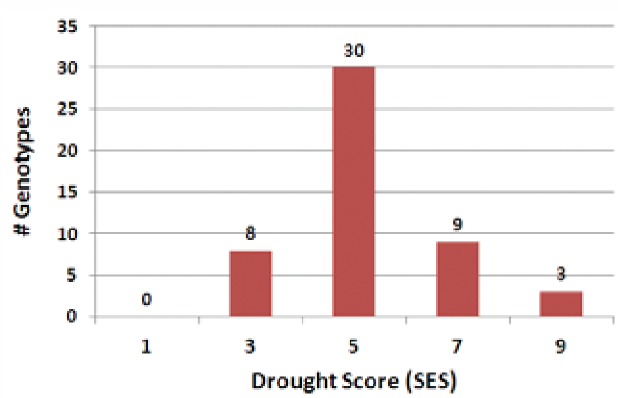


Fig 30. Distribution of 50 genotypes for drought tolerance score

genotypes were moderately susceptible (score 7) and 3 genotypes were highly susceptible (score 9). Based on these parameters, the drought tolerant genotypes identified are Kalakeri, RR517-34-1-1, B6144F_MR-6, VLDT1, Annada, Sukhawan, CRR455-109 etc. (*Table 18*).

Evaluation rice genotypes for association analysis to identify QTLs associated with drought allele mining for grain shape traits and drought tolerance

Two hundred genotypes having different grain shape traits were collected from CRRI genebank and were grown in the field following Alpha Lattice design during *kharif* 2013. Seeds from five plants of each genotype were harvested and grain shape traits were evaluated (100 grain weight, grain length and breadth, length / breadth ratio). Sequences of grain shape genes *GW2*, *GS3* and *GW5* were down loaded and primers were designed. Ninety six genotypes were amplified with these primers. Polymorphisms were observed for each marker. The amplicon will be sequenced to find haplotypes and allelic variations.

A SNP in the WRKY family transcriptional factor (WRKY35 gene with LOC_Os04g39570) was reported to be strong genetic association with the drought tolerance in rice. The gene sequence was downloaded and primers were designed to get an amplicon of 500-600 bp with the specific SNP at the middle. Ninty six drought tolerant genotypes were amplified which will be sequenced to find haplotypes and allelic variations.

Development of resilient rice varieties for rainfed direct seeded upland ecosystem

Development of new varieties combining desirable traits both from adapted and unadapted sources

Twenty two new crosses (including double cross & back cross) were made for the development of resilient varieties for rainfed direct seeded uplands. The details of the parents utilized and the crosses made are given in *Table 19*. Out of these 22 crosses, F_1s of nine crosses were generation advanced during 2014 dry season.

Out of 1200 single plant progenies selected in the previous year, 378 advanced generation lines (F_5 to F_7)

Table 18. Mean performance of the tolerant genotypes for grain yield and other characters

Designation	Days to flowing	Plant height (cm)	Biomass (g / plot)	Grain yield (kg / ha)	Panicle lenth (cm)	Grains / panicle no.	Sterility (%)	Drt. score
RR 517-34-1-1	68	84.1	481	794	18.3	56	42.3	4.1
Kalakeri	65	80.1	456	691	18.6	51	36.4	4.3
B6144F-MR-6	85	80.3	383	630	21.6	40	55.5	2.8
VLDT1	84	81.0	381	613	19.3	28	65.8	4.6
Annada	84	64.9	287	588	16.6	29	53.1	3.0
RR 345-2	70	90.0	419	521	20.5	30	58.9	3.7
UPL Ri 7	79	90.5	402	520	21.9	26	71.9	4.3
Sukhawan	87	96.2	356	474	22.0	50	45.9	5.4
IR84898-B	81	93.6	371	425	20.7	32	57.2	3.3
CR 143-2-2	75	65.0	317	407	16.3	42	43.1	3.1
BAU 408-05	71	93.5	238	405	18.4	31	46.9	4.9
Sukhawan	82	83.5	389	388	18.4	31	57.8	3.9
CRR 455-109	64	78.1	236	375	19.0	41	48.6	3.3
Ranikajal	62	83.9	284	369	19.6	50	47.8	4.1
Vandana	69	82.2	240	348	15.2	46	38.7	4.3
Sahbhagi dhan	84	78.8	265	344	18.7	32	52.5	4.9
Mean	78	78.4	267	271	17.7	32	55.0	4.9
SED (P=0.05)	*1.9*	*7.4*	*88*	*89*	*1.5*	*8.4*	*8.9*	*0.9*

Table 19 : List of crosses made during 2013 WS, Hazaribag for direct seeded upland ecosystem

Sl. No.	Crosses
1	Sadabahar x IR84984-83-481-B-B / / IR86918-B-305X IRBLTAZ Pi / RL
2	Poornima x IRBL9-W(RL) / / Bhalum-1x Naveen
3	Bhalum-3 x IR64 / / Mauls21 x Anjali
4	MTU1010X WITA 12 / / Bhalum-3x IR64
5	Bhalum-3 x Naveen / / Bhalum-3
6	Bhalum-3 x Naveen / / Naveen
7	MAULS11 X Anjali / / Wita 8
8	MAULS21 X Anjali / / Anjali
9	Sahbhagidhan x IR87707-446-B-B / / Sahbhagidhan
10	Naveen x IR87707-446-B-B / / Naveen
11	Sadabahar x IR84984-83-481-B-B / / Sadabahar
12	CR 143-2-2 X Sahbhagidhan
13	CR Dhan 40 x IRBL9-W / RL
14	Anjali x IR84984-83-481-B-B
15	BPT 5204 x WITA-12
16	MAULS11 X IRBL9-W / RL
17	Sadabahar x IR84984-83-15-481-B-B
18	Sadabahar x MAULS 21
19	Abhishek / MTU-1010
20	Sahbhagidhan / IR64-Glab.IL 323
21	CR Dhan 40 / IR64-Glab.IL 345
22	Benibhog / CH 45

from 94 crosses were evaluated during 2013 *kharif* season and based on duration, plant type, panicle characters and reaction to abiotic and biotic stresses, 197 single plants and 25 bulk selections were made. Remaining 822 segregating lines were grown at Cuttack during 2014 *rabi* season for generation advancement.

One hundred and five F_6 breeding lines and their parents were evaluated in favourable upland condition during *kharif* 2013. The promising lines were harvested in bulk. These F_7 lines were grown at Cuttack for generation advancement during the dry season 2014. Among these breeding lines, CRR 693-28-B-1-B, CRR 696-42-B-1-B, CRR 616-1005-B-1-B, CRR 616-1022-B-1-B, CRR 697-74-B-1-B, CRR 697-76-B-1-B, CRR 708-1-B-2-B and CRR 708-7-B-1-B were found to be promising. Agronomical data and reaction to blast and brown spot diseases of these lines are given in *Table 20.*

Preliminary yield trial

Forty two entries along with three checks were evaluated in an alpha-lattice design with three replications under direct seeded rainfed upland condition following recommended packages of practices. The trial was moderately affected by drought during booting to pre-flowering stages during the first fortnight of September. There were significant differences among genotypes for grain yield and other traits. Among the test entries CRR 598-12-1 (3325 kg / ha) produced the highest yield followed by CRR717-2 (3283 kg / ha) and CRR 688-25-B-1-4 (3250 kg / ha) as

Table 20. Performance of the promising breeding lines for agronomical traits and disease reaction

Breeding line	Days to 50% flowering	Panicle no / m²	Grain yield (kg / ha)	Leaf blast score	Brown spot score
CRR 693-28-B-1-B	78	104	1917	0	2
CRR 696-42-B-1-B	73	92	1667	0	4
CRR 616-1005-B-1-B	74	66	1667	0	5
CRR 616-1022-B-1-B	77	84	1958	2	5
CRR 697-74-B-1-B	80	80	1792	0	4
CRR 697-76-B-1-B	78	100	2292	0	5
CRR 708-1-B-2-B	76	58	1875	4	5
CRR 708-7-B-1-B	73	90	1958	0	2
Annada	80	74	1083	5	6
Anjali	67	84	1042	4	6
Vandana	66	100	1250	4	7

compared to highest yielding check Anjali (1867 kg / ha). The entries significantly superior to all the checks (*Table 21*). These promising entries will be multiplied for seed increase for testing under national coordinated trials.

Entries promoted and new nominations in AICRIP trials

IET 23377 (CRR523-2-2-1-1) showed yield advantage of 37.6, 26.9 and 9.7 per cent over national, regional and local checks, respectively on overall basis. This culture was ranked first in AVT-VE trial and promoted for final year of testing. Similarly IET 22747 (CRR 617-B-3-3) and IET 23345 (CRR 680-B-25-4) were promoted for third year of testing in AVT2-E trial. Considering the yield advantage under drought / favourable situation, the other promising entries promoted for advance testing are IET 24049, IET 24051, IET 24053 in AVT-1E (DS), IET 23339, IET 23983 in AVT-1E (TP) and IET 24037 in AVT1-Aerobic. Five promising entries developed at CRURRS have been nominated for initial varietal testing under AICRIP trials during 2014 *kharif* season.

Variety recommended by VIC for release

CRR 451-1-B-2-1 (IET 22020), derived from the cross Vandana / IR64, is an early culture of 68 days flowering duration with intermediate height (100 cm) and excellent grain quality characteristics (*Fig 31*). Averaged over three years, it showed 31.8%, 14.9% and 14.6% yield superiority under drought stress over the national, regional and local checks, respectively in the region 3. This entry is resistant to leaf blast, moderately resistant to brown spot and highly tolerant to drought. It has better grain quality features viz. high HRR (61.4%), long slender grains (kernel length 6.68 cm and L / B ratio 3.35), intermediate ASV (4.5), acceptable AC (26.04%) and soft GC (72). This elite line has been recommended for release for direct seeded rainfed uplands in the states of Jharkhand and Madhya Pradesh by Varietal Identification Committee during 49th Annual Rice Group Meeting at DRR, Hyderabad and CVRC proposal is being submitted to CSC on CSN&RV for its release and notification.

IET 22744 (CRR617-B-47-3), derived from the cross Vandana / UPLRi7 has given a mean yield of 2056 and 2685 kg / ha under drought stress and normal rainfall locations, respectively during 2013 *kharif* season. This entry flowers in 69 days, has intermediate plant height (111 cm) and very good grain quality. This culture is tolerant to drought stress and moderately resistant to leaf blast and brown spot diseases. It has long slender grains, high HRR (66.3%), intermediate ASV (5.0), desirable AC (25.68%) and soft GC (41). Based on its three years of testing, this culture has been found promising for rainfed upland areas of Madhya Pradesh and Chhattisgarh.

Table 21. Performance of the selected entries under PYT, Hazaribagh, WS, 2013

Designation	Days to flowering	Plant height (cm)	Straw yield (kg / ha)	HI	Grain yield (kg / ha)
CRR 598-12-1	76	104.6	6583	0.37	3325
CRR717-2	74	93.0	7333	0.36	3283
CRR 688-25-B-1-4	71	96.9	7333	0.35	3250
CRR 497-RE31-B-1	74	88.5	6278	0.37	3083
CRR 680-B-143-1	72	84.4	6444	0.36	2917
CRR718-1	77	87.3	6278	0.31	2833
CRR 716-4	70	77.7	8278	0.29	2783
CRR 483-24-1-1-1-1	70	93.2	6278	0.32	2667
CRR 687-B-10-B-37	69	95.6	6278	0.31	2625
CRR 562-19-2-1	65	86.0	5222	0.34	2542
Anjali	67	70.4	4167	0.33	1867
Vandana	64	80.6	5083	0.24	1667
Brown Gora	64	76.7	5250	0.20	1458
Mean	71	91.7	5648	0.28	2148
LSD (P=0.05)	2.1	9.0	1407	0.05	632

Fig 31. CRR 451-1-B-2-1 (IET 22020)

Improvement of popular upland varieties for major abiotic (drought) and biotic (blast) stresses through MAB/MAS approach

Marker-assisted backcross breeding approach is being employed to further improve drought tolerance of popular upland variety CR Dhan 40 in terms of grain yield under stress. For the introgression of grain yield under stress QTLs *DTY1.1* and *DTY12*.1, crosses were made between CR Dhan 40 and donors (1. CR Dhan 40 x IR86918-B-305 and 2. CR Dhan 40 x IR84984-83-15-481-B for *DTY1.1* and *DTY12.1*, respectively) during 2012 *kharif* season. The F_1s of the two crosses were raised during 2013 dry season and hybridity confirmed with the linked markers, RM 431 and RM 27981 for *DTY1.1* and *DTY12.1*, respectively. The confirmed F_1s of the two crosses were raised and backcrosses made with recurrent parent during 2013 kharif season. The BC_1F_1s obtained from the two crosses (17 and 25) were grown during 2014 dry season and foreground selection made (*Fig 32*). Seven BC_1F_1s out of 17 plants in the first cross and 11 BC_1F_1s out of 25 in the second cross found confirmed for the linked markers.

Similarly, hybridization was initiated during 2012 *kharif* season to introgress blast resistance genes (*Pi-9*, *Pi ta-2* and *Pi-z5*) in two varieties, namely, Sahbhagidhan and Naveen. The F_1s were raised during 2013 *rabi* season checked for hybridity with linked SSR markers AP 5930, RM 7102 and AP 5659 for *Pi 9, Pi ta-2* and *Piz-5*, respectively. The confirmed F_1 plants were backcrossed with respective recurrent parents during 2013 *kharif* season and BC_1F_1s seeds obtained. The BC_1F_1s were grown during 2014 *rabi* season and foreground selection was conducted with linked markers (*Fig 33*). Cross-wise, the number of BC_1F_1 plants assayed and number plants found confirmed for the target markers in foreground selection are given in *Table 22*.

Molecular detection of blast resistance genes and diversity study of popular rice varieties with HvSSR markers

Twenty seven genotypes including prominent upland rice varieties (Heera, Sneha, Kalinga III, Vandana, Anjali, Virendra, Sadabahar, Annada, CR dhan 40, Poornima, Sahbhagidhan), blast resistant breeding lines (RR166-645, RR222-1, RR345-2, CRR455-109, CRR427-21-2, CRR523-2-2-1-1, CRR616-B-66-2-2, CRR624-207, commonly grown varieties (IR64, Naveen, Abhishek, Hazaridhan) and donors (Moroberekan, Rasi, CR143-2-2, Salumpikit) were screened for the presence of major blast resistance genes using single nucleotide polymorphisms (SNPs) and sequence tagged sites (STS) markers. *Pi b* followed by *Pi zt, Pi k, Pi kp* and *Pi kh* were commonly detected among this set (*Fig 34*). Effective major genes like *Pi ta*/*Pi ta-2* were less commonly detected (six varieties including IR 64). Pi 2 was detected in two varieties (Heera and RR427-27-1). The *Pi 9* was not detected in any of the 27 varieties evaluated. RR222-1, Sahbhagidhan and Poornima

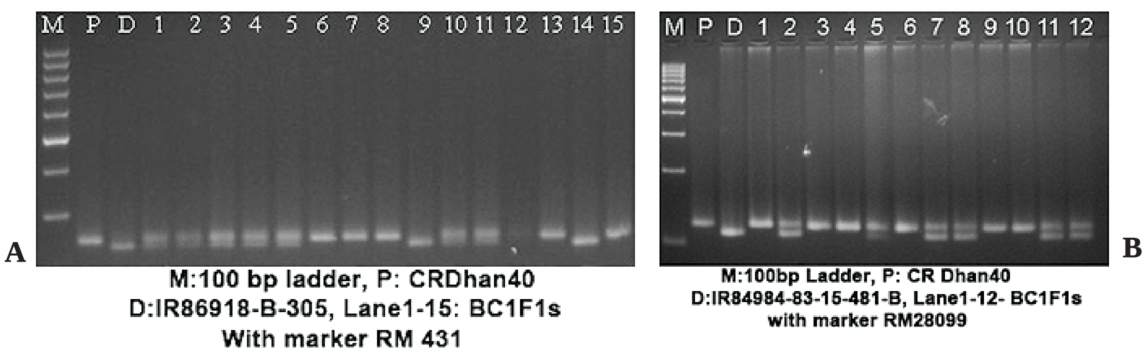


*Fig 32. Foreground selection of BC_1F_1s (CR Dhan 40*2/ IR86918-B-305) (A) and (CR Dhan 40*2 / IR84984-83-15-481-B) (B) with linked markers RM431 and RM27981*

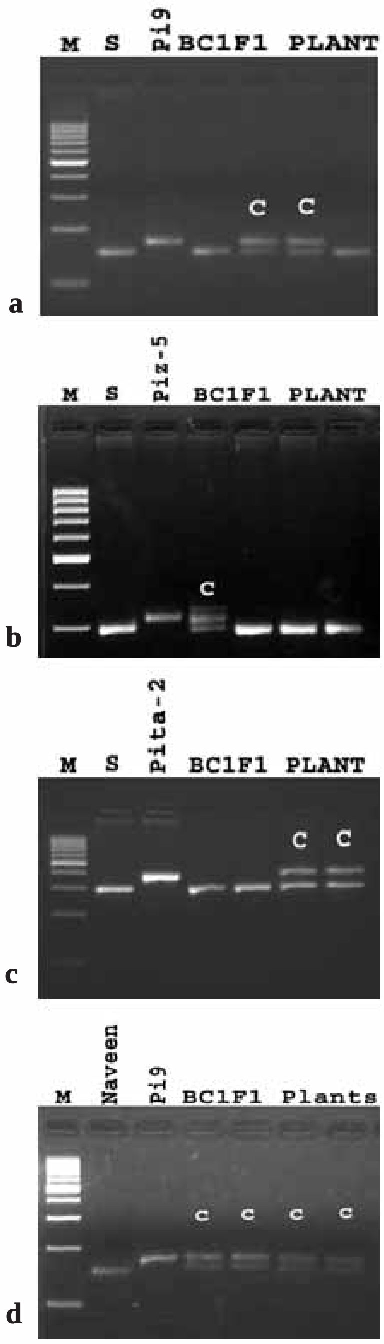


Fig 33. Foreground selection in BC_1F_1s between Sahbhagidhan and Pi9, Pi ta-2 and Piz-5 donor (a-c) and Naveen and Pi9 donor (d) showing the confirmed plants for the linked markers

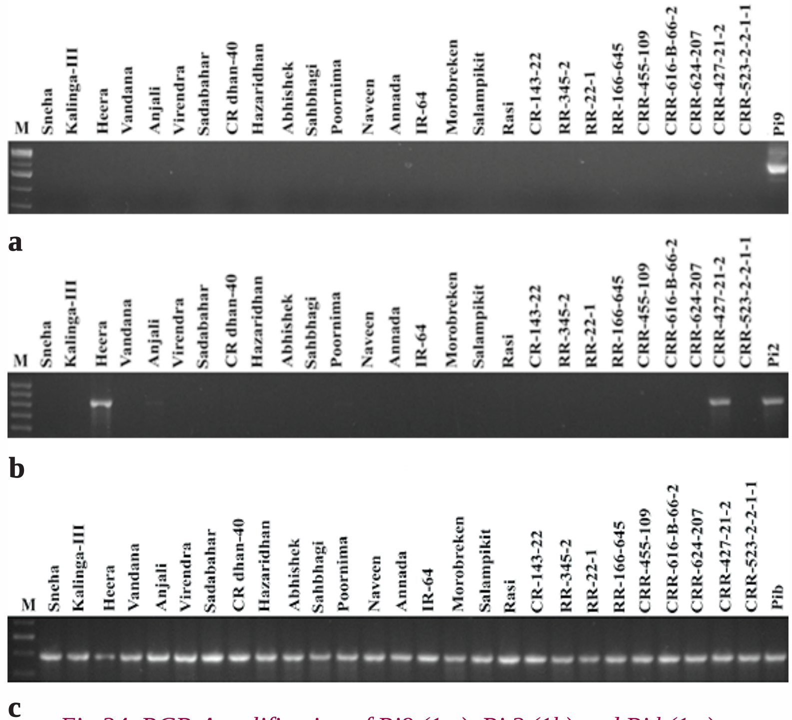


Fig 34. PCR Amplification of Pi9 (1 a), Pi 2 (1b) and Pi b(1 c) genes with SNP based molecular markers

carried all the three members of the *Pi k* gene family. Presence of *Pi k*, *Pikp* and *Pikh* however, did not contribute to resistance in Poornima as it was highly susceptible to blast at Hazaribagh. At the same time, RR222-1 and Sahbhagidhan were resistant indicating that there may be additional genes contributing to resistance in them. Prior knowledge of the genetic constitution of parental lines with respect to their resistance to blast would be useful for gene pyramiding.

The same set of 27 rice genotypes was also used for diversity analysis using 47 highly variable SSR (HvSSR) markers equally distributed across 12 chromosomes. HvSSR loci with repeat lengths in the range of 51–70 bp have been shown to discriminate between rice varieties most efûciently using agarose gel electrophoresis. The marker data were analysed using Statistical software and dendrogram was constructed

Table 22. List of crosses/lines (BC_1F_1s) used for foreground selection

Crosses	Generation	Target marker	# plants assayed	# plants confirmed
Sahbhagidhan*2/*Pi 9*	BC_1F_1	AP 5930	9	4
Sahbhagidhan*2/*Pi ta-2*-RL	BC_1F_1	RM 7102	8	4
Sahbhagidhan*2/*Piz-5*	BC_1F_1	AP 5659	12	5
Naveen*2/*Pi 9*	BC_1F_1	AP 5930	17	9

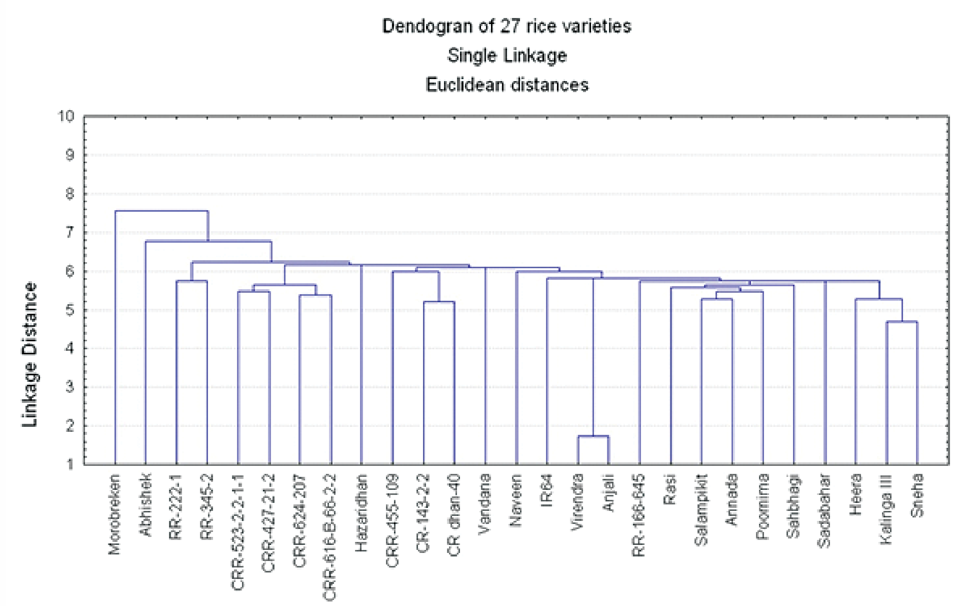


Fig 35. Clustering of 27 rice varieties based on 47 HvSSR markers

(*Fig 35*). Cluster analysis grouped the genotypes into nine clusters at a linkage distance of 6 (0.4 similarity index). Cluster I is the largest group consisting of 13 genotypes mostly released / popular upland varieties like Sneha, Kalinga III, Annada, Rasi, Poornima, Sadabahar, Anjali, Virendra, Sahbhagi dhan etc. The two sister lines, Anjali and Virendra formed a separate sub group within this cluster, differentiated by only two markers i.e. HvSSR-2-44 (chr. 2) and HvSSR-11-75 (chr. 11). Cluster II and Cluster III are mono-genotypic group having Naveen and Vandana, respectively. Cluster IV includes three genotypes of which CR Dhan 40 and CR143-2-2 further sub-grouped together because of their genetic closeness (CR143-2-2 is included in the pedigree of CR Dhan 40). Again Cluster V represented by single genotype *i,e.,* Hazaridhan. Cluster VI and VII had advanced breeding lines, some of these lines having common parent in their lineage, whereas Cluster VIII and IX were distinct with one genotype each, Abhishek and Moroberekan, respectively. Moroberekan which is a tropical *japonica* type clustered separately from all other *indica* genotypes even at a distance of 0.34 similarity index.

AICRIP trials

Advanced Variety Trial, Very Early-Direct Seeded (AVT-VE-DS)

This trial was constituted with six test entries and three checks of very early duration and evaluated in RBD under rainfed uplands. There was deficient rainfall in the month of July and a long dry spell of 15 days (3-17 September) in the month of September corresponding to booting to pre-flowering stage of the crop. Best entry CRR 523-2-2-1-1(2726 kg / ha) out-yielded the national check Anjali by 42%. Other promising entries, CRR 616-B-2-54-1 (2483 kg / ha) and CRR 617-B-47-3 (2431 kg / ha) also yielded significantly better than best check Anjali (1927 kg / ha), giving 29% and 26% yield advantage, respectively.

Initial Variety Trial, Very Early- Direct Seeded (IVT-VE-DS)

Eleven entries along with three checks of very early duration were evaluated in RBD under rainfed uplands. This trial was also affected by drought in the month of September corresponding to pre-flowering stage. The top yielding entries in the trial were CRR 677-1 (2551 kg / ha), CRR 627-35-1-5 (2526 kg / ha) and CRR 676-1 (2398 kg / ha) performing significantly better than highest yielding check Anjali (1964 kg / ha).

Advanced Variety Trial, Early-Direct Seeded (AVT 1-E-DS)

AVT1-E-DS was conducted in rainfed favourable upland under direct seeded condition with thirteen entries including checks. The trial was conducted following RBD with three replication. The top yielding entries in the trial were RP5125-9-6-2-1 (3388 kg / ha), BAU 389-02 (3282 kg / ha) and CR 3617-1-1-2-1-1 (3017 kg / ha) performing significantly better than highest yielding check Sahbhagidhan (2642 kg / ha).

Initial Variety Trial, Early- Direct Seeded (IVT-E-DS)

Twenty four entries including checks were evaluated in two replication. The highest yield was produced by CRR733-1 (2883 kg / ha) but statistically at par with the best check Sahbhagidhan (2598 kg / ha). Other entries were inferior to the highest yielding check variety.

Advanced Variety Trial, 2 Irrigated Mid Early (AVT-2-IME)

Thirteen entries including four checks were evaluated in RBD with three replication during *kharif* 2013. The entry JGL 18065 (5250 kg / ha) was top yielder followed by OR 2404-RKP-4 (4950 kg / ha) and UPRI 2009-9 (4900 kg / ha). Best entry JGL 18065 significantly out yielded all checks and produced 31.3%, 28.0%, 18.0% and 23.5% higher yield than IR 64 (NC), Lalat (RC), US 312 (HC) and Abhishek (LC), respectively.

Advanced Variety Trial, 1 Irrigated Mid Early (AVT-1-IME)

Seventeen entries including four checks were tested in RBD with three replication. Entry OR 1929-4 was the top yielder (4883 kg / ha) followed by Bio-452 (4700 kg / ha) whereas checks yielded 4017 kg / ha (IR-64), 4063 kg ha^{-1} (Lalat), 4400 kg / ha (US 312) and 4203 kg / ha (Abhishek). This variety had yield advantage of 21.3%, 20.2%, 11.0% and 16.2% over IR 64 (NC), Lalat (RC), US 312 (HC) and Abhishek (LC), respectively.

Initial Variety Trial, Irrigated Mid Early (IVT-IME)

Sixty four entries including three checks were evaluated in this trial. Entry NWGR-10011 was the top yielder (4975 kg / ha) followed by RNSK-1054-1 (4800 kg / ha) and RPBio9413-148-S (4725 kg / ha), out-yielding the check Abhishek (4200 kg / ha). NWGR-10011 produced 23.8%, 22.8%, and 18.5% higher yield over the national check (IR 64), regional check (Lalat) and local check (Abhishek), respectively.

INGER Nursery

IURON: Thirty four genetically diverse test entries along with four checks were evaluated in an unreplicated trial under direct seeded rainfed uplands. Based on grain yield, spikelet fertility and phenotypic acceptability, the promising entries identified from the nursery are UPLRi7 (4452 kg / ha), IR08L152 (4281 kg / ha), IR09L348 (4236 kg / ha), IR08L220 (4121 kg / ha) and IR10L398 (4080 kg / ha).

IRHTN: Fifty one entries including three checks were evaluated in RBD with two replication under transplanted condition during 2013 dry season. The maximum temperature ranged from 26.5^{0}C–37^{0}C and 27.5^{0}C-33^{0}C in June and July months, respectively and did not reach 40^{0}C during reproductive stage. The entry HHZ 12-Y4-DT1-Y2 was found top yielder (4700 kg / ha) followed by IR 64197-3B-15-2 (4413 kg / ha) and HHZ 12-SAL8-Y1-Y2 (4375 kg / ha), as compared to checks N-22 (2550 kg / ha), Dular (2425 kg / ha) and Sahbhagidhan (3875 kg / ha). The highest spikelet fertility was observed in HHZ 12-SAL8-Y1-Y2 (83%) followed by IR 64197-3B-15-2 (80%).

Development of rice genotypes for rainfed, flood-prone lowlands

Maintenance of rice germplasm

Eight hundred fifty accessions of rice germplasm were maintained during *kharif* 2013. Observations on days to 50% flowering, plant height and grain yield were recorded. Seed of 250 accessions were deposited in the gene bank for conservation.

Creation of variability through hybridization for pre-flood *ahu* and *boro* rice

Eleven new crosses have been made during *ahu* 2013 for development of pre-flood *ahu* and *boro* rice. The crosses were Kalamanik / IRCTN37, Hasakumora / Swarna, Kalong / Mahsuri, Luit / Swarna, Kalong / Swarna, Hasakumora / VLD65, Hasakumora / Siri614, IRCTN37 / Kalamanik, Kalamanik / VLD221, Kalamanik / DMASZA and Kalong / Siri614.

Evaluation and selection of segregating material

F_3 pedigree nursery of four crosses was grown and 126 F_4 progenies were selected for rainfed lowland (semi-glutinous and soft) rice. BC_1F_2 of 36 crosses for improvement of rainfed shallow lowland rice were also raised and selection was made based on plant type, panicle type, crop duration and plant health. The selected plants were kept separately for BC_1F_3 generation. In the F_4 nursery of *boro* rice grown during *boro* 2012-13, 59 F_4 single plant progenies were selected from 28 crosses based on plant type, plant vigour, panicle type, crop duration and reaction to pests and diseases under field condition.

For the development of pre-flood *ahu* rice, F_3 nursery of 12 crosses were raised for evaluation during *ahu* 2013 and 70 single plant progenies (F_4) were selected.

Performance of promising *boro* cultures in AICRIP trial, 2012-13

IET 23496 (CRL 2-12-7-2-3-2) from the cross IR 64 / Ranjit with medium slender grains ranked fifth in IVT-Boro trial with a mean grain yield of 5291 kg / ha and 133 days to 50% flowering on overall mean basis. It out yielded national, regional and local checks with a yield advantage of 11.97%, 8.41% and 6.41%, respectively. The variety recorded significant superiority over national, regional and local checks at Varanasi (7067 kg / ha), Chinsurah (6833 kg / ha) and Gerua (4502 kg / ha); and over only national check at Titabar (5643 kg / ha). State wise the variety ranked fifth in Tripura (5948 kg / ha) and sixth in West Bengal (5000 kg / ha) with a yield advantage of 19.96% and 6.54% , respectively over the best checks. Quality wise this entry recorded 62.4% HRR, 19.13% AC and soft GC of 64.

Performance of promising cultures for rainfed lowlands in AICRIP trial, *kharif* 2013

Twenty two genotypes representing 5 entries each in IVT-RSL, IVT-DW, NSDWSN and IVT-L while 2 entries in IVT-ASG were nominated for national testing under AICRIP during *kharif* 2013. Three entries, viz., IET 23591 (CRL 77-32-3-3-1-1) and IET 23603 (CRL 67-9-1-1-1-1) under deep water ecology and one genotype, IET 23654 (CRL 96-37-1-1-1) under late category were promoted to AVT1. Furthermore, the entries IET 23593 (CRL 70-44-2-2-1-1) under IVT-DW and IET 23918 (CRL 98-80-3-1-1) under NSDWSN trial will be repeated one more year in the same trial as these two entries showed some good adaptability features found promising.

The entry IET 23193 (CRL 74-89-2-4-1, Pankaj / Padumoni) under aromatic short grain category was promoted from AVT1 to AVT2. IET 23193 with yield of 4312 kg / ha excelled the best check, local and ranked first in the trial. Days to 50% flowering was 111 while the entry exhibited yield advantage of 68.56%, 68.96% and 34.33% over Badshabhog, Kalanamak and local, respectively. It outperformed the best check in Odisha (9.46%), West Bengal (83.31%), Uttar Pradesh (7.52%), Chhattisgarh (78.31%), Assam (71.82%), Maharashtra (22.56%), Andhra Pradesh (95.51%) and Karnataka (26.01%). It recorded high HRR (68.1%), medium slender aromatic grain, intermediate ASV and intermediate AC (24.09%).

Preliminary yield trial for *boro* rice

Ten uniform *boro* breeding lines were evaluated during *boro* 2012-13 and the following three entries were observed to be promising (*Table 23*) and were nominated to AICRIP for IVT-Boro *(boro* 2013-14).

Preliminary yield trial for rice varieties for rainfed lowlands

Fifteen uniform breeding lines of semi deepwater rice and ten fixed cultures of deepwater rice were evaluated in replicated trials during *kharif* 2013. Entries were identified as promising and nominated for testing under AICRIP are given in *Table 24*.

Table 23. Details of entries nominated to IVT-Boro under AICRIP *boro* trial, 2013-14

Designation	Parentage	Days to 50% flowering	Grain yield (t / ha)
CRL 192	Selection from No. 29 (farmers' variety)	154	4.60
CRL 193	Selection in Huanghuazhan (INGER)	138	5.58
CRL 194	Selection in YJ20 (INGER)	132	5.41
IR 64	Regional check	132	3.28
Chandrama	Local check	156	4.07

Table 24. Details of cultures nominated for AICRIP *kharif* 2014 trials

Designation	Parentage	Days to 50% flowering	Grain yield (kg / ha)	Nominations for testing under AICRIP
CRL67-27-2-1-4-1	Utkalprava / Panikekoa	109	3240	IVT- DW (*kharif* 2014)
CRL67-131-1-3-2-1	Utkalprava / Panikekoa	114	3450	
CRL76-33-1-1-1-1	Pankaj / Purnendu	112	3720	
CRL76-48-1-2-1-1	Pankaj / Purnendu	111	3420	
CRL86-21-2-PR-2-1	Purnendu / Ranjit	104	2453	
CRL80-70-2-3-1-1	Pusa44 / Sabita	109	3620	
CRL77-10-1-1-1	Sabita / Ranjit	103	3741	
CRL73-69-1-2-1-1	Pankaj / Sonjul	110	3292	
Jalamagna	NC	127	3130	
Padmanath	LC	112	2980	
CRL76-96-2-1-1-1	Pankaj / Purnendu	104	3517	NSDWSN (*kharif* 2014)
CRL77-30-1-1-1-1	Sabita / Ranjit	110	3992	
CRL80-193-1-PR-1-1	Pusa44 / Sabita	109	3310	
CRL86-21-5-1-3-1	Purnendu / Ranjit	108	2829	
Sabita	NC	122	2646	
Purnendu	RC	128	2341	
Jalashree	LC	109	3212	
CRL9-15-3-3-2-5-1	Gautam / HUR AFG 4-2	105	4400	IVT-ASG (*kharif* 2014)
CRL9-15-6-6-40-1	Gautam / HUR AFG 4-2	98	3653	IVT-RSL (*kharif* 2014)
Ketekijoha	LC	122	3155	

PROGRAMME 2

Enhancing Productivity, Sustainability and Resilience of Rice Based Production System

Development of cost effective and environmentally sustainable rice-based cropping / farming systems for raising farm productivity and farmers' income as well as development of climate resilient production technologies for different rice ecologies are the major thrust areas outlined in CRRI Vision 2050 document. With aforesaid background, this programme was formulated with objectives to develop efficient soil, water, nutrient management options for enhancing the resource use efficiency; to develop appropriate system based rice cultivation for meeting the ecosystem specific problems and enhancing input use efficiency; and to exploit the normal and extreme-tolerant microbial resources from mesophilic and extreme-habitat soil, aquatic and phytonic habitats for nutrition management, plant growth promotion, pest management and prospecting of allelic and non-allelic genes. The programme is having 12 different projects and the progress made during 2013-14 is presented hereunder:

Enhancing nutrient use efficiency and productivity in rice based system

Weed community composition after 43 years of long-term fertilization in tropical rice-rice system

The cumulative effects of various fertilization treatments on weed species composition and diversity along with rice growth and yield were investigated in the long-term fertilizer experiment established in 1969. The experiment included treatments viz. unfertilized control, N, NP, NK, NPK, FYM, N + FYM, NP + FYM, NK + FYM and NPK + FYM. The FYM (5 t / ha) was applied uniformly in the treatments receiving FYM during the last week of May every year. The inorganic fertilizer schedules were 60-40-40 and 80-40-40 N-P_2O_5-K_2O kg / ha for wet and dry seasons, respectively and the fertilizers were applied as per the treatment requirement. Twenty weed species were observed in the study, out of which six species (i.e. *Cyperus difformis*,

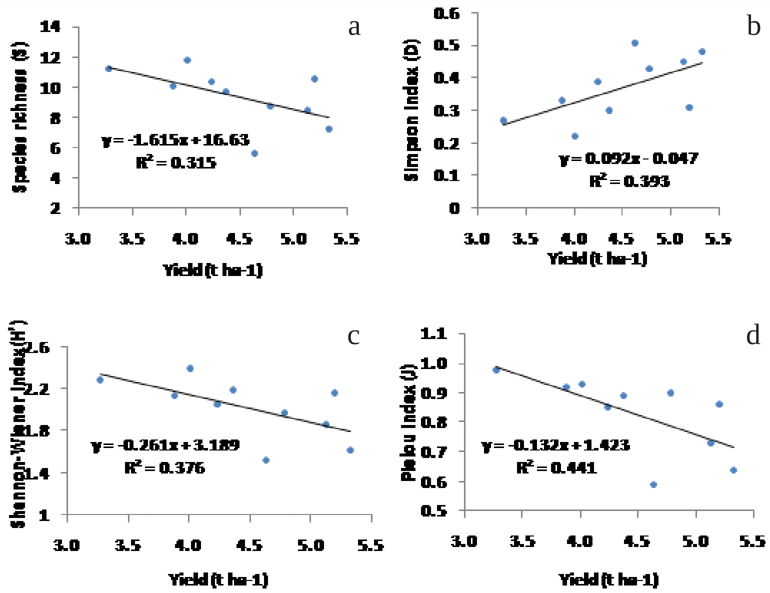


Fig 36. Relationship between rice yield and (a) species richness, (b) Simpson, (c) Shannon"Wiener and (d) Pielou indices of weed communities in rice field

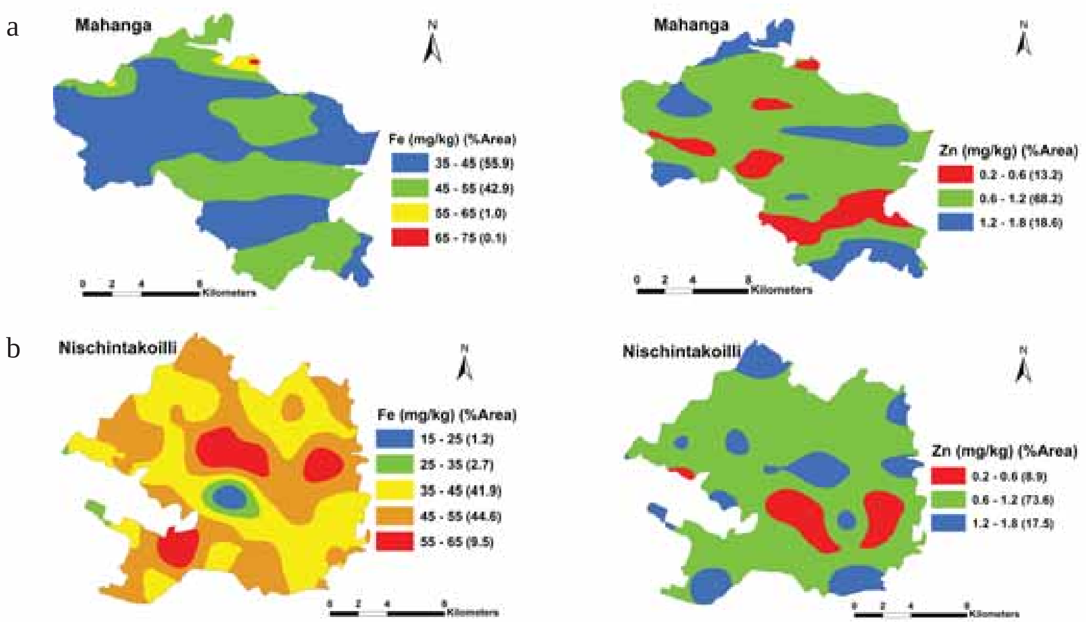
C. tenuspica, Fimbristylis miliacea, Echinochloa colona, Oldenlandia corymbosa, Lindernia anagallis) occurred in all treatments and remaining species occurred only in some of the treatments. Sedges were dominant in all the treatments followed by broad-leaves and grasses. High relative density of weeds was observed in control and FYM treated plots, whereas, low weed density was observed in N, NPK and NPK+FYM treatments. The indices of species diversity (species richness, Shannon–Wiener, Pielou and Simpson indices) showed linear relationships with rice yield (*Fig 36*). The balanced fertilization was more efficient at inhibiting the potential growth of weeds because of the increased growth of rice leading to competition for nutrients. Principal component analysis showed that changes in the weed community composition were due to application of P and FYM. Rice yield is favored by balanced fertilization, whereas, the weed community is favored by NP and FYM fertilization in terms of density and diversity.

Effect of biochar alone or in combination with fly ash on plant growth and yield

A pot culture experiment was conducted to study the effect of rice husk biochar on rice productivity and soil properties when applied alone or in combination with fertilizer and fly ash. The treatments comprised of absolute control, NPK (RFD), NPK+0.5% biochar, NPK+1% biochar, NPK+1.5% biochar, NPK+5% fly ash, 10% fly ash+1% biochar, 5% fly ash+1% biochar, 30% fly ash+1% biochar and N (50%)+30% fly ash+1% biochar. Rice husk biochar was prepared using an anaerobic combustor with partial oxygen supply at 300°C. The resultant biochar contained 47% C, 20.6% ash, 0.90% moisture and 0.31% N with a C / N ratio of 151.6. The biochar was ground and used in the experiment as per the treatment requirement. Results suggested that application of rice husk biochar in addition to RFD showed positive response in terms of yield over control and RFD. Biochar applied treatments recorded significantly higher soil pH vis-à-vis control and RFD indicating higher acid neutralizing capacity of biochar. Biochar treated soils also recorded higher microbial count and enzymatic activities at harvest over control.

Development of soil micronutrient map of Nischintakoilli, Mahanga and Salipur block of Cuttack district

Grid wise (2 km x 2 km) soil samples were collected from Nischnitakoilli, Mahanga and Salipur blocks of Cuttack district of Odisha. The DTPA extractable Fe and Zn were determined. The grid points were digitized in ArcGIS v.10 software and variogram analysis was performed using ArcGIS Geostatistical analyst. Using appropriate semivariograms, the Fe and Zn values were interpolated by ordinary kriging and maps were generated (*Fig 37*). The krigged maps show the regions and loops of fertility status and explain heterogeneity in the region. About 3.8% area in Salipur block had Fe content <5 mg / kg, which is below the critical limit of Fe deficiency. About 68.2%, 73.6% and 55% areas in Mahanga, Nischintakoilli and Salipur respectively had medium Zn content (0.6 – 1.2 mg / kg).



c

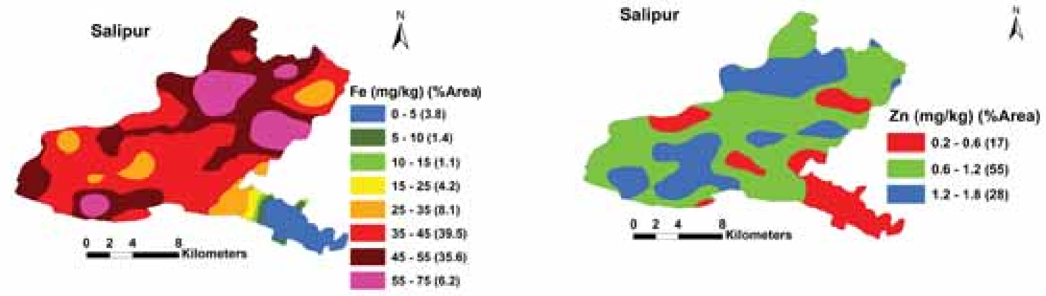


Fig 37. Krigged map of soil DTPA extractable Fe and Zn of (a) Mahanga, (b) Nischintakolli and (c) Salipur Blocks of Cuttack District, Odisha. Values in parenthesis in legends shows the % area of that particular class

Development of soil micronutrient map of Nagpur, Parbhani and Wardha districts of Maharashtra in collaboration with AICRIP (Micronutrients)

Soil samples were collected randomly from 258 locations of Nagpur, 276 locations of Parbhani and 190 locations of Wardha districts of Maharashtra. These soil samples were processed and analyzed in laboratory for DTPA extractable Fe and Zn content. The geographical coordinates of soil sampling points along with Fe and Zn content were acquired from AICRIP (Micronutrients), Bhopal. The soil data was digitized using ArcGIS v.10 software and geostatistical analysis was performed. DTPA extractable Fe and Zn map of Nagpur was prepared using ordinary kriging interpolation technique with circular and spherical variogram models. In case of Parbhani and Wardha using Gaussian variogram model, DTPA extractable Fe map was prepared while DTPA extractable Zn map was prepared using exponential variogram model (*Fig 38*). The resultant map indicated that 7.2 and 27.3%

a

b

c

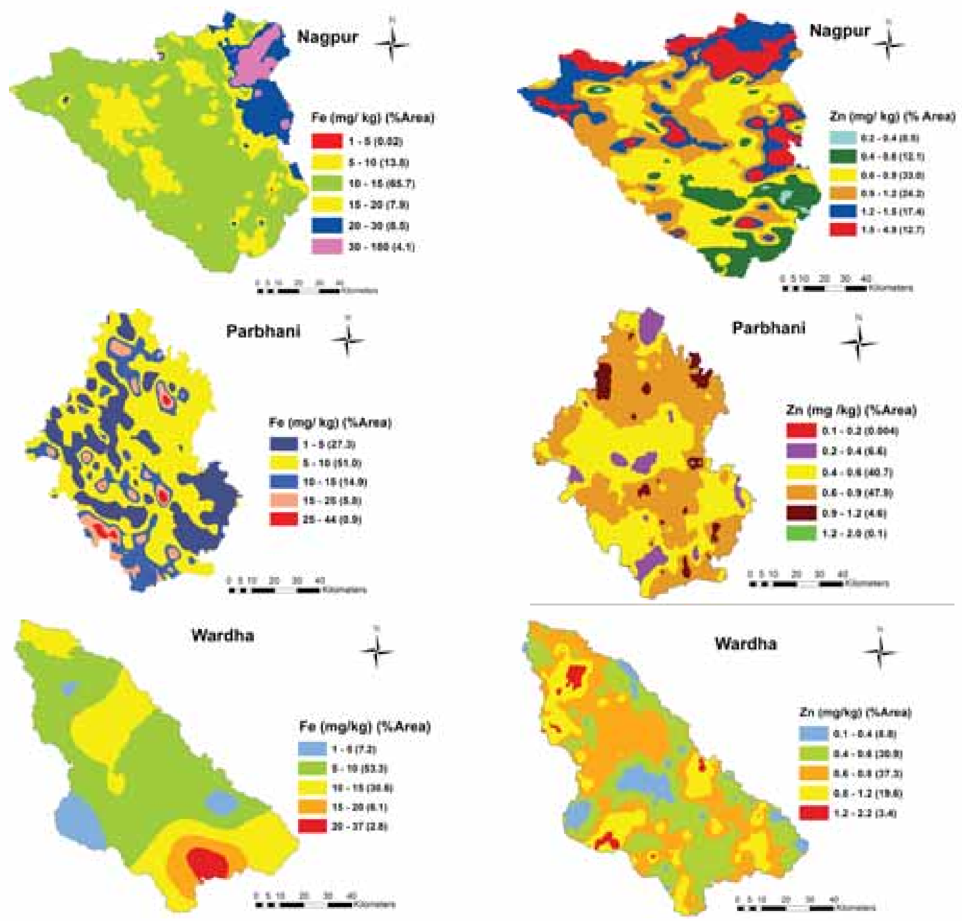


Fig 38. Krigged map of soil DTPA extractable Fe and Zn of (a) Nagpur, (b) Parbhani and (c) Wardha districts of Maharashtra. Values in parenthesis in legends shows the % area of that particular class

area in Wardha and Parbhani are having Fe content <5 mg / kg, which is below the critical limit of Fe deficiency.

Effect of nutrient application on growth and metabolic activities of rice seedlings during flooding stress and subsequent re-aeration

The impact of submergence on the survival, allometry, changes in metabolic activities in four *Indica* rice varieties namely IR-20, IR-64 *Sub1*, Swarna *Sub1* and Savitri *Sub1* was studied. The differential response of flooding under clear and turbid water with different nutrient application schedules were also examined during and after 12 days of complete submergence. Plant survival of all the cultivars was decreased significantly under submergence, and the reduction was considerably greater in turbid water as compared to clear water (*Fig 39*). Savitri *Sub1*, IR-64 *Sub1* and Swarna *Sub1* showed 179.5, 144.3, 101.7%, higher survival, respectively, as compared to sensitive genotype, IR-20. Plant survival was highest (72.2%) when foliar spray of urea was applied after de-submergence along with basal P followed by basal N and P application (68.9%). The plant survival was substantially decreased (45.5%) with pre-submergence N application, especially in turbid water (34%). Submergence substantially reduced allometric parameters but increased the per cent change in chlorophyll, soluble sugars across cultivars with drastic effects on IR-20. Turbid water resulted in higher leaf senescence, lodging, higher depletion of chlorophyll and soluble sugars because of poor light transmission. Pre-submergence N application resulted in higher lodging and leaf senescence. Basal P application reduced the senescence and lodging and foliar spray of post submergence N with basal P improved the retention and regains of chlorophyll, soluble sugar and increased the dry matter, leaf area and root shoot ratio. Plant survival and establishment could therefore be enhanced in areas where untimely flooding is anticipated by applying basal P and foliar spray of urea after de-submergence.

Phenology, photosynthetic rate and yield of submerged rice influenced by application time of nitrogen and phosphorus

In an experiment, rice cultivars IR-64 *Sub1* and IR-64 were compared for their tolerance to complete submergence of 14 days at active tillering, panicle initiation and heading stages with the effects of N and P application time. The role of cultivars, stage of submergence and N and P application on phenology, leaf senescence, photosynthetic (Pn) rate, yield

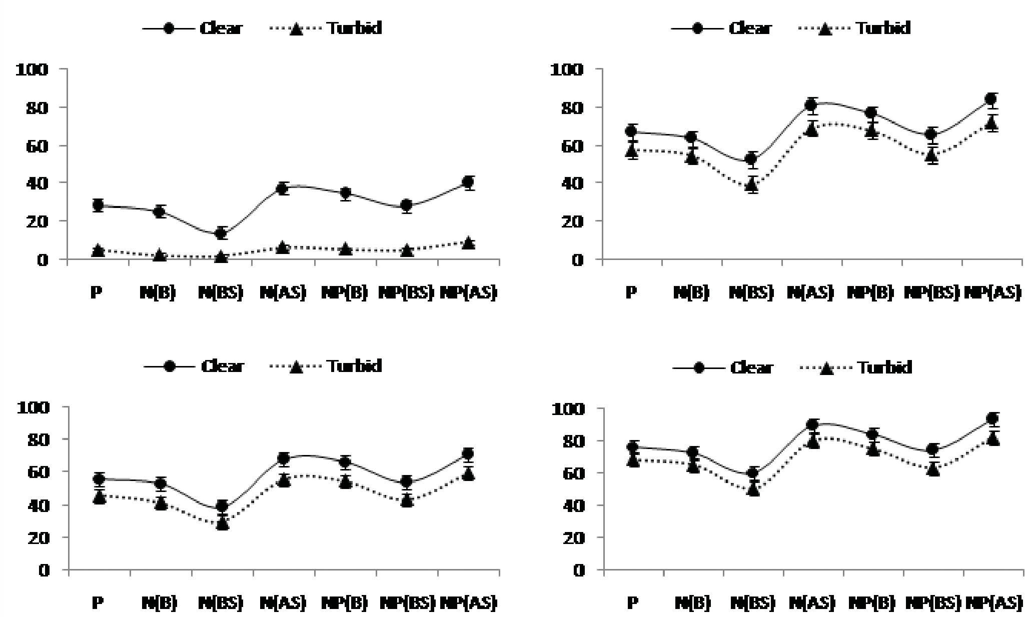


Fig 39. Effect of N and P application on plant survival of IR-20, Swarna Sub1, IR-64 Sub1 and Savitri Sub1 after 7 days of de-submergence in clear and turbid water (Vertical bars in each line represents standard error; B- Basal; BS-Before submergence; AS-After submergence)

attributes and yield were evaluated. Under non-submerged condition, no difference was observed in phenology, Pn rate and yield of both cultivars. Submergence substantially reduced biomass, Pn rate, yield attributes and yield in both the cultivars with more reduction in IR-64. Flowering was substantially delayed by about 30 days in IR-64 and 18 days in IR-64 *Sub1*. Heading stage submergence resulted in significant reduction of all the yield attributes, whereas, submergence at active tillering stage reflected the least damage. Nitrogen application before submergence (applied 48 h before submergence) resulted in less number of tillers (18.3 / hill), panicles (13.8 / hill), spikelets (65.7 / hill) and grain filling (65.8%); these attributes affected more when basal P was not applied. Maximum number of tillers (28.2 / hill), panicles (25.8 / hill), spikelets (86.7 / hill) and grain filling (83.3%) was achieved when N applied 48 h after desubmergence along with basal P. Grain yield was influenced by application of both N and P; positive influence was reflected in case of P application whereas N affected negatively when applied before submergence and positively when applied after desubmergence. When N was applied after desubmergence without basal P resulted in 16.7% yield reduction but when it was combined with basal P then yield loss was only 4.2% as compared to non-submerged condition (*Table 25*). However, N application before submergence along with basal P resulted in yield reduction of 35.3% but when no basal P was supplied, yield subdued up to 44.7% indicating maximum damage. Crop establishment and productivity could therefore be enhanced in flash flood prone areas by basal P application and N application after de-submergence.

Zinc availability and transformation under aerobic condition for devising management strategies

An experiment was conducted during dry season of 2013 to study the effect of different sources of Zn ($ZnSO_4$ and ZnO) under flooded and aerobic moisture regimes on the yield of four rice cultivars viz. Lalat, Naveen, Ratna and Apo. Results revealed that under flooded moisture regime the yield of all the cultivars were higher as compared to the aerobic moisture regime (*Table 26*). Lalat recorded the maximum yield under flooded moisture regime while Naveen recorded maximum yield under aerobic moisture regime. There was an increase in yield for all the four cultivars with the application of Zn. Higher increase in yield was recorded with the application of $ZnSO_4$ as compared to ZnO for all four cultivars under both moisture regimes. Application of $ZnSO_4$ increased the yield of Lalat, Naveen and Ratna under flooded and aerobic moisture regimes compared to control. Hence, it can be concluded that application of $ZnSO_4$ results into higher availability of Zn as compared to ZnO both under flooded and aerobic moisture regimes.

Table 25. Grain yield (g/hill) influenced by interaction effect of cultivar, time of submergence and nutrient application

	IR 64			IR 64 *Sub 1*		
Treatment	Active tillering	Panicle initiation	Heading	Active tillering	Panicle initiation	Heading
PK	96.7c	78.6c	69.8bc	113.7c	104.2c	91.2c
NK(Apply BS)	79.7d	52.4d	43.3d	103d	89.2d	71.3d
NK(Apply AS)	109.8b	93.4b	79.6b	127.7b	119.8b	102.3b
NPK(Apply BS)	94.5c	75.6c	65.4c	110.1cd	101.3c	88.7c
NPK(Apply AS)	121.6a	112.4a	92.3a	143a	131.2a	118.4a
K	86.5cd	67.6c	54.3d	104.4d	94.5c	74.8d
Mean	98.1	80.0	67.4	116.9	106.7	91.1
$LSD_{0.05}$(VxT)	9.68					
$LSD_{0.05}$ (VxN)	15.81					
$LSD_{0.05}$ (TxN)	19.36					
$LSD_{0.05}$ (VxTxN)	27.38					

In a column, values followed by a common letter are not significantly different at $P<0.05$ using least significance difference test. V: variety, T: time of submergence, N: nutrient application, DAT: days after transplanting, BS-before submergence, AS-after submergence

Table 26. Grain yield (t/ha) of rice cultivars with different sources of Zn ($ZnSO_4$ and ZnO) under flooded and aerobic moisture regimes

	Flooded yield (t / ha)				Aerobic yield (t / ha)			
Cultivars	Control	Zn as $ZnSO_4$	Zn as ZnO	Mean	Control	Zn as $ZnSO_4$	Zn as ZnO	Mean
Lalat	4.4	5.0	4.7	4.7	3.9	4.3	4.1	4.1
Naveen	4.2	4.8	4.6	4.5	4.1	4.7	4.3	4.4
Ratna	3.9	4.3	4.1	4.1	3.6	3.9	3.8	3.8
Apo	4.1	4.4	4.3	4.3	4.0	4.3	4.2	4.2

Nitrogen response trial on selected AVT-2ME (aerobic) rice cultures under high and low input management

A field experiment was conducted during 2013 wet season under AICRIP for N response of AVT 2 (aerobic) cultures with high and low input management. The experiment was laid out in a split plot design with three N levels (50% RDN, 100% RDN and 150% RDN where RDN = 80 kg ha^{-1}) in main plots and six AVT 2 aerobic rice cultures (IET 22699, IET 22704, IET 22716, IET 22729, IET 22731 and IET 22737) with six check varieties (IR 36, IR 64, Rasi, MAS 946, Apo and Naveen) in sub plots and replicated thrice. Results indicated that among the varieties IET 22704 recorded a grain yield of 3.55 t / ha followed by IET 22731 (3.33 t / ha) and check variety Apo (3.29 t / ha) which were at par themselves but significantly higher than other cultures and check varieties. Highest grain yield of 4.01 t / ha were observed with 100% RDN application in the culture IET 22704.

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

Agronomic evaluation of rice genotypes under limited water aerobic condition

Field experiments were conducted under limited water aerobic condition during 2013-14 to evaluate promising rice genotypes for higher crop and water productivity. Standard crop and nutrient management practices were followed; measured quantity of irrigation water was applied to maintain root zone (30 cm depth) soil moisture regime at 40-45 kPa.

During dry season in 2013, performance of 20 short to medium maturity duration rice genotypes showed significantly higher grain yield viz. Ajay (4.45 t / ha) followed by CR Dhan 200 (4.25 t / ha) compared to the check variety Apo (4.00 t / ha). Yields of other promising genotypes were Sahbhagidhan (3.65 t / ha), PVS 2 (3.80 t / ha) and PVS 12 (3.85 t / ha). The per day crop productivity rate was higher in Ajay (3.35 g / m^2 / d) followed by CR Dhan 200 (3.30 g / m^2 / d) and Sahbhagidhan (3.25 g / m^2 / d) as compared with Apo (3.50 g / m^2 / d). The water productivity ranged from 0.35 g grain / kg water in Ajay followed by Rajalaxmi (0.33 g grain / kg water), CR Dhan 200 (0.32 g grain / kg water) compared with Apo (0.32 g grain / kg water). During wet season in 2013, CR Dhan 200 produced grain yield of 4.81 t / ha followed by Sahbhagidhan (4.72 t / ha). The per day productivity rate ranged from 4.00 to 4.50 g / m^2 / d with maximum productivity of 4.50 g / m^2 / d in CR Dhan 200 followed by 4.45 g / m^2 / d in Sahbhagidhan. Water productivity varied from 0.26 to 0.40 g grain / kg water applied with maximum of 0.40 g grain / kg water in CR Dhan 200.

Critical growth stage based irrigation scheduling and nitrogen management in aerobic rice for higher yield and water use efficiency

A field experiment was conducted in dry season to study the effect of growth stage based irrigation scheduling and dosage and method of N application on aerobic rice. The experiment was laid out in a split-split plot design with three irrigation intervals (I_1: 4 days during seedling and vegetative stage, I_2: 6 days during seedling stage and 4 days during vegetative stage, and I_3: 6 days during seedling and vegetative stage) in main plots and two N levels (N_1: 100% and N_2: 125% RDN) in subplots and two timings of N application (M_1: 10 - 12 days after emergence (DAE) (33%) + Active tillering (AT) (33%) + Panicle initiation (PI) (33%) and M_2: Basal (25%) + AT (50%) + PI (25%)) and replicated thrice. The crop was irrigated as per treatment requirement with an irrigation water depth of 40 mm during seedling and vegetative stages and 50 mm during flowering stage, respectively. Results indicated that among the irrigation treatments highest grain yield of 3.84 t / ha was achieved when aerobic rice was irrigated with 4 days interval during seedling and vegetative stage (I_1) and was on par with that of yield recorded when irrigated at 6 days interval during seedling stage and 4 days interval during vegetative stage (I_2) but significantly higher grain yield compared to irrigating the crop at 6 days interval during seedling and vegetative stage (I_3). The yield decline in aerobic rice was to the tune of 11.2% due to irrigation at 6 days interval compared to 4 days interval during seedling and vegetative stage in dry season crop. Application of 25% additional N above the RDN of 120 kg / ha as well as timings of N application did not increase the grain yield significantly in aerobic rice.

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

Rice canopy level radiation interception studies under different date of sowing

Field experiment was conducted during *rabi* 2013 with Methods of establishment (M_1: Wet Direct Seeding, M_2: Transplanting and M_3: Modified SRI) in the main plot and Date of main field sowing / nursery sowing (D_1: 10th December, D_2: 20th December, D_3: 30th December and D_4: 10th January) in sub plot and Variety (V_1: Rajalaxmi and V_2: Naveen) in sub sub-plot in order to study the canopy level radiation interception. The results revealed that methods of establishment was not having any significant effect on grain yield while dates of sowing and variety had a significant effect on rice grain yield (*Table 27 and Fig 40*). There existed a significant interaction between Methods of establishment and Date of sowing.

