NRRI
वार्षिक प्रतिवेदन
ANNUAL REPORT
2017-18

125th Birth Anniversary

Padma Bhusan

Dr. Krishnaswamy Ramiah

1892-1988

Founder Director of NRRI

BSCIC NABCB QM 030 ISO 9001 REGISTERED

भाकृअनुप-राष्ट्रीय चावल अनुसंधान संस्थान

(भारतीय कृषि अनुसंधान परिषद)

ICAR-National Rice Research Institute

(Formerly Central Rice Research Institute)

(Indian Council of Agricultural Research)

An ISO 9001:2008 Certified Institute

NRRI

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Annual Report
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भाकृअनुप - राष्ट्रीय चावल अनुसंधान संस्थान
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Dr. Himanshu Pathak
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Editorial Committee
Dr. P Samal
Dr. BC Patra
Dr. P Bhattacharya
Dr. AK Mukherjee
Dr. (Mrs.) P Swain
Dr. GAK Kumar

Editorial Assistance
Mrs. Sandhya Rani Dalal

Layout
Shri SK Sinha

Photography
Shri Prakash Kar
Shri Bhagaban Behera

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

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

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

Visit us at: http://www.icar-nrri.in

Cover Page: The cover design is dedicated to our founder Director Padma Bhushan Dr. Krishnaswamy Ramiah on his 125th birth anniversary. The first institute building of NRRI (them CRRI) is shown at the front side of the cover page. while back page shown the recent NRRI building. Some of the recently released varieties are also shown depicting to the effect of the pioneering rice research by Dr. Ramiah in 1946.

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NRRI

PREFACE

India has the world's largest area and is the second highest producer of rice. The crop is grown under varying climatic and soil conditions under diverse ecologies spread over about 43 million hectares. The crop is cultivated round the year in one or the other parts of the country. It is the staple food for more than two thirds of Indian population contributing more than 40% to the total food grain production, thereby, occupies a pivotal role in the food and livelihood security of people.

During the last decades, significant advancements have been made on developing high yielding and disease-resistant rice varieties and production technologies for different ecologies. The country, so far has released about 1200 varieties. Several viable rice production technologies have also been developed for adoption in the farmers' fields. Along with increasing the productivity, emphasis has been given on developing varieties with improved stress-tolerance and nutritional quality to ensure food and nutritional security for the large section of the population depending on rice as staple food. Currently, about 85% of rice area is covered with high-yielding varieties. With the concerted efforts of researchers, farmers, extension agencies and policy-makers, the country is harvesting about 110 million tons (Mt) in last few years. Almost all the states of the country are now self-sufficient in rice. Rice has now become foreign exchange earner as the country exports about 10 Mt of rice annually.

However, in the backdrop of all these achievements, rice farmers and researchers are facing new challenges of climate change, low water availability, poor soil health, low nutrient use efficiency and increased emergence of insects and diseases. There is now growing concern that non-price factors such as declining scope for further gains from existing modern varieties, deteriorating soil, depletion of ground water supplies, and reduced public investment in research have contributed to poor productivity growth in recent years. The challenge is to integrate productivity and profitability improvement of rice while enhancing the climate resilience and quality of the environment on which production depends.

Year 2017-18 has been very productive and encouraging for ICAR-National Rice Research Institute. The Institute, since its establishment in 1946, has developed 133 high-yielding varieties for various rice ecosystems. In 2017-18, however, we have released 13 varieties: 4 varieties released by Central Variety Released Committee (CVRC); 7 varieties released by State Variety Released Committee (SVRC), Odisha; 1 (var. Gangavati Ageti) by SVRC, Karnataka and 1 (var. Purna) by SVRC, Gujarat. The varieties released by CVRC are CR Dhan 506 and CR Dhan 508 for semi-deep and deep-water ecology; and CR Sugandh Dhan 908 and CR Sugandh Dhan 909, short grain aromatic varieties for irrigated late condition. Varieties released by SVRC, Odisha are CR Dhan 207 (Srimati) and CR Dhan 209 (Priya) for aerobic condition; CR Dhan 409 (Pradhan Dhan), CR Dhan 507 (Prasant) and CR Dhan 800 for low lands; short grain aromatic variety CR Sugandh Dhan 910 and high protein variety CR Dhan 311 (Mukul).

This year, we developed an improved and reproducible *in vitro* method for determination of glycemic index in rice. Also identified unique rice genotype (AC41620), having high anaerobic germination potential. We cloned and transformed C4 enzymes like SiPPDK, SiME, SbCA and SiPEPC into rice genome successfully. The Institute developed, validated and fine-tuned location specific Integrated Pest Management (IPM) package for favourable lowland ecosystem of Odisha. Effective management of stored grain pests in rice by fumigating with new granular formulation of aluminium phosphide (Quickphlow 77.5%) has been established through large-scale evaluation at CWC godown. We developed liquid formulations one each of endo-phytic and rhizospheric nitrogen fixing bio-inoculants for rice crop and liquid formulations of two phosphate solubilizing bacterial (PSB) and two exo-poly-saccharide producing bacteria for rice. Power operated weeder for rice was developed and initial field-testing was completed. Urea briquette applicator attachment for self-propelled rice transplanter was developed.

Currently, the Institute is the nodal agency for the Govt. of India's flagship programme on Bringing Green Revolution to Eastern India (BGREI). In the Mera Gaon Mera Gaurav (MGMG) programme, 20 multi-disciplinary teams with 4 scientists each are regularly visiting 100 villages in 8 districts of Odisha. The Institute has 17 outreach programmes and projects through which we are working with about 32,600 farmers every year. This year 7958 visitors visited the Institute to get information on rice technologies. The Institute participated in 14 exhibitions in different places in the country. The KVK Koderma, established 18 seed villages in *kharif* and 12 in *rabi* in the district. Institute Tribal Sub-Plan program is going on in 6 villages, 2 each in Jajpur district of Odisha, Hazaribagh district of Jharkhand and Baksa district of Assam. We provide fort-nightly agro-advisory for rice crop.

Currently the Institute has 80 externally-aided projects with about Rs. 12 crores budget. We have 50 MSc and PhD students, some are working with Inspire Fellowship of the Department of Science and Technology, Govt. of India. We organized 25 Training Programmes on Rice Production Technology and 3 for ERP and PFMS for the administrative staff of ICAR Institutes in eastern India; observed 5 Special Days; organized 12 Workshops and an International Symposium on Rice Research for Enhancing Productivity, Profitability and Climate Resilience. Our scientists have published around 135 research articles with average NAAS score of 6.3. Nine scientists got prestigious awards at national level including NAAS and other national Fellowships. Six scientists have been selected for international fellowships such as Indo-UK fellowship; Fulbright-Nehru Post Doctoral Fellowship and Endeavour Fellowship. This year, the Institute has received the ICAR Best Annual Report Award in the category of Large Institutes and the ICAR Ganesh Shankar Vidyarthi Hindi Patrika Puraskar for the Institute's Hindi Patrika 'Dhan'. The Institute is now the President, Cuttack Rajbhasha Working Committee and received the Best Organization for Promotion of Rajbhasha Award. The Institute became champion in the ICAR Sports Meet for Eastern Zone with record points.

The Institute sincerely acknowledges the guidance and encouragements received from Dr. T. Mohapatra, Director General, ICAR and Secretary, DARE in guiding various research and development programmes. Our sincere thanks are due to Shri C. Roul, Special Secretary, DARE and Secretary, ICAR; Shri B.N. Tripathi and Shri B. Pradhan, Additional Secretaries, DARE and Financial Advisors, ICAR for their continuous support and guidance. Valuable guidance, encouragement and support received from Dr. S.K. Datta, Chairman, Research Advisory Committee (RAC); Dr. J.S. Sandhu and Dr. A.K. Singh, DDGs (Crop Sciences), ICAR; esteemed members of RAC and Institute Research Council (IRC) are sincerely acknowledged. Thanks and gratitude are due to Dr. I.S. Solanki, ADG (FFC), ICAR and other officials of the Council for their constant support and guidance. I sincerely thank the Heads of the Divisions, Officer In-Charges of Regional Stations, and Administration and Finance sections of the Institute for their whole-hearted efforts and involvement in carrying out the activities of the Institute. My thanks are due to the Publication Committee and Publication Unit for compiling and editing the Annual Report. I heartily appreciate the efforts and commitment of all the staff to serve the rice farmers of the country and taking the Institute to new heights.

The Annual Report 2017-18 is dedicated to Padma Bhushan Dr. K. Ramiah, the founder Director of the Institute, on his 125th birth anniversary. Dr. Ramiah was committed to achieving national food security and farmers' prosperity through rice research. To fulfill his dream, we dedicate ourselves to transform this Institute into one of the best premier research Institutes of the world by 2021 when we will celebrate the Platinum Jubilee.

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

(Himanshu Pathak)
Director

Tribute to
PADMA BHUSHAN DR. KRISHNASWAMY RAMIAH

(1892-1988)
Founder Director
ICAR-National Rice Research Institute, Cuttack

Dr. Krishnaswamy Ramiah was born on April 15, 1892 at Kilakarai (Kizhakarai), a small coastal town in Ramnad district of old Madras Province (Tamil Nadu state). He had a brilliant academic record as a student at Municipal Middle School, Sethupathi High School and Madurai College and Government Agricultural College, Coimbatore during 1897 to 1914. He did Post-Graduate Diploma in Agriculture (Genetics) and M.Sc. from Cambridge University, United Kingdom. Dr. Ramiah returned to India to join as Paddy Specialist, Coimbatore, Govt. of Madras in April 1930.

In March, 1937, he shifted to Indore as cotton Geneticist and Botanist under Indian Central Cotton Committee at the Institute of Plant Industry and continued there till 1945. Since 'rice' was close to his heart, he returned to rice research in January 1946 as the OSD, Imperial Council of Agricultural Research to select a site for locating Central Rice Research Institute. He selected the state agricultural farm at Cuttack (Odisha) and Government of India appointment him as the first Director of the institute in October, 1946. After 37 years of distinguished state and central government service, Dr. Ramiah retired as the Director, Central Rice Research Institute in September, 1951.

Then Dr. Ramiah joined the Food and Agriculture Organization (FAO), United Nations as an expert on rice production and breeding in South-East Asia with head quarters in Bangkok. He spent around six years in International assignment and returned to India in 1957. During the eight-year period from 1957 to 1965 he served in various committees connected with agriculture and rice, in particular, at national and international levels. In 1965, Dr. Ramiah was again invited to Odisha to join as Vice-Chancellor, Orissa University of Agriculture and Technology, Bhubaneswar. After a spell of three years in Odisha, Ramiah was nominated as Member of Rajya Sabha for one term.

After a magnificent career for over 82 years, he spent the last 14 years of his life with his family at Bangalore. The end of this illustrious son of India came on August 2, 1988.

Dr. Ramiah was a pioneer in many areas of rice research such as conventional pure line selection for genetic improvement of rice and systematic hybridization. Soon after the discovery of mutation-inducing properties of x-rays, Dr. Ramiah initiated work on mutation breeding. He conceived the importance of basic cytological studies, and germplasm collection and its utilization. He was the first geneticist to advocate the standardisation of gene symbols in rice and modern geneticists owe to this pioneer for his exceptional idea. He also conceived the inter-specific and inter-racial *indica-japonica* hybridization at CRRI, the outcome being release of rice variety ADT 27 in India and Mahsuri and Malinja in Malaysia. Variety Mahsuri is a popular variety even today in several parts of India. Varieties with tolerance/resistance to biotic and abiotic stresses were also developed early in the history of rice research. Dr. Ramiah conceptualised the importance of hybrid vigour, haploid and tetraploid rice plants, and improved management practices. These formed the blue print for building modern hybrid rice and crop management programmes. He evolved scores of efficient rice varieties. Some of the outstanding varieties are GEB 24, ADT 3, CO 4 and CO 25. Variety GEB 24 has been extensively used in hybridization in national and international breeding programmes and served as a progenitor of over 83 improved varieties developed in India, Philippines and other countries.

At CRRI, Dr. Ramiah demonstrated the practicability of growing a short duration second crop of rice in the canal irrigated area during dry season which became later a regular practice and was adapted in larger areas. He demonstrated the effectiveness of chemical fertilisers in increasing rice production in Odisha. Ramiah's initiative for survey of the Jeypore Tract of Odisha (JBS) was acclaimed as the first ever systematic exploration and collection of germplasm for any crop, later this region was identified as the secondary centre of origin of cultivated rice.

Under the leadership of Dr. Ramiah, CRRI provided training facilities to students at the post-graduate level for M.Sc. and Ph.D. degrees of Utkal University, Bhubaneswar. His scientific leadership and impartiality created an atmosphere of harmony that gave the young workers, the sense of purpose and pride in their profession.

Dr. Ramiah was always ahead of his times. His keen interest in rice and his deep insight enabled him to plan rice research activities on a large scale. He suggested coordinated programmes of rice breeding among the South-East Asian countries. This brought together the rice breeders and scientists of other disciplines to a common platformto initiate efforts for maximising rice production.

His efforts as the FAO Consultant, participation in meetings at Copenhagen(1946), Geneva(1947) and Washington DC(1948) and representation at various International Rice Commission Meetings in Thailand, Myanmar, Indonesia and other countries culminated in a decision to establish the International Rice Research Institute in Los Banos, Philippines for sophisticated global research on all respects of rice research and use this institute as a centre for organising and strengthening the national programmes on rice in various countries. In all these institution building missions, Dr. Ramiah's goal was to see the emergence of a body of talented rice scientists who can take the torch of rice research from his hand and keep its flame high for all times to come.

Dr. Ramiah travelled widely as Member, Standing Advisory Committee in Agriculture of FAO (1946-1948); Member, FAO Mission to Thailand (1948), South Korea (1952) and South Vietnam (1953); Representative of India and Chairman of the Working Party on Rice Breeding under the auspices of International Rice Commission Meetings in Indonesia, Thailand, Philippines and Myanmar; World Bank Mission to Japan (1956); International Seminar on Rice Genetics and Cytogeneticsat IRRI, Philippines (1963) and President, International Rice Commission Working Party on Rice Processing and Strorage meeting at Louisiana, USA (1966).

He had several assignments. The important ones are:

- Member of Technical Committee of the ICAR ever since it came into existence
- Member of ICAR Board
- Chairman of ICAR Review Team
- Advisor, Planning Commission for the working of seed farms and seed distribution
- Member of Indo-American Team of the Ford Foundation to review food production position in India

- Member of the International Team to review the work of ICAR and suggest its reorganisation
- Chairman, Advisory Committee on rice research and also guide the All India Coordinated Rice Improvement Project ever since its establishment
- Member to review the Coffee Research and Extension in Karnataka and Andhra Pradesh and Sericulture work in Karnataka, West Bengal and Bihar
- Member, Coffee Research Committee
- Member of the Silk Board and Chairman of its Research Committee
- Chairman of a committee appointed by Food Ministry to examine market classification of rice
- Member of Sircar Committee to review work of CSIR laboratories and propose their reorganisation
- Chairman of Committee of Economists and Administrators to prepare a report on labour in relation to agriculture and
- Chairman, Panel of Agricultural Scientists to advise Union Minister of Food and Agriculture (1964-66)

In recognition of his unparalleled contribution to agriculture and long distinguished career, Dr. Ramiah was honoured by the Government of India and several scientific bodies.

He was the recipient of the following coveted awards:

- 1955-Padmashree
- 1955-D.Sc., Utkal University, Bhubaneswar
- 1961-International Rice Year Medal
- 1970-Padmabhushan
- 1983-Plaque by the Indian Society of Genetics and Plant Breeding
- 1987-D.Sc. (*Honoris Causa*) by OUAT, Bhubanesawar

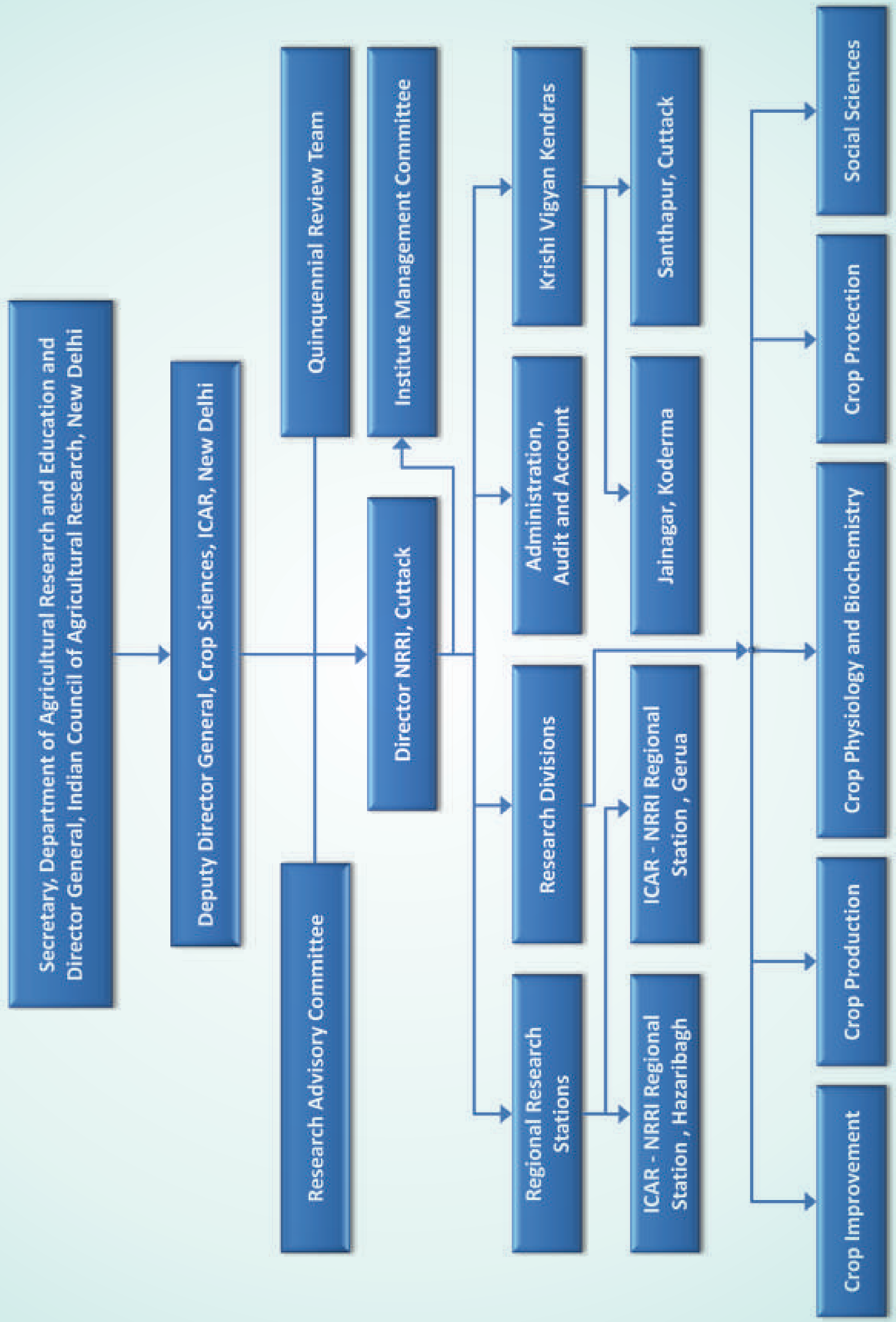
He was also honoured by scientific Societies such as:

- Founder Fellow, Indian Academy of Sciences, Bangalore
- Fellow, Indian National Science Academy, New Delhi(1942)
- Fellow, National Academy of Sciences, Allahabad
- President, Agriculture Section, Indian Science Congress(1941)
- President, Indian Society of Genetics and Plant Breeding(1944)
- Honorary Member, Japanese Breeding Society (1962)

Our tributes

One hundred and twenty five years have passed after this great luminary was born. The multi-faceted contributions of Dr. Ramiah on varietal diversity, plant architecture, polyembryony, protein, aroma, origin, distribution and evolution of rice and innovations in cultivation practices stand testimony for his exceptional brilliance. Best tributes could be paid by carrying forward his mission blended with the principles of sustainable agriculture. Rice scientists of the country salute him as '*Father of Rice Research*' and '*Bheeshmacharya of Indian Agriculture*' with great reverence and pay rich tributes proudly and respectfully.

ORGANOGRAM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ICAR - NRRI Regional Station , Gerua
ICAR - NRRI Regional Station , Hazaribagh
Social Sciences
Crop Protection
Crop Physiology and Biochemistry
Crop Production
Crop Improvement

Executive Summary

The country has made significant progress in rice production. For last few years, the production of rice has been around 110 million tons (Mt). Almost all the states are now self-sufficient in rice and India is also exporting about 10 Mt rice annually. Despite these achievements, rice farmers face serious challenges of low income, degradation of soil and water resources, emergence of new pest and diseases and unforeseen climatic extremes. Vagaries of climate change are more visible during last few years with increase in frequency of the occurrences of abiotic stresses such as drought, flood, high temperature, heavy rainfall besides biotic stresses caused by insects, pests and diseases in rice. The Institute, accordingly has reoriented its research agenda to address these challenges. The crop improvement programme in consultation with the crop protection, physiology and biochemistry programmes of the Institute aims at developing varieties tolerant/resistant to different biotic and abiotic stresses, whereas environment friendly production technologies for these varieties are developed and validatedfor further dissemination to benefit the rice farmers. Salient achievements of various research porgrammes of the Institute are briefly presented below.

Crop Improvement

Genetic improvement of rice is brought with basic, applied and strategic researches involving plant genetic resources (PGR), conventional and molecular marker assisted breeding, transgenic and quality seed. Accordingly, under genetic resources activities two exploration programmes were conducted for collection of trait specific rice germplasm. One was for deep water rice (bao) from Majuli Island in Assam and the other was for saline tolerant rice germplasm from coastal Karnataka. A set of 7324 accessions of germplasm were rejuvenated, characterized and conservedin rice gene bank. Seeds of 4311 accessions were supplied to different researchers for utilization.

Under quality seed research, panicle progeny rows of 52 varieties were grown for maintenance breeding. The selected progeny lines were bulked as nucleus seed and used for production of breeder seed. A total of 603 quintals of breeder seed was produced comprising of 47 varieties and 9 parental lines. Besides, 1030 quintals of TL seed was produced in the farmer's field under the supervision of NRRI Scientists. Several hybridizations were carried out among elite genotypes (Swarna and CR Dhan 307) and donors for resistance to sheath blight (CR 1014, Tetep, Jasmine 85 and two accessions of *O. rufipogon* (AC 100444 and AC 100015), brown plant hopper (two accessions of O. rufipogon (AC 100005, AC 100034) and yellow stem borer (*O. brachyantha* derived line (B2-11) and *O. longistaminata* (AC110404) to develop pre-breeding lines. A set of 1100 markers could be identified from the publicly available genome sequence databases which are common and cross-transferable across all the species belonging to AA genome of *Oryza.* These identified markers can facilitate marker assisted introgression of specific genomic regions of wild rice into cultivated varieties. Aerobic culture IET 26157 (Mahulata/IR20) nominated under AICRIP Trial 2017 out yielded the best checks and promoted to 3rd year of testing to AVT2 aerob. Ninety four genotypes were screened to identify deep rooting. Among them, genotypes VL Dhan 08, N22, Moroberkan, Solo I, AC 36702 and DZ78 were observed to have deep root length with more number of roots at base and ratio of deep root (RDR).

Variety CR Dhan 802 (Subhas) was identified and recommended for the states of Bihar and Madhya Pradesh suitable for rainfed shallow lowland ecology. IET 24471 (CR2683-45-1-2-2-1) has been released in SVRC, Odisha in the name of Mahamani (CR Dhan 410) for rainfed shallow lowlands. Five entries were nominated to AICRIP under advanced variety trial 1-Near isogenic lines (NIL) 2018 carrying five target genes/QTLs namely *Sub1, Xa21, xa13, xa5* and *Xa4* in variety 'Swarna' background. F_1 seeds carrying the genes/QTLs for submergence, drought and bacterial blight *viz., Sub1 + DTY1.1 + qDTY2.1 + qDTY3.1 + Xa21 + xa13 + xa5* were generated by combining different donor parents.

In the quality improvement program, emphasis was laid upon aroma, nutrition, cooking and eating quality of grains and CR Sugandh Dhan 908 was released by CVRC for the states of Odisha, West Bengal and Uttar Pradesh. Gobindbhog, a popular aromatic landrace of West Bengal was purified. Three high protein lines in the background of Swarna have been identified and are in 2nd year of testing in AICRIP-Biofortification trial. IET 27179 (CR 2826-1-1-2-4B-2-1) has been promoted to AVT-1 in AICRIP-Biofortification Trial for its higher Zn content (27 ppm) and higher yield (5.1 t/ha). CRHR 102 (IET 25231), a late duration hybrid, consistently recording higher yield was tested in AVT2-late. Two hybrids, CRHR 103 (IET 25278) and CRHR 113 (IET 26976) were promoted to AVT-1-Late trials. Altogether 16 new hybrids were nominated to AICRP. A total of 34 heterotic hybrids (3 long duration, 10 medium duration, 19-mid-early and 2 early duration) having more than 15% yield heterosis over hybrid checks US 312, Rajalaxmi and CR Dhan 701 were developed. Two mid-early CMS lines, CRMS 54A and CRMS 55A under WA and Kalinga-1 cytoplasm and genetic background of CR 440 were developed.

Variety CR Dhan 511 (CR 2789-9-2; IET 23906) was identified for release for semi-deep water areas in the states of West Bengal and Andhra Pradesh. Three elite lines were promoted to AVT-1 in CSTVT. Multiple stress (salinity and water logging) tolerant line, CR2859-S-B-2-1B-7-1 suitable for coastal saline areas was identified and nominated in multilocational testing. Mapping population consisting 600 F_2 lines was developed from the cross TN1 and Salkathi (BPH tolerant). A core collection consisting of 96 genotypes was generated from 1500 genotypes based on the phenotypic traits related to seedling vigor. Three genes were identified which are differentially expressed within the reported QTLs (*qSSIY3.1*, *qHTSF4.1* and *qSTIPSS9.1*) associated with heat stress tolerance.

Crop Production

Crop production programmes was framed with the broader goal to develop, validate and disseminate environment friendly technologies to enhance productivity, profitability and sustainability of rice production system. In this regard it was concluded that agronomic use efficiency and recovery use efficiency could be increased in the range of 25-33%, through real time N management in lowland rice using customized leaf colour chart (CLCC) along with neem coated urea. Continuous application of NPK with or without FYM encouraged certain bacterial community structure (BCS), whereas N application alone suppressed certain beneficial bacteria and microbial diversity in long term fertilizer experiments (47 years). Agro-ecological based cropping system approach revealed that, feasibility of zero-tillage based rice-maize cropping system in eastern India. It was also reported that rice-toria based pyra-cropping sequence had higher net return in rainfed ecology of Odisha. Environment impact and ecological mechanism was studied in rice fish farming system in different tier system. Special map of weed distribution pattern in coastal Odisha was developed. In weed management aspect weed competitiveness under aerobic rice, weed management in zero-tillage rice, efficacy testing of integrated weed management (chemical + mechanical control) in direct seeded rice and persistence studies of modified herbicide molecule were done.

Ecosystem services of resource conservation technologies (RCTs) both in direct seeded and transplanted rice were estimated, where incorporation of greengram in cropping sequence gave positive impact. Three microbial consortium namely, *Aspergillus* + *Streptomyces* + *Bacteria*, *Aspergillus* + *Streptomyces*, *Trichoderma* + *Streptomyces* were found promising for ex-situ rice straw composting. Two small scale farms implement; one for deep placement urea briquettes applicator attachment in mechanical trans-planter and another power operated two row wet land weeder for rice, were refined and validated. In microbial intervention, sporocarp based formulation of *Azolla* for wet land rice was developed, and performance of diazotrophs under oxidated system was assessed.

Crop Protection

Crop Protection programme focused on identification of new sources of resistance, ecological engineering for pest management, use of biocontrol agents and botanicals and combine them with IPM approaches and also testing new chemicals for the emergency situation. Land races were observed to be good source for resistance against different insect pests and diseases and can be deployed for breeding program. Acc no. IC277274 IC346855, IC277338, IC334193, IC280502, IC346890, IC283249, IC346899, IC256547, IC256780, IC256515, IC346892, IC283226, IC256530, IC256545, IC346237, IC438639, IC426126, IC426139 and IC426148 showed high degrees of resistance against the most devastating insect of present era brown plant hopper (BPH). Aganni, INRC3021, ARC 5984, Kakai (K1417), ARC 6248, PTB 26, PTB 32, IC 332045, RP 6145GMK17-3, RP 6125 GMK17-3, WGL 1127, WGL 1131, WGL 32100, RP 1 were highly resistant against gall midge. AC41772 showed moderately resistance against WBPH. ARC-5787, ARC-7083, ARC-6249, 7412, 10120, 10027 were observed to be resistant against yellow stem borer. Silica showed promise to be used for management of YSB. After screening 1450 lines 153 lines were identified to be promising against bacterial blight diseases. Nineteen (20.2%) ARC, 23 (27.4%) DSN, 116 (33%) NSN1 and 39 (31.5%) NHSN entries were found non-infected to false smut pathogen (U. virens) but none of them could be considered to be promising due to low location severity index (0.4 to 0.8). The false smut infected grains were also showed lower nutrient quality.

Out of the 80 NRVs, nineteen were resistant, twenty one found to be moderately resistant and forty were highly susceptible against leaf blast disease. Insect pests' population remained below economic threshold level in IPM and ecological engineering-based pest management plots compared to conventional pest management regime.

The insect pests *viz.*, yellow stem borer, BPH and GLH population was lower the rice where in vegetables as bund crop. The genetic diversity and geographical distribution of *Xanthomonas oryzae* pv *oryzae* did not show any relation as revealed by molecular markers. False smut is emerging as a major problem in Odisha. Among the five districts surveyed, significantly higher disease incidence was recorded from Cuttack district both the years followed by Jajpur district. While searching for alternate host for *R. solani* it was observed that Dactyloctenium aegyptium showed highest severity followed by Echinochloa colona and Digitaria ciliariswhile least was in Cyperus esculentus.

Seven Trichoderma isolates i.e., CRRIU-1, CRRIU-2, CRRIU-3, CRRIU-4, CRRIU-5, CRRIT-6, and CRRIT-7 were collected from bark of different trees or from parasitized wild mushrooms at Cuttack, Odisha, India and observed to be promising as biocontrol agent (BCA) and biofertilizer. *Bacillus* spp. have great potential to manage rice diseases as observed in the experiments conducted in NRRI field and net house. The bacillus treated plants showed lower disease progress of bacterial blight and sheath rot in comparison to the control and also better growth promotion. The botanicals especially from Cleistanthus collinus having great potential to manage rice insect pests. Cent per cent mortality of Rhyzopertha dominica was observed at 24 hours after treatment with 100% nano emulsion formulation followed by 85 and 75 % nano emulsion formulation which registered 83.33 and 33.33% mortality, respectively. IPM practice was observed to fetch higher income to the farmers. Application of combined formulation of pesticide showed that DPX-RAB 55 + Baan @ (0.48+0.6)ml l^{-1} resulted higher yield with less pest incidence.

Crop Physiology and Biochemistry

The research programme on Physiology and Biochemistry of rice has three major thrust areas namely rice grain and nutritional quality, abiotic stress physiology with mechanism and enhancing photosynthetic efficiency with major objectives to study about low glycemic index (GI) rice, micronutrient (Fe/Zn) dense rice and high protein rice, to identify donors for different abiotic stress tolerance and understand physiological and molecular mechanism of stress tolerance and to enhance photosynthetic efficiency by introduction of C_4 pathway and minimizing photorespiration.

An improved and reproducible in vitro method for determination of Glycemic Index (GI) in rice was developed and validated. It was observed that PB 177 had lowest glycemic index (GI-57.91) and high resistant starch (RS-1.97%) and O. ridleyi had highGI

(75.91) with relatively low RS (0.43%). Wherever the RS was more than 1%, the GI value was less than or equal to 61. Therefore, screening the available germplasm for high RS (>1%) may be one approach to identify a low GI rice.

A simple and rapid method with the help of the xanthoproteic test was standardized to distinguish between high and low protein rice grains, where the former gives more intense yellow/orange color than the latter. Hence this qualitative method can be used to screen large number of germplasm for identification of high protein varieties.

In another study Malondialdehyde (MDA) was estimated which is considered to be an indicator of membrane lipid peroxidation for determining storage periods of rice grains, less generation of MDA favors longer storage duration of a variety. As compared to colored varieties higher level (2 fold) of MDA generation was observed in both scented and non scented, non colored varieties. After nine months of storage, Manipuri black (1.638 µM g^{-1}) among colored varieties, Sugandha dhan (2.289 µM g^{-1}) among the scented varieties and Sahbhagidhan (2.437 µM g^{-1}) among the non-colored and non-scented varieties recorded lower amount of MDA.

Out of 1106 genotypes, 192 genotypes were found to be tolerant (SES score "1") and nine germplasm lines as highly susceptible (SES score '9') for drought. For high temperature tolerance, Annapurna and N-22 showed minimum yield reduction (19.3 to 21.5%), while for lowlight tolerance, Pyari with highest grain yield of 3.93 t ha^{-1} followed by Panindra, were identified to be at par with the tolerant check Swarnaprabha. For salinity tolerance Pokkali was identified as a good Na^+ excluder, while Sabita, the salt sensitive genotype, showed poor Na^+ exclusion at root zone. Under submergence, FR 13A, Kalaputia and Swarna Sub1 had highest volume of air layer on both the leaf surfaces and removal of gas film by Triton X-100 treatment resulted in loss of quiescence ability and increased mortality in submergence tolerant genotypes. However, under anaerobic germination (AG), a robust gene regulatory mechanism involving key physiological processes like C-metabolism, N-metabolism and cellular redox handling under anaerobic condition were identified as key strategies for better AG potential in AC41620 compared to sensitive check Naveen.

For high photosynthetic efficiency, BAM 8296, BAM 247, BAM 8315 and CR 262-4 were observed to have both high crop growth rate (CGR) and panicle growth rate (PGR) indicating their better biomass partitioning efficiency leading to higher yield. For enhancing photosynthetic efficiency and minimizing photorespiration, choloroplast targeted cloning of C_4 pathway genes *viz.* SiPPDK, SiME, SiPEPC (from Seitaria italica) and SbCA (from Sorghum bicolor) was carried out and successfully transformed in rice. In addition, designing of construct encoding E. coli glycolate pathway genes tagged with RuBisCO smaller subunit transit peptide for chloroplastic transformation was carried out and further cloned in pGEMT-Easy vector.