Fig 40. Performance of rice hybrid Rajalaxmi under modified SRI sown in nursery on 10th December

Table 27. Effect of establishment method, date of sowing and varieties on rice grain yield

Treatment	Grain yield (t / ha)
Establishment method (M)	
Wet Direct Seeding	5.69
Transplanting	5.77
Modified SRI	5.84
LSD (P=0.05)	NS
Date of sowing (D)	
10th December	5.85
20th December	5.98
30th December	5.78
10th January	5.46
LSD (P=0.05)	0.351
Variety (V)	
Rajalaxmi	6.29
Naveen	5.24
LSD (P=0.05)	0.187

Relationship between standardized precipitation index and block level rice productivity

The relationship between Block level rice productivity and Standardized Precipitation Index (SPI) was assessed using time series of rainfall data (1983–2008) from 168 rain gauge stations of Odisha. The 1- and 3-month SPI were computed using monthly rainfall data of the wet season. Rice Productivity Index was worked out as the percentage of the technological trend productivity to the actual productivity using the equation $RPI_i = [\{(Y_{ai} / Y_{ti}) - 1\}100]$, where, RPI_i is the Rice Productivity Index for i^{th} year; Y_{ai} and Y_{ti} are actual productivity and technological trend productivity ($Y_t = a + b * year$) of i^{th} year, respectively. Correlation analysis of 1- and 3-month SPI with RPI showed that SPI of 1-month time scale particularly in July (r=0.49) and October (r=0.33) had significantly stronger relationship with RPI than any of the 3-month SPI individually during wet season. Regression models were developed using 1- and 3-month SPI for forecasting rice productivity of blocks with varying proportion of rainfed area in Odisha. Model developed based on 1-month SPI (*Table 28*) accounted for 27% yield variability in rice and could be used for forecasting rice productivity.

Table 28. Multiple regression analysis of 1-month SPI versus block level Rice Productivity Index (RPI)

Rainfed area (%) details	Multiple regression equation	Multiple R	R^2
Blocks with >95% rainfed area	RPI = 0.776 + 0.378 *July* SPI1 + 0.163 *Oct* SPI1 + 0.158 *June* SPI1	0.52	0.27**
Blocks with >90% a rainfed area	RPI = 1.222 + 0.405 *July* SPI1 + 0.161 *Oct* SPI1 + 0.137 *June* SPI1 - 0.070 *Aug* SPI1	0.52	0.27**
Blocks with >75% rainfed area	RPI = 0.021 + 0.387 *July* SPI1 + 0.170 *Oct* SPI1 + 0.125 *June* SPI1 - 0.080 *Aug* SPI1+ 0.060 *Nov* SPI1 - 0.060 *Sept* SPI1	0.51	0.26**
Blocks with >50% rainfed area	RPI = 1.865 + 0.406 *July* SPI1 + 0.143 *Oct* SPI1 + 0.128 *June* SPI1 - 0.060 *Aug* SPI1 - 0.060 *Sept* SPI1	0.50	0.25*
Blocks with >25% rainfed area	RPI = 1.466 + 0.362 *July* SPI1 + 0.147 *Oct* SPI1 + 0.153 *June* SPI1 - 0.060 *Aug* SPI1- 0.050 *Sept* SPI1	0.47	0.22
All blocks	RPI = 0.449 + 0.335 *July* SPI1 + 0.173 *June* SPI1 + 0.135 *Oct* SPI1 - 0.080 *Aug* SPI1+ 0.061 *Nov* SPI1 - 0.050 *Sept* SPI1	0.44	0.20

** Significant at pd ≤ 0.01; * Significant at pd ≤ 0.05

Development of sustainable production technology for rice based cropping systems

System based nutrient management in rice based cropping system

A field experiment was carried out to study the effect of different nutrient management options on the rice based cropping system. The experiment was laid out in a split plot design with two cropping system i.e. rice-maize-cowpea and rice-groundnut-cowpea in main plots and five system based nutrient management option i.e. control-control-control, RDF-RDF-RDF, RDF_{75}+ Crop residue incorporation of previous crop (CRI) - RDF-RDF, RDF_{75}+CRI- RDF+ Straw mulch (SM) - RDF and RDF_{75}+CRI-RDF+SM-RDF_{50} in subplots replicated thrice. Rice yield did not differ significantly with respect to different systems in *kharif* season. The rice equivalent yield (REY) of groundnut was significantly higher compared to maize in *rabi* season. In summer season, significantly higher grain yield of cowpea was recorded in rice-maize-cowpea system compared to rice-groundnut-cowpea system. The REY of cowpea was 1.94 t/ha in rice-maize–cowpea which is 3.73 times of the cowpea yield obtained in rice–groundnut–cowpea system. However, the total productivity of the rice-groundnut-cowpea system was on par with that of rice-maize-cowpea system (*Table 1*). Among the nutrient management options, the highest REY of 13.07 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} treatment but significantly higher than all other nutrient treatments. Thus, RDF_{75}+CRI to rice followed by RDF+SM to maize and 50% of the RDF to cowpea could increase the overall land productivity and help in saving of fertilizer input.

Table 29. Productivity of component crops and the system (rice equivalent yield, REY) of rice based cropping system under nutrient management options

Treatment	Rice Equivalent Yield (t/ha)			
	Kharif	*Rabi*	Summer	System
Cropping system				
Rice - Maize - Cowpea	4.53	4. 37	1.94	10.83
Rice - Groundnut - Cowpea	4.51	6.16	0.52	11.20
CD (P =0.05)	NS	0.62	0.16	NS
Nutrient management				
Control - Control - Control	3.79	2.27	0.26	6.32
RDF - RDF - RDF	4.71	5.66	1.21	11.58
RDF_{75} + CRI - RDF - RDF	4.72	5.81	1.06	11.59
RDF_{75} + CRI – RDF + SM - RDF	4.83	6.17	2.05	13.07
RDF_{75} + CRI - RDF + SM - RDF_{50}	4.52	6.42	1.56	12.51
CD (P =0.05)	0.37	0.41	0.10	0.61

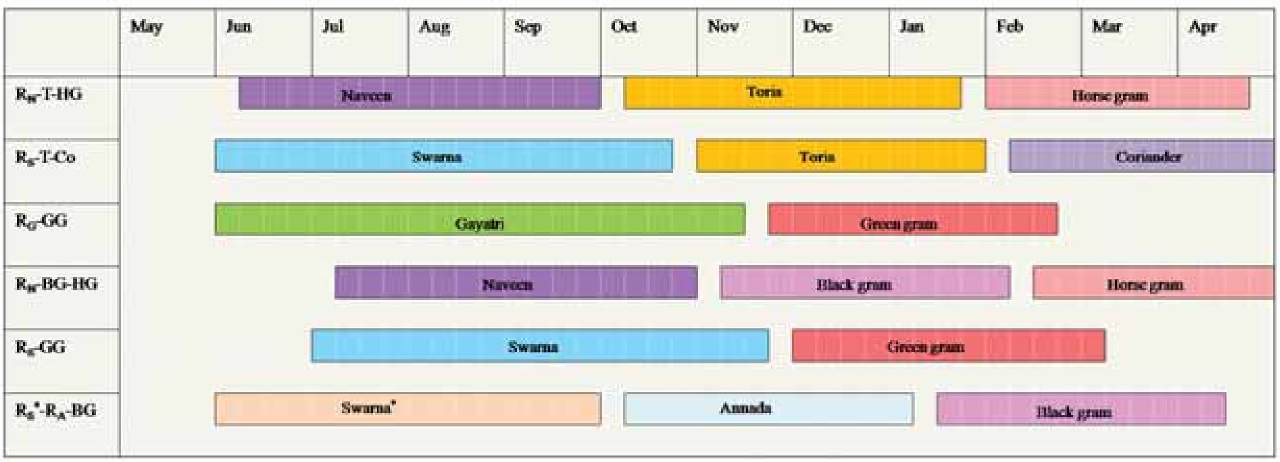
Crop/varietal diversification in rice based cropping system under rainfed condition

A field experiment was conducted during 2013-14 on crop / varietal diversification in rice based cropping system for climate change adaptation involving different cropping systems i.e. rice-toria-horse gram, rice-toria-coriander, rice-green gram, rice-black gram-horse gram, and rice-rice-black gram under rainfed conditions. The experiment was laid out in randomized complete block design and replicated thrice. The cropping systems represent traditional and recent cropping systems in eastern India. Three-rice varieties of different duration Naveen (120 days), Gayatri (160 days) and Swarna (145 days) were transplanted during *kharif* season on 1st week of July and 1st week of August. The rice crop of variety Swarna (transplanted on 1st week of July), was artificially damaged during last week of September assuming aberrant weather conditions like drought or flood, which farmers usually encounter during rice growing season. After harvesting of rice crops, non-rice crops were directly sown on residual moisture to evaluate the production potential of the system to formulate a contingent crop calendar in respect of crop or varietal diversification under rainfed condition (*Fig 41*). Rice varieties transplanted on 1st week of July performed better than 1st week of August transplanted varieties. Naveen and Swarna transplanted on 1st week of July gave 13.1% and 36.4% higher yield as compare to transplanted on 1st week of August. In an aberrant weather scenario where Swarna crop was damaged, a short duration rice variety "Annada" was direct seeded. However, the performance of Annada was poor vis-à-vis previous year owing to the cyclonic weather prevailed during October. System productivity was highest (5.49 t / ha) in rice (swarna)-toria-coriander system.

Farm implements and post harvest technology for rice

Self propelled eight row drum seeder for wet direct seeding of hybrid rice

As the seed rate of hybrid rice is much lower than the inbred varieties, conventional drum seeder could not be used for direct seeding of hybrid rice. Hence, a self propelled eight row drum seeder having cup type feed mechanism was developed (*Fig 42*). To achieve the desired seed rate, cups of varying diameters viz. 7, 8, 9, 10 and 11 mm were used. Five different peripheral speeds i.e. 11.62 m / min, 14.52 m / min, 17.45 m / min, 19.78 m / min and 26.37 m / min were used to find out the optimum speed to avoid scattering of seeds. The result indicated that seed rate of 15 kg / ha was obtained through 8 mm diameter cups with a peripheral speed of 11.62 m / min. It was observed that seeds were choking the passage when cup diameter was below 8mm. It was also found that more seeds were falling than the requirement and scattering occurred when the peripheral speed was more than 11.62 m / min. The seeder was field tested during wet season of 2013. The



*Rice variety Swarna sown on 1st July was artificially damaged in September assuming weather aberration like drought or flood. R-Rice, HG-Horse gram, Co-Coriander, GG-Green gram, T-Toria, BG-Black gram

Fig 41. Crop calendar followed in the experiment of crop /varietal diversification of rainfed rice based cropping system

Fig 42. Self propelled drum seeder with cup type feed mechanism

seeder dropped 1-2 seeds per hill with missing hills up to 20%. Field capacity of the seeder was 0.24 ha / h. Due to vibration of the machine, the seed placement in soil deviated from the intended place. This necessitates further modification of transmission system of the machine.

Modified self propelled eight row drum seeders for wet direct seeding of high yielding rice varieties

The seed rate achieved in wet direct seeding of pre-germinated seeds through existing eight row drum seeder was 60 kg / ha which was higher than the actual requirement. For this reason, number of metering holes of self-propelled drum seeder was reduced from 13 to 8 and diameter of the holes was reduced from 10 mm to 7 mm. Power transmission system was modified in such a way that seeding shaft obtained power directly from engine instead of ground wheel. Float size and shape were also changed for stability of the machine against sinking in the mud. The shape of seed drum was modified from cylindrical to hyperboloid for easy flow of seeds towards metering holes on the drum.

The self propelled eight row pre-germinator paddy seeders having cylindrical and hyperboloid drums were field tested in wet season of 2013 (*Fig 43 and 44*). The row spacing was 20 cm in both the cases. Seeding of 5-6 seeds per hill was observed in cylindrical drum seeder while it was 3-4 seeds in case of hyperbolic drum seeder. Continuous drilling of seed was observed with seeder with cylindrical drum while the hyperboloid drum seeder maintained a hill to hill distance of 5 cm. The seed rate achieved with cylindrical drum seeder and hyperboloid drum seeder were 40 kg / ha and 32 kg / ha, respectively. Field capacity of both seeders was 0.235 ha / h with unit cost of Rs. 70,000 / -. The cost of sowing with this equipment was Rs. 819 / - per hectare.

Field performance of single row power weeder

The single row power weeder developed at CRRI was field tested (Fig 45) with different blade widths and row spacing of 20, 25 and 30 cm in Naveen variety of paddy. Results revealed that plant damage and weed destruction increased with increase of width of blades. Highest weed destruction (90.4%) was observed with 18 cm wide blades in 20 cm row spacing but it caused plant damage up to 30% (*Table 30)*. The weeder requires further modification so that plant damage is minimal and scattered soil does not hit the operator.

Fig 43. Self-propelled drum seeder with cylindrical drum

Fig 44. Self-propelled drum seeder with hyperboloid drum

Table 30. Field performance of the single row power weeder with different size of blades

Width of blades (cm)	Row spacing of rice variety Naveen								
	20 cm			25 cm			30 cm		
	Field capacity (ha / hr)	Plant damage (%)	Weed destruction (%)	Field capacity (ha / hr)	Plant damage (%)	Weed destruction (%)	Field capacity (ha / hr)	Plant damage (%)	Weed destruction (%)
12		Nil	65		Nil	50.2		Nil	42.8
16	0.022	14.0	84.6	0.029	1.57	68.0	0.035	Nil	56.0
18		30.0	90.4		4.5	75.1		Nil	62.5

Fig 45*. Single row power weeder*

Field performance of modified two row self propelled power weeder

Field capacity of the modified two row self propelled power weeder was studied to avoid the problem of stamping in crops by wheels of two row self propelled power weeder with rice cultivar Anjali, sown with a 3-row manual seed drill at spacing of 20 and 25 cm. Plant damage and weed destruction increased with increase of width of the blades. Highest weed destruction (70%) was observed with 12 cm blades with plant damage of 28% in 20 cm row spacing (*Table 31*) which necessiates further modification of the weeder.

Rice husk combustor

The rice husk combustor of 3 kw capacity (*Fig 46*), developed under the project was evaluated to find out its suitability for cooking of food materials. It took 25 minutes to cook 5 kg of raw rice and 1hr for 2 kg of arhar dal with 10 kg vegetables. Amount of husk combusted was 9 kg. While there was no problem in cooking the food, height of the combustor (90 cm) was a constraint for handling the cooking vessels. Based on the feedback from the users, another unit of combustor having 2 kw (*Fig 47*) capacity with reduced height (70 cm) was fabricated. On batch mode, with 3 kg husk, the combustion time for 2 kw unit was 1.5 h having thermal efficiency of 14-15%. On semi continuous mode, the combustor could be used for more than 2 h by removing the ash and by feeding husk intermittently. The previously developed rice husk stove (1 kw) (*Fig 48*) was also modified with similar features as in the combustor but without changing its size. The comparative performance through water boiling of the above two combustors (3 kw and 2 kw) along with the husk stove (1 kw) is presented in *Table 32*. Thermal efficiency of all the three combustion devices was in the range 14-15%. Heat utilization was maximum with the 3 kw size combustor due to high fuel consumption rate. All the three models of combustion devices are suitable for thermal energy application depending up on the amount of heat required for any particular use.

Table 31. Field performance of two row self propelled weeder under different blade widths and row spacing in rice var Anjali

Width of blades (cm)	20 cm row spacing			25 cm row spacing		
	Field capacity (ha / hr)	Rice plant damage (%)	Weed destruction (%)	Field capacity (ha / hr)	Rice plant damage (%)	Weed destruction (%)
6		Nil	40		Nil	32
9	0.043	4.35	55	0.053	1.09	44
12		27.80	70		6.30	56

Fig 46. Rice husk combustor (3 kw)

Fig 47. Rice husk combustor (2 kw)

Fig 48. Small size rice husk combustor/Stove (1 kw)

Table 32. Comparative performance of the rice husk combustors along with husk stove through water boiling test

Operating parameters	Large size rice husk combustor (3 kw)	Medium size rice husk combustor (2 kw)	Small size rice husk combustor / stove (1 kw)
Height (over all), cm	90	70	50
Weight, kg	19.5	15.97	8.13
Initial quantity of husk filled, kg	4.5	2.5	1.2
Water used for boiling, kg	8.0	5.0	3.0
Initial temp. of water, ^{0}C	25	25	25
Time to start ignition, min	5.0	5.0	4.0
Time taken for boiling, min	10	7.0	10
Flame sustained for, min	50	30	20
Further feeding of husk, kg	3.0	0.5	0.2
Total operating time, h-min	2-10	1-30	0-50
Fuel consumption rate, kg / h	3.5	2.0	2.1
Water evaporated, kg	5.12	1.7	0.73
Heat utilized, Kcal	3365	1293	619
Thermal efficiency, %	14.95	14.36	14.7

Field efficiency of CRRI planting machines

Manual transplanting is the most expensive input in traditional rice cultivation but the planting cost of Rs. 9,710 / ha can be reduced to Rs. 600-810 / ha, Rs. 1,432 / ha and Rs. 1,215-1,860 / ha by the use of manual seeders, self propelled hill seeder and transplanters, respectively (*Table 33*). Compared to manual transplanting, mechanized direct seeding and transplanting decreased total cost of cultivation by 22% and increased net returns by 18%. Field capacity of the self-propelled transplanter with mat type seedlings was the highest in puddled soils. In well drained, puddled condition, where standing water remained within 10 mm, planting by manual drum seeder was most economical. Compared to manual transplanting, it reduced cost of planting to 1/14th and increases net profit from rice cultivation by 13%. The grain and straw yields and water productivity did not vary significantly with different methods of planting.

Field efficiency of CRRI weeders

Field efficiency of different weeders was tested against hand weeding and chemical weed control. Results revealed that cost of weeding was minimum in

Table 33. Effect of planting implements on productivity, water productivity and net returns (var. Gayatri, *Kharif* 2013)

Planting implement	Field capacity (ha/h)	Cost of planting (Rs/ha)	Total cost of cultivatuion (Rs/ha)	Plant height (cm)	Ear bearing tillers (No./m²)	Grain yield (t/ha)	Straw yield (t/ha)	Water[á] productivyt (Rs/m²)	Net[#] return (Rs/ha)
Four row manual drum seeder	0.04	810	37,223[$]	105.6	296.3	5.62	8.80	5.08	41827
Six row manual drum seeder	0.053	600	36,690[$]	107.4	300.6	5.58	8.40	5.04	41460
Self propelled hill seeder	0.08	1,432	37,993[$]	106.1	300.4	5.60	9.35	5.03	41357
Four row manual rice transplanter	0.022	1,860	37,364	105.7	307.9	5.35	9.20	4.70	38711
Self propelled 8 row transplanter	0.205	1,215	36,607	106.2	317.0	5.96	8.95	5.69	46843
Manual transplanting	0.0025	9,710	47,609	108.6	308.2	5.92	9.15	4.32	35541
CD (P=0.05)	-	339.16	690.26	0.49	3.63	0.36	0.70	484.26	

[*] Excluding cost of seed / nursery operations [$] Includes cost of one weeding by cono-weeder

[#] Rate of paddy = Rs.1250 / q, Rate of straw = Rs. 100 / q

[á] Water productivity= Net profit / evapotranspiration (823 mm for *Gayatri*)

chemical weed control (Rs. 2,100 / ha) followed by power weeders (Rs.2,921 / ha) whereas, it was highest for manual weeding (Rs. 7,200 / ha). Among the mechanical weeders, highest ear bearing tillers (192 / m²), grain yield (4.06 t / ha) were obtained from the treatments where star-cono weeder was used for weed control although cost of operation was higher than the power weeder (4.1%). Grain yield of mechanically weeded plots were similar to manually weeded plots (*Table 34*), the cost of weeding (Rs. 3,408 / ha) was 111% less than the manually weeded plots (Rs. 7,200 / ha). Highest net returns from rice cultivation was obtained from chemical weed control (Rs. 25,905 / ha) followed by the weeding by star-cono weeder (Rs. 22,536 / ha). The study shows that chemical weeding is better than mechanical and hand weeding but power weeder is a better substitute to hand weeding and weeding by finger weeders from weeding cost and net profit points of view.

Table 34. Effect of weeding methods on productivity, water productivity and net returns (var. Naveen, *Rabi* 2013)

Weeding process	Area covered (ha/h)	Cost of one weeding (Rs/ha)	Cost of cultivation (Rs/ha)	Plant height (cm)	Grain yield (t/ha)	Ear bearing tillers m²	Straw yield (t/ha)	Water[á] productivity (Rs/m²)	Net returns (Rs/ha)
By single row power weeder	0.022	2,911	33,800	89.8	3.82	188	6.97	3.11	20,920
By 2-row self propelled weeder	0.043	2,930	33,200	89.6	3.80	184	6.95	3.16	21,250
By star-cono weeder	0.035	3,046	35,354	91.6	4.06	192	7.14	3.35	22,536
By finger weeder	0.021	4,744	37,125	89.8	3.85	174	6.47	2.60	17,470
Manual weeding	0.014	7,200	41,820	90.3	4.02	188	7.00	2.29	15,430
Chemical weeding	-	2,100	31,820	90.3	4.05	190	7.1	3.85	25,905
No weeding	-	-	25,866	88.4	1.68	126	4.13	-0.11	-736
CD (P=0.05)	-	11,7.52	117.52	0.37	0.13	2.89	0.26	0.083	556.66

[1] Rate of paddy= Rs. 1250 / q Rate of straw=Rs. 100 / q

[á] Water productivity= Net profit / evapotranspiration (673 mm for *Naveen*)

Resource Conservation Technologies for sustainable rice production

Six resource conservation techniques each for direct seeded and transplanted rice were imposed in 1.6 acre experimental plot in CRRI farm. The treatments were: (i) Control, (ii) Seed drilled, (iii) Drum seeded sown, (iv) brown manuring, (v) green manuring and (vi) zero tillage. The variety Pooja was grown. Resource conservation technology, dry direct seeding rice with *dhaincha* (paired row) followed by incorporation of *dhaincha* by cono weeder and CLCC based real time N management was found most promising in terms of yield (6.2 t / ha), energy ratio (15.9) and soil health. Soil labile C pools were significantly higher in rice straw + GM than zero tillage and control in 2nd year of study. Energy input was less and energy ratio was higher in direct seeded rice as compared to that of transplanted rice. The emission of CH_4 was less in direct seeded rice (ranged from 42.6-63.0 kg / ha) than transplanted rice crop (ranged from 51.6-67.1 kg / ha). This best bet technology involving i) Loosening of soil by mould board plough followed by Rotavator or cultivator; ii) Dry direct seeding of rice and *dhaincha* in paired row system by seed drill; iii) Incorporation of *dhaincha* at 25 DAS by cono-weeder if water is available; alternatively knock down of *dhaincha* by 2,4-D at 25 DAS if water is not available; iv) CLCC based real time N application in two splits; v) Harvesting through reaper / combine harvester was evaluated in farmers field at Purvakachi village of Salipur in Cuttack district of Odisha (*Fig 49 to 51*). It was found that adoption of RCT reduced cost of production, saved energy and enhanced the rice yield over the farmers practice.

Fig 49. Farmers field evaluation: Primary tillage through mouldboard plough

Fig 50. Farmers field evaluation: Dry direct seeding by tractor driven seed drill

Fig 51. Farmers field evaluation: Rice crop (var. Pooja) at maximum tillering stage

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

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

Rice-fish-horticulture based integrated farming system with various crops and livestock components was taken up in deepwater ecology. The grain yield of wet season rice var. Gayatri was 6.9 t / ha and that of CR 1014 was 4.6 t / ha in rainfed medium-deep water (up to 50 cm water depth) in the upper part of the field. In the deepwater situation (more than 50 cm water depth) at lower end of the field, the grain yield in

Varshadhan and Durga were 5.2 and 4.6 t / ha, respectively. The yield of various dry season crops grown with harvested rainwater after wet season rice, were 2.8 to 6.5 t / ha in vegetables (bitter gourd, okra) and 4.2 t / ha in rice (cv. Shatabdi). The productivity of other field crops in upland (Tier I and II) was in the range of 11.3-38.6 t / ha in various vegetable crops during dry season and 5.3-8.0 t / ha during wet seasons, 42.2 t / ha in bottle gourd on platform, 6.7-12.2 t / ha in tuber crops and 11.6-14.7 kg fruits / plant in fruit crops. The fish yield was 0.98 t / ha at a stocking density of 6,000 fingerlings / ha. Among the bird components, poultry birds (breed-Vanaraja) attained average weight of 1.9 kg in 90 days, while ducks (breed-Khaki Campbell) recorded an average weight of 1.5-2.0 kg / year.

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

With the aim of further improvement of the model, mushroom and nutritional garden enterprises were integrated in the existing model. These enterprises helped in further stabilizing the system productivity by providing additional income and employment opportunities. After an early crop of rice cv. Sahbhagidhan, submergence tolerant rice variety Swarna *Sub-1* was transplanted in the 1st week of July. During the dry season aromatic rice variety Kudrat was grown. Three rice crops together (Sahbhagidhan, Swarna *Sub-1* and Kudrat) produced a total grain yield of 12.2 t / ha. On the bunds more than 1.2 tones of vegetables and fruits were produced. Around 0.9 q of fish and 2000 fingerlings were harvested in the system and generated an income of Rs. 15,000 / -. As a whole the system could produce about 11 q of food crops, 1.0 q of fish, 0.5 q of meat, 14 q of vegetables and 0.9 q of fruits besides 15 to 20 q of rice straw (used for animal feed) annually to ensure food and nutritional security, stable income on short and long term basis and year round employment of farm family. Efforts were made to popularize the highly productive rice-fish integrated farming system model in irrigated ecology thorough print as well as electronic media (Newspapers, Television and All India Radio).

Management of rice weeds by integrated approach

Study on weed population and dynamics during wet and dry seasons

The population dynamics of major rice weeds was studied under direct seeded and transplanted conditions during wet season, 2013. It was found that *Echinochloa colona* was the most predominant weed species in weedy plots followed by *Cyperus iria* and *Ludwigia octovalvis* in dry direct-sown rice field. The grassy weeds constituted 61% of the total weed population in weedy plots followed by sedges (21%) and broad leaf weeds (18%). In wet direct-sown rice field, the grassy weed *E. colona* was most prevalent (52% of total weed population) at early vegetative stage i.e., at 30 days after sowing (DAS). However, *Leptochloa chinensis*, *C. difformis* and *Sphenochlea zeylanica* were predominant (81%) at 60 DAS. In transplanted rice, the dominance of a mixed population of different weeds viz., *E. colona, E. crus-galli, C. difformis, C. iria, S. zeylanica* and *Marsilea quadrifolia* was recorded at 30 days after transplanting (DAT) in weedy plots. But, at late vegetative stage (60 DAT), *L. chinensis, S. zeylanica* and *Fimbristylis miliacea* were prevalent; grassy weeds constituted 37% of the total weed population followed by broadleaf weeds (35%) and sedges (28%).

The population dynamics of major rice weeds were also studied during dry season, 2013. In dry direct-sown rice field, *E. colona* was the most predominant weed species in weedy plots followed by *L. chinensis* and *C. difformis.* The grassy weeds constituted 57% of the total weed population followed by sedges (26%) and broadleaved weeds (17%). In wet-direct sown rice, the mean relative density of major weed species in weedy plots at 30 DAS were *E. colona* (35%), *L. chinensis* (24%), *C. difformis* (19%) and *S. zeylanica* (15%) along with other species (7%). In case of transplanted rice, it was observed that *E. colona* was the most prevalent weed species (31% of total weed population) followed by *C. difformis* (24%), *L. chinensis* (22%), *S. zeylanica* (11%) and others (12%).

Screening of germplasm against weed competitiveness

One hundred and twenty early maturing rice germplasms (95-115 days duration) with five checks viz. Vandana, Anjali, Heera, Annada and Kalinga III were screened in augmented design with four blocks at KVK, Santhapur for weed competitiveness during wet season, 2013. The germplasms viz., IR 83929-B-B-291-2-1-1-2, IR 83750-B-B-145-4-174-3, IR-84899-B-184-18-1-1-1, IR-84887-B-153-33-1-1-3, IR-84887-B-157-38-1-1-3, IR 83750-B-B-145-4-174-2 and IR 82589-B-B-63-2-148-1 were found to be weed competitive with average plant height ranged from 97-106 cm, total weed biomass (dry weight basis) at 45 days after sowing varied from 11.2-23.3 g / m^2 and grain yield in the range of 398-512 g / m^2.

Management of weeds in dry direct-sown and aerobic rice

A field experiment was carried out during the wet season of 2013 to study the weed spectrum and the efficacy of new low dose herbicides under varying establishment methods in dry direct-sown rice. Three crop establishment methods (broadcast seeding; continuous seeding at 15 cm apart rows; sowing by a seed drill) in main plots and five weed control treatments (bispyribac-sodium (30 g / ha); azimsulfuron (35 g / ha); bensulfuron methyl + pretilachlor at 70+700 g / ha; hand weeding (twice); weedy check) in subplots were evaluated in a split plot design with three replications. It was found that *E. colona* was the most predominant weed species in weedy plots followed by *C. iria* and *L. octovalvis*. Weed infestation was comparatively less in crop established by the seed drill that resulted in better crop growth with highest grain yield (4.97 t / ha). Among the herbicide treated plots, higher grain yield (5.36 t / ha) was recorded in azimsulfuron-treated plots, with weed control efficiency of 88%. The yield reduction in weedy plot was 56%.

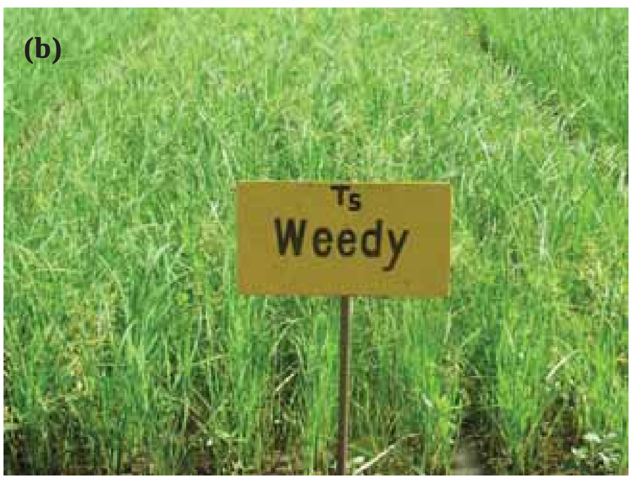


Fig 52. Field view of (a) AZM (35 g/ha) applied plots and (b)weedy check in Dry direct sown rice at 40 DAS

During the dry season of 2013, a field experiment was conducted to study the weed spectrum and efficacy of new low-dose herbicides under different rice establishment methods under aerobic conditions. The experiment was laid out in a split plot design with three establishment methods (broadcast seeding; continuous seeding at 15-cm apart rows; spot seeding at 15 x 15 cm spacing) in main plots and five weed control treatments (weed-free; weedy check; bispyribac-sodium (30 g / ha); azimsulfuron (35 g / ha); flucetosulfuron (25 g / ha)) in subplots. The major weed species in weedy plots were *E. colona*, *C. difformis*, *F. miliacea*, *S. zeylanica*, *L. chinensis*, *Alternanthera sessilis* and *Cleome viscosa*. Among different crop establishment methods, lowest weed population was recorded in the spot-seeded plots that resulted in better crop establishment. Among herbicide treatments, the lowest weed biomass (16.5 g / m^2) was recorded in the azimsulfuron-treated plots with WCE of 85% (*Fig 52*). Application of azimsulfuron to aerobic rice established by spot seeding produced highest yield of 4.1 t / ha.

Effect of low dose herbicide on weed control and grain yield

The efficacy of new low-dose high-efficacy herbicide viz., Flucetosulfuron and Flucetosulfuron followed by Bispyribac sodium (FCS fb BPS) along with herbicide mixtures viz., and Azimsulfuron + Bispyribac sodium (AZM + BPS) in conjunction with recommended herbicide BPS were evaluated during wet season, 2013 in wet direct-sown rice (var. Naveen) and transplanted rice (var. Pooja). Results revealed that application of herbicide mixture AZM + BPS (22 + 25 g / ha) and sequential application of FCS fb BPS (25 and 25 g / ha) showed excellent control of predominant grassy weeds, sedges and annual broadleaf weeds with 91% weed control efficiency(WCE) in wet direct-sown rice. The differences in grain yield due to application of AZM + BPS (4.39 t / ha) and FCS fb BPS (4.28 t / ha) were comparable showing their effectiveness for controlling weeds in wet direct-sown rice. The yield reduction in weedy plots was more than 44% due to weed competition. In transplanted rice also, the herbicide mixture AZM + BPS (22 + 25 g / ha) and sequential application of FCS fb BPS (25 and 25 g / ha) showed excellent control of predominant grassy weeds, sedges and annual broadleaf weeds with WCE of 92% and

89%, respectively. Application of AZM + BPS, 18 days after transplanting (DAT) recorded the highest grain yield (4.85 t / ha) which was 12% higher over the recommended herbicide BPS (30 g / ha) applied at 10 DAT.

A new herbicide, ICH 110 was evaluated for standardizing the application rate against complex weed in rice nursery, direct-sown and transplanted rice crop during wet season 2013. Among different application rates, ICH 110 at 30 g / ha showed excellent control of broad spectrum of weeds (WCE of 91%) when applied 15 days after nursery sowing with lowest weed biomass of 7.8 g / m^2. The efficacy of ICH 110 at 15, 20, 25, 30 g / ha were evaluated with Bispyribac sodium (BPS) at 30 g / ha and azimsulfuron (AZM) at 35 g / ha in wet direct-sown rice (var. Naveen) and transplanted rice (var. Pooja). The results revealed that application of ICH 110 (30 g / ha) at 10 days after sowing (DAS) and AZM (35 g / ha) at 15 DAS controlled broad spectrum of weeds in wet direct-sown rice field with lower weed biomass of 8.9 and 9.6 g / m^2, respectively. However, the differences in grain yields due to application of ICH 110 at 25 g / ha (4.42 t / ha), ICH 110 at 30 g / ha (4.54 t / ha) and AZM at 35 g / ha (4.50 t / ha) were comparable showing their effectiveness for controlling weeds in wet direct-sown rice field. The yield reduction due to weed competition in weedy plots was more than 43%. In transplanted rice also application of AZM (35 g / ha) and ICH 110 (25 and 30 g / ha) resulted in excellent control of predominant grassy weeds, sedges and annual broadleaf weeds with weed control efficiency (WCE) of 91%, 88% and 89%, respectively. Among the herbicide treated plots, the highest yield (4.76 t / ha) was recorded in AZM treated plots when applied at 15 days after transplanting (DAT) but it was comparable with ICH 110 (25 and 30 g / ha) applied at 10 DAT. The yield reduction due to weed competition in weedy plots was more than 36%.

Study on persistence of Pretilachlor under different moisture regimes

A laboratory study was conducted to investigate the persistence of Pretilachlor under different moisture regimes. Pretilachlor was less persistent in submerged soil having 5 cm standing water (SUB) followed by field capacity (FC) and air dried (AR) soil. Recovery of Pretilachlor obtained from soil was in the tune of 0.83-0.87 ppm after 2 hours of spray which dissipated over time to have 0.02-0.05 ppm after 30 days of spray (*Fig 53*) under laboratory condition. Dissipation of Pretilachlor followed first order kinetics with more than 0.96 coefficient of determination. Half lives of Pretilachlor were 16.90, 14.40 and 13.86 days for air dried, field capacity and submerged soils (*Table 1*), respectively.

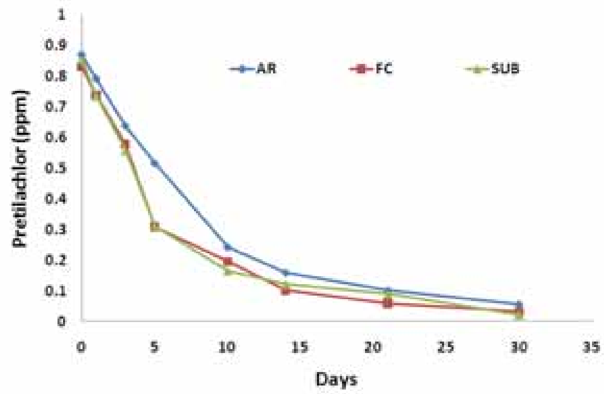


Fig 53. Persistence of Pretilachlor under different moisture regimes

Table 35. Calculation of residual half life of Pretilachlor under different moisture regimes

Condition	Regression equation	Coefficient determination	Residual half life (days)
AR	y=-0.041x-0.103	0.974	16.90
FC	y=-0.048x-0.163	0.961	14.43
SUB	y=-0.050X-0.144	0.966	13.86

Management of problem soils for enhancing productivity of rice

Preparation of soil micronutrient map of Rajnagar block of Kendrapada district

Sixty soil samples (3 km x 3 km) grids were collected from Rajnagar block of Kendrapada district. The soil samples were processed and analyzed for DTPA extractable Iron (Fe), Zinc (Zn), Manganese (Mn) and Copper (Cu). First quartile (Q1) of the dataset indicated that 25% soil samples had DTPA extractable Fe < 44.75 mg / kg, Zn < 0.62 mg / kg, Cu < 2.475 mg / kg and Mn < 0.695 mg / kg. Third quartile showed that 25% soil samples were having DTPA extractable Fe > 90.29 mg / kg, Zn > 1.23 mg / kg, Cu > 3.19 mg / kg and Mn > 9.87 mg / kg. Semivariogram modelling using ArcGIS 10 was performed to determine the best fit variogram model for the grid wise soil data. Different variogram models were fitted and Pentaspherical, Spherical, Exponential and Gaussian models were found best fitted for DTPA extractable Fe, Zn, Mn and Cu respectively based on the root mean square error and average standard error. Soil micronutrient maps were prepared using ordinary kriging interopolation technique with best fit variogram model parameters. (*Fig 54*). Map indicated that Fe content in soil was higher in whole block and no deficiency was observed. About 6.3% area of the block was found to be deficient in Zn with Zn content <0.6 mg/kg which is the critical lower limit whereas 66.3% area had medium Zn content of 0.8-1.2 mg/kg. About 44% area was deficient in Mn content with Mn content <3.5 mg/kg which is critical lower limit for Mn. Cu deficiency was not found in the block and whole area had Cu content >0.4 mg/kg.

Influence of mangrove ecosystem of Bhitarkanika on physico-chemical and biological properties of soil in Rajnagar block of Kendrapada district

Bhitarkanika sanctuary, the second largest mangrove ecosystem of India, is located along eastern coast in Kendrapada distict of Odisha at the confluence of River Bramhini and Baitarani. In this study, changes in some physico-chemical, microbial and enzymatic properties of soils of cultivated rice fields well within the sanctuary and along the Bhitarkanika mangrove forests were quantified. Soil samples were collected from mangrove forest and adjoining cultivated lands based on locations of different estuaries, rivers, sea and mangroves. Total soil organic carbon (TOC), total N, available K and Bray P were higher in mangrove soils compared to soils of cultivated rice fields. Soil pH was in acidic range at all locations but was moderated towards neutral in mangrove soils. Considerable variation was observed between enzymatic activities (Dehydrogenase, Urease, FDA hydrolysis, Acid phosphatase) among the different locations and higher activities were reported in mangrove soil except for acid phosphatase activity which was found higher in soils of cultivated rice fields adjoining the mangroves. Populations of ammonium oxidizer and nitrate oxidizer were higher in mangrove soils whereas populations of aerobic hetreotrophs were higher in cultivated rice fields.

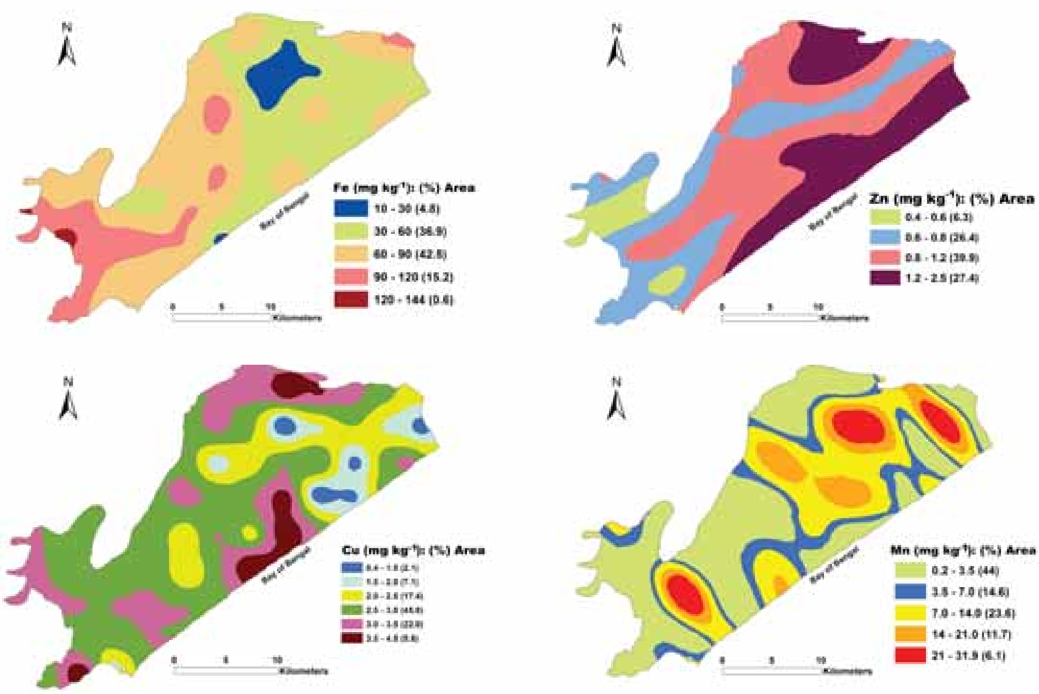


Fig 54. Soil micronutrient map (DTPA extractable Fe, Zn Cu and Mn) of Rajnagar Block in Kendrapada District of Odisha (Figures in parenthesis in legends shows the % area of particular class)

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

Mass production of the potent biocides of leaf folder in cheaper media

The entomopathogenic fungi viz. *Beauveria bassiana* TF6, *Metarhizium anisopliae* TF19 (*Figs 55 and 56*), and *Bacillus thuringiensis* strains TB160, 161, 261 and 263 were mass produced in cheaper media (g / l): (1) molasses 30, yeast extract 10, glycerol 20, pH 7; (2) molasses 30, ground nut cake 25, fish meal 10, pH 7 and (3) soy flour 25, ground nut cake 25, fish meal 10, pH 7, and compared with the conventional nutrient broth (NB) medium i.e. peptone 5, beef extract 3, NaCl 3, pH 7 (*Table 36*).

Growth i.e. spore production ($x10^9$ cfu / ml) of *B. bassiana* TF6, *M. anisopliae* TF19, *B. thuringiensis* TB160, 161, 261 and 263 was more in medium no. 2 and spore production ($x10^9$ cfu / ml) in the medium was 0.85, 0.78, 1.01, 0.59, 4.88 and 3.51, respectively.

Fig 55. Plate culture of formulated B. bassiana

Fig 56. Plate culture of formulated M. anosopliae

Table 36. Optimization of mass production and preservation of biocide formulations

	Mass production		Viability		
Organism	Medium	Colony forming unit ($x10^9$ / ml)	Formulation (%)	Initial viability (%, cfu / g product)	Viability after 6 month (%)
B. bassiana	Molasses 30, ground nut cake 25, fish meal 10, pH 7	0.85	A + glycerin - 1, skim milk - 10	100 (4.22×10^9)*	99.82
M. anisopliae	Do	0.78	A + glycerin - 1, charcoal - 2	100 (5.38×10^9)*	99.61
Bt (TB160)	Do	1.01	A + Formalin – 0.1, charcoal - 1	100 (5.76×10^9)*	99.81
Bt (TB161)	Do	0.59	B + boric acid – 0.2, charcoal – 0.5	100 (4.34×10^9)*	99.86
Bt (TB261)	Do	4.88	A + methyl-p-hydroxy benzoic acid – 0.2, Congo red - 1	100 (4.03×10^9)*	99.80
Bt (TB263)	Do	3.51	B + Na-benzoate 0.2, sun screen 1	100 (5.44×10^9)*	99.98

*Viable cfu immediately after formulation. A = Talc – 40, CMC – 6, Tween 80 – 4, soy flour – 1; B = Bentonite – 40, CMC – 6, Tween 80 – 4, soy flour-1.

Assessment of shelf life of the biocides in formulations of different carriers, preservatives and UV protectants

The mass produced pathogens were formulated separately with each of the carriers (fillers) like kaolin, bentonite, talc powder, mud dust (peat soil) of Patnayak tank of CRRI and vermiculite (40 g) containing the sticker CMC (6 g), spreader Tween 80 (4 g) and C-source soy flour (1 g) containing about 4-5 x 10^9 cfu / g product. Persistence of the biocides differed with formulations. After 6 month storage at 30±1°C in talc-base formulation, optimum viability of *B. bassiana* was 99.82% out of initial 4.22 x 10^9 cfu / g product, *M. anisopliae* was 99.61% out of initial 5.38 x 10^9 cfu / g product, *B. thuringiensis* TB160 was 99.81% out of initial 5.76 x 10^9 cfu / g product and *B. thuringiensis* TB261 was 99.80% out of initial 4.03 x 10^9 cfu / g product (*Table 36*). However, *B. thuringiensis* TB161 and 263 survived more in bentonite-based formulation i.e. 99.86% out of initial 4.34 x 10^9 cfu / g product and 99.98% out of initial 5.44 x 10^9 cfu / g product, respectively (*Table 36*).

Effects of the preservatives viz. glycerin, formalin, Na-benzoate, citric acid, boric acid and methyl p-hydroxy benzoate, and the UV protectants viz. charcoal, Congo red, oxybenzone (sunscreen) and skim milk were assessed for enhancement of shelf life of the biocide formulations up to 6 months (*Table 36*). In talc-based formulation, glycerin (1%) with skim milk (10%) retained about 99% viabile spores of *B. bassiana* TF6; glycerin (1%) with charcoal (2%) supported 99% spore viability of *M. anisopliae* TF19; formalin (0.1%) with charcoal (1%) supported 99% spore viability of *B. thuringiensis* TB160 and methyl-p-hydroxybenzoic acid (0.2%) with Congo red (1%) supported 99% spore survival of TB 261. However, in bentonite-based formulation, boric acid (0.2%) with charcoal (0.5%) favoured 99% spore viability of *B. thuringiensis* TB161 and Na-benzoate (0.2%) with oxybenzone (sunscreen) (1%) supported viability of about 99% of *B. thuringiensis* TB263.

Detection of *cry* genes of formulated *Bacillus thuringiensis*

The *cry1* and *cry2* genes (effective against lepidopteran insects) of the four formulated *B. thuringiensis* strains were detected using their specific primers (*Fig 57*). *B. thuringiensis* strain TB261 and 263 possess both of the expected *cry1* (290 bp) and *cry2* (780 bp) genes. The TB160 possessed neither expected *cry1* nor *cry2* genes but expressed non-specific amplification

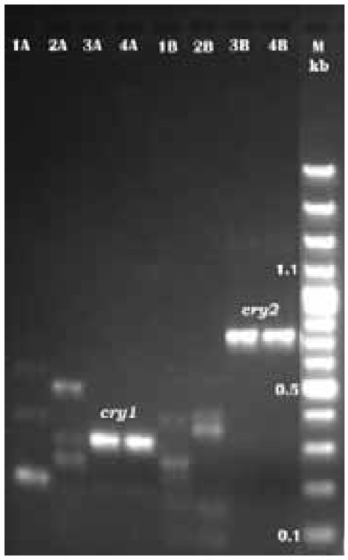


Fig 57. Detection of cry1 and cry 2 genes in 4 formulated B. thuringiensis strains
Lane symbols: A = cry1 *and B =* cry2 *amplicons. 1 = TB160, 2 = TB161, 3 = TB261 and 4 = TB263*

for both of them. The TB161 possessed the expected *cry1* gene (290 bp) along with non-specific amplicons but *cry2* amplicon was smaller than the expected amplicon size. However, presence of both *cry1* and *cry2* genes (either known or allelic) in the formulated strains would increase their virulence against the leaf folder.

Efficacy of stress-tolerant antagonistic isolates against sheath blight disease and bacterial leaf blight disease of rice

The stress-tolerant antagonistic isolates, *Bacillus tequilensis* SHU 41 (NCBI accession no. KF577875), *Paenibacillus* sp. SHU53 (NCBI accession no. KF577876) and *Bacillus amyloliquefaciens* B20 (NCBI accession no. KF577865) were isolated from paddy soil of CRRI, Cuttack and Sundarban, respectively. The crude metabolites of these isolates were extracted using one non-polar solvent (hexane) and two partially polar solvents (n-butanol and ethyl acetate) and their antagonistic efficacy were tested against *Rhizoctonia solani* using pot experiment for rice crop along with positive controls (Bavistin, *T. viridae*) and negative controls (absolute control and *R. solani* alone). The sheath infection (%) in rice crop by *R. solani* was recorded on 7th, 14th, 21st and 28th day of fungal pathogen inoculation. The descending order of sheath infection (%) on 7th day was negative control (18) > SHU41 (8.77) > bavistin (6.77) > SHU53 (5.71) > B20(2.98) > *T. viridae* (2.67); on 14th day was negative control (23.73)>SHU41

(8.78)> B20(8.63) > bavistin (7.51) > SHU53 (6.30) > T. *viridae* (2.73); 21st day was negative control (26.27) > *T. viridae* (8.55) > bavistin (8.38) > B20 (7.56) > SHU41 (6.86) > SHU53 (6.49)] and on 28th day was negative control (28.24) > B20(9.76)) > bavistin (8.35) > SHU41 (8.33) > *T. viridae* (7.80) > SHU53 (6.75). No sheath infection was recorded from outside environment in the absolute control from 7th day to 28th day of observation.

Similarly, the efficacy of an antagonistic isolate (SHU53) against *Xanthomonas oryzae* was also assessed along with positive controls (Plantamycin, *Psudomonas fluorescence*) and negative controls (absolute control and *X. Oryzae* alone) using pot experiment for rice crop. The leaf infection (%) in rice crop by *X. oryzae* was recorded on 7th, 14th, 21st and 28th day of bacterial pathogen inoculation. The descending order of leaf infection (%) on 7th day was negative control (0.91) = SHU53 (0.91) > *P. fuorescence* (0.87) > Plantamycin (0.22); on 14th day was negative control (2.32) > *P. fuorescence* (1.69) > SHU53 (1.66) > Plantamycin (0.93); on 21st day was *P. fuorescence* (13.46 > SHU53 (8.67) > negative control (6.35) > Plantamycin (1.58) and on 28th day was negative control (24.75)) > *P. fuorescence* (16.31) > SHU53 (15.78) > Plantamycin (12.69).

Diversity of thermotolerant plant growth-promoting microbes (PGPM) from four hot springs (Atri, Taptapani, Tarabalo and Deulajhari) of Odisha

Soil and water samples were collected from four hot springs (Atri, Taptapani, Deulajhari and Tarabalo) of Odisha and analyzed for physical, chemical and biological activities. Out of 43 thermotolerant bacteria and 10 fungal isolates, 11 bacteria (TBB1, TBR1, TBR2, TPB4, TPB7, TPB12, TBP13, TP1, TPP2, DE1 and DER8) and 8 fungal isolates (ATF1, DEF1, DEF2, DEF3, DEF4, DEF7, DFR1 and DFR2) showed thermo-tolerance up to 55˚C and also showed polyvalent PGP traits under both ambient (25-35˚C) and elevated temperatures (45-55˚C).

Soil and crop management for productivity enhancement in rainfed upland ecosystem

Response of direct seeded rice to NPK

Performance of elite rice cultures for direct seeding was evaluated under different fertility regimes in red sandy soils. Treatments consisted of three NPK Levels (30:20:15, 60:40:30 and 90:60:45 kg / ha) in main plots and six early maturing elite cultures / varieties (CRR 455-109, CRR 363-136, CRR 616-B-66-2, CRR617-B-47-3, Vandana and Anjali) in sub plots were arranged in split plot design and replicated thrice. Significant variations in the grain yield were observed with moderate level of NPK application (60:40:30 kg / ha) though further increase in NPK level failed to significantly influence grain yield in red sandy soils. The Culture CRR 617-B-47-3 and CRR 616-B-66-2 yielded at par with both the released upland rice varieties 'Vandana' and 'Anjali'.

Agro-techniques for direct seeded rice under aerobic conditions

Direct seeded rice is gaining popularity and its cultivation under aerobic situations makes it possible to achieve substantially higher yield. Experiments were conducted to find out suitable varieties and hybrids under aerobic condition, optimal planting time and seeding density during the 2013 wet season.

For identification of suitable varieties / hybrids and optimum planting time, three sowing dates (20th June, 30th June and 10th July) and six HYVs / hybrids (Sahbhagidhan, Abhishek, DRRH 3, PAC 837, PHB 71 and PAC 801) were arranged in a split plot design. The results indicated that performance of rice varieties varied depending on the time of planting. On an average, hybrids produced higher yield of 0.69 t / ha over the HYVs (*Fig 58*). When averaged over planting dates, maximum grain yield was recorded by PAC 837 followed by PHB 71 and DRH 3. Hybrids yielded better than the high yielding rice varieties. The hybrid PAC 837 produced superior grain yield when planted on June 20 and 30, while PHB 71 registered the highest yield when sown on 10th July. Abhishek excelled over

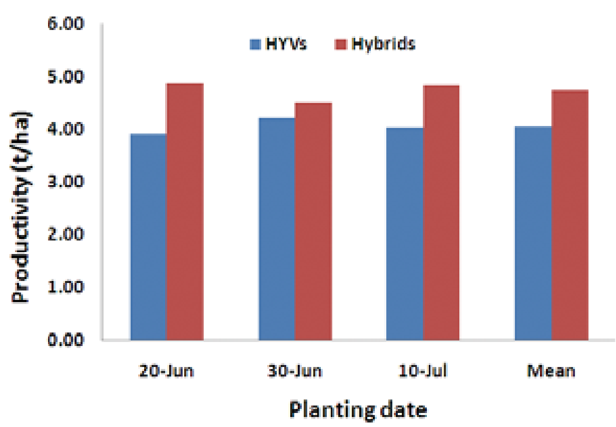


Fig 58. Hybrids vs HYVs: Planting time & productivity

Sahbhagidhan when sown on June 20 and Sahbhagi Dhan performed better than Abhishek on other sowing dates.

Crop intensification in direct seeded rice

Performance of different mustard varieties for their suitability as a sequence crop after harvest of rice was evaluated in medium textured upland soils. Mustard varieties did not differ among themselves in their productivity. Chickpea cultivars showed substantial differences in their yielding ability as a sequence crop after harvest of direct seeded rice. Chickpea varieties KPG 59, Birsa Chana 3 and KWR 108 performed better and produced higher seed yield than Kak 2.

In rice based intercropping studies in red soils, application of full quantity of recommended fertilizer dose along with 20 kg sulfur produced highest rice equivalent yield. Intercropping of rice with soybean or black gram proved superior in 4:2 replacement series.

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

The fixed plot experiment was conducted during the wet seasons (WS) of 2010 and 2011 and was repeated during WS of 2012 and 2013 with an objective of integrating the AM-supportive crop management component options. The AM-supportive component options evaluated for integration were: (i) two rice based crop rotations (two years) viz., (a) pigeon pea –rice (PP / R) in alternate year, (b) maize relay cropped by horse gram in first year and rice in 2^{nd} year (M-HG / R); (ii) Dual inoculum application: on-farm produced soil-root based AMF + P-solubilizer (*Bacillus licheniformis*) inoculum application @ 1.25 t / ha; (iii) three P source combinations: viz.; (a) 100% P as DAP, (b) 100% P as Purulia Rock Phosphate (PRP) containing 18-20% P_2O_5, (iii) 50% P as DAP and 50% as PRP. The first rotation was conducted during wet seasons of 2010 and 2011 and was repeated during 2012 and 2013 for confirmation. A progressive AMF population buildup with additive effects was confirmed in M-HG / R rotation applied with dual inoculum (AMF + P-solubilizer) under P source of 50% P as DAP and 50% as PRP. Higher native AMF Population under this treatment resulted in significantly highest colonization; P uptake and grain yield (*Table 37*).

Identification of new AM-supportive crop management components

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

AM-supportive off-season tillage (OST) schedule of spacing two OST operations by minimum 13 weeks was worked out earlier. Two off season tillage methods viz.; conventional tillage (CT; using tractor drawn cultivator) and deep tillage (DT; using tractor drawn MB plough) were compared following the AM-supportive OST schedule. Conventional tillage supported higher initial (June) and final (October) native AM-fungal population (*Fig 59*) with concomitant increase in P uptake (31.9%) and grain yield (5.6%) in rice variety CR Dhan 40 grown as DSR sown using a seed drill.

Varietal response to AMF

Four advanced breeding lines and one upland variety (Anjali) were evaluated under glass house condition for their early stage (30 DAE) mycorrhiza response (MR) as compared to Sathi 34-36 the established highly responsive variety. Two sets (six replications) of the six test entries were grown under AMF inoculated (AM+) and un-inoculated (AM-)

Table 37. Interactive effects of AM-supportive crop management components on AMF colonization, P uptake and grain yield of upland rice (cv. Vandana, wet season 2013)

	RLC (%)		P uptake (kg P_2O_5 / ha)		Grain yield (t / ha)	
Treatments	PP / R	M-HG / R	PP / R	M-HG / R	PP / R	M-HG / R
100% DAP	13.6 a	22.7 b	13.66 bc	18.50 ef	1.76 b	2.13 cd
100% PRP	21.9 b	28.5 bcd	8.35 a	12.42 b	1.26 a	1.71 b
50% DAP+50% PRP	26.5 bc	33.5 ef	11.80 b	14.95 cd	1.64 b	2.06 cd
100% DAP + MI	33.6 ef	31.1 de	17.99 e	20.10 f	2.25 de	2.40 d
100% PRP + MI	40.9 g	37.1 f	13.68 bc	17.44 de	1.61 b	2.01 c
50% DAP+50% PRP + MI	46.1 g	52.4 h	16.18 cd	22.80 f	2.19 cde	2.65 e

Data under each parameter followed by different letters are significantly different at 5% probability level

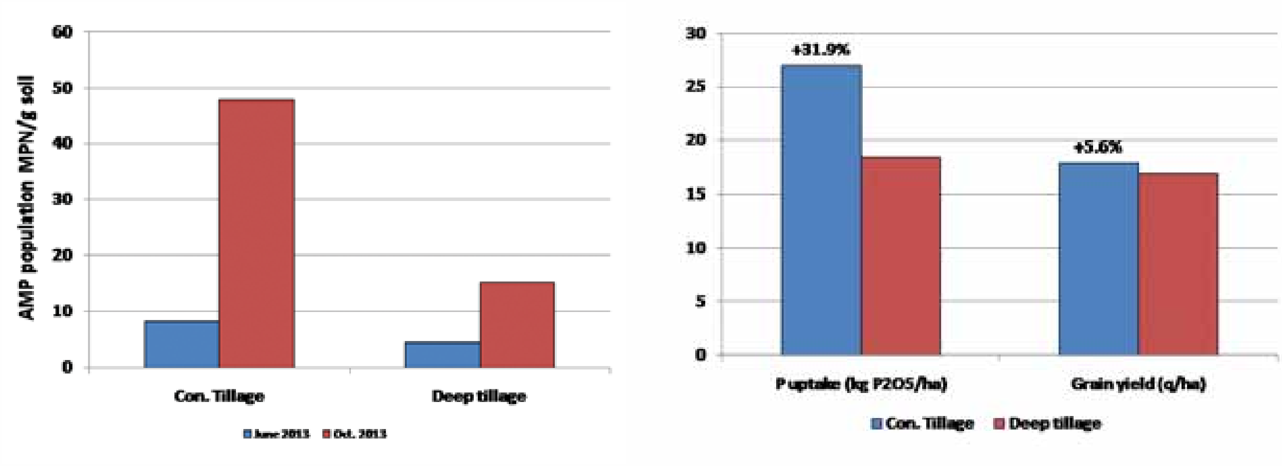


Fig 59. Effects of off-season tillage methods on (A) native AMF population dynamics and (B) P uptake and grain yield in DSR (CR Dhan 40)

conditions. The MR in terms of total dry matter production and P uptake at 30 DAE was calculated as % MR = [((AM+) – (AM-)) / (AM+)]*100. Up to 30 DAE, Anjali showed negative response (% MR) and CRR 676-1 (Vandana NIL) showed highest % MR among the tested four breeding lines which tended to be *at par* with Sathi 34-36 both in terms of biomass production and P uptake (*Fig 60*).

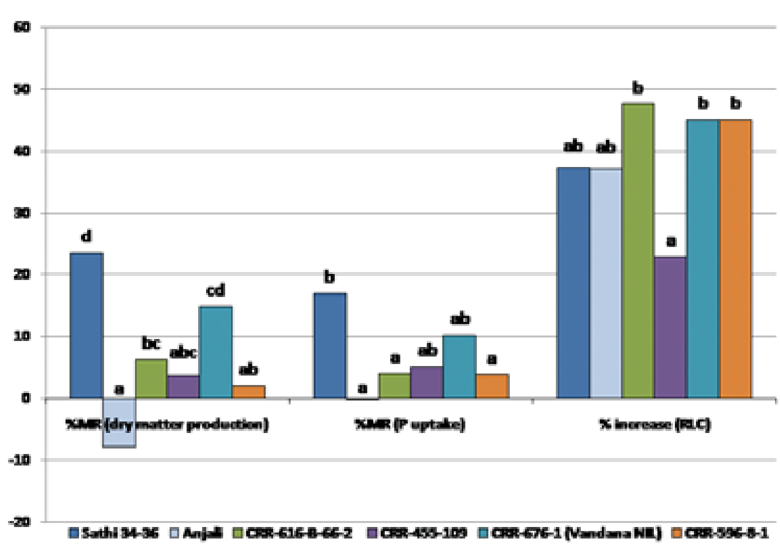


Fig 60. Mycorrhiza response (MR%) of selected advance breeding lines (upland) at early stage (30 DAE)

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

Evaluation of rice varieties, stand establishment methods and crop geometry under post-flood situation in rainfed lowland ecosystem

Four rice varieties (Anjali, Luit, Abhishek and Naveen), three crop stand establishment methods (double transplanting, normal transplanting and direct wet seeding) and two spacing (20x15 cm and 15x15 cm) were evaluated at the experimental farm of Regional Rainfed Lowland Rice Research Station (RRLRRS), Gerua (Assam) during 2013 late *sali* season. The experiment was laid in split-split plot design and replicated thrice. The crop was planted on 10th September, 2013. Rice variety Abhishek was found superior than Naveen, Luit and Anjali under late transplanting condition. The plant height, days to 50% flowering, number of panicles per unit area, number of grains per panicle, grain yield, straw yield differed significantly under different crop establishment methods. The days to 50% flowering increased by 9 days in double transplanting and decreased by 5 days under wet direct seeding methods. Normal transplanting recorded significantly higher grain yield than double transplanting and wet direct sown method. The higher grain yield was due to higher number of panicles per unit area and number of grains per panicle. Spacing had significant effect on grain yield and yield attributes like number of panicles per unit area.