Social Science

In order to narrow down the time gap between the varietal development and its spread, mini-kit trials were conducted in four states, *viz.*, Odisha, Jharkhand, West Bengal and Assam with 20 newly released NRRI varieties involving 186 farmers from 11 districts during *kharif* 2017-18. All the varieties outperformed the existing popular varieties giving a grain yield advantage of about 15-25% over the existing popular varieties in their respective ecologies. The most significant ones included CR Dhan 202 and CR Dhan 305 in Jharkhand; CR Dhan 203 and CR Dhan 304 in West Bengal; CR Dhan 202, CR Dhan 205, CR Dhan 206 (Gopinath), CR Dhan 304, CR Dhan 307 (Maudamani), CR Dhan 311 (Mukul), CR Dhan 408 (Chaka Akhi), CR Dhan 409 (Pradhan Dhan), CR Dhan 500 andCR Dhan 505 in Odisha; and CR Dhan 909 (aromatic) in Assam. It is recommended that these varieties should find place in seed chains of respective states at the earliest for the benefit of rice growers.

Analysis of district wise area, yield and production of rice indicated negative contribution from area and positive contribution of yield for most of the districts. The districts with more rice area (>25,000 ha) and low yield (< 2 t ha^{-1}) are higher in number in Assam (11), Bihar (18), Chhatishgarh (16), Madhya Pradesh (15) and Odisha (16) state.Detailed cost of cultivation data of rice for 18 states of India has been updated up to the year 2014-15 and growth rate calculated with respect to various indicators and the analysis revealed that high increment of cost of cultivation than profit. Further, profit per ha in irrigated states were greater than rainfed states.

Under the 4S4R model of NRRI, three farmer producer companies (FPCs) under Company Registration Act 2013 were registered and two are in pipe line to make the district self-sufficient and sustainable. The first year experience of growing over 134 quintals of foundation seeds of three popular varieties has been very encouraging and motivating with a B:C ratio of 1.33 for the FPC and 2.0 for the seed producing farmers. The B:C ratio is expected to further increase in coming years with the expansion of seed growing area and publicity of FPCs. The on-station varietal Cafeteria with the demonstration of all the popular and newly released varieties has been an eye-opener for over 7000-8000 of stakeholders visiting the institute every year to know, understand, evaluate and experience the varieties.

The Mera Gaon Mera Gaurav (MGMG) programme of the institute with involvement of all scientists in 21 clusters in 105 villages with the direct contact with over 10,000 farm families in 8 districts of Odisha has helped to strengthen research activities of the institute. This has provided the scientists an opportunity to understand the rural societyand its changing requirements, while helping the farmers in providing necessary technological solutions to agricultural problems.

In addition toresearch and extension activities the Institute is contributing significantly in human resource development. Currently about 50 MSc and PhD students are working for their research work.As part of the capacity building, 21 scientists, 12 technical staff and 92 administrative staff were trained in subject matter related to their jobs. The Institute organized 25 training programmes on rice production technology and 3 training programmes for ERP, PFMS for the administrative staff of ICAR Institutes in eastern India; observed 5 Special Days; organized 12 workshops and an International Symposium on Rice Research for Enhancing Productivity, Profitability and Climate Resilience.

The Institute dedicates itself to achieve the national food and nutritional security and improving income and livelihood of rice farmers.

कार्यकारी सारांश

चावल उत्पादन में देश ने महत्वपूर्ण प्रगति की है। पिछले कुछ वर्षों से चावल का उत्पादन लगभग 110 मिलियन टन रहा है। चावल उत्पादन में सभी राज्य अब आत्मनिर्भर हैं तथा भारत अब वार्षिक रूप से लगभग 10 मिलियन टन चावल निर्यात कर रहा है। इन उपलब्धियों के बावजूद, चावल के किसानों को कम आय, मिट्टी एवं जल संसाधनों की गुणवत्ता में ह्रास, नई नाशककीटों एवं रोगों का आविर्भाव तथा अप्रत्याशित जलवायु परिस्थितियों की गंभीर चुनौतियों का सामना करना पड़ रहा है। पिछले कुछ वर्षों में सूखे, बाढ़, उच्च तापमान, अत्यधिक वर्षा तथा चावल के नाशककीटों एवं रोगों के कारण अजैविक दबावों से चावल फसल बाधित हुई है। संस्थान ने तदनुसार, इन चुनौतियों का सामना करने के लिए अपने अनुसंधान कार्यक्रम को नए सिरे से आरंभ किया है। फसल सुधार कार्यक्रम के तहत संस्थान के फसल सुरक्षा, शरीरक्रियाविज्ञान एवं जैवरसायन प्रभागों के साथ परामर्श करके विभिन जैविक एवं अजैविक दबाव के प्रति सहिष्णु/प्रतिरोधी किस्में विकसित की जा रही हैं तथा इन किस्मों के लिए पर्यावरण अनुकूल उत्पादन प्रौद्योगिकियां विकसित की जा रही हैं तथा चावल किसानों के लाभ के लिए इन्हें मान्य किया जा रहा है। संस्थान के विभिन्न अनुसंधान कार्यक्रमों की प्रमुख उपलब्धियां निम्नवत है।

फसल उन्नयन

पौध आनुवंशिक संसाधनों, पारंपरिक एवं आण्विक चिन्हक सहायतित प्रजनन, ट्रांसजेनिक एवं गुणवत्ता बीज को शामिल करते हुए बुनियादी, प्रायोगिक एवं रणनीतिक अनुसंधान के माध्यम से चावल में आनुवंशिक सुधार किया गया। तदनुसार, आनुवंशिक संसाधनों के कार्यकलापों के अंतर्गत, लक्षण विशिष्ट चावल जननद्रव्य के संग्रहण के लिए दो खोज कार्यक्रम आयोजित किए गए। गहराजल चावल के लिए असम के माजुली द्वीप में एक खोज कार्यक्रम किया गया तथा दूसरा कार्यक्रम लवण सहिष्णुता चावल के लिए तटीय कर्नाटक के चार जिलों में किया गया। जननद्रव्य की 7324 प्रविष्टियों की एक सेट को जीर्णोद्धार, लक्षणवर्णन तथा जीन बैंक में संरक्षित रखा गया। जननद्रव्य की 4311 प्रविष्टियों के बीजों को प्रयोग हेतु विभिन्न अनुसंधानकर्ताओं को वितरित किया गया। गुणवत्ता बीज अनुसंधान के तहत, अनुरक्षण प्रजनन के लिए 52 किस्मों की पंक्तियों में खेती की गई। चयनित संतान वंशों को केंद्रक बीज के रूप में थोक किया गया तथा प्रजनक बीज के उत्पादन के लिए प्रयोग किया गया। 47 किस्मों तथा 9 जनक वंशों का कुल 603.07 क्विंटल प्रजनक बीज उत्पादन किया गया। इसके अतिरिक्त, एनआरआरआई वैज्ञानिकों के तत्वावधान में किसानों के खेतों में 1030 क्विंटल विश्वसनीय बीज उत्पादन किया गया। पूर्व-प्रजनन वंश विकसित करने के लिए आच्छद अंगमारी (सीआर 1014, तेतेप, जस्मीन 85 एवं ओ.रुफिपोगन (प्रविष्टि 100444 एवं प्रविष्टि 10015), भूरा पौध माहू (ओ.रुफिपोगन के दो प्रविष्टियां (प्रविष्टि 100005 एवं प्रविष्टि 100034) एवं पीता तना छेदक के प्रति प्रतिरोधिता हेतु (ओ.ब्रेकियांथा वंश बी2-11) तथा ओ.लांगिस्टामिनाटा (प्रविष्टि 110404) उन्नत जीनप्ररूपों (स्वर्णा एवं सीआर धान 307) तथा दाताओं के बीच कई संकर किए गए। सार्वजनिक जीनोम स्रोत में उपलब्ध सिक्वेंस डेटाबेस से 1100 चिन्हकों के एक सेट की पहचान हुई जो साधारण हैं तथा ओराइजा के एए जीनोम के सभी प्रजातियों में पारगम्य हैं। खेतीयोग्य किस्मों में विशिष्ट जीनोमिक क्षेत्रों के जंगली चावल के चिन्हक सहायतित अंतरक्रमण कार्य में सुविधा हेतु पहचाने गए चिन्हक सहायक होंगे। एआईसीआरआईपी परीक्षण 2017 के तहत नामित ऐरोबिक संवर्द्धन आईईटी 26257 (महुलता/आईआर20) की उपज श्रेष्ठ चेक किस्मों की अपेक्षा अधिक थी और इसे एवीटी2 के तृतीय वर्ष के परीक्षण में आगे बढ़ाया गया। लंबी जड़ के लिए चौरानब्बे जीनप्ररूपों का परीक्षण किया गया। इनमें से जीनप्ररूप वीएल धान 08, एन22, मोरोबेरकान, सोलो 1, एसी36702 तथा डीजेड78 में लंबी जड़ एवं अधिक जड़ें पाए गए। एरोबिक दशा के लिए उपयुक्त जीनप्ररूप विकसित करने हेतु इन जीनप्ररूपों का प्रयोग किया जा रहा है। वर्षाश्रित उथली निचलीभूमि पारिस्थितिकी के लिए उपयुक्त धान 802 चावल किस्म (सुभास) की पहचान की गई तथा बिहार एवं मध्य प्रदेश के राज्यों में खेती के लिए संस्तुत की गई। आईईटी 2441 (सीआर2683-45-1-2-2-1) को वर्षाश्रित उथली निचलीभूमि पारिस्थितिकी में खेती करने तथा राज्य किस्म विमोचन समिति, ओडिशा में सीआर धान 410 (महामणि) के नाम से विमोचित करने के लिए प्रस्ताव रखा गया है। स्वर्णा किस्म की पृष्ठभूमि में नियर आइसोजेनिक वंश 2018 जिनमें पाँच लक्षित जीन/क्यूटीएल सब1, एक्सए21, एक्सए13, एक्सए5 तथा एक्सए4 हैं, को विकसित किस्म परीक्षण-1 के

तहत एआईसीआरआईपी में नामित किया गया। विभिन्न दाता जनकों जैसे सब1 एवं डीटीवाई1.1 एवं क्युडीटीवाई2.1 एवं क्युडीटीवाई3.1 तथा एक्सए21 एवं एक्सए13 एवं एक्सए5 के संकरण द्वारा जलनिमग्नता, सूखा तथा जीवाणुज अंगमारी के लिए जीन/क्यूटीएल वाली एफ1 बीज उत्पादन किया गया। गुणवत्ता सुधार कार्यक्रम में, सुगंध, पोषण, खाना पकाने तथा खाने की गुणवत्ता पर जोर दिया गया। सुगंधित लघु दाना वाली चावल किस्म सीआर धान 908 को केंद्रीय किस्म विमोचन समिति द्वारा ओडिशा, पश्चिम बंगाल तथा उत्तर प्रदेश में विमोचित एवं अधिसूचित किया गया। पश्चिम बंगाल की एक लोकप्रिय सुगंधित भूमिजाति गोबिंदभोग को शुद्ध किया गया। स्वर्णा किस्म की पृष्ठभूमि में तीन उच्च प्रोटीनयुक्त वंशों की पहचान की गई है तथा एआईसीआरआईपी-जैवसुदृढ़ीकरण परीक्षण के द्वितीय वर्ष में इनका परीक्षण किया जा रहा है। आईईटी 27179 (सीआर 2826-1-1-2-4बी-2-1) को उच्चतर जस्ता की मात्रा (27 पीपीएम) तथा अधिक उपज (5.1 ट/है.) हेतु एआईसीआरआईपी-जैवसुदृढ़ीकरण परीक्षण के तहत एवीटी-1 कार्यक्रम में आगे बढ़ाया गया। सीआरएचआर 102 (आईईटी 25231) जो कि एक बिलंवित संकर किस्म है तथा जिससे लगातार अधिक उपज प्राप्त हुई है, एवीटी-2 बिलंवित कार्यक्रम में परीक्षण किया गया। दो संकर किस्में, सीआरएचआर 103 (आईईटी 25278) एवं सीआरएचआर 113 (आईईटी 26976) को एवीटी-2 बिलंवित कार्यक्रम में परीक्षण हेतु आगे बढ़ाया गया। कुल मिलाकर एआईसीआरआईपी, 2017 में 16 नए संकर किस्मों को चयनित किया गया। कुल 34 हेटेरोटिक संकर किस्में (तीन दीर्घावधि, 10 मध्यम अवधि, 19 मध्य-शीघ्र एवं 2 शीघ्र अवधि) जिनसे संकर चेक किस्मों यूएस 312, राजलक्ष्मी एवं सीआर धान 701 की अपेक्षा 15 प्रतिशत अधिक उपज मिली, विकसित की गईं। डब्ल्यूए एवं कलिंग-1 की साइटोप्लाज्म तथा सीआर 440 की आनुवंशिक पृष्ठभूमि के अंतर्गत दो मध्यम-शीघ्रावधि वाली सीएमएस वंश, सीआरएमएस 54ए तथा सीआरएमएस 55ए विकसित की गई। सीआर धान 511 (सीआर 2789-9-2, आईईटी 23906) को पश्चिम बंगाल एवं आंध्र प्रदेश के अर्ध-गहराजल क्षेत्रों में खेती हेतु विमोचन के लिए पहचान की गई। तीन श्रेष्ठ वंशों को सीएसटीवीटी के अंतर्गत एवीटी-1 में परीक्षण हेतु आगे बढ़ाया गया। तटीय लवण क्षेत्रों के लिए उपयुक्त बहु-दबाव (लवणता एवं जलाक्रांत) सहिष्णु वाली वंश सीआर 2859-एस-बी-2-1बी-7-1 की पहचान की गई तथा बहुस्थानीय परीक्षण में चयन किया गया। संकर टीएच1 एवं सालकाथी (बीपीएव सहिष्णु) से विकसित 600 एफ2 वंश का मैंपिंग संख्या का विकास किया गया। पौध ओज से संबंधित फिनोटाइपिक लक्षणों के आधार पर 1500 जीनप्ररूपों से 96 जीनप्ररूपों का एक मूल संग्रह विकास किया गया। तापमान दबाव सहिष्णुता के संबंध में क्यूटीएल-क्यूएसएस1वाई3.1, क्यूएचएस1वाई4.1 एवं क्यूएसटीआईपीएसएस9.1 से तीन अलग जीनों की पहचान की गई।

फसल उत्पादन

चावल उत्पादन प्रणाली में उत्पादकता, लाभप्रदता तथा स्थायित्व की वृद्धि हेतु पयार्वरण अनुकूल प्रौद्योगिकियों के विकास, मान्य तथा प्रसार करने के व्यापक लक्ष्य के साथ फसल उत्पादन कार्यक्रम तैयार किए गए। इस संबंध में यह पाया गया कि निचलीभूमि चावल में कस्टमाइज्ड पत्ता रंग चार्ट सहित नीम आलेपित यूरिया का उपयोग करके वास्तविक समय पर नत्रजन प्रबंधन के माध्यम से कृषि संबंधी उपयोग क्षमता तथा प्रतिधारित प्रयोग दक्षता को 25 से 33 प्रतिशत की सीमा तक वृद्धि की जा सकती है। दीर्घकालिक उर्वरक परीक्षण (47 वर्ष) में फार्म यार्ड खाद सहित अथवा इसके बिना नत्रजन, फासफोरस एवं पोटाश के लगातार प्रयोग से विशिष्ट जीवाणुओं की संख्या में वृद्धि हुई जबकि केवल नत्रजन के प्रयोग से विशिष्ट लाभकारी जीवाणुओं तथा माइक्रोबायल विविधता दब गया। कृषि-पारिस्थितिकी आधारित फसल प्रणाली उपाय से पता चला कि पूर्वी भारत में शून्य-जुताई आधारित चावल-मक्का फसल प्रणाली की व्यवस्था संभव है। यह भी पाया गया कि ओडिशा के वर्षाश्रित पारिस्थितिकी में चावल-तोरिया आधारित पायरा-फसल अनुक्रम से अधिक शुद्ध लाभ मिला। चावल-मछली खेती प्रणाली के विभिन्न स्तर प्रणाली में पर्यावरण प्रभाव तथा पारिस्थितिकी क्रियाविधि पर अध्ययन किया गया। तटीय ओडिशा में खरपतवार वितरण पैटर्न का विशेष मानचित्र विकसित किया गया। ऐरोबिक चावल के तहत खरपतवार प्रबंधन में खरपतवार प्रतिस्पर्धा, शून्य-जुताई चावल में खरपतवार प्रबंधन, सीधी बुआई चावल में समन्वित खरपतवार प्रबंधन का प्रभाविकता परीक्षण (रसायन एवं यांत्रिक नियंत्रण) तथा संशोधित शाकनाशी मॉड्यूल का निरंतर अध्ययन किया गया।

सीधी बुआई तथा प्रतिरोपित चावल दोनों में संसाधन संरक्षण प्रौद्योगिकियों की पारितंत्र सेवाओं का आकलन किया गया जिसमें फसल अनुक्रम के तहत मूंग की खेती से अच्छा लाभ

मिला। स्वस्थाने धान पुआल कंपोस्ट के लिए तीन माइक्रोबायल समूह जैसे आस्परजिलस एवं स्ट्रेपटोमाइसेस और जीवाणु, आस्परजिलस एवं स्ट्रेपटोमाइसेस, ट्राइकोडरमा एवं स्ट्रेपटोमाइसेस आशाजनक पाए गए। दो लघु फार्म उपकरण- एक यांत्रिक प्ररोपक में जुड़ा यूरिया ब्रिकेट एप्लिकेटर तथा दूसरा आर्द्रभूमि के लिए शक्तिचालित वीडर में संशोधन तथा मानकीकृत किया गया। माइक्रोबायल हस्तक्षेप में, आर्द्रभूमि चावल के लिए स्पोरोकार्प आधारित अजोला का सूत्रण विकसित किया गया तथा ऑक्सिडेटेड प्रणाली के तहत डायजोट्रोफ के निष्पादन का मूल्यांकन किया गया।

फसल सुरक्षा

प्रतिरोधिता के नए स्रोतों की पहचान, नाशकजीव प्रबंधन के लिए पारिस्थितिकी अनुकूल नियंत्रण तकनीकें, जैवनियंत्रण कारकों एवं वानस्पतिकों का प्रयोग एवं समन्वित नाशकजीव प्रबंधन उपायों के साथ इनका मिश्रित उपयोग तथा आपातकालीन परिस्थिति के लिए नए रसायनों का परीक्षण फसल सुरक्षा कार्यक्रम में शामिल था। यह देखा गया कि विभिन्न नाशकजीवों एवं रोगों के विरुद्ध प्रतिरोधिता के लिए भूमिजातियां एक अच्छी स्रोत हैं तथा प्रजनन कार्यक्रम में उपयोग किया जा सकता है। प्रविष्टि संख्या आईसी277274, आईसी346855, आईसी277338, आईसी334193, आईसी280502, आईसी346890, आईसी283249, आईसी346899, आईसी256547, आईसी256780, आईसी256515, आईसी346892, आईसी283226, आईसी256530, आईसी256545, आईसी346237, आईसी438639, आईसी426126, आईसी426139 तथा आईसी426148 में वर्तमान समय में सर्वाधिक क्षति पहुंचाने वाली कीट-भूरा पौध माहू के विरुद्ध उच्चत्तर प्रतिरोधिता देखी गई। गाल मिज के विरुद्ध अगन्नी, आईएनआरसी3021, एआरसी 5984, ककई (के1417), एआरसी 6248, पीटीबी 26, पीटीबी, 32, आईसी 332045, आरपी 6145जीएमके17-3, आरपी 6125जीएमके17-3, डब्ल्यूजीएल 1127, डब्ल्यूजीएल 1131, डब्ल्यूजीएल 32100, आरपी 1 अत्यधिक प्रतिरोधी पाए गए। सफेदपीठवाला पौध माहू के विरुद्ध एसी41772 में मध्यम रूप से प्रतिरोधिता पाई गई। एआरसी-5787, एआरसी-7083, एआरसी-6249, 7412, 10120, 10027 में पीला तना छेदक के विरुद्ध प्रतिरोधिता पाई गई। पीला तना छेदक के प्रबंधन के लिए सिलिका का प्रयोग आशाजनक पाया गया। 1450 वंशों के परीक्षण के बाद, 153 वंशों को जीवाणुज आच्छद रोग के विरुद्ध आशाजनक के रूप में पहचान की गई। 19 (20.2 प्रतिशत) एआरसी, 23 (27.4 प्रतिशत) डीएसएन, 116 (33 प्रतिशत) एनएसएन1 तथा 39 (31.5 प्रतिशत) एनएचएसएन प्रविष्टियां फाल्स स्मट रोगजनक (यू.वीरेन्स) के प्रति गैर संक्रमित पाए गए किंतु निचली अवस्थिति गंभीरता सूचक (0.4 से 0.8) के कारण कोई भी आशाजनक नहीं पाए गए। फाल्स स्मट संक्रमित दानों में कम पोषक गुणवत्ता भी देखने को मिला। 80 एनआरवी में से, पत्ता प्रध्वंस रोग के विरुद्ध, उन्नीस प्रतिरोधी, इक्कीस मध्यम प्रतिरोधी तथा चालीस अत्यधिक ग्राह्यशील पाए गए। पारंपरिक नाशककीट प्रबंधन की तुलना में समन्वित नाशकजीव प्रबंधन तथा पारिस्थितिक अनुकूल आधारित कीट प्रबंधन खेतों में कीटों की संख्या बहुत रही। प्राकृतिक शत्रुओं में मकड़ी, ओड़ंता, कोसिनेडिल, काराबिड़, स्टेफीलिनिड तथा हाइमेनोप्टेरा परभक्षी शामिल थे। पीता तना छेदक, भूरा पौध माहू तथा हरा पत्ता माहू कीटों की संख्या चावल में कम थीं जबकि बांध पर की गई सब्जी फसल में अधिक देखी गई। जांथोमोनास ओराइजा का आनुवंशिक एवं भौगोलिक वितरण का कोई संबंध देखने को नहीं मिला जैसा कि आणविक चिन्हकों से पता चला है। फाल्स स्मट रोग के कारण मोती किस्म में सर्वाधिक क्षति (5.14) हुई जबकि स्वाद किस्म में उपज हानि सबसे कम (0.10) हुई। परिणामों से पता चला है कि 2016 की तुलना में 2017 में रोग प्रकोप अधिक हुआ है। इससे पता चलता है कि ओडिशा में यह रोग एक प्रमुख समस्या के रूप में उभर रहा है। दोनों वर्षों में सर्वेक्षण किए गए पाँच जिलों में से, कटक जिले में रोग प्रकोप अधिक पाया गया जबकि जाजपुर जिले में यह प्रकोप कम था। आर.सोलानी के लिए विकल्प परजीवी की खोज में यह देखा गया कि डाक्टिलोक्टेनियम एजिप्टीयम, इच्छिलोक्लोआ कोलोना एवं डिजीटारिया सिलियारिस में सर्वाधिक गंभीरता है जबकि साइपरस एसक्यूलेंटस में गंभीरता कम थी। ओडिशा के कटक में विभिन्न पेड़ों के छालों या परजीवी जंगली मशरूम से सात ट्राइकोडर्मा वियुक्त (सीआआरआईयू-1, सीआआरआईयू-2, सीआआरआईयू-3,सीआआरआईयू-4, सीआआरआईयू-5, सीआआरआईटी-6 तथा सीआआरआईटी-7) संग्रहित किए गए तथा आशाजनक जैवनियंत्रक एवं जैवउर्वरक के रूप में पाया गया। एनआरआरआई के प्रक्षेत्र तथा नेट हाउस में किए गए परीक्षणों से पाया गया कि बैसिलस एसपीपी. में धान से संबंधित रोगों के प्रबंधन के लिए काफी क्षमता है। नियंत्रण की

तुलना में बैसिलस उपचारित पौधों में जीवाणुज अंगमारी तथा आच्छद विगलन रोग का फैलाव बहुत धीमा था तथा पौधों की वृद्धि अच्छी हुई। क्लेइस्थानतुस कोलिनस वानस्पति में चावल कीट के प्रबंधन के लिए काफी क्षमता है। 100 प्रतिशत नैनो इमलशन सहित उपचार करने पर 24 घंटे बाद राइजोपर्था डोमिनिका संपूर्ण नष्ट हो गए जबकि 85 प्रतिशत एवं 75 प्रतिशत नैनो इमलशन सहित उपचार करने पर राइजोपर्था डोमिनिका क्रमशः 83.33 प्रतिशत तथा 33.33 प्रतिशत नष्ट हुआ। किसानों को अधिक आय दिलाने के लिए समन्वित नाशकजीव प्रबंधन उपाय अपनाया गया। कीटनाशकों के मिश्रित प्रयोग करने पर यह पता चला कि डीपीएक्स-आरएबी 55 तथा बान् 0.48 एवं 0.6 मिलिलीटर प्रति लीटर की दर से प्रयोग से अधिक उपज मिली तथा कीटों का प्रकोप कम हुआ।

फसल शरीरक्रियाविज्ञान एवं जैवरसायन

चावल के फसल शरीरक्रियाविज्ञान एवं जैवरसायन अनुसंधान कार्यक्रम के तीन प्रमुख क्षेत्र हैं-चावल दाना एवं पौषणिक गुणवत्ता, जैविक दबाव शरीरक्रियाविज्ञान क्रियाविधि तथा प्रकाशसंश्लेषण दक्षता वृद्धि। इसका लक्ष्य है चावल ग्लाइसेमिक सूचक, सूक्ष्मपोषकयुक्त चावल एवं उच्च प्रोटीनयुक्त चावल, विभिन्न अजैविक दबाव सहिष्णुता के लिए दाताओं की पहचान करना तथा कार्यिकी एवं दबाव सहिष्णुता के आण्विक क्रियाविधि की समझ तथा सी4 पाथवे के प्रवेश द्वारा प्रकाशसंश्लेषण दक्षता की वृद्धि एवं प्रकाशश्वसन को कम करना है।

चावल में ग्लाइसेमिक सूचक के निर्धारण के लिए एक सुधरित तथा प्रतिलिपि प्रस्तुत करने योग्य इन विट्रो विधि विकसित एवं मान्य किया गया। यह पाया गया कि पीबी 177 में सबसे कम ग्लाइसेमिक सूचक है एवं उच्च प्रतिरोधी स्टार्च है जबकि ओ.रिडली में ग्लाइसेमिक सूचक अधिक पाया गया एवं प्रतिरोधी स्टार्च कम था। जहाँ प्रतिरोधी स्टार्च एक प्रतिशत से कम था, वहां ग्लाइसेमिक सूचक कम था या 61 के समान था। अतः उच्च प्रतिरोधी स्टार्च के लिए उपलब्ध जननद्रव्य का परीक्षण चावल में कम ग्लाइसेमिक सूचक की पहचान हेतु एक उपाय हो सकता है। उच्च एवं कम प्रोटीनयुक्त चावल दानों के बीच अंतर की पहचान के लिए जांथोप्रोटिक परीक्षण की सहायता से एक आसान एवं शीघ्र विधि का मानकीकृत किया गया जिसमें उच्च प्रोटीनयुक्त चावल दानों में अधिक पीलापन या नारंगी रंग था जबकि कम प्रोटीनयुक्त चावल के दाने में यह रंग कम था। इसलिए उच्च प्रोटीनयुक्त चावल किस्मों की पहचान के लिए अधिक संख्या के जननद्रव्यों के परीक्षण हेतु इस गुणात्मक विधि का उपयोग किया जा सकता है। एक अन्य अध्ययन में, मालोनडिएल्डीहाइड का मूल्यांकन किया गया जो चावल दानों के भंडारण अवधि के निर्धारण हेतु मेमब्रेन लिपिड पेरोक्सिडेशन का सूचक है। मालोनडिएल्डीहाइड की मात्रा कम होने पर किसी किस्म की भंडराण अवधि अधिक होती है।

रंगीन किस्मों की तुलना में, सुगंधित एवं बिन-सुगंधित एवं बेरंग किस्मों में मालोनडिएल्डीहाइड का उच्च स्तर देखा गया। नौ महीनों की अवधि के भंडारण के बाद, रंगीन किस्मों में से मणीपुरी ब्लैक, सुगंधित किस्मों में से सुगंधधान तथा बिन-सुगंधित एवं बेरंग किस्मों में से सहभागीधान में मालोनडिएल्डीहाइड की कम मात्रा पाई गई।

1106 जीनप्ररूपों में से, सूखा के लिए 192 जीनप्ररूपों को सहिष्णु पाया गया जिनका एसईएस स्कोर 1 था तथा नौ जननद्रव्य के वंश अत्यधिक ग्राह्यशील पाए गए जिनका एसईएस स्कोर 9 था। उच्च तापमान सहिष्णुता के लिए अन्नपुर्णा एवं एन-22 में उपज की क्षति कम हुई जबकि कम प्रकाश सहिष्णुता के लिए प्यारी किस्म से 3.93 टन प्रति हैक्टर की सर्वाधिक उपज मिली एवं इससे कम उपज पानिंद्र से मिली जो कि सहिष्णु चेक किस्म स्वर्णप्रभा के समान था। लवण सहिष्णुता के लिए पोकाली की पहचान एक अच्छे लवण अलगाव के रूप में हुई जबकि सबिता जो कि एक लवण संवेदनशील जीनप्ररूप है, जड़ क्षेत्र में लवण अलगाव का निष्पादन खराब रहा। जलनिमग्नता के लिए, एफआर 13ए, कालापुटिया एवं स्वर्णा सब 1 दोनों के पत्तों में वायु परत सर्वाधिक मात्रा पाई गई तथा ट्रीटन एक्स-100 के उपचार द्वारा गैस परत को हटाने पर निष्क्रियता क्षमता में नुकसान हुआ तथा जलनिमग्न सहिष्णु जीनप्ररूपों की नष्ट होने की प्रतिशतता बढ़ गई। किंतु, संवेदनशील चेक किस्म नवीन की तुलना में एसी41620 में बेहतर एनएरोबिक अंकुरण क्षमता के लिए मुख्य रणनीतिक उपायों के रूप में एनएरोबिक अंकुरण के तहत, कार्बन-मेटाबोलिज्म, नत्रजन-मेटाबोलिज्म जैसे प्रमुख शरीरक्रियाविज्ञान क्रियाविधि शामिल करते हुए एक ठोस जीन नियामक तंत्र तथा एनएरोबिक दशा के तहत सेलुलर रिडॉक्स संचालन पहचान की गई।

अधिक प्रकाशसंश्लेषक दक्षता के लिए, बीएएम 8296, बीएएम 247, बीएम 8315 तथा सीआर 262-4 में फसल वृद्धि दर तथा बाली वृद्धि देखने को मिला जिससे उनका बेहतर जैवपदार्थ अलगाव क्षमता के बारे में पता लगा एवं

जिसके कारण अधिक उपज मिली। प्रकाशसंश्लेषक दक्षता की वृद्धि तथा प्रकाश्वसन कम करने के लिए, सी4 पाथवे जीन जैसे एसआईपीपीडीके, एसआईएमई, एसआईपीईपीसी तथा एसबीसीए के क्लोरोप्लास्ट लक्षित क्लोनिंग का कार्य किया गया तथा चावल में सफलतापूर्वक रूपांतरित किया गया। इसके अतिरिक्त, क्लोरोप्लास्ट रूपांतरण के लिए आरयूबीआईएससीओ उपइकाई पारगमन पेपटाइड सहित ई.कोलाई ग्लाइकोलेट पाथवे जीन के बनावट को डीजाइन कार्य किया गया तथा पीजीईएमटी-इजी वेक्टर में आगे और क्लोनिंग किया गया।

समाजविज्ञान

किस्म विकास तथा इसके प्रसार के बीच समय के अंतर को कम करने के लिए खरीफ 2017-18 के दौरान ओडिशा, झारखंड, पश्चिम बंगाल एवं असम के 11 जिलों के 186 किसानों को शामिल करते हुए एनआरआरआई विकसित 20 नई किस्मों के मिनीकीट का परीक्षण किया गया। अपने-अपने पारिस्थितिकियों में मौजूदा लोकप्रिय किस्मों की अपेक्षा एनआरआरआई विकसित सभी किस्मों ने 15 से 25 प्रतिशत अधिक उपज दिए। झारखंड में सीआर धान 305 एवं सीआर धान 305, पश्चिम बंगाल में सीआर धान 203 एवं सीआर धान 304, ओडिशा में सीआर धान 202, सीआर धान 205, सीआर धान 206 (गोपीनाथ), सीआर धान 304, सीआर धान 307 (मौड़मणि), सीआर धान 311 (मुकुल), सीआर धान 408 (चकाआखी), सीआर धान 409, (प्रधान धान), सीआर धान 500 एवं सीआर धान 505 तथा असम में सीआर धान 909 (सुगंधित) प्रमुख था। यह संस्तुत की जाती है कि चावल किसानों के लाभ के लिए अपने-अपने राज्यों में यथाशीघ्र इन किस्मों को बीज श्रृंखला में शामिल कर देना चाहिए।

चावल के क्षेत्र, उपज एवं उत्पादन के जिलेवार विश्लेषण से पता चला कि अधिकांश जिलों में क्षेत्र के प्रति योगदान कम है किंतु उपज के मामले में योगदान सकारात्मक है। जिन जिलों में अधिक चावल क्षेत्र हैं एवं कम उपज है वे हैं असम (11), बिहार (18), छत्तीसगढ़ (16), मध्य प्रदेश (15) तथा ओडिशा में (16) हैं। भारत के 18 राज्यों का चावल की खेती की लागत का विस्तृत आंकड़ा वर्ष 2014-15 के लिए अद्यतन कर दिया गया है तथा विभिन्न सूचकों के आधार पर वृद्धि दर की गणना की गई है तथा विश्लेषण से पता चला है कि लाभ की अपेक्षा लागत की वृद्धि हुई है। इसके अतिरिक्त, वर्षाश्रित राज्यों की अपेक्षा सिंचित राज्यों में लाभ प्रति हैक्टर अधिक है।

एनआरआरआई विकसित 4एस4आर नमूना से कंपनी पंजीकरण अधिनियम 2013 के तहत तीन किसान उत्पादन कंपनियों का पंजीकरण करने में सफलता मिली है तथा कटक जिले को चावल में आत्मनिर्भर एवं स्थिरता लाने के लिए और दो कंपनियों का पंजीकरण प्रस्तावित है। प्रथम वर्ष में तीन लोकप्रिय किस्मों के फांउडेशन बीज का 134 क्विंटल का उत्पादन काफी उत्साहजनक एवं प्रेरक था। इसमें किसान उत्पादन कंपनियों का लाभ-लागत अनुपात 1.33 जबकि बीज उत्पादन किसानों के लिए यह अनुपात 2.0 था। इस मॉडल की पुनरावृत्ति संभव है। जानने, समझने, मूल्यांकन तथा किस्मों को अनुभव करने के लिए संस्थान में प्रत्येक वर्ष आ रहे लगभग 7000-8000 हितधारकों के लिए केंद्र में सभी लोकप्रिय एवं नई विमोचित किस्मों का प्रदर्शन मंच ज्ञानवर्धक है।

'मेरा गांव मेरा गौरव' में कार्यक्रम के तहत, संस्थान के वैज्ञानिकों ने आडिशा के आठ जिलों के 105 गांवों के 21 क्लस्टरों में 10,000 से अधिक किसान परिवारों के साथ मिलकर संस्थान के अनुसंधान कार्यकलापों को मजबूती प्रदान की है। इससे ग्रामीण समाज एवं इसके बदलते मांग को समझने के लिए वैज्ञानिकों को एक अवसर मिला है तथा साथ ही कृषि संबंधित समस्याओं के लिए आवश्यक तकनीकी समाधान उपलब्ध कराने के लिए किसानों को सहायता मिल रही है। संस्थान के अनुसंधान एवं विस्तार कार्यकलापों के अलावा, संस्थान मानव संसाधन विकास में महत्वपूर्ण भूमिका निभा रहा है। वर्तमान 50 एमएससी तथा पीएचडी के विद्यार्थी अध्यननरत हैं। क्षमता निर्माण के तहत, 21 वैज्ञानिक, 12 तकनीकी एवं 92 प्रशासनिक कार्मिकों को उनके विषय के संबंध में प्रशिक्षित किया गया। चावल उत्पादन प्रौद्योगिकी पर 25 प्रशिक्षण कार्यक्रम आयोजित किया जा चुका है। पूर्वी भारत में स्थित परिषद के संस्थानों के प्रशासनिक कार्मिकों के लिए ईआरपी एवं पीएफएमएस पर तीन प्रशिक्षण कार्यक्रमों का आयोजन किया गया। पाँच विशेष दिवस, 12 कार्यशालाओं तथा उत्पादकता, लाभप्रदता एवं पर्यावरण परिवर्तन संबंधित चावल अनुसंधान पर एक अंतरराष्ट्रीय परिसंवाद आयोजित किया जा चुका है। संस्थान चावल किसानों के जीविका एवं उनके आय में वृद्धि हेतु राष्ट्रीय खाद्य एवं पौषणिक सुरक्षा की प्राप्ति के लिए सदा प्रयासरत है।

Introduction

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

Vision

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

Goal

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

Mission

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

Mandate

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

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

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

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

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

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

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

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

Thrust Areas

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

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

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

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

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

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

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

Research Achievements

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

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

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

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

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

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

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

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

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

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

Addressing rice production constrains in eastern India through BGREI programme.