The interaction effect between variety and stand establishment methods was significant in respect of number of panicles per unit area, number of grains per panicle and grain yield. Normal transplanting of Abhishek at 15x15 cm spacing recorded higher grain yield (5.60 t / ha), number of panicles (288 / m^2) and grains per panicle (114.7) as compared to wider spacing and double transplanting or direct wet seeding.

Influence of integrated weed management practices on weed flora and productivity of *boro* rice

Performance of transplanted rice under different weed management practices was evaluated during *boro* / early *ahu* season of 2012-13 at the experimental farm of RRLRRS, Gerua. The treatments consisted of seven weed management practices, *viz*., Butachlor @ 1.5 kg ai / ha (W1), Butachlor @ 1.0 kg ai / ha + 2, 4-D @ 1.0 kg ai / ha (W2), Bensulfuron methyl 0.6% + Pretilachlor 6% G @ 10.0 kg / ha (W3), Chlorimuron + Metsulfuron-methyl 20 WP @ 4 g ai / ha (W4), Pyrazosulfuron ethyl @ 30 g / ha (W5), Hand weeding twice at 25 and 50 days after transplanting (W6) and Weedy check (W7). The highest grain yield (7.2 t / ha) was obtained from W6 (hand weeding twice) which was statistically on par with pre-emergence application of Pyrazosulfuron ethyl (6.7 t / ha) and ready-mix Chlorimuron + Metsulfuron methyl (6.2 t / ha). The highest net return (Rs. 53,950 / ha) and B:C ratio (2.39) was obtained from hand weeding twice followed by Pyrazosulfuron ethyl application and Chlorimuron + Metsulfuron methyl application.

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

During *boro* 2012-13, an experiment was carried out in split-plot design with two varieties (Chandrama and Naveen) in the main plots and five different dates of transplanting (5th January, 15th January, 25th January, 5th February and 15th February) in the sub plots. Among the varieties, Chandrama recorded significantly higher grain yield (6.77 t / ha) over Naveen (5.10 t / ha). Highest grain yield (6.45 t / ha) was obtained with 25th January transplanting followed by 5th February transplanting (6.23 t / ha) while the lowest with 5th January transplanting. It was observed that there was gradual increase in yield up to 25th January and thereafter gradual reduction in the grain yield. Transplanting on 15th February resulted in more number of chaffy grains per panicle.

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

An experiment was laid out in split-plot design during *boro* 2012-13 at the experimental farm of RRLRRS, Gerua with two rice varieties – Chandrama and Naveen – in main plots and five different age of seedings – 50, 60, 70, 80 and 90 days – in the sub plots. Maximum grain yields of 6.23 t / ha in Chandrama and 4.73 t / ha in Naveen were obtained with 50 days old seedlings. Thereafter, progressive reduction in yield was observed with increase in the age of seedlings in both the varieties.

PROGRAMME 3

Rice Pests and Diseases–Emerging Problems and Their Management

The programme envisages improvement of rice productivity through monitoring and management of the pests and diseases of rice. Therefore, the activities of the programme were focused to reveal and conjecture the diversity, dynamics and functionalities of different pests and diseases through laboratory, net house, storehouse and field experiments to improve / sustain rice production in various ecologies and develop deliverable technologies. During the period, the scientists have developed thorough knowledge of prevalent pests and pathogens of rice, resistant genotypes, ecofriendly beneficial bioagents and active principles of botanical biocides effective against the pest and diseases. Integrated management techniques have been developed or being developed and demonstrated in the field to sustain rice production.

During 2013-14, resistant varieties against brown spot (n=2), RTD (n=2), brown plant hopper (BPH) (n= 24) and WBPH (n=2 with moderate resistance), GM (n=750) and root knot nematode (n=2) were identified. Scientists have studied dynamics of the various pests, beneficial insects and diseases from different parts of the country.

Effects of different pesticides / insecticides on the pests, beneficial insects and pathogens have been worked out to exploit them for chemical control. The active ingredient of *Ocimum sanctum* oil has been identified as eugenol. Besides, the biocontrol agents like one *Trichoderma* spp. against seedling rot, two bacteria against seedling blight (*Sclerotium* sp.) and one endophyte (*Acremonium* sp.) against *R. solani* (sheath blight disease of rice) and *Sclerotium rolfsi* (seedling blight of rice) were identified which can be used in the field without affecting the environmental and biological health. The results would be helpful to improve rice production in the country.

Management of rice diseases in different ecologies

Several diseases are responsible for the reduction of yield in rice in different ecologies. In order combat the yield loss due to diseases, various measurements are being taken which include the use of fungicides, bio-control agents, resistant genotypes etc. But evolution of new races / strains of the pathogen has made it difficult for the farmers to stick to a particular technology. Therefore, there is a need to study the effectiveness of new formulations, identification of indigenous bio-control agents, variations among different rice pathogens and identification of new donors for resistance against different diseases.

Identification of resistant/tolerant donors against rice diseases

Rice germplasm lines were screened during *kharif* 2013 against sheath blight, blast, bacterial blight and brown spot diseases using standard evaluation technique under field condition by artificial inoculation. One thousand two hundred fifty eight germplasm lines were screened for identification of donors against sheath blight resistance and it was observed that 52 of them were highly susceptible, 1070 were moderately susceptible, 53 were moderately resistant. Similarly, out of 1670 lines, only two lines showed resistant reaction against brown spot, whereas, out of 1685 lines, 118 lines showed resistant reaction and 1242 lines showed moderate to high susceptibility against bacterial leaf blight diseases.

Isolation of indigenous biocontrol agents for management of rice diseases

Thirteen native *Trichoderma* strains were isolated from Cuttack (*Fig 61*). The *Trichoderma* species were identified using RNA Polymerase-II (RPB-II), Translation elongation factor 1 (TEF-1) and ITS regions. The biocontrol efficiency of all these isolates were tested using dual culture method against the *Sclerotium oryzae* pathogens *Rhozoctonia solani*, *Sclerotium oryzae*, *Fusarium* sp. and *Curvularia* sp. (*Fig 62*). Based on the result of dual culture, five isolates have been selected for further studies. Two isolates were used to study the effect on seedling mortality in rice and it was observed that the seeds treated with isolate T-2 showed 95% post emergence survival compared to 60% survival of the control.

Fig 61. *Different isolates of Trichoderma obtained from CRRI, Cuttack*

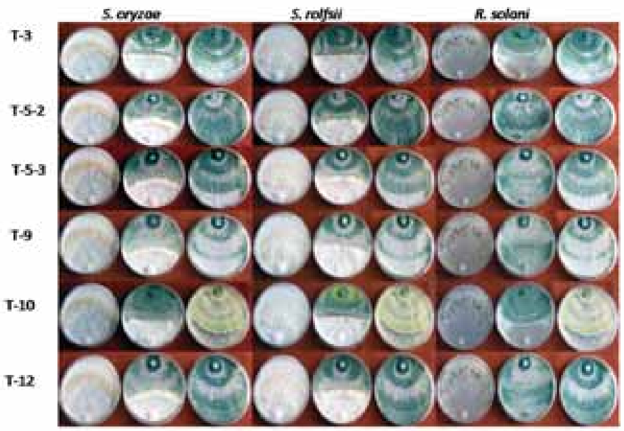


Fig 62. *Dual culture of different representative Trichoderma spp. showing inhibition of growth of different pathogens*

Bacteriophage specific to *Xanthomonas oryzae* pv. *oryzae* (X.o.o) effective for biocontrol of X.o.o has been isolated from CRRI field. The lysis property of the bacteriophage was tested against X.o.o and it was observed that the isolate collected from germplasm maintenance field was the best pathogen (*Fig 63*).

The bio-control agents i.e. the bacterial isolates, BC_1 and BC_2 were effective against the seedling blight (causal agent (c.o.) *Sclerotium* sp.) of rice var. Satabdi. Yield of Satabdi increased 1.6 times after treatment with bio-control agents BC_1 and 1.4 times by BC_2. Effective management of seedling blight (c.o. *Sclerotium* sp.) of Ketakijoha by bio-control agents BC_1 and BC_2 was done in seed bed during *kharif* 2013. Endophytic *Acremonium* sp. from rice var. Karuna was found to be effective against the blast pathogen in dual culture.

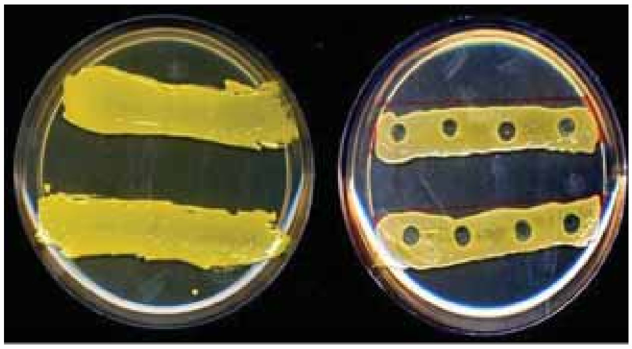


Fig 63. Bacteriophage specific to Xanthomonas oryzae pv. *oryzae showing complete lysis of X.o.o (C=control, T= treated with bacteriophage)*

Identification and genetic variability of emerging diseases

Severe incidence of seedling blight of rice (c.o. *Sclerotium* sp.) was reported during 2009-10 in seedbeds of rice var. Sarala. Since then it was observed on various rice cultivars during 2012 and 2013. The isolates collected during previous years were compared with the pathogen isolated during 2013 and variability in their nucleotide sequences was evident.

Samples of eight *R. solani* isolates infecting rice have been collected from four different states and studied their morphological variability. It was observed that the morphological characters of the isolates, especially in the formation and orientation of sclerotia, are highly different (*Fig 64*).

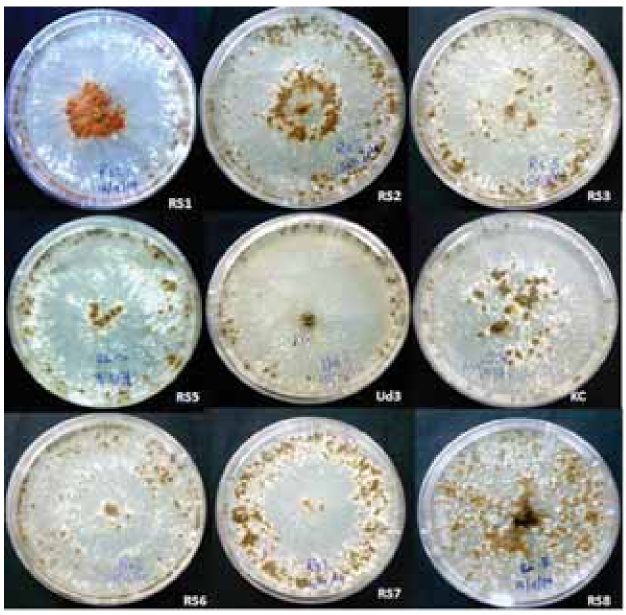


Fig 64. Different isolates of R. solani *showing variations in sclerotia formation and orientation*

Studies on toxin producing micro-flora and its management strategies

Basic information for designing RAPD-SCAR markers for detecting aflatoxigenic *Aspergillus flavus* was generated. RAPD primer 3B could differentiate aflatoxigenic and non-toxigenic isolates.

Biopolymer i.e. polycaprolactone (PCL) beads were not found useful for controlled drug delivery against toxigenic *A. flavus*. The PCL beads were used for controlled delivery of Tilt (propiconazole 25% EC) for management of toxigenic *A. flavus*. The PCL beads were impregnated *in vitro* in various concentration of Tilt (propiconazole 25% EC). Tilt 0.15% was very effective and 100% inhibition was observed, whereas, ten times more quantity of Tilt delivered through PCL beads had shown about 60% inhibition of growth of the fungus.

Partial purification and isolation of active ingredient from *Ocimum sanctum*

Isolation and identification of active principle from *O. sanctum* was accomplished. The isolated and purified compound has been subjected to ultraviolet (UV), infrared-spectroscopy (IR), nuclear magnetic resonance spectroscopy (for both 1H-NMR and 13C-NMR), mass spectroscopy and elemental analysis. Spectral analysis of the isolated compound revealed that the active constituent in *O. sanctum* could be tentatively identified as eugenol. However, for a final confirmation with regard to the structural elucidation of the compound is being processed through outsourcing (SAIF, Chandigarh) and is likely to be completed soon.

Elemental analysis interpretation

The elemental analysis of purified active compound showed the presence of carbon, hydrogen and oxygen as follows: carbon (73.08%), hydrogen (7.31%) and oxygen (19.49%).

The tentative structure of bioactive compound is presented in *Fig 65*.

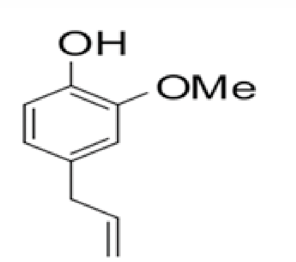


Fig 65. Tentative structure of bioactive compound (eugenol)

Shelf-life test

AME+A+ and SAEA+ up to 0.01% concentration showed almost complete inhibition (98%) of *P. grisea* for 30 and 24 months storage (*Table 38 and 39*).

Table 38. Shelf-life effect of coded formulating agent (A+) with aqueous extract of *Aegle marmelos* against conidial germination of *P. grisea*

Extracts	Treatment concentration (%)	Storage period (months)														
		0 (Fresh)			8			16			24			30		
		Conidial germination(%)														
		I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Aqueous	1	2 a (8.1)	2a (8.1)	2 a (8.1)	98 (81.9)	2 a (8.1)	2 a (8.1)	98 (81.9)	2 a (8.1)	2 a (8.1)	98 (81.9)	2 a (8.1)	2 a (8.1)	98 (81.9)	2 a (8.1)	2 a (8.1)
	0.1	30 bg (33.2)	2 a (8.1)	2 a (8.1)	98 (81.9)	2 a (8.1)	2 a (8.1)	98 (81.9)	2 a (8.1)	2 a (8.1)	98 (81.9)	2 a (8.1)	2 a (8.1)	98 (81.9)	2 a (8.1)	2 a (8.1)
	0.01	80 bg (63.4)	2 a (8.1)	2 a (8.1)	98 (81.9)	2 a (8.1)	2 a (8.1)	98 (81.9)	2 a (8.1)	2 a (8.1)	98 (81.9)	2 a (8.1)	2 a (8.1)	98 (81.9)	2 a (8.1)	2 a (8.1)
	0.001	98 (81.9)	20 bg (26.5)	20 bg (26.5)	98 (81.9)	20 bg (26.6)	20 bg (26.6)	98 (81.9)	60 bg (50.8)	40 bg (39.2)	98 (81.9)	80 bge (63.4)	60 bge (50.8)	98 (81.9)	90 be (71.6)	65 bge (53.8)
	Control	98 (81.9)	98 (81.9)	98 (81.9)	98 (81.9)	98 (81.9)	98 (81.9)	98 (81.9)	98 (81.9)	98 (81.9)	98 (81.9)	98 (81.9)	98 (81.9)	98 (81.9)	98 (81.9)	98 (81.9)

C.D. 5%= 1.2; Data in parentheses represents angular values; Complete inhibition is represented as 2%; a= un-germinated conidia; b= reduced germ tube; g= granulated germ tube; e= Thickened gem tube

Table 39. Assessment of shelf-life and efficacy of botanical formulation against rice blast inciting *P. grisea*

Extracts	Concentration (%)	Storage period (months)											
		Fresh			8			16			24		
		I	II	III	I	II	III	I	II	III	I	II	III
SAE	1	2 1 (8.13)	21 (8.13)	21 (8.13)	21 (8.13)	21 (8.13)	21 (8.13)	21 (8.13)	98 (8.13)	21 (8.13)	21 (8.13)	98 (8.13)	21 (8.13)
	0.1	2 1 (8.13)	21 (8.13)	21 (8.13)	21 (8.13)	98 2,7 (81.87)	21 (8.13)	21 (8.13)	98 (8.13)	21 (8.13)	21 (8.13)	98 (8.13)	21 (8.13)
	0.01	2 1 (8.13)	30 1,2 (33.21)	21 (8.13)	21 (8.13)	98 (81.87)	21 (8.13)	21 (8.13)	98 (8.13)	21 (8.13)	41 (11.54)	98 (8.13)	21 (8.13)
	0.001	30 1,2,7 (33.21)	80 1,6,10 (63.44)	35 2,7 (36.3)	30 1,2,7 (33.21)	98 (81.87)	35 2,7 (36.3)	30 1,2,7 (33.21)	98 (8.13)	35 2,7 (36.3)	30 1,2,7 (33.21)	98 (8.13)	35 2,7 (36.3)
	0.0001	98 (81.87)	98 (81.87)	98 (81.87)	98 (81.87)	98 (81.87)	98 (81.87)	98 (81.87)	98 (8.13)	98 (81.87)	98 (81.87)	98 (8.13)	98 (81.87)
	Control	98 (81.87)	98 (81.87)	98 (81.87)	98 (81.87)	98 (81.87)	98 (81.87)	98 (81.87)	98 (81.87)	98 (81.87)	98 (81.87)	98 (81.87)	98 (81.87)

C.D. 5%= 3.31, I=SAEA+, II=SAE, III=A+. Data in parentheses represents angular values, 1= granulation in conidial cytoplasm, 2= reduced germ tube, 6= coiled germ tube, 7= granulated germ tube, 10= thin germ tube

Evaluation of pesticides and bio-pesticides against rice sheath blight disease

Six fungicides and their mixture namely, Trifloxystrobin 25%+Tebuconazole 50% (Navito 75WG @ 0.8 g), Kresoxim methyl (Ergon 44.3SC @ 2ml), Azoxystrobin (Amistar 25SC @ 2 ml), Tricylazole (Beam 75WP @ 1.2 g), Carbendazim (Bavistin 50WP @ 2g), Propiconazole (Tilt 25EC @ 2 ml) along with control were evaluated against artificially inoculated sheath blight disease under tropical low land rice (variety Annapurna) ecosystem. Among the six tested fungicides, Azoxystrobin controlled sheath blight effectively (13.76% infection), whereas, control has 23.69% infection (*Fig 66*). It might be due to higher shelf life of Azoxystrobin. Highest yield (3387.5 kg / ha) was obtained in azoxystrobin treated plot. But yield did not vary significantly among the treatments. Effects of synthetic fungicides on soil microbial activities namely microbial biomass carbon, fluorescein hydrolase, dehydrogenase activities were studied. Short-term effect of synthetic fungicides on soil microbial activities was noticed, but after 30 days of spray no difference among the treatments were found. *Pseudomonas* had shown better control of sheath blight disease of variety Tapaswini compare to *Trichoderma* sp. (*Fig 67*).

Rice endophyte interaction with pathogens and pests in relation to environment

The strains of endophytic *Dendryphiella* sp. were isolated from rice cultivar Sarala and Savitri. *Dendryphiella sp* (NCBI Accession No.KC832507) could completely check the growth of pathogenic *R. oryzae sativae.* Sclerotia production was significantly (90%) reduced. Endophyte strains FV25 and FV16-II of *Dendryphiella* were very effective against pathogenic *Rhizoctonia solani* (c.o. of sheath blight disease of rice) and *Sclerotium rolfsi* (c.o. of seedling blight of rice) (*Fig 68 and 69*). Temperature between 30-35^{0} C was favourable for the *Dendryphiella* strains.

Effect against insect pests

The cell free cultural filtrates (ccf) of *Dendryphiella* strain FV9, FV 25, FV16-I, FV16-II were applied as foliar spray on susceptible TN1 plants or seedlings according to insect infestation. For gall midge, 15-day-old seedlings, raised in test trays in replicated design (3 replication), were sprayed uniformly with the test solutions and gall midge adults were released uniformly in each replication and control trays. The rate of silver shoot formation was observed after 20 days

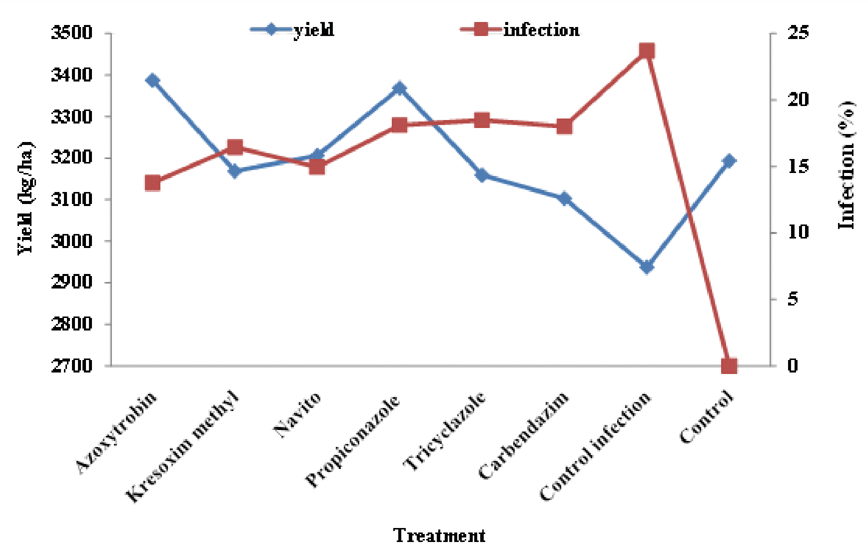


Fig 66. Efficacy of synthetic fungicides against sheath blight of rice (Variety: Annapurna)

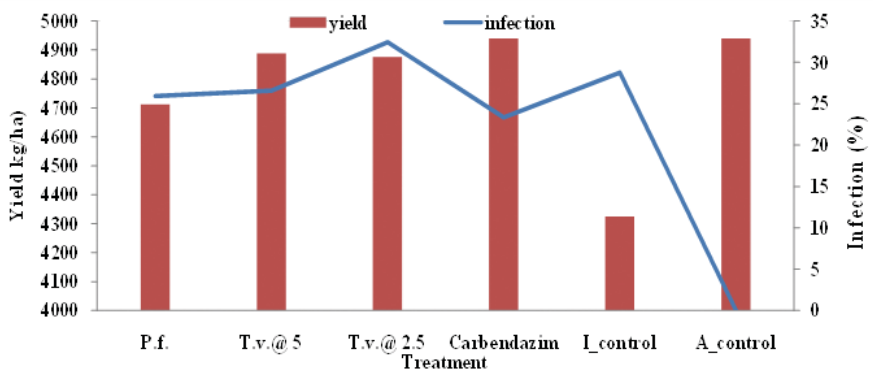
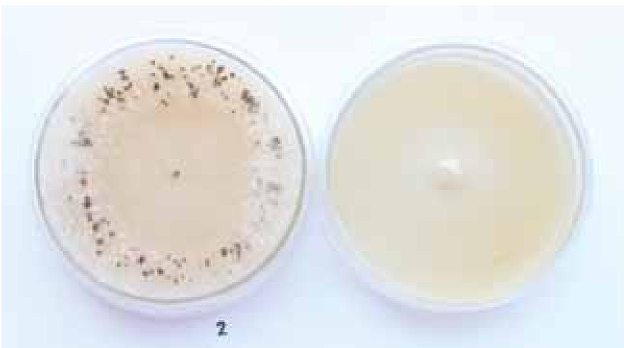


Fig 67. Efficacy of bio-fungicides against sheath blight of rice (var. Tapaswini)



Control *Rhizoctonia solani*

Rhizoctonia solani treated with CCF of *Dendryphiella* strain FV16-II

Fig 68. Effect of cell free cultural filtrate of Dendryphiella strain FV16-II on causal agent of sheath blight of rice

Sclerotium rolfsi tracted with CCF of *Dendryphiella* strain FV 16-II

Control *sclerotium rolfsi*

Fig 69. Effect of cell free cultural filtrate of Dendryphiella strain FV16-II on causal agent of seedling blight of rice of release. Thirty-five day old potted TN1 plants were sprayed with uniform amount of filtrate of FV9 (instead of FV25) for both BPH and leaf folder infestation. The mortality and nymphal hatching was observed with gravid BPH females whereas rate of leaf feeding was recorded with leaf folder larvae. All the three endophytic filtrates reduced silver shoot formation but FV-II was most effective. No filtrate showed immediate mortality of neither BPH nor any persistent toxicity. However, nymphal hatching was reduced to 23.62, 28.66 and 44.17% in FV9, FV-I and FV-II, respectively. Likewise, feeding of leaf folder was also reduced by 71% and 41% in FV16-I and FV16-II respectively against 100% in untreated control.

Identification and utilization of host resistance in rice against major insect and nematode pest

Brown plant hopper resistance was confirmed in nine farmers' varieties and one CRRI developed breeding line CR 3006-8-2, whereas, 14 more varieties were identified as highly resistant through mass screening. Two wild accessions of *O. rufipogan*, i.e. AC 100174 and AC 100444 were highly resistant to BPH. The AC 42494 and AC 42518 were moderately resistant (Score-3) to WBPH. The accessions AC 42494, AC 42499, AC 42513 and AC 42532 rated damage score of 2 at vegetative stage, while wild rice genotypes ZA / BCP-17, ZA / BCP -18, ZA / BCP-27, PM-117 and PM-125 rated stem borer damage score of 1 in reproductive stage. Two NBPGR accessions (IC No. 298563, IC No. 2159) and four aerobic varieties (Solani, Sathia, Laxman sal, Mugi) were tolerant to rice root knot nematode.

Brown plant hopper (BPH)

Confirmation of resistant reaction of genotypes through replicated design

Fourteen genotypes were resistant to BPH earlier in mass screening of farmers' varieties, were screened further in replicated design. The varieties like SSTL No. 142, 227, 317, 395, 405, 490, 609, 680 and 691 showed resistance of '1' score, whereas, SSTL No. 66, 567, 959, 1109 and 1249 showed '3' score with plant death ranging within 11.0 – 14.6%. Highly resistance reaction of CR 3006-8-2 (Pusa 44 x Salkathi) against BPH was again confirmed in multi-location testing under AICRIP, DRR, Hyderabad (AICRIP, 2013).

Mass screening of farmers' varieties

Mass screening of 392 farmers' varieties was carried out in greenhouse condition against BPH. Fourteen were highly resistant with score '1', 42 were resistant with score '3', 27 were of score '5', 30 were of score '7' and remainder were highly susceptible. The highly resistant varieties were Jalgudi, Reg. 2011 / 885, 888, B-Kalakrushna, 2011 / 1170, 1104, 648, 995, 973, 1102, 1063, 1221 and 1010. They are to be tested again in replicated design for further confirmation of resistant reaction.

Wild rice screening

Twenty-five accessions of *Oryza rufipogan* were screened against BPH under greenhouse condition. The accessions R-28, R-55, R-58, R-49, R-7, ND-44 (R), R-8 and R-48 recorded high resistance. Furthermore, the resistant accessions ND-44(R), R-58 and R-28 were tested in replicated design for insect preference by releasing 2rd-4th instars nymphs @ 150 insects in each replication separately and then caged with susceptible TN1 of 60 days old which was without insects. Accumulation of insects was highest (300 nos.) in TN1 after 24 hours of caging. However, lowest accumulation of insects (40) was observed in ND-44 followed by R-28 (65) after 10 days of insect release when TN1 was completely dead.

AICRIP trials

Thirty entries from Multiple Resistance Screening Trial (MRST) and 90 entries from Planthopper Screening (PHS) trial received from DRR, Hyderabad were screened against BPH in greenhouse condition. Entries KAUM 166-2, KAUM 168-1, CR 3006-8-2, IR 65482-7-216-1-2-B, KAUM 179-1, KAUM 179-2, KAUM 179-4, TRG 167 (BPH 18) and TRG 170 (BPH 20 / 21) were highly resistant.

Evaluation of known gene differentials

Twelve differentials of BPH received from DRR, Hyderabad under AICRIP were screened in replicated design in greenhouse condition. ASD 7 (Bph 2), Rathu Heenati (BPH 3+ BPH 17), Babawee (BPH 4), Swarnalatha (BPH 6), T 12 (BPH 7), Chinsaba (BPH 8), Pokkali (BPH 9), IR 64 (BPH 1), IR 65482-7-216-1-2-B (BPH 18), IR 36 (BPH 2) and IR 71033-121-15 (BPH 20 / 21) were found susceptible to BPH population of CRRI, whereas, Ptb 33 (BPH 2 + BPH 3) was highly resistant with score '1' along with RP 2068-18-3-6 of unknown gene source. Both the entries IR 65482-7-216-1-2-B (BPH 18) and IR 71033-121-15 (BPH 20 / 21) were highly resistant in PHS trial and the seed source was found to be different from DRR, Hyderabad for both the trials. So, both these lines are to be tested again for confirmation of their reaction.

Gall midge

Green house screening of 392 farmers' varieties was carried out at CRRI, Cuttack with repetition of 100 varieties from the earlier screening material. The varieties, Reg. 907, 866, 1244, 513, 363, 635 and 743 were highly resistant with score '0'. They will be further screened under replicated design for confirming the present reaction. All entries of AICRIP-MRST (DRR, Hyderabad) trial showed susceptible reaction to CRRI gall midge (Biotype 2).

Biotype study

Eleven differentials with known gall midge resistant genes and 3 genotypes with unknown source of resistance were screened against gall midge in green house condition. The differentials W1263 (GM 1), BG 380-2 (GM 10) and an unknown gene source Aganni were highly resistant with score 1, whereas, Kavya (GM1), Phalguna (GM 2), ARC 5984 (GM 5), DUKONG 1 (GM 6), RP 2333-156-8 (GM 7), MADHURI L9 (GM 9), MR 1523 (GM 11), RP 2068-18-3-1(GM 3) and Abhaya (GM 4) were susceptible.

White backed plant hopper (WBPH)

Eighty-six rice germplasm were evaluated excluding resistant and susceptible check against WBPH under net house condition out of which AC 42494 and AC 42518 were moderately resistant (score 3). Fifteen genotypes were of score 5, seventeen of score 7 and remainder forty two were highly susceptible (score 9).

Yellow stem borer (YSB)

Preliminary net house screening of 60 accessions of rice collected from CRRI Gene Bank showed that AC 42494, AC 42499, AC 42513 and AC 42532 had damage score 2 at vegetative stage, while wild rice genotypes viz. ZA / BCP-17, ZA / BCP -18, ZA / BCP-27, PM-117, PM-125 rated stem borer damage score 1 at reproductive stage. One hundred fifty two breeding lines were screened against yellow stem borer, *Scirpophaga incertulas* in the field under natural condition. Entries like C226-9-2-1-1, C226-10-3-2-1, C226-11-4-1-1 and C226-13-12-1-2 had no white ear head (WEH) formation with a damage score of 1 while C226-11-3-1-2 registered highest WEH (54.3%) followed by C226-12-4-1-1 (50%).

Rice aphid

Sixty wild / weedy rice and twenty five accessions of cultivated rice were screened in the greenhouse against rice aphid, of which the wild / weedy rice collections from Assam such as ZA / BCP-20, ZA / BCP-24, ZA / BCP-26, ZA / BCP-27, ZA / BCP-28, ZA / BCP-32 showed no damage by rice aphid, *Hysteroneura setariae* (Thomas), whereas, ZA / BCP-08, ZA / BCP-13, ZA / BCP-14, ZA / BCP-18 showed heavy aphid infestation (*Fig 70*).

Rice root knot nematode

In order to identify the resistant donor to rice root knot nematode, *Meloidogyne graminicola*, 152 rice accessions / cultivars (68 NBPGR accessions, 81 aerobic varieties and 3 hybrids) were screened by artificial inoculation. Two NBPGR accessions (IC No. 298563, IC No. 2159) and four aerobic varieties (Solani, Sathia, Laxman sal and Mugi) were tolerant with 11-30% galling in roots.

Bio-ecology and management of pests under changing climatic scenario

Estimation of predatory potential of rice aphid, Hysteroneura setariae

Hysteroneura setariae (Thomas), rice aphid (Hemiptera: Aphididae) is now appearing in Indian sub-continent. Both adults and nymphs of this insect cause damage to plants by sucking the sap from immature grains and leaves. The nymphs are rusty brown or deep purple. Aphids are found on the secondary branches of panicles, some on the spikelets, and very few on the leaves. Grains showed brown necrotic spots when moderately infested, while all spikelets become brown and chaffy when heavily infested. Heavy infestation on milk-stage results in empty grains and turns all spikelets brown and chaffy. When the upper portion of rice plant dries up, this pest migrates to the basal portion and remains in the stubbles. Predatory potential of adult stage of an aphidophagous ladybird beetle, *Cheilomenes*

Fig 70. Rice panicle infestd with aphid

Fig 71. Cheilomenes sexmaculatus predating on aphid

sexmaculatus (F.) was evaluated against rice aphid under net-house condition (*Fig 71*). Twenty-four hours starved adult male and female (7 days old) ladybird beetles were provided with rice plant containing 100 rice aphids which was covered with transparent plastic for 24 h after which the unconsumed aphids were counted. The experiment was conducted in 10 replicates. Results revealed that per day mean consumption of aphids was 26.4 ± 2.6 by male adult beetle whereas, 29.6 ± 3.4 in female adult beetle which shows that the female consumed more prey than the male.

Effect of long term use of pesticide in rice ecology

In long term pesticide trial during *rabi* 2013 (*Table 40*), lowest dead heart (2.67%), white ear head (3.02%), gundhi bug damage (5.65%) and leaf folder (2.22%) observed in plots treated with cartap 4G @ 1kg a.i./ha followed by chlorpyriphos 1.5% dust @ 0.5 kg a.i./ha (*Table*). The highest grain yield of 4.93 t/ha was recorded in the variety Naveen treated with cartap followed by 4.77 t/ ha in chlorpyriphos. Similar trend was also observed in *kharif* where in the treatment cartap 4G @ 1 kg a.i./ha recorded lowest pest damage i.e. DH (2.62%), WEH (3.3%), Leaf folder (1.92%) and gundhi bug (6.07%) followed by chlorpyriphos 1.5% dust @ 0.5 kg a.i./ha application. The highest grain yield of 5.38 t/ha was recorded in the treatment cartap, followed by 5.32 t/ha in chlorpyriphos treated plots. Sampling of natural enemies, especially predators indicated that chlorpyriphos most affected the spider population with 2.5 spiders/sweep, while cartap least affected with 5.7 spider/sweep. There was no significant difference among the treatments as regards parasitoid population.

Table 40. Long term effect of pesticides against insect pest of rice during *rabi* and *kharif*, 2013

Treatments	%DH		%WEH		%LF damage		%G.bug damage		%Blast		Yield (t ha-1)	
	R	K	R	K	R	K	R	K	R	K	R	K
Cartap @1kg a.i./ha	2.67 (9.39)d	2.62 (9.27)c	3.02 (10.01)d	3.3 (9.81)b	2.22 (8.56)d	1.92 (7.96)d	5.65 (13.74)b	6.07 (14.26)c	2.97 (9.88)b	2.8 (9.60)b	4.93a	5.38a
Chlorpyriphos @0.5kg a.i./ha	3.12 (10.17)c	3.37 (10.58)b	3.65 (11.01)c	3.4 (10.58)b	2.95 (9.88)c	2.42 (8.95)c	5.72 (13.83)b	6.62 (14.91)b	2.15 (8.41)c	2.47 (9.02)b	4.77ab	5.32ab
Carbendazim @0.1%	4.65 (12.44)b	4.95 (12.85)a	4.85 (12.71)b	4.85 (12.85)a	4.55 (12.3)b	3.82 (11.27)b	7.57 (15.97)a	8.12 (16.61)a	1.3 (6.54)d	1.5 (7.01)c	3.81bc	3.86bc
Pritilachlor @0.75kg a.i./ha	5.25 (13.24)a	4.92 (12.81)a	5.3 (13.31) ab	4.95 (12.85)a	4.67 (12.48)ab	4.15 (11.74)b	7.82 (16.24)	8.22 (16.66)a	4.3 (11.95)a	4.4 (12.10)a	3.73c	3.88c
Control	5.55 (13.62)a	5.35 (13.37)a	5.5 (13.55)a	5.32 (13.37)a	5.15 (13.11)a	5.02 (12.94)a	7.82 (16.24)	8.42 (16.87)a	4.37 (12.05)a	4.65 (12.44)a	3.63c	3.6c
CD (P>0.5)	0.70	0.86	0.59	0.80	0.75	0.79	0.55	0.59	1.15	1.0	0.98	1.46

Data in parentheses are angular transformed values, DH = dead heart, WEH = white ear head, G. bug = Gundhi bug. Values in each coloumn followed by a different letter are significantly different DMRT

Persistence of pesticides under long-term pesticide trial

An analytical method was standardized for estimation of Pretilachlor residue from soil using gas liquid chromatography. Pretilachlor residue was not detected in field sample collected during *rabi* 2013 under long term pesticide trial. However, during *kharif* 2013, Pretilachlor residue was detected to the tune of 0.69 mg / kg of soil on the day of application of pesticide. The applied pesticide residue decreased over a period of time. After 15 days of spray it decreased to 0.05 mg / kg. Chlorpyriphos residue got reduced from 0.25 mg / kg of soil from the day of application to less than 0.01 mg / kg after 15 days of application (*Fig 72*).

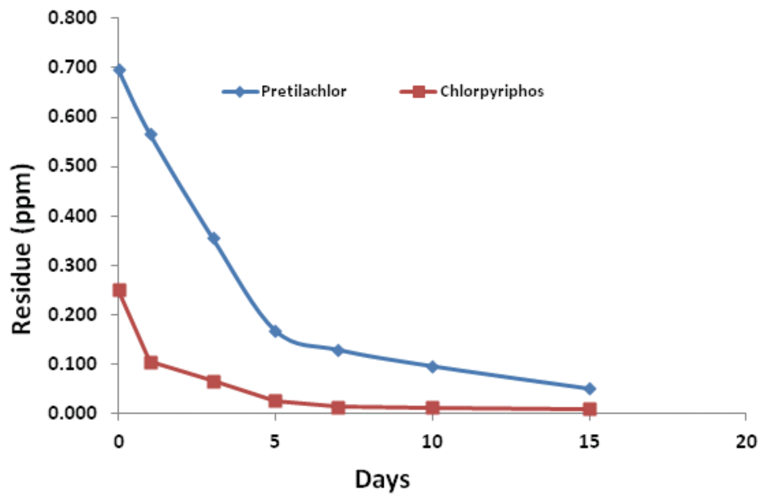


Fig 72. Persistence of pesticides under long term pesticide trial

Pheromone trap data on yellow stem borer (YSB) revealed high and prolonged YSB brood emergence during dry season of 2013 (*Fig* 73). There was an increase in population from 2rd standard meteorological week (SMW) that reached its peak in 6th SMW and again decreased towards 9 SMW. The population was more than the last two years, i.e. 2011 and 2012. Though high brood emergence was prolonged from 4-8 SMW, it did not show considerable damage symptom at 30 DAT (6 SMW) resulting to only 6.12% dead heart formation. Observations showed smaller sized egg masses laid by the females with 0- 5 eggs per egg mass during 3rd – 5th SMW. Normal egg masses were laid by the population that emerged during 6th-8th SMW, the number of eggs ranging from 18 - 53 per egg mass. This observation was supported by increased dead heart formation up to 44.62% towards 50 DAT (9 SMW) in untreated control plots.

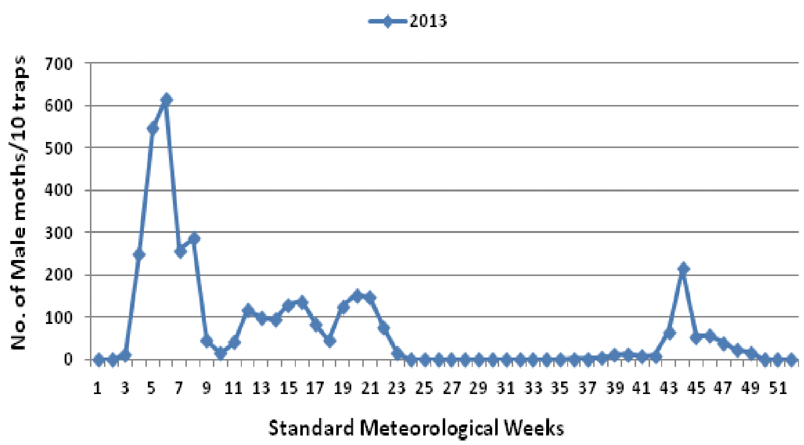


Fig 73. Pheromone trap catch of YSB male moths during rabi and kharif seasons of 2013

During *kharif* 2013, YSB incidence started during 1st week of September but the population was low (2-3 male moths / SMW / pheromone trap) up to 3rd week after which it gradually increased to 30 moths / SMW towards 1st week of October. The population decreased during 2nd / 3rd week of October, possibly due to the cyclone *Phailin* and heavy rainfall. It again increased towards 4th week of October and prevailed up to 1st week of December. Since the brood emergence was late and after the panicle initiation stage, the crop did not suffer much in terms of WEH. But the late duration varieties like Varshadhan were infested by YSB.

The damage (%) in the plots with auto-confusion trap was on par with untreated plots during dry season (23% and 27%, respectively) indicating repeat evaluation of the same is required to confirm the efficacy.

Influence of agrochemicals on natural enemies/predators of rice pests

Among the five insecticides tested in the field on rice cv. Lalat, it was observed that species richness did not vary much among the treatments and varied between 6 and 8. Incidence of dead heart (DH) and white ear head (WEH) was recorded to be minimum in Cartap treated plot (10.8% and 3.6% respectively) compared to 23.9% DH and 12.6% WEH in the control.

Observations on predator population especially spiders and odonates indicated that among the treatments Coragen was highly detrimental registering negligible (0.0- 0.3 sweep) spider population, whereas, Sutathion affected the least with 3.6 sweep followed by Imidacloprid (1.6-3.3 sweep). Among the organic treatments application of neem oil did not harm the spider population (4.5/sweep) and was at par with control (5.0/sweep).

Among the herbicides tested under field condition Azimsulfuron highly reduced the spider population (1.5 spiders/sweep) followed by Bispyribac sodium (2.6 spiders/sweep) and Flucetosulfuron (3 spiders/ sweep). Similarly odonate population was also reduced (0.5 insects/sweep) in Azimsulfuron treated plots. It was observed that weedy plots harboured more population of gundhi bug (7 insects/sweep) compared to weed free plots (3.2 insects/sweep). All the herbicide treated plots recorded minimum gundhi bugs and Azimsulfuron had the lowest of all (0.3 insects/sweep) treatments.

In the *Azolla* treated plots, DH and WEH records were 15.5% and 11.0%, respectively. Maximum spider population of 11 spiders/sweep was recorded under dual cropping of *Azolla* compared to 5 spiders/sweep in the control. In other insecticide treated plots spider population varied between 2-4 individuals. Thus dual cropping of *Azolla* encourages spider population in the field.

Formulation, validation and refinement of IPM modules in rice

Pest monitoring/surveillance in farmers' fields during *kharif* 2013 (shallow lowland in Cuttack)

A survey was conducted for the incidence of major rice diseases and insect pests during *kharif* 2012 in Sankilo village of Nischintikoil, Cuttack. Diseases and insect pest incidences were recorded in rice varieties namely Swarna and Pooja grown by the farmers. Insects namely stem borer, leaf folder, gundhi bug and diseases namely sheath blight were observed. Stem borer infestation caused 3.5-5.4% dead heart, leaf folder damage was 4.4-6.7% and sheath blight damage was 6.4-7.5% during November 2013. Cartap @ 10 kg per acre against LF and YSB, and Carbendazim @ 2 g/lit against sheath blight were effective against these pests.

Validation of IPM module in rainfed shallow lowland at Cuttack

Thirty-three farmers were selected for validation of IPM modules in rainfed shallow land situation in Sankilo village in Cuttack district. Farmers were trained to identify the harmful and beneficial insects in farmer's field. In IPM practice, farmers followed seed treatment with Carbendazim @ 2 g/kg seed before sowing in nursery for two popular varieties Swarna and Pooja along with clean cultivation and line transplanting. They followed need-based applications of pesticides in the affected areas viz. 1. Carbendazim @ 2 g/lit water against sheath blight; 2. Cartap @ 1 kg a.i./ha against YSB, LF and BPH and Chlorpyriphos @ 0.5 kg a.i./ha against gundhi bug; 3. Pheromone trap and auto confusion trap for monitoring and trichocards for bio control of YSB and 4. Regular field visit were followed to assess the insect pest infestation. In farmer's practice, they use pesticide in whole plot and in schedule based manner, irrespective of pest incidence, at least 4-5 times in a season. The farmer's practice, cost of plant protection was increased as compare to IPM practice and natural enemies were destroyed and environmental pollution was made without much increase in grain yield.

In the validation of IPM modules in rainfed shallow lowland, the variety Swarna with IPM practice registered significantly higher yield (5.96 t/ha) as compare to farmer's practice (5.25 t/ha). Variety Pooja with IPM practice also recorded significantly higher yield (5.48 t/ha) compare to farmer's practice (5.03 t/ ha). The dead heart, white ear head, leaf folder damage gundhi bug damage, sheath blight, false smut damage and straw yield were significantly less and natural enemies population was significantly more in IPM practice in both the tested varieties (*Table 41*).

Twenty acres upland in a compact block was selected in the village Chorkari and Manahari in the District of Chatra in Jharkhand and experiments were conducted in farmers fields with the following interventions.

IPM interventions

Seed dressing with Bavistin @ 4 g/kg seed, fertilizers: N - 40, P - 40, K - 20, basal application: 10:40.20, Nominee Gold (Bispyribac sodium) spray @ 100 ml/acre 25 days after seeding, Top dressing: 15 kg N after 30 days of seeding, 15 kg N after 60 days of seeding, one hand weeding, need based spray of Tilt, Beam 75 to control brown spot and blast and Chlorpyriphos spray to control Gundhi bug infestation.

Table 41. Effect of IPM in shallow rainfed rice ecology during *kharif* 2013

Treatment	DH (%)	WEH (%)	LF (%)	GB (%)	blight (%)	False smut (%)	NE / m^2	Straw yield t / ha	Grain yield t / ha
Swarna IPM	3.52(10.81)	3.55(10.85)	4.40(12.1)	6.70(15.0)	6.47(14.74)	5.37(13.4)	3.2	8.91	5.96
Swarna NIPM	5.42(13.46)	5.32(13.34)	5.60(13.68)	8.25(16.58)	8.35(16.79)	6.25(14.47)	2.1	8.32	5.25
Pooja IPM	4.40(12.1)	4.40(12.1)	5.25(13.12)	6.20(16.63)	5.30(13.30)	6.30(14.53)	4.2	8.85	5.48
Pooja NIPM	5.40(13.43)	6.10(14.28)	6.37(14.62)	9.30(17.55)	7.52(15.92)	7.02(15.36)	2.7	8.30	5.03
CD at 5%	0.56	0.56	0.6	0.43	0.43	0.29	0.46	0.31	0.21

Data in parenthesis are angular transformed values, NE=natural enemies

Farmers' practices/non-IPM

Rice variety: Kalamdani (Village Manahari), Kalamdani (Village Chorkari), source of seed farmers own seed, no seed dressing fungicides, one hand weeding, 20 kg N in the form of urea as top dressing, no spraying of insecticides to control gundhi bug infestation.

Pest and disease incidence were recorded. In IPM plot, the dry weed biomass was 65 g / m^2 with 165 g / m^2 in the non-IPM. The infected panicles of gandhi bug was 4.8 / m^2 in non-IPM and 1.4 / m^2 in IPM. Brown was spot recorded 4% and 11% in IPM and non-IPM, respectively. There were few panicles infected by stem borer and neck blast in the field in both the villages but infestation was below ETL. Average grain yield of IPM plot was 3.43 and non-IPM 2.06 t / ha in village Chorkari, while in village Manahari, yield of IPM plot was 3.86 t / ha and non-IPM plot 1.98 t / ha. The yield of improved variety was 35-45% more than the traditional variety. The farmers were happy with the technology and ready to adopt in the ensuing *kharif* 2014.

Refinement and validation of IPM modules in rice

Twenty hectare low land in a compact block was selected in the farmer's field involving 30 farmers in the village Galdighala of Mukalmua block of Nalbari district of Assam was selected for the study during *rabi* / *boro*, 2013-14 with the following interventions:

IPM interventions were: 1. Treatment of seeds of Naveen and Abhisek with Carbendazim 50% WP (Bavistin) @ 2.0 g / kg seed, 2. Application of insecticide Carbofuran 3% G @ 1.2 kg for nursery area for planting one acre of land, 3. Seedling root dip treatment with Tricel (Chloropyriphos 20% EC) @ 1 ml / litre before transplanting in the main field, 4. Application of fertilizers at the dosage of 60:30:30 kg NPK / ha with basal dose of 30:30:15 kg NPK / ha in the main field before transplanting, top dressing with 15 kg N, 15 kg K_2O per hectare after 30 days and 15 kg N / ha after 60 days of transplanting, 5. Application of the herbicide Eraser (Pretilachlor 50% EC) within 4-5 days of transplanting and 6. Need based spraying of Chlorpyriphos 20% EC (Tricel) @ 2.5 ml / litre against stem borer, leaf folder; Carbendazim 50% WP (Bavistin) @ 2.0 g / litre against brown spot, *bakanae* diseases.

Farmer's practice (Non-IPM) were: 1. No seed dressing fungicides in case of Naveen and Abhisek (seeds supplied by RRLRRS, Gerua + farmer's own seed), 2. Fertilizers at the dosage of 40:20:20 kg NPK / ha were applied with basal application of 20:20:15 kg NPK and top dressing with 20:5 kg N, K_2O / ha and 3. No application of fungicides and insecticides against diseases and insect, pests in the main field after transplanting.

Diseases and insect pest incidences were recorded both in IPM and non-IPM plots. In case of Naveen IPM, 4.14% *bakanae*, 3.86 % DH due to stem borer and 2.72% brown spot were recorded. Whereas in case of Naveen under non-IPM, 12.44% *bakanae*, 7.46% DH and 6.3% brown spot were recorded. In some plots weed infestation was found to be more which surpressed the growth of rice plants significantly, particularly in case of Naveen non-IPM. For Abhisek IPM, 1.38% *bakanae*, 2.03% DH and 4.3% brown spot were recorded; while in Abhisek non-IPM, 3.82% bakanae, 5.6% DH and 6.77% brown spots were observed.

Economic analysis of IPM modules in rice

The economic analysis of IPM trial (in shallow lowland irrigated ecology) conducted at Sankhilo village of Nischntakoili block, Cuttack district during *kharif* 2013 revealed that there was a net additional return of Rs. 14,468 and Rs. 11,022 per ha in IPM trial over non-IPM plots in Swarna and Pooja variety, respectively. Besides the additional net returns, there was a cost saving of Rs. 3,043 per ha in IPM trial due to less use of chemicals. Therefore, the total gain due to adoption of IPM practice was Rs. 17,511 and Rs. 14,065 per ha from Swarna and Pooja variety, respectively.

Validation of IPM package in farmers' field of favourable lowland ecology

The trial was conducted in Mahanga block, Cuttack district with Pooja variety in about 25 acres and with multiple insect resistant line CR 2711-76 (Tapaswini x Dhobanumberi) in about 1 hectare. The IPM practice consisted of: (1) seed treatment with Bavitin @ 2 g / kg of seed, (2) Monitoring for thrips, case worm and hispa during August-September, for YSB, BPH, WBPH and leaf folder during mid September-October and for gundhi bug at milk stage of flowering, (3) Fixing pheromone traps @ 2 traps / acre from September for monitoring YSB and (4) Need-based application of Imidacloprid for case worm during last week of August and need based application of neem oil for leaf folder and BPH during 1st week of October.

The farmers' practice constituted of (1) Application of insecticides (Chlorpyrifos @ 2-3 ml / litre) during 3rd week of September for caseworm, during 2nd week of October for BPH and leaf folder and even for BLB, misunderstanding the disease for BPH infestation and (2) Scheduled based application of Phorate / Carbofuran granule for YSB control.

The observation revealed no insect incidence in resistant genotype CR 2711-76, hence no insecticide was applied by the farmers. However, though very low, sheath blight symptom was visible in about 1-2 tillers of 2-3% hills. But, no pesticide was applied for disease incidence. The grain yield was within the range of 5.60 – 6.72 t / ha with an average of 6.15 t / ha.

In IPM with Pooja, effective monitoring in IPM plots could detect case worm, leaf folder and BPH at the initial stage of occurrence. Foliar spray of Imdacloprid @ 50 ml a.i. / ha could control the pest and there was no further spread. Disease incidences were meager. The grain yield was within the range of 5.3 – 5.8 t / ha.

However, in farmers' practice, case worm attacked 10 acres as observation was delayed. Two – three foliar sprays with Chlorpyriphos were applied to control the pest during 3rd – 4th week of September. Though YSB was not severe (0-3 moths / trap / week in general and 3-12 moths / trap / week in about 2 acre area), blanket application of granules was made. Bacterial leaf and sheath blight were prominent at early tillering stage, whereas, fungal sheath blight was more in late tillering stage. Farmers applied Bavistin (Carbendazim) or Contaf @ 2 g / litre for sheath blight at late stage of disease infection. The average grain yield varied within 3.5 – 4.7 t / ha.

On-farm validation of IPM module in rainfed lowland rice ecosystem

On-farm IPM validation trial on rice (cv. Swarna *Sub 1*) was conducted in the Pipili block of Puri District with a latitude of $20^{0}08'$N and longitude of $85^{0}50'$E. The pest scenario and strategies were evaluated under two regimes viz. 1. Farmers' practice (FP): (a) Direct seeding (b) Non-specific pest monitoring both in the nursery and main fields (c) Application of pesticides after seeing the damage; 2. IPM treatments: (a) Row planting (20 x 15 cm) (b) Field monitoring trough roving survey (b) Cartap hydrochloride 4G @ 25 kg / ha applied at 15 DAT (c) need based application of foliar spray of Chlorantraniliprole 18.5 SC @ 30 g a.i. / ha and (d) need based application of fungicide. The population of major insect pests and damage (%) due to stem borer, gall midge was recorded both in IPM plots and FP plots. In case of IPM, 8.2% DH, 4.5% WEH, 5.8% silver shoot due to gall midge, 6.8% sheath blight infections were recorded; whereas, in case of FP, 12.5% DH, 7.2% WEH due to stem borer, 10.6% sheath blight, 2.8% false smut infections were found. Under IPM predator population was more (6.2 / sweep) compared to farmers practice (5.4 / sweep) which includes spider, damselfly, dragon fly, mirid bugs whereas parasitoid population was 4.5 / sweep in IPM and 4.1 / sweep in FP plots (*Table 42*). The grain and straw yields in IPM treatments were 5.4, 10.4 t / ha respectively compared to 4.3 and 9.5 t / ha in FP treatment. BC ratio in IPM was calculated to be 1.84 whereas, in FP it was 1.69. Farmers were trained for the identification of insect pests and their natural enemies to decide the timing of pest management practices.

Status of Natural enemies

Observations on natural enemies population in IPM and non-IPM plots indicated that spider population was 4 spiders / sweep in the IPM plots compared to 1.3 / sweep in the non-IPM plots. As regards adult population of parasitoids *Xanthopimpla flavolineata*, *Cardiochiles nigricollis* were present in good numbers i.e. 2.0 / sweep which was not observed in the non-IPM fields.

Table 42. Insect pest incidence and their influence on grain and straw yield in rice

Treatment	EBT / m2	GM (SS%)	SB DH %	SB WEH %	No / sweep net Predators	No / sweep net Parasitoids	Grain yield t / ha	Straw yield t / ha	BC ratio
IPM	235.0	5.8(13.9)	8.2(16.4)	4.5(12.2)	6.2(2.58)	4.5(2.23)	5.4	10.4	1.84
FP	198.0	8.5(16.9)	12.5(20.7)	7.2(15.5)	5.4(2.42)	4.1(2.14)	4.3	9.5	1.69
CD at 5%	21.02	(1.15)	(1.68)	(1.28)	(0.27)	NS	0.51	1.1	-

EBT: Ear bearing tiller; GM: Gall midge; SB : Stem borer, SS : Silver shoot; DH: Dead heart; WEH: White ear head

Evaluation of botanicals-oils as grain protectant against rice weevil, *Sitophilus oryzae*

Nine plant oils *viz*., sesamum (*Sesamum indicum*), karanja (*Pongamia pinnata*), bael (*Aegle marmelos*), castor (*Ricinus communis*), morchand (*Vitex negundo*), citronella (*Cymbopogon citratus*), crown oil (*Shorea robusta*), groundnut (*Arachys hypogea*) and mustard (*Brassica campestris*) were tested against rice weevil, one of the major insect pest of stored paddy / milled rice under controlled condition using the rice variety Ratna during April-December, 2013. Only castor, morchand, bael and crown oils showed promising grain protection (population below 50%) but none of the products could absolutely controlled multiplication of the test insect (*Table 43*).

Chemical control of insect pest of rice in *rabi* 2013

Nine insecticides were evaluated against insect pest of rice during *rabi* 2013 out of which Fipronil 5% (Tzed) @ 1000 ml / ha was best insecticide (6.3 t / ha) and was at par in increasing the grain yield with all other tested insecticides i.e. Bifenthrin 10% (Marker) @ 500 ml / ha, Quinalphus 25% (Ekalux) @ 1500 ml / ha, Dimethoate 30% (Tafgor) @ 830 ml / ha, Imidacloprid 17.8% (Maharaja) @ 300 ml / ha, Lambda cyhalothrin 2.5% (Cheeta) @ 500 ml / ha, Thiamethoxam 25% (Kemstar) @ 100 ml / ha, Flubendimide 39.35% (Fame) @ 50 ml / ha, Acephate 75% (Hythene) @ 1000 ml / ha. The dead heart and white ear head and gundhi bug damage was less in treatment Fipronil 5% (Tzed) @ 1000 ml / ha followed by Bifenthrin 10% (Marker) @ 500 ml / ha and Quinalphus 25% (Ekalux) @ 1500 ml / ha, during *rabi* season 2013 (*Table 44*).

Chemical control of insect pest of rice in *kharif* 2013

Eight pesticides (2 insecticide and 2 fungicide and their combinations) were evaluated against insect and disease of rice during *kharif* 2013. Among the treatments, RIL-IS-109 @ 1.75 ml / l + Baan @ 0.6 ml / l was best insecticide fungicide combination (5.4 t / ha) and was at par with RIL-IS-109 @ 1.75 ml / l + Contaf plus @ 2 ml / l (4.85 t / ha). Both were effective against stem borer and leaf folder and leaf blight in variety TN1 (*Table 45*).

Table 43. Evaluation of botanicals as grain protectants against Rice weevil (*Sitophilus oryzae*)

Treatment	Adult population 120 Days	Adult population 180 Days	Adult population 270 Days
Citronella (*Cymbopogon citratus*)	17.33(300)	22.28(496)	30.50(930)
Crown oil (*Shorea robusta*)	19.50(380)	24.09(580)	26.84(720)
Karanja (*Pongamia pinnata*)	20.01(400)	24.70(610)	36.06(1300)
Bael (*Aegle marmelos*)	15.18(230)	20.33(413)	24.96(623)
Five-leaved chaste tree; Horseshoe vitex (Nirgundi) (*Vitex negundo*)	14.15(200)	18.42(339)	21.36(456)
Castor (*Ricinus communis*)	10.74(115)	13.65(186)	17.62(310)
Til (*Sesamum indicum*)	23.67(560)	28.59(817)	41.23(1700)
Mustard (*Brassica campestris*)	22.59(510)	27.50(756)	39.12(1530)
Control	25.50(650)	31.31(980)	47.96(2300)

Table 44. Testing of some new insecticide against insect pest of rice during *rabi* 2013

Treatment	ai (%)	g or ml / ha	DH (%)	WEB (%)	LF (%) damage	G. bug damage (%)	NE	Yield t / ha
Fipronil (Tzed)	5	1000	3.4 (10.62)g	3.46 (10.73)h	2.2 (8.52)f	3.4 (10.62)h	3.33b	6.3a
Bifenthrin (Marker)	10	500	3.6 (10.93)f	3.66 (11.03)g	2.86 (9.73)e	3.63 (10.98)gh	3.0b	5.95a
Quinalphus (Ekalux)	25	1500	3.63 (10.98)f	3.8 (11.24)g	3.5 (10.24)de	3.73 (11.13)g	3.33b	5.8a
Dimethoate (Tafgor)	30	830	4.0 (11.53)e	4.06 (11.63)f	3.2 (10.28)de	3.86 (11.33)fg	2.66b	5.76a
Imidacloprid (Maharaja)	17.8	300	4.1 (11.68)e	4.26 (11.92)e	3.36 (10.55)cde	4.06 (11.63)ef	3.0b 3.33b	5.73a 45.7a
Lambda cyhalothrin (Cheeta)	2.5	500	4.4 (12.10)d	4.46 (12.20)d	3.43 (10.65)cde	4.36 (12.06)de		
Thiamethoxam (Kemstar)	25	100	4.53 (12.28)cd	4.56 (12.33)cd	3.53 (10.81)cd	4.5 (12.24)cd	3.0b	5.7a
Flubendimide (Fame)	39.35	50	4.7 (12.52)bc	4.73 (12.56)c	3.93 (11.43)bc	4.73 (12.56)bc	3.33b	5.68a
Acephate (Hythene)	75	1000	4.8 (12.65)b	5.0 (12.92)b	4.2 (11.82)b	5.06 (13.0)b	3.66b	5.45a
Control	Water	500l	6.26 (14.49)a	6.5 (14.77)a	5.53 (13.6)	6.96 (15.3)	5.0a	3.73b
CD at 5%			0.28	0.27	0.92	0.44	1.19	1.27

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

Table 45. Testing of some pesticide against rice pest during *kharif* 2013

Treatment	Dose g or ml / l	DH (%)	WEH (%)	LF (%)	Leaf blight (%)	Yield t / ha
RIL-IS-109 Flubendimide4% (35g)+	1.75	2.7 (9.61)c	3.13 (10.18)d	2.56 (9.19)b	30.36 (33.43)b	3.81ab
Buprofezin 20% (175 g) Sutathion (Triazophus 40%EC)	1.5	3.5 (10.78)b	3.26 (10.41)cd	2.9 (9.78)b	29.26 (32.74)b	3.84ab
Contaf plus (Hexaconazole 5%SC)	2	5.3 (13.3)a	5.2 (13.18)ab	5.2 (13.18)a	26.1 (30.71)c	3.73abc
Baan (Tricyclazole 75%)	0.6	5.36 (13.39)a	5.03 (12.95)b	5.23 (13.21)a	24.86 (29.90)cd	3.63bc
RIL-IS-109+ Contaf plus	1.75 + 2	3.2 (10.27)bc	3.7 (11.09)c	2.53 (9.14)b	26.2 (30.78)c	4.85ab
RIL-IS-109 + Baan	1.75 + 0.6	3.23 (10.35)bc	3.7 (11.08)c	2.83 (9.66)b	23.36 (28.90)d	5.41a
Sutathion + Contaf plus	1.5 + 2	3.36 (10.57)b	3.43cd (10.66)	3.2 (10.21)b	25.26 (30.16)cd	3.97ab
Sutathion + Baan	1.5 + 0.6	3.43 (10.67)b	3.3 (10.45)cd	2.86 (9.67)b	24.60 (29.73)cd	4.4ab
Control	Water	5.83 (13.97)a	5.66 (13.77)a	6.1 (14.29)a	34.50 (35.96)a	2.03c
CD at 5%		0.83	0.76	1.63	1.56	1.74

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

Efficacy of insecticides against rice insect pests

During *rabi* 2013, in spite of heavy YSB incidence (44% dead heart in untreated control plots), 20% and 48% yield advantage was achieved in 75 g and 90 g a.i. foliar spray treatments of sulfoxaflor, respectively. Rynaxypyr was most effective against YSB when applied as foliar spray at brood emergence. Among the 6 treatments applied at 15 and at 30 DAT, Rynaxypyr (Coragen 20% SC) @ 30 ml a.i./ha could reduce the dead heart formation to 1.37% at 50 DAT as compared to 6.44–24.3% DH in Triazophos, Acephate, Monocrotophos and Sulfoxaflor against 44.86% in untreated control.

In controlled condition, immediate knock down effect against 5th instar nymphs of BPH was 100% with Acephate 75% SP (30 g a.i./ha), Dinetofuran 20% SG (500 g a.i./ha), Imidacloprid 70 WG (20 g a.i./ha) and Thiamethoxam 25% EC (30 g a.i./ha), whereas, effective persistent toxicity (above 50% mortality) up to 3 days was observed with Acephate, Dinetofuran, Imidacloprid and Thiamethoxam. When insecticide was applied on plants already having 3 -5 day old eggs of gall midge, only Dinetofuran was promising in reducing silver shoot formation at 0.04% a.i. concentration.

Effective microbial isolates evaluated in farmers' field conditions.

Formulation of three Bt, and one *Metarhizium* and *Beauveria* each were sprayed in 3 farmer's field in Salkilo village of Nischinkoil block of Cuttack district. The biocides were sprayed @ 0, 10^5, 10^7 and 10^9 spores/ml in 3 replication against the leaf folder *Brachmia* sp. However, the cyclonic rain from 3rd day of treatment washed out the crop and data could not be collected.

Isolation of fluorescence *Pseudomonas* spp. from micro plots of Nematology, maintenance of pure culture and testing their efficacy against nematodes

The study was conducted to investigate biocontrol potential of native *Pseudomonas fluorescence* against rice root-knot nematode, *Meloidogyne graminicola* under laboratory condition following standard procedure. Soil samples were taken from the nematode infested fields of Cuttack region. Two ml culture filtrate of each of 9 *Pseudomonas fluorescence* isolates was added to 2 ml nematode suspension (50±5 juveniles/2 ml) and incubated for 72 hours at 28^{o}C to check immobilized and killed nematodes followed by their revival by transferring the immobilized nematodes into fresh water to confirm mortality. The isolates were effective against *M. graminicola* under laboratory condition controlling to the extent of 45-70% nematodes. The isolate SF-A2 effected highest mortality followed by SF-A4. However, the lowest mortality was observed for isolate MF-A3. Apart from their nematicidal activity, the bacteria also showed various plant-growth promoting (PGP) traits like P-solubilization, IAA, HCN and siderophore production. The isolates SFA2 and SFA4 may be used as a potential biocontrol agents for RRKN management.

Biotic stress management in rainfed upland rice ecology

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

Cultural management of false smut of rice under rainfed transplanted condition: Combinations of transplanting dates (3) and fertilizer doses (3) were evaluated using hybrid rice variety PHB 71 (recommended for Jharkhand and susceptible to false smut) under natural disease condition for false smut incidence. Three dates of transplanting (20 July, 27 July and 3 August) were evaluated with combinations of fertilizer regimes (NPK - 80:40:40, 100:60:40 and 120:80:40). Both late (3 August) and early (20 July) transplanting significantly reduced disease intensity over that of normal transplanting (27 July). But late transplanting significantly reduced yield over other two dates of transplanting. Lowest disease pressure coupled with agronomic advantages of early transplanting under rainfed ecology resulted in significantly highest grain yield in earliest transplanting (20 July). Among the fertilizer doses, on the other hand, 100:60:40 resulted in lowest disease intensity with concomitantly higher grain yield. Similarly, the interactive effects of both DT and fertilizer doses revealed that 20th July transplanting with moderate fertilizer (NPK - 100:60:40) resulted in least disease with highest grain yield.

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

Characterization of blast pathogen by trap nursery

Trap nurseries were established at three screening sites (Tilra, Chatra; Jainagar, Koderma and CRURRS, Hazaribagh), to characterize the blast pathogen population of Jharkhand. The trap nurseries consisted of 24 monogenic differential varieties with known resistance genes and the R (Tetep) and S (Co 39) checks. Trays of 20-25 day old seedlings of the monogenic lines grown under aseptic conditions in a phenotyping facility were exposed to the natural inoculum in farmers' fields during wet season of 2013 for a week, brought back to the phenotyping facility, maintained separately under hoods. Disease incidence on the differentials were recorded after one week and the fungus was isolated for virulence analyses.

Tetep and monogenic differential with *Pi –z5* were resistant at all the three locations, whereas, the lines with *Pi 9, Pi ta2* (Reiho) and *Pi 5* showed resistance at two locations and restricted lesion development at the third location. Other differentials including the susceptible check were susceptible at one or the other locations (*Fig 74*). Among them, differentials with *Pi b, Pi k, Pi km, Pi sh, Pi 12(t) and Pi 20(t)* had differential reaction across sites and hence were good candidates for virulence monitoring. Trap nursery captured the differential reaction of the monogenic lines within a small geographical region comprising three districts and appears to be an effective tool to characterize the virulence spectrum of blast pathogen population using limited resources. A limited set of monogenic lines showing differential reaction can be deployed for virulence monitoring and prophylactic action based on the genetic constitution of the varieties grown in a locality.

Development of NILs against specific lineages/virulence of *M. grisea*

Near-isogenic lines (NILs) or differential sets of rice with single blast resistance gene are an efficient tool to describe the pathogenicity of blast isolates and also as a source of resistance for breeding programs. A set of monogenic and near-isogenic lines also offers great advantages for allelism test in NILs, compared to donor cultivars where resistance is often conferred by two or more major genes. NILs for rice blast resistant genes are mostly available in *japonica* background. A set of NILs in good agronomic *indica* background would be more useful for breeding blast resistant varieties for tropical countries like India. Poornima, a variety highly susceptible to blast but otherwise agronomically superior, was selected as recurrent parent for the development of NILs. Two resistant donors viz. IRBL9-W (Pi9), IRBLZ5-CA (Piz-5), were selected for the development of NILs based on their broad spectrum resistance to blast in eastern India. The recurrent parent Poornima was crossed in the wet season of 2012. The F1s were raised during 2013 DS and hybridity was confirmed with linked SSR markers AP5930 and AP5659-5 for the gene *Pi9* and *PiZ-5*, respectively. The confirmed F_1s were backcrossed with the recurrent parent during 2013 wet season, and 24 and 18 BC_1F_1s seeds were obtained from the two crosses. The BC_1F_1s of Poornima*2 / IRBL9-W was raised during 2014 DS and foreground selection conducted with the linked marker AP5930 (*Fig 75*). Four plants, out of 10, were

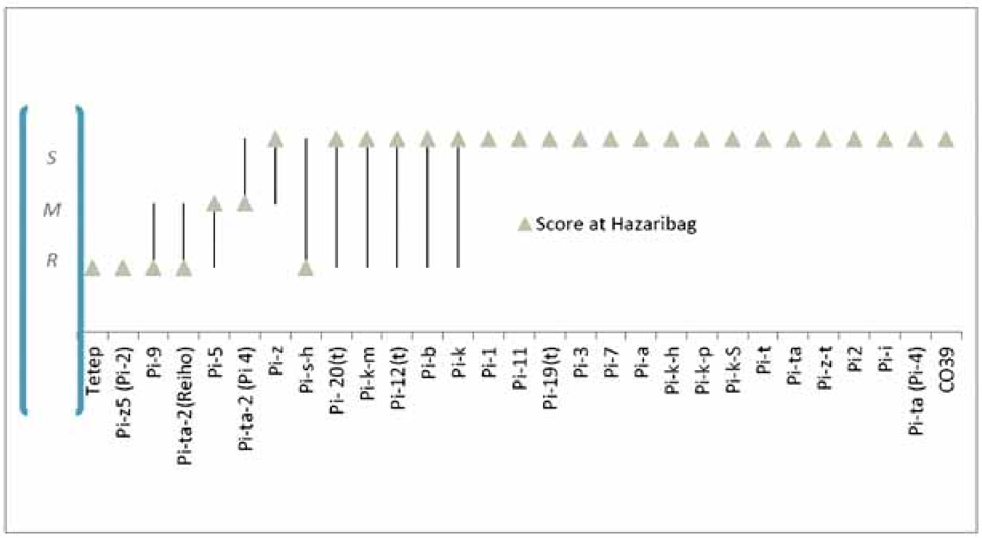


Fig 74. Reaction of monogenic blast differentials at there districts of Jharkhand

*Fig 75. Foreground selection of BC_1F_1s (Poornima*2/ IRBL9-W) with linked markers AP5930*

confirmed for the target marker. The BC_1F_1s of Poornima*2 / IRBLZ5-CA are being grown and foreground selection will be conducted to confirm the presence of *Piz-5* gene.

Management of major rice diseases in rainfed flood prone lowlands

Eco-friendly management of sheath blight disease of rice using bio-control agents

The bio-control agent, *Trichoderma viride* (Pest Control India Collection), reduced the sheath blight incidence by 53.82% followed by treatment with *T. viride* (OUAT, Bhubaneswar collection) by 45.8% and the standard fungicide, Validamycin 3%L by 43.66%. The grain yield was highest (4.94 t / ha) in treatment with *T. viride* (PCI Collection) followed by 4.33 t / ha in the treatment with *T. viride* (OUAT, Bhubaneswar collection) and 4.15 t / ha with Validamycin 3%L, while it was 2.88 t / ha in control.

Management of sheath blight disease of rice using new fungicides

The fungicide Azoxystrobin 25 SC (Amistar) @ 1.0 ml / lit of water caused 50.6% reduction in sheath blight severity and 53.98% reduction in sheath blight disease incidence. It was followed by Trifloxystrobin 25% + Tebuconazole 50% (Nativo 75 WG) @ 0.4 g / lit of water and Kresoxim methyl (Ergon 44.3 SC) @ 1 ml / lit of water–the former reduced the disease severity by 43.88% and disease incidence by 46.39% and the latter reduced disease severity by 38.01% and disease incidence by 40.88%. Grain yield was the highest (5.15 t / ha) in the treatment with Azoxystrobin 25 SC followed by 4.65 t / ha in the treatment with Trifloxystrobin 25% + Tebuconazole 50%, while it was 2.58 t / ha in control.

Survey of occurrence of virus and phytoplasma diseases affecting rice in rainfed, flood-prone lowlands with special reference to *tungro*

Incidence of rice *tungro* disease (RTD) was recorded in thirteen districts of Assam viz. Barpeta, Baksa, Cachar, Hailakandi, Kamrup and Nalbari districts in summer rice 2012-13 and Darrang, Morigaon, Nagaon, Sonitpur, Udalguri, Karbi, Anglong and Kokrajhar in winter rice 2013. Some of the varieties viz. Mahsuri, Ranjit, Baismuthi, Swarna *Sub1*, Swarna, IR 64, China boro, Arize 6444, DRRH 2, JKRH 401, PAC 837, Sahyadri 4. Barring Dalgaon sub-division of Darrang district and Rowta sub-division of Udalguri district, RTD incidence in other sub-divisions / districts was less than 1%.

Transmission of virus and phytoplasma diseases using viruliferous vectors under greenhouse conditions

Significant incidence of RTD in *sali/kharif* 2013 season was apprehended in Dalgaon sub-division of Darrang district and Rowta sub-division of Udalguri district of Assam. In some pockets, extent of incidence varied from 4 to 11%. The varieties affected were Ranjit, Mahsuri, Swarna and Baismuthi. Apparently, *tungro*-affected plants were collected from the village Bhalukmari No. 2 in Rowta sub-division of Udalguri district. RTD incidence was ascertained by transmitting the disease from apparently affected field samples of Ranjit and Swarna to healthy T(N)1 using viruliferous green leafhoppers.

Survey on the incidence of major fungal and bacterial diseases of rice

Surveys were conducted in the farmers' fields of Darrang, Sonitpur, Nalbari and Barpeta districts of Assam during *sali / kharif*, 2013 at different crop growth stages. In the Nalbari district, villages covered were 2 No. Ghoga Madulabari, Chanda, Bartala and rice varieties covered were Baismuthi, Aijong (Mahsuri), Ranjit, Mala and Swarna Mahsuri. In most of the varieties, incidence of brown spot, sheath blight and sheath rot diseases were observed. Sheath blight and sheath rot diseases occurred more frequently in the varieties Swarna and Mahsuri respectively, which were 6.26% for sheath blight and 6.94% for sheath rot.

In the Barpeta district, the villages covered were Chenga and Barbila and the varieties covered were

Baismuthi, IR 36, Mala. Sheath blight, sheath rot, brown spot and false smut diseases were of more common occurrence. Sheath blight and brown spot disease incidences in the varieties (Mala and Baismuthi) were 7.26% and 7.14% respectively. Altogether 6.12% incidence of false smut was observed in the variety Baismuthi.

In Darrang district, villages covered were Bijlibari, Satgharia, 2 No. Machgaon Pub and commonly grown rice varieties were Baismuthi, Ranjit, Bahadur, Mahsuri, Swarna, Kalajoha. Brown spot, bacterial leaf blight, bacterial leaf streak and blast were observed in the most of the varieties. Brown spot incidence was highest (7.82%) in Ranjit, whereas, blast incidence was highest (7.64%) in Mahsuri.

In Sonitpur district, villages covered during survey were No. 2 Bhalukmari, Pub Gelabil and the varieties grown were Ranjit, Baismuthi, Swarna, Mahsuri. Important diseases found to affect majority of the varieties grown were brown spot, sheath blight and blast. Sheath blight was found to be the highest (12.94%) in variety Swarna while blast disease was highest (10.62%) in Mahsuri.

Host range of sheath blight pathogen in rainfed lowlands

To ascertain the role of weeds in perpetuation of rice sheath blight pathogen, *Rhizoctonia solani* Kuhn; different weeds namely yellow nut sedge (*Cyperus esculentus*), Bermuda grass (*Cynodon dactylon*), common crab grass (*Digitaria sanguinalis*), viper grass (*Dimbraretroflexa*), jungle rice (*Echinochloa colonum*), cockspur grass (*Echinochloa glabrescens*) and hoorah grass (*Fimbristylis miliacea*) were artificially inoculated with the sheath blight pathogen. The pathogen, *R. solani* produced typical sheath blight lesions in all seven weed species. Incubation period of the pathogen in different weed species varied from 4 to 6 days. Highest lesion length (33.2 mm) was recorded in *D. sanguinalis* which was followed by *E. colonum* (31.3 mm) and *E. glabrescens* (30.2 mm) whereas the lowest lesion length (4.4 mm) was observed in *C. esculentus* (*Table 46*).

Identification of sources of resistance/ tolerance against sheath blight of rice

Ten genotypes, namely IET 17885, IET 17886, IET 19140, IET 20230, IET 20252, IET 20443, IET 20553, IET 20755, ADT 39 and Mansarovar, received from Crop Improvement Division, CRRI, Cuttack were evaluated for the 2nd year during *sali*/*kharif* 2013 in the experimental farm of RRLRRS, Gerua for resistance/ tolerance against sheath blight disease. Two entries, IET 17886 and IET 20443 were found to be moderately resistant while three entries, viz., IET 20755, ADT 39 and Mansarovar showed tolerance to sheath blight disease. The 695 entries (NSN1 - 196 entries, NSN2- 306 entries, NSN-H- 80 entries and NHSN- 113 entries) tested in AICRIP national screening nurseries to evaluate their resistance against sheath blight disease (*Rhizoctonia solani* Kuhn), no entry exhibited resistant reaction. One hundred eighty one entries (59 entries under NSN1, 75 entries under NSN2, 23 entries under NSN-H and 24 entries under NHSN) showed moderate resistance and the remaining 514 entries (137 entries under NSN1, 231 entries under NSN2, 57 entries under NSN-H and 89 entries under NHSN) showed susceptible to highly susceptible reaction.

Identification of sources of resistance against rice *tungro* disease

The 942 entries (NSN1 – 203 Nos.; NSN2 – 551 Nos.; NSN-H – 47 Nos.; NHSN – 106 Nos.; and DSN – 35 Nos.) tested in AICRIP national screening nurseries for their resistance against rice *tungro* disease, no entry was found to be resistant. Seventy five entries (17 in NSN1, 43 in NSN2, 7 in NSN-H, 3 in NHSN and 5 in DSN) showed moderate resistance and the remaining 867 entries showed tolerance to highly susceptible reaction.

Table 46. Experimental host range of sheath blight pathogen

Weed species	Pathogenic reaction	Time required for appearance of disease symptoms (days)	Lesion length(mm)
Cyperus esculentus	+	6	4.4
Cynodon dactylon	+	4	16.7
Digitaria sanguinalis	+	4	33.2
Dimbra retroflexa	+	4	26.9
Echinochloa colonum	+	4	31.3
Echinochloa glabrescens	+	5	30.2
Fimbristylis miliacea	+	6	5.3

‘+’ indicates infection

PROGRAMME 4

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

There are four projects under this program. The first project has been undertaken with the view to evaluate rice germplasm, breeding lines and varieties for their grain and nutritional quality, specialty traits such as availability of nutraceuticals and suitability for diabetics and to develop value added products. Rice with high protein content, iron, zinc and anthocyanins have been identified.

As proper phenotyping is the key to success in identifying gene / QTL of interest as well in developing new varieties, chlorophyll a fluorescence based screening of rice germplasm tolerant to salinity was standardized, which distinguished between tolerant and susceptible genotypes and separated out best tolerant genotypes from the tolerant group. A genotype AC 39416 was found to be tolerant to salinity, stagnant flooding with salinity, drought and anaerobic germination.

Looking to the climatic scenario and water scarcity research efforts have been initiated to identify and develop resistant / tolerant varieties, to understand their intrinsic behavior under moisture / high temperature stress and physiological basis of stress tolerance, with special emphasis on exploitation of genetic variability to identify genetic sources for component traits and superior alleles. Based on root traits, osmotic adjustment and survival, four cultivars AC 43020, AC 42994, AC 42997 and CR 143-2-2 found tolerant to vegetative stage drought.

The fourth project is on evaluation of rice genotypes for their physiological adaptation to low light stress and improvement of photosynthetic efficiency, light spectral analysis in relation to physiological changes and yield potential of rice and QTL analysis for some low light adapted traits of rice plant. Sterility (%) in the rice genotype Lalitgiri under low light was the least (9.99%). Another objective is to genetically engineer rice by introducing C_4 genes viz. NADP-Malate dehydrogenase and NADP-Malic enzymes into rice genome. The NADP–Malic enzyme gene was cloned and used to transform rice cv. Naveen. Colony PCR result confirmed the cloning.

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

Biochemical characterization of specialty rices including low GI, *'Soak and eat'*, pigmented and aromatic rice

Identification and characterization of low Glycemic Index (GI) rice

Three rice cultivars were evaluated for GI values as per approval of the Institute Ethics Committee (IEC). The GI value of a red pericarp rice variety, Sharavathi and a high protein rice cultivar ARC 10075 was 73, whereas, that of Improved Lalat (MAS) was quite low. However, this will be reconfirmed. Process for *in vitro* GI determination of 20 rice genotypes including improved Lalat (MAS) has been initiated.

Identification, characterization and promotion of *'soak n eat'* rice

A multi-location trial was initiated (2012-13) with three '*soak n eat*' rice cultivars viz. Aghoni, Nalbora and Ashambiroin in six states (Odisha, West Bengal, Assam, Bihar, Jharkhand and Meghalaya where the parboiled grains maintain the soaking time in subsequent seasons) to identify regions most suited for cultivation of '*soak n eat*' rice cultivars. The soaking time did not change for Aghoni and Nalbora in the first season of cultivation in samples grown at Cuttack, though increase in soaking time was observed in samples grown at other sites (Ranchi and Pusa). Analysis of the second season samples (2013-14)

Table 47. Soaking time of three '*soak n eat' rice* varieties grown at different locations (2013-14)

Place of cultivation	Soaking time of parboiled grains of rice cultivars (minutes)		
	Nalbora	Aghoni	Asham Biroin
Gerua, Assam	No response	55	95*
Chinsurah, WB	No response	58	75
Cuttack, Odisha	No response	90	95*

**Hard core remains*

indicated that only one rice cultivar i.e. Aghoni maintained the soaking time (but only when grown at Gerua, Assam or at Chinsurah, WB). Other two cultivars showed substantial increase in soaking time (*Table 47*). Besides, a hard core was also noticed in the soaked grains of these two cultivars.

Evaluation of rice varieties for suitability to make popped paddy (*khai/kheel*)

With a view to identify rice varieties suitable for commercial exploitation, eight rice varieties (Sarala, Gayatri, Pooja, Lunishree, Savitri, Varshadhan, Swarna and Mayurkantha) were evaluated for their volume expansion, when the paddy grains are converted to popped paddy. The CRRI rice varieties Sarala and Gayatri were found to be the best as each of them exhibited ten times volume expansion.

Characterization of rice (including pigmented rice) for nutrients especially micronutrients (Fe and Zn) and protein

Ten red rice germplasms were analyzed for grain protein, Fe and Zn content in brown, as well as, milled rice grains. Crude protein content of brown rice varied from as low as 8.33% to 13.20% in the rice cultivar Mamihangar. Iron and Zn contents varied from 7.12 to 10.50 ppm and 15.40 to 26.85 ppm, respectively.

Evaluation of rice germplasms for grain micronutrient content

One hundred ninety rice genotypes were evaluated for grain micronutrient (Fe / Zn) content after milling. Some of the cultivars viz. Upahar, Saria, Kamesh, Setka-36, Nilagiri, Balam and Beria Bhanga and IR 50 were found to contain more than 6.00 ppm Fe in the milled grains. Some of the cultivars or land races, viz. Saria, Setka-36, Asrasali, Bazailsali, Ranidhan, VLD-16, Ekrasali, Pathara, Prasan, Nila, Akisali and PS-2 and IR 50 contained more than 20 ppm Zn after milling. In the *Sali* rice germplasms of Assam, grain Fe concentration varied from 1 ppm in Matangini to 6.29 ppm in Birapak 7 while Zn content varied from 6.25 ppm in Jitendra to 19 ppm in Mukh badal 2; Mn concentration ranged from 5.98 ppm in Lati Sali to 12.42 ppm in Jul bao 3 and Cu concentration varied from 0.63 ppm in Jul bao 3 to 2.47 ppm in Jul bao 1. Among the germplasms studied Birpak 7 possess higher concentration of all these micronutrients.

Estimation of extent of loss of phytate during processing and cooking of rice grain

Phytic acid content of raw white rice of 25 popular rice varieties varied from 0.13% in Indira to 1.37% in Harisankar. It was also observed that there was progressive loss of grain phytate during milling, washing and cooking. Milling of raw paddy resulted in a loss of 22.70 to 31.17% phytate, whereas, washing and cooking resulted in 55.38 to 70% and 74.32 to 85% loss, respectively. Parboiling of paddy caused slightly lesser loss of phytate (milling: 7-8%, washing: 3-7% and cooking: 1-4%).

Evaluation of mapping populations/breeding lines for grain protein content

Two hundred lines of a BC_3F_4 (Naveen x high protein donor 2) population were analyzed for grain protein content (GPC), which varied from 5.06 to 14.14%, while single grain protein content varied from 0.87 to 3.06 mg. Among the high protein (>10% GPC) lines identified from BC_3F_3 generation, 77.41% maintained the high GPC trait (>10% GPC). Eight selected lines (F_8) from crosses with high protein donors and high yielding recipients were analyzed for GPC. Protein content of the bulked samples varied from 10.72 to 12.89%, while single grain protein content varied from 1.75 to 2.48 mg.

Validation of transcriptome results

Eight genes which were found to be differentially expressed in Sharbati and Lalat were further validated through RT-PCR using gene specific primers viz. OsYSL4, OsYSL6, OsYSL7, OsYSL9, OsNRAMP4, NRAMP5, OsNAAT1 and OsNAS2. Among these, only four genes viz. OsYSL4, OsYSL6, OsYSL9 and OsNAAT1 were highly expressed in the developing grain of Sharbati compared to Lalat.

Assessment of physiological and biochemical parameters responsible for high temperature stress tolerance

Twenty six rice germplasms were exposed to high temperature (Max. / Min.=40-58°C / 20-26°C) at grain filling stage and continued till maturity. It was observed that only IET-21577, US-312, US-382 and N-22 performed better in respect to effective grain number, effective tillers and test weight (*Table 48*). Tolerant germplasms showed higher activity of superoxide dismutase (SOD) enzyme in the flag leaf (35 to 40% inhibition). Superoxide dismutase activity was also lower in the control than that of the stressed plants. Higher photosynthetic rates were observed in N-22 (26.27 µmol CO_2 / m^2 / s), US-312 (25.92 µmol CO_2 / m^2 / s) and IET-22308 (24.54 µmol CO_2 / m^2 / s) under heat stressed condition. Transpiration rate (µmol CO_2 / m^2 / s) and stomatal conductance (µmol CO_2 / m^2 / s) were also higher in IET-22308 (10.88 and 1.16, respectively) and N-22 (14.74 and 0.71, respectively) under heat stress. But IET-21577 and US-382 maintained significantly lower transpiration rate under heat stress compared to normal condition (*Table 1*). It signifies that these cultivars conserved water efficiently in their system under heat stress. Total chlorophyll content was higher in normally grown plants than those under heat stress. Heat stressed plants had lower content of chl a than chl b under heat stress.

Table 48. Physiological parameters of rice germplasm under heat stress

Cultivar	Treatement	Effective tiller no.	Filled grain no. / panicle	1000 grain wt (g)	SOD activity (% inhibition)	Photosynthetic rate (µmol CO_2 / m^2 / s)	Total chl (mg / g)	Transpiration rate (mmol H_2O / m^2 / s)	Stomatal conductabce H_2O / m^2 / s)
N-22	Ambient	10.33	49.67	16.50	31.25	27.42	26.98	15.84	0.85
	Heat stress	9.33	47.00	18.23	39.65	26.27	14.79	14.74	0.71
US-312	Ambient	11.67	55.67	19.17	28.85	19.49	25.40	10.97	1.44
	Heat stress	10.67	49.33	21.10	35.21	25.92	18.10	9.74	0.97
IET-22308	Ambient	10.33	57.00	24.80	27.24	28.93	26.70	11.36	0.65
	Heat stress	8.67	23.67	19.40	38.56	24.54	19.40	10.88	1.16
IET-21577	Ambient	6.67	87.00	19.37	29.12	21.76	28.92	13.06	1.53
	Heat stress	4.67	53.33	18.37	39.44	12.95	20.50	5.52	0.30
US-382	Ambient	4.67	49.00	22.10	26.52	19.15	27.42	9.06	0.87
	Heat stress	4.33	48.33	19.40	38.62	12.09	21.24	5.76	0.30

Phenomics of rice for tolerance to multiple abiotic stresses

Screening of rice germplasm for submergence tolerance

Two hundred fifty rice germplasms (including fixed breeding materials) were evaluated for submergence tolerance with ten known lines tolerant to submergence stress. Among the fixed breeding lines NDR 9481 and IR 88776-SUB 8-1-1-2 showed more than 80 % survival after 14 days of complete submergence (*Table 49*). Survival percentage of susceptible checks was below 10%. Among the germplasm lines, three namely, DP / BCP – 1, DP / BCP – 2066 and DP / BCP - 8 were highly tolerant (survival more than 90%).

Screening of rice germplasm for multiple abiotic stress tolerance

Ten lines viz., IET22116, IET20924, IET21515, IET22218, AK Dhan, AC 39416, NS1, NS2, NS3 and NS4 obtained from AICRIP were tested for tolerance to submergence, drought and salinity and ability to germinate under anaerobic conditions. None of the materials was tolerant to submergence. AC 39416 was found to be tolerant to drought and salinity and showed moderate tolerance to anaerobic germination (*Fig 76*).

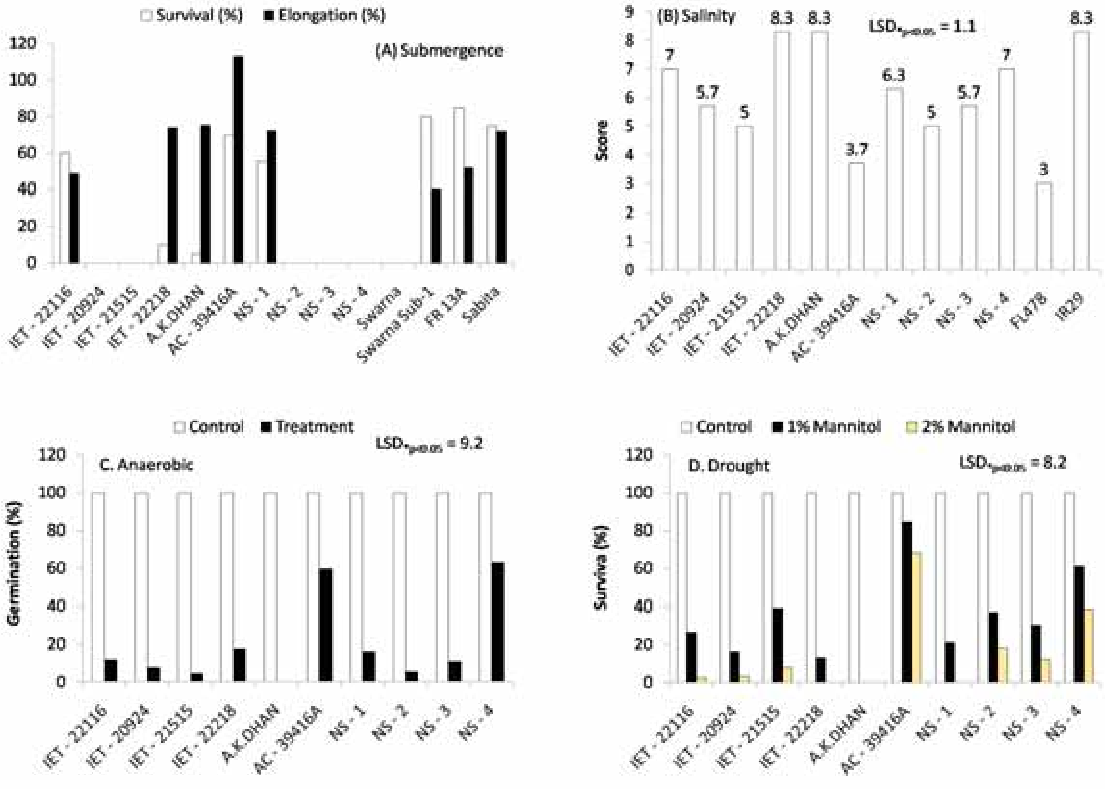


Fig 76. Interaction of certain rice genotypes under multiple abiotic stresses

Table 49. Effect of submergence on elongation ability and plant survival

Name	Plant height before submergence (cm)	Plant height after submergence (cm)	Elognation (cm)	Elongation (%)	Survival (%)
A. Tolerant type					
DP / BCP - 2066	51	59	8	16	89
DP / BCP - 1	52	58	6	11	85
NDR 9481	44	71	28	64	85
DP / BCP - 72	57	70	12	21	85
DP / BCP - 80	48	58	11	22	80
IR 88776-SUB 8-1-1-2	35	50	15	42	80
IR 85086-SUB 33-3-2-1	45	52	6	14	70
DP / BCP - 30	43	58	15	36	68
IR 87439-BTN-88-3-2	48	62	14	29	65
IR 86256-6-2-2-2	37	43	7	18	60
B. Avoiding type					
DP / BCP - 2065	52	82	30	58	100
RAU 1472-17	48	103	54	112	90
AC39416A	61	103	42	70	55
Swarna *Sub1* (Tolerant check)	37	42	5	14	50
FR13A (Tolerant check)	63	75	11	18	90
Sabita (Avoiding type check)	55	101	46	84	60

Basis of multiple abiotic stress tolerance (drought and salinity)

The experiment was conducted with four rice cultivars namely, CR143-2-2, IR 20, AC 39416A and Kalaputia. Accumulation of Na^+ was higher under 12 dS/m salinity followed by combined effect of salinity (12 dS/m) and polyethylene glycol (PEG, -1.5 bars) in CR143-2-2, IR 20, Kalaputia and AC 39416(A). Uptake of Na^+ increased under high salinity (12 dS/m) compared to control, polyethylene glycol induced (PEG, -1.5 bars) drought and combined effect of drought and salinity (-1.5 bars + 12 dS/m) conditions (*Table 50*). Cultivar AC 39416 (A) was found to be highly tolerant under combined stress of drought and salinity.

Studies on the mechanism of waterlogging tolerance

The study revealed that under continuous salinity (4 dS/m) with waterlogging (~ 50 cm water depth), grain yield drastically decreased due to loss of chlorophyll, impairment of chloroplast structure and functional integrity and overall increase of spikelet sterility (97.2% in case of susceptible cultivar Varshadhan). Panicle numbers per pot greatly decreased due to waterlogging and combined effect of waterlogging and salinity, except in AC 39416A (*Fig 77A*). The percentage of chaff was greater in susceptible cv. Varshadjan (94.4%) followed by Ravan (45%) due to combined effect of waterlogging and salinity (*Fig 77B*). Similarly, panicle weight and grain yield also decreased due to combined effects of waterlogging and salinity in all the cultivars (*Fig 77 C and D*). However, the reduction of these parameters was greater in Varshadhan compared to other cultivars. The percentage reduction in grain yield (*Fig 78*) was maximum in Varshadhan (97.2%), followed by Kamini (72.6%) and SR26B (68.5%); the grain yield reduction was minimum in AC 39416A (30.6%).

Table 50. Combined effect of NaCl and polyethylene glycol induced salinity and drought in accumulation of sodium and potassium ions

Name of the genotypes	Treatments	Sodium (mg/g dry weight)	Potassium (mg/g dry weight)	Sodium: Potassium ratio
CR143-2-2	T1	24.1	76.9	0.31
	T2	127.7	36.4	3.53
	T3	30.3	66.8	0.45
	T4	61.2	40.3	1.52
IR20	T1	24.1	88.4	0.27
	T2	89.5	46.5	1.92
	T3	27.2	58.9	0.46
	T4	45.3	56.7	0.79
AC 39416A	T1	38.0	108.3	0.35
	T2	60.2	66.5	0.93
	T3	27.7	86.1	0.32
	T4	32.4	81.2	0.40
Kalaputia	T1	26.2	96.5	0.27
	T2	61.2	58.9	1.03
	T3	32.4	75.9	0.42
	T4	46.3	58.3	0.79
$LSD_{*p<0.05}$		8.1	4.5	0.24

T1-control, T2- NaCl (12 dS/m), T3- polyethylene glycol (-1.5 bars), T4- combined effect of NaCl (12 dS/m) and polyethylene glycol (-1.5 bars)

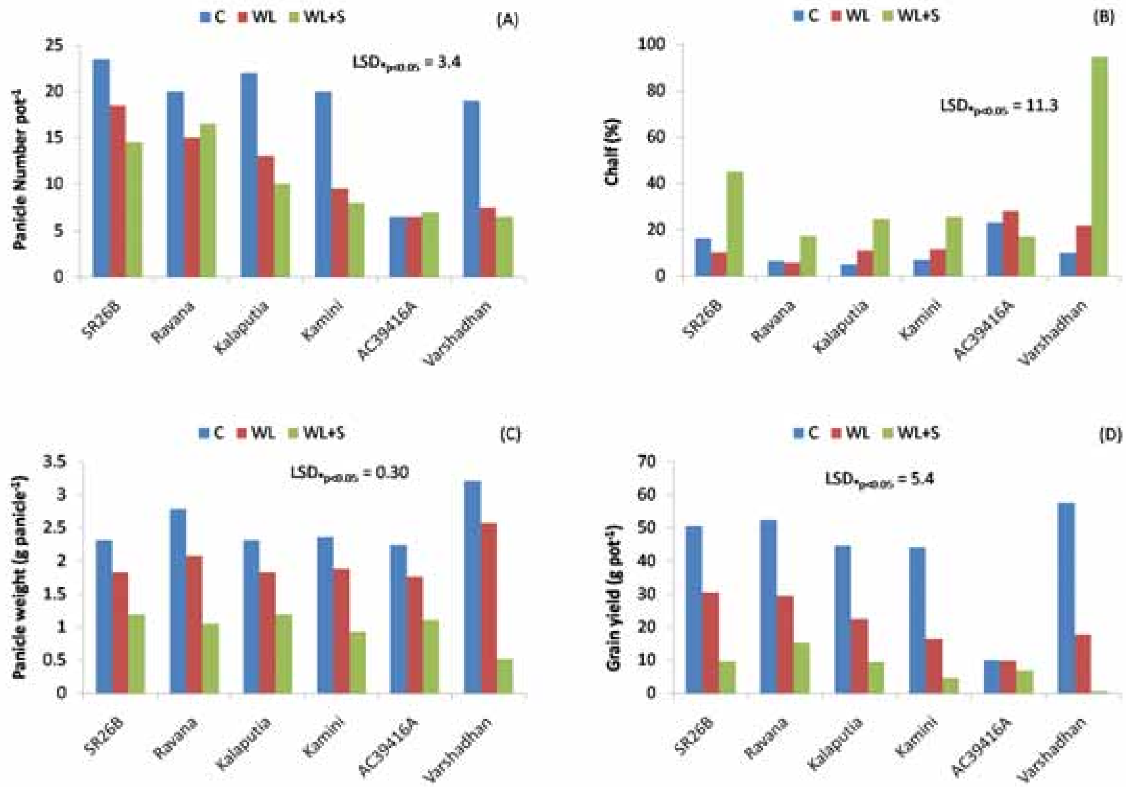


Fig 77. Grain yield and yield attributing parameters in different cultivars of rice under combined effect of waterlogging and salinity

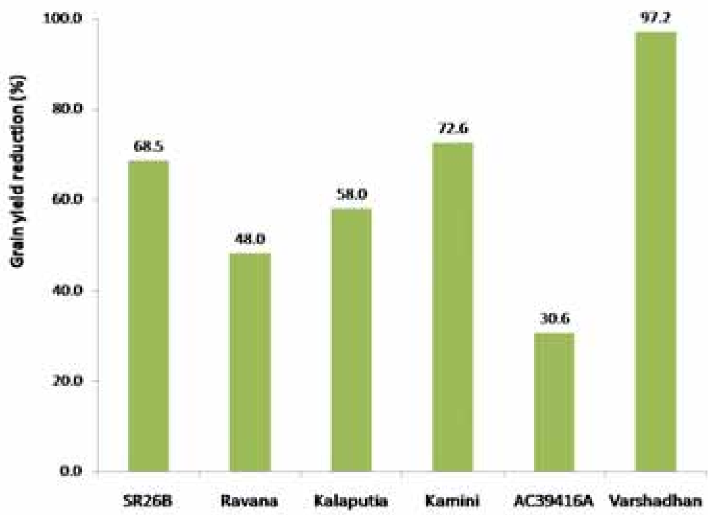


Fig 78. Grain yield reduction (%) under combined effect of waterlogging and salinity compared to waterlogging

Evaluation of salt-tolerant rice cultivars for tissue tolerance at seedling stage

Ten rice cultivars were evaluated for tissue tolerance to salt stress at seedling stage by growing them at varying salinity levels (EC 0, 6, 12 and 18 dS/m). Chlorophyll and Na^+ contents of 3rd leaf from bottom were measured and then Na^+ level causing 50% reduction in chlorophyll content was computed. The susceptible cultivar IR 29 showed maximum tissue tolerance, with 50% reduction in chlorophyll at Na^+ content of 26.5 µg/mg leaf weight (*Fig 79*). It was followed by moderately tolerant cultivar Marisal, with 50% reduction in chlorophyll at 20.9 µg Na^+/mg leaf weight. However, FL 478, Nagalmutha, Rashpanjor and Ravana were comparable to Marisal. Cultivar Rupsal showed minimum tissue tolerance, recording 50% reduction in chlorophyll at 9.7 µg Na^+ / mg leaf weight. Kamini is known to have similar level of salinity tolerance as FL 478, but its tissue tolerance was significantly lower compared to FL 478.

Evaluation of submergence-tolerant rice genotypes for salinity tolerance

A set of 25 submergence-tolerant rice genotypes along with sensitive cultivar Swarna and salt-tolerant cultivars Pokkali and Chettivirippu was evaluated for salinity tolerance at reproductive stage at EC 6-8 dS/m under simulated condition. Pokkali recorded least yield reduction due to salt stress compared to the control (*Table 51*). Among the submergence-tolerant cultivars, AC 39416(A) with 24% grain yield reduction under salt stress compared to the control was found to be most promising, followed by Pantara with 30.4% grain yield reduction. The two cultivars were comparable to salinity-tolerant cultivar Chettivirippu, which recorded 26% yield reduction. AC 253330 and Sabita showed 41 and 44% yield reduction over the control, respectively. AC 917, AC 34304 and AC 41620 did not flower or recorded nil yields in salinity treatment.

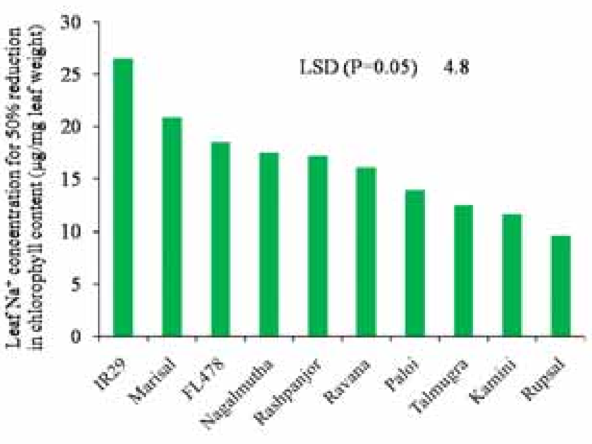


Fig 79. Tissue tolerance measured as leaf Na^+ concentration for 50% reduction in chlorophyll content

Table 51. Grain yield of different rice genotypes in the control and salinity treatment and reduction in grain yield under salt stress over the control

Rice genotype	Grain yield (g/plant) Control	Grain yield (g/plant) Salinity	Reducation in grain yield (%)
AC 38575	4.1	1.6	60.2
AC 253330	4.4	2.6	40.9
IC 258990	5.6	0.9	83.9
AC 20431(W)	6.3	2.1	66.7
AC 20431(B)	5.6	0.7	87.0
AC 37887	8.4	1.9	77.2
AC 41644(R)	6.1	2.9	53.0
AC 40634	12.0	1.5	87.5
AC 917	5.5	0.0	100.0
AC 1785	5.7	2.3	59.3
AC 1125	14.8	2.7	82.0
AC 34304	9.6	0.0	100.0
AC 41620	7.0	0.0	100.0
AC 39416(A)	7.9	6.0	24.0
Kalaputia	4.1	0.9	77.9
Khoda	13.4	1.0	92.3
Kusuma	10.5	3.7	64.9
Gangasiuli	6.7	0.8	88.1
Pantara	6.9	4.8	30.4
Savita	14.2	8.0	43.9
FR13A	10.9	1.9	82.6
JRS 4	5.0	2.3	54.3
JRS 5	10.5	1.5	85.4
JRS 8	13.3	0.9	93.5
AC 41644(B)	7.9	2.1	73.9
Swarna	8.4	1.0	88.0
Pokkali	5.4	5.2	3.7
Chettivirippu	7.3	5.4	26.0
LSD (P=0.05)	2.3	1.8	4.7

Effect of submergence on yield and yield attributes under different seed rate on main field

The experiment was conducted with two varieties viz. Savitri and Savitri-*Sub1*. Crop was raised under direct seeding with three rates of seeds such as 4, 6, and 8 g / m^2 on main rice field. After 24 days of seeding, the plants were submerged for 10 days. A control set was maintained in another field to compare the yield and yield associated parameters. However, in control plot, direct seeding was done one month later (*Table 52*). Savitri-*Sub1* matured early compare to Savitri. Flowering date of Savitri-*Sub1* was 11^{th} November, 2013 in control whereas it was on 28^{th} October, 2013 in submergence plot. As compared to control, grain yield decreased greatly under submergence in both the cultivars. Reduction in grain yield was greater under submergence in Savitri-*Sub1* due to greater sterility (40%). This might be due to the cyclone '*Phailin*', which hit on 12^{th} October, 2013. Spikelet sterility was not severe in control plots, probably because flowering date was in the middle of November or the plots escaped the high intensity wind.

Management of nursery and its impact on yield and yield attributes under complete submergence

The experiment was conducted with two varieties viz., Savitri and Savitri *Sub1*. Seedlings were raised with two seed rates and three doses of phosphorous (*Table 53*). Phosphorous status of the soil was medium. Date of sowing was 28^{th} June, 2013, whereas, the date of transplanting (both under control and submergence treatment) was 30^{th} July, 2013. Nursery management did not influence the grain yield much. Savitri-*Sub1* flowered on 25^{th} October, 2013, yet grain filling was more or less good and comparable with Savitri. Savitri-*Sub1* produced greater grain yield under control condition compared to Savitri.

After 16 days of transplanting, the plot was submerged for 14 days. There was high mortality even in Savitri-*Sub1*. Savitri showed 100% mortality under submergence. Phosphorous application at the rate of 60 kg / ha in the seed bed improved the survival chance and greater production of yield compared to 'no-phosphorous' treatment (*Fig 80*). Data showed that growing Savitri-*Sub1* rather than Savitri was better to obtain good harvest under control conditions, as Savitri-*Sub1* gave some grain yield even under submergence. Application of even 30 kg P / ha was beneficial.

Table 52. Effect of submergence on yield and yield attributes under different seed rate on main field

Variety	Treatment	Seed rate (g / m^2)	Panicle (No. / m^2)	Chalf (%)	Straw (t / ha)	Grain (t / ha)	Flowering date
Savitri	Control	4	256	28.9	7.24	4.37	18.11.2013
		6	263	31.4	7.44	4.42	
		8	279	29.1	7.82	4.62	
	Submergence	4	137	26.0	4.94	3.25	05.11.2013
		6	151	28.6	5.73	3.28	
		8	182	21.8	5.84	3.40	
Savitri-Sub1	Control	4	179	19.1	6.43	4.90	11.11.2013
		6	224	21.4	7.01	4.90	
		8	250	22.1	7.10	5.27	
	Submergence	4	151	38.9	4.65	2.59	28.10.2013
		6	155	42.8	4.66	2.54	
		8	194	42.7	4.75	3.15	
LSD*p< 0.05			13	4.6	0.66	0.32	*Phailin* 12.10.2013

Submergence plot, date of sowing: 26.06.2013; Control plot, date of sowing: 27.07.2013

Table 53. Yield and yield attributes under different seed rate and phosphorous level on seed bed under control condition.

Variety	Seed rate (g/m²)	Phospohrous level (kg/ha)	Panicle (No./m²)	Fertile spikelet (%)	Grain yield (t/ha)	Flower date
Savitri	25	0	213	81	5.61	01.11.2013
		30	209	79	5.35	
		60	203	80	5.23	
	50	0	202	80	5.65	
		30	204	80	5.49	
		60	192	78	5.32	
Savitri *Sub1*	25	0	188	84	5.73	25.10.2013
		30	201	84	5.78	
		60	194	79	5.49	
	50	0	211	81	5.63	
		30	210	82	5.64	
		60	218	78	5.75	
LSD*p< 0.05			16	NS	0.28	*Phailin* 12.10.2013

Date of sowing on seed bed: 28.06.2013; Date of transplanting: 30.07.2013

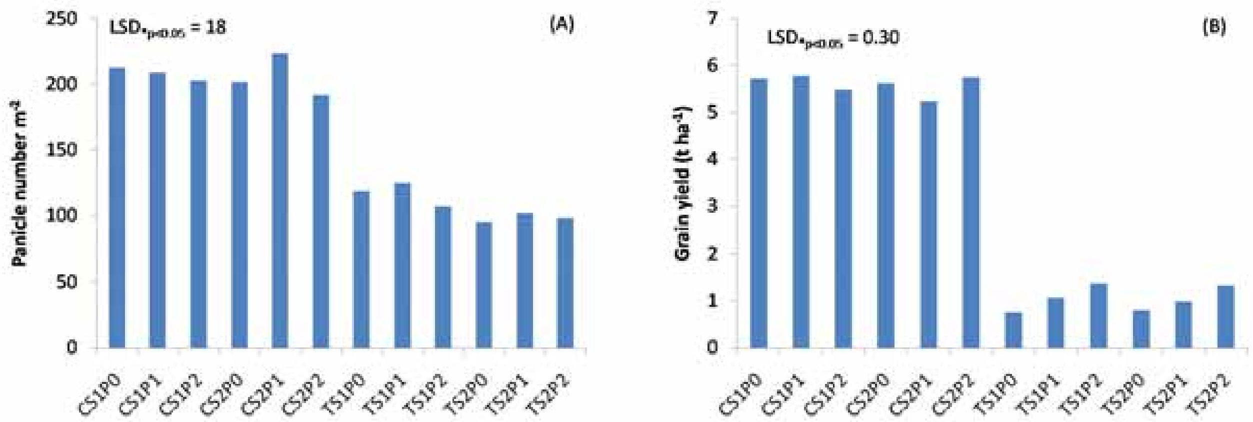


Fig 80. Seed bed management and its impact on panicle numbers and grain yield under control and submerged conditions. C, control; T, submergence; S1 and S2, seed rate 25 and 50 g/m² at seed bed; P0, P_1 and P_2, application of phosphorous @ 0, 30 and 60 kg P/ha at seed bed, respectively.

ICAR-IRRI collaborative projects (EAP 128 and EAP 157A: salinity component)

Evaluation of promising salt-tolerant elite lines through participatory varietal selection

Seven promising salt-tolerant lines along with two tolerant checks (FL 478 and CR Dhan 405) and a farmer's variety Patitpaban were evaluated with improved crop management practices in an on-farm trial at Ersama, Jagatsinghpur during dry season under moderate to high salinity. CR2815-4-23-5-S-2-1-1 produced the highest grain yield of 4.48 t/ha, followed by CR2814-1-19-4-2-1-1 with grain yield of 3.66 t/ha (*Fig 81*). The two genotypes were significantly superior to recently-released variety CR Dhan 405 (grain yield 3.27 t/ha), registering yield advantage of 37.0 and 11.9%, respectively. The farmer's variety Patitpaban produced the lowest grain yield of 0.66 t/ha. Preference analysis was conducted by involving 34 farmers and based on the preference score two most preferred

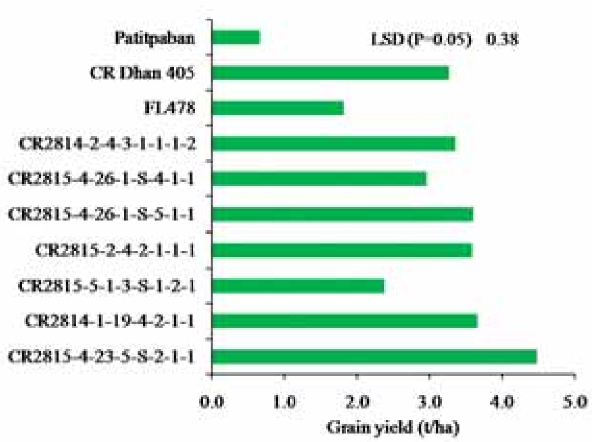


Fig 81. Grain yield of salt-tolerant elite lines at Ersama, Jagatsinghpur during the dry season

genotypes were CR2814-1-19-4-2-1-1 and CR2815-4-23-5-S-2-1-1. During the wet season, 10 promising salt-tolerant lines along with the tolerant check SR 26B and farmer's variety Bhaluki were evaluated at the same location, but the crop was completely damaged due to severe cyclonic storm *'Phailin'* that hit Odisha coast in October, 2013.

Farmer-managed baby trials

Performance of short-duration salt-tolerant rice genotypes CR 2472-1-6-2, CR Dhan 405 and OM 6051 (a variety from Vietnam) selected from the previous years' participatory varietal selection (PVS) trials was evaluated under farmer's management at 15 locations in Ersama block during the dry season, using the farmer's variety Khandagiri / Naveen for comparison. The grain yield of CR 2472-1-6-2, CR Dhan 405 and OM 6051 was in the range of 3.45-4.25, 3.25-4.20 and 3.15-4.30 t / ha with mean yield of 3.75, 3.69 and 3.77 t / ha , respectively, as against 2.90-3.67 t / ha (mean yield 3.31 t / ha) for the farmer's variety. On an average, the three genotypes recorded 11.5-13.9% higher grain yield than the farmer's variety. In the wet season, performance of improved salt-tolerant rice varieties Luna Suvarna (CR Dhan 402) and Luna Sampad (CR Dhan 403) was evaluated under farmer's management at 20 locations in Ersama and 10 locations in Astarang blocks. However, the crop was completely damaged in all the locations due to the cyclonic storm '*Phailin*'.

Method of crop establishment

In the dry season, performance of direct wet seeding was compared with that of transplanting on three different dates of sowing (Dec 18, 28 and Jan 7) under saline condition in an on-farm trial at Ersama using the rice variety CR Dhan 405. In transplanting treatments, sowing was done on the same dates and seedlings were planted on Jan 18, 28 and Feb 7. In general, the grain yield was significantly higher under transplanting (1.64-2.29 t / ha) than under direct wet seeding (1.40-1.98 t / ha), irrespective of the date of sowing (*Fig 82*). Delay in planting decreased yield under both the methods of crop establishment but the last two dates were comparable. The yields in this experiment were poor due to shortage of fresh water for irrigation during the reproductive stage.

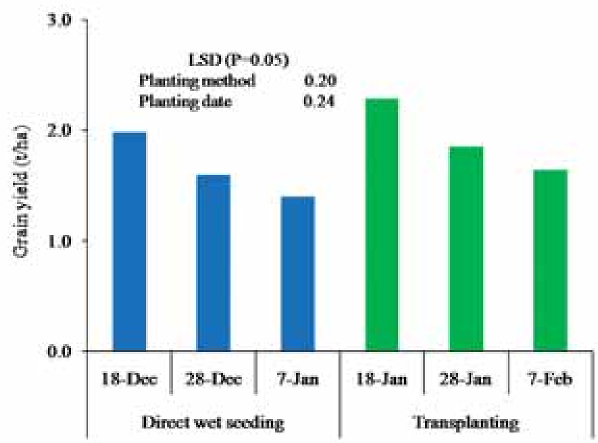


Fig 82. Grain yield of rice CR Dhan 405 under direct wet seeding and transplanting on different dates at Ersama block of Jagatsinghpur during the dry season

Nutrient management

An on-farm trial with six different nutrient management treatments was conducted at Ersama, Jagatsinghpur during the dry season using rice variety CR Dhan 405. The treatments were: T_1 - N_0:P_{40}:K_{40}, T_2 - N_{60}:P_{40}:K_{40} (50% N applied as basal and the rest 50% based on LCC readings), T_3 - N_{80}:P_{40}:K_{40} (N applied as in treatment T_2), T_4 - N_{80}:P_{40}:K_{40} (50% N applied as basal, 25% at tillering and the rest 25% at panicle initiation), T_5 - N_{40}:P_{20}:K_{20} (N applied as in treatment T_4) + FYM at 10 t / ha, and T_6 - N_{40}:P_{20}:K_{20} (N applied as in Treatment T_2) + FYM at 10 t / ha. Phosphate and potassium fertilizers were applied as basal before transplanting. Grain yield was highest (3.79 t / ha) in treatment T_6 receiving 50% of the recommended dose of NPK fertilizers along with FYM @ 10 t / ha , when half the N was applied as basal during transplanting and the remaining N in two equal splits based on the LCC readings (*Fig 83*). The treatment with similar doses of fertilizers and FYM but with the conventional method of N application (50% as basal and 25% each at maximum tillering and panicle initiation) recorded second highest grain yield of 2.98 t/ha. In a separate on-farm demonstration conducted at 10 locations, the grain yield of rice in *Azolla* dual cropping treatment was 3.51-4.15 t/ha (mean 3.77 t/ha) as compared to 3.08-3.57 t/ha (mean 3.38 t/ha) in no-*Azolla* treatment. *Azolla* application increased the grain yield by 7.3-18.5% (mean 11.8%) over no-*Azolla* treatment.

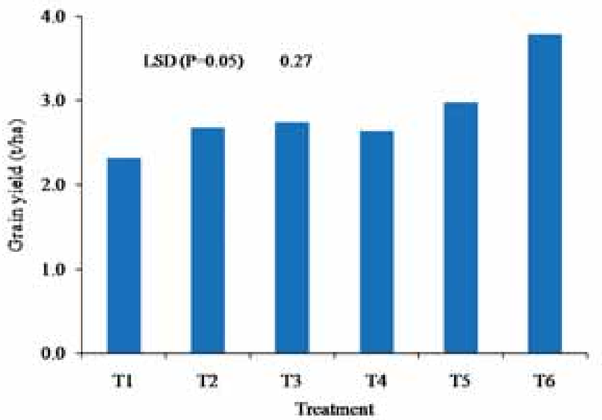


Fig 83. Grain yield of rice variety CR Dhan 405 under different nutrient management treatments at Ersama block of Jagatsinghpur during the dry season

Best bet management

In an on-farm trial conducted during the dry season at 15 sites in Ersama block of Jagatsinghpur, performance of improved salt-tolerant rice variety CR Dhan 405 grown with improved crop management practices was compared with that of locally-grown variety (Khandagiri/Naveen) under farmer's management practices. Grain yield of the locally-grown variety under farmer's management was 3.67-5.20 t/ha (mean 4.35 t/ha). Salt-tolerant variety CR Dhan 405 grown with improved management practices gave the yield of 4.53-5.87 t/ha (mean yield 5.17 t/ha), registering an yield advantage of 0.5-1.1 t/ha (9.9-28.1%) over the farmer's variety with farmer's management.

Rice physiology under drought and high temperature stress

Identification of potential donors for vegetative stage drought tolerance

Thirty five days old seedlings of 940 lines consisting of germplasm lines, breeding materials, mapping populations along with the parents including tolerant and susceptible checks were exposed to moisture stress during 1st week of March. Out of 940 lines, 180 lines were observed to be tolerant to drought with SES score '1' (*Fig 84*) followed by 314 lines of SES '3', 255 of SES '5', 102 of SES'7' and 6 of SES '9' under soil moisture content 6.0 to 11.6% and soil moisture tension -60 to -70 kPa. Eighty three lines observed to be drought escaping type and flowered at the onset of stress.

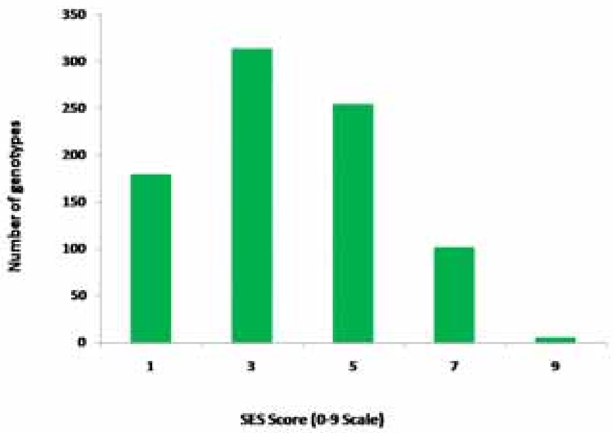


Fig 84. Reaction of genotypes to drought score

Identification of potential donors for reproductive stage drought tolerance

Fifty genotypes (previously observed as vegetative stage drought tolerant) of 100-120 days duration including 5 checks were exposed to drought stress at reproductive stage. Genotypes such as BVD-109 recorded highest grain yield of 2.15 t/ha followed by Kalakeri (2.08 t/ha) and IC 416249 (2.02 t/ha). RMP-1, Udaygiri, IET 18208, Kulia, CR 143-2-2, Vandana, RR 2-6, and N-22 had yield in the range of 1.7 to 1.95 t/ha, 12 entries had < 1.0 t/ha and rest had 1.0 to 1.7 t/ha, while under irrigated control condition AP 143-4-1-3-3 had highest yield of 5.05 t/ha followed by Udaygiri 4.7 t/ha. Eleven entries had > 4.5 t/ha, 11 entries had 3.0 to 4.0 t/ha, 17 entries had 2.0 to 3.00 t/ha and 3 entries had < 2.0 t/ha.

Same set of genotypes in another experiment was exposed to reproductive stage stress in 2 treatments (20 days before flowering, 20 DBF and 10 days before flowering, 10 DBF). In general, days to 50% flowering reduced by 9 days in 10 DBF and by 12 days in 20 DFB. Stress at 20 DFB had significant reduction in yield > 70%, while 10DBF had 60% yield reduction compared to control irrigated condition. This might have been due to the longer period of exposure to stress during primordial initiation (PI) which might have caused degeneration of more spikelets and lesser partitioning resulting in reduced grain filling in 20 DFB (54%) as compared to 10 DBF (67%) and irrigated (>80%) conditions.

Evaluation of promising rice genotypes for drought tolerance and yield potential under irrigated and rain-fed upland conditions (including AICRIP entries)

Forty two rice varieties including 27 cultivars from AICRIP were grown under rainfed upland condition at KVK, Santhapur. The crop experienced four intermittent drought spells of 7-9 days duration (2 times in vegetative stage and 2 times in flowering and grain filling stage).

Under irrigated condition Sahbhagidhan recorded highest grain yield (4.67 t / ha) followed by RR 270-5 (4.31 t / ha), RR 2-6 (3.88 t / ha), IET 18736 (3.33 t / ha) and Kalakeri (3.25 t / ha) with HI in the range of 0.34 to 0.39.

However, under RFU condition, IC 516130 and IET 18208 recorded highest yield of 2.70 t / ha followed by BVD-109 (2.62 t / ha), CR 143-2-2 (2.55 t / ha) and Kalakeri (2.54 t / ha) and Kulia, Garia, Sahabhagidhan and IET 18736 (2.0 to 2.5 t / ha). The HI varied between 0.30 - 0.33 in these promising lines. These genotypes, though experienced moderate stress of 7 days duration during flowering time, yet had lower spikelet sterility (9.0 – 14.7%) compared to others.

Physiological traits associated with drought tolerance of rice

A set of 160 rice genotypes grown under field condition, were exposed to moisture stress at vegetative stage (30 days after sowing) and morpho-physiological observations were taken.

Significant negative correlation was found to exist between drought score and RWC (r= -0.78*, n=160) (*Fig 85*) and drought score vs. Fv / Fm (r= -0.610*, n=160) (*Fig 86*).

But a significant positive correlation existed between RWC and Fv / Fm (r=0.71*, n=160) indicating that plants having higher water content are able to harvest most of the photon falling on the canopy and radiate less amount of energy in the form of fluorescence (*Fig 87*).