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

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

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

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

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

Linkages

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

Location

The institute is located at Cuttack about 35 km from Bhubaneswar airport and 7 km from the Cuttack railway station on the Cuttack-Paradeep State Highway. The institute lies approximately between 85^{0}55'48″ E to 85^{0}56'48″ longitudes and 20^{0}26'35″ N to 20^{0}27'35″ N latitudes with the general elevation of the farm being 24m above the MSL. The annual rainfall at Cuttack is 1200 mm to 1500 mm, received mostly during June to October (*kharif or wet season)* from the southwest monsoon. Minimal rainfall is received from November to May (*rabi* or *dry* season).

High Protein Rice in the Crop

PROGRAMME : 1

Genetic Improvement of Rice for Enhancing Yield, Quality and Climate Resilience

Basic, applied and strategic researches involving PGR, conventional and molecular marker assisted breeding, transgenic and quality seed are conducted for the genetic improvement of rice.

Under genetic resources activities, two exploration programmes were conducted for collection of trait specific rice germplasm. One was for deep water rice (bao) from Majuli Island in Assam and the other was for saline tolerant rice germplasm from coastal Karnataka. A set of 7324 accessions of germplasm were rejuvenated, characterized and conserved in rice gene bank. Seeds of 4311 accessions were supplied to different researchers for utilization. In quality seed research, panicle progeny rows of 52 varieties were grown for maintenance breeding. The selected progeny lines were bulked as nucleus seed and used for production of breeder seed. A total of 603.07 quintals of breeder seed was produced comprising of 47 varieties and 9 parental lines. Besides, 1030.00 quintals of TL seed was produced in the farmer's field under the supervision of NRRI Scientists. Several hybridizations were carried out among elite genotypes (Swarna and CR Dhan 307) and donors for resistance to sheath blight (CR 1014, Tetep, Jasmine 85 and two accessions of *O. rufipogon* (AC 100444 and AC 100015), brown plant hopper (two accessions of *O. rufipogon* (AC 100005, AC 100034) and yellow stem borer (*O. brachyantha* derived line (B2-11) and *O. longistaminata* (AC110404) to develop pre-breeding lines. A set of 1100 markers could be identified from the publicly available genome sequence databases which are common and cross-transferable across all the species belonging to AA genome of *Oryza*. These identified markers can facilitate marker assisted introgression of specific genomic regions of wild rice into cultivated varieties. Aerobic culture IET 26157 (Mahulata / IR20) nominated under AICRIP Trial 2017 out yielded the best checks and promoted to 3rd year of testing to AVT2 aerob. Ninety four genotypes were screened to identify deep rooting. Among them, genotypes VL Dhan 08, N22, Moroberkan, Solo I, AC 36702 and DZ78 were observed to have deep root length with more number of roots at base and ratio of deep root (RDR).

CR Dhan 802 (Subhas) was identified and recommended for the states of Bihar and Madhya Pradesh suitable for rainfed shallow lowland ecology. IET 24471 (CR2683-45-1-2-2-1) has been released in SVRC, Odisha in the name of Mahamani (CR Dhan 410) for rainfed shallow lowlands. Five entries were nominated to AICRIP under advanced variety trial 1- Near isogenic lines (NIL) 2018 carrying five target genes/QTLs namely Sub1, Xa21, xa13, xa5 and Xa4 in variety 'Swarna' background. F1 seeds carrying the genes/QTLs for submergence, drought and bacterial blight viz., Sub1 + DTY1.1 + qDTY2.1 + qDTY3.1 + Xa21 + xa13 + xa5 were generated by combining different donor parents.

In the quality improvement program, emphasis was laid upon aroma, nutrition, cooking and eating quality of grains and CR Sugandh Dhan 908 was released by CVRC for the states of Odisha, West Bengal and Uttar Pradesh. Gobindbhog, a popular aromatic landrace of West Bengal was purified. Three high protein lines in the background of Swarna have been identified and are in 2nd year of testing in AICRIP-Biofortification trial. IET 27179 (CR 2826-1-1-2-4B-2-1) has been promoted to AVT-1 in AICRIP-Biofortification Trial for its higher Zn content (27 ppm) and higher yield (5.1 t/ha). CRHR 102 (IET 25231), a late duration hybrid, consistently recording higher yield was tested in AVT2-late. Two hybrids, CRHR 103 (IET 25278) and CRHR 113 (IET 26976) were promoted to AVT-1-Late trials. Altogether 16 new hybrids were nominated to AICRP. A total of 34 heterotic hybrids (3 long duration, 10 medium duration, 19-mid-early and 2 early duration) having more than 15% yield heterosis over hybrid checks US 312, Rajalaxmi and CR Dhan 701 were developed. Two mid-early CMS lines, CRMS 54A and CRMS 55A under WA and Kalinga-1 cytoplasm and genetic background of CR 440 were developed.

CR Dhan 511 (CR 2789-9-2; IET 23906) was identified for release for semi-deep water areas in the states of West Bengal and Andhra Pradesh. Three elite lines were promoted to AVT-1 in CSTVT. Multiple stress (salinity and water logging) tolerant line, CR2859-S-B-2-1B-7-1 suitable for coastal saline areas was identified and nominated in multilocational testing. Mapping population consisting 600 F_2 lines was developed from the cross TN1 and Salkathi (BPH tolerant). A core collection consisting of 96 genotypes was generated from 1500 genotypes based on the phenotypic traits related to seedling vigor. Three genes were identified which are differentially expressed within the reported QTLs (*qSSIY3.1, qHTSF4.1*, and *qSTIPSS9.1*) associated with heat stress tolerance.

Exploration, characterization and conservation of genetic resources for rice improvement

Exploration and collection of rice germplasm

Two exploration programmes were conducted for collection of trait specific rice germplasm. The first exploration programme was conducted during 19-28 November 2017 for collecting rice germplasm especially the deepwater rice cultivars from Majuli islands, Dhemaji and North Lakhimpur districts of Assam. A total of 91 traditional rice germplasm accessions were collected which comprised of deepwater rice (Bao), sticky rice (Bora), aromatic rice (Joha) and other winter rice (Sali) cultivars. Another programme was conducted during 27th Nov. to 6th Dec. 2017 in collaboration with ICAR-NBPGR Base Center, Cuttack for collection of rice landraces for salinity tolerance from Uttar Kannada, Dakshin Kannada, Udupi & Shivmoga districts of Karnataka. A total of 69 accessions were collected. Some of the land races were collected from high saline areas like Bili Kagga, Red Ajaga and Rajamudi. The collected germplasm have been conserved in NRRI rice gene bank.

Rejuvenation of the conserved germplasm and the new collections

Periodic monitoring of seed viability was done for the stored gene bank accessions. A set of 7500 accessions of rice germplasm conserved in National Gene Bank of LTS facility in different years were received for rejuvenation, multiplication and characterization purpose. Besides, 629 accessions of ARC materials conserved in MTS were rejuvenated to increase the seed quantity and maintaining viability.

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

Agro-morphological characterization

A total of 7500 accessions of rice germplasm were grown for characterization on 30 agro-morphological traits as per the DUS descriptors. The data on nineteen qualitative and eleven quantitative characters were recorded at appropriate stages of crop growth and maturity as per the descriptors (Table 1.1). These materials were harvested, processed, packed and stored in the gene bank for future use.

Another set of Assam Rice collections (ARC) were characterized phenotypically based on various qualitative and quantitative characters. Majority of the accessions were observed with green basal leaf sheath, having no awn and with intermediate panicle type and flag leaf angle (Fig.1.1). Wide range of variation among the accessions for the traits like 100 grain weight (79.80%) followed by grain yield/plant (55.09%) (Table1.2). ARC 10061 was observed with short plant height (43.33 cm) and ARC 10229 was the tallest plant (130.67 cm). The earliest flowering line was ARC 6001(83 days) while flowering in ARC11233 took 148 days. Among the yield attributing traits, average number of tillers observed in the collection was 6.19 with highest value (12.00) observed in ARC 6076. Panicle length was ranged from 11.05-39.13 cm with lowest and highest value observed in ARC 11254 and ARC10342, respectively. Mean grain yield in the germplasm was 6.83g/plant while highest yield was recorded in ARC 5764 (27.83g/plant). The 100 grain weight was ranged from 1.01-3.32g with highest grain weight in ARC 11118.

Molecular characterization

Screening of Phosphorus related gene (PSTOL1/PUP1) in weedy rice

In recent times, weedy rice (*Oryza sativa* f. *spontanea*) has become one of the most troublesome weeds infesting rice fields worldwide. Weedy rice is known for adaptation in problematic soils and is tolerant to major abiotic and biotic stresses. Since, phosphorus deficiency in soil is considered as a major limiting factor for the rice yield, a set of 71 weedy rice collected from Manipur were used for screening of phosphorus

Table 1.1.Variability observed for Quantitative traits

Quantitative Characters	Minimum		Maximum		Mean
	Value	AC/IC No.	Value	AC/IC No.	
Days to Maturity	83	IC-459631	208	IC-256958	147.11
Days to 50% Flowering	58	IC-459631		IC-256958	119.07
No. of Effective Tillers	1.0	IC-591485	22.0	IC-465212	6.52
Plant Height (cm)	50	IC-248068	224	IC-464154	138.01
Panicle Length (cm)	10	IC-611187	58	IC-253383	24.75
100 grain weight (gm)	0.84	IC-323566	4.05	IC-256703	2.49
Grain yield per Plant (gm)	1.62	IC-276788	54.27	IC-466115	13.83

Table 1.2: Variability observed for quantitative traits in ARC materials

Sl No.	Character	Mean±S.E	Range	C.V (%)
1	Plant height(cm)	92.79±0.62	43.33-130.67 (ARC 10061-ARC10229)	15.38
2	Leaf length(cm)	28.55±0.34	15.13 – 53.38 (ARC 6001-ARC10187)	27.55
3	Leaf width(cm)	0.81±0.01	0.3-1.8 (ARC 10258-ARC6620)	28.55
4	Days to 50% flowering	117.17±0.28	83-148 (ARC 6001- ARC 6097, 11233)	29.28
5.	Days to maturity	139.53± 1.18	113-176 (ARC 6001,6007- ARC 6097, 11233)	21.29
6	No. of Effective tillers	6.19±0.08	2.00-12.00 (ARC 5832,11303,11524 -ARC6076)	28.72
7	Panicle length(cm)	18.79±0.13	11.05-39.13 (ARC 11254-ARC10342)	15.91
8.	Grain yield/plant(gm)	6.83 ±0.19	1.15-27.83 (ARC 10682 – ARC 5764)	55.09
9.	100 grain weight(gm)	2.33 ± 0.08	1.01-3.32 (ARC 7119 - ARC 11118)	79.80

deficiency tolerance. Eleven SSR markers comprised of 7 dominant SSR markers (Pup1-K41, Pup1-K42, Pup1-K43, Pup1-K46, Pup1-K48, Pup1-K52, and Pup1-K59) in INDEL region and 4 co-dominant (Pup1-K4, Pup1-K5, Pup1-K20, and Pup1-K29) markers located in Pup1 genomic region were used for genotyping. Different markers showed varied results for the presence of positive-negative allele of PSTOL1 gene. Out of 71, 14 weedy rice accessions were found to be positive to *PSTOL1* gene based on PUP1-K46 markers which could be utilized in identification of novel allele (Fig 1.2).

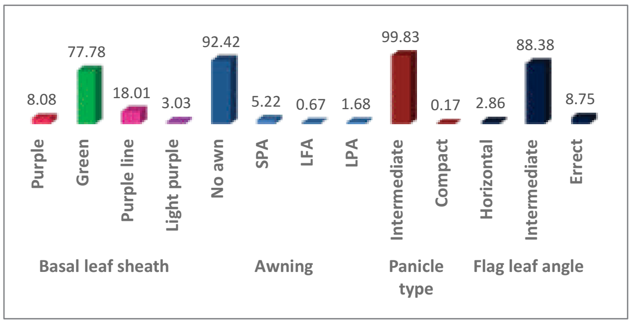


Fig:1.1 Variability observed for qualitative traits in ARC materials

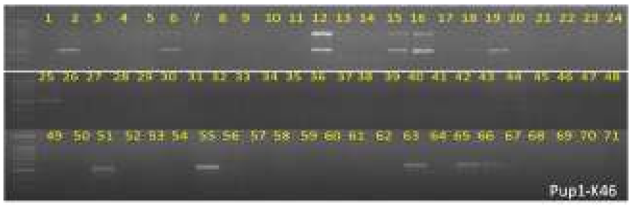


Fig.1.2 Screening of PSTOL1 gene in weedy rice using gene specific marker Pup1-K46.

Evaluation of genetic diversity in NRRI released rice varieties

Assessment of genetic diversity is prerequisite for any crop improvement programme as it helps breeders in deciding suitable breeding strategies for their future plant improvement. SSR markers have proven to be a marker of choice for studying the genetic diversity. Therefore, the present study was undertaken with the aim to characterize and assess trends of genetic diversity in rice varieties released between 1965 and 2014 using SSR markers. A set of 135 SSR markers from 12 chromosomes were used for genotyping 96 NRRI's released rice varieties. Based on 44 SSR markers, 96 varieties formed 7 major groups (Fig1.3). This genotyping data of 135 SSR markers could be useful for association mapping of important agronomic traits.

Cross-transferability of SSR markers in identification of wild rice

Sixteen wild rice accessions with different genomes were characterized using cross-transferability of SSR markers along with two cultivated rice, Nipponbare and Swarna. A total of 105 SSR markers covering whole genome were used, out of which 70 markers were found to be useful for analysis. The overall cross transferability of SSR markers ranged from 57.4 to 86.5% (Table 1.3). However, AA genome species showed the transferability ranging from 42.9 to 100%. These markers could be useful in identification of alien gene transfer/introgression from wild rice to cultivated rice (Fig 1.4).

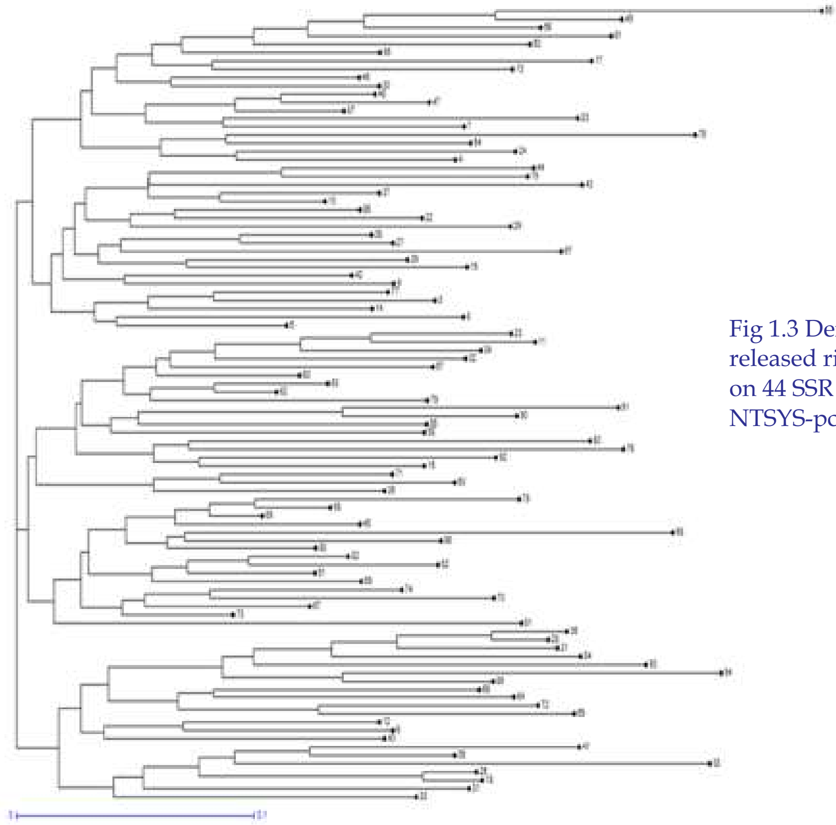


Fig 1.3 Dendrogram of 96 released rice varieties based on 44 SSR markers using NTSYS-pc 2.21 software.

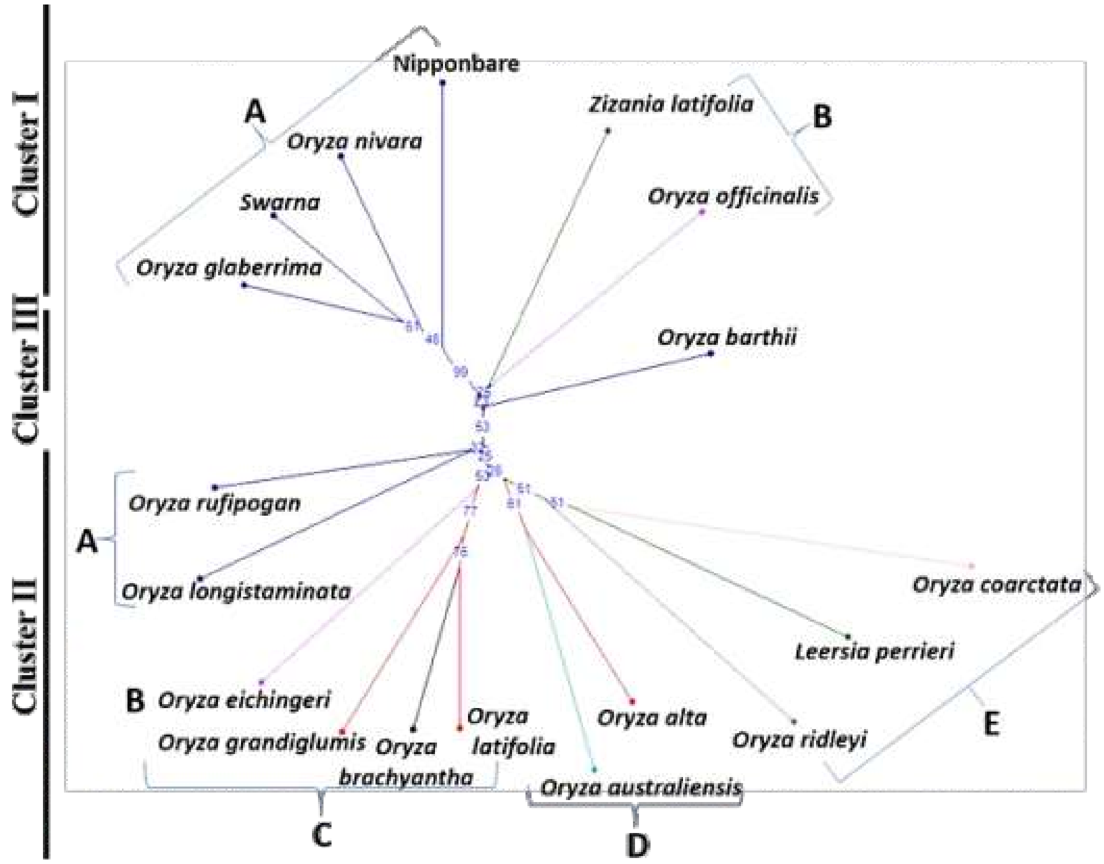


Fig 1.4. Phylogenetic tree of 16 wild rice along with rice Nipponbare and Swarna

Table 1.3. Cross transferability of SSR markers in wild rice

Chromosome	Transferability (%)
1	83.33
2	86.5
3	68.52
4	57.4
5	80.95
6	85.64
7	62.96
8	67.78
9	80.55
11	77.77
12	69.45

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

Germplasm conservation

Seven thousand three hundred and twenty four (7324) accessions of rice germplasm were rejuvenated, characterized and conserved as Medium Term Storage (MTS) in NRRI gene bank. This includes 7000 accessions received from National gene bank, DUS testing materials, newly collected cultivated and wild rice germplasm.

Supply of Germplasm seeds

Four thousand three hundred and eleven (4311) accessions of rice germplasm / elite lines / donors/ varieties were shared with researchers for their utilization. Out of 4311 accessions, 373 accessions were shared with different institutes/ organizations throughout the country through proper signing of Material Transfer Agreement (MTA).

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

Nucleus seed and breeder seed production

Panicle progeny rows of 52 varieties were grown for maintenance breeding. After thorough rouging and rejection of probable variants in progeny lines, true to the type panicles were collected for next generation nucleus seed production. The remaining lines were harvested, threshed separately and after table top examination pure lines were bulked as nucleus seed. In 2017-18, a total of 12.48q nucleus seed of 52 varieties were produced (Table 1.4). The bulk nucleus seed is used to produce Breeder Seed of the same variety. Breeder seed was produced as per DAC indent. A total of 603.07q of breeder seed, comprising of 47 varieties and 9 parental lines were produced (Table 1.5).

Participatory Seed Production

Under National Seed Project, Farmer's Participatory Seed Production was undertaken at farmer's field in-agreement (MoU) with Mahanga Krushak Vikash Manch (Goudagop), Mahatma Gandhi Farmer's Club (Kendrapara) and Achyutananda Farmer's Producer Company Ltd (Kendrapara). The seeds of 4 popular varieties (Pooja, Sarala, Gayatri and Swarna Sub-1) were produced in 3 villages namely (i) Goudagop, Mahanga,Cuttack, (ii) Bhandilo, Kendrapara and (iii) Nischintakoili, Cuttack. This seed production programme was jointly performed with the involvement of the farmers and under the supervision of NRRI Scientists. Proper monitoring of farmer's field and suggestive measures were followed to fit the seed standard. Seed quality testing was done at NRRI. A total of 1030q seed qualified as per TL seed standard. The seeds were procured back from the FPOs and was sold as TL Seed to needy farmers.

Table 1.4. Nucleus Seed Production during 2017-18

Sl. No.	Variety name	Nucleus seed produced (Kg)
1.	Annada	25
2.	Bina Dhan 11	52
3.	Bina Dhan 12	50
4.	CR 1014	9
5.	CR 1009 sub 1	55
6.	CR Boro Dhan-2	8
7.	CR Dhan 10	7
8.	CR Dhan 101	7
9.	CR Dhan 300	7
10.	CR Dhan 303	20
11.	CR Dhan 304	11
12.	CR Dhan 305	6
13.	CR Dhan 307	13
14.	CR Dhan 310	15
15.	CR Dhan 311	4
16.	CR Dhan 401	7
17.	CR Dhan 405	10
18.	CR Dhan 500	75
19.	CR Dhan 501	10
20.	CR Dhan 502	3
21.	CR Dhan 505	6
22.	CR Dhan 601	78
23.	CR Sugandh Dhan 3	5
24.	CR Sugandh Dhan 907	6
25.	Dharitri	18
26.	Durga	4
27.	Gayatri	12
28.	Geetanjali	7
29.	Improved Lalat	18
30.	Ketekijoha	6
31.	Khitish	18

32.	Luna Sampad	5	43.	Ranjit	10
33.	Luna Suvarna	5	44.	Ratna	3
34.	Lunishree	6	45.	Sahbhagidhan	15
35.	Moti	3	46.	Sarala	22
36.	Naveen	57	47.	Satyabhama	28
37.	Nua Chinikamini	4	48.	Savitri	18
38.	Nua Kalajeera	4	49.	Shatabdi	70
39.	Padmini	5	50.	Swarna Sub 1	322
40.	Phalguni	6	51.	Utkalprava	4
41.	Pooja	65	52.	Varshadhan	21
42.	Poorna Bhog	3		**Total**	**1248**

Table 1.5. Breeder Seed Production during 2017-18

Sl. No.	Variety name	Production during *Rabi* 2016 - 17 (q)	Production during *Kharif* 2017 (q)	Total Production (q)
1.	Annada	17.10	-	17.10
2.	CR 1009 sub 1	-	1.20	1.20
3.	CR 1014	-	1.40	1.40
4.	CR Boro Dhan-2	3.00	-	3.00
5.	CR Dhan 10	10.50	0.60	11.10
6.	CR Dhan 101	1.00	-	1.00
7.	CR Dhan 201	1.50	-	1.50
8.	CR Dhan 203	-	0.15	0.15
9.	CR Dhan 300	-	1.80	1.80
10.	CR Dhan 303	2.40	-	2.40
11.	CR Dhan 307	19.80	1.80	21.60
12.	CR Dhan 310	16.50	-	16.50
13.	CR Dhan 310	-	2.20	2.20
14.	CR Dhan 401	-	2.20	2.20
15.	CR Dhan 405	2.00	-	2.00

16.	CR Dhan 500	-	27.80	27.80
17.	CR Dhan 502	-	0.10	0.10
18.	CR Dhan 601	4.80	-	4.80
19.	CR Sugandh Dhan 3	-	0.40	0.40
20.	CR Sugandh Dhan 907	-	1.00	1.00
21.	Dharitri	-	3.60	3.60
22.	Durga	-	1.00	1.00
23.	Gayatri	-	7.50	7.50
24.	Improved Lalat	7.50	-	7.50
25.	Ketekijoha	-	0.20	0.20
26.	Khitish	6.60	-	6.60
27.	Luna Sampad	-	0.40	0.40
28.	Luna Suvarna	-	1.00	1.00
29.	Lunishree	-	0.50	0.50
30.	Moti	-	0.50	0.50
31.	Naveen	100.00	-	100.00
32.	Nua Chinikamini	-	1.00	1.00
33.	Nua Kalajeera	-	0.20	0.20
34.	Padmini	-	0.20	0.20
35.	Phalguni	12.60	-	12.60
36.	Pooja	-	70.20	70.20
37.	Ranjit	-	5.70	5.70
38.	Sahbhagidhan	2.00	-	2.00
39.	Sarala	-	22.00	22.00
40.	Satyabhama	2.00	-	2.00
41.	Savitri	-	2.00	2.00
42.	Shatabdi	39.00	-	39.00
43.	Swarna sub 1	-	190.00	190.00

44.	Utkalprava	-	0.70	0.70
45.	Varshadhan	-	4.50	4.50
46.	Ajay 'A'line	-	0.45	0.45
47.	Ajay 'B'line	-	0.27	0.27
48.	Ajay 'R'line	-	0.35	0.35
49.	Rajalaxmi 'A' line	-	0.65	0.65
50.	Rajalaxmi 'B' line	-	0.33	0.33
51.	Rajalaxmi 'R' line	-	0.25	0.25
52.	CR Dhan 701 'A' line	-	0.40	0.40
53.	CR Dhan 701 'B' line	-	0.20	0.20
54.	CR Dhan 701 'R' line	-	0.42	0.42
	Total	**248.3**	**354.77**	**603.07**

Identification of genes/QTLs associated with seed vigour

About 500 rice genotypes were phenotyped for seed vigour traits. The lines were consisting of different grain size and types. All these lines were tested for seed vigour, seed size, germination rate and mean germination time. A group of selected materials will be used as panel for genotyping on identification of associated genes/ alleles.

Utilization of wild and cultivated gene pool of rice for resistance to biotic stresses

Maintenance of wild *Oryza* gene pool

Thirty five accessions of wild *Oryza* species with different genome types (AA, BB, CC, EE, FF, CCDD, BBCC, HHJJ and KKLL) are being maintained *ex situ* in field gene bank. Besides these, trait specific wild *rice species* which include accessions with vegetative stage drought tolerance (*O. nivara*- AC 100476, AC 100374), tolerance to YSB [*O. brachyantha* (AC 100499) and *O. longistaminata* (AC 110404)], resistance to BPH and tolerance to sheath blight (*O. rufipogon*- AC 100005, AC 100034) and other distant genome hybrids [(**AxC), (AxE), (AxF), (ACD) & (ABC)]** are also maintained through stubbles.

Wide hybridization for developing pre-breeding lines and mapping population

In order to develop pre-breeding lines, hybridization was carried out between elite genotypes (Swarna and CR Dhan 307) and donors for resistance to sheath blight (CR 1014, Tetep, Jasmine 85 and two accessions of *O. rufipogon* namely AC 100444 and AC 100015), Brown Plant Hopper (two accessions of *O. rufipogon* namely AC 100005, AC 100034) and Yellow Stem Borer (*O. brachyantha* derived line (B2-11) and *O. longistaminata* (AC 110404).

In order to develop mapping population for sheath blight, BPH and YSB resistance, F_1 progenies have been derived between resistant wild species accessions or its wild derivatives and susceptible cultivated rice genotypes for respective traits. The list of cross combinations has been presented in Table 1.6.

Development of cross-transferable markers for AA-genome *Oryza* species

Oryza AA-genome is represented by eight different species showing global distribution under diverse ecologies. These are store-house of novel genes and alleles for adaptive traits and are amenable for development of introgression lines in the background

Table 1.6. Cross combinations generated for developing mapping population.

Traits	Tolerant/Resistant	Susceptible
Sheath blight	*Oryza rufipogon* (AC 100015)	Annapurna
	Oryza rufipogon(AC 100444)	Annapurna
BPH	*Oryza rufipogon* (AC 100005)	TN 1
	Oryza rufipogon (AC 100034)	TN 1
YSB	B 2-11 (*Oryza brachyantha* derivative)	TN 1

of cultivated rice. Hence, these eight species, which cumulatively constitute *Oryza sativa* complex, can serve as ideal resource for future rice improvement. However, for their judicious utilization, availability of genome-wide high density molecular markers is required. Development of common set of genome wide markers from whole genome sequence data will be most useful for which targeted efforts are lacking. Attempts were made to identify a common set of cross transferable markers from the publicly available genome sequence databases (Fig.1.5).

Using bioinformatics pipeline developed, 23,499 *O. sativa* derived Sequence Tagged Microsatellite (STMS) markers were screened for cross transferability from Gramene database (www.gramene.org). Differential cross-transferability of these markers was observed, where expectedly, the cross-transferability was higher in case of Asian species and it gradually reduced in African species followed by South American species and finally was lowest in Australian species. Conspicuous variations in the number of cross-transferable markers among species-pairs were also evident. Finally 1100 markers could be identified which are common and cross-transferable across all the species belonging to A-genome of *Oryza*. These markers were distributed well across the genome

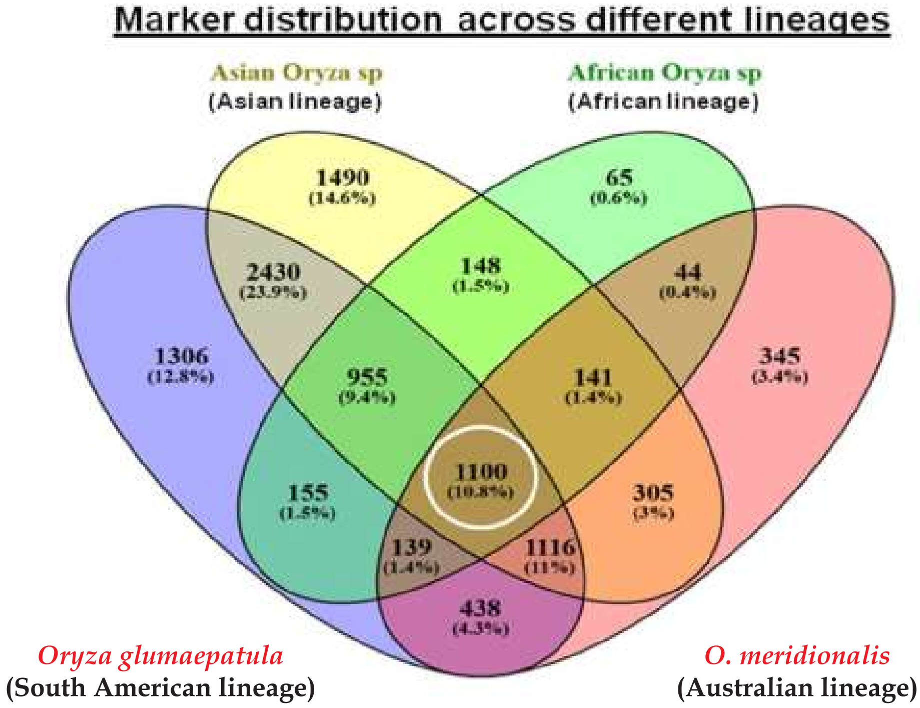


Fig.1.5. Common cross-transferable markers across different lineages AA genome containing *Oryza* species

(with minor exceptions). A random sample of 352 markers form these 1100 has been validated in all the species (Fig.1.6). With few exceptions, all the markers were amplified in all genotypes and showed predicted band size. Thus, a unique resource of cross transferable microsatellite markers could be developed for all the member species of A-genome of *Oryza*. The 1100 markers identified can facilitate marker assisted introgression of specific genomic regions of wild rice in cultivated varieties besides their other uses like diversity analysis, evolutionary studies etc. A database development for these markers is in progress.