A positive correlation (r=0.62*, n=160) was also observed between relative chlorophyll content (by SPAD) and Normalized difference vegetation index (NDVI) (*Fig 88*) which suggest plants having higher

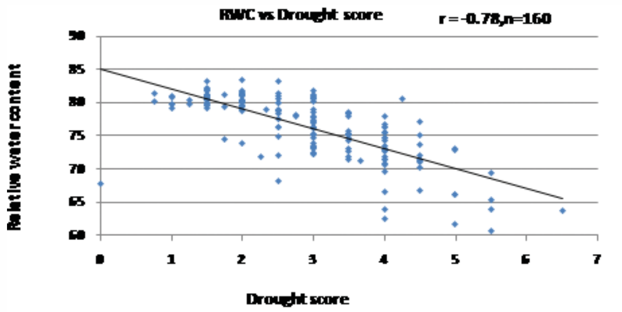


Fig 85. Correlation between RWC and drought score after 35 days of stress imposed

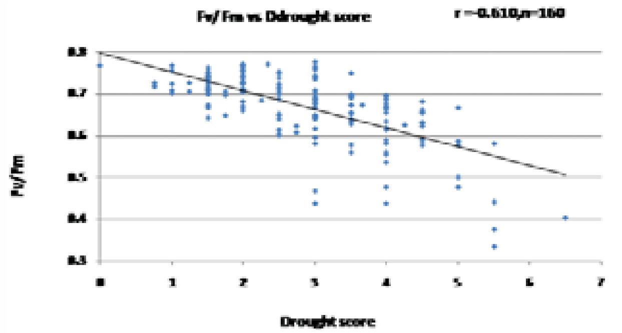


Fig 86. Correlation between Fv/Fm and drought score after 35 days of stress imposed

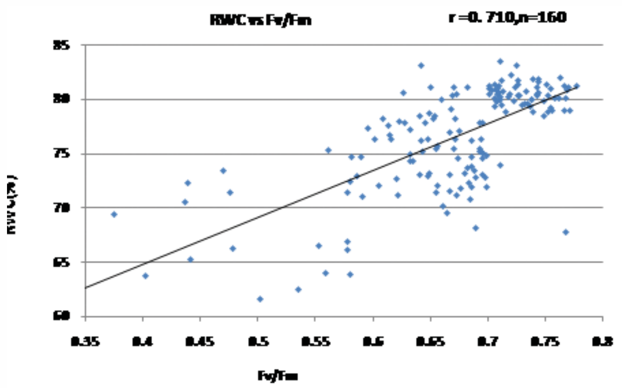


Fig 87. Correlation between RWC and Fv/Fm after 35 days of stress imposed

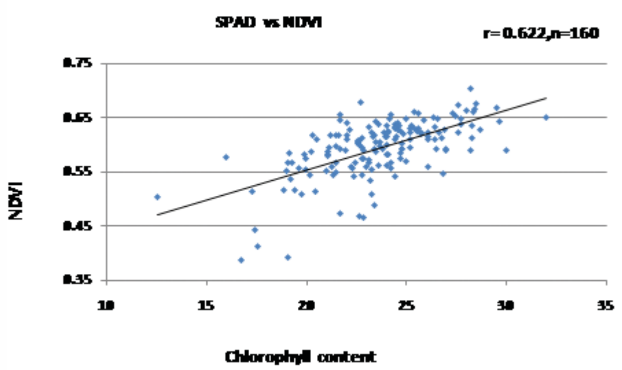


Fig 88. Correlation between SPAD and NDVI after 35 days of stress imposed

chlorophyll content are able to produce more biomass and have better growth. All of the above correlations were found significant at p=0.01 level.

Yield potential of promising drought tolerant lines under irrigated condition

Twenty four promising drought tolerant genotypes were grown under controlled irrigated condition during wet season to find their yield potential. Total duration varied from 113 (Rasi) to 138 (Mahulata) days. Sahbhagidhan recorded highest grain yield of 4.98 t/ha followed by Brahman nakhi (4.94 t/ha), Naveen (4.81 t/ha), Mahulata (4.58 t/ha) and Vandana (4.52 t/ha). Six genotypes had 4.0 to 4.5 t/ha and 10 genotypes had 3.0 to 4.0 t/ha while Kalakeri, Kalinga III and N-22 had lower yield of 2.07 to 2.77 t/ha (*Table 54*). Sahbhagidhan and Kamesh had highest grain filling (89%). Higher yield of top 5 genotypes was contributed due to the high HI of 0.45 to 0.50, moderate panicle number/m² (224-278) and higher grain filling potential (>85%).

Evaluation and improvement of photosynthetic efficiency of rice

Evaluation of rice genotypes for their low light adaptability

Seventy two rice genotypes including HYVs and landraces were grown under two light regimes: normal (100%) and 75% light intensity. The yield loss and the chlorophyll b accumulation under shade grown crop over the normal light grown plants were assessed. The yield loss ranged from 2.6% in Lalitgiri to 49.2% in Kalinga-II. The chlorophyll b accumulation, which is

Table 54. Yield potential of promising drought tolerant lines under irrigated condition

Name	Plant height (cm)	TDM (g/m²)	HI	Grain yield (t/ha)	Panicle no./m²	Grain filling (%)	100 grain weight (g)
Vandana	152.2	955.62	0.47	4.52	229.97	85.0	19.64
Vanaprava	140.6	860.64	0.51	4.43	263.60	75.16	23.45
Sallumpikit	159.7	709.96	0.45	3.24	181.64	83.13	43.23
CR-143-2-2	86.2	870.91	0.48	4.22	209.97	72.8	19.57
IR-20	82.3	815.91	0.47	3.87	249.97	62.64	18.12
Kallinga-III	138.7	588.90	0.37	2.21	209.97	86.25	21.33
Browngora	129.2	772.45	0.50	3.90	271.63	68.14	27.78
Zhu-11-26	77.5	795.13	0.48	3.86	378.29	83.54	24.04
Lalat	106.8	970.35	0.44	4.32	279.97	63.16	23.63
Satabdi	98.0	735.60	0.47	3.59	281.63	79.85	16.85
Brahamaninakhi	140.2	987.01	0.49	4.93	226.64	87.61	15.95
Mahulata	68.8	874.17	0.52	4.58	244.97	85.79	23.16
Kalakeri	118.7	543.94	0.50	2.76	248.30	56.0	22.55
Anapurna	89.6	857.53	0.51	4.45	299.97	65.79	22.67
N22	122.1	456.32	0.45	2.07	291.97	82.22	18.71
Sahabhagi dhan	103.5	927.97	0.53	4.98	224.97	89.15	20.99
Gobinda	84.0	870.88	0.50	4.43	329.97	86.96	20.23
Tulasi	89.3	725.36	0.50	3.63	266.64	76.41	20.03
Naveen	125.8	948.38	0.50	4.80	278.30	85.96	17.91
Annada	96.9	784.93	0.48	3.80	223.31	76.48	20.02
R-36	84.2	679.06	0.46	3.14	269.97	74.51	17.73
IR-64	98.6	902.61	0.49	4.45	228.30	75.36	23.48
Kamesh	124.2	845.38	0.43	3.67	184.98	89.04	18.63
Rasi	97.5	669.16	0.51	3.41	263.30	79.49	18.65
LSD at 5%	18.6	120.32	0.32	0.69	39.70	6.66	2.68

considered as the selection parameter for the low light tolerance showed maximum % increase in Govinda followed by CSR-4, Suphala and PS-2. The sterility % in the rice genotypes grown under low light ranging from 9.99% in Lalitgiri to 40.99 in WGL-32100 (*Table 55*)

Impact of growth retardant (Paclobutrazol) on physiological efficiency and grain yield of rice

Impact of plant growth retardant, paclobutrazol (PBZ) on the photosynthetic efficiency and yield was studied by taking three rice varieties (Varshadhan, Sarala and Durga). Seedlings were treated at the time of pricking out with soil applications of PBZ at 0, 15 and

Table 55. Yield loss (%), sterility % and increase/decrease in chlorophyll b in the shade grown rice genotypes over the normal light grown crop

Genotype	% of yield loss over control	Sterility (%) under low light	Increase / decrease in Chl b (%) over control	Genotype	% of yield loss over control	Sterility (%) under low light	Increase / decrease in Chl b (%) over control
Suphala	8.8	24.89	83.10	Annda	32.1	19.54	24.12
Lalitagiri	2.6	9.93	39.69	Narendra-1	30.5	15.97	24.13
Kalinga-III	9.1	23.77	22.20	GOUR-3	31.7	36.96	0.67
ASD-16	8.5	19.64	-5.25	Govinda	38.7	12.04	90.22
Saket-4	9.7	16.84	26.13	CR-44-35	33.3	11.23	63.40
PB-1	7.5	18.99	61.08	Milyang-46	39.3	25.72	11.80
Satyakrishna	5.6	22.54	35.32	IR-72	34.2	15.30	-16.60
Tapaswani	3.7	18.63	21.07	Satyam	39.3	39.24	-12.33
Sadabahar	18.9	23.51	28.50	Shaktiman	35.2	40.09	20.73
Sidhanta	19.2	29.50	23.90	VLD-16	33.1	14.91	68.58
Kalyani-II	13.5	18.30	11.69	Bhavani	35.5	31.24	15.31
Karuna	18.4	13.08	43.68	Indira	32.9	20.99	13.57
IR-64	10.7	20.16	0.31	Rasi	39.7	14.03	-1.87
Srabani	13.3	22.10	34.01	Sneha	47.5	24.69	-3.90
Daya	12.6	27.70	15.84	Dhala Heera	46.5	27.11	28.72
Pusa-33	10.5	40.38	7.44	Kalinga-II	49.2	24.80	45.74
Chandrama	10.4	34.41	7.09	Sarasa	44.1	26.28	-25.99
Jaya	15.6	17.60	13.87	Purba	41.2	19.01	29.80
CSR-4	15.2	26.55	84.32	Tara	46.2	26.40	49.58
Jajati	12.0	24.42	51.02	Prasan	40.2	34.14	10.20
PS-2	27.6	21.16	82.46	Sahabhagidhan	41.4	19.58	12.84
Tripti	20.2	17.93	17.29	Virendra	48.7	21.75	-6.12
Bindeli	25.1	18.86	63.96	IR-36	44.0	20.17	70.38
Nilagiri	25.7	13.71	64.59	Parijata	40.4	27.47	30.22
Phalguni	21.1	25.56	57.09	Sarathi	47.8	25.31	4.75
Anjali	29.3	14.79	-18.00	Naveen	47.7	17.55	69.63
Heera	29.6	34.45	36.91	Sebati	42.2	25.59	41.23
Kamesh	26.2	26.40	61.55	PR 113	44.4	27.90	31.44
Banprabha	26.6	30.42	61.42	VLD-221	40.1	14.95	15.51
WGL-32183	23.2	19.99	48.92	Gajapati	49.9	28.17	4.56
WGL-32100	23.5	40.99	61.40	Udaya	48.7	21.40	76.75
BAS 370	26.5	38.04	46.32	Khira	46.1	18.83	31.99
Geetanjali	25.4	30.22	27.18	Bramhannaki	47.8	40.25	5.71
Sattari	37.8	28.93	12.72	IR-64	47.0	21.95	3.65
Pathara	36.4	25.29	78.66	S. Prabha (C)	24.4	28.46	48.62

Fig 89. Growth of 25 days old seedlings of Varshadhan, Sarala and Durga treated with distilled water (control), 15 and 20 ppm of Paclobutrazol (PBZ)

20ppm. Seedlings of 25, 45 and 60 days were transplanted in the field in three replications following RCBD. PBZ inhibited the vegetative growth of rice seedlings. The height of the seedlings decreased significantly in plots treated with 15 and 20 ppm PBZ, irrespective of variety and the age of the seedlings (*Fig 89*). Tiller number, leaf number and dry weight per seedling increased significantly in the treated plants as compared to the control.

Varshadhan and Durga recorded increase in grain yield, when 60 days old seedlings (DOS) were transplanted in plots treated with 15 ppm PBZ; however Sarala did not exhibit any such trend (*Fig 90*). The reduced height and increased thickness of the young plant stem, as well as the accelerated leaf formation are the significant advantage of the PBZ treatment, contributing to the improvement of seedling quality at planting and in turn giving better yield over control.

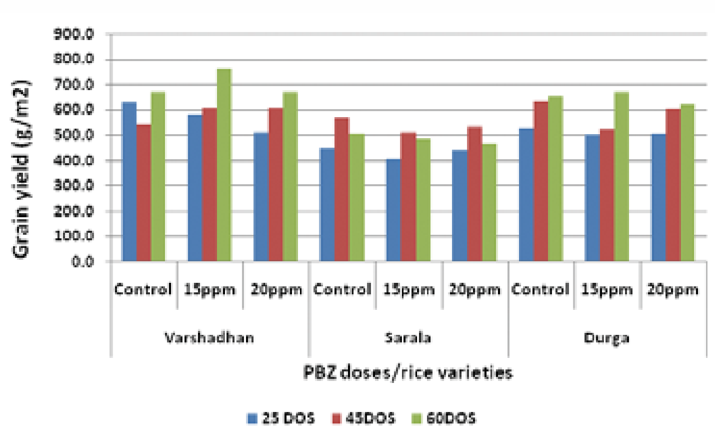


Fig 90. Impact of Paclobutrazol on the grain yield of rice varieties

Cloning and transformation of C_4 photosynthetic maize NADP- malic enzyme into *indica* rice

The NADP–Malic Enzyme gene was cloned and used to transform rice cv Naveen. Colony PCR result confirms the cloning [*Fig 91 (a)*]. We achieved efficient transformation efficiency and GUS expression of the transformants to confirm the existence of the desired gene in the callus [*Fig 91(b)*] and the putative transgenic plant was developed with NADP-ME [*Fig 91 (c)*].

Fig 91 (a). Colony PCR amplification of maize NADP-ME. Lane M- 1 kb Molecular weight marker, Lane 3&4 are positive colony

Fig 91(b). GUS expression of the infected callus

Fig 91 (c). Putative transgenic plant with NADP-ME in RM without antibiotic selection without antibiotic selection

Morphological and physiological characterization of ploidy series of rice

The ploidy series of rice, Diploid (2x) and Tetraploid (4x) developed at CRRI and confirmed by the lead centre, IGFRI, Jhansi by Flow Cytometric method (*Fig 92 and 93*) and previously developed Haploid (1x) and Triploid (3x) were grown and evaluated for their morpho-physiological characters. Significant differences were observed in the photosynthetic rate among the ploidy series of rice with the maximum photosynthetic rate recorded in Diploids (36.21 µ mol $CO_2/m^2/s$) followed by Haploids (326.46 µ mol $CO_2/m^2/s$) and Triploids (31.42 µ mol $CO_2/m^2/s$). Other photosynthesis related parameters like stomatal conductance, intercellular CO_2 concentration, transpiration rate and the *Ci/Ca* also varied significantly in the members of the series. The total dry matter production also related to the photosynthetic rate with a maximum yield potential observed in Diploid followed by Triploids.

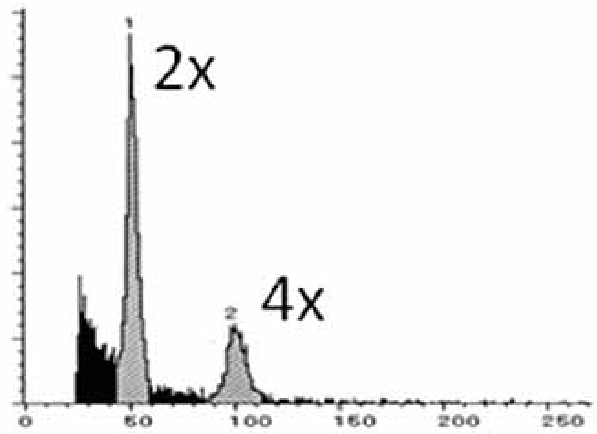


Fig 92. Flow cytometric (FCM) characterization of diploid (2x) and tetraploid (4x) rice lines

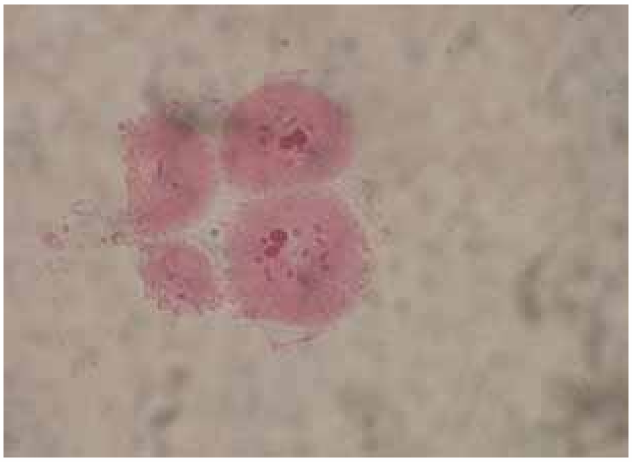


Fig 93. Diploid rice (2n=2x=24) PMC Meosis at Diakinesis showing 12 IIs

PROGRAMME 5

Socio-economic Research and Extension for Rice in Development

The results relating to returns from different cropping sequences introduced in the model village cluster indicated that recently introduced rice-onion crop sequence was more remunerative (Rs.92,065 / acre) in the rice-based cropping systems. The improved varieties namely, Sahbhagidhan, Swarna *Sub1*, Pooja, Ketekijoha, Varshadhan and Naveen were adopted by the farmers which produced higher yield (16 to 20 q / acre). Among the various socio-economic characteristics land holding size, non-farm income, labour force participation rate, provision for irrigation etc. were important factors apart from the improved traits of rice varieties like high yielding potential, low disease infestation and better grain quality for their adoption as well as shifting of crop choices by the farmers. In case of designing and testing of gender sensitive approaches in rice farming, the mean labour used in man days by different categories for half acre rice demonstrations revealed that the major labour intensive activities in descending order were harvesting and transportation, uprooting and transplanting, main field preparation and threshing and winnowing. Out of the total 36.58 man days used for half acre rice cultivation and processing, women contributed 67.03% of total labour hours against 25.04% by men. The technologies namely power tiller, line transplanting, thresher-cum-winnower, rice husk stove, mat type nursery and 2 and 4-row manual rice transplanter were found in the range satisfactory to highly satisfactory as perceived by the farmwomen. The findings of feedback analysis indicated that the 'BGREI' and 'procurement of paddy at minimum support price (MSP)' schemes of the government had been great changers and boons for making rice cultivation a profit making enterprise as perceived by the beneficiary farmers. Feedback on the performance of CRRI paddy seeds revealed that majority of the farmers procured rice varieties like, Pooja, Sarala, Gayatri, Moti, CR-1014, Savitri, Durga and Varshadhan; and the major reason cited for procurement was all round performance like better seed quality, germination, tiilering and more yield over any other source of seed.

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

Development of model village, evaluation of interventions and recommendations

Approaches for development of rice-based model village in rainfed situation have been undertaken in Gurujang-Guali Cluster, Tangi-Choudwar Block of Cuttack district during last three years. Two major interventions namely, (i) varietal substitution of rice in different ecologies and (ii) crop diversification have been focused besides targeting holistic development of the village for improving the livelihood of the households.

During the year 2012-13, two special strategies *viz.* (i) broad-based participation through inclusion of scheduled caste and women farmers and (ii) cultivation of vegetable under crop diversification after rice using available water were tried. Keeping in view the severe menace of stray cattle and wild buffaloes in *rabi* season and strong reluctance of the farming community to grow green gram, few vegetable crops were demonstrated in the back-yard rice fields under rice-vegetable cropping system to compensate the loss of green gram. Six scheduled caste farmers received Sahbhagidhan seeds and other critical inputs and grew the crops over 3 acres area which was partially damaged by Phailin. Coverage by CRRI varieties in *kharif*, 2013 under varietal substitution revealed that out of 113 ha available rice land, 72 ha were under CRRI varieties which accounts for 63% of the total rice area of the village. However, all the rice varieties were affected to varying intensities by Phailin and subsequent heavy down pour during *kharif*, 2013.

A survey was conducted to evaluate the returns from different cropping sequences introduced in the cluster and to identify the factors which influenced the adoption of improved rice varieties, as well as, crop diversification. The results indicated that recently introduced rice-onion crop sequence was more remunerative (Rs. 92,065 / acre) than any other type of

Demonstration of six row manual drum seeder with pre-germinated paddy seeds

Farmers being trained in operating power reaper in model village

vegetables like bhindi, cucumber, tomato, pumpkin, bitter gourd in the rice-based cropping systems. During focus-group discussion, farmers reported that they were growing local rice varieties (e.g. Saruchina, Kalamalata, Mathura etc.) and harvesting very meager yield (6.0 to 10.0 q / acre). The improved varieties namely, Sahabhagidhan, Swarna *Sub-1*, Pooja, Ketekijoha, Varshadhan and Naveen were adopted by the farmers which produced higher yield (16 to 20 q / acre). Among various socio-economic characteristics; land holding size, non-farm income, labour force participation rate, provision for irrigation etc. were important factors apart from the improved traits of rice varieties like high yielding potential, low disease infestation and better grain quality for their adoption as well as shifting of crop choices by the farmers. Vegetables grown after rice provided better opportunities to the women for employment, family nutrition and income as indicated by the farmers.

A village level meeting for development departments, NGOs and farmers was held on 26 December, 2013 to strengthen convergence. The agencies were also contacted in various forms to channelize their support for development. The three priority needs of the cluster were rainwater harvesting under watershed and minor irrigation programme (Rank-I), control of wild buffaloes and stray cattle during *rabi* (Rank-II) and management of weeds in rice and vegetable crops (Rank-III).

Designing and testing of gender sensitive approaches in rice farming

Under "Designing and testing of gender sensitive approaches in rice farming," evaluation of interventions and recommendations were taken up in Sankilo village of Cuttack district. During the period, demonstrations on seven rice varieties by 30 farmwomen on a half acre land each, mat type nursery, seed treatment, line transplanting, 2 and 4-row manual rice transplanter,

Scientists collecting data on rice-onion cropping system

Foreign delegates from UK visiting demonstration plots in model village balanced fertilizer application and need based pesticides application were conducted along with technical guidance with women perspective. An awareness training on IPM in rice, two training-cum-demonstrations in paddy-straw mushroom cultivation, CRRI Rice parboiling unit and rice-husk stove were also conducted. "Women in Agriculture Day" was celebrated on 6 December, 2013 in which more than sixty farm women participated and prepared various value-added food products from rice.

The findings related to performance of CRRI rice varieties revealed that among the HYVs, Pooja gave highest average yield i.e. 5.8 t/ha followed by Naveen 5.3 t/ha in respective ecosystems; while among rice hybrids Ajay produced the highest average yield of 6.4 t/ha. The major pest and diseases observed were mealy bug and sheath blight.

Data recorded by the participating women in rice farming on their involvement, access to farm resources, extent of control over the outputs and benefits from rice farming were analyzed. The summary of the findings is given below.

With regards to extent of participation of respondents and their family members on different activities of 30 rice demonstrations indicated that cent per cent of participating farm women participated in the activities like, nursery management, uprooting and transplanting, water management, harvesting, threshing and winnowing, storage and value addition. In case of involvement of family women and men, majority participated in uprooting, transplanting (64.29%), storage and marketing (63.64%), respectively (*Table 56*).

Scientists examining plant health and providing advisory services to women farmers

Crop cutting experiments being performed for different rice varieties

Table 56. Distribution of respondents and their family members on different activities of 30 demonstrations

Name of the operation	Self(N=30)	Family Women (N=14)	Family Men (N=44)
Nursery management	30 (100.00)	5 (35.71)	13 (29.55)
Main field preparation	20 (66.67)	4 (28.57)	20 (45.45)
Uprooting and transplanting	30 (100.00)	9 (64.29)	10 (22.73)
Weed management	25 (83.33)	4 (28.57)	12 (27.27)
Fertilizer application	8 (26.67)	1 (7.14)	23 (52.27)
Water management	30 (100.00)	3 (21.43)	6 (13.64)
Plant protection	1 (3.33)	0 (0.00)	22 (50.00)
Harvesting and transportation	30 (100.00)	6 (42.86)	24 (54.55)
Threshing an winnowing	30 (100.00)	6 (42.86)	23 (52.27)
Storage and marketing	30 (100.00)	2 (14.29)	28 (63.64)
Value addition	30 (100.00)	7 (50.00)	2 (4.55)

Women farmers being trained in raising mat-type rice nursery in trays

Training-cum-demonstration of four-row manual transplanter for women empowerment

The mean labour used in mandays by different categories for half acre rice demonstrations (*Table 57*) revealed that the major labour intensive activities in descending order was harvesting and transportation, uprooting and transplanting, main field preparation and threshing and winnowing. Out of the total 36.58 mandays used for half acre rice cultivation and processing, women contributed 67.03% of total labour hours against 25.04% by men. Women participation is low particularly in plant protection activity due to various socio-cultural reasons. However, changes in their attitude and appropriate social environment are required.

The technologies namely power tiller, line transplanting, thresher-cum-winnower, rice husk stove, mat type nursery and 2 and 4-row manual rice transplanter were found in the range satisfactory to highly satisfactory (*Table 58*). None of the respondents expressed their dissatisfaction on any of the technologies.

In case of accessing resources/inputs for rice cultivation majority of respondents were very successful in accessing resources like rice production technology training (100%), land (93.33%), family labour (93.33%), threshing floor (93.33%), polythene bag (93.33%) etc. whereas, 30% did not succeed in accessing marketing and market information (*Table 59*).

Table 57. Mean Labour used in mandays by different categories for half acre rice demonstration (N=30)

Name of the operation	Self	Family Women	Family Men	Hired Labour	Total
Nursery management	0.46	0.17	0.21	0.04	0.88
Main field preparation	1.69	0.12	2.55	0.79	5.15
Uprooting and transplanting	5.27	0.36	0.52	0.91	7.06
Weed management	1.84	0.14	0.46	0.00	2.44
Fertilizer application	0.08	0.01	0.33	0.07	0.49
Water management	1.36	0.14	0.19	0.00	1.69
Plant protection	0.03	0.00	0.40	0.00	0.43
Harvesting and transportation	4.66	0.38	1.59	0.52	7.15
Threshing and winnowing	2.03	0.71	1.57	0.57	4.88
Storage and marketing	1.57	0.05	1.29	0.00	2.91
Value addition	2.52	0.93	0.05	0.00	3.50
Total	21.51 (58.80)	3.01 (8.23)	9.16 (25.04)	2.90 (7.93)	36.58 (100.00)

Table 58. Level of satisfaction of farm women in practising technologies/implements (N=30)

Name of the Operation	Technology / implement tested	Nos. of Farmwomen Practised / Experienced	Perceived level of satisfaction				
			-2	-1	0	1	2
Nursery management	Mat nursery	2 (6.67)	0 (0.00)	0 (0.00)	0 (0.00)	2 (100.00)	0 (0.00)
	Power tiller	28 (93.33)	0 (0.00)	0 (0.00)	0 (0.00)	1 (3.57)	27 (96.43)
Main field preparation	Power tiller	30 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (6.67)	28 (93.33)
Uprooting and transplanting	Two & 4-row manual rice transplanter	2 (6.67)	0 (0.00)	0 (0.00)	0 (0.00)	2(100.00)	0(0.00)
	Line transplanting	28 (93.33)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	28 (100.00)
Weed management	Conoweeder	12 (40.00)	0 (0.00)	0 (0.00)	0 (0.00)	4 (33.33)	8 (66.67)
	Weedicide	6 (20.00)	0 (0.00)	0 (0.00)	3 (50.00)	3 (50.00)	0 (0.00)
Fertilizer application	Fertilizer application in three split doses	30 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (10.00)	27(90.00)
Plant protection	Pesticides / fungicides	23 (76.67)	0 (0.00)	0 (0.00)	1 (4.35)	8 (34.78)	14 (60.87)
Threshing and winnowing	Thresher-cum-winnower	30 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (6.67)	28(93.33)
Value addition	CRRI Rice-parboiling unit	30 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	11 (36.67)	19 (63.33)
	Rice-husk stove	30 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	30 (100.00)

Table 59. Accessing resources /inputs for rice cultivation by women rice growers (N=30)

	Extent of success			
Name of the resources	Very successful	Moderately successful	Little successful	Not successful
Land	28 (93.33)	2 (6.67)	0 (0.00)	0 (0.00)
Family labour	28 (93.33)	2 (6.67)	0 (0.00)	0 (0.00)
FYM	23 (76.67)	3 (10.00)	1 (3.33)	3 (10.00)
Hard cash	14 (46.67)	6 (20.00)	9 (30.00)	1 (3.33)
Water	23 (76.67)	6 (20.00)	1 (3.33)	0 (0.00)
Implement	7 (23.33)	19 (63.33)	4 (13.33)	0 (0.00)
Threshing floor	28 (93.33)	2 (6.67)	0 (0.00)	0 (0.00)
Polythene bag	28 (93.33)	2 (6.67)	0 (0.00)	0 (0.00)
Storage space	16 (53.33)	14 (46.67)	0 (0.00)	0 (0.00)
Marketing and market information	6 (20.00)	8 (26.67)	7 (23.33)	9 (30.00)
Electricity	22 (73.33)	4 (13.33)	0 (0.00)	4 (13.33)
Rice production technology training	30 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)

Scientists supervising the demonstration plots along with women rice growers

Women operating four-row manual rice transplanter

The observations further revealed that the access of farmwomen to 'Hard Cash' and 'Marketing and Market Information' is a matter of concern. As both the resources are required for sustainable rice cultivation, appropriate policy measures should be taken to provide institutional credit to the farm women through simplified procedures. Training on sources of market information and marketing channels for rice products, by-products and value-added products should be provided by using different electronic systems especially to women leaders.

With regard to extent of control over outputs, majority had full control over rice chaff (80%) and straw (70%) whereas, highest percentage of women (43.33%) had conditional full control over rice (*Table 60*). Thirty per cent of the participating women did not feel happy in the existing system of control over the produced grain implying that they needed to be more independent to decide the uses of the grain. For this reason, gender sensitive institutional mechanism can strengthen the women's control over the products.

Demonstration of CRRI rice parboiling unit in gender village

Demonstration of CRRI rice-husk stove for effective use of rice by-products

Table 60. Extent of control over outputs by the women rice growers (N=30)

Name of the outputs	Extent of Control				Are you happy with the existing level of control	
	Full control	Full control with some conditions	Weak control	No control	Yes	No
Rice	10 (33.33)	13 (43.33)	4 (13.33)	3(10.00)	21(70.00)	9(30.00)
Straw	21 (70.00)	4(13.33)	4(13.33)	1(3.33)	24(80.00)	6(20.00)
Chaff	24(80.00)	2(6.67)	3(10.00)	1(3.33)	26(86.67)	4(13.33)

Training-cum-demonstration on paddy straw mushroom cultivation

Director, CRRI interacting with women rice growers in demonstration plots

Regarding benefits accrued in rice farming to individual women, the results were highly encouraging. The women growers perceived that their recognition in family (100%), in community (66.67%) and at the organizational level (60%) had increased. Similarly, there were major changes in the mindset of male members of family / society towards women-managed rice farming (90%) and need for their exposure to rice knowledge (93.33%), also saw their confidence of growing better crop over male counterparts (70%). Remarkable changes in behavior of women rice growers was found with regard to knowledge (100%), skill (93.33%), decision-making capacity (86.67%) and group effort (76.67%), respectively (*Table 61*).

The findings on demonstration on paddy straw mushroom indicated that the intake of various nutrients by the family members was found to be highest in the production class category of more than 2 kg / bed and lowest for the category i.e. up to 1 kg / bed suggesting that increase in productivity level would likely to increase the household nutrient consumption. Hence, steps are required to improve the knowledge and skill of the farmwomen to practice mushroom farming for income generation and providing household nutritional security (*Table 62*).

Table 61. Benefits in fice farming as perceived by women rice growers (N=30)

Broad categories	Class	Response		
		Yes	No	Undecided
a) Recognition	i) Family	30 (100.00)	0 (0.00)	0 (0.00)
	ii) Community	20 (66.67)	10 (33.33)	0 (0.00)
	iii) Organization	18 (60.00)	12 (40.00)	0 (0.00)
b) Change in mindset of male members	i) Women can manage rice independently	27 (90.00)	0 (0.00)	3 (10.00)
	ii) Women need exposure to rice knowledge	28 (93.33)	0 (0.00)	2 (6.67)
	iii) Women can grow better crop than men	21 (70.00)	0 (0.00)	9 (30.00)
c) Change in behaviour	i) Knowledge	30 (100.00)	0 (0.00)	0 (0.00)
	ii) Skill	28 (93.33)	0 (0.00)	2 (6.67)
	iii) Capacity in decision-making	26 (86.67)	0 (0.00)	4 (13.33)
	iv) Group Spirit	23 (76.67)	0 (0.00)	7 (23.33)

Table 62. Result of demonstration on paddy straw mushroom (N=21)

Production class	No. of units	Average yield (kg)	Average numbers of family members	Nutritional benefits per person					
				Water (g)	Calorie (kcal)	Protein (g)	Fat (g)	Fibre (g)	Iron (mg)
Up to 1kg / bed	4	1.0	5	168.80	32.00	9.96	0.50	2.76	5.84
1-2 kg / bed	15	1.5	4.93	256.57	48.64	15.13	0.76	4.19	8.87
More than 2kg / bed	2	2.2	5	375.58	71.20	22.16	1.11	6.14	12.99

Feedback on Rice Production Technologies as Perceived by the Different Stakeholders

During 2013-14, feedback on the performance of different rice production technologies (RPTs) and government sponsored programmes and schemes were collected randomly by accidental sampling from 220 rice farmers from Bihar (70), Odisha (60), Jharkhand (50), West Bengal (20), Chhattisgarh (10) and Meghalaya (10) through a structured interview schedule. Analysis revealed that farmers were convinced about the better performance of 'System of Rice Intensification (SRI) method' (with mean weighted score (MWS) of 4.62 out of 5 in a 5-point scale) and 'Line transplanting' (MWS of 4.60) over the traditional random transplanting (MWS of 4.20). It was seen that many farmers were using farm machineries in rice farming, mainly, tractor mounted tiller (58.18%), power tiller (29.55%), tractor mounted cage wheel (24.09), power thresher (28.64%), power winnower (20.90%) and sprayer (53.18%). About the performance of various government sponsored programmes and schemes, 'BGREI programme' was highest rated among the beneficiaries (MWS of 4.55), followed by 'procurement of paddy at minimum support price (MSP)' (MWS of 4.23) and training -cum- exposure programme of ATMA' (MWS of 3.39).

Among various problems being faced by the farmers in rice cultivation, 'unavailability of quality seeds in time' was perceived as number one problem (MWS of 4.24), closely followed by 'unavailability labourers during cropping season' (MWS of 4.04), 'infestation of diseases and pests' (MWS of 3.87), 'lack of irrigation facility' (MWS of 3.82) and 'poor farmer-extension officer linkage' (MWS of 3.77). It is seen that almost all major problems were related to state agricultural department. Hence, necessary policy measures like providing quality paddy seeds, making all villages seed self-sufficient and strengthening of irrigation facilities may be taken care of by the governments to address the farmers' problems and issues.

Data on performance of CRRI paddy seeds being collected

Feedback on the performance of CRRI paddy seeds was also collected from sixty visiting rice farmers of Odisha who procured seeds from the institute. Majority of the farmers came to CRRI to procure rice varieties like Pooja (86.67%), Sarala (80.0%), Gayatri (70.0%), Moti (53.33%), CR-1014 (36.67%), Savitri (25.0%), Durga (25.0%), Varshadhan (23.33) and Naveen (20.0%). The most important reason cited by all of them was all round performance like better seed quality, germination, tilering and more yield over any other source of seed. Other major reasons included 'replacement of own seed' (76.67%), 'non-availability of seed in nearby locality' (63.33%), and 'testing of new variety' (23.33%).

Demonstration of CRRI Rice Varieties

Result of DS 2013-14

During DS 2013-14, it was observed that rice hybrid Rajalaxmi gave the highest y8eld of 7.3 t/ha while Kamesh gave the lowest yield of 3.2 t/ha. The of the other varieties in the demonstration in order of decreasing yield were Ajay (7.1 t/ha), Satyakrishna (6.1 t/ha), Chandan (5.4 t/ha), Sahbhagidhan (5.0 t/ha), Phalguni (5.0 t/ha), CR Dhan 300 (4.8 t/ha), Swarna Sub1 (4.8 t/ha), Naveen (4.8 t/ha), Pyari (4.4 t/ha), Luna Sankhi (4.3 t/ha), Satyabhama (4.2 t/ha), Lalat MAS (4.1 t/ha), Chandrama (4.0 t/ha), Geetanjali (4.0 t/ha), Abhisek (4.0 t/ha), IR 64 Sub1 (3.8 t/ha), Hazaridhan (3.8 t/ha), Sadabahar (3.6 t/ha) and Hue (3.4 t/ha).

Result of WS 2013-14

During WS 2013-14, it was observed that rice hybrid Rajalaxmi gave the highest yield of 7.0 t/ha while, Ajay and CRHR 32 gave the yield of 6.8 t/ha and 5.8 t/ha, respectively. Among the aromatic varieties Ketekijoha, Nua Kalajira and Geetanjali gave the yield of 4.0, 3.8 and 3.8 t/ha, respectively. In upland situation the varieties Sahbhagidhan, Abhisek, Kamesh, and Hazaridhan gave the yield of 4.4, 4.2, 4.1 and 3.8, respectively. Under irrigated situation the varieties Satyakrishna, Phalguni, Chandrama, Chandan, Swarna Sub1, Naveen, Pyari, Lalat MAS, Satyabhama, and IR 64 Sub1 and IR 64 MAS gave the yield of 5.8, 4.9, 4.8, 4.6, 4.6, 4.5, 4.4, 4.1, 4.0, 3.6 and 3.4 t/ha, respectively. The other salt tolerant variety Luna Sankhi gave the yield of 4.2 t/ha.

Dissemination of Rice production Technology through KVKs (Santhapur and Koderma)

KVK, Santhapur

One on-farm trial (OFT) was conducted on "Assessment of Bensulfuron methyl + Pretilachlor (Londex power) in transplanted rice" in an area of 2.5 ha involving 10 farmers. The most popular rice variety "Pooja" has been taken by the farmers which yielded 5.20 t / ha in treated plot and 5.02 t / ha in farmers' field. The yield increment was only 4.6% but total savings was Rs. 7000 due to savings of labour cost in hand weeding. The herbicide is available in granular form is easily applicable, kills all type of weeds hence, accepted by the farmers. Front line demonstration of popular high yielding Sahbhagidhan in 6 ha, Varshadhan in 1 ha and Ketakijoha in 1 ha was conducted involving 45 farmers and farm women. The variety Sahbhagidhan yielded 4.85 t / ha which was 19% higher than farmers variety Khandagiri (4.08 t / ha). The variety Varshadhan on an average yielded 5.28 t / ha which was 8.87% higher than local race Budhathengua (4.85 t / ha). The scented variety Ketakijoha yielded 5.20 t / ha which was 6% less than farmers choice Pooja (5.50 t / ha) but farmers are happy by growing Ketakijoha because by selling it they got Rs. 1900 per quintal instead of Rs. 1300 of Pooja. Eleven off-campus training programmes related to rice covering the topics "Scientific nursery raising for healthy seedlings", "Integrated nutrient management in rice", "Integrated weed management in rice and "Integrated pest management in rice" in different villages for 300 farmers, farm women and rural youth were conducted.

KVK, Koderma

On-farm trials on suitable weed management for DSR, newly released short duration varieties of rice for DSR and effect of Brown manuring on the yield of paddy were conducted. Similarly, 39 demonstrations with variety Sahbhagidhan, 22 demonstration covering 10 ha area with variety Abhishek and 246 demonstrations of rice cv. Sahbhagidhan covering 100 ha area sponsored by IRRI-NFSM scheme were conducted during 2013-14. Also 27 training courses were organized in integrated nutrient management, water harvesting, seed production technique, vermi-compost production, balanced fertilization, System of Rice Intensification and advance agronomical practices for increasing oilseeds and pulses production, contingent crop and resource conservation technologies, with a total of 723 participants. Three field days and two *kisan goshthies* have also been organized.

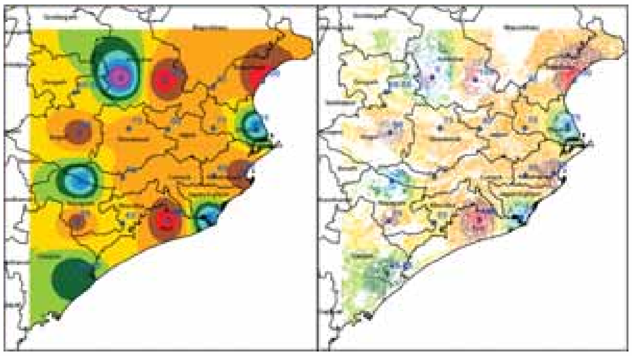
Characterization of Resources and Innovations to Aid Rice Research and Develop Extension Models

As part of designing resource-characterisation based general simulation model of diffusion of rice technologies, adoption data was collected from 19 locales situated at 50 km grids from CRRI. The districts covered under the study were Cuttack, Kendrapada, Jajapur, Dhenkanal, Jagatsinghpur, Khorda, Puri, Nayagarh, Angul, Debgarh, Keojhar, Bhadrak, Balasore and parts of Mayurbhanj and Ganjam encompassing 6.05 m ha geographical area out of which the area under rice cultivation is 1.73 m ha (based on the remote sensing imagery data obtained from NCFC, New Delhi). Further, the adoption data was interpolated using Inverse Distance Weighted (IDW) scheme which resulted in generation of interpolated rice variety adoption maps which is shown in following figures. The results revealed that a large area of rice fields was predominantly covered by high yielding varieties of rice (08.35%), while the rest of rice fields (31.65%) was covered with local varieties. It was also observed that the coastal saline area under Bhadrak, Kendrapada and Jagatsinghpur and remote areas of Keojhar and Nayagarh were dominated by local varieties.

Using the grid data of adoption for various CRRI HYVs, maps were generated. It was found that Pooja was most popular variety covering 17.69% of rice area under study followed by Sarala 6.54%, Gayatri 6.38% and CR 5.00%.

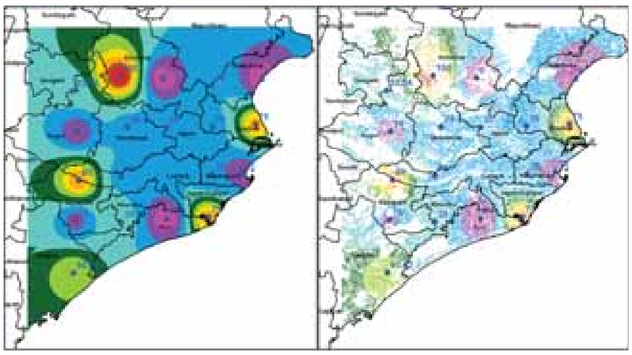
The diffusion of CRRI was found to be significantly positively correlated with easiness of labour availability (Spearman rho r=0.567* significant at 0.01 level of significance). Diffusion of CRRI variety was regressed with labour availability, pesticide availability, distance of selling produce, percentage of lowland, percentage of medium deepwater land, percentage of irrigated land, percentage of coastal saline land and acreage of other HYVs.

The result show that 73.6 per cent of change in diffusion of CRRI varieties can be explained by change in independent variables such as labour availability, pesticide availability, distance of selling produce, percentage of lowland, percentage of medium deepwater land, percentage of irrigated land, percentage of coastal saline land and acreage of other HYVs. It may be noted that almost 50 per cent (49.8%) change in diffusion of CRRI varieties is attributed to change in labour availability and percentage of irrigated land.



(a) (b)

Colour Code	Percentage Adoption	HYV Area	
		Total Area (ha)	K Rice Area (ha)
	0 - 10	22607	2591.6
	10 - 20	30030.2	3969.96
	20 - 30	97967.1	26377.2
	30 - 40	160297	39523.2
	40 -50	414548	109052
	50 - 60	842413	195234
	60 - 70	1519740	373745
	70 - 80	2350790	747672
	80 - 90	475715	179518
	90 - 100	131876	48126.4



(c) (d)

Colour Code	Percentage Adoption	Local Variety Area	
		Total Area (ha)	K Rice Area (ha)
	0 - 10	131876	48126.4
	10 - 20	475715	179518
	20 - 30	2350790	747672
	30 - 40	1519740	373745
	40 -50	842413	195234
	50 - 60	414547	109052
	60 - 70	160297	39523.2
	70 - 80	97966.8	26377.2
	80 - 90	30030.2	3969.96
	90 - 100	22607	2591.6

Fig 94. Maps showing extent of Adoption of HYV and Local Varieties of Rice (a and c) and their respective maps overlaid with rice area map derived from satellite images (b and d)

Impact analysis and database updation in relation to policy and programmes on rice

Policy makers and funding agencies often enquire about the returns to investments in research and benefits accrued to farmers. CRRI has developed many varieties during the post green revolution period and farmers are growing them. However, firm data is not available on the spread of these varieties. Therefore, it is high time to assess the spread of these varieties and other technologies in different states and their contribution to Indian economy.

Good planning requires an updated database. These databases (area, production and yield of rice in different states of India and other countries, cost of cultivation of rice in different states and volume and value of exports of rice to different countries of the world) will help in our research planning, answering queries of our policy makers and other stakeholders. Therefore, it has been planned to update the databases in this project (*Fig 94*).

Estimation of area under CRRI varieties in different states

The variety wise seed distribution and HYV area information for 5 years (2008-09 to 2012-13) are used to estimate the area under different rice varieties in three states viz., Odisha, Maharashtra and Madhya Pradesh.

The rice varieties with larger area coverage in Odisha state are Swarna, MTU-1001, Pooja, Lalat, MTU-1010, Pratikshya and Khandagiri. CRRI varieties covered 698,223 ha in the state of Odisha and accounted for 20.4% of the total HYV area in the state. They are grown to the extent of 690,886 ha during *kharif* and 7,337 ha during *rabi* / summer season. Among CRRI varieties, Pooja was grown extensively in all the districts and covered about 4.53 lakh ha in the state. The coverage under other prominent *kharif* season CRRI varieties like CR-1018, Sarala, Naveen, CR-1009, CR-1014, Moti and Varshadhan was 74,868 ha, 44,987 ha, 42,300 ha, 31,679 ha, 7,650 ha, 7,448 ha and 7,448 ha respectively. During *rabi* / summer season, two CRRI varieties grown in a sizeable area were Naveen and Satabdi.

In Maharashtra state, rice is grown mainly during *kharif* season. The mega varieties (covering more than 1 lakh ha area) of the state were MTU-1010, Indrayani, PKV-HMT, Ratna and Jaya. The CRRI variety Ratna was grown to the extent of 133,255 ha in the state and mainly confined to Konkan region. In Madhya Pradesh also rice is grown predominantly during *kharif* season. Data analysis for Madhya Pradesh revealed that the mega varieties of the state were IR-64, Kranti, IR-36 and MTU-1010. CRRI varieties were grown to the extent of 22,455 ha in Madhya Pradesh and they were Vandana, Satabdi, Anjali, Annada and Pooja.

The Punjab rice production data for the period 1960-61 to 2009-10 was analyzed using ARIMA models for forecasting and it was found that ARIMA (1, 1, 2) explained the rice production scenario better. This model was used for forecasting the rice production for the year 2020 and the forecasted rice production was found to be 12.58 million tonnes.

Study of efficiency and effectiveness of PPP in adoption of rice transplanters by farmers of Odisha

Secondary data analysis on the spread of rice transplanters revealed that public private partnership (PPP) mode of promotion is effective for their adoption in the state of Odisha. The rapid adoption stage is in progress and the number of transplanters purchased by farmers in PPP mode during the year 2013-14 was 634 from a mere three numbers during 2005-06. The transplanters are adopted by large farmers mainly in irrigated areas of Balasore, Cuttack, Kalahandi, Kendrapara, Puri, Sambalpur, Sonepur and Sundergarh districts to overcome labour shortage during peak period. Among the models approved by the Government, the model promoted by VST Tillers and Tractors i.e. Yanji Shakti 2ZT-238-8 has been adopted by majority of the farmers followed by the model promoted by Kubota Agriculture Machinery India Pvt. Ltd., i.e. NSP 4W due to aggressive marketing by these two firms.

Primary data were collected with the help of a questionnaire from 60 transplanter owners covering fifteen districts in Odisha to find out the efficiency of self-propelled transplanters in comparison to manual transplanting and how the small farmers are benefitted from the program. The transplanter owners were selected on the basis of stratified random sampling from the four major agro climatic zones of Odisha viz., Eastern Ghats, Central Table Land, Northern Plateau and Coastal Plains. The computation of cost of planting was done for inland Odisha (Eastern Ghats, Central Table Land, Northern Plateau zones) and Coastal Odisha separately due to differential wage rates. The cost of transplanting by use of self-propelled transplanter was Rs.6,750/- per ha in inland Odisha in comparison to Rs.12,650/- in manual transplanting. The cost of planting per ha in coastal Odisha was higher due to higher wage rate and the planting cost was Rs.7,550/- for power operated transplanters in comparison to Rs.16,100/- by manual transplanting. The cost saving per ha due to use of self-propelled transplanters was Rs.5,900/- per ha in inland Odisha and Rs.8,550/- per ha in coastal Odisha. There was an increase in yield by 0.75 t/ha in machine transplanted plots over manual transplanted plots. The total monetary gain per ha in machine transplanting over manual transplanting was Rs.15,725/- and Rs.18,375/- in inland and coastal Odisha respectively. The labor saving due to transplanter use was 53 man-days per ha over manual transplanting. Besides the above advantage, if the farmer uses weeder for weeding the field, there will be further labor saving with an income gain of Rs.1,500/- to Rs.2,000/- per ha.

Though the PPP program was effective in adoption of power operated transplanters in Odisha, it was not inclusive in terms of covering large section of small and marginal farmers. It was observed from the survey that 42% owners have not extended custom hiring service at all to other farmers and have used the planters in their own land only. Among the planter owners who have extended custom hiring service, there was a bias towards large farmers. Among the total farmers covered, the percentage coverage of small and marginal farmers was 42%, while 92% of farmers are small and marginal in the state of Odisha. Besides the above, there are other bottlenecks in the program also. The transplanters were promoted/sold through PPP mode without imparting proper training to operator and educating the owners the techniques of raising of mat type nursery. As a result, 58% of the owners are of the opinion that, the machine is underutilized during the season. Timely supply of canal water helps in timely planting. But, the farmers (77% of total transplanter owners surveyed) who depend on supply of canal water for preparation of main field were of the opinion that they did not get canal water in time. About 92% of the owners complained against timely supply of spare parts and prompt after sales service.

The following policy implications emerged from the study to make the program more efficient and inclusive. A legal bond should be executed with the owners that at least 30 to 50 small and marginal farmers per year should be covered through custom hiring by the owners and the report regarding coverage should be submitted to the District Agriculture Officer at the end of each season. Before supply of machine, training to driver and the techniques of raising mat type of nursery should be made compulsory. Spare parts should be kept ready by dealers, so that the machine does not remain idle for more days as the duration of planting time is limited. Co-operation with irrigation department is essential for timely release of water for field preparation, so that planting can be taken up in time. A transplanter which will use older seedlings needs to be designed, which will be helpful not only for rainfed areas but also irrigated areas.

Stress tolerance rice for poor farmers in Africa and South Asia-Socioeconomic survey and impact assessment

The impact assessment of Swarna *Sub-1* was carried out in the submergence/flood prone project area to assess the area spread and benefits accrued to farmers. Two surveys were conducted to assess the area spread, one before the introduction of the variety (during 2009) to assess the area under existing varieties and the other, four year after the introduction (during 2013) by interviewing 100 farmers. The change in varietal composition during the period is presented in *Table*. Until 2007 *kharif* season, Swarna *Sub-1* was confined to one farmer in the mother trial. Encouraged by its performance, neighboring 13 farmers have grown the variety in 3.5 ha area in rainfed shallow lowland during 2008. By 2012 *kharif* season, the variety has covered 35.7% of the shallow lowland in the project area and almost all the farmers have adopted the variety. The varieties which were replaced by Swarna *Sub1* were Swarna, Jangalajhata, Gayatri and Pooja because of its submergence tolerant ability and comparable grain quality (*Table 63*).

Further, data analysis revealed that Swarna *Sub-1* has marginal advantage in yield and income over its competing varieties. The yield advantage was 8.9% and the net return obtained was 4% higher over the competing varieties. The additional return per ha obtained from Swarna *Sub-1* was Rs. 2,883/- and the reduction in cost of production per quintal was Rs. 39/- in comparison to its competing varieties.

Table 63. Percentage coverage of rice varieties in medium land during *kharif* 2008 and 2012

Name of varieties	2012	No. of farmers area	2008	No. of farmers area
Swarna *Sub1*	35.7	100	3.5	13
Swarna	20.7	78	28.9	77
Sarchuna	14.5	44	15.0	37
Jangalihata	11.0	32	22.9	28
Bankisarua	7.2	34	6.1	25
Pooja	4.9	20	6.1	10
Gayatri	3.4	10	14.3	34
Others*	4.0	15	2.6	20
Total	100.0(83.07)	100	100.0(78.44)	100

*Others include Kalachampa, Bangarmadhei, Sitabhog, Kalasree, Basumati, Nalida and Jagabalia

Publication

Research Papers

Akhtar J, Lal HC, Kumar Y, Singh PK, Ghosh J, Khan Z and Gautam NK. 2014. Multiple disease resistance in greengram and blackgram germplasm and management through chemicals under rainfed conditions. *Legume Research,* **37**(1): 101-109.

Bal HB, Das S, Dangar TK and Adhya TK. 2013. ACC deaminase and IAA producing growth promoting bacteria from the rhizosphere soil of tropical rice plants. *Journal of Basic Microbiology*. **53**: 972–984. DOI: 10.1002 / jobm.201200445.

Behera L, Mohanty S, Pradhan SK, Singh S, Singh ON, Sahu RK, Sahu SC, Dash SK and Mohapatra T. 2013. Assessment of genetic diversity of rainfed lowland rice genotypes. *Indian Journal of Genetics*. **73**(2): 142-152.

Bhattacharyya P, Das S and Adhya TK. 2013. Root exudates of rice (*Oryza sativa* L.) cultivars affect rhizospheric P dynamics in soils with different P-status. *Communications in Soil Science and Plant Analysis.* **44**(10): 1643-1658.

Bhattacharyya P, Neogi S, Roy KS, Dash PK, Nayak AK and Mohapatra T. 2014. Tropical low land rice ecosystem is a net carbon sink. *Agriculture, Ecosystems and Environment*. **189**: 127-135.

Bhattacharyya P, Roy KS, Dash PK, Neogi S, Shahid M, Nayak AK, Raja R, Karthikeyan S, Balachandar D and Rao KS. 2014. Effect of elevated carbon dioxide and temperature on phosphorus uptake in tropical flooded rice (*Oryza sativa* L.). *European Journal of Agronomy*. **53**: 28–37.

Bhattacharyya P, Roy KS, Neogi S, Das PK, Nayak AK, Mohanty S, Baig MJ, Sarkar RK and Rao KS. 2013. Impact of elevated CO_2 and temperature on soil carbon and nitrogen dynamics in relation to CH_4 and N_2O emission from tropical flooded rice. *Science of the Total Environment*. **461 & 462**: 601-611.

Bhattacharyya P, Roy KS, Neogi S, Manna MC, Adhya TK, Rao KS and Nayak AK. 2013. Influence of elevated carbon dioxide and temperature on belowground carbon allocation and enzyme activities in tropical flooded soil planted to rice. *Environmental Monitoring and Assessment*. **185**(10): 8659-8671.

Bhattacharyya P, Sinhababu DP, Roy KS, Dash PK, Sahu PK, Dandapat R, Neogi S and Mohanty S. 2013. Effect of fish species on methane and nitrous oxide emission in relation to soil C, N pools and enzymatic activities in rainfed shallow lowland rice-fish farming system. *Agriculture Ecosystem and Environment*. **176**: 53-62.

Bose LK, Jambhulkar NN, Pande K and Singh ON. 2014. Use of AMMI and other different stability statistics in the simultaneous selection of rice genotypes for yield and stability under direct-seeded condition. *Chilean Journal of Agricultural Research.* **74**(1): 3-9.

Bose LK, Kar MK, Bhattacharya B, Jambhulkar NN and Singh ON. 2014. A highly efficient and improved protocol for exploitation of somaclonal variation for enhancing alien gene introgression in wide cross hybrid of *Oryza sativa / Oryza brachyantha. African Journal of Agricultural Research*. **9**(2): 262-268.

Chakraborty K and Rath PC. 2013. Population dynamics of rice yellow stem borer in West Bengal, India. *Indian Journal of Plant protection*. **41**(2):172-174.

Chattopadhyay K, Nath D, Mohanta RL, Bhattacharyya S, Marndi BC, Nayak AK, Singh DP, Sarkar RK and Singh ON. 2014. Diversity and validation of microsatellite markers in'Saltol'QTL region in contrasting rice genotypes for salt tolerance at the early vegetative stage. *Australian Journal of Crop Science*. **8**(3): 356-362.

Chhotaray A, Dhua U, Behera L and Mukherjee AK. 2014. Detection of seedborne *Aspergillus flavus* from rice cultivars using molecular markers, *Archives of Phytopathology and Plant Protection*. DOI: 10.1080 / 03235408.2014.886420.

Collard BCY, Septiningsih EM, Das SR, Carandang J, Pamplona A, Sanchez D, Ye G, Reddy JN, Singh US, Iftekharuddaula KM, Venuprasad R, Vera-Cruz CN, Mackill DJ and Ismail AM. 2013. Developing new flood-tolerant varieties at the International Rice Research Institute (IRRI) towards 2025. *SABRAO Journal of Breeding Genetics*. **45**(1); 42-56.

Das J, Dangar TK and Adhya TK. 2013. Microbial dynamics and diversity of *Bacillus thuringiensis* in textile effluent polluted and non-polluted rice field soils of Orissa, India. *Indian Journal of Microbiology*. **53**(1), 18–27.

Dash PK, Roy KS, Neogi S, Nayak AK and Bhattacharyya P. 2014. Gaseous carbon emission in relation to soil carbon fractions and microbial diversities as affected by organic amendments in tropical rice soil. *Archives of Agronomy and Soil Science*. **60**(10): 1345-1361.

Devi BN, Mishra SK, Das L, Pawar NA and Chanu TI 2013. Traditional fishing methods in central valley region of Manipur, India. *Indian Journal of Traditional Knowledge* **12**(1): 137-143.

Devi BN, Mishra SK, Pawar NA, Das L and Das S. 2013. Traditional fish aggregating wisdom of Manipur, Northeastern India. *Indian Journal of Traditional Knowledge*, **12**(1): 130-136.

Gautam P, Nayak AK, Lal B, Bhattachryya P, Tripathi R, Shahid M, Mohanty S, Raja R and Panda BB. 2014. Submergence tolerance in relation to application time of nitrogen and phosphorus in rice (*Oryza sativa* L.). *Environmental and Experimental Botany*. **99** : 159-166.

Henry A, Dixit S, Mandal NP, Anantha MS, Torres R and Kumar A. 2014. Grain yield and physiological traits of rice drought-yield QTL qDTY12.1 lines showed different responses to drought and soil characteristics in upland environments. *Functional Plant Biology*. (Accepted).

Imam J, Alam S, Mandal NP, Variar M and Shukla P. 2013. Molecular screening for identification of blast resistance genes in North East and eastern Indian rice germplasm (*Oryza sativa L.*) with PCR based makers. *Euphytica*. **196**: 199-211.

Imam J, Alam S, Variar M and Shukla P. 2013. Identification of Rice Blast Resistance Gene Pi9 from Indian rice land races with STS marker and its verification by virulence analysis. *Proceedings of National Academy of Sciences, India, Section B: Biological Sciences.* DOI 10.1007 / s40011-013-0186-6.

Jha SK, Nayak AK and Sharma YK. 2013. Evaluation of spatial distribution of groundwater fluoride using geo-statistical technique in Unnao district Uttar Pradesh, India. *International Journal of Environmental Protection*. **3**(11): 39-45.

Joshi E, Kumar D, Lal B, Nepalia V, Gautam P and Vyas AK. 2013. Management of direct seeded rice for enhanced resource use efficiency. *Plant Knowledge Journal.* **2**(3): 119-134.

Karan AK, Kar S, Singh VK and Singh CV. 2013. Effects of liming and soil moisture regimes on time changes of soil pH, redox potential, availability of native sulfur and micronutrients to rice (*Oryza sativa* L.,) in acid soils. *International Journal of Soil Science*,DOI:10.3923 / ijss.2013: 1-15.

Karan AK, Singh CV and Kar S. 2012. Availability of soil nutrients and their interrelationship as influenced by characteristics of rice growing acid laterite and alluvial soils of West Bengal. *Journal of Research (BAU)*, **24** (1): 71-79.

Kumar R, Nitin M, Khalkho AS, Sultan NS and Kumar Y. 2013. Impact assessment of pesticides on growth response of beneficial soil bacterium. *International Journal of Recent Scientific Research.* **4** (4): 415-419.

Kumar U, Vithal L and Annapurna K. 2013. Antagonistic potential and functional diversity of endo- and rhizospheric bacteria of basmati rice. *Oryza.* **50** (2): 162-168.

Kumar Y, Clarice JC, Jinguo Hu, Kwon SJ, Ted K, Gee RM and Sarker A. 2014. Target Region Amplification Polymorphism (TRAP) for assessing genetic diversity and marker-trait associations in chickpea germplasm. *Genetic Research and Crop Evolution* 61: 965-977**.**

Maiti D, Singh CV, Variar M, Mandal NP and Anantha MS. 2013. Impact of rainfall pattern on native arbuscular-mycorrhizal activity influencing phosphorus utilization by direct seeded rainfed upland rice. *Proceedings of National Academy of Sciences, India, Section B: Biological Sciences* **83**(2): 159-162.

Mall AK, Pradhan SK, Dash SK and Singh ON. 2013. Aerobic response index and diversity analysis for identification of aerobic rice donor parents *Oryza*. **49** (1): 45.

Mandal S, Kar I, Mukherjee AK and Acharya P. 2013. Elicitor-Induced defense responses in *Solanum lycopersicum* against *Ralstonia solanacearum*. *The Scientific World Journal* DOI:10.1155 / 2013 / 561056.

Manna MC, Bhattacharyya P, Adhya TK, Singh M, Wanjari RH, Ramana S, Tripathi AK, Singh KN, Reddy KS, Subba Rao A, Sisodia RS, Dongre M, Jha P, Neogi S, Roy KS, Rao KS, Sawarkar SD and Rao VR. 2013. Carbon fractions and productivity under changed climate scenario in soybean–wheat system. *Field Crops Research*. **145**: 10-20.

Mhatre PH, Sirohi A, Kumar J, Adak T and Singh K. 2013. Bioefficacy of slow release formulations of salicylic acid against *Heterodera avenae*. *Annals of Plant Protection Sciences.* **21**(2): 457-459.

Mishra VK, Nayak AK, Singh CS, Jha SK, Tripathi R, Shahid M, Raja R and Sharma DK. 2013. Changes in soil aggregate-associated organic carbon and nitrogen after ten years under different land use and soil management systems in Indo-Gangetic sodic soil. *Communications in Soil Science and Plant Analysis*. **45**:1293–1304.

Mohanty S, Nayak AK, Kumar A, Tripathi R, Shahid M, Bhattacharyya P, Raja R and Panda BB. 2013. Carbon and nitrogen mineralization kinetics in soil of rice-rice system under long term application of chemical fertilizers and farmyard manure. *European Journal of Soil Biology*. **58**: 113-121.

Mohapatra NK, Mukherjee AK, Rao AVS, Jambhulkar NN and Nayak P. 2014. Comparison of different parameters for evaluation of partial resistance to rice blast disease. *American Journal of Experimental Agriculture*. **4**(1): 58-79.

Mohapatra PC, Patel SP, Din M and Mishra P. 2013. Performance evaluation weeders in rice cultivation. *Oryza*. **50**(2): 169-172.

Mohapatra SD and Chattopadhyay C. 2012. Perception of constraints for pigeonpea production in India. *Indian Journal of Plant Protection*. **40**(3): 171-174.

Mohapatra SD, Mishra PN and Singh MP. 2013. Management of white grub, *Holotrichia longipennis* Blanch through post-sown soil application of insecticides in upland rice. *Oryza*. **50**(4): 419-421.

Mondal B, Singh A and Sekar I. 2013. Dimensions and determinants of people's participation in watershed development programmes in Bundelkhand region of Madhya Pradesh: An economic analysis. *Indian Journal of Soil Conservation*. **41**(2): 177-184.

Mondal B, Singh A, Singh SD, Sinha MK and Suresh KD. 2013. Decomposition of productivity growth in watersheds: A study in Bundelkhand region of Madhya Pradesh, India. *Scientific Research and Essays*. **8**(48): 2312-2317.

Mukherjee AK , Mohapatra NK and Nayak P. 2013. Identification of stable slow blasting rice genotypes through multivariate analysis of components of resistance. *ARPN Journal of Agricultural and Biological Science*. **8**: 125-138.

Mukherjee AK , Mohapatra NK, Bose LK, Jambhulkar NN and Nayak P. 2013. Additive main effects and multiplicative interaction (AMMI) analysis of GxE interactions in rice-blast pathosystem to identify stable resistant genotypes. *African Journal of Agricultural Research*. **8**(44).

Mukherjee AK, Sampat Kumar A, Kranthi S and Mukherjee PK. 2013. Biocontrol potential of three novel *Trichoderma* strains: Isolation, evaluation and formulation. 3*Biotech*. DOI: 10.1007/s13205-013-0150-4 *Springer*.

Nayak AK, Kumar A, Raja R, Rao KS, Mohanty S, Shahid M, Tripathi R, Panda BB and Bhattacharyya P. 2013. Fly ash addition affects microbial biomass and carbon mineralization in agricultural soils. *Bulletin of Environmental Contamination and Toxicology*. **92**: 160-164.

Nayak AK, Lal B, Shahid M, Panda BB, Tripathi R, Raja R and Mohapatra T. 2013. Fertilizer best management practices in rice for higher productivity. *Indian Journal of Fertilizers*. **9**(4): 54-66.

Neogi S, Bhattacharyya P, Roy KS, Panda BB, Nayak AK, Rao KS and Manna MC. 2014. Soil respiration, labile carbon pools and enzyme activities as affected by tillage practices in a tropical rice-maize-cowpea cropping system. *Environmental Monitoring and Assessment*. **186**(7): 4223-4236.

Nitin M, Alam S, Anantha MS, Kumar Y and Maiti D. 2013. Comparative homology modeling and docking study of mat 1-2-1 protein for designing bio-active molecule effective against rice false smut (*Ustilaginoidea virens)* disease. *Journal of Advanced Bioinformatics Applications and Research*. **4**(3): 72-79.

Nitin M, Khalko AS, Kumar R, Sinha R, Sultan N and Kumar Y. 2013. Eco-behavioral assessment of organophosphates and bio-pesticides: A comparative case study of pesticidal influence on the growth of selected bacterial population (*Pseudomonas*) in soil biota. *Ecology, Environment and Conservation*. **19**(3): 927-930.

Nitin M, Kumar R, Khalko AS, Sinha R, Anantha MS and Kumar Y. 2014. 16S rDNA identification and molecular characterization of *Xanthomonadaceae NML 03-0222* bacterial isolates from agricultural soil of Jharkhand. *International Journal of Current Research*. **6**(1): 4492-4496.

Panda D and Sarkar RK. 2013a. Natural leaf senescence: probed by chlorophyll fluorescence, CO_2 photosynthetic rate and antioxidant enzyme activities during grain filling in different rice cultivars. *Physiology and Molecular Biology of Plants*. **19**: 43-51.

Panda D and Sarkar RK. 2013b. Structural carbohydrates and lignifications associated with submergence tolerance in rice (*Oryza sativa* L.). *Journal of Stress Physiology & Biochemistry*. **9**:299-306.

Panda D and Sarkar RK. 2013c. Characterization of leaf gas exchange and anti-oxidant defense of rice (*Oryza sativa* L.) cultivars differing in submergence tolerance owing to complete submergence and consequent re-aeration. *Agricultural Research*. **2**: 301-308.

Panda D and Sarkar RK. 2014. Mechanism associated with nonstructural carbohydrate accumulation in submergence tolerant rice (*Oryza sativa* L.) cultivars. *Journal of Plant Interactions*. **9**: 62-68.

Pani DR, Sarangi SK, Mishar RC, Pradhan SK and Mondal TP. 2013.Performance of rice germplasm under coastal saline condition. *Journal of Indian Coastal Agriculture Research*. **31**(1): 1-7.

Pradhan SK, Singh S, Singh ON, Mall AK and Ghosh A. 2013. Sumit (CR 662-22-1-1-1-1) a lowland rice variety for Odisha. *Indian Journal Genetics*. **73**(1): 349.

Pradhan SK, Singh S, Swain P, Samal P, Mall AK, Ghosh A, Ram T, Prakash A, Singh ON 2013. Pyari (CR-2624, IR55423-01) for aerobic conditions. *Indian Journal of Genetics and Plant Breeding*. **73**(3): 350.

Raghuveer P, Subrhamanyam D, Sailaja B, Singh RP, Ravichandran V, Rao GV, Sudershan SP, Sharma SG, Saha S, Nadaradjan S, Reddy PJR, Shukla A, Dey PC, Patel DP, Ravichandran S and Voleti SR. 2013. Influence of boron on spikelet fertility under varied soil conditions in rice genotypes. *Journal of Plant Nutrition*. **36**(3): 390-400.

Raja R, Nayak AK, Panda BB, Lal B, Tripathi R, Shahid M, Kumar A, Mohanty S, Samal P, Gautam P and Rao KS. 2014. Monitoring of meteorological drought and its impact on rice (*Oryza sativa* L.) productivity in Odisha using Standardized Precipitation Index. *Archives of Agronomy and Soil Science*. DOI:10.1080 / 03650340.2014.912033

Raja R, Nayak AK, Rao KS, Puree C, Shahid M, Panda BB, Kumar A, Tripathi R, Bhattacharyya P, Baig MJ, Lal B, Mohanty S and Gautam P. 2014. Effect of fly ash deposition on photosynthesis, growth and yield of rice. *Bulletin of environmental contamination and Toxicology*. **93**:106–112.

Rath PC. 2013. Field efficacy of granular insecticides against yellow stem borer and gundhi bug of rice. *Oryza*. **50**(2): 194-195.

Reddy JN, Patnaik SSC, Sakar RK, Das SR, Singh VN, Dana I, Singh NK, Sharma RN, Ahmed T, Sharma KK, Verulkar S, Collard BCY, Pamplona A, Singh US, Sarkarung S, Mackill DJ and Ismail AM. 2013. Overview of the Eastern India Rainfed Lowland Shuttle Breeding Network (EIRLSBN). *SABRAO Journal of Breeding Genetics*. **45**(1): 57-66.

Reddy KKR, Jain A, Nagendra K, Payasi D, Varma MK, Patil KG, Anantha MS, Shashidhar HE and Shenoy V. 2014. Identification of drought tolerant restorer lines and association between pollen fertility and spikelet fertility in CMS based rice (*Oryza sativa L.*) hybrids. *International Journal of Current Research*. **6**(2): 4900-4905.

Rout S, Thatoi HN and Tewari SN. 2013. Combating sheath blight pathogen (*Rhizoctonia solani*) of rice with *Aegle marmelos* Corr. extract based Amalab, a formulated botanical product. *Indian Phytopathology*. **66**(2): 168-171.

Rout S, Thatoi HN and Tewari SN. 2013**.** Efficacy of essential oil of *Aegle marmelos* based Amaext-eo, a formulated product against *Pyricularia grisea* causing blast disease of rice. *Journal of Pure and Applied Microbiology*. **7**(1): 767-775.

Rout S, Thatoi HN and Tewari SN. 2014**.** Sensitivity of ethanolic extract of *Aegle marmelos*-based Amasof-e, an organic antifungal product, against *Pyricularia grisea* that causes blast disease of rice. *Archives of Phytopathology and Plant Protection*. http://dx.doi.org/10.1080/03235408.2014.882124.

Roy KS, Neogi S, Nayak AK and Bhattacharyya P. 2014. Effect of nitrogen fertilization on methane and carbon dioxide production potential in relation to labile carbon pools in tropical flooded rice soils in eastern India. *Archives of Agronomy and Soil Science*. **60**(10): 1329-1344.

Sahoo R, Mohanty S and Dangar TK. 2013. Field evaluation of native *Azotobacter* and *Azospirillum* spp. formulations for rice (*Oryza sativa* L. var. *Khandagiri*) productivity in laterite soil. *Oryza*. **50**: 65-69.

Sahoo RK, Ansari MW, Dangar TK, Mohanty S and Tuteja N. 2013. Phenotypic and molecular characterization of efficient nitrogen fixing *Azotobacter* strains from rice fields for crop improvement. *Protoplasma*. DOI 10.1007 / s00709-013-0547-2.

Sahoo RK, Ansari MW, Pradhan M, Dangar TK, Mohanty S and Tuteja N. 2014. Phenotypic and molecular characterization of native *Azospirillum* strains from rice fields to improve crop productivity. *Protoplasma*. DOI 10.1007 / s00709-013-0607-7.

Samal P and Sadangi BN. 2013. Rural livelihood diversification in flood prone ecosystem: The case of Odisha. *Agricultural Economics Research Review*. **26**: 234.

Sarkar RK, Mahata KR and Singh DP. 2013. Differential responses of antioxidant system and photosynthetic characteristics in four rice cultivars differing in sensitivity to sodium chloride stress. *Acta Physiologiae Plantarum*. **35:** 2915–2926.

Shahid M, Nayak AK, Shukla AK, Tripathi R, Kumar A, Raja R, Panda BB, Meher J, Bhattacharyya P and Dash D. 2014. Mitigation of iron toxicity and iron, zinc and manganese nutrition of wetland rice cultivars (*Oryza sativa* L.) grown in iron-toxic soil. *Clean-Soil, Air, Water*. **42**: 1-6.

Singh US, Dar MH, Singh S, Zaidi NW, Bari MA, Mackill DJ, Collard BCY, Singh VN, Reddy JN, Singh RK and Ismail AM. 2013. Field performance, dissemination, tracking and impact of submergence tolerant (*Sub1*) rice varieties in South Asia. *SABRAO Journal Breeding Genetics*. **45**(1): 112-131.

Singh YP, Nayak AK, Sharma DK, Gautam RK, Singh RK, Singh R, Mishra VK, Paris T and Ismail AM. 2013. Farmers' participatory varietal selection: A sustainable crop improvement approach for the 21st Century. *Agroecology and Sustainable Food Systems*. **38**(4): 427-444.

Singh YP, Nayak AK, Sharma DK, Gautam RK, Singh RK, Singh Ranbir, Mishra VK, Paris T and Ismail AM. 2013. Varietal selection in sodic soils of indo-gangetic plain through farmers participatory approach. *African Journal of Agricultural Research*. **8**(23): 2849-2860.

Sinha MK, Dhaka JP and Mondal B. 2014. Analysing social attributes of loan default among small Indian dairy farms: A discriminant approach. *Scientific Research and Essays*. **9**(2).

Sinhababu DP, Saha S and Sahu PK. 2013. Performance of different fish species for controlling weeds in rainfed lowland rice field. *Biocontrol Science and Technology*. **23**(12): 1362-1372.

Swain P, Anumalla M. Prusty S, Marndi BC and Rao GJN. 2014. Characterization of some Indian native land race rice accessions for drought tolerance at seedling stage. *Australian Journal of Crop Science*. **8**(3): 324-331.

Swamy BPM., Ahmed HU, Henry A , Mauleon R, Dixit S, Vikram P, Ram T, Verulkar SB, Perraju P, Mandal NP, Variar M, Robin S, Chandrababu R, Singh ON, Dwivedi JL, Das SP, Mishra KK, Yadaw RB, Aditya TL, Karmakar B, Satoh K, Moumeni A, Kikuchi S, Leung H and Kumar A. 2013. Genetic, physiological, and gene expression analyses reveal that multiple QTL enhance yield of rice mega-variety IR64 under drought. *PLoS one* **8**(5): e62795. DOI:10.1371 / journal.pone.0062795.

Toppo NN, Srivastava AK and Maiti D. 2013. Effect of arbuscular mycorrhizal (AM) inoculation on upland rice root system. *The Bioscan*. **8**(2): 533-536.

Tripathi R, Nayak AK, Bhattacharyya P, Shukla AK, Shahid M, Raja R, Panda BB, Mohanty S, Kumar A and Thilagam VK. 2013. Soil aggregation and distribution of carbon and nitrogen in different fractions after 41 years long-term fertilizer experiment in tropical rice–rice system. *Geoderma*. **213**: 280-286.

Upadhyaya S and Tewari SN. 2013. Oscilene-e, an ethanolic extract produced from *Ocimum sanctum* L. leaves as biofungitoxicant in the management strategy of rice blast disease. *Journal of Agricultural Technology*. **9**(4): 877-888.

Upadhyaya S, Prakash A and Tewari SN. 2013. Efficacy of an organic formulated product developed from *Ocimum sanctum* L. essential oil as plant protectant especially in rice blast disease management. *International Journal of Scientific and Engineering Research*. **4**(11): 1045-1052.

Upadhyaya S, Tewari SN and Behera J. 2014**.** Isolation and characterization of a bioactive Phenylpropanoid from *Ocimum sanctum* L. leaves through chromatographic and spectroscopic methods. *American Chemical Science Journal*. **4**(3): 286-297.

Upadhyaya S. and Tewari S.N. 2013. Oscilene-e, an ethanolic extract product from *Ocimum sanctum L.* leaves as biofungitoxicant in the management strategy of rice blast disease. *Journal of Agricultural Technology*. **9**(4): 877-888.

Yogendra ND, Kumara BH, Chandrashekar N, Prakash NB, Anantha MS and Jayadeva HM. 2014. Effect of silicon on real time nitrogen management in a rice ecosystem. *African Journal of Agricultural Research* **.** **9**(9): 831-840.

Yogesh K, Coyne CJ, Hu J, Kwon SJ, Kisha T, McGee R and A. Sarker (2014). Target region amplification polymorphism (TRAP) for assessing genetic diversity and marker-trait associations in chickpea germplasm. *Genetic Research & Crop Evolution*. DOI 10.1007 / s10722-014-0089-2**.**

Popular Articles

Adak T, Berliner J, Pokhare SS, Munda S, Kumar U and Prakash A. 2013. Info chemicals in insect interaction. *Agrobios Newsletter*. **11** (9): 56-57.

Berliner J, Adak T, Pokhare SS, Munda S, Kumar U and Prakash A. 2013. Harvester termite. *Agrobios Newsletter*. **12** (12): 44-46.

Berliner J, Adak T, Pokhare SS, Munda S, Kumar U, Shashank PR and Prakash A. 2013. Harvester Termite. *Agrobios Newsletter*. **12** (9): 44-45.

Bhattacharya P, Pradhan SK, Tripathy R, Adak T, Din M, Anandan A, Sharma SG and Samal P. 2013. Gene pyramiding and stacking for multiple stress tolerance in rice. *In*: Samal P, Lipi Das and Sadangi BN. *Innovations in Agricultural Science.* Published on the eve of Agriculture Education Day by the Director, CRRI, Cuttack.

Dangar TK, Kumar Upendra. 2013. Characterization of phosphate solubilizing and siderophore producing fungi from rice rhizosphere. CRRI News letter. April-June **34** (2): 14.

Gautam P, Lal B and Rana R and Sharma GD. 2013. Intercropping: An alternative pathway for sustainable agriculture. *Popular Kheti*. **1**(4): 216-220.

Gautam P, Lal B and Rana R. 2013. Biodynamic Farming- An occult form of organic f arming. *Popular Kheti*. **1**(4): 38-44.

Joshi E, Gautam P and Lal B. 2013. Alternate wetting and drying method: To save water in Rice. *Agrobios Newsletter*, **12**(1): 24-26.

Joshi E, Gautam P, Kumar M and Lal B. 2013. Coir Compost: A Source of Plant Nutrient in Organic Farming. *Popular Kheti*. **1**(4): 142-145.

Joshi E, Gautam P, Lal B and Kumar M. 2013. Management of Nutrient Deficiencies in Direct Seeded Rice. *Popular Kheti*. **1**(3): 40-43.

Kar M, Das L and Mohapatra T. 2013. Sabke liye dhan. *Kheti*. **66**(4): 3-7.

Kumar U and Dangar TK. 2013. Functional role of plant growth promoting endo-and rhizobacteria in major cereal crops. *Popular Kheti.* **1**(1): 37-40.

Lal B, Nayak AK, Gautam P, Tripathi R, Singh T and Katara JL. 2013. Aerobic rice: A water saving approach for rice production. *Popular Kheti*, April-June **1** (2): 1-4.

Lenka S, Tewari SN, Pun KB and Das SK. 2014. *Dhana, phasalara mahisha roga damana re bael 'o' tulsi patra ra byabahara*. *Krushak Sambad*, March 2014.

Meena RK, Singh YV, Nath P C, Bana RS and Lal B. 2013 Importance, prospects and constraints of organic farming in India. *Popular Kheti.* **1**(4): 26-31.

Mohapatra SD and Chattopadhyay C. 2013. Spotted pod borer, *Maruca vitrata*: A potential threat to short duration pigeonpea. *Indian Farming.* **62**(12): 27-29.

Mohapatra SD and Patra BC. 2013. Rusty plum aphid, *Hysteronema setariae* (Thomas), an emerging pest of rice. CRRI Newsletter, October-December **34**(4): 22.

Mohapatra SD, Dash SK, Behera L, Pradhan SK and Meher J. 2013. Dhana phasalare samanwita keeta prabandhan. *Krusak Sambad.* 2013: 10-11.

Mukherjee AK. 2013. Molecular detection of rice pathogens. In: Practical Manual on Biotic Stress Management in Rice ICAR Sponsored Summer School on *New Horizons in Biotic Stress Management in Rice under Changing Climate Scenario* organized at CRRI, Cuttack during 10-30 September, 2013: 21-24.

Nayak AK, Lal B, Tripathi R, Raja R, Shahid M, Gautam P, Mohanty S, Bhattacharyya P, Panda BB, Kumar A, Sarangi DR and Prasad SM. 2013. Development of soil nutrient map of Nischintakoilli and Mahanga block of Cuttack District. CRRI News letter, July-September **34** (3): 12.

Nayak AK, Mohanty S, Raja R, Shahid M, Lal B, Tripathi R, Bhattacharyya P, Panda BB, Gautam P, Thilagam VK, Kumar A, Meher J and Rao KS

2013. Customized leaf colour chart for nitrogen management in rice for different ecologies. CRRI News letter, January-March **34** (1): 14.

Nayak AK, Raja R, Rao, KS and Panda BB. 2014. *Fly ash ka chawal utpadan main prayog*. *Kheti*, **12**: 42-44.

Patra BC, Mohapatra S, Das S, Srinivasan K and Mohapatra T. 2013. Identification and characterization of a unique rice germplasm with very high grain weight (IC301206). CRRI Newsletter, October-December **34**(4): 20-21.

Patra BC. 2013. Rice diversity still holds the key for food security under changing climate in Odisha. Odisha Environment Congress (OEC), 20-21 December 2013 on Agriculture and Environment – issues, challenges and potentials for Odisha.

Pokhare SS, Adak T, Berliner J, Kumar Upendra and Prakash A and Somnath S. 2013. Induced resistance: New strategy for plant protection. *Agrobios Newsletter*. **11** (9): 71-72.

Raja R, Nayak AK, Panda BB, Lal B, Tripathi R, Shahid M, Kumar A, Mohanty S, Samal P, Gautam P and Rao KS. 2013. Drought risk assessment of Odisha based on standardized precipitation Index. CRRI News letter, April-June **34** (2): 13.

Ray S, Pokhare SS, Berliner J, Sanghamitra P and Raja R. 2013. Agriculture and Allied Sciences: Options and opportunities as a career. Published on the eve of Agriculture Education Day by the Director, CRRI, Cuttack.

Samal P, Das L and Sadangi BN. 2013. Innovations in Agricultural Science. Published on the eve of Agriculture Education Day by the Director, CRRI, Cuttack.

Satapathy, BS, Singh, T and Pun, KB. 2013. Rice-Fish-Horticulture Farming System: Option for Sustaining Livelihood of North Eastern Region of India. *Indian Farming* **63** (1): 3-5.

Singh AK, Jaiswal AK, Singh CV, Pan RS, Prasad S, Sinha PB, Kumar M, Raghav D and Saini KP. 2013. Success Stories, NAIP Project–Developing sustainable farming system models for prioritized micro watershed in rainfed areas in Jharkhand. Published by NAIP Lead Institute BAU. pp. 1-32.

Singh CV. 2013. Mixed and Intercropping in Rice. *Kheti*. November 2013: 33-35.

Singh T, Lal B and Satapathy BS. 2013. Weed management in paddy. *Popular Kheti* **1** (2): 10-15

Thilagam VK, Mohanty S, Shahid M, Tripathi R, Nayak AK and Kumar A. 2014. Role of Silicon as Beneficial Nutrient for Rice Crop. *Popular Kheti*. **2** (1), 105-107.

Papers presented in Workshop/Seminars/Symposia/Conferences

Acharya S, Das J, Behera KS and Dangar TK. 2014. Plant growth promotion and biocontrol functions of rhizospheric and phytonic *Bacillus thuringiensis* of rice. In: AZRA Silver Jubilee International Conference, CRRI, Cuttack, India, 16-18 February: 43-44.

Adak T, Munda S, Kumar U, Berliner J, Pokhare SS and Bhattacharyya P. 2014. Dissipation of chlorpyriphos under elevated CO_2 and temperature. In: AZRA Silver Jubilee International Conference, CRRI, Cuttack, India, 16-18 February:157.

Alam S, Imam J, Maiti D, Prasad C, Sharma TR, Mandal NP and Variar M 2013. Genetic diversity of Magnaporthe oryzae population in eastern and North eastern India revealed by DNA fingerprinting and virulence analysis (Abstr.). In: Proceedings of the *Indian Phytopathological society*, CRURRS, Hazaribag, Jharkhand.

Anandan A. 2014. Consistency in performance of rice genotypes under stagnant flooding condition. In: AZRA Silver Jubilee International Conference on Probing Biosciences for Food Security and Environmental Safety, Cuttack, India, 16-18 February: 178-179.

Anupam A, Imam J, Alam S, Quatadah SM, Variar M, Mandal, NP. 2013. Validation of Pita-2 gene in IR64 drought QTL introgression lines with gene based marker. In: National Symposium on Crop pathosystem interactions under aberrant weather and perspectives for crop health management & 26th AGM of Indian Phytopathological Society (EZ) organized by CRURRS, Hazaribag, 24-25 October: 58.

Archak S, Srinivasan K, Singh R, Patra BC, Singh SP, Sarawgi AK, Sharma SK, Viraktamath BC, Subbarao LV, Kumar V, Shaheen R, Singh A, Rai A, Das S, Mohapatra S, Ojha GC, Pachauri A, Chauhan MS, SV and Bansal KC. 2013. National rice resource database: Information source on 15K Indian rice germplasm. International Symposium on Functional Genomics held at New Delhi, 20-23 October.

Baig MJ, Swain P, Behera D and Swain A. 2013. Physiological efficiency in relation to photosynthesis and productivity of some scented rice genotypes under low light environment. Paper presented in the 11th International Symposium on Rice Functional Genomics Sustaining Food and Nutritional Security, New Delhi, 20-23 November: 86.

Banik A and Dangar TK. 2013. Dynamics and *nif*H diversity of phytonic diazotrophs of rice (*Oryza* spp.). In: Annu. conf. AMI and Int. symp. Front. discover. innov. microbiol. interdis. relev. Rohtak, India, November 17-20: 55.

Bardhan S, Saha S, Pande K, Das L, Rao KS and Jena SR. 2013. Participatory varietal selection of rice cultivars under wet sown diect seeded condition. In The proceedings of ARRAW Golden Jubillee Symposium -2013 "Sustainable Rice Production and Food Security: Challenges &Opportunities", March 02-05, Organized by Association of Rice Reasearch Workers Cuttack-753006 (Odisha) India: 382-384.

Behera L, Mohanty SK, Panda RS, Mohapatra SL, Jena M, Sahu RK, Sahu SC and Mohapatra T. 2013. Quantitative trait loci (QTL) associated with resistance against Cuttack population of brown plant hopper in rice. In: International symposium on rice functional genomics sustaining food and nutrition security. New Delhi, 20-23 November: PVII-168:134.

Berliner J, Mishra CD, Pokhar SS, Adak T, Kumar U and Rath PC. 2014. Long term effect of pesticides on rice root knot nematode, *Meloidogyne graminicola* and rice root nematode, *Hirschmanniella spp.* In: AZRA Silver Jubilee International Conference, CRRI, Cuttack, India, 16-18 February: 156.

Bose LK, Jena M, Roy S, Patra BC, Singh ON and Mohapatra T. 2014. Utilization of new alleles through pre-breeding to improve yield and BPH resistance in cultivated rice. In: AZRA Silver Jubilee International Conference, CRRI, Cuttack, India, 16-18 February: 202-203.

Das A, Sharma SG and Mohapatra T. 2013. An insight into differential Fe accumulation in developing rice grain through high throughput RNA-seq. Presented in the 11th International Symposium on Rice Functional Genomics, New Delhi, 20 – 23 November: 103.

Dash SK, Katara JL, Pradhan SK, Rao RN, Behera L, Pande K and Singh ON. 2012. Screening of New Plant Types In rice for Hybrid Development Using Morphological and Molecular Markers; In The proceedings of International Conference On" Biotechnology Advances : Omics Approaches and way Forward": organized by Centre of Biotechnology(ICBA-2012)", 'SOA' University, Bhubaneswar 20-22 December: 77.

Dash SK, Pradhan SK, Rao GJN, Pande K, Baksh SKY, Padhy B, Meher J, Behera L and Singh ON. 2013. Development and further utilization of new plant types in rice (*O. sativa*) for India.In The proceedings of ARRAW Golden Jubillee Symposium - 2013 "Sustainable Rice Production and Food Security : Challenges & Opportunities", Organized by Association of Rice Research Workers Cuttack-753006 (Odisha) India, 02-05 March: 111-112.

Dash N, Pahari A and Dangar TK. 2013. Functional characterization of phosphate solubilizing bacteria from coastal rice soils in India. In: Annu. conf. AMI and Int. symp. Front. discover. innov. microbiol. interdis. relev. Rohtak, India, November 17-20: 406-407.

Dey A, Kumar U and Mishra BB. 2013. Population dynamics and characterization of selected plant growth promoting rhizobacteria (PGPR) from pesticide treated paddy soil. In: 9th Annual convention students association of microbiologists & National seminar on "Exploration of microbes for social welfare", OUAT, Bhubaneswar, India, 25th December: 59.

Gautam P, Lal B, Nayak AK, Raja R and Shahid M 2014. Submergence tolerance in relation to nutrient application in submerged rice. In: ISTS-IUFRO conference on "Sustainable Resource Management for Climate Change Mitigation and Social Security" Chandigarh, 13-15 March: 26-27.

Imam J, Alam S, Maiti D, Mandal NP, Shukla P and Variar M. 2013. Analyzing avirulence genes, molecular diversity of Magnaporthe oryzae from Eastern India and molecular identification of rice germplasm with resistance to blast pathogen. In: National Symposium on Crop pathosystem interactions under aberrant weather and perspectives for crop health management & 26th AGM of Indian Phytopathological Society (EZ) organized by CRURRS, Hazaribag ,24-25 October: 62.

Imam J, Alam S, Mandal NP, Variar M and Shukla P 2013. DNA Fingerprinting, Avr genes analysis and comparative transcriptional profiling of rice early response to *Magnaporthe oryzae*. Paper presented in the symposium, Department of Microbiology, AMI and NIFTEM at Maharshi Dayanand University, Rohtak, Haryana, India, 17-20 November.

Jena M. 2013. Pest management for flash flood and water logging condition. In: Training cum planning workshop on management of rice in flood – prone areas.

Kumar SB, Jena PP, Kumar J, Singh ON, Reddy JN, Mohapatra T. 2013. Identification of local rice germplasm with multiple abiotic stress tolerance. Page50. In: 11th International Symposium on Rice Functional Genomics (ISRFG) on "Sustainable Food and Nutritional Security" held at New Delhi, India, 20-23 November: PI 03.

Kumar U and Adak T. 2013. Techniques of developing biopesticide formulations. In: ICAR sponsored Summer school "New horizon in biotic stress management in rice under changing climate scenario", CRRI, Cuttack, India, September 10-30: 51-54.

Kumar U and Mishra S. 2014. Functional and genetic diversity of primary and secondary - metabolites producing fluorescent pseudomonads from rhizosphere of rice (*Oryza sativa* L.). In: AZRA Silver Jubilee International Conference, CRRI, Cuttack, India, 16-18 February: 116-117.

Kumar Upendra. 2013. Characterization of extreme-tolerant antagonistic bacteria from diverse rice ecologies. In: 9th Annual convention students association of microbiologists & National seminar on "Exploration of microbes for social welfare", OUAT, Bhubaneswar, India, 25th December: 43.

Lal B, Panda BB, Gautam P, Nayak AK, Raja R. 2014. Crop / varietal diversification in rice based cropping system for climate change adaptation. In: ISTS-IUFRO conference on "Sustainable resource management for climate change mitigation and social security", Chandigarh, 13-15 March: 25-26.

Lenka S, Pun KB, Saha S, Patra BC, Mukherjee AK and Medhi B. 2014. Studies on the host range of *Rhizoctonia solani* Kunh causing sheath blight disease in rice. In: AZRA Silver Jubilee International Conference, CRRI, Cuttack, India, 16-18 February:100-101.

Lenka S, Pun KB, Medhi B, Satapathy BS and Singh T. 2013. Efficacy of new fungicides against *Rhizoctonia solani* Kuhn causing sheath blight disease in rice under field conditions. Abstract of paper presented in: National Symposium on 'Crop pathosystem interactions under aberrant weather and perspectives for crop health management' held at CRURRS, Hazaribagh, India, October 24-25: 53.

Mahto D, Imam J, Variar M, and Mandal NP. 2013. Detection of molecular diversity of blast resistance genes in rice germplasm using molecular markers. In: National Symposium on Crop pathosystem interactions under aberrant weather and perspectives for crop health management & 26th AGM of Indian Phytopathological Society (EZ) organized by CRURRS, Hazaribag, 24-25 October: 35.

Mandal NP, Imam J, Anupam A, Shukla VD, Kumar Y and Variar M. 2013. Development of NILs against specific lineages / virulences of M. grisea in the background of *indica* variety Poornima. ***In***: National symposium on crop pathosystem interactions under aberrant weather and perspectives for crop health management organized by Indian Phytopathological Society (EZ) and CRURRS (CRRI), Hazaribag, 24-25 October : 17-36.

Meher J, Panda BB, Nayak AK, Mohanty S, Pradhan SK, Dash SK, Pande K, Rao GJN and Singh ON. 2013. Evaluation of popular Indian rice cultivars for agronomic nitrogen use efficiency in breeding for improvement. In: AZRA Silver Jubilee International Conference, CRRI, Cuttack, India, 16-18 February: 95-96.

Mishra S and Kumar U**.** 2013. Functional and genetic characterization of fluorescent pseudomonads from rhizosphere of rice (*Oryza sativa L.*). In: 9th Annual convention students association of microbiologists & National seminar on "Exploration of microbes for social welfare", OUAT, Bhubaneswar, India, 25th December: 48.

Mohanty SK, Panda RS, Mohapatra SL, Jena M, Behera L, Sahu RK and Sahu SC. 2013. Genetics of resistance to rice brown plant hopper (Nilaparvata lugens Stal) in the land race Salkathi. In: National seminar on climate change and biodiversity organized by School of Biodiversity and Conservation of Natural resources, Central University of Orissa, Koraput on 23- 24 November: 90-91.

Mohapatra S D and Saxena H. 2014. Integrated management strategies for thrips infesting summer mungbean. In: International Conference on Entomology – 2014 at Punjabi University, Patiala from 21-23 February:12-15.

Mohapatra S D, Singh, S K and Singh F. 2013. Sustainable management of spotted pod borer, *Maruca vitrata* (Geyer) in early pigeonpea. In: 2nd Global conference on entomology at Kuching, Sarawak, Malaysia from 8-12 November: 65-67.

Mohapatra SD and Saxena H. 2014. Integrated management strategies for thrips infesting summer mungbean. In: International Conference on Entomology – 2014 at Punjabi University, Patiala from 21-23 February: 12-15.

Mondal B and Singh A. 2014. Impact of watershed development programmes in Bundelkhand region of Madhya Pradesh: Role of institutions and people's participation'. In: Conference on 'Farmers First for Conserving Soil and Water Resources in Northern Region (FFCSWR-2014), Dehradun, India, 22-24 March: 1-3.

Mukherjee AK. 2013. "Identification of genes expressed during pathogen induced accelerated programmed cell death in plants" in the National seminar on Food Security and GM Crops, Department of Biotechnology, Visva Bharati University, Shantiniketan, 31 October and 1 November.

Mukherjee AK. 2013. "Genetic Diversity of Mangroves of Bhitar Kanika" in the National Seminar on National Seminar on "Climate Change and Biodiversity" organized by the School of Biodiversity & Conservation of Natural Resources, Central University of Orissa, Koraput, Odisha, 23-24 November.

Mukherjee AK. 2013. Isolation, characterization, evaluation of local biocontrol agents for management of plant pathogens in sustainable agriculture" in the National Seminar on "Exploration of microbes for social welfare" organised by Dept of Microbiology and Students Association of Microbiology, OUAT, Bhubaneswar, 25 December.

Mukherjee AK. 2014. "Identification and characterization of a bacterial biocontrol agent for broad spectrum antifungal activity In: AZRA Silver jubilee international conference, CRRI, Cuttack, India, 16-18 February.

Munda S, Saha S and Adak T. 2014. Weed management in aerobic rice under varying establishment methods. In: AZRA Silver jubilee international conference, CRRI, Cuttack, India, 16-18 February: 98

Nayak D, Singh S, Barik SR, Sahoo J, Mohanty S, Mohanty SP, Pande K and Pradhan SK. 2013. CR DHAN 500: A multiple resistant high yielding deep watervariety. In The proceedings of ARRAW Golden Jubillee Symposium-2013 "Sustainable Rice Production and Food Security: Challenges & Opportunities", Organized by Association of Rice Reasearch Workers Cuttack-753006 (Odisha) India, 2-5 March: 106.

Neogi S and Bhattacharyya P. 2013. Characteristics of net ecosystem CO_2 exchange with relation to meteorological variables in tropical flooded soil planted to rice. In: National seminar on climate change and biodiversity in Central University of Orissa, Koraput, November 23-24: 58.

Nitin M, Alam S, Anantha MS, Kumar Y and Maiti D. 2013. Comparative homology modeling and docking study of MAT 1-2-1 protein and designing bio-active molecule effective against rice false smut (*Ustilaginoidea virens*). In: National symposium on crop pathosystem interactions under aberrant weather and perspectives for crop health management organized by Indian Phytopathological Society (EZ) and CRURRS (CRRI), Hazaribag, 24-25 October: 2.13, 33.

Panda BB. 2013. Aerobic rice: A production system for coping with water scarcity. In: National seminar held at OUAT, Bhubaneswar and organized by the Odisha Chapter of Indian society of Agronomy on 21st December 2013.

Pande K, Dash SK, Pradhan SK, Bose LK, Meher J, Dhua SR, and Singh ON. 2013. Development of semi dwarf photoperiod insensitive cultivars for direct seeded wetland conditions in rice In the poster proceedings of the "100th year of Indian Science Congress" held at Kolkata, 3-7 January: 87-88.

Pande K, Kar M., Patnaik SSC, Singh ON, Pradhan SK, Meher J and Dash SK. 2013. GXE interaction studies in various dry season rice In The proceedings of ARRAW Golden Jubillee Symposium - 2013Sustainable Rice Production and Food Security: Challenges & Opportunities, Association of Rice Research Workers Cuttack-753006 (Odisha). India, 2-5 March: 19-20.

Patra BC, Mohapatra S, Das S and Mohapatra T. 2014. Evolutionary variations in wild and weedy rices collected from Assam. In: AZRA Silver Jubilee International Conference on "Probing bio-sciences for food security & environmental safety", Cuttack, India, 16-18 February: 102-103.

Patra BC. 2013. Rice diversity still holds the key for food security under changing climate in Odisha. In: Odisha environment congress (OEC) agriculture and environment – issues, challenges and potentials for Odisha, 20-21 December.

Patra BC. 2014. Rice genetic resources - its collection, utilization and conservation. Souvenir article in UGC sponsored National Seminar on "Phytoresources: Utilization and conservation" held at North Orissa University, Baripada during 24-25 March. 4-10.

Pokhare SS, Kumar U, Berliner J, Mohapatra S, Adak T and Rath PC. 2014. Evaluation of Pseudomonas fluorescence against rice root-knot nematode. In: AZRA silver jubilee international conference, CRRI, Cuttack,India, 16-18 February: 56

Pradhan SK, Singh S, Dash SK, Behera L, Meher J, Patra BC, Pande K, Singh ON and Mohapatra T. 2013. Breeding for Yield ceiling in rice at CRRI: New generation rice approach. In The proceedings of ARRAW Golden Jubillee Symposium -2013 "Sustainable Rice Production and Food Security: Challenges &Opportunities", Association of Rice Research Workers, Cuttack 753006, Odisha, India, 2-5 March: 100-101.

Prakash A, Mukherjee AK, Berliner J, Pokhare SS, Adak T and Mohapatra S. 2014. Changing rice pest scenario in India.In: AZRA silver jubilee international conference, CRRI, Cuttack, India, 16-18 February: 76

Priyadarshini A, Sharma SG and Das A. 2014. Activity of Nitrogen Assimilating Enzymes in Relation to Grain Protein Content in Some Traditional Rice Cultivars (*Oryza sativa* L) presented in the National Seminar on Food Science and Nutrition, Sambalpur University, Orissa, 21-22 March.

Pun KB, Ghosh A, and Lenka S. 2014. Some insect-transmitted virus and virus-like diseases of plants in the north-eastern sub-Himalayan region. Abstract of paper presented in: AZRA Silver Jubilee International Conference, CRRI, Cuttack, India, 16-18 February: 107-108.

Pun KB, Pant RP, Kar MK and Lenka S. 2013. Virus and virus-like diseases affecting major crop plants in the north-eastern sub-Himalayan region of India under aberrant weather conditions with special reference to rice *tungro* disease. Abstract of paper presented in: National Symposium on 'Crop pathosystem interactions under aberrant weather and perspectives for crop health management' held at CRURRS, Hazaribagh, India, October 24-25: 4-5.

Quatadah SM, Imam J, Anantha MS and Mandal NP. 2013. Evaluation of Jhum rice germplasm from Tripura against blast pathogen under nursery conditions at Hazaribag. In: National symposium on crop pathosystem interactions under aberrant weather and perspectives for crop health management organized by Indian Phytopathological Society (EZ) and CRURRS (CRRI), Hazaribag, 24-25 October: P.P. 1.13, 35.

Rao GJN, Das G, Prasad D, Das KM, Reddy JN, Marndi BC, Kar MK, Varier M, Prakash A, Mohapatra T. 2013. Marker aided pyramiding of nine genes / QTLs for management of biotic and abiotic stresses in rice. Page155. In: 11th International Symposium on Rice Functional Genomics (ISRFG) on "Sustainable Food and Nutritional Security," New Delhi, India, 20-23 November: PVIII-207.

Rath PC, Jena M, Behera K and Sasmal S. 2014.Pest outbreaks and resurgence in rice ecosystem in Odisha-A Retrospect. *In: Souvenir*, 7th National seminar on emerging climate change issues and sustainable management strategies. OUAT Bhubaneswar, Odisha, India 8-10 February: 20-21.

Rath PC. 2014. Field testing of new insecticides against insect pest of rice. In: AZRA Silver jubilee international conference, CRRI, Cuttack, India, 16-18 February: 147-148.

Reddy JN, Sarkar RK and Patnaik SSC . 2013. Rice breeding and an overview of the EIRLSBN at the coordinating center. CRRI, Cuttack. In: EIRLSBN: Twenty years of achievements in rice breeding, (Eds. Collard BCY, Ismail AM and Hardy B), International Rice Research Institute, Los Banos, Philippines: 7-29.

Roy KS and Bhattacharyya P. 2013. Impact of elevated CO_2 and temperature on grain yield, leaf area index and carbon allocations in low land rice

(*Oryza sativa* L.). In: National seminar on climate change and biodiversity in Central University of Orissa, Koraput, November 23-24: 56.

Saha S, Patra BC, Munda S and Mohapatra T. 2014. Weedy rice: problems and its management. Extended Summary in Biennial Conference of Indian Society of Weed Science on “Emerging challenges in Weed management” Directorate of Weed Science Research, Jabalpur during 15-17 February.

Sahoo B, Behera KS, TK Dangar 2014. Molecular characterization, formulation and field performance of *Beauveria* and *Metarhizium* spp. against rice leaf folder (*Cnaphalocrocis medinalis* Guenee). In: AZRA Silver Jubilee International Conference, CRRI, Cuttack, India, 16-18 February: 44-45.

Sahu S and Dangar TK. 2013. Structural and functional diversity of rice endophytes in wide ecological niches. In: Annu. conf. AMI and Int. symp. Front. discover. innov. microbiol. interdis. relev. Rohtak, India, November 17-20: 96.

Sangeetha G, Anandan A and Ravikumar S. 2014. Bioactive natural compounds for the management of sheath blight disease of rice. In: AZRA Silver jubilee international conference, CRRI, Cuttack, India, 16-18 February: 124-125.

Sarkar RK and Singh DP. 2013. Rice diversity for developing climate resilient varieties to ensure food security. In: National Seminar on “Climate Change and Biodiversity”, Central University of Orissa, Koraput, 23-24 November: 34.

Sarkar RK. 2013. Submergence tolerance and productivity in rice. In: National Conference of Plant Physiology-2013 on “Current Trends in Plant Biology Research”, DGR, Junagadh, 13-16 December: 82.

Shamshad A, Imam J, Maiti D, Prasad C, Sharma TR, Mandal NP and Variar M. 2013. Genetic diversity of Magnaporthe oryzae population in Eastern and North Eastern India revealed by DNA fingerprinting and virulence analysis.In: Proc. Indian Phytopathological society, CRURRS, Hazaribag, Jharkhand.

Sharma SG and Das A 2013. A study on red rice varieties and landraces for promotion as health food. Presented in the International conference on role of plant biochemistry and biotechnology in food and nutritional security held at Tirupati, India, 11–14 December.

Sharma SG, Pande K, Acharya B, Nayak DK, Barik S, Meher J, Dash SK and Pradhan SK. 2012. Introduction of appropriate Crop Diversification to enhance agricultural and Livestock production and protection in the context of climate change. In the proceedings of the ‘’National Symposium on Agriculture production and protection in the context of climate change”(NSAPPCC-2012), 3-5 November: 35.

Shukla VD, Prakash A, Variar M, Kumar Y, Singh CV and Kumar S. 2014. Dissemination and validation of selected IPM technologies under direct seeded upland rice in Jharkhand. In: AZRA Silver jubilee international conference, CRRI, Cuttack, India, 16-18 February: 140-141.

Singh CV, D Maiti, VD Shukla and M Variar. 2013. Scope for integration of cultural practices to manage disease and pests in rice based cropping systems. In: Abstracts – National symposium on “Crop pathosystem interactions under aberrant weather and perspectives for crop health management, organized by Indian Phytopathological Society (EZ) and CRURRS (CRRI), Hazaribag, 24-25 October: 56-57.

Singh CV. 2014. Crop intensification in rainfed uplands for livelihood support. Paper presented (oral) in the State Level Workshop organized by Lead Institute BAU, Ranchi in collaboration with associated lead centres of NAIP C3 project, BAU, Kanke, Ranchi, January 4, 2014.

Singh ON, Jena PP, Kumar SB, Katara JL, Marndi BC, Swain P, Sarkar RK, Singh DP, Reddy JN and Mohapatra T. 2013. Improvement of locally adapted rice cultivars to abiotic stress tolerance through marker assisted backcross breeding. Page150. In: 11th International Symposium on Rice Functional Genomics (ISRFG) on “Sustainable Food and Nutritional Security”, New Delhi, India, 20-23 November 2013: PVII-199.

Singh ON, Pande K, Singh S, Das SK, Meher J and Pradhan SK. 2013. CR DHAN 601: A high yielding boro rice for Assam, Odisha and West-Bengal. In The proceedings of ARRAW Golden Jubillee Symposium-2013 “Sustainable Rice Production and Food Security: Challenges & Opportunities”, Association of Rice Research Workers Cuttack-753006 (Odisha) India, 02-05 March2013: 99-100.

Singh PK, Lal HC, Mahto CS, Karmakar S and Kumar Y .2013. Development and testing of IPM modules against major pests of field pea. *In*: National Symposium on Crop pathosystem interactions under aberrant weather and perspectives for crop health management organized by Indian Phytopathological Society (EZ) and CRURRS (CRRI), Hazaribag, Octoberober: P.P. 3.28, 55-56.

Singh T, Satapathy BS, Pun KB and Lenka S. 2014. Evaluation of pre-emergence herbicides and hand weeding on weed control efficiency and performance of transplanted early *ahu (boro)* rice. Abstract of the paper presented in: National Seminar on 'Adaptation and Mitigation Strategies of Climate Change for Sustainable Livelihood', Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, March, 5-7: 78.

Tripathi, R. 2014. Site specific nitrogen management in rice using remote sensing and geostatistical tools. In: "Indian Science Congress-Young Scientist Award Programme" held in Jammu University, Jammu, India from February 03-07, 2014.

Swain P. 2014. "Drought tolerance in rice with reference to Climate change". Invited Lecture in National Seminar on Current trends in Stress Biology, Utkal University, Vanivihar, Bhubaneswar, 26 March.

Syed MQ, Jahangir I, Anantha MS and Mandal NP. 2013. Evaluation of Jhum rice germplasm from Tripura against blast pathogen under nursery conditions at Hazaribag. In: National Symposium on Crop pathosystem interactions under aberrant weather and perspectives for crop health management organized by Indian Phytopathological Society (EZ) and CRURRS (CRRI), Hazaribag from 24-25 October: 1.13, 35.

Training Manuals/Compendium

Das L., Mishra SK and Rao KS 2013. Book on 'Rice-Fish Farming System' published during the trainers' training programme organized at CRRI, Cuttack during 17-23 September, 2013 sponsored by DAO, Ampati, Government of Meghalaya: 1-180.

Kumar R. 2013. *Insect Pests diagnostics and estimation of leaf folder, Cnaphalocrosis medinalis* (Guenee) *damage in rice*. CRRI, Cuttack: 15.

Lenka S, Pun KB, Tewari SN and Medhi B. 2013. Identification of rice diseases and their management through integrated disease management. *In:* Training manual on 'Rice knowledge management for food and nutritional security', Published by ICAR Research Complex for NEH Region, Sikkim Centre, Tadong, Gangtok, Sikkim: 226-236,

Satapathy BS and Pun KB. 2013. Problems and prospects of rice-fish farming system in north-east India: Sharing of Experience. *In:* L Das, SK Mishra and KS Rao (Eds.) Rice-Fish Farming System', CRRI, Cuttack, pp. 55-63.

Book Chapter

Adak T, Berliner J, Pokhare SS, Munda S, Kumar U and Prakash A. 2013. Pesticide residue analysis in rice. *In*: New horizon in biotic stress management in rice under changing climate scenario, CRRI, Cuttack. pp: 55-56.

Behera L, Panda RS, Mohapatra SL, Mohanty SK and Mohapatra SD. 2013. Molecular techniques for identification of rice insect pests. *In*: *New horizon in biotic stress management in rice under changing climate scenario,* CRRI, Cuttack, 10 to 30 September: 10-16.

Bhatia A, Jain N, Bhattacharyya P, Srinivasarao C, Prasad JVNS and Pathak H. 2013. Measurement of greenhouse gas emissions from crop fields. *In*: Pathak, H., Upadhyay, R. C., Muralidhar, M., Bhattacharyya, P. and Venkateswarlu, B. (Eds.). *Measurement of greenhouse gas emission from crop, livestock and aquaculture*. Indian Agricultural Research Institute, New Delhi, ISBN: 978-81-88708-98-7, pp. 9-17.

Bhattacharyya P, Mohanty S, Sarkar RK, Bhatia A, Jain N, Kumar A and Pathak H. (2013). Measurement of integrated greenhouse gas flux with eddy covariance technique. *In*: H Pathak, RC Upadhyay, M Muralidhar, P Bhattacharyya and B Venkateswarlu (Eds.), *Measurement of greenhouse gas emission from crop, livestock and aquaculture*. Indian Agricultural Research Institute, New Delhi, (ISBN: 978-81-88708-98-7). pp. 18-28.

Bhattacharyya P, Nayak AK, Neogi S and Roy KS. 2013. Greenhouse gas emission reduction strategies in agriculture to mitigate climate change. *In*: GR Chary, C Srinivasarao, K Srinivas, GRM Sankar, RN Kumar, B Venkateswarlu (Eds): Adaptation and mitigation strategies for climate resilient agriculture. Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad (ISBN: 978-93-80883-25-0). pp. 260-271.

Dangar TK, Rath J. 2013. Green house gases; environmental and biological perspective. *In*: Sinha BK (Eds.). Challenges of biology in the 21st century. Published by Sarat Impress Pvt. Ltd., Howrah, India: 57-64.

Jena M, Rath PC, Panda RS and Mohanty SK. 2013.Screening techniques to assess the resistance level to insect pets in rice. *In*: *New horizon in biotic stress management in rice under changing climate scenario*, CRRI, Cuttack, 10 to 30 September 2013: pp. 42-44.

Jena M. 2013. Prospect of pest management with forest based botanicals. *In: Forest Health Management*. Institute of Forest Genetics and Tree Breeding (ICFRE), Coimbatore, Tamil Nadu, India. pp. 255-265.

Jena M. 2013. Recent advances in sucking pests research in rice under changing climate scenario with emphasis on ITKs. *In*: New horizon in biotic stress management in rice under changing climate scenario, CRRI, Cuttack: DVD ROM.

Jena M., Rath PC, Panda RS and Mohanty SK. 2013. Screening techniques to assess the resistance level to insect pets in rice. *In*: New horizon in biotic stress management in rice under changing climate scenario, CRRI, Cuttack. pp. 42-44.

Jena M.. 2013. Prospect of pest management with forest based botanicals. Book chapter. Forest Health Management. Published by Institute of Forest Genetics and Tree Breeding(ICFRE), Coimbatore, Tamil Nadu. India pp. 255-265.

Kumar U and Adak T. 2013. Techniques of developing bio-pesticide formulations. *In*: *New horizon in biotic stress management in rice under changing climate scenario*, CRRI, Cuttack, 10 to 30 September: pp. 51-54.

Kumar U, Gupta SK, Dangar TK and Annapurna K. 2014. Functional interaction of diazotrophs and antagonistic rhizobacteria in sustainable development of agricultural products. *In*: Chauhan A and Bharati PK (Eds.). *Environment conservation and biotechnology*. Discovery Publishing House Pvt. Ltd., New Delhi, India pp. 149-166.

Lenka S, Pun KB, Tewari SN and Medhi B. 2013. Identification of rice diseases and their management through integrated disease management. Pages 226-236, In the training mannual on 'Rice knowledge management for food and nutritional security', Published by ICAR Research Complex for NEH Region, Sikkim Centre, Tadong, Gangtok, Sikkim

Mohapatra SD, Jena M, Dash SK and Prakash A. 2013. Biotic stress management in rice. *In*: New horizon in biotic stress management in rice under changing climate scenario, CRRI, Cuttack, 10 to 30 September: pp. 63.

Mohapatra SD, Saikia K, Jena M and Prakash A. 2013. Identification of insect pests in different rice ecologies. *In*: New horizon in biotic stress management in rice under changing climate scenario, CRRI, Cuttack. pp. 1-5.

Mukherjee AK. 2013. Molecular detection of rice pathogens. *In*: New horizon in biotic stress management in rice under changing climate scenario, CRRI, Cuttack, 10-30 September: pp. 21-24.

Mukherjee AK. 2013. Molecular diagnostics of rice diseases. *In*: New horizon in biotic stress management in rice under changing climate scenario, CRRI, Cuttack, 10 to 30 September 2013.

Nayak AK, Lal B, Mohapatra SD, Shahid M, Raja R, Mohanty S, Tripathy R, Bhatacharya P, Kumar A and Gautam P. 2013. Nutrient deficiency diseases vis-a-vis pathogenic diseases in rice: Diagnosis and management of nutrient deficiency. *In*: New horizon in biotic stress management in rice under changing climate scenario, CRRI, Cuttack. DVD ROM: 11.

Pokhare SS, Berliner J, Adak T and Prakash A. 2013. Basic techniques in Nematology. *In*: New horizon in biotic stress management in rice under changing climate scenario, CRRI, Cuttack. 25-26.

Prakash A, Rao J, Mukherjee AK, Berliner J, Behera KS, Pokhare SS, Adak T, Saikia K and Lenka S. 2014. In: AZRA Silver Jubilee International Conference, CRRI, Cuttack, India, 16-18 February: 230.

Prakash A, Rao J, Mukherjee AK, Berliner J, Pokhare SS, Adak T, Munda S, Shashank PR. 2014. Climate Change: impact on crop pests. In: AZRA Silver Jubilee International Conference, CRRI, Cuttack, India, 16-18 February:ISBN-81-9000947-2-7. pp. 205.

Raja R, Nayak AK, Panda BB, Tripathi R, Lal B, Shahid Md., Kumar A and Gautam, P. 2013 Application of remote sensing and GIS in insect pests and diseases assessment in rice. *In*: New horizon in biotic stress management in rice under changing climate scenario, CRRI, Cuttack. (DVD ROM) 6p.

Reddy JN, Sarkar RK and Patnaik SSC. 2013. Rice breeding and an overview of the EIRLSBN at the coordinating center, CRRI, Cuttack. In EIRLSBN: *Twenty years of achievements in rice breeding*. (Eds. Collard BCY, Ismail AM and Hardy B), International Rice Research Institute, Los Banos, Philippines, pp 7-29.

Sahoo RK**,** Dangar TK, Tuteja N. 2013. Formulation of associative nitrogen fixing *Azotobacter* and *Azospirillum* biofertilizers for improvement of rice production a review. In: Thatoi H, Mishra BB (Eds.). Advances in Biotechnology. Published by Studium Press LLC, Houston, USA: pp. 101-124.

Satapathy BS and Pun KB. 2013. Problems and prospects of rice-fish farming system in north-east India: Sharing of Experience, Pages 55-63, In the training manual 'Rice-Fish Farming System' L Das, SK Mishra and KS Rao (Eds.), Published by CRRI, Cuttack.

Research Bulletins

Sarkar RK, Das KK, Panda D, Reddy JN, Patnaik SSC, Patra BC and Singh DP. 2014. Submergence tolerance in rice: Biophysical constraints physiological basis and Identification of Donors. Central Rice Research Institute, Cuttack, India p. 36.

Policy paper

Mishra P, Gupta RK and Dash SK. 2014. Road map for post-harvest processing and value addition in rice. CRRI policy paper no.1, Cuttack India p. 48.

Technology bulletins

Din M, Mishra P, Patel SP and Mohapatra PC. 2013. *Chawal ke kheti ke liye upaykt CRRI dwara bikasit upkaran* (Hindi), CRRI Technology Bulletin No. 96, Cuttack, India.

Din M, Mishra P, Patel SP and Mohapatra PC. 2013. *CRRI Implements for Rice Mechanization*. CRRI Technology Bulletin No. 89, Cuttack, India.

Nayak AK, Mohanty S, Raja R, Shahid M, Lal B, Tripathi R, Bhattacharyya P, Panda B B, Gautam P, Kasthuri TV, Kumar A, Meher J and Rao KS (Odia, Hindi, English). 2013. Customized Leaf Colour Chart for Nitrogen Management in Rice for Different Ecologies. CRRI Technology Bulletin no…., Cuttack, India.

Nayak AK, Shahid, M, Raja, R, Lal B, Gautam, P, Bhattacharyya P, Kumar A, Tripathi R, Mohanty S, Panda BB, Mohapatra SD Das KM and Shukla AK. 2013. Identification and management of nutrient disorders and diseases in rice: A visual diagnostic tool. CRRI Technology Bulletin no…., Cuttack, India.50 p.

Pradhan SK, Behera L, Barik SR, Dash SK, Mishra JR, Ghosh A, Sadangi BN, Singh ON and Mohapatra T . 2013. *CR Dhan 500-A high yielding rice variety for rainfed lowland and waterlogged areas of Odisha and Uttarpradesh.* (Odia), CRRI Technology Bulletin No. 87, Cuttack, India.

Pradhan SK, Behera L, Barik SR, Dash SK, Mishra JR, Ghosh A, Sadangi BN, Singh ON and Mohapatra T. 2013. *CR Dhan 500-A high yielding rice variety for rainfed lowland and waterlogged areas of Odisha and Uttarpradesh*. CRRI Technology Bulletin No. 91, Cuttack, India.

Pradhan SK, Behera L, Barik SR, Dash SK, Mishra JR, Ghosh A, Sadangi BN, Singh ON and Mohapatra T. 2013. *CR Dhan 500 - Odisha tatha Uttar Pradesh ke varshasrit nichili bhumi tatha jalakrant khetrono ke liye adhik upaj dene bali chawal ki kheti* (Hindi), CRRI Technology Bulletin No. 94, Cuttack, India.

Rao RN, Rao KS, Baig MJ, Patnaik, SSC, Rao GJN, Behera KS and Das KM. 2013. *Production Technology for Rice Hybrid CR Dhan 701 (CRHR 32).* CRRI Technology Bulletin No. 88, Cuttack, India.

Rao RN, Rao KS, Baig MJ, Patnaik SSC, Rao GJN, Behera KS and Das KM. 2013. *CR Dhan 701 - Sankar chawal ke liye utpadan prodyogiki* (Hindi). CRRI Technology Bulletin No. 95, Cuttack, India

Rao RN, Ratho SN, Panda D, Rao KS, Sarkunan V, Behera KS, Patnaik SSC, Mohanty SK, Das S, Swain P and Das KM. 2013. *Production Technology for Hybrid Rice - Rajalaxmi* (English), CRRI Technology Bulletin No. 59 (1st revision), Cuttack, India.

Rao RN, Ratho SN, Panda D, Rao KS, Sarkunan V, Behera KS, Patnaik SSC, Mohanty SK, Das S, Swain P and Das KM. 2013. *Production Technology for Hybrid Rice - Ajay* (English), CRRI Technology Bulletin No. 60 (1st revision), Cuttack, India.

Saha S and Patra BC. 2013. *Chawal main samanuit kharpatwar prabhandan* (Hindi), CRRI Technology Bulletin No. 97, Cuttack, India.

Saha S and Patra BC. 2013. *Integrated Weed Management in Rice*. CRRI Technology Bulletin No. 90, Cuttack, India.

Sahu RK and Dhua SR. 2013. *Unnat manara dhan bihana utpadana padhati* (Odia), CRRI Technology Bulletin No. 92, Cuttack, India

Sharma SG and Das A 2013. *Rice bran oil - a cooking medium with health benefits* (English), CRRI Technology Bulletin No. 61 (1st revision), Cuttack, India

Sharma SG and Mishra P. 2014. A farmer's guide to proper storage and improving out turn ratio (OTR) of paddy rice. CRRI Technology Bulletin No.98, Cuttack, India.

Swain P, Mohanty S, Bhattacharyya P, Baig MJ, Chattopadhya K, Singh ON and Sarkar RK. 2013. *Paribartita jalabayure barshasrita dhipajami o marudi prapidita anchala paini dhan chasa* (Odia). CRRI Technology Bulletin No. 93, Cuttack, India

Agripreneurs' Flyers

Din M, Kumar GAK and Sadangi BN. 2013. Custom Hiring of Agricultural Implements. CRRI Agripreneurs' Flyer No. 1. Cuttack, India

Sinhababu DP, Rao KS, Kumar GAK and Sadangi BN. 2013. Commercial Rice-Fish Integrated Farming System. CRRI Agripreneurs' Flyer No. 2. Cuttack, India

Sinhababu DP, Rao KS, Kumar GAK and Sadangi BN. 2013. Fish Integrated Farming System for small farmers. CRRI Agripreneurs' Flyer No. 3. Cuttack, India

Prakash A, Dangar TK, Behera KS and Sahoo B. 2013. Potential Bioagents for Insect and Pests of Rice. CRRI Agripreneurs' Flyer No. 4. Cuttack, India

Din M, Kumar GAK and Sadangi BN. 2013. Manufacturing of Selected CRRI Implements. CRRI Agripreneurs' Flyer No. 5. Cuttack, India

Sharma SG, Mishra P, and Das A. 2013. Rice Bran Oil. CRRI Agripreneurs' Flyer No. 6. Cuttack, India

Singh ON, Patnaik SSC, Sahu RK and Samal P. 2013. Seed Production of CRRI High Yielding Rice Varieties for Lowland Ecosystems. CRRI Agripreneurs' Flyer No. 7. Cuttack, India

Book

Adak T and Mukherjee I. 2013. Environmental fate of spinosad, LAP Lambert Academic Publishing, ISBN-13: 978-3659358012, pp. 116.

Nayak AK, Shahid M, Raja R,Lal B, Gautam P, Bhattachryya P, Kumar A, Tripathi R, Mohanty S, Panda BB, Mohapatra S D, Das KM and Shukla AK. 2013. *Identification and Management of Nutrients Disorders and Diseases in Rice: A Visual Diagnostic Tool*. Central Rice Research Institute, Cuttack, India, pp. 54.

Pathak H, Upadhyay RC, Muralidhar M, Bhattacharyya P and Venkateswarlu B. 2013. Measurement of greenhouse gas emission from crop, livestock and aquaculture. Indian Agricultural Research Institute, New Delhi, pp. 101.