New molecular marker useful for species level identification in *Oryza* species with AA genome

Among the different species of *Oryza* belonging to AA genome, a new category (Variant of STMS) of molecular markers has been identified which is able to identify *Oryza sativa* var. *japonica, O. rufipogon*, *O. longistaminata, O. glumaepatula* and *O. meridionalis* through simple PCR based reaction (Fig.1.7).

Identification of genome wide STMS markers for *Oryza coarctata*

Oryza coarctata (HHKK- Genome) is a species naturally found in the coastal mangrove areas. It flowers and sets seeds even at high 40 E.Ce dS m^{-1}

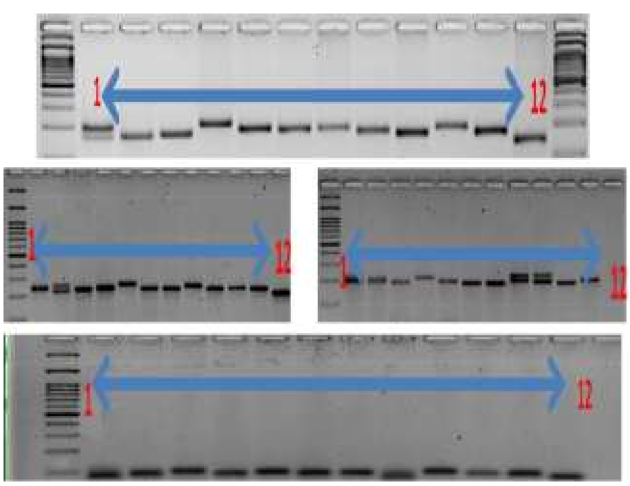


Fig.1.6: *In-vitro* validation of cross transferable markers. Genotypes: 1. *O. sativa* var. *japonica* (Nipponbare), 2. *O. sativa* var. *japonica* (T-309), 3. *O. sativa* var. *indica* (Kasalath), 4. *O. sativa* var. *indica* (Tetep), 5. *O. rufipogon*, 6. *O. nivara*, 8. *O. glaberrima*, 9. *O. barthii*, 10. *O. longistaminata*, 11. *O. glumaepatula* and 12. *Oryza meridonalis*

saline soil. This is considered as a highly potential species for identification of genes for salinity tolerance. However, genomic resources for this species are very limited. Recently, ICAR-NRCPB has completed the whole genome sequence of this species. This resource was utilized for identification of genome wide cross transferable STMS markers with respect to *Oryza sativa* using the developed bioinformatics pipeline. Out of 23,499 *O. sativa* derived Sequence Tagged Microsatellite (STMS) markers of *Oryza sativa*, only 359 markers were found to be cross transferable in *Oryza coarctata*. On comparing the 359 markers with 1100 STMS markers conserved among all members of AA genome, only 84 markers were found to be common. A total of 82 out of 84 markers were found to be amplified during *in-vitro* validation (Fig.1.8).

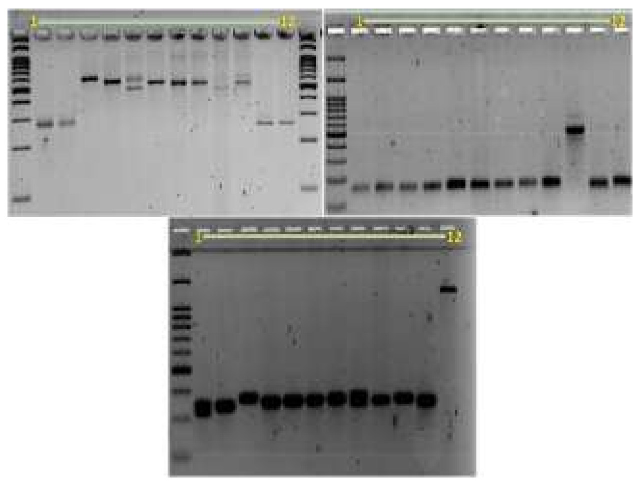
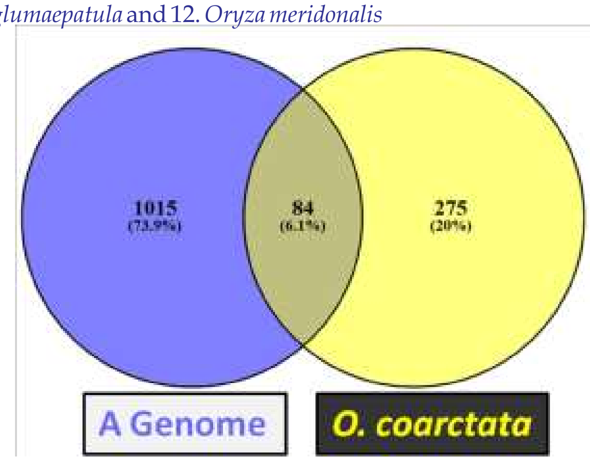


Fig.1.7: Species specific markers for different *Oryza* species. Genotypes: 1. *O. sativa* var. *japonica* (Nipponbare), 2. *O. sativa* var. *japonica* (T-309), 3. *O. sativa* var. *indica* (Kasalath), 4. *O. sativa* var. *indica* (Tetep), 5. *O. rufipogon*, 6. *O. nivara*, 8. *O. glaberrima*, 9. *O. barthii*, 10. *O. longistaminata*, 11. *O. glumaepatula* and 12. *Oryza meridonalis*



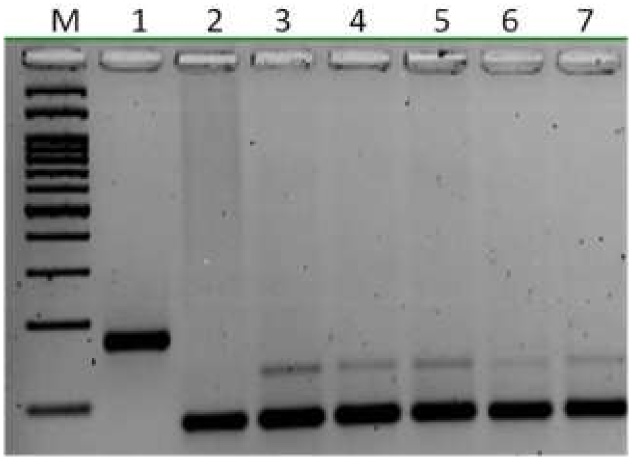


Fig.1.8: *In-vitro* validation of cross transferable markers of *Oryza coarctata*. Genotypes: **M.** 50 bp Ladder. **1.** *O. sativa* var. *japonica* (Nipponbare), **2-7:** Six accessions of *Oryza coarctata*.

Development of promising breeding materials with bacterial blight and blast resistance

Generation advancement of a three parent cross combination (Naveen/ CRMAS 2231-37 // Naveen/ CRMAS 2620-1) was carried out for combining BB and blast resistance. Presently 66 BC_3F_3 lines carrying different gene combinations for blast and BLB resistance in Naveen background are available which will be further multiplied and evaluated phenotypically.

Besides these, Near Isogenic lines (NILs) of Pooja and Naveen carrying *Xa38* gene have also been developed and advanced to BC_2F_5 generation. A backcross series of IRBB 60 (carrying four BB resistance genes) in six different cultivars namely CAU-R1, Shahsarang, Lampnah, Ranjit, PD-10 and VL-82 have been advanced to BC_2F_2 stage. Total 93 selected lines with various combinations of Bacterial Blight resistance gene from these crosses are available.

AICRIP trial performances and new entries

During 2017, three new entries were promoted to different stages of advanced varietal trials of AICRIP for Irrigated (IM) and Rainfed Shallow Lowland (RSL) ecologies. The details have been presented in Table 1.7.

Genetic improvement of rice for enhancing input use efficiency

i) Identification of suitable donors and developing nitrogen and phosphorus use efficient genotypes

a) Generation of breeding materials for nitrogen and phosphorus use efficiency under dry direct seeded condition

With the intention of developing high yielding nutrient use efficient genotypes for dry direct seeded condition, popular high yielding rice varieties were crossed with nitrogen and phosphorus use efficient donors. During wet season 2017, earlier reported nitrogen use efficient donors viz., Vardhan, N22 and Indira and phosphorus deficiency tolerant donors viz., Dular and IR64-Pup1 were crossed with popular high yielding rice varieties (Table 1.8).

Table 1.7. Performance of entries in AICRIP trials

Entry name	Pedigree	Promoted to	Zone (s)	Specific features
CR 3808-13 (IET 25997)	Selection from male sterility facilitated recurrent selection	AVT-2 (IM)	Zone V (Central Region)	Yield advantage (10.95%) over best national check. Medium slender grains, with 109 days to 50% flowering.
CR3993-13-3-67-43-2 (IET No. 26843)	CR1009 / *O. brachyantha* // CR1009	AVT-1 (IM)	Zone VII (Southern zone)	Ranked1st in Andhra Pradesh with yield of 7.77 t/ha
CR3993-15-1-5 (IET No. 25904)	CR1009 / O. *brachyantha* // CR1009	AVT-1 (RSL)	Zone VII (Southern zone)	Promoted based on superior yield performance

During the year 2018, 16 entries have been nominated for 10 different Initial Varietal Trials (IVT) of AICRIP.

Table 1.8. Nutrient use efficient donors were crossed with high yielding rice varieties

Nitrogen	Phosphorus
Vardhan x B-21	Improved Lalat x Dular
CR DHAN-205 x N22	Improved Lalat x IR-64 PUP-1
Indira x B-1	Improved Lalat x CR Dhan 801
Indira x B-21	

b) Forwarding of mapping population for low P condition

The phosphorus tolerant line AC 100219 was crossed with MTU 1010 to generate RIL population during *Rabi* 2016. During wet season 2016, crossing was attempeted and F_2 and F_3 population was raised under low P @ 10-11 kg/ha during dry and wet season of 2017, respectively.The F_2 population was found to be normally distributed for all the traits except plant height and panicle length.

ii) Identification of donors and high buffering traits for higher yield at field capacity under direct seeded condition.

a) Identification of donors for seedling vigour under field capacity

During dry season 2017,1500 genotypes were screened for seedling vigour under dry direct seeded condition. A core collection was generated from 1500 genotypes, consisting of 96 lines and they were evaluated for two seasons viz., wet season 2017 and

Table 1.9. Performance of mini core collection for early seedling vigour under direct seeded condition during wet season 2017

Genotypes	14 DAS			28 DAS				RGR (g/g/day)	AGR (cm/day)	CGR (m2)
	Plant ht (cm)	no. of leaves/pl	Seedling dry wt/pl (g)	Pl ht (cm)	Tiller no.	No. of leaves/pl	seedling dry wt (g)			
Tapaswini x Annapurna (11)	15.94	2.9	0.0137	39.42	1.7	7.1	0.2221	0.1990	1.6771	0.4962
Tapaswini x Annapurna (100)	14.57	2.5	0.0092	36.36	1.3	5.5	0.176	0.2108	1.5564	0.3971
Tapaswini x Annapurna (112)	12.99	2.5	0.0107	36.41	1.4	5.9	0.1573	0.1920	1.6729	0.3490
Tapaswini x Annapurna (64)	14.88	2.7	0.0113	33.44	1.3	5.5	0.1574	0.1881	1.3257	0.3479
Tapaswini x Dular (4)	19.58	2.7	0.0125	36.73	1.1	4.9	0.157	0.1808	1.2250	0.3440
Tapaswini x Dular (21)	15.99	2.8	0.0078	41.7	1.6	6.7	0.1506	0.2115	1.8364	0.3400
EAP 217 -12	19.11	2.7	0.0145	41.15	1.5	6.1	0.1544	0.1690	1.5743	0.3331
Tapaswini x Dular (25)	18.54	2.6	0.0124	39.75	1.1	5.3	0.1515	0.1788	1.5150	0.3312
Tapaswini x Dular (18)	19.15	2.7	0.0106	36.83	1.3	5.7	0.1482	0.1884	1.2629	0.3276
Rathu Hennati x IR-64	16.37	2.9	0.0089	40.78	1.2	4.9	0.1406	0.1971	1.7436	0.3136
Mean	**16.58**	**2.77**	**0.013**	**36.02**	**1.25**	**5.30**	**0.090**	**0.137**	**1.389**	**0.185**
CD5%	**0.39**	**0.03**	**0.0005**	**0.82**	**0.04**	**0.15**	**0.007**	**0.005**	**0.059**	**0.016**

dry season 2018, in two replications with 15 checks. The genotypes which had higher biomass, superior over the checks were identified and presented in Table 1.9 and 1.10 of wet season and dry season, respectively. Based on the crop growth rate (CGR), the better performing lines were identified and attempted to generate F_1 between better and poor performing genotypes with intention of developing biparental mapping population to identify QTLs for early seedling vigour. Further, the core collection has been planned to study GWAS to identify genes/QTLs responsible for seedling vigour in rice. The identified lines can be utilized as donors in breeding program to infuse seedling vigour trait into high yielding varieties.

b) Identification of donors and high buffering traits for higher yield at field capacity

Ninety six genotypes were screened during wet season 2017 under dry direct seeded condition in two replications with 12 checks, to identify donors for tiller number and biomass under field capacity. Among them ARC 11211 recorded biomass of 91 gm with 15 productive tillers, followed by IR 93349:38-B-16-15-6-1RGA-2RGA-1-B-B and NSIC RC 336 ranked second and third, respectively (Table 1.11). The genotypes possessing higher biomass with good number of ear bearing tillers could be utilized in breeding program to improve harvest index under direct seeded condition.

Table 1.10. Performance of mini core collection for early seedling vigour under direct seeded condition during dry season 2018

Genotypes	14 DAS				28 DAS					RGR (g/g/day)	AGR (cm/day)	CGR (m2)
	Plant ht (cm)	No. of leaves plant^{-1}	Root lt. (cm)	Shoot dry wt plant^{-1}	Plant ht (cm)	No. of leaves plant^{-1}	Tiller no.	Root lt. (cm)	Shoot dry wt plant^{-1}			
Tapaswini x Dular (18)	14.07	3.1	5.11	0.015	22.86	5.2	1.3	12	0.163	0.170	0.628	0.352
Tapaswini x Dular(4)	18.58	3.1	6.13	0.0231	21.00	4.2	1.1	14.87	0.149	0.133	0.173	0.300
Tapaswini x Dular(37)	17.67	3.1	3.66	0.0202	22.70	5.3	1.4	15.87	0.144	0.140	0.359	0.295
Tapaswini x Dular(63)	16.76	3.1	4.08	0.0197	27.08	4.5	1.2	12.49	0.143	0.142	0.737	0.294
Tapaswini x Annapurna (103)	18.8	3	4.75	0.0206	20.82	4.5	1.1	15.12	0.125	0.129	0.144	0.249
MTU1010	21.23	3.2	5.11	0.0158	28.57	6.1	1.6	13.01	0.12	0.145	0.524	0.248
IR 93336:72-B-15-4-8-1RGA-2RGA-1-B-B	14.79	3	4.1	0.0156	24.54	4.8	1.1	15.44	0.119	0.145	0.696	0.246
ARC6076	15.51	3.1	4.7	0.0182	24.89	5.4	1.3	14.45	0.118	0.134	0.670	0.238
Tapaswini x Dular(43)	17.2	3	5.24	0.0243	23.62	4.9	1.3	14.87	0.124	0.116	0.459	0.237
Tapaswini x Annapurna (98)	19.14	3.1	5.18	0.0214	21.72	5.5	1.3	15.3	0.118	0.122	0.184	0.230
Mean (n=111)	**15.79**	**3.05**	**4.79**	**0.019**	**23.65**	**4.99**	**1.24**	**13.55**	**0.066**	**0.087**	**0.561**	**0.113**
CD5%	**0.31**	**0.03**	**0.14**	**0.002**	**0.52**	**0.11**	**0.03**	**0.32**	**0.005**	**0.006**	**0.042**	**0.012**

Table 1.11. List of genotypes performed well in dry direct seeded condition at field capacity

Genotype	Plant ht(cm)	Panicle length (cm)	Ear bearing tiller	Biomass (g)
NSIC RC 336	122.90	24.20	17.17	89.25
IR 93349:38-B-16-15-6-1RGA-2RGA-1-B-B	117.65	23.47	15.33	90.65
ARC11211	118.33	22.77	15.17	91.18
IR 93334:47-B-23-16-12-1RGA-2RGA-1-B-B	110.37	23.65	15.00	86.43
ARC6101	120.57	23.62	14.67	75.78
ARC7415	127.82	23.30	14.67	79.68
ARC11260	114.68	22.65	14.67	74.25
Mean	**116.43**	**23.90**	**10.46**	**82.94**

c) Evaluation of anther culture derived DH lines under aerobic condition

To understand the performance of 112 anther culture derived double haploid (DH) fixed lines, an experiment was made under aerobic situation in augmented design during dry season 2017. Among them, 73 better performing entries were forwarded to next stage of evaluation and were raised during wet season 2017 in one square meter plot under aerobic condition. Thirteen DH lines performed well and recorded higher grain yield compared to the general mean of 0.245 kg m^{-2} (Table 1.12). Therefore, the better preformed lines were selected and forwarded to next stage of evaluation in subsequent season in bigger plots.

d) Evaluation of advanced breeding lines under aerobic condition during wet season 2017

Twenty five entries of advanced breeding lines were tested in aerobic condition with 5 checks viz., Pyari, CR Dhan 202, CR Dhan 203, CR Dhan 204 and CR Dhan 205 in two replications. Among them, grain yield was recorded significantly higher in five entries namely CR 3999-377-2-1-2, CR 4116-565-3-1-4-4, CR 4010-8-3- GSR IR1-DQ122-Y5-Y1, CR 4011-8-3- GSR IR1-DQ136-Y8-Y1 and CR 4007-547-11-2-1-2-3-3 compared to that of superior check Pyari (4.22 t ha^{-1}) (Table 1.13). Further, those five entries were nominated for AICRIP 2018 trial.

Table 1.12. List of selected DH lines tested under aerobic condition during wet season 2017

Sl. No.	G. Code	Parent	Yield (kg) m^{-2}	Yield (t/ha)
1	DH 100	27P63	0.477	4.77
2	DH 110	27P63	0.480	4.80
3	DH 106	27P63	0.434	4.34
4	DH 7	CRHR32	0.399	3.99
5	DH 14	CRHR32	0.495	4.95
6	DH 97	27P63	0.507	5.07
7	DH 14	CRHR32	0.495	4.95
8	DH 2	CRHR32	0.428	4.28
9	DH 8	CRHR32	0.432	4.32
10	DH 90	27P63	0.427	4.27
11	DH 92	27P63	0.426	4.26
12	DH 5	CRHR32	0.433	4.33
13	DH 13	CRHR32	0.429	4.29
		Mean (n=73)	0.245	2.45

Employing marker assisted back cross approach to improve the aerobic rice CR Dhan 202

To begin with, the gene specific markers for yield attributing traits were validated in a diverse set of germplasm comprising 130 genotypes. Based on the phenotypic and genotypic data, the genotype TR 128 was selected as the donor for the introgression of two yield attributing genes (*Gn1a* and *OsSPL14*) into the genetic background of CR Dhan 202. The markers selected for Gn 1a and OsSPL14, showed clear polymorphism between the selected donor and the recipient genotype. Therefore, the identified donor TR-128 (NPT line) was

Table 1.13. List of genotypes performed well under advanced yield trial in aerobic condition

Genotype	Grain yield (kg/ha)
CR 4007-547-11-2-1-2-3-3	5.34
CR 3999-377-2-1-2	5.02
CR 4116-565-3-1-4-4	5.17
CR 4010-8-3- GSR IR1-DQ122-Y5-Y1	5.32
CR 4011-8-3- GSR IR1-DQ136-Y8-Y1	5.33
Pyari (Check)	4.22
Mean (n=25)	4.37

crossed with CR Dhan 202 to generate F_1 during *Kharif* 2017 and the crossed seeds were raised during *Rabi* 2018 to generate BC_1F_1 generation.

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

To target aerobic rice situation, 21 F_1s were obtained by cross combination of one upland drought tolerant parent with high yielding irrigated/low land variety with good grain quality during wet season of 2017. From the ongoing 71 lines of F_2 generation, single plant progenies were selected and 33 lines were advanced to F_3 generation. In another set, 112 F_4 lines were advanced based on single plant progenies to F_5 generation. Eighteen promising lines of F_8 generation were bulked for next season initial yield evaluation trial.

iii) Generation of variability and development of genotypes for vegetative and/or reproductive stage moisture stress tolerance

Root involves in nutrient and water absorption, and helps plants to survive under moisture stress condition. Therefore, a study was undertaken to identify the efficient donor and variability among the genotypes for root depth and angle. Seeds of 94 genotypes were sown in a plastic mess basket that placed in 12' x 4' bag. The experiment was laid in two replicates. Forty five days after sowing, irrigation was stopped and plants were exposed to moisture stress for next twenty days to attain 65-70 kpa. Sixty days after sowing, plants were uprooted and several root related parameters were measured. Genotypes like VL Dhan 08 (G51), N22 (G15), Moroberkan (G43), Solo I (G30), AC36702 (G44), DZ78 (G22) were observed to have deep root length with more number of roots in base and ratio of deep root (RDR) (Fig 1.9). Further, these 94 genotypes were subjected with 32 root related SSR markers and the principal component analysis (PCA) was done. PCA has clearly distinguished the genotypes according to root depth and angle and was very much similar to biplot of phenotypic traits (Fig 1.10). Therefore, the above mentioned genotypes could be used in breeding program to improve root depth in drought susceptible genotypes through marker assisted breeding (Fig 1.11).

Fig 1.9. Rice genotypes screened for root length and angle

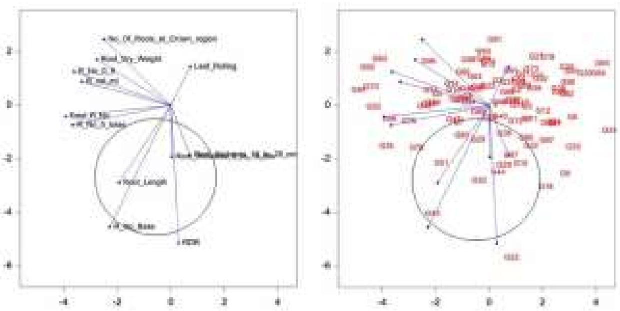


Fig 1.10. Biplot graph depicts the variation among genotypes screened for root angle and depth under moisture stress

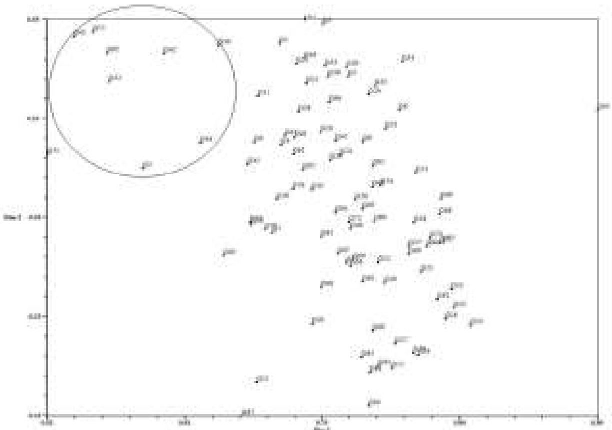


Fig 1.11 Grouping of genotypes based on functional root linked markers

ICAR-NRRI has released nine rice varieties suitable for dry direct seeded / aerobic condition. Those varieties were tested for their root parameters to understand their tolerance towards moisture stress. Among the nine genotypes, CR Dhan 202 and CR Dhan 205 recorded significantly deeper root length and root volume (Table 1.14) with good tolerance towards moisture stress (Fig 1.12).

Fig 1.12 Rooting pattern of CR Dhan 205 and CR dhan 200.

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

The popular drought tolerant donor N22 was targeted for introgression of blast resistance gene Pi9 and another major QTL, *qDTY12.1* for higher grain yield

Table 1.14. Root traits of aerobic rice varieties

Genotype	Root Length (cm)	Total no. of roots	No. of roots at base	RDR	Root volume	Root thickness (0 to 10 cm)	Root thickness (10 to 20 cm)	Root dry wt. (g)	RWC
CR Dhan 200	24.9	53	6.5	0.12	8	0.44	0.15	1.67	71.42
CR Dhan 201	25.3	43.5	5.5	0.13	5	0.48	0.14	1.25	69.94
CR Dhan 202	38.1	48	5.5	0.12	15	0.41	0.14	1.39	70.81
CR Dhan 203	28.3	87	5.5	0.06	11.5	0.63	0.19	2.56	77.16
CR Dhan 204	30.1	49.5	6	0.12	7.5	0.44	0.14	2.22	89.31
CR Dhan 205	37.5	57	6	0.11	12	0.58	0.17	1.22	84.36
CR Dhan 206	29.6	80	9.5	0.12	14	0.68	0.14	2.57	70.25
CR Dhan 207	25.7	66	8.5	0.13	12	0.6	0.2	1.45	71.72
CR Dhan 209	23.2	64	8.5	0.15	5.5	0.71	0.15	1.21	78.32
Mean	**29.19**	**60.89**	**6.83**	**0.12**	**10.06**	**0.55**	**0.16**	**1.73**	**75.92**

under drought. Therefore, N 22 was hybridized with CRMAS2620-1 for Pi9 and Way Rarem for *qDTY12.1*. The final product i.e., improved N22 is supposed to have three drought tolerant QTLs viz., *qDTY12.1*, *qDTY2.3*, *qDTY3.2* through MABC approach. During 2016-17, a total of 52 BC_2F_3 lines were genotyped for presence of *Pi9*, *qDTY12.1*, 2.3 and 3.2. *Pi9* was detected using gene specific primer (Fig 1.13). The qDTYs were detected using co-dominant SSR markers. Forty out of 52 lines were found to contain all three qDTYs and Pi9 gene. Out of these 40 lines 12 were homozygous at all loci. Representative gel picture show the amplification pattern of some BC_2F_3 lines. Plants that are homozygous for all qDTYs and *Pi9* are highlighted in red. The homozygous plants would be phenotyped for resistance and grain yield under stress.

Understanding the bacterial diversity to develop suitable rice variety for aerobic condition

16S Illumina MiSeq metagenomics was done to study the structural diversity pattern of bacteria in aerobic and anaerobic soil where monocropping was practiced for last ten years. The diversity pattern between aerobic and anaerobic was compared to understand the interaction pattern between rice plant and bacteria to develop suitable rice genotypes for aerobic/dry direct seeded condition to improve the nutrient use efficiency. Around 42.7% of population was found to be common between aerobic and anaerobic condition, 29.1% were found to be unique under aerobic. It was observed that the most abundant genus was WD2101 (Planctomycetes) followed by either *Kaistobacter* sp (Proteobacteria) or the

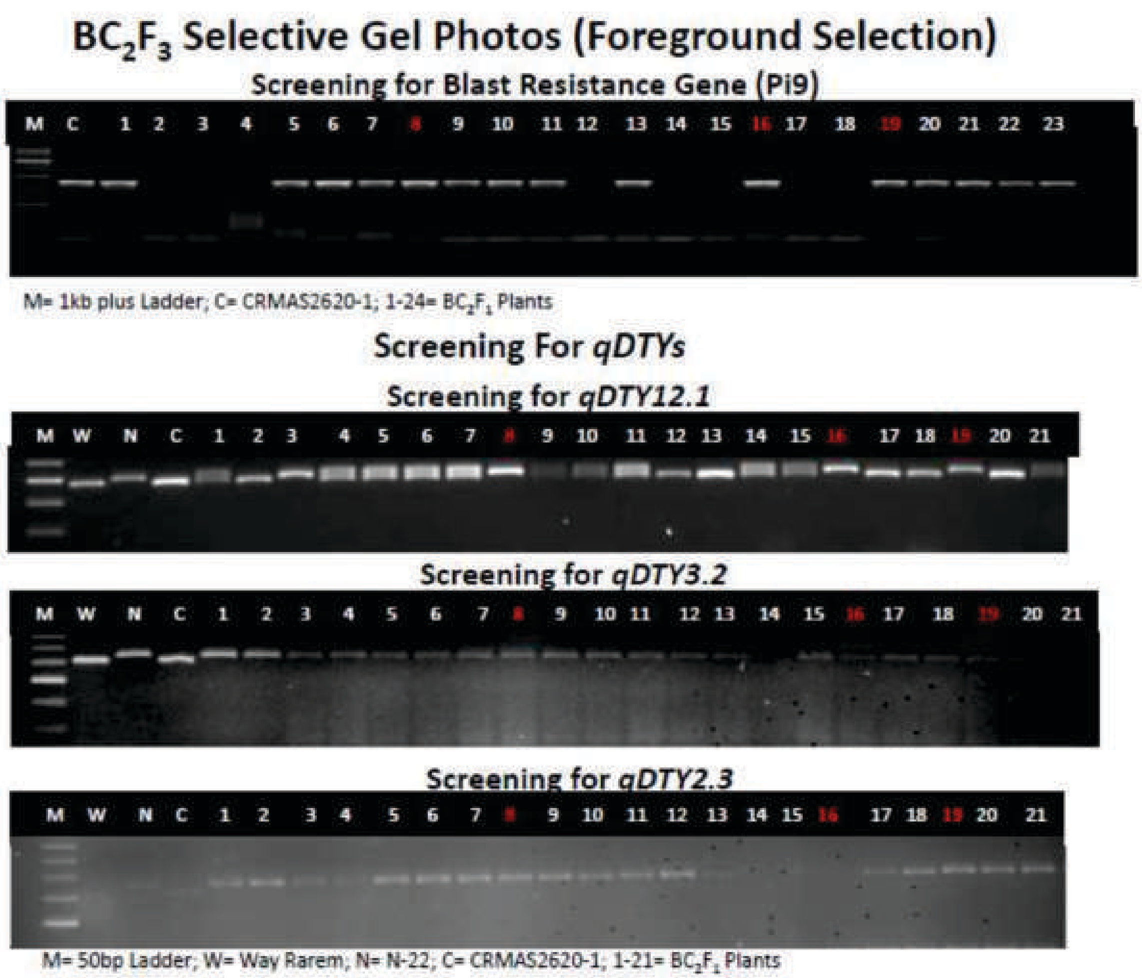


Fig 1.13 Representative Gel photo of BC2F3 Population

unclassified genus from acidobacteria. As aerobic soil is rich in content of nitrate, the population of Planctomycetes is found to be higher. Therefore, more emphasis should be given to develop nitrate response lines to achieve higher yield and to get complementary effect of microbes under aerobic condition.

Genetic improvement of rice for aroma, nutrition and grain quality

Evaluation of genotypes for identification of donors and/or breeding lines for quality traits

Cooking quality parameters

Sixty one genotypes comprising of twenty five landraces and thirty six released varieties were analyzed for thirteen different quality parameters to evaluate the existing diversity for physical parameters of grain and their cooking and eating qualities. It was observed that diversity exists for all the traits under the study. However, the range of variation was found to be more for Water uptake, Alkali spreading value (ASV), Length/ Breadth Ratio, Amylose content, Kernel breadth and Gel consistency (GC) in which the Coefficient of variation (CV)was more than 15%. Narrow range of variation was observed in case of hulling and milling percentage and Volume expansion in which the CV was less than 5%. Intermediate variation was observed in case of Head rice recovery percentage (HRR %), kernel length after cooking, elongation ratio and kernel length (Table 1.15). The existing diversity in the quality traits under study revealed the scope of their genetic improvement. Thirty five out of sixty one genotypes have been found to possess superior eating and cooking quality based on their Amylose content. Chakha, Manipuri Black rice and Tadukan have been classified as sticky based on their amylose content which is less than 10% and can be used as parents for breeding rice for North Eastern states of India where sticky rice is preferred.

Antioxidant content

Eighty-two rice genotypes were evaluated for

Table 1.15. Quality parameters of 61 genotypes

Quality Traits Analyzed	Mean	SD	Range	CV
Hulling (%)	76.07	1.51	74-80	2.0
Volume Expansion Ratio	3.83	0.12	3.75-4.0	3.0
Milling (%)	63.20	2.22	60-68	3.5
HRR (%)	55.85	5.58	43-66	10.0
Kernel Length After cooking (mm)	9.46	1.09	7.0-12.4	11.5
Elongation Ratio	1.83	0.22	1.47-2.67	12.0
Kernel Length (mm)	5.21	0.76	3.44-6.66	14.7
GC (mm)	51.05	7.95	36.0-75.0	15.6
Kernel Breadth (mm)	1.86	0.33	1.39-2.7	17.9
Amylose Content (%)	21.51	4.12	5.92-26.1	19.2
L:B Ratio	2.88	0.63	1.67-4.65	21.9
ASV	3.49	1.04	3.0-7.0	29.9
Water Uptake (ml/100g)	113.36	50.35	55-260	44.4

identification of donors for various antioxidants such as total anthocyanin content,gammaoryzanols, total phenolic content, total flavonoids and 2,2-diphenyl 2-picrylhydrazyl (DPPH) antioxidant activity (Table1.16). Highest variability was observed for total phenolic content (81.61%) and lowest value was observed for gammaoryzanols (26.53%). The total anthocyanin content was ranged from 0.175 to 1.92mg/100g with highest value observed in landrace Rayada. Genotype DZ 78 was observed with highest gammaoryzanols (84.0mg/100g).Total phenolic content ranged from 10.34-280.45 mg CEt with highest value observed in the genotype Lakhi whereas genotype Chhola Boro was identified with highest total flavonoids (115.89mg CE/100g) and DPPH activity(93.72% inhibition).