Prakash A, Rao J, Mukherjee AK, Berliner J, Pokhare SS, Adak T, Munda S and Shashank PR. 2014. Climate change: impact on crop pests. Published by Applied Zoologist Research Association. CRRI, Cuttack,India .ISBN-81-9000947-2-7. 2013 205.

Thirugnanakumar S, Anandan A and Anitha VY. 2014. Basics of mutation breeding. Published by New India Publishing Agency, New Delhi, India.

Database/DVD-ROM developed

Raja R, Nayak AK, Saha S, Panda BB, Bhattacharyya P, Mohanty S, Shahid M, Lal B, Tripathi R, Gautam P, Mohapatra SD, Kumar A, Baig MJ, Rao KS and Mohapatra, T. 2013. Interactive Database of Long Term Weather of CRRI (DVD ROM), Central Rice Research Institute, Cuttack

Other Publications

Annonymous 2013. *CRRI Annual Report* 2012-13. Central Rice Research Institute, Cuttack , India.

Annonymous (2013-14) CRRI Newsletters viz., April-June' 13: **34**(2), July-September' 13: **34**(3), Octoberober–December' 13: **34**(4), January-March' 14: **35**(1). Central Rice Research Institute, Cuttack, India.

Events and Activities

IJSC, IMC, IRC, RAC and SAC Meetings

Institute Joint Staff Council

The 8th IJSC meeting was held on 8 July 2013 and its 9th meeting was held on 22 March, 2014 at CRRI, Cuttack under the Chairmanship of Dr. T Mohapatra, Director, CRRI. Various administrative and financial matters were discussed and finalized.

Institute Management Committee

The 25th meeting of the Institute Management Committee (IMC) was held on 20 July, 2013 under the Chairmanship of Dr. T Mohapatra, Director, CRRI. Matters related to infrastructure development and budgetary provisions were discussed.

Institute Research Council

The 32nd meeting of the Institute Research Council (IRC) was held from 10 to 15 June, 2013 under the Chairmanship of Dr. T Mohapatra, Director, CRRI. The work progress of the scientists were presented and reviewed for the period April 2012 to March 2013.

Research Advisory Committee

The XIXth Meeting of the Research Advisory Committee (RAC) of CRRI was held at CRRI, Cuttack on 13 to 14 December 2013. Dr. RB Singh, Chairman, RAC and members Dr. ML Lodha, Dr. R Sridhar, Dr. (Mrs.) Shailaja Hittalmani were present during the meeting. The Chairman along with the members conducted a pre-meeting briefing with the Director followed by an open session. Dr. T Mohapatra, Director, CRRI presented the highlights of the research achievements and infrastructural developments since the last RAC meeting. Dr. (Mrs.) Mayabini Jena, Member-Secretary, Institute Research Council (IRC) highlighted the salient features of the programme of work approved by the IRC 2013. Dr. JN Reddy, Member-Secretary, RAC presented the details of the action taken report on the recommendations of the XVIIIth RAC followed by presentations of the Programme / Co-Programme Leaders (Dr. ON Singh, Dr. Anand Prakash, Dr. AK Nayak, Dr. SG Sharma and Dr. BN Sadangi). During the meeting, nine technology bulletins prepared by the CRRI scientists were released by the Chairman and members of the RAC. The RAC

Chairman and Members, RAC interacting with the scientists in an open session

Members also visited different divisions and had discussions with the scientists of concerned disciplines.

SAC meetings of Krishi Vigyan Kendra

KVK, Santhapur

The 15th Scientific Advisory Committee (SAC) meeting of the Krishi Vigyan Kendra, Santhapur was held at its campus on 24 March, 2014 under the Chairmanship of Dr. T Mohapatra, Director, CRRI. State Government officials of concerned departments; Head, CARI Regional Centre, Bhubaneswar; Heads of Division of CRRI, farmers and farmwomen representatives attended the meeting. ATR and the progress report of KVK for 2013-14 were presented by Dr. SM Prasad, Programme Coordinator and the Action Plan for 2014-15 was finalized after rigorous discussion.

Director, CRRI discussing during the SAC Meeting of KVK, Santhapur

KVK, Koderma

The Scientific Advisory Committee (SAC) meeting of the Krishi Vigyan Kendra, Koderma was held at its campus on 5 February 2014 under the Chairmanship of Dr. M Variar, OIC, CRURRS, Hazaribag. Dr. SK Roy, Principal Scientist, ZPD Unit, Zone II, Kolkata, District Agriculture Officer, District Fisheries Officer, District Dairy Development Officer, Koderma & representatives of other line department, DDM, NABARD, LDM, representative of NGO, progressive farmers & farm women, representative of rural youth, scientists of CRURRS, Programme Coordinator, KVK, Hazaribag and staff of KVK, Koderma attended the meeting. Action taken report (ATR), large adoption of technology by farmers, and the progress report of KVK for 2013-14 were presented by Dr. VK Singh, Programme Coordinator and the Action Plan for 2014-15 was finalized after rigorous discussion.

SAC meeting in progress at KVK, Koderma (Jainagar)

Participation in Exhibitions

The Institute participated in the following exhibitions for showcasing the CRRI technologies:

National Agricultural Exhibition - 4th Krishi Fair 2013 at Puri during 19 to 23 May 2013.

Kisan Mela, organized by KVK, Santhapur at Sagar village, Narsinghpur, Cuttack on 5 July, 2013

Industry Day celebration organized at CRRI Cuttack on 21 September 2013.

The 33rd India International Trade Fair (IITF) at Pragati Maidan, New Delhi from 14 to 27 November 2013.

***Hon'ble Governor of Odisha Dr. SC Jamir visitng the CRRI stall in** the 4th Krishi Fair 2013 at Puri*

The 2nd 'Interface Meet of the ICAR institutes–SAU–State Departments for the year 2013-14' for Odisha at CRRI, Cuttack on 26 and 27 November 2013.

Agricuture Education Day celebration at CRRI, Cuttack on 18 November 2013.

Technology Week celebration at Directorate of Research on Women in Agriculture, Bhubaneswar on 27 January 2014.

National Agriculture Fair-cum-Exhibition "Krishi Vasant 2014" at the Central Institute for Cotton Research (CICR) Complex, Nagpur during 9-13 February 2014.

Pusa Krishi Vigyan Mela at IARI, New Delhi during 26-28 February 2014.

Eastern Zone Regional Agriculture Fair 2013-2014 during 26-28 February 2014 at CRRI, Cuttack.

Visitors looking at the CRRI rice varieties displayed during Krishi Vasant National Agriculture Fair-cum-Exhibition at Nagpur

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

The Annual Planning and Review Workshop of STRASA project from 9-12 April, 2013 at NASC complex, New Delhi.	Dr. P Swain
The Annual Group Meeting and Planning for 2013-14 of STRASA at NASC complex, New Delhi from 11-13 April 2013	Drs JN Reddy, SSC Patnaik, M Variar, VD Shukla, NP Mandal, P Swain and Yogesh Kumar
Attended 48th Annual rice group meeting at Sher-e-Kashmir University of Agriculture Science and Technology of Kashmir, Srinagar from 13-16 April 2013	Drs T Mohapatra, ON Singh, KS Rao, GJN Rao, SR Dhua, M Jena, P Swain, RN Rao, JN Reddy, A Patnaik, SSC Patnaik, SK Pradhan, M Variar, NP Mandal, CV Singh and N Bhakta
Attended 9th PAC Meeting of Fly Ash Unit, DST, New Delhi on 16-17th April 2013	Dr R Raja
The XXI Meeting of the ICAR Regional Committee No. 3 at Assam Agricultural University, Jorhat from 17-18 April 2013	Drs KB Pun, T Singh and Mr BS Satapathy
Attend a meeting on 'Addressing Barriers to Rice Trade between India and Bangladesh' on 19-20 April, 2013 at Kolkata, which was organized by CUTS International	Dr P Samal
Climate Prediction Sciences application Workshop on held at Utah Climate Centre, Utah state University, Logan, Utah from 23 -25 April 2013	Dr BB Panda
The 'Annual group meeting of AICRP on Weed Control' at CSKHPKVV Palampur, Himachal Pradesh from 26 to 27 April 2013	Dr S Saha
The XXVIII Annual group meeting of AICRP (NSP) at PAU, Ludhiana from 27-29 April 2013	Dr SR Dhua and Mr. RK Sahu
International Consultation on 'Molecular genetics: science-technology-regulation' at MSSRF, Chennai from 29 to 30 April 2013	Dr T Mohapatra
Attended District level *kharif* strategy meeting at Collectorate, Cuttack on 2 May 2013	Dr SM Prasad
Training-cum-Review workshop on Horticultural programmes and presented report and action plan of horticulture at OUAT from 3-4 May 2013	Mr TR Sahoo
Participated in the ZREAC on 4th May, 2013 at Regional Agricultural Research Station, AAU, Gossaigaon, Kokrajhar (Assam)	Drs KB Pun, N Bhakta and T Singh
Attended the 'State level monitoring team meeting of BGREI programme West Bengal' at Writers' Building, Kolkata, West Bengal on 6 May 2013	Dr S Saha
Dr. Sanjoy Saha made a Monitoring Trip to *"Review the progress under BGREI Program, West Bengal in Burdwan district"* on 7 May, 2013	Dr S Saha
The Training-cum-Workshop on Rice for KVK scientists – Organized by ZPD, Zone VII, Jabalpur & CRRI, Cuttack , 14-15 May 2013	Dr M Jena
Review meeting of state level planning of *kharif* crops 2013 under BGREI at Patna and Ranchi on 17-18 May 2013	Dr T Mohapatra

The review and planning meeting of BGREI at Ranchi on 18 May 2013	Drs VD Shukla and NP Mandal
Attended the Training cum Planning workshop on "Participatory abiotic stress tolerant seed production." At Goudgope Village of Mahanga block, Cuttack district on 21 May 2013	Dr. Mayabini Jena
Review meeting of state level planning of *kharif* crops under BGREI at Lucknow, U.P. on 24 May 2013	Dr. T Mohapatra
Attended 21 days Summer School on "Bio-drainage for reclamation of waterlogging in high rainfall deltaic areas" from 7th May to 27th May 2013 at Directorate of Water Management, Bhubaneswar, Odisha	Dr. B Lal
The meeting of the State Seed Sub-Committee for Agriculture convened by the Agricultural Production Commissioner, Govt. Of Assam on 27 May 2013	Drs KB Pun, N Bhakta and T Singh
Participated in the Annual Zonal Workshop (2012-13) of the kvks under Zone III at College of Veterinary Science, Assam Agricultural University, Khanapara, Guwahati on 27 May 2013	Drs KBPun, S Lenka and T Singh
Attended Farmers-Scientist Interaction programme and delivered talk on 'Integrated pest management in SRI' at ATMA conference Hall Cuttack on 29 May 2013	Dr M Chourasia
Meeting organized by the Jharkhand Tribal Development Society in the village Hojenda to discuss with farmers regarding the direct seeding technology of rice on 29 May 2013	Drs VD Shukla and Yogesh Kumar
Attended the 'Review meeting of BGREI program' at Kolkata, West Bengal on 31 May 2013	Dr S Saha
One day Workshop on Review of "Phenomics of moisture deficit and low temperature stress tolerance in rice" Project at IARI, New Delhi-1st June 2013	Dr P Swain
Participated in the meeting convened by the Secretary, DAC to review the performance of BGREI (2012-13) in Assam and strategy for 2013-14 on1 June, 2013	Drs KB Pun and T Singh
Attended the Officer's Conference on Pre-*kharif* planning at ATMA Conference Hall, Cuttack on 4 June 2013	Dr. SM Prasad
Attended Pre Zonal Workshop of kvks of Odisha at OUAT, BBSR on 7 June 2013	Drs SM Prasad and M Chourasia
Participated in one day 'Awareness Workshop' on BGREI programme in Assam which was organized jointly by RRLRRS, Gerua and Department of Agriculture, Assam on 17 June 2013	Drs KB Pun and T Singh
NFSM progress (2012) and planning (2013) meeting at Ranchi on 18 June 2013	Dr VD Shukla
Meeting of DBT advisory board at RAU, Pusa, Bihar on 19 June 2013	Dr T Mohapatra
CAFT Training Programme on "Recent Advances in Statistical Modeling Techniques" under the aegis of Education Division, ICAR, New Delhi held at IASRI, New Delhi from May 31- June 20, 2013	Dr M Shahid
A review programme of BGREI of Chhattisgarh State at Raipur on 21 June 2013 and visited Durg on 22 June 2013	Drs KS Rao and M Din

Attended a workshop in OUAT on "Nutrient Omission Plot Trials" held in OUAT, Bhubaneswar organized by in "Cereal Systems Initiative for South Asia" (CSISA), Hub, Bhubaneshwar on 28th june 2013	Drs AK Nayak, BB Panda, R Tripathi, M Shahid, and B.Lal
The Annual Zonal Workshop (2012-13) of the kvks under Zone III at College of Veterinary Science, Assam Agricultural University, Khanapara, Guwahati on 28 June 2013	Drs KB Pun, SK Lenka, T Singh, N Bhakta and Mr. BS Satpathy
NICRA Review Workshop at UBKV, Coochbehar, WB held from 4-5 July 2013 and presented the progress report for the period of 2012-13 and Action plan 2013-14	Dr VK Singh
Attended brainstorming meeting on 'Biological nitrogen fixation in rice' at NRCPB, New Delhi on 12 July 2013	Drs TK Dangar and U Kumar
Directors' meet at NCAP, New Delhi and ICAR Foundation Day at NASC Complex from 15-17 July 2013	Dr T Mohapatra
Attended 21 days training program on 'Advances in Statistical Genetics' organized by Centre of Advanced Faculty Training (CAFT) at Indian Agricultural Statistics Research Institute, New Delhi from 2-22 July 2013	Dr MS Anantha
The review meeting of kvks of Odisha under Chairmanship of Hon'ble Minister of Agriculture, Govt. Of Odisha at OUAT, Bhubaneswar on 24 July 2013	Dr SM Prasad
Attended 66th meeting of Central Sub-Committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops and the meeting for finalization of draft guidelines of aicrps at DMR, Pusa, New Delhi from 29-30 July 2013	Dr T Mohapatra
The Stakeholders' Consultative Workshop- SRI as a Socio-technical Movement in India at XIMB, Bhubaneswar on 2 August 2013	Dr KS Rao
Expert consultation on 'Fish genomics research in India' at NBFGR, Lucknow on 2 August 2013	Dr T Mohapatra
Participated in National Workshop on Water quality issues, opportunities and socio cultural concerns of waste water use in Agriculture held at DWM, Bhubaneswar on 7 & 8th August 2013	Dr BB Panda
Meeting at ICAR, RCER, Patna on 13 August 2013 to discuss about the contingent plan of Bihar and Jharkhand	Dr VK Singh
Meeting on 'Generation, characterization and utilization of EMS Mutagenesis of upland variety Nagina 22 for rice functional genomics at UAS, Bangalore from 16-17 August 2013	Dr T Mohapatra
Attended meeting with the Secretary and Director of Agriculture, Government of Bihar from 19 to 20 August to discuss contingency measures to address the unprecedented drought situation of the state	Drs T Mohapatra, KS Rao and M Variar
A meeting with Secretary, Agriculture, Govt. of Jharkhand and Director, ICAR Research Complex for Eastern Region, Patna at Ranchi on 22 August to discuss contingency measures to address the unprecedented drought situation of the state	Dr D Maiti
National Conference on 'Women in sugarcane agriculture and industry' at Indian Institute of Sugarcane Research, Lucknow (U.P.) from 19-23 August 2013 and presented paper entitled 'Role of women in sugarcane production and their training needs'	Dr. VK Singh

The VIII Annual Review Meeting of ICAR Seed Project-'Seed Production in Agricultural Crop' at New Delhi from 26-27 August 2013	Mr RK Sahu
The '*Review-cum-Awareness Workshop*' of BGREI Program West Bengal at Kolkata, West Bengal on 30 August 2013. He also visited two districts of West Bengal *viz.*, Nadia and North 24 Paraganas on 29 August 2013 for monitoring BGREI Program	Dr S Saha
NFSM state monitoring meeting at Krishi Bhavan, Ranchi on 30 August 2013	Drs M Variar and Yogesh Kumar
Training cum Planning Workshop on Management of rice in flood prone areas. On 3 September 2013 at CRRI, Cuttack	Dr. M Jena
Training Workshop on "Quality and Sustainable Seed Production of Stress Tolerant Rice Varieties" as resource persons organized by IRRI, Philippines in collaboration with Department of Agriculture, Government of Odisha at Bhubaneswar on 7 September 2013	Drs JN Reddy and RK Sahu
The *rabi* strategy meeting of Cuttack district at Collectorate on 11 September 2013	Mr DR Sarangi
21st Annual Conference of the Agricultural Economics Research Association (India) at Sher-e-Kashmir University of Agriculture and Technology, Srinagar from 10-12 September 2013 and presented a paper on 'Rural livelihood diversification in flood prone ecosystem: The case of Odisha'	Dr P Samal
Third Ramalingaswami Fellows' Conclave at Pune from 13 to 14 September 2013	Dr T Mohapatra
Five days training programme on 'Training of trainers on entrepreneurship development' at NIMSME, Yosufguda, and Hyderabad from 16-20 September 2013	Mr TR Sahoo
One day workshop on Nitrogen Use Efficiency of NICRA Project at DRR, Hyderabad - 19th September 2013	Dr P Swain
Launching workshop of BPD Unit of CRRI under NAIP-Component-1 on 21st September 2013	Dr P Swain
One day Workshop on 'Nitrogen Use Efficiency' under National Initiative on Climate Resilient Agriculture (NICRA) project at Directorate of Rice Research, Hyderabad on 23 September 2013	Dr P Swain
Acted as a resource person on 18.09.2013 in the farmers training on 'Rice-Fish farming System' organized by CRRI, Cuttack from 17-23 Septemer, 2013	Mr BS Satapathy
Participated in the 41stzonal Research & Extension Advisory Committee meeting for rabi 2013-14 for the Lower Brahmaputra Valley Zone of Assam held at College of Veterinary Sciences, Assam Agricultural University, Khanapara on the 24 September, 2013	Dr S Lenka
Seminar-cum-Workshop on *rabi* cropping programme at ATMA on 25 September 2013 delivered a talk on 'Improved pulse production technologies for higher productivity	Dr SM Prasad

The two-day symposium organised by the Department of Plant Molecular Biology on the occasion of its 25th year of existence, at University of Delhi (South Campus), New Delhi during 27-28 September 2013 and delivered a talk on "Functional Genomics of Natural Genetic Variation in Rice"	Dr T Mohapatra
21 days ICAR sponsored summer school on 'New horizons in biotic stress management in rice under changing climate scenario' at CRRI, Cuttack from 10-30 September 2013	Dr M Chourasia
Visited Bali Island on 2 October 2013 and demonstrated working of CRRI design 4-rows manual rice transplanter to farmers	Dr. M Din
Workshop on 'Sustainable food security through technological interventions for production, processing and logistics' at IIT, Kharagpur on 5 October 2013	Dr P Mishra
Second Annual Workshop "Enhancing Research Collaborations through NKN" project held from October 17-19, 2013 in Bengaluru, India	Dr R Tripathi
The 'Agribusiness Event', organized by NAIP at NASC, New Delhi on 19 October 2013	Dr GAK Kumar
Foundation Day of Agrinnovate India Ltd., (Agln.) On 'Innovative Partnerships' at New Delhi on 19 October 2013	Drs T Mohapatra, GAK Kumar
Institute Management Committee meeting of National Centre for Integrated Pest Management, New Delhi as an external member on 24 October 2013	Dr KB Pun
8th National Conference of KVK at UAS, Bangalore from 23 to 25 October 2013	Drs SM Prasad and VK Singh
National Symposium and the 26th Annual General Meeting of Indian Phytopathological Society (Eastern Zone) at CRURRS, Hazaribag from 24-26 October 2013	Drs KB Pun and S Lenka
First Orientation Workshop and Hands-on Training Program for BPD Units in the NARS at NAARM, Hyderabad from 24 to 26 October 2013	Dr BC Patra
Delivered a lecture on 'Environmentally Sustainable Food Security' in the 32nd Foundation Day Function of Orissa Environmental Society, Bhubaneswar on 27 October 2013	Dr. T Mohapatra
Meeting of RFD Nodal Officers and Co-Nodal Officers of Crop Science Division Institutes for reviewing the Mid-Term achievements of FRD 2013-2014 of RCs at ICAR, Krishi Bhawan, New Delhi on 29 October 2013	Dr NN Jambhulkar
Workshop on 'Implementation of Management Information System (MIS) including Finance Management System (FMS) in ICAR' under the NAIP funded project at IINRG, Ranchi on 31 October 2013	Dr NN Jambhulkar, Mr PK Das, Mr B Kumar, Mr NC Parija, Mr CP Murmu, Mr SK Behera
5th Meeting of Programme Advisory Committee on Plant Sciences under Science & Engineering Research Board' (SERB) at Lucknow from 30-31 October 2013	Dr T Mohapatra
Lecture in DBT sponsored short course / training programme on 'Advances in Plant Genetic Engineering' at NRCPB, New Delhi on 1 November 2013.	Dr T Mohapatra

Visited Sonepur from 9 to 10 October and from 5-7 November 2013 for monitoring the progress of BGREI Program	Dr P Mishra
67th meeting of Central Sub-Committee on 'Crop Standards, Notification and Release of Varieties for Agricultural Crops' at ICAR, New Delhi on 13 November 2013	Dr T Mohapatra
Visited four districts of West Bengal viz., Darjeeling, Malda, Dakhin Dinajpur and Uttar Dinajpur for monitoring the progress of BGREI Program in West Bengal from 11-16 November 2013	Dr S Saha
The meeting on 'Contingent plant for cyclone-flood affected district in Odisha at OUAT, Bhubaneswar on 20 November 2013	Dr SM Prasad
The RPSC meeting at All India Radio, Cuttack on 22 November 2013	Dr SM Prasad
Attended and delivered plenary lecture on 'Functional Genomics Analysis of Genetic Variation in Plant Height and Seed Size induced by EMS in Upland Rice Variety Nagina 22' in the 11th International Symposium on Rice Functional Genomics at New Delhi from 20-22 November 2013	Dr T Mohapatra
Visited Sundergarh for monitoring the progress of BGREI program from 22 to 24 November 2013	Dr GAK Kumar
The National Seminar on 'Climate Change and Biodiversity at Central University of Orissa, Koraput from 23-24 November 2013 to deliver lecture on 'Rice diversity for developing climate resilient varieties to ensure food security'	Dr RK Sarkar
Attended and delivered a lecture on 'Innovations in Agricultural Sciences for Meeting Challenges of Food Security' in the 16th Odisha Bigyan Congress at Indian Science Congress Association, Bhubaneswar from 23-24 November 2013	Dr T Mohapatra
9th Annual review meeting of the DBT funded research project entitled 'Establishment of National Rice Resource Database' at NBPGR, New Delhi on 25 November 2013	Dr BC Patra
The Scientific Advisory Committee meeting at Regional Plant Resource Centre, Bhubaneswar on 28 November 2013	Dr T Mohapatra
the training programme on 'Protection of Plant Varieties and Farmers ' Right Act, 2001' at Jabalpur on 30 November 2013	Dr M Chourasia
State Level Workshop on 'Addressing Barriers to Rice Seeds Trade between India and Bangladesh' organized by CUTS International at Hotel Crown, Bhubaneswar on 30 November 2013	Dr T Mohapatra
Acted as a resource person on 30 November 2013 in the training programme on "Rice knowledge management for food and nutritional security" organized by ICAR Research Complex for NEH, Sikkim Centre, Tadong, Gangtok, Sikkim	Dr S. Lenka
Visited demonstration blocks of paddy in Kanker, Jagdalpur and Kondagaon districts of Chhattisgarh from 23 to 28 October 2013 and visited Mahasamund, Balod and Durg districts from 29 November to 3 December 2013 under BGREI program.	Dr M Din

Attended and presented invited lecture on 'Genetic Improvement of Rice for Bacterial Leaf Blight Resistance at CRRI' in the 4th International Conference on Bacterial Blight of Rice at Hyderabad from 2-4 December 2013	Dr T Mohapatra
Three days workshop on Water Use and Water Use Efficiency at UAS, Bangalore from 2 to 4 December 2013	Dr. P Swain
The Training cum Workshop on 'Participatory Seed Production' at Goudgop village, Mahanga block, Cuttack district on 6 December 2013	Dr. Mayabini Jena
Attended three days training programme on "Basic and application of Eddy covariance system in agriculture" from 5-7th December, 2013 at CRRI, Cuttack organized by CRRI, Cuttack in collaboration with Campbell scientific, Canada and Elcome technology Pvt. Ltd., India	Drs R Raja and P Bhattacharyya
Review meeting of KVKs of Jharkhand at BAU, Ranchi on 7 December 2013 and presented on progress report of KVK from April to September 2013	Dr VK Singh
Annual Function of Bigyan Prachar Samiti, Cuttack, Odisha as a Chief Speaker on 8 December 2013	Dr T Mohapatra
'International conference on Extension Educational Strategies for Sustainable Agriculture Development - A global perspective' at UAS, Bangalore to present an oral paper entitled 'Role of women in rice production and their training needs' from 5-8 December 2013	Mrs Chanchila Kumari
A talk on 'Protection of Plant varieties for IPR' for the sensitization programme on IPR issues among the scientists of ICAR institutes located at Bhubaneswar on 11 December 2013	Dr. BC Patra
The National Conference of Plant Physiology-2013 on 'Current Trends in Plant Biology Research' at Directorate of Groundnut Research, Junagadh, and Gujarat from 13 to 16 December 2013. He presented a lead paper on 'Submergence tolerance and productivity in rice' on a special session on 'Abiotic stress management'	Dr RK Sarkar
A Monitoring Trip to "*Review the progress under BGREI Program, West Bengal in Paschim & Purba Medinipur district*" during December 17-18, 2013	Dr S Saha
The central steering committee to review the implementation of the programme of 'Bringing Green Revolution to Eastern India' at Krishi Bhawan, New Delhi on 20 December 2013	Dr T Mohapatra
The Institute Management Committee (IMC) meeting at NRCPB, New Delhi on 20 December 2013	Dr T Mohapatra
A lecture in National seminar on 'Exploration of microbes for social welfare' at OUAT, Bhubaneswar on 25 December 2013	Dr U Kumar
Participated in the model training course on "Integrated Farming System for enhancing resource use efficiency and livelihood security of small and marginal farmers" during 20-27 December,2013 at the Division of Agronomy, IARI, New Delhi	Mr BS.Satapathy
The state level workshop on "Impact of National Agricultural Innovative Projects and Strategies for their Sustainability" and presented abstract on "Scope of crop diversification in upland to support livelihood" at BAU, Ranchi during 4 January 2014	Dr CV Singh

Meeting on Rice Hybrids at ICAR, New Delhi on 8 January 2014	Dr T Mohapatra
Meeting on 'Formulating price policy report on kharif crops for the year 2014-15' on 10th January, 2014 at Krishi Bhawan, New Delhi, organized by the Commission on Agricultural Costs and Prices, Government of India	Dr P Samal
Participated in the 1st Assam International Agri-Horti Show 2014 organized by Indian Chamber of Commerce, Kolkata at College of Veterinary Science, Khanapara, Guwahati from 8-11 January, 2014	Dr KB Pun T Singh S Lenka
Directors' Conference at Baramati, Pune from 19-20 January 2014	Dr T Mohapatra
A talk on 'Benefit sharing provisions in the PPVFR Act and DUS test guidelines for different crops' at OUAT, Bhubaneswar in the training programme on PPV & FRA, 2001 on 22 January 2014	Dr BC Patra
Visited two districts of West Bengal viz., Howrah and Hooghly for monitoring the progress of BGREI Program in West Bengal during 20-23 January 2014	Dr S Saha
Round Table discussions on "SPT Technology and Hybrids" at New Delhi on 27 January 2014	Dr T Mohapatra
Participated as Expert (Crop Science) in Farmer's - Scientist's Interface on 27th January 2014 during celebration of Technology Week for Women in Agriculture at Directorate of Research on Women in Agriculture, Bhubaneswar	Dr P Swain
Attended ATMA Governing Board Meeting at Cuttack Collectorate on 30 January 2014	Dr SM Prasad
The Platinum Jubilee Lecture on "Development and use of genomic resources for understanding genetic variation in complex abiotic stress tolerant traits in rice" in the Section of Agriculture and Forestry Sciences at the 101st Indian Science Congress at University of Jammu, Jammu during 3-5 February 2014	Dr T Mohapatra
The 1st Asia-Africa Agribusiness Forum Meet at Hotel Kempinsky Ambience, New Delhi organized by FICCI, India during 4-6 February 2014	Drs BC Patra and GAK Kumar
Visited demonstration blocks of paddy in Bilaspur and Mungeli Districts of Chhattisgarh State on 6 and 7 February 2014 under BGREI program	Dr M Din
Attended the '*Review-cum-Awareness Workshop*' of BGREI Program West Bengal at Kolkata to review the progress of BGREI Program in West Bengal on 7 February 2014	Dr S Saha
A talk on "Appropriate farm mechanization and Entrepreneurship Scope in Custom Hiring of Agricultural Implements in Chhattisgarh State" in the Agritech Krishi Mela -2014 at Janjgir Champa, Chhattisgarh during 8-9 February 2014	Dr M Din
The 7th National Seminar on "Emerging Climate Change Issues and Sustainable Management Strategies" organised at OUAT, Bhubaneswar and presented abstract on "Pest outbreaks and resurgence in rice ecosystem in Odisha" during 8-10 February 2014	Dr. PC Rath
A Round Table on "GM Crops for Nutritional Security" on 12 February 2014 at NAAS premises, New Delhi	Dr T Mohapatra

The 68th meeting of the Central Sub-Committee on "Crop Standards, Notification and Release of Varieties for Agricultural Crops on 14 February 2014 at Horticulture Division of ICAR, New Delhi	Dr T Mohapatra
Attended a refresher course on "Agricultural Research Management" from 3-15 Feburary, 2014 at NAARM, Hyderabad	Dr T Singh
The Biennial Conference of Indian Society of Weed Science on "Emerging Challenges in Weed Management" at Directorate of Weed Science Research, Jabalpur and delivered a lecture on "Weedy rice: problems and its management" during 15-17 February 2014	Dr S Saha
Participated in the AZRA Silver Jubilee International Conference on 'Probing biosciences for food security and environmental safety', organized by Applied Zologists Research Association & Central Rice Research Institute at Cuttack during February 16-18, 2014	Drs.KB Pun and S Lenka
"Breeding for novel traits: Rice experience" in the 3rd International Plant Phenotyping Symposium (3rd IPPS) at M.S. Swaminathan Research Foundation, Chennai during 17-18 February 2014	Dr T Mohapatra
Institute Management Committee meeting of National Centre for Integrated Pest Management, New Delhi as a Member on 18 February 2014	Dr KB Pun
Participated in the AZRA Silver Jubilee International Conference on "Probing biosciences for Food security & environmental safety" held at CRRI, Cuttack during 16-18 February 2014	Drs A Prakash, KS Behera, PC Rath, AK Mukherjee, SS Pokhare, J Berliner, T Adak, ON Singh, BC Patra, LK Bose, S Roy, TK Dangar, U Kumar, S Munda, VD Shukla, KB Pun and S Lenka
Presentation on "Development and use of mutants induced by EMS in the background of upland variety Nagina 22 for rice functional genomics" in the 4th International Symposium on "Next Generation Genomics and Integrated Genomics and Breeding for Crop Improvement" at ICRISAT, Hyderabad during 19-21 February 2014	Dr T Mohapatra
A talk on 'PPV & Farmers' Rights Act' in the training–cum-awareness programme on PPV & FR Act, 2001 organised at CRRI on 21 February 2014	Dr BC Patra
A talk on 'Protection of Plant varieties Act, 2001 and DUS Testing' in a Training-cum-workshop on PPVFRA held at CRRI, organized by KVK, Santhapur for the farmers and other stakeholders of Cuttack district on 22 February 2014	Dr BC Patra
The Training cum Workshop on "Protection of plant varieties and Farmers' Rights Act-2001." On 22 February, 2014 at CRRI, Cuttack	Dr M Jena
"Regulation of gene expression in prokaryotes and eukaryotes" at College of Engineering and Technology, Bhubaneswar on 25 February 2014	Dr U Kumar
Attended ICAR sponsored two days Training –cum-Workshop on "Backyard poultry and duck production for sustainable livelihood" jointly organized by Regional Centre, CARI, BBSR and OUAT, BBSR at Directorate of Extension Education, OUAT, Bhubaneswar on 3-4 March 2014	Mr DR Sarangi and Dr SM Prasad

RPSC Meeting of Akashwani Cuttack organized at OUAT, Bhubaneswar on 4 March 2014	Dr SM Prasad
Participated in the National Conference on "Adaptation and Mitigation Strategies of Climate Change for Sustainable Livelihood" during March 05-07, 2014 organized by COBACAS, UBKV, Pundibari, Cooch Behar	Dr. T Singh
The meeting convened by the Director (Agriculture), Assam on 10 March 2014 to discuss Action Plan (2014-15) of the state	Drs KB Pun, N Bhakta, and T Singh
Participated in the meeting convened by the Director (Agriculture), Assam to hold discussion with the Director General and Scientists, IRRI. Philippines at Hotel Gateway Grandeur, Guwahati on 12th March, 2014.	Dr KB Pun, Dr N Bhakta and Dr T Singh
"*Kharif* Strategy Meeting" conducted at Residence Office of Collector, Cuttack on 14 March 2014	Mr DR Sarangi
Attended "Annual Convention of the Bhubaneswar Chapter of Indian Society of Soil Science" held at Orissa University of Agriculture and Technology, Bhubaneswar on 14th March, 2014	Drs R Tripathi, S Mohanty and M Shahid
Attended and presented paper in ISTS-IUFRO conference on "sustainable Resource Management for Climate Change Mitigation and Social Security" from 13-15 March 2014 at Chandigarh	Dr B Lal P Gautam
Lecture on 'Weedy rice: problems and its management' in the Biennial Conference of Indian Society of Weed Science at Jabalpur on 15-17 March 2014	Dr S Saha
Attended the Brain storming session on 'Pre-breeding and resistant gene resourcing. DRR, Hyderabad on 18 March 2014	Dr M Jena
The Final Workshop of Livelihood Improvement Project of CIFA, Bhubaneswar as CMU Member on 21 March 2014	Dr BN Sadangi
One day Expert Commitee Review Meeting of NICRA Project at CRIDA, Hyderabad - 21st March, 2014	Dr P Swain
Training programme on "Production technology of vegetable crops" as resource person at Purusottampur (Ganjam) under NAIP project of CRRI on 21 March 2014	Mr TR Sahoo
ICAR sponsored three days training for Subject Matter Specialist (Soil Science) at OUAT, Bhubaneswar during 20-22 March 2014	Mr DR Sarangi
Attended brainstorming session on "Improvement of Jhum Cultivation" at ICAR Research Complex for NEH Region, Meghalaya on 22 March 2014	Drs KB. Pun, T Singh and S Lenka
Conference on 'Farmers First for Conserving Soil and Water Resources in Northern Region (FFCSWR-2014)' held at Dehradun during 22-24 March 2014	Dr B Mondal
National Seminar on "Phytoresources: Utilization and conservation" organised at North Orissa University, Baripada and contributed an article on "Rice genetic resources-its collection, utilization and conservation" during 24-25 March 2014	Dr BC Patra
A lecture on "Application of NGS in structural & functional genomics of rice" in the symposium on "Next Generation Sequence: Challenges & Opportunities" organized at School of Biotechnology, KIIT University, Bhubaneswar on 25 March 2014	Dr T Mohapatra

National Seminar on Current trends in Stress Biology on 26 March 2014 at Utkal University, Vanivihar, Bhubaneswar and delivered an invited lecture on "Drought tolerance in rice with reference to Climate change".	Dr P Swain
Attended Farmers- Scientists Interaction at KVK, West Garo Hills, Tura (under ICAR Research Complex for NEH Region, Meghalaya) on 26th March 2014	Drs KB Pun and T Singh
A lecture on "Genomics for genetic improvement of crops" in the National Symposium on "Emerging Trends in Biotechnology: Present scenario and future dimensions" at Utkal University, Bhubaneswar on 29 March 2014	Dr T Mohapatra

Organisation of Events, Workshops, Seminars and Farmers' Day

67th Foundation Day and Dhan Diwas

The 67th Foundation Day and Dhan Diwas was celebrated on 23 April 2013. Dr. Mangala Rai, the Agriculture Advisor to the Chief Minister, Government of Bihar and former Secretary, DARE, and DG, ICAR graced the occasion as Chief Guest. Speaking on the occasion, Dr. Rai emphasized on robust policy intervention and incentives for the farm sector to vigorously promote inclusive agricultural development. He urged upon the scientists to develop mechanism to reduce the time gap between technology generation and its field application. Dr. SK Datta, DDG Crop Science, ICAR and the Guest of Honour spoke on the importance of rice crop in the socio-cultural, economic and food security context. Dr. T Mohapatra, Director highlighted the significant achievements of the institute, specially, the recently released varieties and their suitability for different ecologies. He also stated the thrust areas and vision particularly for attaining yield of more than 10 t ha^{-1} in the coming years.

Release of CRRI publications during the Foundation Day Celebration

Dr. Mangala Rai, the Agriculture Advisor to the Chief Minister, Government of Bihar and the former Secretary, DARE, and DG, ICAR delivered the 4th Foundation Day Lecture on 'Accelerating agricultural growth in India in the light of recent success in Bihar' on 23rd April, 2013 at CRRI, Cuttack. Dr. SK Datta, DDG (Crop Science), ICAR, New Delhi chaired the meeting.

Dr. Mangala Rai, the Agriculture Advisor to the Chief Minister, Government of Bihar delivering the lecture

Eastern Zone Regional Agriculture Fair

The Three-day Eastern Zone Regional Agricultural Fair (RAF) 2013-14 sponsored by Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India was organized at the Institute from 26-28 February 2014 with the active participation of nine hundred farmers and farmwomen from Bihar, Chhattisgarh, Jharkhand, Odisha and West Bengal. Besides, hundreds of visitors from the neighbouring areas got exposed to CRRI technologies. The fair and exhibition was inaugurated by Dr. Mangala Rai, Agriculture Advisor to Chief Minister of Bihar, Government of Bihar.

On this occasion, Dr. T Mohapatra, Director, CRRI and Chairman of RAF, explained the objectives and importance of RAF at the outset and outlined the activities during the three days' events.

Dr. Sanjeev Chadha, IFS, Director of Horticulture, Government of Odisha; Dr. SS Nanda, Dean of Extension, OUAT, Bhubaneswar and Dr. YR Meena, Addi-

Chief Guest Dr. Mangala Rai addressing the gathering tional Commissioner, DAC, Government of India addressed the gathering. Prof. M Kar, Vice Chancellor, OUAT, Bhubaneswar and Chief Guest of the valedictory function distributed awards to progressive farmers, best stalls and winners of quiz, debate and Kisan Gosthi. Sixty exhibition stalls displaying various agricultural technologies, information and programmes were put up by ICAR institutes, State Government Agencies, Central Government organizations and private companies.

Women in Agriculture Day

Krishi Vigyan Kendra, Santhapur, Cuttack observed the 'Women in Agriculture Day' on 6 December 2013 at Sankilo, Cuttack on the theme 'Value addition of local agricultural produces'. Smt. Santilata Nayak, an elderly farm women leader, inaugurated the day's programme by lighting the lamp along with other farmwomen. Awareness-cum-training programme was organized with the participation of ninety seven farmwomen from six neighboring villages.

Demonstration, question-answer session and quiz competition were held on the theme. An impressive and thought-provoking exhibition on traditional value-added products prepared by 32 farm women using rice, black gram and green gram attracted the attention of everyone and drew a large audience.

Women in Agriculture Day in progress

Industry Day

Industry Day was celebrated by Central Rice Research Institute, Cuttack on 21 September 2013 under the Chairmanship of Dr. T Mohapatra, Director, CRRI. The industry day was attended by various industrialists associated with rice milling, farm machineries, pesticides, fertilizers, retail, agro-processing and other stakeholders from line departments, research institutes

Mr. Santosh Kumar Agrawal, Secreatry, All Odisha Rice Millers Association (AROMA) addressing the participants

and farmers. Initiating the programme, Dr. SG Sharma, Head, BPES explained the objectives of holding the Industry Day. Various technologies including CRRI varieties for commercialization, seed production technologies for Hybrid / HYV, integrated farming systems for various rice ecosystems, farm machineries for commercialization, formulations and commercialization of biopesticides, technologies for rice bran stabilization, Rice Bran Oil extraction and refining and its health benefits were presented. Director, CRRI chaired the presentation and session on interface with the industry. Shri Santosh Agrawal, Secretary, All Odisha Rice Millers Association (AORMA) was the distinguished guest of the day.

Agriculture Education Day

The Central Rice Research Institute, Cuttack celebrated its 2nd Agriculture Education Day on 18 November 2013 in its premises with the participation of 180 students of High School and +2 standard from 18 Schools / Junior Colleges around the city along with their teachers / guides. The function started with an inauguration programme chaired by Dr. T Mohapatra,

Director, CRRI, Cuttack. Dr. P Jayasankar, Director, CIFA, Bhubaneswar inaugurated the function and the exhibition, showcasing the projects developed by the students on 'Application of agriculture science', as the Chief Guest. On this occasion the Chief Guest released two educational bulletins entitled 'Agriculture and Allied Sciences: Options and Opportunities as a Career' and 'Innovations in Agricultural Science'.

Interface Meet

The 2nd 'Interface Meet of the ICAR institutes–SAU–State Departments for the year 2013-14' for Odisha was organized at CRRI, Cuttack from 26 to 27 November 2013. Inaugurating the meet, the Chief Guest of the function Shri Rajesh Verma, IAS, Principal Secretary Agriculture, Govt. of Odisha appreciated the efforts of ICAR to hold this meet to bring all stakeholders of agricultural development of the state to a single platform.

Chairing the two-day meet, Prof. (Dr.) Manoranjan Kar, Vice-Chancellor, OUAT, Bhubaneswar said ICAR-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 efficiently transfer technologies. Dr. T Mohapatra, Director, CRRI and Convener of the meet presented the ATR on the recommendations of the last year's Interface Meet held from 30 to 31 July 2012.

Major concerns for research that emerged from the two days interface were development and availability of short duration mustard varieties, varieties of groundnut, sesamum and sunflower with high oil content and yield, varieties of sugarcane with drought tolerance, good ratoon ability and red rot resistance, high yielding jute varieties suitable for Odisha condition, development of a medium duration rice variety as an alternative to Swarna, contingency and diversification plan for the state, bio-control in coconut, low fiber and better keeping quality in zinger, technology for balanced use of surface and ground water, more efficient solar fish driers and aerator for brackish water fishery and development of vaccines for ducks.

Kisan Mela

Kharif Kisan Mela was organized on 30 October 2013 in the village Mayapur in Chatra district, under the Chaired by Dr. MC Divakar, Director, Directorate of Rice Development, Patna, Bihar and Co-chaired by Dr. Mukund Variar, Officer In-charge, CRURRS Hazaribag. About more than 500 farmers were participated in this fair.

Rabi Kisan mela was organized on 20 March 2014 in the village Mayapur from Chatra district under the Chairmanship of Dr. M Variar, Officer In-charge, CRURRS Hazaribag and Chif Guest of Dr. VD Shukla, Ex. Principal Scientist (Plant Pathology), CRURRS Hazaribag. More than 200 farmers will be participated in this fair.

Field Day on Hybrid Rice

A field day on hybrid rice (Ajay and Rajalaxmi) was organized on 7 December 2013 in village Mukundapur of Derabish block of Kendrapada district in which more than 50 farmers of the cluster attended. Dr. T Mohapatra, Director, CRRI presided over the program and advised the farmers to grow more of hybrid rice Ajay and Rajalaxmi for increasing the productivity of rice. The program was also attended by the scientists of the Institute.

RRLRRS, Gerua organized one field day on rice variety 'Naveen' on 03 June, 2013 in Village – Galdighala, District – Nalbari (Assam).

Dignitaries looking at the exhibits during the interface meet at CRRI

Dr. T Mohapatra, Director, CRRI visited Mukundapur village of Kendrapada

RRLRRS, Gerua organized one field day on rice on rice hybrid 'Ajay' on 04 June, 2013 in the village – Laruajan in Kamrup district.

Hindi Fortnight Closing Ceremony

The closing ceremony of Hindi Fortnight 2013 was organized on 30 September 2013 in the auditorium of the Institute. On this occasion Dr. TP Rajendran, ADG (Plant Protection), ICAR, New Delhi was the Chief Guest of the function. Dr. T Mohapatra, Director, CRRI presided over the function. The Hindi Fortnight was celebrated at CRRI, Cuttack from 9 to 23 September 2013. During this period five Hindi Competitions *viz.*, Correct and Speed Hindi Writing, Hindi Reading, Hindi Transliteration Writing, Hindi General Knowledge and Hindi Noting and Drafting were conducted for non-Hindi speaking staff. CRRI substation at Gerua also organized celebration of Hindi Saptah during 14-21 September, 2013.

Dr. TP Rajendran, ADG (Plant Protection), ICAR giving away prizes to winners

Launching Workshop of CRRI BPD Unit

The launching workshop of Business Planning and Development (BPD) Unit at Central Rice Research Institute was inaugurated on 21 September 2013 by Dr. D Rama Rao, National Director, National Agriculture Innovation Project (NAIP). Farmers, farmwomen, industrialists, rice millers and officials from various line departments participated in the event. While welcoming the gathering, Dr. BN Sadangi, Head, Division of Social Science gave a brief introduction of the BPD Unit and explained the role of stakeholders. Addressing the gathering, the Chief Guest Dr. D Rama Rao, spoke about the objectives of the project and how innovations in the field of agriculture would turn around the trends in traditional system of farming. On this occasion seven

Seven Agripreneurs' flyers showcasing the commercial values of various technologies of CRRI being released by Dr. D Rama Rao, National Director, NAIP

Agripreneurs' flyers showcasing the commercial values of various technologies of CRRI were released by the Chief Guest. The opening session was followed by a panel discussion on the role of various institutions in agribusiness and agripreneurship development in rice based farming systems which was chaired by Dr. T Mohapatra, Director, CRRI.

Vigilance Awareness Week

The Vigilance Awareness Week 2013 was observed from 28 October to 2 November 2013. Shri Gopal Chandra Nanda, IPS, retired DG, Police, Govt. of Odisha was the Chief Guest. He spoke on different dimensions of corruption and the different means to reduce it. He also gave away certificates to staff of the CRRI, Cuttack who had participated in a debate competition on 'Good Governance Practices for Effective Vigilance' held in Hindi, English and Odia.

Chief Guest Shri GC Nanda, IPS, retired DG, Police, Govt. of Odisha addressing the staff of CRRI

22nd Dr. Gopinath Sahu Memorial Lecture

The 22nd Dr. Gopinath Sahu Memorial lecture was jointly organized by the Association of Rice Research Workers (ARRW), Dr. Gopinath Sahu Memorial Trust (GSMT) and Central Rice Research Institute, Cuttack on 1 December 2013. Dr. Swapan Kumar Datta, DDG (Crop Science), ICAR, New Delhi was the Guest Speaker and Dr. Pramod Kumar Mohapatra, Member, GSMT and Executive Editor of the popular Odia daily, The Samaja was the Chief Guest.

Dr. SK Datta in his speech highlighted the importance of modern science for rice improvement. He pointed out that rice is a fascinating crop and signifies prosperity for Asians and more so for the Indians. He said that rich genetic diversity of rice is a real asset and must be judiciously utilized to solve specific problems.

Dr SK Datta, DDG (CS), ICAR inaugurating the 22nd Dr. Gopinath Sahu Memorial Lecture at CRRI

National Symposium

The national symposium on, 'Crop pathosystem interactions under weather and perspectives for crop health management' was organized at CRURRS, Hazaribag from 24 to 25 October, 2013.

The symposium was inaugurated on 24 October 2013 by Prof. MP Pandey, Hon'ble Vice Chancellor, Birsa Agricultural University, Ranchi. The occasion was graced by Dr. T Mohapatra, Director, Central Rice Research Institute, Cuttack, and Dr. S Kumar, Head, ICAR Research Complex for Eastern India- Research Centre (Ranchi).

Seventy six abstracts were accepted for the symposium, including invited lead lectures and submissions for MJ Narasimhan Merit Academic Award contest. Fourteen oral presentations and 23 poster presentations were made under three sub-themes *viz.*(I) Shifting pattern of crop-pathosystem interactions and emergent diseases under changing climate, (II) Innovative measures to address climate change impact on biotic stress management and (III) Integrated crop health care under stress.

The Abstract book of the National Symposium on "Crop pathosystem interactions under weather and perspectives for crop health management" being released by the Chief Guest

Technology Week organized

'Technology Week" was organized by KVK, Jainagar during 6 to 10 January , 2014. It was participated by 500 farmers, farmwomen and extension functionaries including Dr. M Variar (OIC, CRURRS), Dr. D Maiti (PS, CRURRS), District Agriculture Officer, Koderma, DDM, NABARD, LDM, Koderma, District Dairy Development officer, In-charge BAIF. Dr. AK Singh, ZPD, Zone II, Kolkata was the Chief Guest in closing ceremony on 10 January 2014.

Technical bulletin in Hindi entitled "Krishak Prasnottari" *being released by the ZPD, Zone II on the closing ceremony of Technology Week at KVK, Koderma (Jainagar)*

Eastern India Rainfed Lowland Shuttle Breeding Network (EIRLSBN) Selection Activity

Under ICAR-IRRI collaborative Eastern India Rainfed Lowland Shuttle Breeding Network (EIRLSBN), breeders from Eastern India involved in the network *viz*,. Dr. T Ahmed from RARS, Titabar, AAU, Assam, Dr. NK Singh from RAU, Pusa, Bihar, Dr. (Ms.) Indrani Dana, RRS, Chinsurah, West Bengal, Dr. DN Bastia, OUAT, Bhubaneswar, Odisha, Dr. SR Das, Adjunct Professor, OUAT, Bhubaneshwar, Odisha and Dr. JN Reddy, CRRI, Cuttack along with Dr. Endang Septiningsih, Mr. Jerome Carandang and Dr. Surapong Sarkaurng from IRRI, Philippines participated in the selection activity at CRRI, Cuttack from 19 to 20 November, 2013. Ms. Baphiralin Kharshiing and Ms. Rita Bahun Mylliem Umlong from Department of Agriculture, Government of Meghalaya also participated in the meeting as special invitees. The group had interaction with Dr. T Mohapatra, Director, CRRI and discussed about different activities under the network programme. During the selection activity, single plant selections were made by the breeders from the segregating populations involving about 417 (F_5-F_7) progenies as per their location specific requirements. The selected material will be supplied to the cooperators for location specific evaluation by CRRI, Cuttack, the coordinating center for this activity.

Discussion Meeting on 'Road Map for Rice Mechanization'

A discussion meeting on 'Road map for rice mechanization' was held at CRRI, Cuttack under the chairmanship of Dr. MM Pandey, DDG (Engg.) ICAR on 27 May 2013. The meeting was attended by scientists and HODs of CRRI, subject experts from different ICAR Institutes and SAUs, and representative of Escorts Ltd., local manufacturing industries and CIMMYT-CSISA Hub. The dignitaries who graced this occasion included Shri R S Gopalan, IAS, Director, Agriculture and Food Production, Odisha and Dr. CR Mehta, Project Coordinator (AICRP on Farm Implements and Machinery) CIAE, Bhopal. Dr. T Mohapatra, Director, CRRI stressed upon introducing latest farm machineries, which are labor saving, cost effective and energy efficient. Shri Gopalan emphasized upon the need to find out the most optimal way for rice mechanization. The chairman, Dr. Pandey suggested to develop packages of technologies based on socio-economic condition and needs of farmers.

Two committees; one for rice mechanization and another for rice post harvest processing were formed for compilation of the information and preparing the document 'Road map for rice mechanization'.

***Participants of the** EIRLSBN meet*

Brain Storming Session

A brain storming session on 'Development of approaches for paddy seed self sufficiency' was organized on 17 June 2013 at CRRI, Cuttack under the chairmanship of Dr. T Mohapatra, Director, CRRI for developing and refining suitable mechanisms and approaches in order to attain selfsufficiency in quality rice seed at village level. The programme was attended by different stakeholders including senior government officials from OSSOPCA, OSSCL, OUAT, CRRI, NGOs, farmers' organizations, and some progressive farmers.

Summer School on Biotic Stress Management in Rice

ICAR Sponsored 21 days Summer Schoool on 'New horizons in biotic stress management in rice under changing climate scenario' was organized from 10 to 30 September, 2013 at Central Rice Research Institute (CRRI), Cuttack.

Prof. Manoranjan Kar, Vice Chancellor, Orissa University of Agriculture and Technology, Bhubaneswar inaugurated the programme. In his address as Chief Guest, Dr. Kar highlighted the importance of sustainable management of biotic stresses *viz*., insect pests, diseases, nematodes, weeds etc. in rice. He appreciated the efforts of CRRI for hosting this training programme which is very timely for the benefit of the scientists. Dr. T Mohapatra, Director, CRRI in the opening remarks as chairman, elucidated the current research needs and future strategies for enhancing rice production in the country through efficient management of biotic stresses that has assumed greater importance in the climate change regime.

Dr. TP Rajendran, Assistant Director General (Plant Protection), ICAR, New Delhi graced the valedictory function as Chief Guest on 30th September, 2013.

Official Language Implementation Committee Meeting held

Dr. T. Mohapatra, Director, CRRI chaired the quarterly meeting of the Official Language Implementation Committee (OLIC) of the Institute for the quarter ending January-March 2014 held on 27 March, 2014. All the Heads of Divisions, the Chief Finance and Accounts Officer, Senior Administrative Officer and Administrative Officer, as the Members of this Committee, attended the meeting. Senior Technical Officer (OL) was the Member Secretary. Director, CRRI reviewed the status of the progress of Official Language at the Institute. He pressed upon sensitizing the Assistant Administrative Officers regarding the rules and regulations of Official Language for compliance. A number of decisions were taken to implement the Official Language policy effectively at the Institute.

ICAR Zonal Sports Tournament

The Tournament of Eastern Zone (TEZ 2013) was organized from 18 to 22 October, 2013 at CRRI, Cuttack. Dr. T Mohapatra, Director, CRRI inaugurated the tournament on 18 October, 2013. The participants included 404 men and women from 14 ICAR institutes. They competed in 19 events spread over 18 to 22 October, 2013. Dr. SG Sharma, Head BPES and Shri BK Sinha, Senior Administrative Officer of CRRI, Cuttack were the Chairman and Organizing secretary, respectively of the tournament.

Participants of summer school with the Director, CRRI

Chief Guest Shri Soumendra Priyadarshi, IG, Police (Operation), Govt. of Odisha during closing ceremony of TEZ 2013 at CRRI

Training Programmes

The following State and National level training programmes were organized during the year 2013-14.

Training programme on 'Improved Rice production Technology' sponsored by OTELP, SC & ST Development Department, Odisha was organized during 26 to 30th April, 2013. Dr. N C Rath coordinated the programme.

One day on-campus training on 'Rice Production Technology with special reference to variety Chandrama' was organized on 24 May,2013 for the farmers of Borka Krishak Samannay Samiti.

RRLRRS, Gerua in collaboration with the NGO, Lotus Progressive Centre, Morowa, Nalbari organized a one day exposure visit-cum-farmers training on "Rice production technology" on 5 July, 2013 for 27 farmers of Nalbari district.

One day exposure visit-cum-farmers training on 'Improved Rice Production Technology' was organized on 17 July, 2013 in collaboration with the Project Director, ATMA, Darrang district (Assam) for 25 farmers of Darrang district

Training programme on 'Rice Production Technology' sponsored by ATMA, Koderma, Jharkhand was organized during 16 to 20 August 2013.

Training programme on 'Improved Rice Production Technology' sponsored by Gramin Vikash Kendra, Nalanda, Bihar was organized during 1 to 5 September 2013.

Training programme on 'Rice-Fish Farming System' sponsored by the District Agriculture Officer, South West Garo Hills, Ampati, Meghalaya was organized during 17 to 23 September 2013.

Training programme on 'Improved Rice Production Technology' sponsored by ATMA, Nadia, West Bengal was organized during 24 to 28th September, 2013.

Training programme on 'Improved Rice Production Technology' sponsored by ATMA, Dumka, Jharkhand during 12 to 16 November 2013.

Training programme on 'Package and Practices of Improved Rice Production Technology' sponsored by ATMA, Deoghar, Jharkhand during 17 to 21 December 2013.

Two training programmes on "Improved package of practices for increasing rice productivity" sponsored by Gramin Vikash Kendra, Nalanda, Bihar during 3-7 March 2014 and 10-14 March 2014.

Training-cum-Visit programme on 'Improved Rice Production Technologies' sponsored by the Centre for Agriculture and Rural Development (CARD), New Delhi during 22 to 23 May 2013.

Training-cum-demonstration programme on "Paddy straw mushroom cultivation" was organized under the Project - "Gender in rice in village Sankilo" on 8 March 2014 on the eve of International Women's Day.

Drs. Lipi Das and SK Mishra coordinated the training programmes.

Participants of the training programme 'Improved rice production technology' with the Director, Dr. T. Mohapatra

Training-cum-Review workshop on ‘Capacity building on rice production technologies’ for KVK personnel of Zone VII held on 14 and 15 May 2013 which was jointly organized by Zonal Project Directorate, Zone VII, Jabalpur and CRRI, Cuttack. Dr. SM Prasad Coordinated the programme.

Professional Attachment Training was imparted to Mr. Rakesh Kumar, Scientist (Agril. Entomology), NCIPM, New Delhi during 13 May to 5 June 2013 under the supervision of Dr. SD Mohapatra.

Training cum planning workshop on ‘Management of rice in flood-prone areas’ at CRRI Cuttack under National Initiative on Climate Resilient Agriculture (NICRA) during 3 to 4 September 2013. Dr RK Sarkar coordinated the programme.

HRD training programme on ‘Statistical Analysis using SAS Software’ during 3 to 5 October 2013 for the scientists of the institute. Dr. NN Jambhulkar coordinated the programme.

Training programme on ‘Basic and Application of Eddy Covariance System in Agriculture’ during 5 to 7 December 2013. Dr. AK Nayak coordinated the programme.

Training-cum-Workshop on ‘Participatory Seed Production’ was organized at Goudgop, Mahanga, Cuttack on 6 December 2013. Dr. RK Sahoo coordinated the programme.

RRLRRS, Gerua in collaboration with District Agriculture Officer, Ampati, South West Garo Hills, Meghalaya organized two days’ farmers training programme on ‘Integrated rice-fish farming system’ during December 10 & 11, 2013 for eight progressive rural youths.

A farmer trainee receiving portable water pump set and sprinkler irrigation system from the Chief Guest, Dr. RP Mishra

Four training programmes were conducted at the institute by BPD unit including one training programme on “Comprehensive Agribusiness Incubation” in three phases during 6-11 January 2014, 27 January to 1 February 2014 and 31 March to 4 April 2014. Three training programmes on “Technology Based Agribusiness Programmes” during 15-21 January, 10-13 February and 31 March to 4 April 2014. Drs GAK Kumar and Alok Agnibesh coordinated the programme.

Three days farmers training programme on “Efficient use of water resources for climate change adaptation in flood prone areas” was organized at Pratapur, Ganjam from 19 – 21st March 2014 under GEF funded project entitled “Strategies to enhance adaptive capacity to climate change in vulnerable regions”.

Training programme on “Strategies to enhance adaptive capacity to climate change in vulnerable regions” were conducted under the NAIP GEF project on 26 March 2014 at CRRI, Cuttack. Drs BB Panda and R Raja coordinated the programme.

Training-cum-Workshop on ‘Participatory Seed Production’ was organized at Goudgop, Mahanga, Cuttack on 6 December 2013 under the Chairmanship of Dr. T Mohapatra, Director, CRRI. Mahanga Krushak Vikash Mancha who has signed MoU with CRRI, has taken up this quality seed production of the variety Pooja in a single patch of 52 acres of area in the farmers’ field under participatory seed production. For educating the farmers about quality seed production, there were lectures on Participatory Seed Production, Agronomic Management, Insect Pest Management and Management of Rice Diseases by Drs RK Sahu, AK Nayak, Mayabini Jena and Urmila Dhua, respectively. Besides, extensive field visit programme was arranged where the Chairman and other experts of the team visited the participatory seed production plots and directly interacted with the farmers discussing with them on rouging of off types and admixtures, plant protection measures and other finer points on quality seed production.

Exposure Visits

Four thousand six hundred fifty visitors including farmers, farmwomen, students, agriculture officers and scientists from Odisha, Seemandhra and Telegana, Chhattishgarh, Jharkhand, West Bengal, Tamil Nadu, Madhya Pradesh, Bihar visited CRRI experimental plots, demonstrations, agricultural implement workshops, net houses and *Oryza* museum and were addressed by the rice experts of the institute.

Distinguished Visitors

Dr. VS Korikanthimath, Ex-Director, ICAR Research Complex, Goa visited CRRI, Cuttack on 6 April 2013.

Dr. Gouttam Nodig, Metahadix Life Sciences Limited, Bangalore visited CRRI on 7 April 2013.

Dr. MC Diwakar, Director, Directorate of Rice Development, Patna visited CRURRS, Hazaribag during 1st week of September for monitoring NFSM activities in the district and held discussion with scientists on the crop situation.

Dr. SK Datta, DDG (Crop Sciences), ICAR and Dr. Achin Doberrmann, DDG (Research), IRRI, Philippines visited CRURRS and on-farm trials conducted by CRURRS on 8 September 2013.

Dr. Halima of Niger visited KVK, Santhapur and adopted village Biswanathpur (Salepur).

Dr. Achin Dobermann, DDG (Research), IRRI acompanied with Dr. SK Datta, DDG (CS), ICAR and scientists of CRURRS visiting experimental plots

Dr. Halima of Niger visiting KVK, Santhapur

Foreign Deputation

Dr. M Variar, Principal Scientist and OIC, CRURRS, Hazaribagh, Dr. JN Reddy, Principal Scientist and Dr. D P Singh, Principal Scientist attended 12th Annual Review and Screening Committee Meeting of the Consortium for Unfavorable Rice Environments (CURE) at Indonesia from 23 to 25 April, 2013

Dr. BB Panda, Senior Scientist (Agronomy) attended an International training on "Climate Change modeling at Department of Plant Sciences, College of Agriculture and Environmental Sciences, UC Davis, California from 18 April to 8 May, 2013

Dr. T Mohapatra, Director attended the special session of the International Rice Commission at Food and Agriculture Organization (FAO) Hqrs at Rome, Italy from 13 to 14 June, 2013.

Dr. P Bhattacharyya is on deputation to University of Georgia, USA for undertaking training program on Eddy Covariance and carbon modeling from 31st March to 28th June, 2014.

Dr. S Mohanty, Scientist visited the Sustainable Soils and Grassland Systems Department, Rothamsted Research, North Wyke, Devon, UK to undergo training on "Application of GIS and other tools in Natural Resources management" for 21 days from 29 July to 18 August, 2013, under NAIP-GEF funded project entitled 'Strategies to enhance adaptive capacity to climate change in vulnerable regions'.

Dr. R Raja, Senior Scientist was deputed to Irrigated Agriculture Research and Extension Center, Washington State University, Washington, USA from 6 to 25 August, 2013 to undergo training on "Decision Support System for Agro technology Transfer" funded by World Bank-Global Environmental Facility-NAIP project.

Mr. JL Katara, Scientist attended training at IRRI, Manila, Philippines from 2 to 13 September, 2013.

Dr. NP Mandal, Principal Scientist and Shri MS Anantha, Scientist attended the '7th International Rice Genetics Symposium (RG-7)' at International Rice Research Institute, Philippines from 5 to 8 November, 2013.

Dr. (Mrs) L Das, Sr. Scientist attended workshop on 'Food Value Chain Analysis: Tools and Application' organized by International Rice Research Institute, Philippines held at Bangkok, Thailand from 4 to 8 December, 2013.

Dr. Sanjoy Saha attended International Training Workshop on *'Characterization of rice growing environments for dissemination of stress tolerant varieties in South*

Asia' at Cox Bazar, Bangladesh during March 27-29, 2014.

Dr. ON Singh, Principal Scientist and Head, Division of Crop Improvement and Dr. S Saha, Principal Scientist, Crop Production Divison attended a workshop on "Characterization of Rice Growing of Dissemination of Stress Tolerant Varieties in South Asia" held in Cox Bazar, Bangladesh from 27-29 March, 2014.

Seminar

Dr. EI Hadji Djibo Halima, Post-Doctorate Fellow, CV Raman International Fellowship for Htricah Researchers, 2013 (Niger) delivered seminar on 'Agricultural Research in Niger' on 31 August, 2013.

Prof. Ian Graham, Director, Centre for Novel Agril. Products, University of York delivered a seminar on 'Molecular breeding of medicinal crops and discoveries along the ways' on 11 November, 2013.

Dr. M Nagaraju, Ex-Principal Scientist, CRRI delivered a seminar on 'Enhancement of genetic yield potential of rainfed lowland rice with emphasis on semi-deep ecology' on 16 November, 2013.

Dr. Robert Rice, Director, Market Development, APAC delivered a seminar on 'QIAGEN solutions for plant research' on 19 November, 2013.

Dr. Dilip K. Lakshman, Research Plant Pathologist, USDA-ARS, USA delivered a lecture on "Molecular investigation for accurate identification, classification and understanding virulence on 1 March, 2014.

Prof. Susan McCouch delivered a lecture on "Genome wide Association Studies (GWAS) provide blueprint for marker assisted breeding in rice" on 10 March, 2014.

Dr. N Baisakh, Assistant Professor, School of Plant, Environment and Soil Science, Louisiana State University Agricultural Centre gave talk on "Translating natural variations to improve stress tolerance in rice" on 22 March, 2014.

Dr. R Acharya, Scientific Officer (Grade G), Associates Professor HBNI, DAE, BARC, Trombay, Department of Atomic Energy gave a talk on "Developments and applications of Nuclear analytical technologies of quantification of major trace elements" on 28 March, 2014.

Awards/Recognition

Dr. AK Nayak received ISSS-Dr. JSP Yadav Memorial Award for Excellence in Soil Science in the 78th Annual convention of Indian Society of Soil Science (ISSS) organized at Central Arid Zone Research Institute (CAZRI), Jodhpur from 23 to 26 October 2013.

Mr. Mukesh Nitin, SRF received the Best Poster Presentation Award and Shamsad Alam, SRF received the 3rd Best Poster Presentation Award under the Sub-theme II of the National Symposium on "Crop pathosystem interactions under weather and perspectives for crop health management", Hazaribag, India, 24-25 October 2013.

Dr. T Mohapatra, Director, CRRI received The 3rd Prasana Kumar Dash Memorial Lecture Award for the year 2013 of the *Odisha Environmental Society* at Bhubaneswar on 27 October 2013.

Dr. T Mohapatra, Director, CRRI received Dr. Gopal Chandra Patnaik Memorial Lecture Award for the year 2013 of the *Bigyan Prachar Samiti*, Cuttack, Odisha on 8 December 2013.

Dr. Sanjoy Saha, Principal Scientist (Agronomy) awarded "ISWS Fellow – 2012" in recognition of outstanding contributions to Weed Science by *Indian Society of Weed Science* in the Biennial Conference of the Society on '*Emerging Challenges in Weed Management"* held during 15-17 February, 2014 at the DWSR, Jabalpur, M.P.

Dr. Upendra Kumar received the Edita David Memorial Award for the year 2013-2014 in AZRA Silver Jubilee International Conference on "Probing Bioscience for food & Nutritional Security and Safer Environment" for the best original paper entitled "Functional and genetic diversity of primary and secondary-metabolites producing fluorescent pseudomonads from rhizosphere of rice (*Oryza sativa* L.) on 16th February, 2014 at CRRI, Cuttack.

Miss Sonali Acharya, SRF (DST, Inspire) received the Best Paper Presentation Award 2014 in AZRA Silver Jubilee International Conference on "Probing Bioscience for food & Nutritional Security and Safer Environment" on 16th February, 2014 at CRRI, Cuttack.

Dr. T. Adak, Scienctist, CRRI, Cuttack awarded AZRA Young Scientist Award-2014 during AZRA Silver Jubilee International Conference, 16-18 February, 2014.

Shri Sudhansu Sekhar Nayak, Progressive Farmer from KVK adopted village Sankilo, Nischintakoili secured Mahindra Samriddhi Award 2013 for East Zone of the country on 24 February 2014. He has been awarded cash prize of Rs. 51,000/- and trophy with a certificate for adopting and disseminating CRRI technologies under the guidance and supervision of KVK, Cuttack.

Mr. Jahangir Imam, SRF was selected and nominated by the Zonal President (IPS – East Zone) for contesting in the MJ Narasimhan Award contest in the Annual Symposium of the Society to be held at IGKV, Raipur from 26 to 28 February 2014.

Dr. B Mandal, Senior Scientist, Social Science Division was awarded by Indian Association of Soil and Water Conservationists (IASWC), Dehradun for Best Research Paper on 22 March, 2014

Dr S Saha received the 'ISWS-Fellow-2012'

Dr B Mandal receiving the IASWC award

Dr. TK Dangar, PS, Microbiology, CRRI, Cuttack has been elected as Executive Council Member of Association of Microbiologist of India, Bhubaneswar-Cuttack chapter.

Drs Mukund Variar and Dipankar Maiti were nominated as Zonal president and Zonal Councilor, respectively of the East Zone chapter of the Indian Phytopathological Society for the year 2013.

Mr. Anjani Kumar has been selected for the International Plant Nutrition Institute (IPNI) scholar award for the year 2013. This award is an annual competition among students enrolled in graduate degree programs supporting the science of plant nutrition and crop nutrient management and Mr. Anjani Kumar is one among the selected 26 candidates in the world to receive this award.

CRRI Champions in ICAR Zonal Sports Championship

The institute was awarded the Overall Championship Trophy in the Tournament of Eastern Zone (TEZ 2013) was organized from 18 to 22 October, 2013 at CRRI, Cuttack.

CRRI Champions in ICAR Inter-Zonal Sports Championship

For the fourth time, CRRI lifted the ICAR Inter-Zonal Sports Championship held at NAARM, Hyderabad from 17 to 20 December, 2013. The participants included 46 ICAR institutes in India. Shri PK Parida, CRRI was adjudged the Best All-rounder (Men). Shri SK Mathur was the Chief-de-Mission while Shri Sudhakar Dash was the Manager of the team.

Mr. Anjani Kumar receiving the IPNI Scholar Award

Mr. P. Parida receiving the Best Athlete award from the Chief Gust during TEZ 2013 at CRRI, Cuttack

Best Workers of CRRI-2013

Name	Designation	Category
Dr. AK Nayak	Principal Scientist	Principal Scientist
Dr. P Bhattacharya	Senior Scientist	Senior Scientist
Dr. S Mohanty	Scientist	Scientist / Scientist (SS)
Dr. P K Sahu	Technical Officer	Technical (T6,T7 & T8)
Mr. A Mohammad	T-4	Technical(T4 & T5)
Mrs. B Nayak	T-3	Technical (T1,T2 & T3)
Sri S K Sahu	Assistant	Administrative
Sri B Sahoo	SS Grade	SS Grade

Commercialization of Hybrid Rice and other Technologies

List of MoUs signed in the year 2013-14 for Commercialization

Name of the variety / hybrid / technology	Name of the Institute / Company	Period of MOU
Mini parboiling unit, Manual transplanter, Drum seeder, Cono weeder, Finger weeder etc	Sidheswar Engineering, Cuttack	3 years (May, 2013 to April, 2016)
Customised Leaf Colour Chart (CLCC)	Nitrogen Parameters P.B. No.8707, Adambakkam, Chennai-600088, India	5 years (May, 2013 to April, 2018)
Hybrid rice Ajay-(CRHR 7)	Balaji Agri Biotech Pvt.Ltd. Paikmal, Odisha	3 years(May, 2013 to April, 2016)
Hybrid rice Rajalaxmi-(CRHR 5)	Bharat Nursery Pvt. Ltd. 60A, Arabinda Sarani, Kolkata-5, West Bengal	3 years (June, 2013 to May,2016)
Hybrid rice Ajay- (CRHR 7)	Sai Shradha Agronomics and Husbandry Pvt. Ltd. Plot No.1811, Rench Sasan, Balanga, Puri-752114, Odisha	3 years (June, 2013 to May,2016)
Hybrid rice CR Dhan 701-(CRHR-32)	Sri Sai Swarupa Seeds Pvt. Ltd., Ananthasagar(V), Warangal(Dt.) Andhra Pradesh	3 years (July, 2013 to June, 2016)
Integrated Pest Management in rice or rice-based cropping systems	NCIPM, New Delhi	3 years (June, 2013 to May, 2016)
Hybrid rice Rajalaxmi-(CRHR 5)	Vibha Agrotech Ltd., Hyderabad	3 years (October, 2013 to Sept., 2016)
Hybrid rice CR Dhan 701-(CRHR-32)	Vibha Agrotech Ltd., Hyderabad	3 years (October, 2013 to Sept., 2016)
Hybrid rice Rajalaxmi-(CRHR 5)	Sansar Agropol Pvt.Ltd., Bhubaneswar	3 years (December, 2013 to November, 2016)
Hybrid rice Ajay- (CRHR 7)	Sansar Agropol Pvt.Ltd., Bhubaneswar	3 years (December, 2013 to November, 2016)

Patent

Patent filed for Alternate Energy Light Trap vide Indian Patent Application No.341 / KOL / 2014, dated 18 March, 2014 (*Dr SD Mahapatra & Dr M Jena*)

In-charge and members of different cells

Research Advisory Committee

Prof. VL Chopra, Ex-Secretary, DARE & Director Genreal, ICAR, Chairman
Dr. AK Singh, Principal Scientist, Division of Genetics, (IARI), New Delhi , Member
Dr. VK Dadhwal, Director, National Remote Sensing Centre, Balanagar, Hyderabad, Member
Dr. BV David, Chairman, Internal Institute of Biotechnology & Toxicology, Chennai, Member
Dr. (Mrs) K Srinath, Emeritus Scientist, Chennai, Member
Dr. T Mohapatra, Director, CRRI, Cuttack, Member
Assistant Director General(FFC), ICAR, NewDelhi, Member
Shri K Rout, Ex-MLA, Kendrapara, Odisha, Member
Shri UK Parida, Kendrapara, Odisha, Member
Dr. JN Reddy, Principal Scientist, CRRI, Cuttack, Member Secretary

Institute Management Committee

Dr. T Mohapatra, Director, CRRI, Chairman
Director of Agrilculture & Food Production, Govt. of Odisha, Member
Director of Agriculture, Jharkhand, Ranchi, Member
Dr. P.C. Das, Dean of Research, OUAT, Bhubaneswar, Member
Dr. (Ms) N Sarala, Principal Scientist, Directorate of Rice Research, Hyderabad, Member
Dr. S Dixit, Principal Scientist, Central Research Institute for Dryland Agriculture, Hyderabad, Member
Dr. A Prakash, Principal Scientist and HOD,CRRI,Cuttack, Member
Dr. SG Sharm, Principal Scientist and HOD,CRRI,Cuttack, Member
Dr. RP Dua, ADG(FC), ICAR,New Delhi, Member
Finance & Account Officer, CIFA, Bhubaneswar, Member
Administrative Officer, CRRI, Cuttack, Member Secreatary
Shri K Rout, Ex-MLA, Kendrapara, Odisha, Member
Shri U K Parida, Kendrapara, Odisha, Member

Institute Joint Staff Council (IJSC)

Dr. T Mohapatra, Director, CRRI, Chairman
Dr. ON Singh, Member
Dr. AK Nayak, Member
Dr. (Mrs) A Poonam, Member
Shri BK Sinha, Member
Shri SR Khuntia, Member
Shri DK Mohanty, Secretary (Official side)
Shri N K Swain, Member
Shri S K Sahu, Member
Shri D R Sahoo, Member
Shri K C Bhoi, Member
Shri P Moharana, Member & Secretary (Staff Side)
Shri B K Behera, Member
Shri D Das, Member
Shri P Bhoi, Member

Central Public Information Officer

Shri B K Sahoo

PME Cell

Dr. (Mrs) M Jena
Dr. TK Dangar
Shri SSC Patnaik
Dr. JN Reddy
Dr. AK Nayak
Dr. GAK Kumar
Dr. (Mrs) M K Kar
Dr. NN Jambhulkar
Shri SK Sinha
Dr. R Chandra
Shri J Sethi
Shri M Nayak

Women Cell

Dr. (Mrs) M Jena
Dr. (Mrs) S Samantaray
Dr. (Mrs) M K Kar
Dr. (Ms) S Mohanty
Ms. S Sahu
Mrs. N Biswal
Mrs. S Biswal
Dr. (Ms) J Pattanaik
Dr. (Mrs) A Poonam

Institute Grievance Cell

Dr. T Mohapatra, Director, CRRI, Chairman
Dr. ON Singh
Shri BK Sinha
Shri SR Khuntia
Dr. AK Mukherjee
Dr. PK Sahu
Shri RK Behera
Shri B Khatua
Shri NC Parija

Institutional Bio-Safety Committee

Dr. ON Singh
Dr. MJ Baig, Member, Secretary
Dr. R Srinivasan, Professor and Project Director, NRCPB, IARI, New Delhi
Dr. GR Raut, Head, Department of Agri-Biotechnology, OUAT, Bhubaneswar
Dr. J Dandapat, Head, Department of Biotechnology, Utkal University, Vanivihar, Bhubaneswar
Dr. PK Mohapatra, Head, Biotechnology, Ravenshaw University, Cuttack
Dr. SG Sharma
Dr. (Mrs) M Jena
Dr. L Behera
Dr. N Das

Personnel

Staff strength as on 31 March, 2014

Category	Posts at CRRI and it's two Substations			Posts at KVK, Santhpur			Posts at KVK, Koderma		
	Sanctioned	Filled	Vacant	Sanctioned	Filled	Vacant	Sanctioned	Filled	Vacant
Scientist	114	82	32	04	01	03	01	01	00
Technical	175	101	74	11	06	05	11	07	04
Administrative	94	73	21	02	01	01	02	00	02
Skilled Support Staff	163	49	114	02	01	01	02	01	01
Others	05	05	—	—	—	—	—	—	—
RMP	01	01	—	—	—	—	—	—	—
Total	552	311	241	19	09	10	16	09	07

Dr.Trilochan Mohapatra .... Director

Scientific Staff

Division of Crop Improvement

Dr. O N Singh .... Head
Dr. K Pande .... Pr. Scientist
Dr. J N Reddy .... Pr. Scientist
Dr (Mrs)M Kar .... Pr. Scientist
Dr. S K Pradhan .... Pr. Scientist
Dr. B C Patra .... Pr. Scientist
Dr. L Behera .... Pr. Scientist
Dr (Mrs) S. Samantaray .... Pr. Scientist
Dr. H N Subudhi .... Sr. Scientist
Dr. L K Bose .... Sr. Scientist
Dr. K Chattopadhyay .... Sr. Scientist
Dr. S K Dash .... Sr. Scientist
Dr. A Anandan .... Sr. Scientist
Sri R K Sahu .... Scientist (SG)
Sri S S C Pattanaik .... Scientist (SG)
Sri B C Marndi .... Scientist (SG)
Sri J Meher .... Scientist (SS)
Sri B S Subramanian .... Scientist (Absconded)
Sri J L Katara .... Scientist
Dr. R L Verma .... Scientist
Sri S Ray .... Scientist
Dr. (Mrs) P Sanghamitra .... Scientist
Sri N Umakanta .... Scientist

Division of Crop Production

Dr. P C Mohapatra .... Pr. Scientist
Dr. P N Mishra .... Pr. Scientist
Sri S P Patel .... Pr. Scientist
Dr. T K Dangar .... Pr. Scientist
Dr. P K Nayak .... Pr. Scientist
Dr. M Din .... Pr. Scientist
Dr. A Ghosh .... Pr. Scientist
Dr. S Saha .... Pr. Scientist
Dr. A K Nayak .... Pr. Scientist
Dr. P Bhattacharyya .... Sr. Scientist
Dr.(Mrs)A Poonam .... Sr. Scientist
Dr. R Raja .... Sr. Scientist
Dr. B B Panda .... Sr. Scientist
Dr. R Tripathi .... Scientist
Dr. (Ms)S Mohanty .... Scientist
Dr. M Shahid .... Scientist
Sri A Kumar .... Scientist
Dr. U Kumar .... Scientist
Sri B Lal .... Scientist
Dr.(Mrs) S Munda .... Scientist
Mrs P Gautam .... Scientist

Division of Crop Protection

Dr. A Prakash .... I/c Head
Dr. (Mrs) U Dhua .... Pr. Scientist
Dr. S N Tiwari .... Pr. Scientist
Sri K S Behera .... Pr. Scientist
Dr.(Mrs) M Jena .... Pr. Scientist
Dr. P C Rath .... Pr. Scientist
Dr. S D Mohapatra .... Sr. Scientist
Dr. A K Mukherjee .... Sr. Scientist
Dr. K Saikia .... Sr. Scientist
Dr. T Adak .... Scientist
Sri J Berliner .... Scientist
Sri S S Pokhare .... Scientist

Division of Crop Physiology and Biochemistry

Dr. S G Sharma .... I/c Head
Dr. D P Singh .... Pr. Scientist
Dr. R K Sarkar .... Pr. Scientist
Dr. (Mrs) P Swain .... Pr. Scientist
Dr. M J Baig .... Pr. Scientist
Dr. A Das .... Pr. Scientist
Sri T B Bagchi .... Scientist

Division of Social Science

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 .... Sr. Scientist
Dr. (Mrs) L Das .... Sr. Scientist
Dr. B Mandal .... Sr. Scientist
Sri N N Jambhulkar .... Scientist

Central Rainfed Upland Rice Research Station, Hazaribag

Dr. M Variar .... O.I.C.
Dr. D Maiti .... Pr. Scientist
Dr. N P Mandal .... Pr. Scientist
Dr. C V Singh .... Sr. Scientist
Dr. Y Kumar .... Sr. Scientist
Sri Anantha M S .... Scientist

Regional Rainfed Lowland Rice Research Station, Gerua

Dr. K B Pun .... O.I.C.
Dr. S Lenka .... Sr. Scientist
Dr. T Singh .... Sr. Scientist
Sri B S Satapathy .... Scientist

Krishi Vigyan Kendra, Santhpur, Cuttack

Dr. S M Prasad .... Sr. Scientist

Krishi Vigyan Kendra, Jainagar, Koderma

Dr. V K Singh .... Sr. Scientist

Administrative Staff

Sri S R Khuntia .... Chief F & Aco. Officer
Sri B K Sinha .... Sr Admn. Officer
Sri S K Mathur .... Admn. Officer
Sri B K Sahoo .... Asstt. Admn. Officer
Sri B Bhoi .... Asstt. Admn. Officer
Sri B K Moharana .... Asstt. Admn. Officer
Sri S K Dash .... Asstt. Admn. Officer
Sri N C Parija (RRLRRS) .... Asstt. Admn. Officer
Sri S K Sahoo .... Asstt. Admn. Officer
Sri D K Mohanty .... Asstt. Admn. Officer
Sri S K Jena .... Asstt. Admn. Officer
Sri N K Das .... Security Officer
Sri S K Ram .... Assistant
Sri B C Tudu .... Assistant
Sri F Soren .... Assistant
Sri N K .Swain .... Assistant
Sri C P Murmu .... Assistant
Sri K K Sarangi .... Assistant
Sri S K Behera .... Assistant
Sri S Nayak .... Assistant
Sri S K Sahoo .... Assistant
Sri R K Behera .... Assistant
Sri R C Das .... Assistant
Smt R Kido .... Assistant
Sri N P Behura .... Assistant
Sri S K Sahoo .... Assistant
Sri M Mohanty .... Assistant
Sri S K Nayak .... Assistant
Sri D K Parida .... Assistant
Sri S K Satapathy .... Assistant
Sri R C Pradhan(RRLRRS) .... Assistant
Sri M K Sethy .... Assistant
Sri K.C Behera .... Assistant
Sri P C Das .... Assistant
Sri A K Pradhan .... Assistant
Sri S Sen .... Assistant
Smt G Dei .... U.D.C.
Sri S K Lenka .... U.D.C.
Sri S K Sahoo .... U.D.C.
Smt M Das .... U.D.C.
Sri R C Naik .... U.D.C.
Sri S Pradhan .... U.D.C.
Smt A Sethi .... U.D.C.
Sri M Sahoo .... U.D.C.
Sri C R Dangi (CRURRS) .... U.D.C.
Sri R Sahoo .... U.D.C.
Sri A K Sinha (CRURRS) .... L. D.C.
Smt J Das (RRLRRS) .... L. D.C.
Sri A K Das (CRURRS) .... L. D.C.
Sri B K Gochhayat .... L. D.C.
Sri H Marandi .... L. D.C.
Sri S K Bhoi .... L. D.C.
Sri D Muduli .... L. D.C.
Sri S K Pandey (CRURRS) .... L. D.C.
Sri S N Rout .... Private Secretary
Sri A K Sethi .... Private Secretary
Sri N Mohavoi .... Private Secretary
Sri G K Sahoo .... Personal Assistant
Sri N N Mohanty .... Personal Assistant
Sri J Nayak .... Personal Assistant
Sri Trilochan Ram .... Personal Assistant
Sri A Kullu .... Personal Assistant
Sri R Paswan(CRURRS) .... Personal Assistant
Smt B Mahana .... Personal Assistant
Smt N Jena .... Personal Assistant
Miss S Sahoo .... Personal Assistant
Sri M Swain .... Steno

KVK, Santhpur, Cuttack

Sri BB Polai .... Steno

Skilled Support Staff (SSS)

Sri S N Bhoi (Mali) .... SSS
Sri B Rout .... SSS
Sri S Soren .... SSS
Sri R Das .... SSS
Sri S Marandi .... SSS
Sri B K Behera .... SSS
Sri B N Beja .... SSS
Sri S N Patra .... SSS
Smt G Dei (F) .... SSS
Sri B Sahoo .... SSS
Sri P Sahoo .... SSS
Sri P C Sahu .... SSS
Sri G Rout .... SSS
Sri D Das .... SSS
M M Nayak .... SSS
A B Khan .... SSS
Sri F C Sahu .... SSS
Sri J Biswal .... SSS
Smt. S Biswal (F) .... SSS
Sri S Das .... SSS

Sri B B Barik .... SSS
Smt N Singh (F) .... SSS
Sri L Murmu .... SSS
Sri S Parida .... SSS
Sri S C Mohanty .... SSS
Sri P Bhoi .... SSS
Sri A k Bhoi .... SSS
Smt S Hembram (F) .... SSS
Smt M Hembram (F) .... SSS
Sri K C Ram .... SSS
Sri D Naik .... SSS
Sri K Naik .... SSS
Smt I Bewa (F) .... SSS
Sri P Majhi .... SSS
Sri J Bhoi .... SSS
Sri P Bhoi .... SSS
Sri A Naik .... SSS
Sri N Sahoo .... SSS
Sri P Bhoi (Nemato.) .... SSS
Sri D Naik .... SSS
Sri G C Sahoo .... SSS
Sri B Khatua .... SSS
Sri R Dalai .... SSS

Others (Canteen staff), CRRI, Cuttack

Sri A Jena .... Manager
Sri M Sahu .... Bearer
Sri M Nayak .... Bearer
Sri N Naik .... Wash Boy

CRURRS, Hazaribag, Jharkhand

Sri R Ram .... SSS
Sri L Mahato .... SSS
Smt S Devi .... SSS
RRLRRS, Gerua, Assam
Sri M Das .... SSS
KVK, Koderma, Jharkhand
Sri M Ram .... SSS
KVK, Santhpur, Cuttack
Sri R Pradhan .... SSS

Technical Staff

CRRI,Cuttack

Sri A K Naik .... Technician
Sri A K Panda .... Technician
Sri K C Das .... Technician
Sri A C Nayak .... Technician
Sri B Pradhan .... Technician
Sri PK Sahoo .... Sr. Technician
Sri G Bihari .... Sr. Technician
Sri D Behera .... Sr. Technician
Sri P K Ojha .... Sr. Technician
Sri R Beshra .... Sr. Technician
Sri C K Ojha .... Sr. Technician
Sri S Pradhan .... Sr. Technician
Sri D Majhi .... Sr. Technician
Sri B Hembram .... Sr. Technician
Sri S K Tripathy .... Sr. Technician
Sri S Biswal .... Sr. Technician
Sri P K Parida .... Sr. Technician
Sri D Parida .... Sr. Technician
Sri A K Nayak .... Sr. Technician
Sri J Bhoi .... Technical Assistant
Sri A C Moharana .... Technical Assistant
Sri B Swain .... Technical Assistant
Sri P Sahu .... Technical Assistant
Sri S K Mohapatra .... Technical Assistant
Sri K B Rout .... Technical Assistant
Sri M Soren .... Technical Assistant
Sri S Panda .... Technical Assistant
Sri N Barik .... Technical Assistant
Sri B C Behera .... Technical Assistant
Sri P Behera .... Technical Assistant
Sri G C Sahu .... Technical Assistant
Sri K C Mallick .... Technical Assistant
Sri C Naik .... Technical Assistant
Sri M Rout .... Technical Assistant
Mrs. C Majhi .... Technical Assistant
Sri B Ojha .... Technical Assistant
Sri K C Bhoi .... Technical Assistant
Sri P K Jena .... Technical Assistant
Sri A K Moharana .... Technical Assistant
Sri D R Sahoo .... Technical Assistant
Sri P Moharana .... Technical Assistant
Sri A K Parida .... Technical Assistant
Sri R Jamunda .... Technical Assistant
Sri A Mallick .... Technical Assistant
Mrs. N Biswal .... Sr. Technical Assistant
Sri S K Ojha .... Sr. Technical Assistant
Sri J P Behura .... Sr. Technical Assistant
Sri K C Palaur .... Sr. Technical Assistant
Sri A Panda .... Sr. Technical Assistant
Sri A K Mishra .... Technical Officer
Sri K K Suman .... Technical Officer
Sri S K Behura .... Technical Officer
Sri H C Satapathy .... Technical Officer
Sri A Sahoo .... Technical Officer
Sri R K Sethi .... Technical Officer
Sri J C Hansda .... Technical Officer
Sk A Samad .... Technical Officer
Sri S S Singh .... Technical Officer
Sri R S Jamuda .... Technical Officer
Sri S Pradhan .... Technical Officer
Sri M N Mallick .... Technical Officer
Sri K C Bhoi .... Technical Officer
Sri B Behera .... Technical Officer
Sri P K Singh .... Technical Officer
Sri N Bhattacharya .... Technical Officer
Smt. C Tudu .... Sr. Technical Assistant
Smt. R G Kumari .... Sr. Technical Assistant
Smt. B Nayak .... Sr. Technical Assistant
Smt. R Swain .... Sr. Technical Assistant
Smt. S Dalal .... Sr. Technical Assistant
Miss M Majhi .... Sr. Technical Assistant
Sri B Das .... Sr. Technical Assistant
Sri P Kumar .... Sr. Technical Assistant
Sri J Sai Anand .... Sr. Technical Assistant
Sri P L Dehury .... Sr. Technical Assistant
Sri M K Nayak .... Sr. Technical Assistant
Sri L K Singh .... Sr. Technical Assistant
Sri S K Sethi .... Sr. Technical Assistant

Sri S Rout .... Sr. Technical Assistant
Sri S K Sinha .... Sr. Technical Assistant
Sri B K Mohanty .... Sr. Technical Officer
Sri R K Mishra .... Technical Officer
Dr P K Sahoo .... Sr. Technical Officer
Sri A K Dalai .... Sr. Technical Officer
Dr. R Chandra .... Sr. Technical Officer
Sri AVG Sharma .... Assistant Chief Technical Officer
Sri P Kar .... Assistant Chief Technical Officer
Sri P Jana .... Assistant Chief Technical Officer
Sri K K Swain .... Chief Technical Officer

CRURRS, Hazaribag (Jharkhand)

Sri U Saw .... Sr. Technician
Sri S Oran .... Sr. Technical Assistant
Sri A Kumar .... Sr. Technical Assistant
Sri A N Singh .... Sr. Technical Assistant
Sri R Tirky .... Sr. Technical Assistant
Sri J Prasad .... Technician
Sri R P Sah .... Technical Officer
Sri D Singh .... Technical Officer
Sri J Terom .... Chief Technical Officer

RRLRRS, Gerua (Assam)

Sri H Thakuria .... Sr. Technical Assistant
Sri B Kalita .... Technician
Sri B Medhi .... Sr. Technical Assistant

K.V.K., Santhpur, Cuttack

Sri M Behera .... T-3 (Tractor Driver)
Sri A Bisoi .... T-1 (Driver)
Mrs. S Sethy .... T (7-8), SMS (Home Sci.)
Sri D R Sarangi .... T-6 SMS (Soil Science)
Sri T R Sahoo .... T-6 SMS (Horticulture)
Dr. M Chourasia .... T-6 SMS (Plant Protection)

K.V.K., Jainagar, Koderma

Sri Kumar .... T-2 (Driver Vehicle)
Sri R Ranjan .... T-4, Trg. Asst. (A.F)
Sri M Kumar .... T-4, Trg. Asst. (Agril.)
Sri M Asif .... T-4, Computer (Asst.)
Mrs. C Kumari .... T (7-8), STA (H.S.)
Dr. S Sekhar .... T (7-8), STA (V. Sc.)
Sri B Singh .... T-6, SMS (Horticulture)

Financial Statement for 2013-14

(As on 31 March 2014)

(Rs. in Lakh)

Plan 2013-14		
Head of Account	RE	Expenditure
TA	25.00	25.00
HRD	10.00	10.00
Contingency	395.00	395.00
Total	**430.00**	**430.00**

Non-Plan 2013-14		
Head of Account	RE	Expenditure
Establishment charges	2,350.00	2,350.00
Wages	172.94	171.67
OTA	0.50	0.50
TA	20.00	20.00
Pension	2,370.00	2,331.91
Repair & Maintenance		-
Equipment	20.00	20.00
Office Buildidng	115.00	115.00
Residential building	28.00	28.00
Contingency	502.00	502.00
Capital		-
Equipment	5.00	4.95
Library Books	1.00	1.00
Furniture	3.00	2.99
Total	**5,587.44**	**5,548.02**

Work Plan for 2013-14

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-PIs): BC Marndi, HN Subudhi, S Samantray, JL Katara, LK Bose, N Mandal, N Bhakta and P Sanghamitra.

Maintenance breeding and seed quality enhancement

Principal Investigator: RK Sahu

Co-Principal Investigator (Co-PIs): GJN Rao, ON Singh, RL Verma, K Pande, A Patnaik, SSC Patnaik, L Behera, SK Pradhan, U Dhua, M Jena, KS Behera, T Bagchi, A Poonam, CV Singh, NP Mandal, N Bhakta, BC Marndi and P Sanghamitra

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

Principal Investigator: LK Bose

Co-Principal Investigator (Co-PIs): HN Subudhi, S Samantaray, P Swain, M Jena, KS Behera and P Sanghamitra

Hybrid rice for different ecologies

Principal Investigator: ON Singh

Co-Principal Investigator (Co-PIs): RL Verma, JL Katara, GJN Rao, L Behera, KS Behera , MS Ananta, NP Mandal D Maiti and SS Pokhare

Development of high yielding genotypes for rainfed shallow lowlands

Principal Investigator: SK Pradhan

Co-Principal Investigator (Co-PIs): ON Singh, SSC Pattanaik, JN Reddy, SK Dash, MK Kar, L Behera, S Samantray , P Swain, K Pande , J Meher, N Bhakta, A Prakash and A Anandan

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

Principal Investigator: JN Reddy

Co-Principal Investigator (Co-PIs): SK Pradhan, SSC Patnaik, JL Katara, N Bhakta, RK Sarkar, P Swain, A Prakash and A Anandan

Breeding rice varieties for coastal saline areas

Principal Investigator: K Chattopadhyay

Co-Principal Investigator (Co-PIs): BC Marndi, DP Singh, AK Nayak, A Poonam, JN Reddy and A Prakash

Development of Super Rice for different ecologies

Principal Investigator: SK Dash

Co-Principal Investigator (Co-PIs): SK Pradhan, ON Singh, NP Mandal, MS Anantha, M Variar, M Kar, K Pande, J Meher, L Behera, BC Marndi, P Swain, MJ Baig, L K Bose, M Jena, SS Pokhare and J Berliner

Resistance breeding for multiple insect - pests and diseases

Principal Investigator: MK Kar

Co-Principal Investigator (Co-PIs): RK Sahu, JN Reddy, SK Pradhan, GJN Rao, L Behera, S Roy, M Jena, A Prakash, SD Mohapatra, A Mukharjee, U Dhua, S Lenka and KB Pun

Resistance breeding for multiple insect - pests and diseases

Principal Investigator : K Pande

Co-Principal Investigator (Co-PIs): J Meher, SK Dash, ON Singh, A Ghosh, MK Kar, SK Pradhan, LK Bose, L Behera, N Bhakta, JL Katara, S Samantaray, HN Subudhi, GJN Rao, AK Nayak, U Dhua, A Prakash, P Swain, SG Sharma, NN Jambhulkar and A Anandan

Breeding for aroma, grain and nutritional quality

Principal Investigator: SSC Patnaik

Co-Principal Investigator (Co-PIs): GJN Rao, K Chattopadhyay, BC Marndi, S Samantray, L Behera, SG Sharma, A Das, TB Bagchi, M Shahid, KS Behera and P Sanghamitra

Improvement of rice through in vitro and transgenic approaches

Principal Investigator: S Samantaray

Co-Principal Investigator (Co-PIs): GJN Rao, RN Rao, LK Bose and RL Verma

Development and use of genomic resources for genetic improvement of rice

Principal Investigator: L Behera

Co-Principal Investigator (Co-PIs): GJN Rao, M Variar, SC Sahu, SK Pradhan, RK Sahu, M Jena, NP Mandal, SK Dash, BC Marndi, J Meher, K Chattopadhay, P Swain, S Samantray, MS Anantha, HN Subudhi, NN Jambhulkar and N Umakanta

Development of resilient rice varieties for rainfed direct seeded upland ecosystem

Principal Investigator: NP Mandal

Co-Principal Investigator (Co-PIs): MS Anantha, Y Kumar, VD Shukla, M Variar, D Maiti, SK Dash, P Swain and CV Singh

Development of rice genotypes for rainfed flood-prone lowlands

Principal Investigator: N Bhakta

Co-Principal Investigator (Co-PIs): KB Pun, SK Pradhan, L Behera and S Lenka

Programme 2: Enhancing productivity, sustainability and resilience of rice based production system: KS Rao/AK Nayak

Enhancing nutrient use efficiency and productivity in rice based system

Principal Investigator: AK Nayak

Co-Principal Investigator (Co-PIs): S Mohanty, M Shahid, P Bhattacharya, R Tripathi, A Kumar, V K Thilagam, R Raja, BB Panda, KS Rao, A Ghosh, P Gautam, B Lal, S Munda and SS Pokhare

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

Principal Investigator: A Ghosh

Co-Principal Investigator (Co-PIs): KS Rao, P Swain, M Din, CV Singh, BB Panda, A Poonam, R Tripathy, J Berliner and P Gautam

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

Principal Investigator: R Raja

Co-Principal Investigator (Co-PIs): BB Panda, AK Nayak, P Bhattacharyya, MJ Beig, R Tripathi, K S Rao, K Thilagam, P Gautam, A Kumar and BS Satpathy

Development of sustainable production technologies for rice based cropping systems

Principal Investigator: BB Panda

Co-Principal Investigator (Co-PIs): R Raja, AK Nayak, A Gosh, KS Rao, Teekam Singh, B Lal, R Tripathy, SD Mohapatra, M Shahid , A Kumar and S Pokhare

Farm implements and post harvest technology for rice

Principal Investigator: PC Mohapatra

Co-Principal Investigator (Co-PIs): P Mishra, SP Patel, M Din, 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-PIs): AK Nayak, R Tripathi, M Din, KS Rao, BB Panda, R Raja, S Mohanty, M Shahid, A Kumar, S Saha, A Ghosh, S Munda and B Lal

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

Principal Investigator: A Poonam

Co-Principal Investigator (Co-PIs): K S Rao, 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-PIs): KS Rao, B Lal, BC Patra, SK Das, KS Behera , U Kumar, T Adak and S Munda

Management of problem soils for enhancing the productivity of rice

Principal Investigator: R Tripathy

Co-Principal Investigator (Co-PIs): M Shahid, AK Nayak, A Kumar, S Mohanty, K Thilgam, R Raja and DP Singh

Bio-prospecting and use of microbial resources for soil, pest and residue management

Principal Investigator: U Kumar

Co-Principal Investigator (Co-PIs): TK Dangar and KS Behera

Soil and crop management for productivity enhancement in rainfed upland ecosystem

Principal Investigator : CV Singh

Co-Principal Investigator (Co-PIs): MS Anantha, Y Kumar, VD Shukla, 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-PIs): S Saha, T Singh, A Kumar, KB Pun, S Lenka and NN Jambhulkar.

Programme 3: Rice pests and diseases-emerging problems and their management: A Prakash/ U Dhua

Management of rice diseases in different ecologies

Principal Investigator: AK Mukherjee

Co-Principal Investigator (Co-PIs): U Dhua, SN Tewari, SD Mohapatra, SK Singh, T Adak, J Berliner and SS Pokhare

Rice endophyte interaction with pathogens and pests in relation to environment

Principal Investigator: U Dhua

Co-Principal Investigator (Co-PIs): KS Behera, M Jena and A Mukharjee

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

Principal Investigator: M Jena

Co-Principal Investigator (Co-PIs): KS Behera, A Prakash, PC Rath, SD Mohapatra, J Berliner, SS Pokhare, SC Sahu, RK Sahu and SK Pradhan

Bio-ecology and management of pests under changing climatic scenario

Principal Investigator: KS Behera

Co-Principal Investigator (Co-PIs): SC Sahu, R Raja, M Jena, PC. Rath, SD Mohapatra, J Berliner, SS Pokhare, S Saha, U Kumar, SN Tewari, A Prakash, AK Nayak, NN Jambhulkar and T Adak

Formulation, validation and refinement of IPM modules in rice

Principal Investigator: PC Rath

Co-Principal Investigator (Co-PIs): A Prakash, KS Behera, M Jena, SD Mohapatra, J Berliner, SS. Pokhare, U Dhua, P Samal, S Saha, VD Shukla, S Lenka, TK Dangar, and T Adak

Biotic stress management in rainfed upland rice ecology

Principal Investigator: VD Shukla

Co-Principal Investigator (Co-PIs): M Variar, D Maiti, CV Singh, NP Mandal and Y Kumar

Management of major rice diseases in rainfed flood prone lowlands

Principal Investigator: KB Pun

Co-Principal Investigator (Co-PIs): U Dhua, M Kar, SK Singh, SS Pokhare, 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 / DP Singh

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

Principal Investigator: A Das

Co-Principal Investigator (Co-PIs): SG Sharma, TB Bagchi, BC Marandi, N Bhakta, P Mishra, A Ghosh, U Kumar, M Shahid, T Adak and P Sanghamitra

Phenomics of rice for tolerance to multiple abiotic stresses

Principal Investigator: RK Sarkar

Co-Principal Investigator (Co-PIs): DP Singh, P Swain, MJ Baig and TB Bagchi

Rice physiology under drought and high temperature stress

Principal Investigator: P Swain

Co-Principal Investigator (Co-PIs): ON Singh, NP Mandal, TB Bagchi, MJ Baig, SK Pradhan, J Meher and JL Katara

Evaluation and improvement of photosynthetic efficiency of rice

Principal Investigator: MJ Baig

Co-Principal Investigator (Co-PIs): 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-PIs): 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-PIs): BN Sadangi, L Das, NN Jambhulkar, M Din, SG Sharma, M Jena, RL Verma and SK Mishra

Impact analysis and database updation in relation to rice technologies, policy and programmes

Principal Investigator: P Samal

Co-Principal Investigator (Co-PIs): NN Jambhulkar, BN Sadangi, GAK Kumar, L Das, ON Singh, SK Pradhan, and M Din

Ongoing Externally Aided Projects (EAPs)

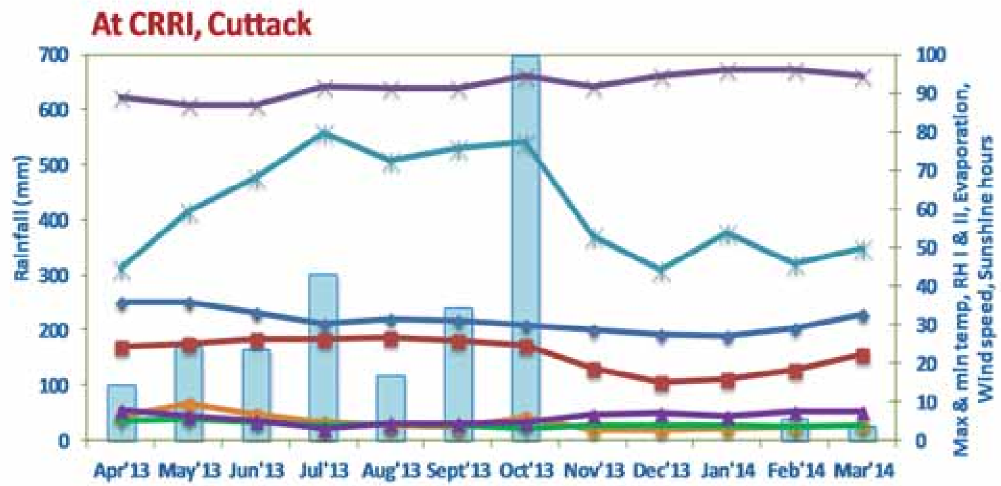
Number	Title of the Project	Principal Investigator	Source of Funding
EAP12	Multilocation evaluation of rice germplasm (NBPFR project) for 2012-13	HN Subudhi	NBPGR
EAP 27	Revolving fund scheme for seed production of upland rice varieties at CRURRS, Hazaribagh	VD Shukla	AP Cess
EAP 36	National Seed Project (Crops)	RK SahuU 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	VD Shukla	DAC
EAP 99	Transgenic in crops	GJN Rao	ICAR Network
EAP 100	Seed Production in Agricultural Crops and Fisheries – "Mega Seed Project"	RK Sahu	ICAR
EAP 104	Microbial diversity and identification	TK Dangar	ICAR Network
EAP 105	Nutrient management	TK Dangar	ICAR Network
EAP 106	Microbial bioremediation	TK Dargar	ICAR Network
EAP 121	Developing Sustainable Farming System Models for Prioritized Micro Watershed in Rainfed Areas in Jharkhand	CV Singh	ICAR (NAIP)
EAP 122	Allele Mining and Expression Profiling of Resistance-and Avirulence-genes in Rice Blast Pathosystem for Development of Race Non-Specific Disease Resistance	M Variar	ICAR (NAIP)
EAP 123	Enhancing and stabilizing productivity of salt affected areas through incorporation of genes for tolerance of abiotic stresses in rice	DP Singh	IRRI (BMZ) – 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 VD Shukla 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	JN Reddy SSC Patnaik	ICAR – IRRI (B&MGF)
EAP 128	Stress tolerant rice for poor farmers of Africa and South Asia- Saline prone areas (STRASA)	DP Singh	ICAR – IRRI (B&MGF)
EAP 129	Stress tolerant rice for poor farmers of Africa and South Asia- Socio-economic survey and impact assessment	P Samal	ICAR-IRRI (B&MGF)
EAP 130	All India Network Project on Soil Biodiversity-Biofertilizers	D Maiti	ICAR Network Project
EAP 133	Capitalization of prominent landraces of rice in Orissa through Value Chain Approach	A Patnaik GJN Rao SSC Patnaik SG Sharma	NAIP
EAP 134	Development and maintenance of rice knowledge management Portal	GAK Kumar	NAIP

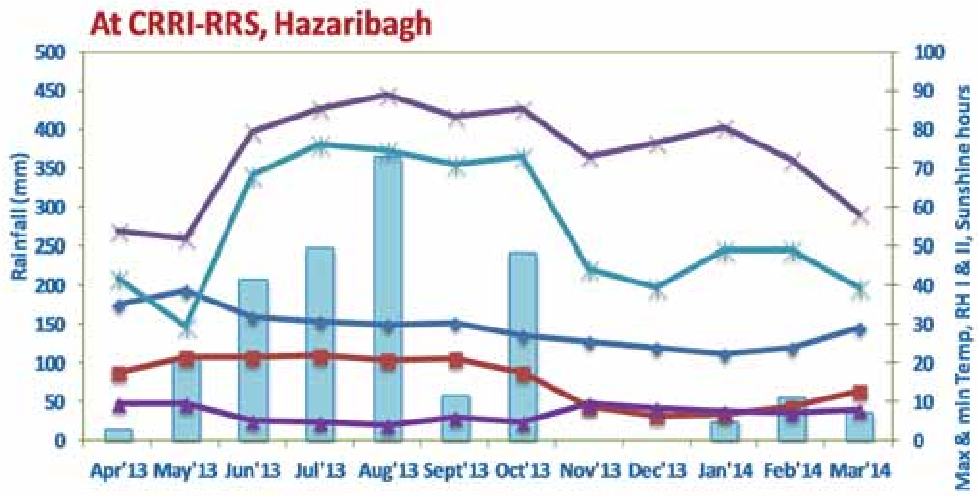
Number	Title of the Project	Principal Investigator	Source of Funding
EAP 135	Bioprospecting of genes and allele mining for abiotic stress tolerance	GJN Rao	NAIP
EAP 137	Establishment of National Rice Resources Database	BC Patra	DBT
EAP 139	Renewable Energy Sources for Agriculture and Agro-based Industries	PN Mishra	AICRP
EAP 140	Intellectual Property Management and Transfer / commercialization of agricultural technology Scheme	BC PatraU Dhua	ICAR
EAP 141	DUS Testing and documentation	BC Patra	PPV&FRA
EAP 143	Identification of molecular markers for enhanced Arbuscular mycorrhiza (AM) response and marker assisted selection of high am responsive varieties for efficient phosphorus nutrition of upland rice	D Maiti NP Mandal D Mandal (BCKV)	DBT
EAP 145	Identification and functional analysis of genes related to yield and biotic stresses	SC Sahu M Jena L Behera RK Sahu	DBT
EAP 146	Confidence building and facilitation of large scale use of fly ash as an ameliorant and nutrient source for enhancing rice productivity and soil health	R Raja AK Nayak	DST
EAP 147	Agro-techniques for sustaining productivity of wet direct sown summer rice in flood prone lowlands	S Saha KS Rao K Panda KS Behera BB Panda L Das	DST
EAP 148	Strategies to enhance adaptive capacity to climate change in vulnerable regions	BB Panda S Mohanty R Raja	NAIP
EAP 150	Development, dissemination and popularization of location specific IPM strategies in different rice agro-ecosystems	A Prakash	NCIPM, ICAR
EAP 151	Hybrid Rice Research network	RN Rao	AICRP
EAP 152	Mapping and Marker Assisted selection for RTV resistant genes	MK Kar GJN RaoJ Rao	AICRP
EAP 153	Development of molecular markers linked to genes for resistance to Brown Planthopper	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	JN Reddy ON Singh DP Singh RK Sarkar P Swain NP Mandal 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 GJN Rao SK Das	DBT, GOI

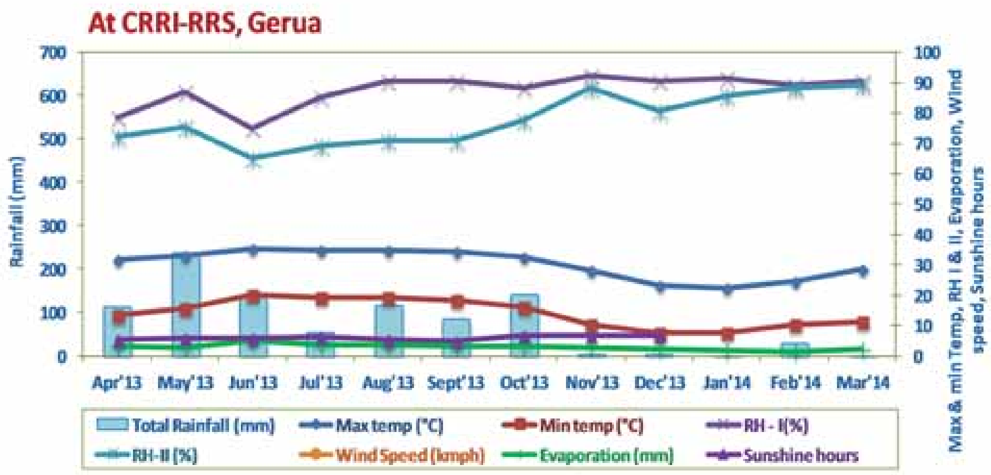
Number	Title of the Project	Principal Investigator	Source of Funding
EAP 157	CURE Salinity Project: Enabling poor rice farmers to improve livelihood and overcome poverty in South and Southeast Asia (A)-Salinity(B)-Submergence	DP Singh (A) JN Reddy(B)	IFAD through IRRI
EAP 158	National Initiative on Climate Resilient Agriculture for XIth Plan	RK Sarkar	ICAR
EAP 159	Diversity of osmotolerant and bio-strains of endophytic microorganisms of rice	Supriya Sahu (TK Dangar)	DST
EAP 160	Identification of Major QTLs for Grain Yield under drought stress in 'Jhum' rice varieties of North Eastern Region for use in marker assisted breeding to improve yield under drought	NP Mandal	DBT
EAP 161	Monitoring of the new initiative of "Bringing Green Revolution to Eastern India (BGREI) under the Rashtriya Krishi Vikas Yojana"	T Mohapatra KS Rao	DAC, GOI
EAP 162	Stress tolerant rice for poor farmers of Africa and South Asia – Subgrant, Seed (CRURRS, Hazaribagh)	VD Shukla NP Mandal M Variar VK Singh	IRRI-ICAR (STRASA)
EAP 163	Stress tolerant rice for poor farmers of Africa and South Asia – Sub grant, Seed (CRRI, Cuttack)	SR Dhua 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	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) Project Code: Phen-2015
EAP 166	Development, dissemination and popularization of location specific IPM strategies in different rice agro-ecosystem	VD Shukla	NCIPM, (ICAR), New Delhi
EAP 167	ICAR Net work project on Marker Assisted Selection for resistance to biotic and abiotic stresses in rice	NP Mandal	DRR, ICAR
EAP 168	Multi-institutional demonstration trials showing efficacy of liquid seaweed sap from Kappaphycus alvarezii and Gracilaria edulis on different crops	S Saha D Maity	CSIR
EAP 169	Genetic Diversity of farmers' rice varieties collected from different parts of the State of Odisha,India	L Behera U Dhua	PPV&FRA
EAP 170	GCP – Targeting Drought-Avoidance Root Traits to enhance Rice Productivity under Water Limited Environments	P Swain	ICAR-IRRI
EAP 171	DUS- Special Test	U DhuaM Jena	PPV&FRA
EAP 173	"Crop Pest Survellance and Advisory Project 2011-12" in Maharastra	A Prakash	Govt. of Maharastra
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

Number	Title of the Project	Principal Investigator	Source of Funding
EAP 176	Using wild ancestor plants to make rice more resilient to increasingly unpredictable water availability	SK Das P Swain L Behera B Sadangi	DBT-BBSRC (DFI, UK)
EAP 177	Bioefficacy field trial of CASH Plus on paddy crop	A Ghosh KS Rao	Agrimis Chemicals Limited
EAP 178	National Initiative on Climate Resilient Agriculture	VK Singh	NICRA (ICAR)
EAP 179	Evaluation of the applicability of a dominant nuclear male sterility system in rice for hybrid seed production	ON Singh SK Sen(IIT, KGP)	NFBSFARA
EAP 180	Business planning and development (BPD) unit in CRRI	GAK Kumar BN Sadangi BC Patra BB Panda M Din RK Sahu SSC Pattanayak NC Rath	NAIP – C1
EAP 181	Hastening the transfer of tolerance to drought from *O. nivara* into cultivated rice through another 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 R Raja M Shahid R Tripathi B Lal P Gautam AK Mukherjee	ICAR-IRRI
EAP 183	Functional genomics of osmotolerant microbes of coastal saline rice ecosystem	S 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	S 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

Weather


At CRRI, Cuttack
Rainfall (mm)
Max & min temp, RH I & II, Evaporation, Wind speed, Sunshine hours
Apr'13 May'13 Jun'13 Jul'13 Aug'13 Sept'13 Oct'13 Nov'13 Dec'13 Jan'14 Feb'14 Mar'14

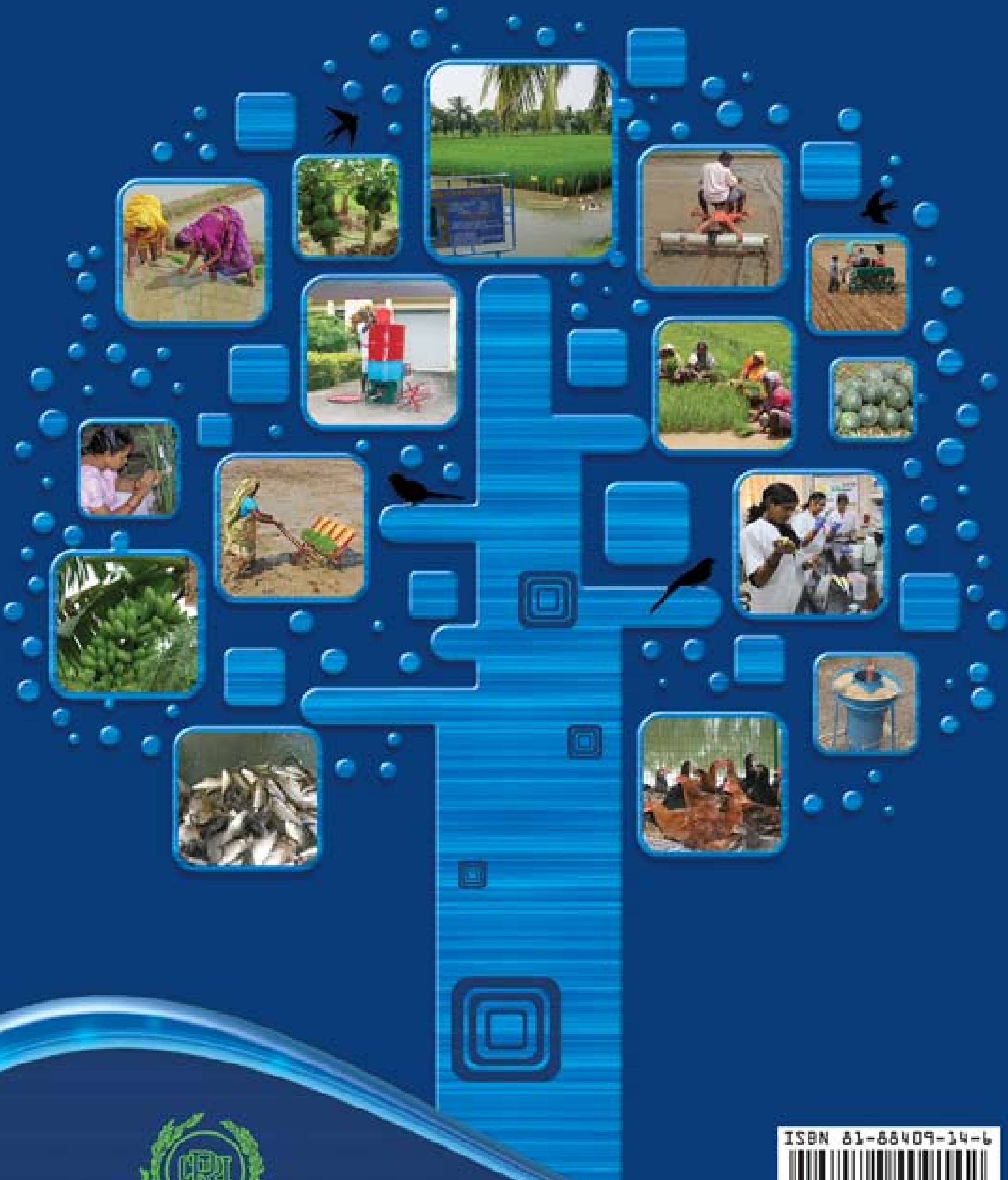

At CRRI-RRS, Hazaribagh
Rainfall (mm)
Max & min Temp, RH I & II, Sunshine hours
Apr'13 May'13 Jun'13 Jul'13 Aug'13 Sept'13 Oct'13 Nov'13 Dec'13 Jan'14 Feb'14 Mar'14


At CRRI-RRS, Gerua
Rainfall (mm)
Max & min Temp, RH I & II, Evaporation, Wind speed, Sunshine hours
Apr'13 May'13 Jun'13 Jul'13 Aug'13 Sept'13 Oct'13 Nov'13 Dec'13 Jan'14 Feb'14 Mar'14
Total Rainfall (mm)
Max temp (°C)
Min temp (°C)
RH - I(%)
RH-II (%)
Wind Speed (kmph)
Evaporation (mm)
Sunshine hours

Acronyms

AICRIP	:	All India Coordinated Rice Improvement Project
ATMA	:	Agricultural Technology Management Agency
AVT	:	Advanced Varietal Trial
AWD	:	Alternate Wetting and Drying
AYT	:	Advance Yield Trial
BB / BLB	:	Bacterial Leaf Blight
BPH	:	Brown Planthopper
Bt	:	*Bacillus thuringiensis*
CMS	:	Cytoplasmic Male Sterile / Sterility
CRIDA	:	Central Research Institute for Dryland Agriculture, Hyderabad
CRRI	:	Central Rice Research Institute, Cuttack
CRURRS	:	Central Rainfed Upland Rice Research Station, Hazaribag
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
DAT	:	Days After Transplanting
DTPA	:	Diethylene triamine penta acetic acid
DAS	:	Days after Sowing
DBN	:	Drought Breeding Network
DBT	:	Department of Biotechnology
DFF	:	Days to 50 % Flowering
DH	:	Dead Hearts
DRR	:	Directorate of Rice Research, Hyderabad
DST	:	Department of Science and Technology
EAP	:	Externally Aided Projects
EC / ECe	:	Electrical Conductivity
ET	:	Evapotranspiration
FLD	:	Frontline Demonstration
FYM	:	Farmyard Manure
g	:	Gram
GLH	:	Green Leafhopper
GM	:	Green Manuring / Gall Midge
GWUE	:	Grain Water Use Efficiency
h	:	Hour
ha	:	Hectare
HI	:	Harvest Index
HRR	:	Head Rice Recovery
HYV	:	High-yielding variety
ICAR	:	Indian Council of Agricultural Research
IDM	:	Integrated Disease Management
IJSC	:	Institute Joint Staff Council
IMC	:	Institute Management Committee
INGER	:	International Network for Genetic Evaluation of Rice
INM	:	Integrated Nutrient Management
INSA	:	Indian National Science Academy
IPM	:	Integrated Pest Management
IPR	:	Intellectual Property Rights
IRRI	:	International Rice Research Institute, Philippines
IVT	:	Initial Varietal Trial
Kg	:	Kilogram
KVK	:	Krishi Vigyan Kendra
L / l / ltr	:	Litre
LB	:	Long-bold
LCC	:	Leaf Colour Chart
LF	:	Leaf Folder
LS	:	Long-slender
LSI	:	Location Severity Index
MB	:	Medium Bold
MLT	:	Multilocation Trial
MS	:	Medium-Slender
NAIP	:	National Agricultural Innovation Project
NARS	:	National Agricultural Research System
NBPGR	:	National Bureau of Plant Genetic Resources, New Delhi
NFSM	:	National Food Security Mission

NGO	:	Non-governmental Organization
NIL	:	Near-isogenic Lines
NPK	:	Nitrogen, Phosphorous, Potassium
NPT	:	New Plant Type
NRC	:	National Research Centre
NRCPB	:	National Research Centre for Plant Bio-technology, New Delhi
NSN	:	National Screening Nursery
NSP	:	National Seed Project
OFT	:	On-farm Trials
OUAT	:	Orissa University of Agriculture and Technology, Bhubaneswar
OYT	:	Observational Yield Trial
PI	:	Panicle Initiation
PMYT	:	Preliminary Multilocational Yield Trial
PVS	:	Participatory Varietal Selection
PYT	:	Preliminary Yield Trial
q	:	Quintal
QTL	:	Quantitative Trait Loci
RAC	:	Research Advisory Committee
RAPD	:	Random Amplified Polymorphic DNA
RBD	:	Randomized Block Design
RCC	:	Reinforced Cement Concrete
RFLP	:	Restriction Fragment Length Polymorphism
RH	:	Relative Humidity
RIL	:	Recombinant Inbred Line
RRLRRS	:	Regional Rainfed Lowland Rice Research Station, Gerua
RTV/RTD	:	Rice Tungro Virus / Disease
SAC	:	Scientific Advisory Committee
SAU	:	State Agricultural University
SB	:	Short-bold
SBN	:	Salinity Breeding Network
SES	:	Standard Evaluation System
SRI	:	System of Rice Intensification
STRASA	:	Stress Tolerant Rice for Poor Farmers in Africa and South Asia
t	:	Tonne
UBN	:	Uniform Blast Nursery
WBPH	:	White-backed Plant Hopper
WCE	:	Weed Control Efficiency
WEH	:	White Ear Head
WTCER	:	Water Technology Centre for Eastern Region
WUE	:	Water-use Efficiency
YSB	:	Yellow Stem Borer



ISBN 81-88409-14-6

केंद्रीय चावल अनुसंधान संस्थान
भारतीय कृषि अनुसंधान परिषद
Central Rice Research Institute
Indian Council of Agricultural Research