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

Three hundred and nineteen aromatic short grain segregating lines belonging to twenty four cross combinations in F_3 to F_7 generations were evaluated in irrigated condition and four hundred nineteen single plant selections and thirty six bulks were made based on their uniformity, agro-morphological characters and aroma. In an advanced yield station trial seventeen uniform breeding lines along with two aromatic check varieties were evaluated. CR 2982-26-8-2 performed best with an average yield of 5.045 t/ha against the best check variety Sobhini (4.56 t/ha).

Maintenance and collection of Aromatic Short Grain rice

Two hundred twenty six aromatic short grain rice germplasm accessions belonging to different states of India were evaluated and conserved in the NRRI gene bank for future use.

Donor line screening for imparting Bacterial Blight Resistance in "Geetanjali" variety

To identify suitable donor for aromatic long grain genotype Geetanjali, three varieties along with their NIL for Bacterial Blight resistance were evaluated through artificial inoculation. All the pyramided lines displayed resistance response. The long grained pyramided basmati genotype Improved Pusa Sugandh-5 was identified as suitable donor and crosses between this genotype and Geetanjali was generated (Table 1.17).

Evaluation of elite cultures in national trials at NRRI, Cuttack

a) AdvanceVarietyTrial1-AromaticShortGrain (AVT 1- ASG): Nine entries including six check varieties National (Shobini**)**, Zonal (CR SugandhDhan 907), quality (Dubraj, Ketekijoha, Kalanamak) and local (CR Dhan 909) were evaluated in a randomized block design with three replications under irrigated conditions. The experimental mean yield was 5.726 t/ha with 106 average days to flowering, plant height 113.2 cm and 344 panicles/m^2. Among the different entries, the entry IET 24617 performed best with an average grain yield of 6.55 t/ha, against the best check CR Dhan 909 with 6.5 t/ha.

b) *Initial Variety Trial*-Aromatic Short Grain (IVT - ASG): The trial was conducted with sixteen entries and six check varieties National (Shobini**)**, Zonal (CR Sugandh Dhan 907), quality (Dubraj, Ketekijoha,

Table 1.16: Variability observed in antioxidants and antioxidant activity in rice genotypes

Character	Mean	Range	Genotypes with highest value	CV (%)
TAC(mg/100g)	0.692	0.175-1.92	Rayada	62.89
Gammaoryzanols (mg/100g)	41.337	19.67-84.0	DZ 78	26.53
Total phenolic content (mgCEt/100g)	102.927	10.34-280.45	Lakhi	81.61
Total flavonoid content(mg CE/100g)	45.935	13.22-115.89	Chhola Boro	58.19
DPPH(% inhibition)	50.317	3.75-93.70	Chhola Boro	58.47

CEt-Catechine equivalent, CE-Catechol equivalent

Table 1.17: Disease reaction of genotypes for bacterial blight inoculation bearing different resistance genes

Genotypes	Disease Reaction	Gene combinations
Geetanjali	Susceptible	--
Pusa Sugandh-5	Susceptible	--
Improved Pusa Sugandh-5	Resistant	*xa13* and *Xa21*
Pusa Basmati-1	Susceptible	--
Improved Pusa Basmati-1	Resistant	*xa13* and *Xa21*
Samba Mahsuri (BPT-5204)	Susceptible	--
Improved Samba Mahsuri	Resistant	*Xa5, xa13 and Xa21*

Kalanamak) and local (Poornabhog).The experimental mean yield was 5.95 t/ha with 116 average days to flowering, plant height 113.2 cm and 312 panicles/m^2. Highest grain yield of 5.95 t/ha was recorded from Entry No 4815(CR 2849-2) in comparison to best check Shobhini5.80 t/ha.

c) AdvanceVarietyTrial2- Rice Biofortification (AVT 2 -Biofort): Fifteen entries including checks Kalanamak, Chittimuthyalu, IR 64 and Samba Mahsuri were evaluated in a replicated trial under irrigated conditions. The experimental mean yield was 5.26 t/ha with 103 average days to flowering and plant height 111.8 cm. Among the different entries, the check variety BPT 5204 performed best with an average grain yield of 7.60 t/ha.

d) AdvanceVarietyTrial1- Rice Biofortification (AVT 1 -Biofort): Sixteen entries including four checks were evaluated in a replicated trial under irrigated conditions. The experimental mean yield was 5.03 t/ha with 106 average days to flowering and plant height 107.0 cm and among the different entries, the entry IET 26398 (CR 2830-PLS-17) performed best with an average grain yield of 5.03 t/ha against the best check IR 64 (4.26 t/ha).

e) Initial *Variety Trial*- Rice Biofortification (IVT -Biofort): Thirty-five entries including four checks Kalanamak, Chittimuthyalu, IR 64, and Samba Mahsuri were evaluated in a replicated trial under irrigated conditions. The experimental mean yield was 4.49 t/ha with 94 average days to flowering and plant height 108.0 cm and among the different entries, the entry IET 27183 performed best with an average grain yield of 6.75 t/ha against the best check variety Samba Mahsuri 3.84 t/ha.

(f) Advance Variety Trial 2 Medium Slender Grain (AVT 2-MS): Seventeen entries including five checks National (WGL-14, BPT 5204), Zonal (Improved Samba Mahsuri), Hybrid (DRRH 3) and Local (CRS Dhan 907) were evaluated in replicated trial under irrigated conditions, the entry IET 25489 performed best with an average grain yield of 8.56 t/ha against the best check WGL 14 (8.48t/ha).

(g) Advance Variety Trial 1 Medium Slender Grain (AVT 1-MS): Twenty six entries including five checks National (WGL-14, BPT 5204), Zonal (Improved Samba Mahsuri), Hybrid (DRRH 3) and Local(CRS Dhan 907) were evaluated in a replicated trial under irrigated conditions, the local check CRS Dhan907 performed best with an average grain yield of 8.33 t/ha.

(h)Initial Variety Trial Medium Slender Grain (IVT-MS): Sixty four entries including five checks National (WGL-14, BPT 5204), Zonal (Improved Samba Mahsuri) and local check (CRS Dhan 907) were evaluated in a replicated trial under irrigated conditions, the entry No 6154 (IET 27146) performed best with an average grain yield of 7.77 t/ha against the best check WGL 14 (5.70 t/ha).

Performance of entries nominated in AICRIP trials

The aromatic genotype CR 2948-2-4-6 was found to be the first ranking entry in IVT ASG with average grain yield of 5.876 t/ha in overall six locations followed by the entry CR 2982-2-4-6with an average yield of 5.38 t/ha and became the third ranking entry. The MS grain genotype CR 3505-7-1-1-1-2-1 derived from the cross of IR 36/Vijetha ranked third in Eastern Zone with 22.85% yield advantage over best check and ranked first both in Central and Western Zones with 20.3% and 11.47% yield advantage over the best check.

New nominations for AICRIP trials

Five promising high yielding, semi dwarf aromatic cultures CR 2981-16-2-6, CR 3663-261-8-4, CR 3715-119-18-9-2and CR 2982-14-6-3 having grain yield potential of more than 4.5 t/ha and good grain quality were nominated for AICRIP trial IVT-ASG.

Release of varieties

The aromatic short grain rice variety CR SugandhDhan 908 developed from the cross Swarna/Geetanjali was released and notified by Central Variety Release Committee in 2017 for the states of Odisha, West Bengal and Uttar Pradesh for irrigated late condition.It has total duration of 143-148 days, plant height of 93.7cm, medium slender grain and desirable grain characters with grain yield potential of 5.5 t/ha.

Genetic improvement of popular landraces

Popular short grain aromatic landrace Gobindbhog collected from farmers' field in West Bengal has been purified into four sets based on their grain type, panicle architecture and intensity of aroma, following the Panicle progeny row method of selected plants.

Breeding for superior nutritional qualities

Development of new breeding lines

To combine various grain nutritional and quality traits in high yielding lines, F_2 seeds from the following three way crosses were harvested in *Kharif*-2017 and will be advanced further for selection of superior genotypes (Table 1.18)

Fig.1.14. Field photograph, panicle and grains of CR Sugandh Dhan-908

Table 1.18. New cross combinations generated for combining high yield and nutritional quality

<table>
<tr><th>Sl. No.</th><th>Genotype</th><th>Parentage</th><th>Donors</th></tr>
<tr><td>1</td><td>CR 4107</td><td>BPT 5204 Sub1/CR Dhan 310//Kalinga-III</td><td rowspan="3">Bindli- High protein (12%), High Zn (24 ppm) & low phytate
Kalinga III- High protein (11%) and Zn content (24 ppm)
CR Dhan 310, CR2829-PLN-116, CR 2830-PLS-17- High yielding high protein (9-10%) varieties/lines in Naveen and Swarna background
Kalinga III and BPT 5204 Sub1 – Good cooking & eating quality</td></tr>
<tr><td>2</td><td>CR 4109</td><td>CR 2829-PLN-116/Kalinga-III//Bindli</td></tr>
<tr><td>3</td><td>CR 4110</td><td>CR 2830-PLS-17/BPT5204 Sub1//Swarna Sub1</td></tr>
</table>

Performance of entries in AICRIP Trials

Three high protein lines in the background of popular variety Swarna have been identified which are in second year of testing in AICRIP-Biofortification trial. One genotype IET 26398 (CR 2830-PLS-17) with average 93-98 cm plant height yielded 5266 kg/ha along with 9.70 % Grain Protein Content (GPC) and 510 kg/ha protein yield as compared to local check Swarna with 8.5% GPC and 408 kg/ha protein yield. Another genotype IET 26393 (CR2830-PLS-124) recorded higher yield (5.1-6.1 t/ha) with average of 9.5% GPC in Puri and Jagatsingpur districts in on farm trials. A genotype IET 27179 (CR 2826-1-1-2-4B-2-1), has been promoted to AVT-1 in AICRIP-Biofortification Trial for its higher Zn content (27 ppm) and 5104 kg/ha yield.

Fig 1.15. High protein rice genotype IET 26398 (CR 2830-PLS-17) in 'Swarna' background

Development of high yielding genotypes for rainfed shallow lowlands

CR Dhan 802 (Subhas; IET 25673; CR3925-22-7), a cross between Swarna-Sub1*4 / IR81896-B-B-195 was identified for release in the states of Bihar and Madhya Pradesh for rainfed shallow lowland ecology. The average yield of the culture is 2344 kg/ha under drought stress and 6508 kg/ha under normal condition on overall basis in AICRIP testing. The genotype is weakly photosensitive with average maturity duration of 135-145 days. It possesses short bold grain with a test weight of 19g. It is resistant to stem borer (both dead heart and white ear heads), leaf folder, plant hopper and case worm while moderately resistant to bacterial blight, sheath rot and rice tungro virus (Fig 1.16). CR Dhan 802 has good hulling, milling and head rice recovery like the recipient parent and qualifying varieties. It possesses intermediate amylose content, short bold grain and other desirable grain quality parameters.

Fig1.16. CR Dhan 802 (Subhas)

Fig 1.17.CR Dhan 410 (Mahamani)

Fig 1.18.Grains of CR Dhan 410

CR Dhan 410 (Mahamani; IET 24471; CR2683-45-1-2-2-1) is proposed for release in the state of Odisha for cultivation in rainfed shallow lowlands. The promising culture is developed from the breeding materials of cross CRLC/AC38700. The mean yield of the variety in Odisha is 4353 kg/ha. The genotype is strongly photosensitive with average maturity duration of 160-165 days. It possesses long slender grain with long heavy panicle having moderate test weight (24g). It is resistant to stem borer (both dead heart and white ear heads) and leaf folder while moderately resistant to neck blast, bacterial blight, sheath rot and brown spot diseases (Fig 1.17). CR Dhan 410 has good hulling, milling and head rice recovery as compared to check and qualifying varieties. It possesses intermediate amylose content, long slender grain and other desirable grain quality parameters (Fig 1.18).

Five entries were nominated to AICRIP under advanced variety trial 1-Near isogenic lines (NIL) 2018 carrying five target genes/QTLs namely Sub1, Xa21, xa13, xa5 and Xa4 in variety 'Swarna' background. The entries nominated to the national trial were CR4050-121-28-13-1, CR4050-121-28-13-2, CR4050-121-28-13-3, CR4050-121-28-13-4 and CR4050-121-28-13-5. During the year, F_1 seeds carrying the genes/QTLs for submergence, drought and bacterial blight *viz*., Sub1 + DTY1.1 + qDTY2.1 + qDTY3.1 + Xa21 + xa13 + xa5 were generated by combining different donor parents. One breeding line containing **Sub1** + Xa21 +xa13 + xa5 (CR 4050-121-28-13-1 and CR 4050-121-28-13-2) were hybridized with CR Dhan 801 to obtain the desired genes/QTLs combination in F_1 seeds. In the 2nd cross series, Swarna-Sub1 is hybridized to combine Dro1 and Pup1 QTLs from Suryamukhi. However, in Pooja background, the F_1 seeds carrying the resistance genes Xa21, xa13 and xa5 for bacterial blight has been obtained from cross of Pooja with CR Dhan 800.

Around 225 superior progenies of F_4 generations of ten three way crosses were grown in F_4 pedigree nursery with a population size of around 200 plants/progeny. Amongst the three parents of each cross, one line was a *tropical japonica* derivative; another was submergence tolerant parent (Savitri-Sub1) with third parent (CR Dhan 300) for good grain quality and better yielding ability. The ten different *tropical japonica* derivatives used in the crossing programme were viz., CR 2683-45-1-2, CR 2683-28-12-1-4, CR 2687-2-3-5-2-1, CR2682-2-3-1-1-1, CR2678-5-3-2-1-1, CR2683-15-5-2-1, CR 2683-45-1-2, CR 2683-28-12-1-4, CR 2687-2-3-5-2-1 and CR2683-15-5-2-1 which were used for their heavy panicle, high grain number, strong culm and for dark and upright top leaf characters. A total of 185 single plant progenies were selected from the segregating material of the ten crosses.

Observational yield trial for rainfed shallow lowland was conducted during wet season, 2017 to evaluate the elite lines developed for nomination to the national trial. A total of 22 promising single plant fixed progenies along with 3 checks were taken in randomized block design with two replications. The performances of 8 entries were observed to be better than the three check varieties.

Advanced variety trial 2-late (AVT 2 Late)

The trial was conducted with 10 test entries including checks promoted from advanced variety trial 1-late for zone 3 of the country. Highest grain yield of 6626 kg/ha was recorded from IET 23610 followed by zonal check 6132 kg/ha and local check 5608 kg/ha, respectively, from top three entries while highest grain yield of 6132 kg/ha was obtained from regional check amongst the check varieties.

Advanced variety trial 1-late (AVT 1 Late)

The trial was conducted with 17 entries including checks promoted from initial variety trial-late for zone 3. Highest grain yield of 6998 kg/ha was recorded from IET 25967(Sonagathi) followed by 6805 kg/ha and 6243 kg/ha from IET 25042(MTU1197) and IET 25971(CR3984-1-4-4-2-1), respectively from top three entries while top grain yield of 5059 kg/ha was obtained from zonal check amongst the check varieties.

Initial Variety trial-late (IVT-Late)

Initial variety trial for late duration was conducted with 60 test entries and four check varieties generated at different breeding centers of the country. Highest grain yield of 7500 kg/ha was recorded from IET 26983 followed by 7400 kg/ha and 7150 kg/ha from IET 26926 and 26927, respectively from top three entries while highest grain yield of 5700 kg/ha was obtained from local check (Reeta) amongst the check varieties.

Initial variety trial-rainfed shallow lowland (IVT-RSL)

Initial variety trial-rainfed shallow lowland was conducted with 56 test entries including 4 checks in shallow lowland plot. Highest grain yield of 7503 kg/ha was recorded from IET 25219 followed by 7164 kg/ha and 7007 kg/ha from IET 25856 and IET 26695, respectively from top three entries while highest grain yield was obtained from zonal check Swarna-Sub1 amongst the check varieties.

Genetic improvement of rice for multiple stress tolerance in unfavorable rainfed ecology

Generation, selection and advancement of breeding material suitable for semi-deep water conditions

Two hundred and ninety four single plant selections were made at the time of flowering and maturity on the basis of plant and panicle characters from 594 single plant progenies (F_3-F_7) grown under semi-deep water conditions during *kharif*, 2017. Further, thirty five uniform lines were also bulk harvested to see their performance in next season.

Advancement of mapping population derived from Swarna Sub1 x AC 20431B for mapping of three weeks submergence tolerance genes in rice

The F_4 population generated from Swarna Sub1 x AC 20431B were advanced to F_5 generation for development of recombinant advanced lines. On the other hand, the F_2 plants (survived after 21 days submergence) were selfed to advance the generation and F_3 lines were also subjected to submergence for 21 days; the phenotype of survived plants were scored during flowering stage. The F_3 lines survived for 21 days submergence showing phenotype similar to Swarna-Sub1 were again backcrossed with Swarna-Sub1 for the incorporation of tolerance genes in to Swarna-Sub1. A total of ~800 BC_1F_1 (Swarna-Sub1x F_3) were grown and advanced to BC_1F_2. They will again be grown for phenotyping of 21 days submergence stress and the plants similar to Swarna-Sub1 showing 21 days submergence tolerance will be identified.

Validation of reported tolerant genotypes and developing mapping population for anaerobic germination (AG) tolerance

During wet season 2017, 77 highly and moderately reported AG tolerant lines were taken from gene bank and they were validated under net house condition. Among them, ARC 10424 was found to perform better with more than 95 per cent of germination under anaerobic low oxygen condition. Therefore, the genotype ARC 10424 was selected to generate biparental mapping population to identify QTLs responsible for AG tolerance.

Evaluation of advance breeding lines for yield and other traits under semi-deep water conditions- Station trial at NRRI, Cuttack

Forty improved genotypes including five check varieties (Sabita, Varshadhan, Jalamani, CR Dhan 505 and CR Dhan 510) were tested in a replicated trial under semi-deep water logged condition during *kharif*, 2017. Among the different entries, CR 3145-4-1-3-3-1 performed best with an average yield of 4.98 t/ha followed by CR 2859-S-B-2-1B-7-1 (4.29 t/ha), CR 3932-15-1-2-2 (4.05 t/ha) against the best check variety Varshadhan (4.37 t/ha) (Table 1.19).

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

(a)National Semi-Deep Water Screening Nursery (NSDWSN)

Forty five 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. 634 (IET 26678; CR 3101-1-5-1-4-1) performed best with an average grain yield of 3.52 t/ha followed by Entry No. 612 (IET 26657; OR 2439-16) with 3.12 t/ha and Entry No. 644 (Local check Varshadhan) with 3.11 t/ha.

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

Fifteen entries including three check varieties (Sabita, Purnendu and Varshadhan) were evaluated in a randomized block design with three replications under semi-deep water conditions. Among the different entries, Entry No. 504 (IET 25887; CN 2066) performed best with an average grain yield of 3.22 t/ha followed by Entry No. 507 (IET 25903; CN 2068) with 2.67 t/ha and Entry No. 509 (IET 25909; CR 3898-113-4-2-1) with 2.66 t/ha against the best check Varshadhan (2.65 t/ha).

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

Thirteen entries including three check varieties (Sabita, Purnendu and Varshadhan) were evaluated in a randomized block design with three replications under semi-deep water conditions. Among the different entries, Entry No. 402 (IET 24505; OR 2437-11) performed best with an average grain yield of 4.58

Table 1.19. Promising entries in station trial during *kharif*, 2017

Sl No	Designation	DFF	Pl Ht (cm)	EBT/m^2	Grain yield (kg/ha)
1	CR 3145-4-1-3-3-1	133	133.7	265	4980
2	Varshadhan (Check)	132	144.7	195	4372
3	CR 2859-S-B-2-1B-7-1	125	112.5	205	4286
4	CR 3932-15-1-2-2	128	111	205	4052
5	CR 3257-5-2-1-2-2-2	133	117.6	220	3691
6	CR 3237-2-4-1-1-4-1	134	151.6	206	3583
7	CR 3932-30-1-2-1	127	122.3	128	3455
8	CR 3157-9-1-1-2-2-3	132	154	250	3455
9	CR 3261-4-1-2-1-1-2	130	117.6	208	3434
10	CR 3933-35-1-3-1	128	111	249	3391
	Expt. Mean	**131**	**130.4**	**200**	**2736**
	C.D (5%)	**0.681**	**17.2**	**43**	**876**
	C.V. (%)	**0.257**	**6.5**	**10.7**	**15.8**

t/ha followed by Entry No. 408 (IET 25212; OR 2413-9) with 4.53 t/ha and Entry No. 409 (IET 25209; CR 3816-1-2-1-2-2) with 3.99 t/ha against the best check variety Varshadhan (3.63 t/ha).

Variety identified

CR Dhan 511 (CR 2789-9-2; IET 23906) was developed from the cross Gayatri / Mahsuri//CR 997 (**Fig. 1.19**). It is strongly photosensitive with average maturity duration of 160-162 days. It possesses short bold grain with heavy, long panicle having moderate test weight (21.8g). It has purple pigmented leaf sheath and apiculus colour which is good for weed management purpose. It is moderately resistant to leaf blast, neck blast, bacterial blight, stem borer (both dead heart and white ear heads) and leaf folder. It possesses intermediate amylose content, short bold grain and other desirable grain quality parameters. It was identified by VIC for semi-deep areas in the states of West Bengal and Andhra Pradesh during 53rd ARGM held at IIRR, Hyderabad during April 13-16, 2018.

Fig. 1.19. Field view and grain of CR Dhan 511

Development and evaluation of mapping population for identification of QTLs for multiple abiotic stress tolerance

A set of RIL population (R_6) from the cross Savitri/Pokkali (AC39416a) was developed. Pokkali (AC 39416a) is a multiple stress (salinity, water logging and germination stress oxygen deficiency) tolerant variety. Parental polymorphism between Savitri and Pokkali (AC39416a) was studied. In this year, among 884 SSR primers tested 76 have been found polymorphic. Phenotyping under control and water logging condition (>50 cm water depth) of this RIL population revealed normal distribution of different component traits, such as plant height, panicle length, panicle number, spikelet sterility and grain yield. The average grain yield/plant and spikelet sterility (%) were 6.38g and 33.1%, respectively in water logged situation as compared to 9.76g and 9.77%, respectively, in control situation.

Breeding for multiple stress tolerance in coastal saline areas for wet season

To breed multiple stress tolerant lines for coastal saline areas, six F_3 populations were derived. Among them a population derived from Swarna/ Kamini// Gangasiuli and another population IR64/Pokkali (AC41585)// Gangasuili were evaluated for submergence tolerance. Around 1500 submergence tolerant plants were rescued. Here, Gangasiuli is tolerant to submergence and water logging and Kamini and Pokkali (AC41585) are salinity tolerant. Twenty five elite lines and checks were evaluated under coastal saline areas under moderate level of salinity (EC= 1.2 – 5.8 dSm-1). Some of the lines performed at par or better than best check (Luna Suvarna). A few of them were found tolerant or moderately tolerant (SES score- 3-5) to salinity stress at seedling stage (at 12 dSm-1). They are presented in Table 1.20.

Table 1.20. Promising lines identified for coastal saline areas in *kharif* 2017

Elite lines	IET No.	Parentage	SES score	Yield (kg/ha)
CR2860-S-B-189-1-1-1	IET 27060	Varshadhan/SR 26B	3	3150.94
CR2459-23-2-1-1-S-B1-2-B-1	IET 25101	Gayatri/Rahspunjar	3	3742.00
CR 3437-1*-S-200-98-1		Naveen/Korgut	3	3238.00
CR2859-S-B-2-1B-7-1		Varshadhan/FL496	3	3607.30
CR2839-1-S-10-B2-B-43-2B-1	IET 25078	Swarna/FL 496	5	3293.67
CR2218-41-2-1-1-S-B3-B-1	IET 24426	Savitri/Pateni	5	4141.51
CR-2851-S-1-4-B-1		Gayatri/SR 26B	5	3166.67
CR 2850-S-2B-12-1-1		Gayatri/FL496	5	3481.13
CR2851-S-B-1-2B-1		Gayatri/SR 26B	5	3481.48
CR2851-S-1-6-2B-4-1		Gayatri/SR 26B	5	3551.89
CR 2851-S-1-B-189-1-1-1	IET 27051	Gayatri/SR 26B	5	3298.11
Luna Suvarna (Check)			5	3158.70
Rahspunjar (Check)			5	2806.50
CD (p<0.001)				118.06

Multilocational testing of promising lines were conducted at farmers' fields in Puri, Jagatsingpur and Bhadrak districts. IET 27051, IET 25078, IET 24426 were found promising with 3-6.4 t/ha grain yield under different salinity level (1.5- 6.8 dSm-1). IET 27051 and IET 25078 were also found promising in Basanti block (Sundarbans) of South 24 Parganas of West Bengal under combined stress (saline and water logged) situation. Saline tolerant line, CR2859-S-B-2-1B-7-1 (Varshadhan/FL 496) was also found promising under water logged situation with 4286 kg/ha grain yield in station trial. This was nominated in AICRIP trial 2018. Three elite lines, CR 3909-192-1-8-2 (IET 27040), CR 2860-S-B-189-1-1-1 (IET 27060) and CR 2851-S-1-B-189-1-1-1 (IET 27051) were promoted to the AVT-1 in CSTVT. Two AICRIP trials, IVT-CSTVT and AVT-CSTVT were conducted under coastal saline situation. Twelve lines have been nominated for IVT-CSTVT in 2018 based on performance in coastal saline areas.

Evaluation of pre-breeding lines and studies on adaptability of selected wide cross derivative lines for unfavourable ecosystem

Ten disomic lines of derivatives from Savitri/*O. brachyantha*//Savitri were evaluated in farmers field of Ersama block in coastal saline areas during wet season 2017. CR3993-15-11-5-6-11 (3560 kg/ha) and CR4156-509-22-25-1 (3486 kg/ha) were recorded higher yield than Luna Suvarna (2960 kg/ha) under moderate salinity level (EC- 2.4-5.8 dSm-1). They were also found moderately tolerant (SES score 5) to salinity at seedling stage under control condition (EC= 12 dSm-1).

Development of elite breeding lines for coastal saline areas for dry season

F_1 seeds (from 10 cross combinations) were generated from crossing high yielding parents, Naveen, CR Dhan 310, SR 48-2-1, TJ-12-2-2 and TJ-115-3 with saline tolerant donors *viz.* FL478, FL496, Luna Sankhi, Binadhan10, AC39416, AC39417, Bhurarati, SR26B and CST-7-1. Two thousand and thirty five BC_1F_3 short duration salt tolerant lines were planted for generation advancement and 1748 single plants were selected. Eighteen short duration salt tolerant genotypes with two checks (Luna Sankhi and Naveen) were evaluated at stress condition at farmer's field in replicated trials. The water EC was measured throughout the growth period of crop. The water EC ranged from 4.6 to 7.5dSm^{-1}. The highest yield was recorded in CR 3881-M-3-1-5-1-1-1 (4.36 t/ha) followed by CR 3881-M-3-1-5-2-5-1 (4.09 t/ha). Tolerant and susceptible checks yielded 3.15 t/ha and 2.86 t/ha, respectively.

Yield evaluation of varieties and elite breeding lines in target site

An experiment was conducted in the farmer's field with moderate salinity of 2.1 to 8.4 dSm^{-1}at Ersama block, village Kujang during the wet season of 2017. Three salt tolerant rice varieties with local one check (V_1; Luna Barial 8, V_2: Luna Suvarna 10, V_3: Bhaluki (Local Check) were taken in the main plot and different ages of seedlings (S_1: 20 days, S_2; 40 days, S_3: 60 days) were taken in the sub plot immediately after the first shower. Results revealed that varieties Luna Barial and Luna Suvarna exhibited significantly higher grain yield when 20 and 40 days old seedlings were transplanted over 60 days old seedlings. Local variety Bhaluki did not show any yield difference with different ages of seedlings (Fig 1.20).

Harnessing heterosis for enhancing yield and quality of rice

Source nursery

A total of 1137 diverse breeding lines/ varieties including male sterility sources were maintained in parental lines stock. Six hundred and thirty four of these were screened for presence of restorer (Rf) genes of which 22 lines were found positive for Rf 3 & Rf 4, they are being utilized in crossing programme.

Identification of new CMS source

Diversification of CMS sources is essential to sustain the challenges and boost this venture for future. Keeping in view, one alternative to WA-CMS was identified from *O. rufipogon* where strong restorer of WA cytoplasm i.e. IR 42266-29-3R and Pusa 33-30-3 do behave as maintainer. Sterile back-cross (BCN 726; *O. rufipogon*/IR42266-29-3R) is advanced to BC_3F_1 generation.

Identification of maintainer, restorer and new hybrid combinations

To test the combining, maintaining and restorer ability of promising genotypes, altogether five

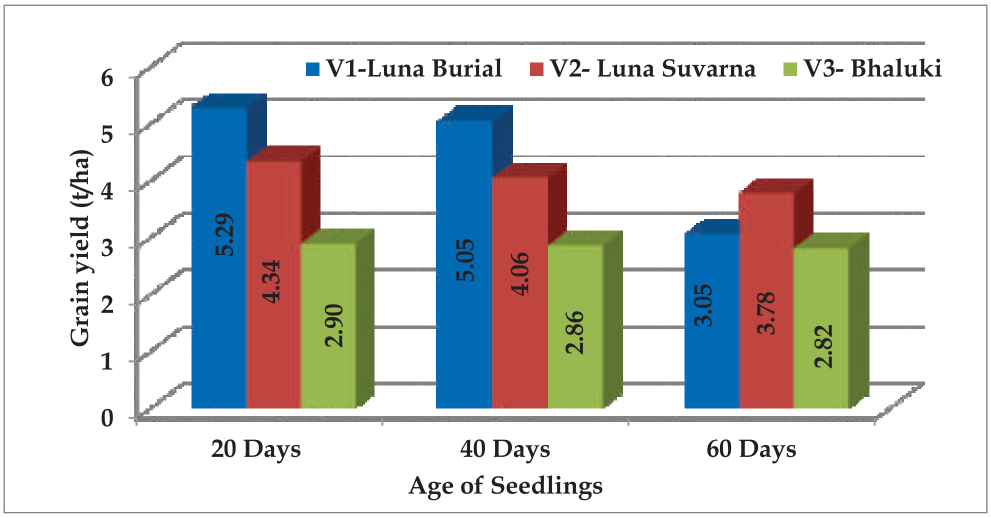


Fig 1.20.Effect of varieties and age of seedlings on grain yield of rice under saline soil condition

hundred and fifty five test crosses involving 9 CMS (CRMS 31A, CRMS 32A, PMS 17A, APMS 6A, PUSA 5A, PUSA 6A, IR 79156A, CRMS 51A, CRMS 52A, CRMS 54A and CRMS 55A) were evaluated. The evaluation results showed that 16 lines/pollen parents were promising maintainers and 69 lines/pollen parents were effective restorers (restored > 85% fertility in respective F_1). Twenty six out of 69 identified restorers were found good combiners with CRMS 31A, CRMS 32A, RTN 12A, PMS 17A, IR 80555A, IR 79156A and PUSA 5A; they were re-tested for their consistency validation (Table-1.21). Moreover, a total of 643 new test crosses (involving 12 CMS lines) were generated and will be evaluated in Rabi-2017-18 (Table-1.22).

Table 1.21. List of promising restorers identified during-2017-18

TR 6, TR 7, TR 22, SR 56-1, SR 76-1, SR 153-1, CR 87-32-244, G2579, N 371, CR 149-PS78B-32B, FF3, CR 174, CR 182, GK 155, Bio-226, GK-5017, NP 9368, NP-9361, BIO-633, Susartasan, CR 328, CRRP-1-12-13, CRRP-1-12-18, CR 302, CR 326, CR 350, CR 351, CR 368, CR 404, N 369, CR 395, CR 227, CSR 7, CR 786, CR 972, CR 1014, NP 124-8, NP 256, NP 4201, NP 7060, NP 9361, DRR Dhan 39, ATPDG 5094, ATPDG 5090, PNPH 24, HR 4111/28R, HR 4111/27R, 2830 PLN 156, INH 12049, GK Gauri, MO 18, KSP 177, GK 9560, Varadhan, Bourani, Purnedi-1, BRRI 75, NPH 2003, VL Dhan 206, HR 411126R, WGL 821, RP 5951-121-15-6-1-1B, RTN 65-1-2-2-2, ASG 3774, ATPDG 5092, NPH 911, NP 9742R, NP 125, NP 1248

Table 1.22. Number of test-crosses generated during kh-2017

CMS lines	No. of crosses generated
CRMS 31A	160
CRMS 32A	125
RTN 12A	13
PUSA 5A PUSA 6A	11 24
APMS 6A	15
PMS 17A	154
IR 58025A IR 79156A CRMS 8A IR 68897A IR 80555A	29 24 46 32 10
Total	**643**

Development of new CMS lines

CRMS 54A (WA): This is a mid-early duration semi-dwarf statured CMS (122 day duration) having medium slender (MS) grain with wide spikelet opening and purple color dual stigma exsertion (Fig 1.21). It is developed by introgression of stigma exsertion trait from DRR7B into CRMS 31B (CR 440) through conventional back-cross breeding. This is a very good combiner CMS, having >30% out crossing ability, thus, will be of immense use in development of mid-early to medium duration hybrids.

CRMS 55A (Kalinga-1): This is a semi-dwarf, medium duration CMS, developed under nucleus background of CR 440 (improved CRMS 31B) having purple dual stigma and medium slender (MS) grains, might be useful in development of hybrids for boro/rabi season (Table 1.23).

Besides, fifty eight (52-BC_2-BC_8; and 6 new crosses) sterile crosses were advanced in backcross generation and evaluated during Rabi-2017-18. Some of the promising lines with stable male sterility, good out crossing, good floret opening, along with considerable panicle and stigma exertion traits are listed in Table 1.24.

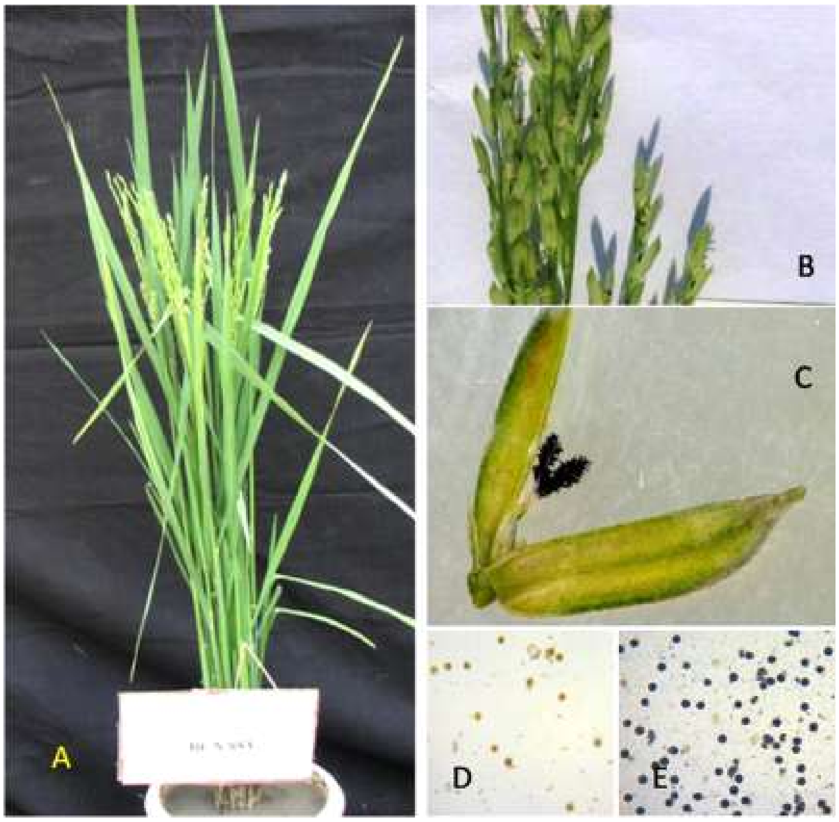


Fig.1.21. WA-CMS, CRMS54A: A-single plant view, B & C-spikelet opening and stigma exsertion, D-sterile pollen of A line, and E-fertile pollen of corresponding B line

Table 1.23. Morphological data of CMS lines evaluated during Kh-2017

CMS Line	DFF	Ht.(cm)	PN	PE%	GT	PS%	OC%
CRMS31A	100	84	11	65	LS	100	28
CRMS32A	103	85	10	62	LS	100	26
PMS 17A	104	95	13	66	LS	100	24
CRMS 54A*	98	84	10	66	LS	100	34
CRMS 55A*	102	80	11	64	LS	100	32

DFF=Days to 50% flowering, HT= plant height; PN=Panicle number; PE=Panicle exsertion; GT= grain type; PS=pollen sterility; OC=Out-crossing; *= promising CMS lines

Table 1.24. Promising sterile backcross derived lines advanced during 2017-18

S. No.	BCN No.	Recurrent parent	Source of cytoplasm	Remarks
1	BCN9199A	CR2234-1020 (WA)	WA	Good floret opening
2	BCN9200A	CR2234-1020	Kalinga-I	Good floret opening
3	BCN799A	A-180-12-1(87)	WA	Short duration, drought tolerant
4	BCN9180A	CR 2234-834(WA)	WA	Good floret opening and stigma exsertion
5	BCN7140A	IR 68301-11-64-3-6-6	Kalinga-I	Complete panicle emergence
6	BCN6853A	CR 25B-244B-440	WA	Good floret opening and purple stigma exsertion
7	BCN6862A	31B-GP-18	WA	CRMS 31B Gene pyramid with 4 BLB genes
8	BCN5863A	32B-GP- 39	Kalinga-I	CRMS 32B Gene pyramid with 4 BLB genes
9	BCN4275A	CRMP1-07-1010	WA	Good floret opening, mid late
10	BCN4276A	CRMP1-07-1010	Kalinga-I	Good floret opening, mid late
11	BCN4278A	Kuderat-2	WA	Medium duration
12	BCN4279A	Kuderat-2	Kalinga-I	Medium duration
13	BCN4346A	CR-172	WA	Late duration
14	BCN3121A	CRRP 1	WA	One time more floret opening
15	BCN2118A	CRHR-330-1	WA	Complete panicle emergence
16	BCN2582A	CR 25B-32B-337	WA	Mid-late duration, good floret opening and stigma exsertion
17	BCN3583A	CR 25B-32B-337	Kalinga-I	Mid-late duration, good floret opening and stigma exsertion
18	BCN3591A	CR 1071-C18-1840	WA	Mid-late duration, good floret opening and long stigma exsertion
19	BCN3592A	CR 1071-C18-1840	Kalinga-I	Mid-late duration, good floret opening and long stigma exsertion

Parental Line Improvement

Trait development in CMS and restorer lines

In order to make hybrids more substantial and sustainable, MABC based trait development strategies for grain yield, quality, biotic and abiotic stresses have been adopted.

Bacterial blight resistance: Parents of Ajay and Rajalaxmi were introgressed with four BB resistant genes (Xa 21, xa 13, xa 4 and Xa 5). Introgression of four BB resistance genes (Xa 21, xa 13, xa 4 and Xa 5) in restorers, CRL 22R and in IR 42266-29-3R were advanced to BC_1F_1 generation. Additionally, introgression of four BB resistance genes (Xa 21, xa 13, xa 4 and Xa 5) into a well combiner restorer Pusa 33-30-3R is under process (BC_2F_1).

Salinity and submergence tolerance: The crosses were made for introgression of *Saltol* and *Sub-1* genes into IR 42266-29-3R from FL 478 and Swarna Sub-1. F_1s were evaluated and intermated to BCF_1 generation.

Cooking quality: To improve the cooking quality of hybrid Rajalaxmi, introgression of Wx gene in respective parental lines was taken up. A total of 50 quality rice genotypes were screened for gene specific markers of SSIIa and Wx loci (cooking quality of rice), identified donor will be utilized in crossing programme.

Sheath blight resistance: It is a devastating disease for rice CMS lines, hence, MABC strategy to improve parents of Rajalaxmi was taken up. Marker validation for sheath blight resistant QTLs, qShB9-2, qSB-$9^{Tq,}$ qSB-11^{LE} and qSBR11-1 in the donors Jasmine 85, Teqing, Lemont and Tetep were completed, identified donors will be utilized for improvement of hybrids.

Genetic gain for yield: Improving genetic gain for yield traits in parents is crucial to sustain this technology in future. The markers for yield attributing traits were validated in a set of genotypes and super rice culture TR-128 was selected as the donor for the introgression of grain yield attributing traits. The marker Gn1a Indel 3 and SCM 39K pro can be utilized for restorer, IR 42266-29-3R and Gn1a 27K and SCM 39K pro for maintainer CRMS-32B.

Out-crossing: To enhance seed producibility in CMS, stigma exsertion trait was introgressed into CRMS 31A and CRMS 32A from *O. longistaminata* which is now advanced to BC_2F_1.

Complete fertility in restorer: Introgression of Rf3 and Rf4 genes conferring complete fertility in CMS based hybrids are under introgression in four well combiner partial restorers, Akshaydhan, Azucena (BC_3F_2), INH 10001 and NP 801 (BC_2F_3).

Parental lines improvement through DH approach

Twenty one DHs of maintainers (CRMS32B/RTN12B and CRMS32B/IR79156B) and 7 of restorer crosses (IR42266-29-3R/MTU1071) were developed and utilized in development of new CMS and hybrids. Notably, DH 79 (CRMS32B/RTN12B) was found to be good maintainer (maintains 100% male sterility of WA cytoplasm) having substantial out-crossing feature like stigma exsertion and now is being converted into new CMS (BC_5F_1).

Genotyping of parents by using functional markers

A total of 95 genotypes (including Nipponbare and Ratna as *japonica* and *indica* checks) were genotyped using gene based markers (functional markers) for the presence of yield related allele(s). Of them, 4 genotypes (AVT-55, CR-780-1937-2, PAN-5010 and PAN-5027) were found to possess genes for grain number per panicle {*Gna1* (*OsCKX2*)}, *STRONG CULM2 (SCM2)* and *SPIKELET NUMBER (SPIKE)* gene. Similarly, six genotypes viz. CRMS32B/IR-64, CRMS32B/244B-92, RP-Bio-226, ATPDG-5098, PTB-22 and PAN-6305 were found positive for functional allele of 1000-grain weight gene along with *Gn1a* and *SCM2*.

Restorer and maintainer breeding

For diversification and improvement of parental lines, a total 2608 single plant progenies (F_3 to F_{11} generations) generated through recombination breeding (from 109 crosses; AxR, RxR and BxB) were evaluated in pedigree nursery. Out of these, total 28 desirable fixed lines (F_8-F_{11} generation) were selected which will be evaluated under station trials. Besides, eight promising lines were used in crossing programme.

Moreover, four random mating maintainer populations (each population was constituted with 5 maintainers of specific trait) and two medium duration random mating restorer populations (each with 5 well combiner restorers) were advanced to 7^{th} random mating generations. During Kharif-2017, ten new F_1 combinations of GMS with 6 promising restorers and 6 maintainers were generated and will be evaluated in Kh-2018.

Besides, inter-subspecific crosses made to constitute MAGIC populations consisting of 10 component genotypes (one for restorer and one for maintainer) were evaluated and advanced to next intercrossing level.

Development of Iso-cytorestorer

To get-rid of CMS load from three-line hybrids, iso-cytorestorers (encourage auto-plasmic hybrids) known to be more heterotic were utilized in the breeding program. A total of 122 iso-cytorestorers from 8 hybrids were developed of those 15 were utilized in crossing programme. Total 45 test crosses were evaluated, of which 6 crosses consistently yielded superior (1.33 to 13.13% heterosis) over parent hybrid BS 6444G.

Seed production of hybrids

During the period, truthfully labeled seeds of twenty four hybrid combinations (including three released, Rajalaxmi (185.0 kg), Ajay (140.0 kg) and CR Dhan 701 (80.0 kg) were produced and distributed to the farmers and research communities. Besides, breeder seeds of CMS, CRMS 31A (110.0 kg) and CRMS 32A (85 kg); and nucleus seeds of parents of three hybrids were also produced.

Release of Hybrid /New promising hybrid combinations

Late duration hybrid, CRHR 102 (IET 25231), performed consistently in national evaluation trials and evaluated in AVT2-late trials. Besides, other hybrids CRHR 103 (IET 25278) and CRHR 113 (IET 26976) were promoted to AVT-1Late trials. Notably, 16 new hybrids, CRHR 111 (IVT-L), CRHR 112 (IVT-L), CRHR 113 (IVT-L), CRHR 114 (IVT-L), CRHR 117 (IVT-L); CRHR 115 (IHRT-MS), CRHR 116 (IHRT-MS), CRHR 118 (IHRT-MS), CRHR 119 (IHRT-MS); CRHR 120 (IHRT-ME), CRHR 123 (IHRT-ME) , CRHR 124 (IHRT-ME); and CRHR 125 (IHRT-M), CRHR 126 (IHRT-M), CRHR 127 (IHRT-M) were nominated to AICRP -2017. Moreover, a total of 34 promising combinations (3 long duration, 10 medium duration, 19-mid-early and 2 early duration) having more than 15% yield heterosis over hybrid checks US 312, Rajalaxmi & CR Dhan 701were developed.

Evaluation of AICRIP trials on rice Hybrids

During Kharif 2017, altogether three AICRIP hybrid rice trials were evaluated to identify the suitability of the test entry in Odisha. Data were recorded, analyzed and submitted to the coordinator.

1. Under IHRT-M, total 31 test entries (including one local check, Tapaswini) were evaluated, IHRT-M-20 (PHI-17101) recorded highest yield of 8091.00 kg/ha followed by entry IHRT-M-27 (HRI-174) with 7896.00 kg/ha.
2. In IHRT-MS, total 20 test entries, where HRT-MS-18 recorded highest yield of 8231.0 kg/ha followed by HRT-MS-12 (CRHR 19) with 7859.0 kg/ha.
3. In MLT of released hybrids trial, total 21 test entries including one LCV-Tapaswini were evaluated, where hybrid GK-5022 recorded highest yield of 6728.0 kg/ha followed by US-312 with 6411.0 kg/ha.

Development of new generation rice (NGR) for breaking yield ceiling

Evaluation of morpho-physiological traits of promising/elite lines for higher physiological efficiency

Eight NGR cultures were tested and it was found that some were equivalent with the Photosynthetic rate (µ mol CO_2 m^{-2} s^{-1}) of best check i.e., MTU 1010. The genotype with high photosynthetic rate did not produce maximum grain yield (SR 1-3-1-1). However, some of the genotypes with high yield could produce high photosynthesis, therefore, could be utilized further (Fig 1.22).

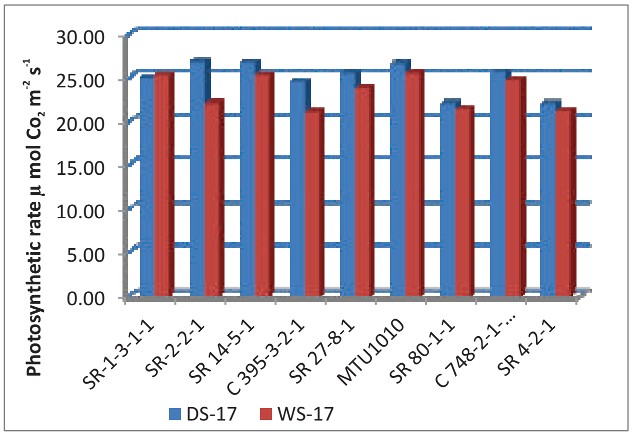


Fig 1.22.Depicting high yield with high photosynthetic rate

The pattern of biomass accumulation shows that total biomass was higher than the best check, particularly at 50-55 days after planting till maturity. However, at early stage the biomass of NGRs were comparable with checks because of less no. of tillers. Thus, it was clear that biomass played an important role in higher grain yield in NGRs both in dry (Fig 1.23) as well as wet season (Fig 1.24).

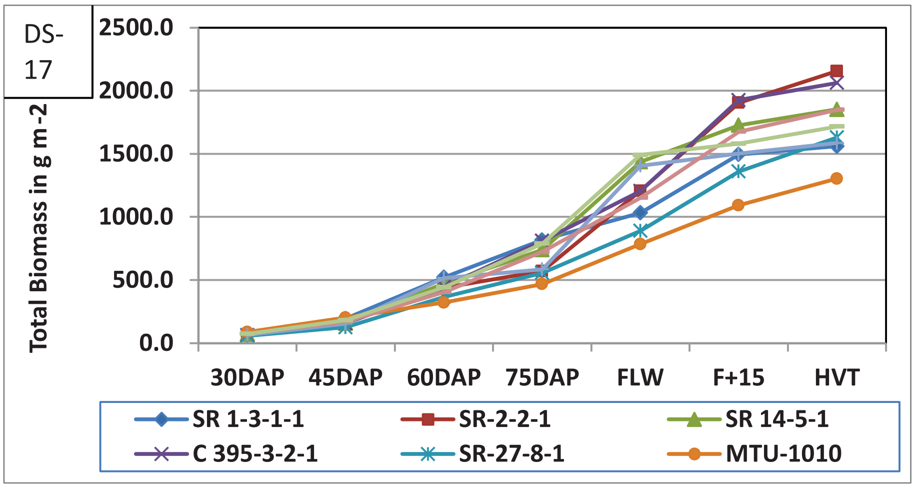


Fig 1.23. Higher grain yield with total biomass in rabi season

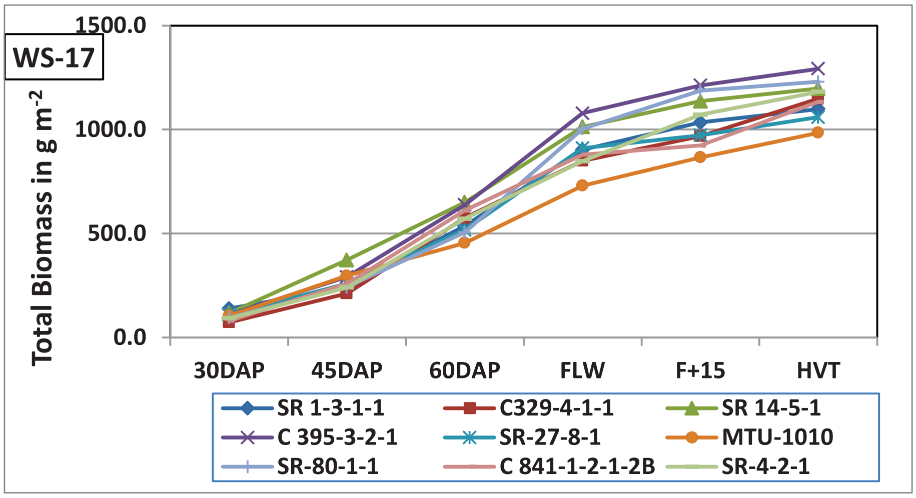


Fig 1.24. Higher grain yield with total biomass in kharif season

Generation of variability and selection superior transgressive segregants conferring to the ideotype of NGR along with high yield, field tolerance to major biotic stress and acceptable grain quality

During Rabi 2017, 70 NGRs basically derived from second generation NPTs were tested in AYT for evaluating their grain yield and morpho-physiological traits under higher fertilizer dose (120: 50:50::N:P_2O_5:K_2O). The entries were tested in Randomized Complete Block Design (RCBD) with two replications against the checks viz., Naveen, IR-64, MTU-1010 and Swarna. Among the genotypes, SR 27-1-2 recorded highest yield of 7.91 t/ha followed by SR 64-1, SR 48-2-2, SR 36-2-1 and SR 55-1 with grain yield of 7.66, 7.44, 7.13 and 7.00 t/ha, respectively, in small plot experiments. There were yield advantages of 33.1%, 28.9%, 25.3%, 20.1% and 17.9%, respectively, against best check Ajay (5.94 t/ha). Similarly, during kharif 2017, the same set of genotypes was planted under similar experimental condition. Out of all the lines, SR-18-7-1 performed the best (7.56 t/ha) followed by SR-1-5-1-1(SG) (5.96 t/ha), SR-30-1-1 (5.62 t/ha), C-395-3-2-1(5.61 t/ha) and SR-67-1 (5.31 t/ha). There were yield advantages of 60.8 %, 26.8%, 19.6%, 13.0% and 12.6 % against hybrid check (Ajay). It was analyzed that, there were appreciable number of ear bearing tillers/m^2, better fertile grain number, along with higher 1000 grain weight contributed to higher grain yield in comparison to checks (Table 1.25).

Table 1.25. Promising Selections with distinct superiority over checks, AYT 1

Genotype	Grain Yield (t/ha)	% inc.~ Check	Plant height	Panicle length	Avg Le. Len.	Avg. Leaf Width	Tiller	No. of Grains/ Panicle	1000 G WT.	Flowering duration
SR-27-1-2	7.91	33.1	107.5	34.5	35.96	1.56	7.3	147.85	22.488	126
SR-64-1	7.66	28.9	100.8	30	33.85	1.28	6.9	97.55	27.012	93.5
SR-48-2-2	7.44	25.3	129.1	30.8	49.5	1.41	9.4	124.5	23.514	124
SR-36-2-1	7.13	20.1	100.7	30.8	41.65	1.785	5.2	108.43	27.185	120
SR-55-1	7.00	17.9	96.1	27.1	41.3	1.155	7.4	91.05	28.968	133.5
SR-27-8-1	6.89	16.0	117.4	32.6	40.6	1.48	9.0	105.0	20.34	123
SR-9-2-1	6.67	12.3	130.2	32.3	45.1	1.275	7.7	78.72	28.106	121
SR-27-4-1-1-1	6.47	9.0	104.9	31.8	39.75	1.23	7.1	134.5	20.892	124
C-542-3-2--1-1-1-1	6.45	8.6	114.8	30.8	52.45	1.53	8.3	109.3	20.997	135
SR-36-6-1	6.38	7.5	121.4	32.4	48.25	1.325	9.1	93.4	27.784	119.5
C-345-5-1-1-2	6.35	6.9	109.2	29.3	42.95	1.755	9.4	112.2	24.26	126.5
SR-45-3-1	6.33	6.6	96.4	27.7	38.95	1.64	7.6	196.1	21.341	93.5
SR-6-1-1-1	6.19	4.3	97.1	26.1	32.45	1.355	8.2	103.7	26.061	145
Ajay	5.94	-	116.1	30.1	41.75	1.265	7.4	139.3	23.531	122
CD(0.05)	0.69	-	5.7	3.2	4.2	0.26	1.8	13.5	2.11	3.8

In PYT during Kharif 2017, some of the genotypes performing well in comparison to check were found to be the recombinants of tropical *japonica* with WC genes. These genotypes were having medium maturity and height and would be further tested for their superiority and stability (Table 1.26).

One of the NGR genotypes previously identified as superior and supposed to be the best among the lot **CR 3856-44-22-2-1-11-5 (SR 1-3-1)** was tried for multilocational trial (MLT) in 6 different districts of Odisha (Fig 1.25). The MLTs were conducted in farmers' field under the supervision of Deputy Directors of Agriculture, Govt. of Odisha. The results were encouraging with 36.49% higher productivity over the farmers adopted variety. The trial with recommended dose of fertilizer and package of practice could record a grain yield 65.28 to 96.0 q/ha, with potential grain yield of 96 q/ha (Fig.1.26).

Performance of genotypes in AICRIP

NPT: Out of three entries in AVT 1, CR 3969-24-1-2-1-1(IET 26418) and CR 3856-44-22-2-1-10-1-5 (IET 26420) performed better over the best check with 41% (overall) and 31% (Zone VII) yield superiority respectively. Similarly, in IVT NPT two entries namely, CR 4113-3-2-1 (IET 27263) and CR 3856-44-22-2-1-9-1 (IET 27267) performed superior w.r.t. best check with 21% and 11% higher yield than the best check in Zone III.

RSL: CR 4112-3-2-1-1-1-1-1 (IET 26716) was promoted to AVT 1 with 10.0% yield superiority over best check.

Boro: One entry CR 3724-1(IET 25692) was promoted to AVT 2 with 32% yield superiority over best check. Similarly, CR 3856-44-22-2-1-10-1-5(IET 26439), CR 3938-2-1-1-2-1 (IET 26428) and CR 3856-11-2-1-1-1-1-1(IET 26436) were promoted to AVT 1 with better productivity of 15%, 34% and 5% over best check.

Table 1.26. Promising recombinants with high grain yield

DESIG	Cross	Grain Yld	% inc. over chk	Duration	Height
CR 4113-3-2-1-1-1-1	CR 3724-1/ TJ 171-1*	7.15	74.0	114	116
CR 3856-72-1-2-1-1-2-1-1-1	CR 2324-1/ IR 73963-86-1-5-2	6.83	66.2	118	75
C-741-6-2-3-1-4-2-2-1	Cr 3504-181-3-1/CR 3727-12-1	6.54	59.2	105	88
CR 3856-44-22-2-11-1-4	CR 2324-1/ IR 73963-86-1-5-2	6.1	48.4	113	116.4
C-638-6-2-1-1-2-1	NDR 1045/WC 69//Naveen	5.04	22.6	112	113.8
C-861-1-2-1	CR 2324-1(N)/ IR 73963-86-1-5-2	5.02	22.2	104	97
C-636-6-2-1-2-1-1	MTU 1010/Wc 274//MTU 1010	5.02	22.1	107	104.2
Naveen (B.C)	-	4.11	--	100	111.3
CD(0.05)		0.64	--	-	-

* WC indicates Tropical japonica with wide compatibility gene

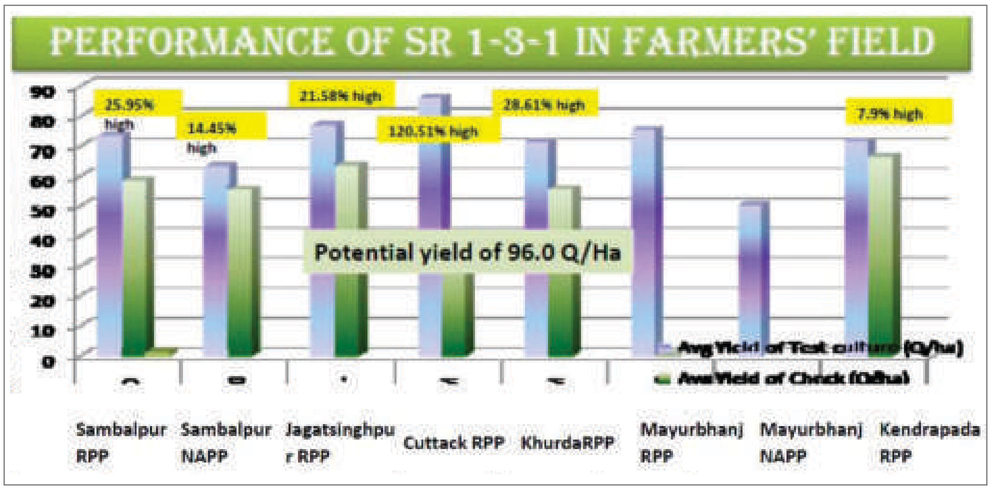


Fig 1.25. Performance of SR 1-3-1 in farmers' field (Multilocation trial) (RPP: Adoption of Recommended package of practices; N.A.P.P: Non-adoption of Recommended package of practices)

Generation of variability for NGR ideotype suitable for favorable uplands

To generate variability for traits related to ideotype of NGR, six new crosses were generated during 2017 involving new plant type lines: SR-1-5-1 x Anjali F1(Anjali12.1NIL x IR877077-118-B-B-qDTY2.2&4.1); Sahbhagidhan x NPT-PSR-8; Vandana x NPT-PSR-17; Kalyani-2 x NPT-PSR-13; Anjali x NPT-PSR-15; Kalyani-2 x NPT-PSR-15

Evaluation of advanced breeding lines in Kharif 2017 under rainfed transplanted favourable upland conditions

Experiments were laid out in randomized block design under rainfed shallow lowland conditions with a fertilizer dose of 80:60:40. Among the four F_7 lines Anjali x NPT-PSR-14 (IR74714-141-3-3-2-3) cross, none recorded higher yield than Anjali. Out of four F_7 lines of Sahbhagidhan x NPT-PSR-18 (IR73893-71-2-6-3) cross, one line (CRR796-2) was recorded with significantly higher yield (761.3 g/m^2) than Sahbhagidhan (632.5 g/m^2). A total of 85 advanced progenies from CR Dhan 40 x NPT-PSR-14(IR74714-141-3-3-2-3); CR Dhan 40 x (IR64xCG14)-345 and CR Dhan 40 x NPT-PSR-12(IR73963-86-1-5-2-2) crosses, 22 progenies showed higher yield than CR Dhan 40. Performance of some promising progenies has been given in Table 1.27. During the experiment there was no moisture stress.

Screening and evaluation of fixed NGR cultures for field tolerance to major biotic stress (sheath blight pathogen, *Rhizoctonia solani*) *Kharif*, 2017

Thirty seven NGR lines were artificially inoculated with the sheath blight pathogen, *R. solani* along with susceptible check Tapaswini. Two lines viz., C 226-52-1-1-1-1-1-1-1 (MR) and C 226-76-1-1-2-1-1-1 (MR) showed moderately resistant reaction (SES score of

Fig 1.26. Performance of SR 1-3-1 in farmers' field at maturity stage in Cuttack district

Table 1.27. Performance of promising breeding lines from CRDhan40 x IR73963-86-1-5-2-2 cross in *kharif* 2017

Entries	Days to flowering	Plant height (cm)	Panicles/ hill	Panicle length (cm)	Grain length (mm)	Grain width (mm)	Grain yield (kg/ha)
CRR789-11	65	126.1	18.0	24.4	8.3	2.6	10750
CRR789-8	67	125.3	14.9	24.1	8.8	2.8	10250
CRR795-6	55	130.9	20.5	24.6	6.6	2.4	10140
CRR790-74	59	134.4	19.1	25.4	9.2	2.8	9525
CRR790-60	61	119.2	18.0	22.9	7.7	2.4	9468
CR Dhan 40	56	132.8	13.5	23.7	7.8	2.7	6688
LSD (5%)	*0.9*	*1.7*	*1.2*	*1.8*	*0.2*	*0.1*	*1462.0*

1.1-3), 4 lines being tolerant (score of 3.1-5) whereas, 31 lines were found to be susceptible (score 5.1-7) to highly susceptible (score 7.1-9). Similarly, SNP genotyping was done for NGR cultures and it was found that genotypes viz., SR-76 and SR-4-2-1 were found with resistance for Xa4 and Xa 21; C-772-2-2-1-1-1-1 and M-1203 with Xa4 + 5 and WC-361 with Xa13. Hence these genotypes would be further phenotyped and could be used as potential parents with high grain yield.

Genetic improvement for BLB and sheath blight in NGR cultures by classical and molecular breeding

One of the NGR genotypes with very high yield, CR 3856-44-22-2-1-11-1 (SR1) endowed with super agronomic traits viz., heavy panicle, high grain number, semi-dwarf height, strong culm, erect long and wide top three leaves along with field tolerance to major diseases and pests was performing outstanding, consistently over seasons in irrigated situation. SR 1 was reportedly susceptible to BLB and sheath blight. There is one ongoing programme of introgression of three genes namely, xa5, xa13 and Xa21 in to SR1. In this context, SR 1 was crossed with IRBB-60 for genes viz., Xa21, xa13 and xa5. Marker assisted backcrossing was done in foreground selections for BC_1F_1 for the presence of genes. During 2017-18, backcrosses were performed and BC_2F_1 plants were grown during Rabi 2017. Foreground selection was carried out in BC_2F_1 with *Xa21*, *xa13* and *xa5* specific markers (Fig 1.27). BC_2F_2 seeds were collected and grown during Rabi 2018. Foreground selection was carried out in 443 BC_2F_2 plants with *Xa21*, *xa13* and *xa5* specific markers and plants with different gene combinations were identified. The number of 3 gene and 2 gene combinations were found to be 10 and 8, respectively.

For sheath blight, few moderately resistant donors have been identified viz., Tetep, Jasmine 85, Lemont and CR1014. These have been crossed with NGR culture CR 3856-44-22-2-1-11-1 during kharif 2017.The F_1 with true hybridity would be crossed with introgressed culture homozygous for BLB. Some of the markers such as RM 7443 has been found to have good polymorphism with the donors and recipient and could be utilized with other markers.

Genetic improvement for yield and grain quality traits in available NGR cultures by classical and molecular breeding

Thirty three reported markers for grain yield and related traits were tested in 48 NGR fixed lines and 11

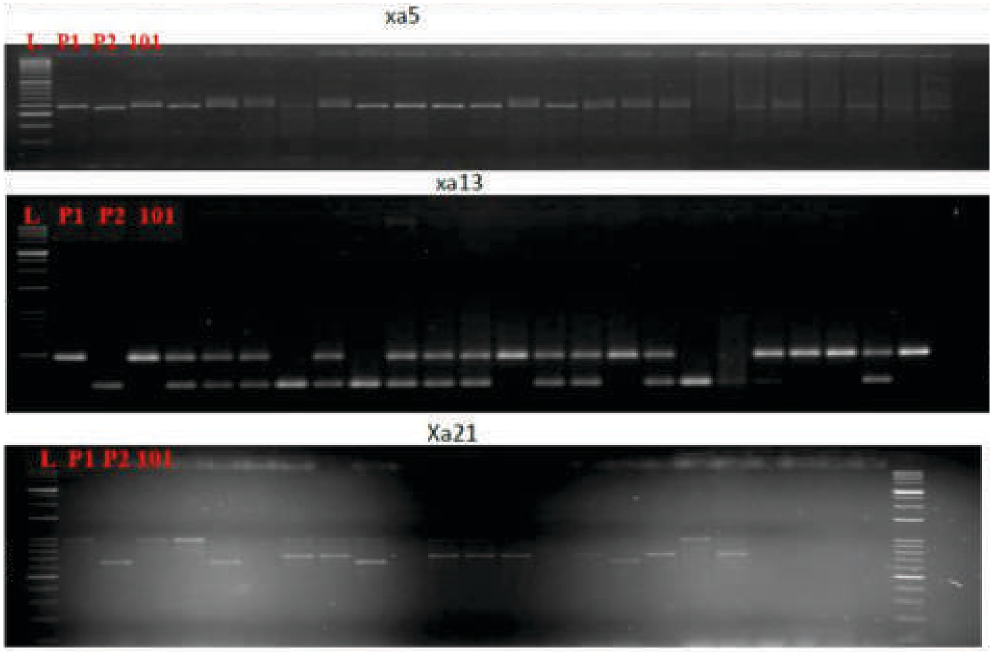


Fig 1.27.Out of 245 plants screened of resistant alleles of xa5,xa13 and Xa21,Plant number 101 carried all three resistant alleles fot BB Resistance.

were found polymorphic. These polymorphic markers represented grain size, grain number, grain weight, erect panicle and strong culm. The genotype SR 55-1-2 was found to be positive for maximum number of alleles (six) representing thicker grain size, higher grain number, panicle branching, height and grain yield. Further, the genotypes viz., SR 15-2-1, IR 102699-3-4 and SR 1-3-1 showed positive for five alleles each. The culture SR 15-2-1 was recorded positive for thicker grain size, higher panicle branching, height and grain number. Similarly, IR 102699-3-4 was found positive for higher grain width, erect panicle, grain number, strong culm, height and grain yield, whereas, SR 1-3-1 had positive allele for thicker grain size, erect panicle, higher grain number, panicle branching, height and yield.

Screening of functional OsSPL14 gene in 96 NRRI released varieties using functional markers

OsSPL14 is one of the important yield genes which enhances yield through increasing branching and grain numbers per panicle. Amplification of genomes of 96 NRRI released varieties with functional markers WFP and IPA1 specific for *OsSPL14* gene indicated the presence of WFP in 10 varieties while IPA1 in 69 varieties. All the 10 rice varieties for WFP (except Phalguni) also carry positive allele of IPA1 functional marker.

Screening of functional *OsSPL14* gene in Super Rice using functional marker

The amplification of genomes of NGR genotypes, SR18-7-1, SR14-5-1, SR6-1-1, SR1-5-1, SR395-3-2-1and SR1-3-1 with functional markers WFP and IPA1 specific for *OsSPL14* gene indicated the absence of WFP, while presence of IPA1 in all the six genotypes, indicating the scope of yield potential improvement in these NGRs cultures by introgression of positive allele of WFP gene (Fig 1.28).

Development of gene-based markers for SPL gene family in rice

SQUAMOSA (SQUA) promoter-binding-like (SPL) genes represent a family of plant-specific transcription factors that controls plant development. There are 19 SPL gene families in Nipponbare genome. A total of 58 SSR markers for 16 SPL genes were designed ranging from 1 to 8 markers per gene using the gene sequences downloaded from RGAP database. A total of 9 markers for 7 SPL genes viz., *SPL6, SPL7, SPL8, SPL10, SPL13, SPL14* and *SPL15* showed differential amplification between the NGR (SR-18-7-1, SR-6-1-1) and other low yielding rice (IR-64, Nalbora) genotypes (Fig 1.29). These markers will be utilized for characterization of other super rice collection for yield related traits.

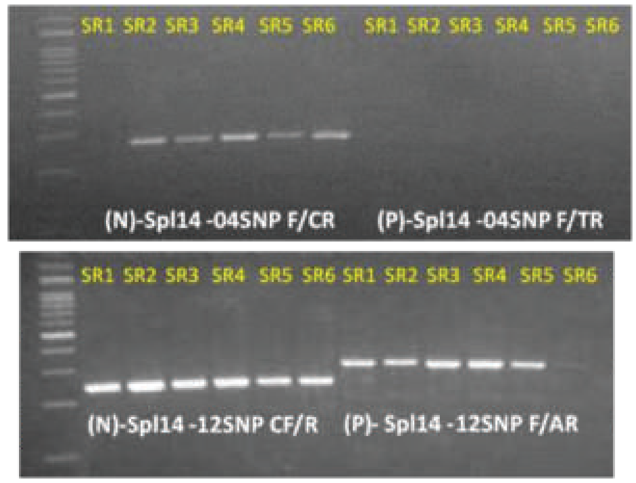


Fig 1.28. Screening of functional OsSPL14 gene in Super Rice cultures using functional markers
SR: SUPER RICE LINES
Sr1: SR 18-7-1, SR2: SR 14-5-1, SR3: SR 6-1-1, SR4: SR 1-5-1, SR5: SR395-3-2-1 , SR6: SR1-3-1

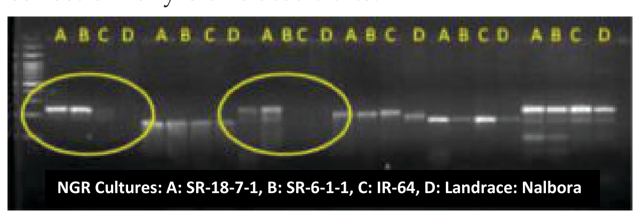


Fig 1.29: Variation in gene-based markers for SPL gene family in NGR showing differential amplification with other low yielder rice.

Association studies to identify QTLs for grain yield and its attributing traits

A panel of 60 rice genotypes comprising of 48 new plant types (NPT), with yield of ~5 to ~9.8 t/ha (including 6 *indica*, 3 *tropical japonica,* and 3 *temperate japonica*) were used to identify QTLs associated with 11 grain yield and yield attributing traits.

A total of 85 simple sequence repeat (SSR) markers was employed in association mapping to detect quantitative trait loci for yield attributing traits. Sixty-six (77.65%) out of 85 SSR markers were found to be polymorphic, which amplified 154 alleles with an average of 2.33 alleles /locus. The PIC values varied from 0.516 to 0.92 with an average of 0.704. A moderate level of genetic diversity (0.39) was detected among genotypes. GLM, MLM and FaST model based association analysis identified 46, 15 and 22 SSR markers significantly associated with grain yield and yield attributing traits, respectively. All SSRs were found significantly associated with a trait in four seasons and their mean at the 5 % level of FDR. The 30 SSR markers had a positive association with QTLs, which have been reported earlier. A total of 16 novel QTLs for seven traits, namely, tiller number (*QTL-6.1)*, panicle length *(qPL-1.1, qPL-5.1, qPL-7.1, qPL-8.1*), flag leaf length *(qFLL-9.1*), flag leaf width *(qFLW-5.1, qFLW-8.1),* 1000-grain weight *(qTG-2.2, qTGW-5.1, qTGW-8.1),* l/b ratio *(qSlb-3)* and grain yield per plant *(qYLD-5.1, qYLD-6.1a, qYLD-7.1, qYLD-11.1)* were identified.

In this context, prospective introgression of these novel QTLs into elite rice cultivars would help them in increasing yield potentiality and breaking yield ceiling.

Identification of Polymorphic markers between *japonica* and *indica* rice

A set of 152 STMS markers were used for genotyping *indica* and *japonica* ecotypes. Out of 152 markers, 151markers were found to be amplified in both the ecotypes while one was unique to *japonica*. Further, the markers common to both the ecotypes were used for polymorphism survey among them. Out of the 151 common markers, 41 were found to be polymorphic and 12 markers spread over eight chromosomes showing distinctly different band size among the cultivars of two geographical races (Fig 1.30). These polymorphic markers will be very useful for study of diversity among the cultivars of the two ecotypes and will be used for construction of linkage map in a mapping population derived from hybridization among them.

Biotechnological Strategies for Genetic Improvement of Rice

Androgenesis in generation of green plants from F_1s of Chakhao X IR20

The androgenic method standardized for F_1 of Chakhao (Manipuri black rice) X IR20 in *Kharif,* 2017

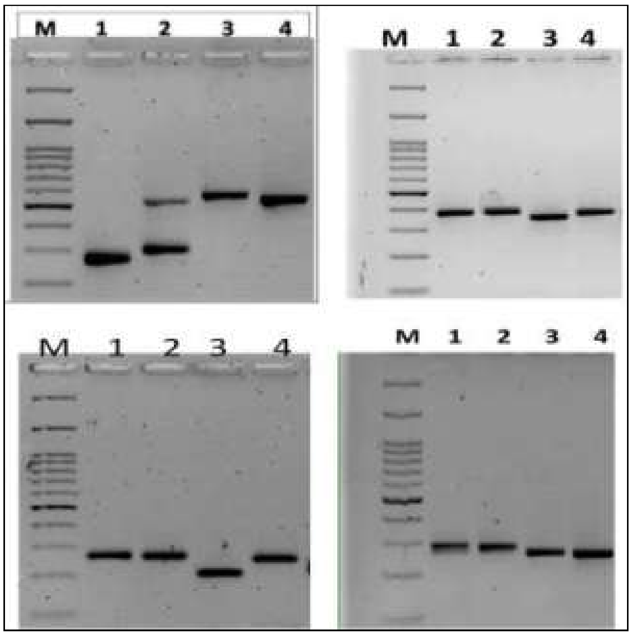


Fig. 1,2,3 & 4: Gel picture depicting marker distinguishing Japonica and Indica rice. M: 100 bp ladder; 1: Nipponbare; 2: T-309; 3. Kasalath and 4. Tetep.

Fig 1.30.Distintiveness between *indica* and *japonica*

was tested to check the reproducibility of androgenesis and generation of more number of DHs using anthers of F_2 in *Kharif*, 2017. The established callusing media, N6 semi-solid media supplemented with auxin-to-cytokinin ratio of 4:1 showed its reproducibility by producing 28% callus induction when the anthers were cultured at the mid-late uninucleate stages of the microspore after 3-4 weeks of culture. Similarly, light brown calli cultured in MS media along with cytokinin -to- auxin ratio of 2:1 responded to 75% green shoot regeneration after 2-5 weeks of culture. Subsequently, after elongation of green shoots, a total of micro shoots formed a high percentage (100%) of roots grown in MS media supplemented with auxin and cytokinin in 10:1 ratio. A total of 52 green plants were generated and transferred to net house for ploidy evaluation.

Evaluation of ploidy status of green plants derived from F_1s of Chakhao X IR20

A total of 52 green plants developed through anther culture of F_1s of Chakhao x IR20 were evaluated to confirm the ploidy status of 52 plants after seed set; all were found to be diploids (Fig.1.31). Surprisingly, no other ploids like haploids, tetraploids and polyploids were observed among the green regenerants in this culture. A large range of variability in morpho-agronomic characters was noticed in all DHs in A0 generation. All the diploids were found to be doubled haploids and were confirmed through SSR markers.

Fig. 1.31 Ploidy status in DHs of F1s of Chakhao X IR20

Assessment of parental allelic contribution in doubled haploids, derivatives 27P63

A total of 650 SSR markers were screened to test the hybridity in 27P63, out of which 16 pairs were identified. Further, all 16 markers were used to check out the allelic distribution of either parent in 92 randomly selected DHs generated from 27P63. Based on the $\chi 2$ test at $p < 0.01$ and 0.05 , all 16 markers (100%) favored parental alleles revealing the expected 1:1 ratio for the parental alleles at $p < 0.05$ which included markers randomly distributed in all 12 chromosomes (Table 1.28). Genotyping of the randomly selected 92 DHs from 325 revealed the expected 1:1 allelic ratio, suggesting that DH lines are true representatives of the gametic constitution and are derived from the F_1 pollen of 27P63.

From a total of 32 loci characterized from 92 DH lines, 48.85 % of the alleles were of the first allele type while 51.15 % were of the second parent type. Among these 16 markers, no segregation deviating from the expected 1:1 ratio was observed, indicating that an equal amount of genetic material from each parent has been transmitted to the progenies through anther culture, which is evident from the even distribution of alleles in the DH population confirmed through Chi-square test.

Table 1.28. Parental allelic contribution in DHS showing 1:1 ratio using SSR Markers

Primer	DH population (1:1 expected ratio)		$\chi 2$
	F_a	F_b	
RM 26868	48.91	51.09	0.054
RM 23310	42.39	57.61	2.141
RM 23248	55.43	44.57	1.098
RM 17322	48.91	51.09	0.054
RM 17903	50.00	50.00	0.011
RM 20046	48.91	51.09	0.054
RM 20539	47.83	52.17	0.185
RM 219	51.09	48.91	0.054
RM 240	46.74	53.26	0.402
RM 14487	46.74	53.26	0.402
RM 14602	43.48	56.52	1.576
RM 16291	58.70	41.30	2.793
RM 21580	46.74	53.26	0.402
RM 15441	53.26	46.74	0.402
RM 20691	45.65	54.35	0.707
RM 28011	46.74	53.26	0.402

F_a=frequency of 'a' allele; F_b=frequency of 'b' allele; (*) significant difference at 0.05 ($\chi 2$ (t) = 3.84, ("d) significant difference at 0.01 ($\chi 2$ (t) = 6.64.

In vitro mutation in callus culture for evaluation of glyphosate tolerance/resistance

Calli mutagenesis and subsequent selection of regenerants in herbicide selective medium would be an improved approach for the development of herbicide tolerant rice for targeted herbicide which not only saves time but also is cost effective. Therefore, a preliminary study was carried out to mutate the calli raised from a variety, Shaktiman. The 4-week old calli were treated with 0.2% EMS for 2, 4 and 6 hours and cultured in the callusing media supplemented with 2, 4, 8, 10 ppm glyphosate separately along with control. Since, 2 hour EMS treated calli proliferated significantly in 2 ppm glyphosate, these calli were used for shoot regeneration and responded after 3-4 weeks of culture in MS media supplemented with auxin and cytokinin (Fig.1.32). Subsequently, 7 plants were produced and transferred to net house (Fig.1.33). The seeds were collected from individual plants and grown to check the tolerance/resistance to glyphosate.

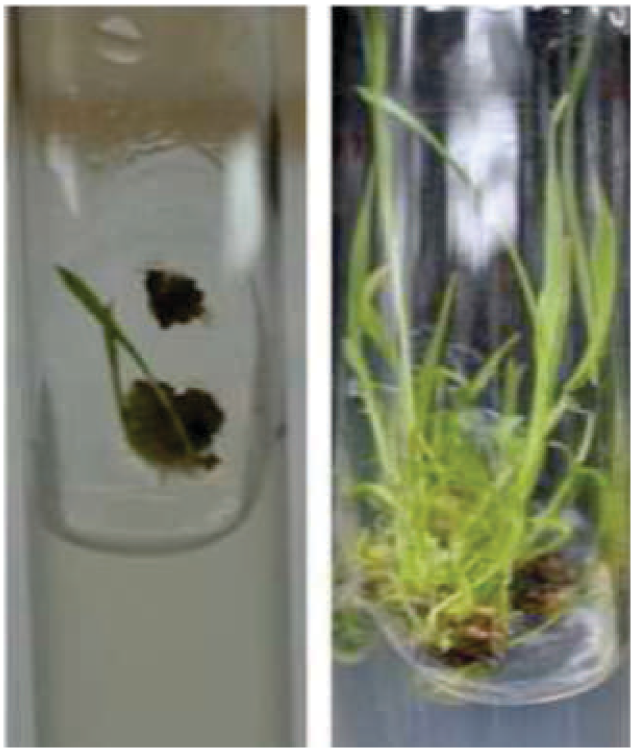


Fig.1.32: Green shoot regeneration from putative tolerant calli in selection media with 2ppm glyphosate

Fig 1.33. Putative glyphosate tolerant rice in M0 generation

Preliminary evaluation for selection of promising DHs

Evaluation of DHs derived from the rice hybrid, 27P63 at NRRI

A preliminary evaluation of 325 DHs derived from a popular quality hybrid, 26P73 were made during *kharif*, 2017 to select the promising DH lines. All the individual DHs were planted in augmented design and morpho-agronomic characters were recorded. A large variability was observed within the DHs (Table 1.29). Based on the morpho-agronomic characters such as maturity duration, plant height, tiller number, panicle length, grain fertility (%) and test weight, 325 DHs were compared with the donor hybrid (Fig.1.34) . On the basis of these characters, 92 promising DH lines were selected (Fig.1.35) for advance trial to check the homogeneity.

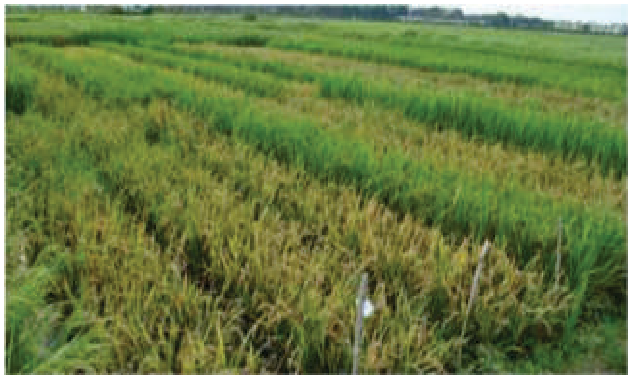


Fig 1.34. Field view of DHs of 27P63 showing variability

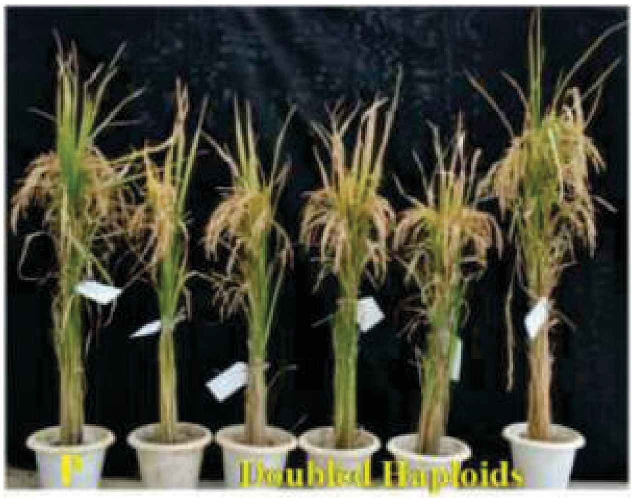


Fig. 1.35. Promising DHs (representatives of 92 selected DHs) of 27P63

Table 1.29. Agronomic characters of 325 DHs derived from 27P63 at NRRI

Character	Parent	Range	<parental value	>parental value
Duration (days)	135	78-142	313	12
Plant ht (cm)	105	40-116	301	24
Tiller number	14	6-28	24	301
Panicle length (cm)	21	12-26	22	303
Grain fertility (%)	95	84-98	208	117
1000 grain wt. (gm)	13.9	7.6-17.9	299	26

Evaluation of DHs under rainfed favorable upland condition at CRURRS, Hazaribag

Ninety-six DHs of early duration were evaluated along with four checks (Abhishek, IR64Drt1, Sadabahar and Sahbhagidhan) in rainfed favourable upland in *Kharif*, 2017 (Fig.1.36). The design of experiment was alpha lattice with two replications and 10 blocks. Each entry was grown in 1m^2 plot. During the growth period there was no moisture stress. Two DHs namely CR1-4, SP19 recorded significantly higher grain yield (6960, 6500 kg/ha) than the best check, Abhishek. Grain yield and other agro-morphological traits of ten best DH lines are given in Table 1.30. Replicated yield trials of ten promising DH lines will be conducted under rainfed upland (DSR) and transplanted favorable upland conditions.

Replicated yield trial of DHs of CRHR32 and BS6444G in *Kharif* -2017

A total of nine doubled haploid lines derived from BS 6444G and CRHR 32 were evaluated for yield and other yield traits in RBD design with checks BS 6444G, CRHR 32 and Tapaswini. The yield of CRAC 3995-27-1, DH of BS 6444G was recorded 5530.0 kg/ha which is at par with parent, BS 6444G (6220.0 kg/ha). Among the DHs of CRHR 32, CRAC 3994-1-1 and CRAC 3994-3-2 recorded 5380.0 kg/ha and 5350.0 kg/ha, respectively which are almost similar with parent, CRHR 32 (5510.0 kg/ha) and more than varietal check Tapaswini (4580.0 kg/ha). The yield traits like days to flowering, plant height (cm), ear bearing tillers are presented in Table 1.31.

Fig. 1.36. Field view of DHs evaluated in rainfed favourable upland condition

Table 1.30. Preliminary evaluation of DHs developed from hybrid rice (CRHR 32 and 27P63) and Savitri/Pokkali in CRURRS, Hazaribag

SN	Entry	Dtf	Pht	Pan/hl	PanLen	PanWt/pl	GYLD (Kg/ha)
1.	CR 1-4	90.1	99.7	12.3	18.8	39.8	6960
2.	SP19	91.2	75.0	15.7	20.5	42.6	6500
3.	CR-7-4	88.8	72.3	14.7	24.2	53.3	5750
4.	SP 9	90.8	101.7	10.7	22.2	38.5	5735
5.	27P63-10-1	85.2	65.3	12.5	20.0	33.3	5325
6.	CR-5-1	91.5	115.5	10.3	21.2	39.1	5320
7.	27P63 -6-1	96.5	65.2	10.0	19.4	26.0	5300
8.	SP-25	91.4	111.5	16.5	17.4	44.6	5280
9.	CR 6-1	89.3	110.8	10.3	28.9	39.6	5275
10.	27P63-56	93.8	73.7	14.2	20.1	32.6	5250
C1	Abhishek	86.2	96.8	10.7	20.4	35.2	5025
C2	IR64Drt1	87.0	97.0	42.2	24.4	29.3	4915
C3	Sadabahar	72.9	79.2	12.2	21.1	32.1	3275
C4	Sahbhagidhan	86.1	98.2	11.5	22.7	34.7	4595
	CD (5%)	6.4	12.0	9.4	3.2	10.3	1274.2

Table 1.31. Replicated yield trial of selected promising DH lines in *Kharif*, 2017

Genotypes	DFF(days)	Pl.ht(cm)	EBT	Yield(kg/ha)
PA-139	99	100.6	7.6	4780
PA-66-3	93	114.8	10.2	4720
PA-27-1	90	106.6	11.4	5550
PA-80-2	107	102.4	9.4	3840
Y-1-1	99	120.6	6.2	5380
Y-3-2	102	126.4	7.8	5350
Y-6-1	92	121.0	10.8	4290
Y-2-1	99	111.8	8.0	4220
Y-2-5	98	119.0	7.2	4060
BS6444G	104	124.6	10.0	6220
Tapaswini	96	117.8	8.0	4580
CRDhan701	112	118.0	8.0	5510
CD	6.52	6.24	1.28	834.0

Construction of *IPA1* and *DEP1* genes specific CRISPR/Cas9 cassette for rice

Rice plant architecture is one of the most important traits for grain yield. The ideal plant architecture (IPA) of rice displays low tiller numbers with few unproductive tillers, more grains per panicle, and thick and sturdy stems which substantially enhances rice grain yield. Recently, a QTL named as *IPA1* (Ideal Plant Architecture 1) was cloned and characterized for plant architecture of rice and encodes *OsSPL14* (SOUAMOSA PROMOTER BINDING PROTEIN-LIKE 14) and is regulated by micro RNA (miRNA), *OsmiR156*. A point mutation at 874 bp in the third exon of *OsSPL14* interrupts the cleavage of *OsSPL14* transcripts by *OsmiR156* and results in ideal plant architecture phenotype in rice. For optimizing the CRISPR/Cas9 system in genome editing of rice, *IPA1* gene was selected to target specific region of *IPA1* gene for the interruption of the cleavage by *OsmiR156*. Dense erect panicle 1 (DEP1) gene is also another important yield related trait that increased panicle density and high spikelet number per unit panicle length with the loss of function. Therefore, the full coding sequences of these two genes (*IPA1 and DEP1*) were downloaded from Rice genome annotation project (RGAP) database and analysed in CRISPR-P 2.0 online tool and identified a sgRNA (20 bp) target site. The gRNA expression cassette was synthesized using PYLsgRNA_OsU6a plasmid vector (Addgene, USA) by overlapping PCR method. Then, sgRNA expression cassette was cloned to the linearized PYLCRISPR/Cas9Pubi-H vector (Addgene, USA) using *Bsa*I, restriction enzyme through Golden Gate ligation approach and recombinant constructs were transformed into *Escherichia coli* strain DH5α (Fig.1.37A). The positive clones were confirmed through PCR by using a pair of specific primers (sgF & sgR) corresponded to sgRNA expression cassette (Fig.1.37B). The positive clones were transferred to *Agrobacterium* cell for further mobilized into rice callus.

Cloning of *HsfA2a* coding sequence and promoter in pGEMT easy vector

The transgenic expression of *aus* specific *HsfA2a* allele requires cloning of the coding region and the upstream promoter region. Thus, the coding sequence and the promoter region were amplified from cDNA and genomic DNA, respectively. The amplified fragment was ligated in pGEMT easy vector and transformed into *E.coli* through heat shock method. The white colonies were screened through colony PCR and plasmids isolated. The isolated plasmids were restricted digested to identify the presence of the insert (Fig 1.38). The analysis showed ~ 1.1 kb coding sequence and 2 kb promoter were released after restriction digestion. Further, the gene and promoter will be cloned in binary vector and mobilized into *Agrobacterium* for genetic transformation into rice.

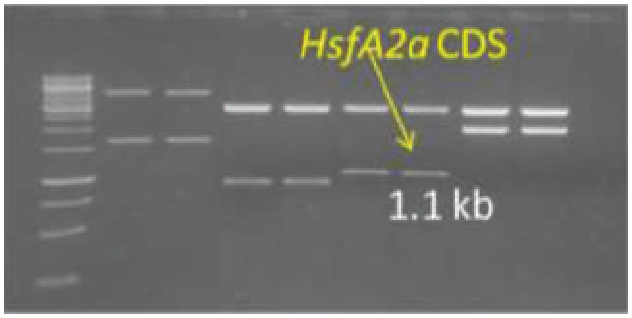


Fig. 1.38. Cloning of *HsfA2a* CDS

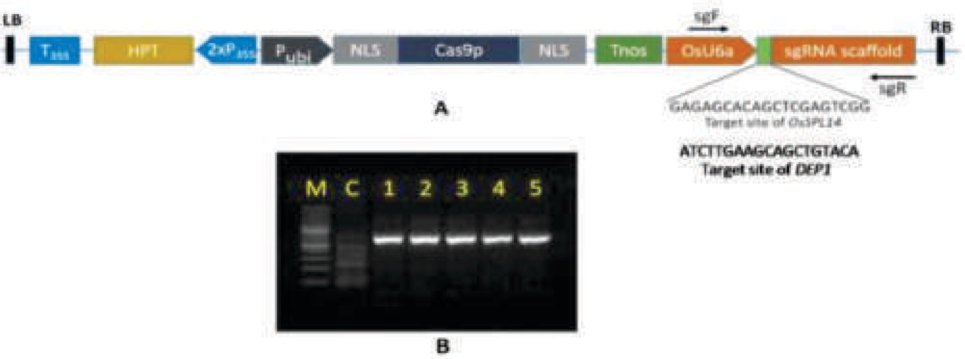


Fig. 1.37A & B. Cloning of sgRNA expression cassette into the CRISPRCas9 binary vector; A. Cloning of sgRNA expression cassette of OsSPL14IPA1 and B. DEP1 genes into the CRISPRCas9 binary vector

Development of Cleaved amplified polymorphic sequence marker for *aus* specific *HsfA2a* (Heat shock transcription factor) allele

Heat shock transcription factor (*Hsfs*) regulates the expression of heat stress responsive proteins during heat stress in rice. One of the *Hsfs* in rice namely, *OsHsfA2a* was found to contain *aus* specific non-synonymous substitution altering the amino acid aspartate to glutamate in the DBD (DNA Binding Domain) of the protein. The non-reference allele frequency of this substitution was about 99.49% in *aus* type rice lines. Thus, cloning and characterization of *aus* allele of the gene might provide information about heat stress response in rice. However, development of markers for identification and validation of *aus* allele in *HsfA2a* will be useful for development of transgenic plants and also for marker assisted introgression of the gene. Thus, the coding sequence of *HsfA2a* was compared and one particular restriction enzyme MboII found to cut the *aus* allele was identified. A marker was developed and validated in *aus* rice varieties through CAPS marker **(Fig. 1.39)**.

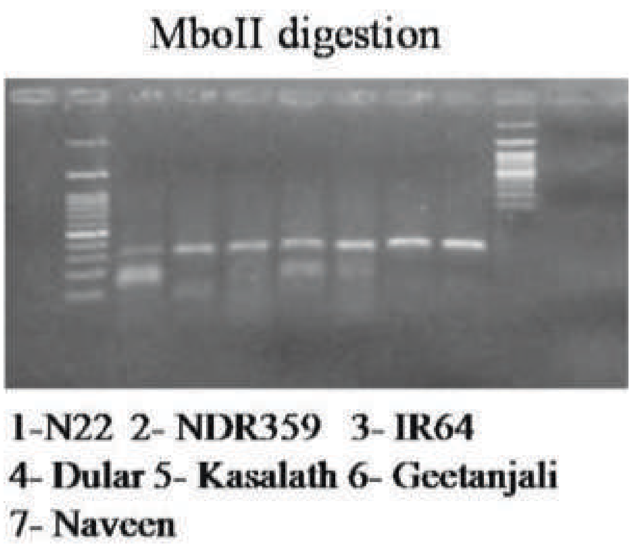


Fig1.39. Confirmation of *HsfA2a* allele through CAPS

Cloning of promoter of *HK6* (cytokinin receptor) in rice to understand its expression during *Rhizobium* infection

Cytokinin genes play an important role in legume nodulation. The mutation of cytokinin receptor gene *CRE1* showed reduced nodulation in *Medicago*. Thus, the homologs of CRE1 gene in rice and green gram were identified through BLASTP analysis. The analysis showed there were four cytokinin receptor homologs in rice and green gram. Further, multiple alignment and phylogenetic analysis was performed in MEGA7 software for *Arabidopsis,* rice and green gram cytokinin receptors (Fig 1.40). There were two major groups identified in the phylogenetic reconstruction analysis. The closest homolog of the CRE1 in rice (LOC_Os02g50480) was identified and the promoter region was cloned in pGEMT easy and pCAMBIA1304 binary vector (Fig 1.41). The cloned promoter will be transformed into rice calli through *Agrobacterium* mediated transformation and expression of the promoter: GUS constructs will be evaluated during *Rhizobium* infection.

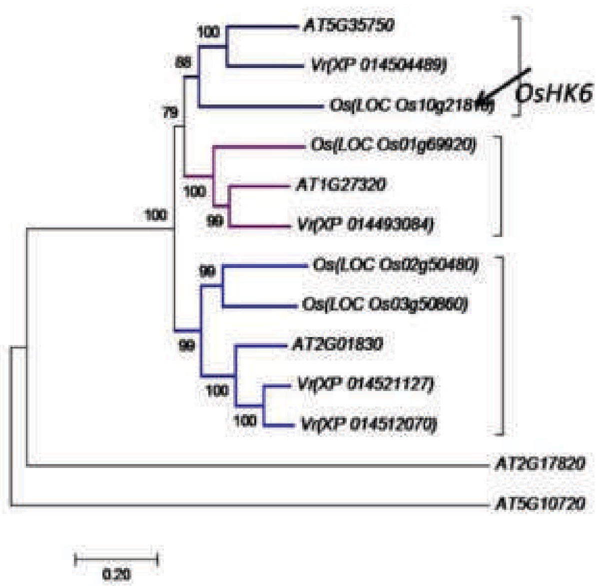


Fig. 1.40. Phylogenetic analysis of cytokinin receptor

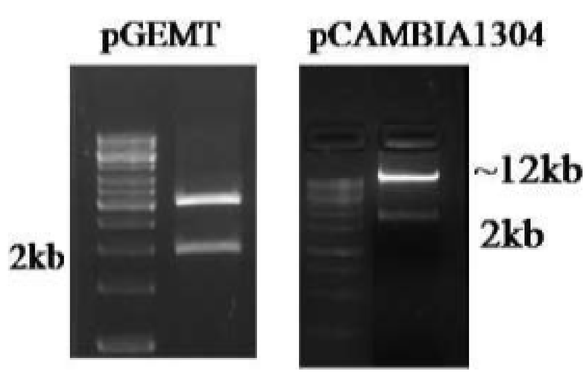


Fig 1.41. Cloning of HK6 promoter

Promotion of DH line in AICRIP: CRAC 3995-48 (IET 26446) DH line derived from BS6444G was promoted to AVT -1-Boro in AICRIP- 2018.

Nomination of DH lines: Seven DH lines, CRAC 3994-9-1-6, CRAC 3994-2-08, CRAC 3994-2-6, CRAC 3994-3-4, of CRHR 32 and CRAC 3995-66-3, CRAC 3995-139-4, CRAC 3995-80-3 were nominated for evaluation in AICRP-2018.

Development of Genomic Resources for Rice Improvement

1a) Development of mapping population for identification and mapping of genes/ QTLs associated with pigmentation, antioxidants and proteins.

F_6 RIL mapping population from the cross Mummy Hunger / IR64 was grown in the field for generation advancement during Kharif 2017. The self seeds (F_7) were collected from each RIL for phenotyping and genotyping for identification of QTLs associated with pigmentation, antioxidants and proteins.

1b) Development of mapping population for fine mapping of QTLs associated with BPH Resistant var- 'Salkathi'

Mapping population consisting of 300 F_2 lines developed from the cross TN1 and Salkathi (BPH resistant) was grown during wet season 2017 and F_3seeds were collected. Individual F_3 lines and another batch of 300 F_2 lines were grown during dry season 2018. About 250 F_3 lines were screened for reaction to BPH in green house conditions.

2) Association mapping to identify genes/ QTLs associated with seedling vigour

During dry season 2017, 1500 genotypes were screened for seedling vigor under dry direct seeded condition. Based on the phenotype data, a core collection consisting of 96 genotypes was generated from 1500 genotypes and they were precisely evaluated for 15 traits related to seedling vigor during two seasons viz., wet season 2017 and dry season 2018, in two replications with 15 checks. Seventeen traits were studied to identify the distribution pattern of seedling vigour traits to utilize them in GWAS analysis. Among them the mean, median and mode of shoot length on 14 and 28 days, no. of leaves and culm diameter on 14 days and shoot weight on 28 days were not equal. Hence, the distribution was asymmetrical (Fig 1.42). The mean was greater than median and mode, indicating that the distribution was positively skewed (Table 1.32). Therefore, the above said traits need to be transformed before GWAS analysis to identify QTLs/genes responsible for seedling vigour. The present study has indicated that the core collection has ample variation to study seedling vigour traits to improve the efficiency of genotypes for dry direct seeded system.

3) Gene prospecting and allele mining for tolerance to heat stress

Expression pattern of genes during heat stress might be relevant in understanding the function of the genes. N22, a heat tolerant cultivar showed up regulation of around 250 genes during heat stress in reproductive tissues. Also, few QTLs have been identified for spikelet fertility under heat stress in rice using N22 as tolerant donor. Thus, allele mining of these genes could provide N22 specific alleles which may be the causal factor for heat stress tolerance. Thus, genes which differentially expressed within the QTLs (*qSSIY3.1, qHTSF4.1*, and *qSTIPSS9.1*) were identified for heat stress tolerance. The promoter/cis-regulatory region specific primers were designed for the identified candidate genes (LOC_Os03g42520, LOC_Os04g31270, LOC_Os09g27830, and LOC_Os09g27750) in the QTL regions. These primers were used for genotyping selected varieties and few indels in the promoter region were identified to be specific to the N22 genotype (Fig 1.43). Also, the spikelet sterility analysis under field condition showed continuous distribution and for the selected genotypes was in the range of 6-15%. Since, there were only two subpopulations and most of the alleles were N22 specific, a mapping population of cross NDR359 x N22 was developed and the alleles identified will be validated in $F_{2:3}$ populations for further analysis.

Table 1.32. Range of distribution for seedling vigour traits on 14 and 28 days after sowing under dry direct seeded condition

	SH_14	No. of Leaves_14	Stem_dia_14	Root_lt_14	No_roots_14	Shoot_wt_14	SH_28	No. of_Leaves_28	Tiller_no_28	Stem_dia_28	Root_lt_28	No_roots_28	Shoot_wt_28	Root_wt_28	RGR_(g/g/day)	AGR_(cm/day)	CGR_(m2)
Min	12.73	3.00	0.61	3.19	8.10	0.010	19.74	4.00	1.00	0.88	10.96	9.80	0.018	0.006	0.000	0.091	0.000
Max	22.31	3.40	1.90	6.91	16.00	0.029	29.69	6.50	1.90	1.64	18.04	20.20	0.163	0.085	0.170	1.146	0.352
Mean	15.97	3.07	0.82	4.82	10.86	0.018	24.02	5.00	1.25	1.27	13.96	14.14	0.067	0.031	0.090	0.575	0.117
Stand. dev	1.54	0.08	0.14	0.74	1.41	0.004	2.62	0.60	0.21	0.17	1.37	2.06	0.029	0.014	0.029	0.223	0.067
Median	15.70	3.10	0.80	4.84	10.70	0.017	23.62	4.90	1.20	1.27	13.86	13.80	0.062	0.029	0.088	0.561	0.109
25 prcntil	15.02	3.00	0.75	4.21	9.80	0.015	21.76	4.50	1.10	1.14	12.83	12.70	0.048	0.021	0.065	0.406	0.069
75 prcntil	16.55	3.10	0.89	5.25	11.80	0.021	26.05	5.40	1.40	1.41	15.10	15.60	0.076	0.038	0.110	0.737	0.140
Skewness	1.51	1.22	4.90	0.18	0.54	0.365	0.49	0.69	0.97	0.05	0.41	0.48	1.130	1.180	0.029	0.120	1.184
Kurtosis	3.62	2.24	38.33	-0.26	0.64	-0.561	-0.83	-0.31	0.27	-0.75	-0.04	-0.17	1.263	2.204	0.072	-0.500	1.509
Coeff. var	9.66	2.56	16.88	15.33	13.01	22.168	10.89	12.09	17.10	13.52	9.79	14.58	43.129	46.336	32.723	38.893	56.999
Std. error	0.16	0.01	0.01	0.07	0.14	0.000	0.26	0.06	0.02	0.02	0.14	0.21	0.003	0.001	0.003	0.022	0.007

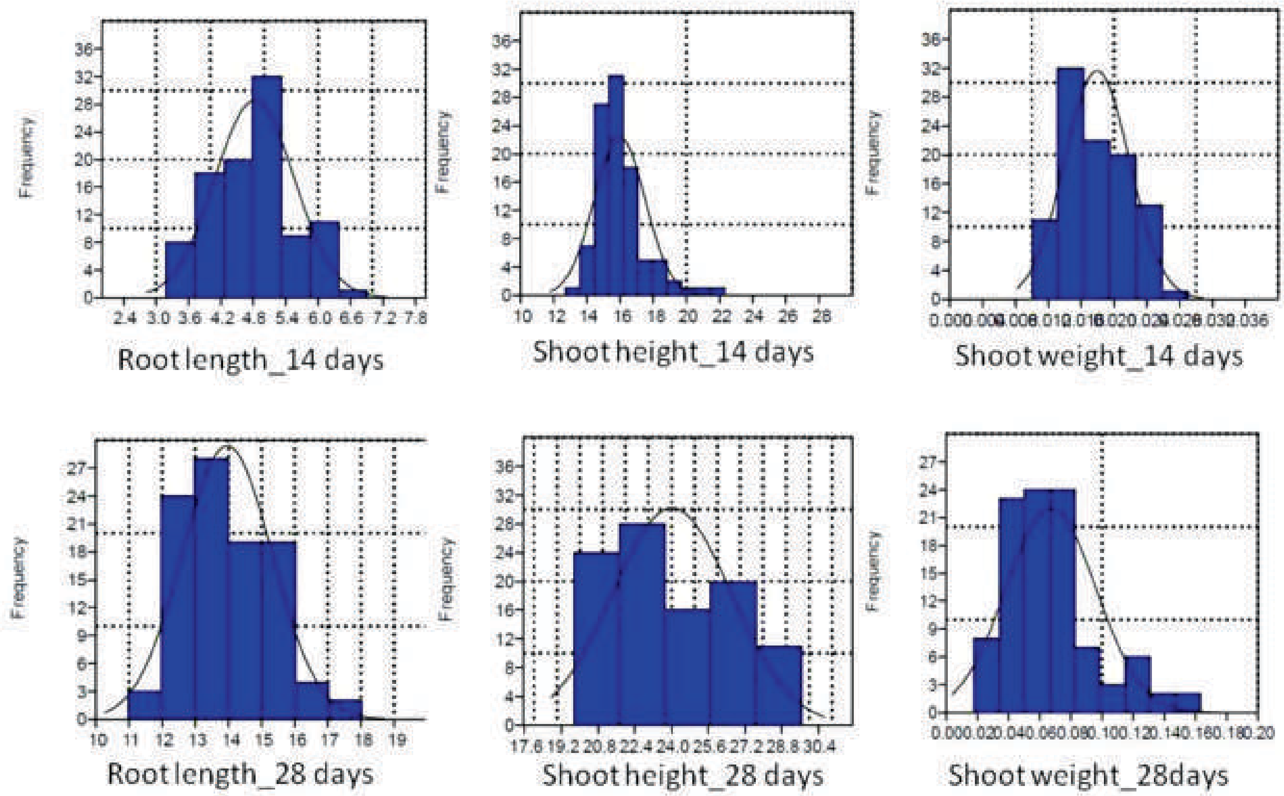


Fig 1.42. Frequency distribution of seedling vigour traits

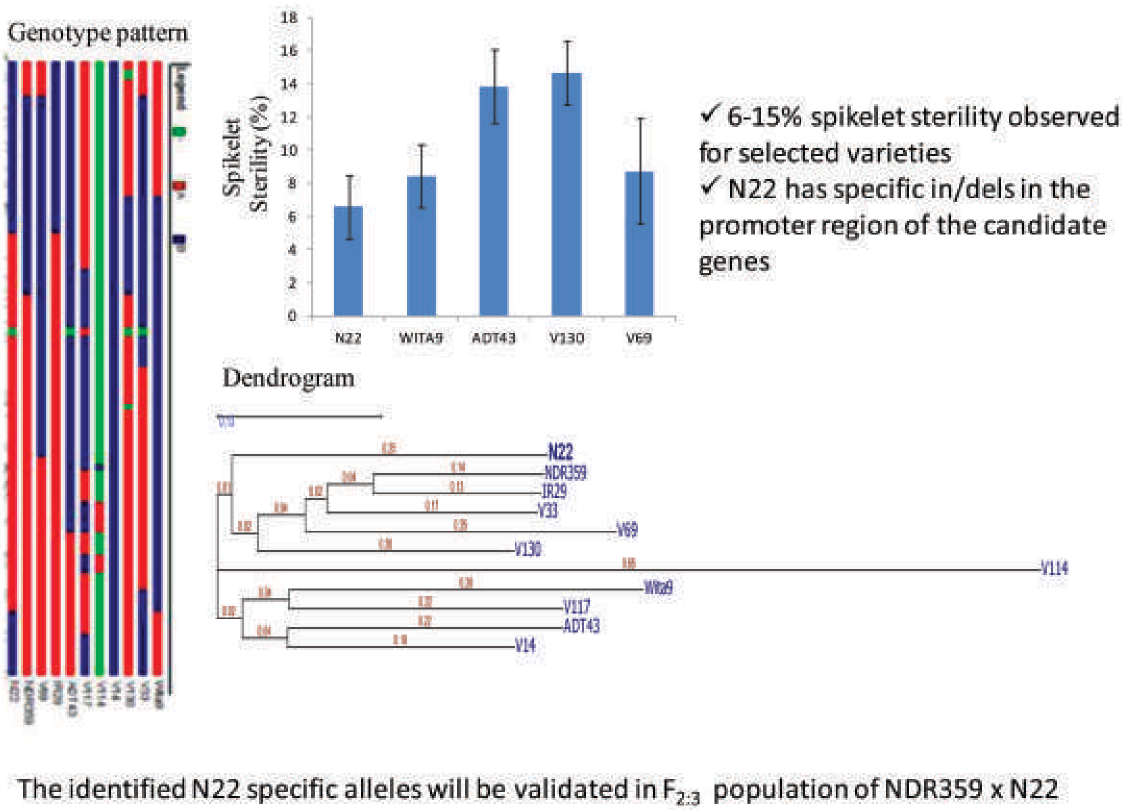


Fig 1.43. Genotyping of cis-regulatory regions for heat stress responsive genes

PROGRAMME : 2

Enhancing Productivity, Sustainability and Resilience of Rice Based Production System

Resource use efficiency in agriculture is still low in our country and more so in rice production system. Although India achieved record production of rice in last couple of years, sustainability, productivity and profitability of rice system related to environment are the burgeoning issues which need to be tackled effectively. In order to address the above mentioned issues, this programme was framed with the aim to develop, validate and disseminate environment friendly technologies to enhance productivity, profitability and sustainability of rice production system.

The main objectives of the programme are to (i) enhance nutrient and water use efficiency in rice by technological intervention, (ii) to increase productivity and profitability of rice based cropping and farming system including site specific weed management, (iii) economic or environment friendly utilization of soil, water, nutrient and residues (straw) by resource conservation technology and microbial intervention and (iv) to develop, refine and validate small scale farm implements for small and marginal farmers.

Some of the related activities to achieve the objectives were undertaken in 2017-18. Salient findings of those are summarized here. Agronomic use efficiency and recovery use efficiency was increased in the range of 25-33%, through real time N management in lowland rice using customized leaf colour chart (CLCC) along with neem coated urea. APLSIM-*Oryza* simulation model was successfully validated under long-term nutrient management in lowland rice in eastern India. It was also found that, continuous application of NPK with or without FYM encouraged certain bacterial community structure (BCS), whereas N application alone suppressed certain beneficial bacteria and microbial diversity. Agro-ecological-based cropping system approach revealed that, feasibility of zero-tillage-based rice-maize cropping system in eastern India and stand establishment with hydrogel in DSR have positive effect on B:C ratio. It was also reported that rice-toria-based pyra-cropping sequence had higher net return in *rainfed* ecology of Odisha. Environment impact and ecological mechanism was studied in rice-fish farming system in different tier system. Special map of weed distribution pattern in coastal Odisha was developed. In weed management aspect weed competitiveness under aerobic rice, weed control in zero-tillage rice, efficacy testing of integrated weed management (chemical + mechanical control) in direct seeded rice and persistence studies of modified herbicide molecule were done.

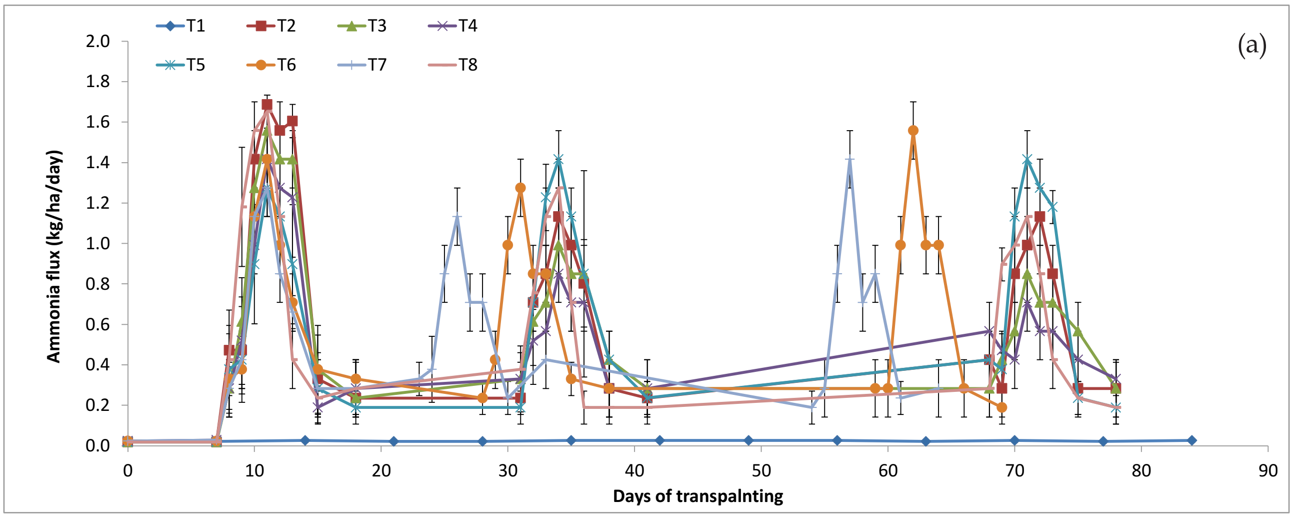
In resource conservation front ecosystem services of six resource conservation technologies (RCTs) both in direct seeded and transplanted rice were estimated, where greengram played a vital positive role. Characterization of 19 varieties of rice straw on the basis of cellulose, hemicellulose, lignin was done and evaluation of three microbial consortia (*Aspergillus* + *Streptomyces* + Bacteria, *Aspergillus* + *Streptomyces*, *Trichoderma* + *Streptomyces*) for *ex-situ* rice straw composting were conducted in large scale. Two small scale farm implements; one for deep placement urea briquettes applicator attachment in mechanical trans-planter and another power operated two row wet land weeder for rice, were refined and validated. In microbial intervention, sporocarp based formulation of *Azolla* for wet land rice was developed, and performance of diazotrophs under oxidated system was assessed.

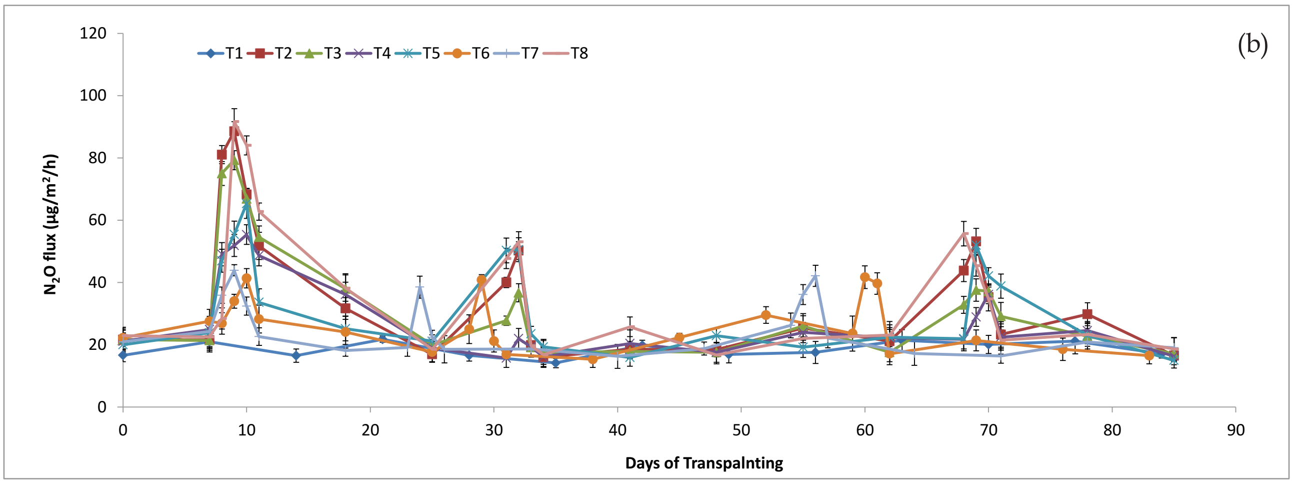
The Division would continue to focus on enhancing N, water use efficiency, and profitability in rice production system. Real time nutrient management, modelling, cropping/farming system interventions for sustainability, farm-mechanization and microbial intervention in economic and environment friendly manner are the other priority areas of research.

Nutrient management for enhancing productivity and resource use efficiency in rice

Enhancing nitrogen use efficiency of lowland rice through real time nitrogen management using customized leaf colour chart (CLCC)

A field experiment was conducted in *kharif* 2017 with an objective to evaluate the effect of customized leaf colour char (CLCC) and different doses of neem coated urea (NCU) on nitrogen (N) use efficiency and yield of rice. The different treatments used in this experiment was T_1: N_0 (control); T_2: 80 kg N ha^{-1} (NCU); T_3: 60 kg N ha^{-1} (NCU); T_4: 40 kg N ha^{-1} (NCU); T_5: 80 kg N ha^{-1} (NCU) (CLCC); T_6: 60 kg N ha^{-1} (NCU) (CLCC); T_7: 40 kg N ha^{-1} (NCU) (CLCC); T_8: 80 kg N ha^{-1}(Prilled urea, PU). The temporal variations in NH_3 volatilization flux from different treatments during rice-growing period are shown in Fig. 2.1a. However, temporal variations in NH_3 volatilization showed a similar pattern for all the N treatments, significant differences in NH_3 volatilization among different treatments were observed during a short period after N fertilization. The maximum flux was recorded in 80 kg N ha^{-1} (NCU) (T_2) treatment and lowest was in control (T_1). We could say that the amount of ammonia released from the NCU applied plots were slightly higher than PU applied plot and the highest NH_3 is released from T_2. NH_3 released from 60 kg N ha^{-1} (NCU) (T_6) was 8.8% less than the ammonia released from 80 kg N ha^{-1} (NCU) (T_2). The N_2O emission ranged from 14.1–91.6 µg N_2O-N m^{-2} hr^{-1} (Fig 2.1b) . The highest peak was recorded in the treatment where 100% of N was applied as basal through PU (T_8). Total N_2O-N emission during the season ranged from 0.38 to 0.61 kg ha^{-1}. N_2O emitted from T_6 is 22.8% less from T_8 and 18.8% less from T_2. Hence, 75% RDF plus CLCC (i.e. 60 kg N ha^{-1} (NCU) (CLCC)) could save 25% N fertilizer by reducing the losses through N_2O emission. Highest agronomic use efficiency (AE_N) was obtained in 75% RDF in CLCC treatment (T_6). AE_N of T_6 was 25.74% higher than T_2 and 41.93% higher than T_8. Highest AE_N (23.93 kg kg^{-1}) was in (T_6) and lowest 19.03 kg kg^{-1} was under T_1. Highest recovery use efficiency (RE_N) was also obtained at 75% RDF in CLCC in T_6. RE_N of T_6 was 33.14% higher than T_2 and 56.28% higher than T_8. Highest RE_N (49.93%) in T_6 and lowest 37.50% under T_1 (Fig. 2.1c,d).





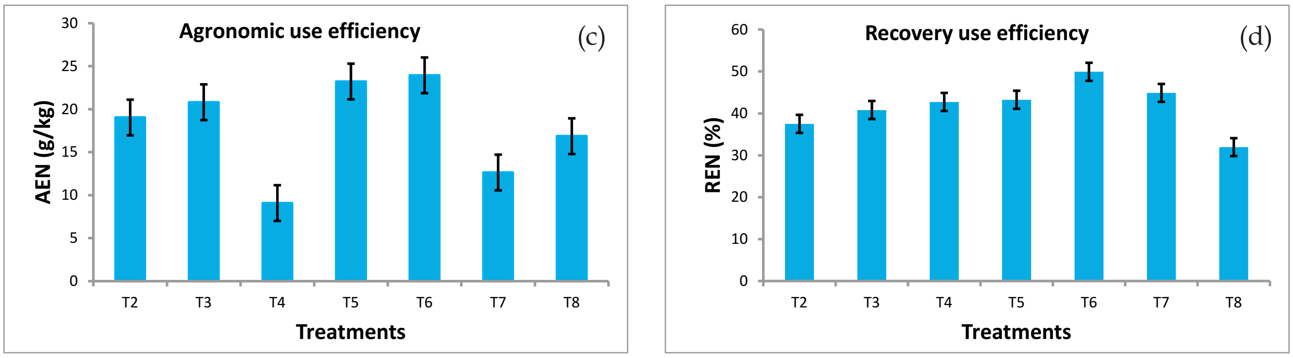


Fig. 2.1. Ammonia volatilization (a), N_2O emission (b), Agronomic use efficiency (c) and Recovery use efficiency (d) under different nitrogen application practices. [T_1L: N_0 (control); T_2: 80 kg N ha^{-1} (NCU); T_3: 60 kg N ha^{-1} (NCU); T_4: 40 kg N ha^{-1} (NCU); T_5: 80 kg N ha^{-1} (NCU) (CLCC); T_6: 60 kg N ha^{-1} (NCU) (CLCC); T_7: 40 kg N ha^{-1} (NCU) (CLCC); T_8: 80 kg N ha^{-1}(Prilled urea, PU)]

Evaluation of rice varieties for phosphorus use efficiency under diversified ecology

The experiment was conducted in *kharif*, 2017 in ICAR-NRRI farm with four graded doses of P (P_0: control; P_1: 20 kg P ha^{-1}; P_2: 40 kg P ha^{-1} and P_3: 60 kg P ha^{-1}) and eight cultivars, namely IR36, IR64, Kasalath, Pooja, Gayatri, Sarala, Padmini and CR1014. The yield of rice was highest in Gayatri followed by Sarala (Fig. 2.2). Plant height was found highest in Padmini. At 30 days after transplanting (DAT), the plant samples were uprooted by keeping the root system intact, and root samples were scanned for quantifying the root morphological features using Win Rhizo TM Root Scanner. Results indicated that the root morphological parameters of the tested cultivars have been responsive towards P fertilizer (mostly at 40 and 60 kg P ha^{-1} level) application. The cultivar IR 36 had the maximum root length and root length per volume while Sarala showed the maximum surface area and root volume and the both were observed at 60 kg P ha^{-1} (P_3) level. However, thickness of root as measured by average root diameter was found highest in Padmini at 60 kg P ha^{-1} (P_3) level compared to other cultivars tested.

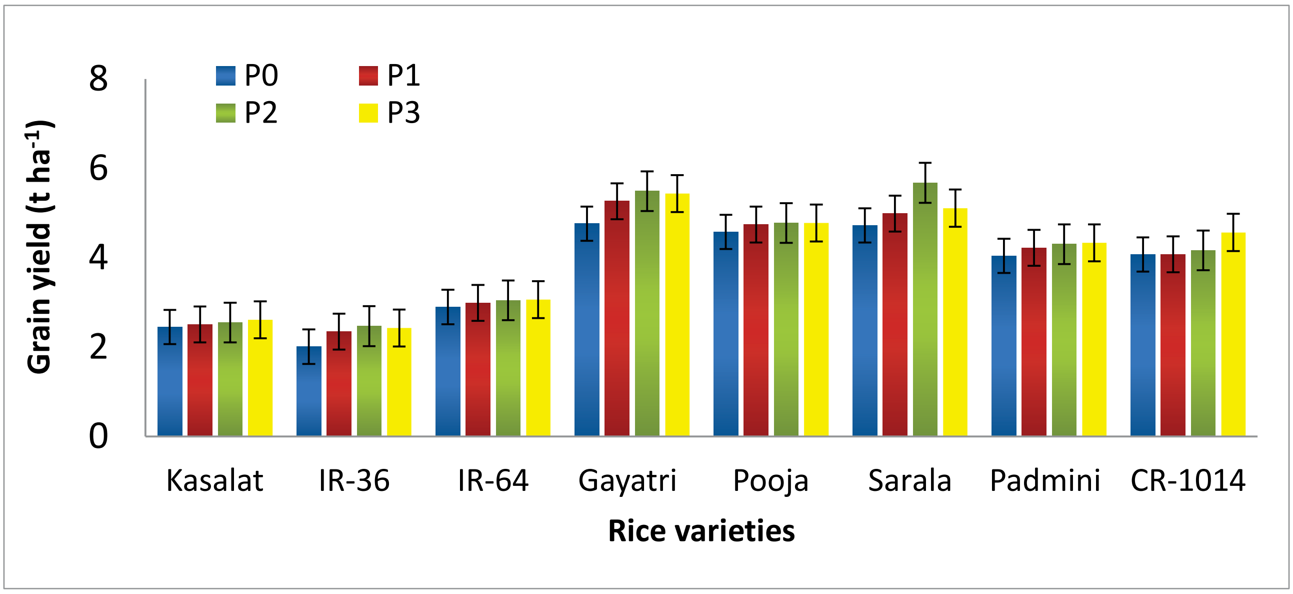


Fig. 2.2. Yield of rice varieties under graded doses of phosphorus.
[P: P_0: control; P_1: 20 kg P ha^{-1}; P_2: 40 kg P ha^{-1} and P_3: 60 kg P ha^{-1}]

Calibration and validation of APSIM-Oryza model for yield simulation of Lalat and Gayatri under nutrient management practices

Crop simulation models are the important tools in simulating crop yield under various crop management practices. APSIM modelling framework was used to simulate the yield of two rice varieties of eastern India, namely Lalat and Gayatri by calibrating the model for the inorganic nutrient management, i.e NPK (recommended dose of fertilizer) for the year 2010-2011 by incorporating N doses in the model, considering P and K sufficiency in the soil. APSIM-Oryza model was used in the study. The independent data on grain yield and biomass under NPK treatment for year 2012-2014 and NPK+FYM treatment (FYM 5 t ha^{-1} applied at the end of May every year) for the year 2012 in the long term fertilizer experiment of NRRI, Cuttack was used for validation of the model. The calibrated APSIM-Oryza predicted well the grain yield and biomass yield under NPK treatment with a modelling efficiency of 0.80 and NPK+FYM treatments with a modelling efficiency of 0.97 under model validation. Simulated vs. observed grain yield data for model calibration (2010) and validation (2012) under NPK treatment is shown below (Fig. 2.3).

Effect of air temperature variability on long-term yield anomaly of dry season rice-rice system with different nutrient management in Eastern India

Yield anomaly of rice under nutrient management practices namely NPK and NPK+FYM along with the absolute control (no nutrient applied) was analyzed for 24 years in a long-term rice-rice system with respect to maximum and minimum air temperatures. Analysis showed that an increase of mean + 1 °C for both the maximum and minimum air temperatures during the vegetative stage had positive effect but during the reproductive and ripening stages had negative effect on yield. An interesting fact was that increase in minimum temperature during the vegetative stage had greater positive effect on yield compared to maximum temperature. Magnitudes of negative yield anomaly in reproductive and ripening stage were less with the NPK+FYM treatment (-0.77% and -0.74%, respectively) compared to the control treatment (-4.52% and -5.31%, respectively). The temperature trends in different crop growth stages during the 24 year study period are graphically presented (Fig. 2.4).

Bacterial community structural diversity under influence of 47 years continuous application of inorganic and organic fertilizers in paddy soil

Soil bacteria are considered as an essential member of the microbial community, contributing to soil health. Continuous application of chemical fertilizers alters the bacterial community structure (BCS) thereby disturbing the soil biogeochemical cycling. The present study highlights the 16S rRNA amplicon sequencing-based variation of BCS through Illumina-MiSeq® in a 47 years old long-term fertilized paddy soil and their relation with grain yield (GY), straw biomass (SB) and other soil properties. The six treatments considered were, control (no fertilizer),

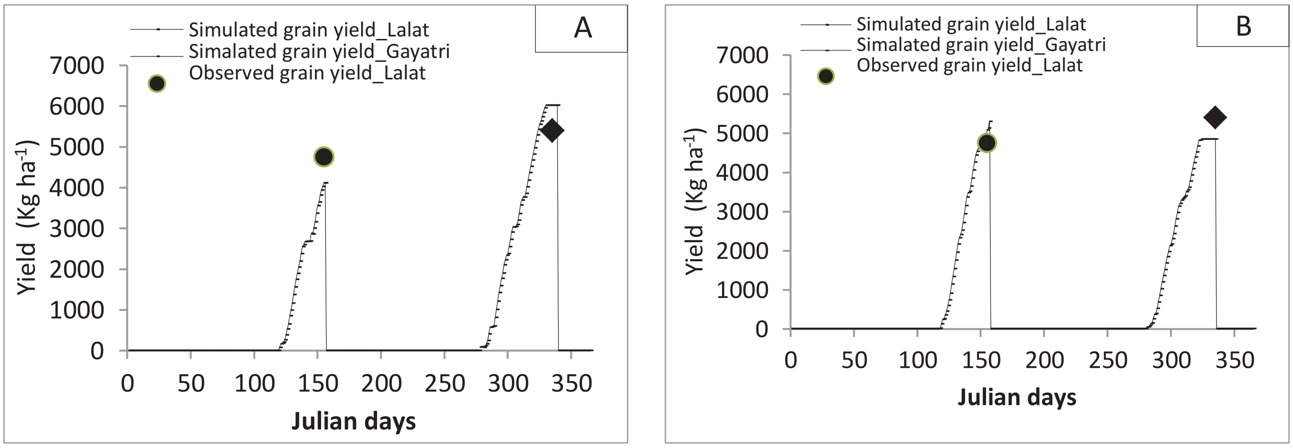


Fig. 2.3. Simulated vs. observed grain yield data for model calibration year 2010 (A), and validation year 2012 (B) under NPK treatment.

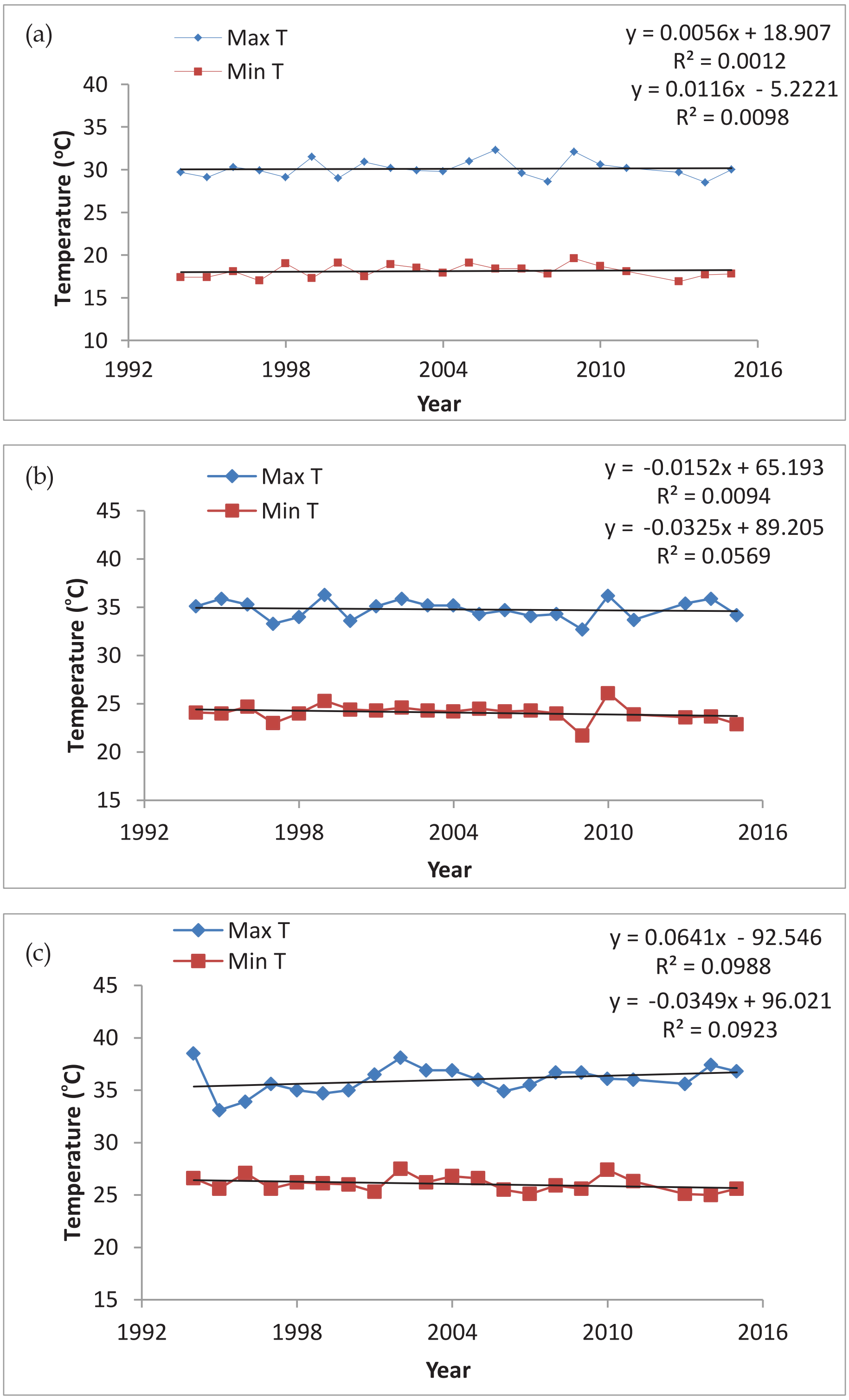


Fig. 2.4. Trends in maximum and minimum temperature from 1994-2015 for dry season in vegetative stage (a), reproductive stage (b), and ripening stage (c)

nitrogen (N), nitrogen + phosphorus (P) + potassium (K) (NPK), farmyard manure (FYM), FYM+N and FYM+NPK. Grain yield and SB significantly ($p \leq 0.05$) enhanced by 45.1%-49.3% and 36.9-39.4% in FYM+NPK compared to control, respectivelty. Relative abundance of bacterial phyla varied across inorganic and organic fertilizers. Dominant phyla across the treatments were Proteobacteria, Acidobacteria, Actinobacteria, Chloroflexi, and Firmicutes, accounting for about 80-85% of total operational taxonomic units (OTUs) (Fig. 2.5). N application alone over 47 years encouraged certain bacterial phyla (Firmicutes, Actinobacteria, and Nitrospira) (Fig. 2.6) while major (Proteobacteria, Acidobacteria and Cyanobacteria) and minor (Fibrobacteres, Spirochaetes, TM7 and GNO4) bacterial phyla were found to be suppressed compared to other treatments (Fig. 2.7). Moreover, continuous use of chemical N considerably suppressed some diazotrophs taxon, viz. Burkholderiales, Entero bacteriaceae and *Kaistobacter, Anaeromyxobacter, Bdellovibrio*and MND1 in paddy soil. Redundancy analysis coupled with principal component analysis revealed that BCS was significantly influenced by soil pH and presence of higher N content (Fig. 2.8). Interestingly, the highest proportion of bacterial OTUs were recorded in balanced inorganic fertilization (NPK) (without FYM) and therefore, this result suggested that continuous application of NPK encouraged the beneficial bacterial community without compromising GY and SB in lowland paddy having sandy clay loam texture and sufficient amount of soil organic carbon. Overall, the present study indicated that continuous application of N and NPK with or without FYM for more than four decades in paddy soil encouraged certain BCS whereas, N application alone suppressed certain beneficial bacterial phyla, resulting in the alteration of soil biodiversity and net rice productivity.

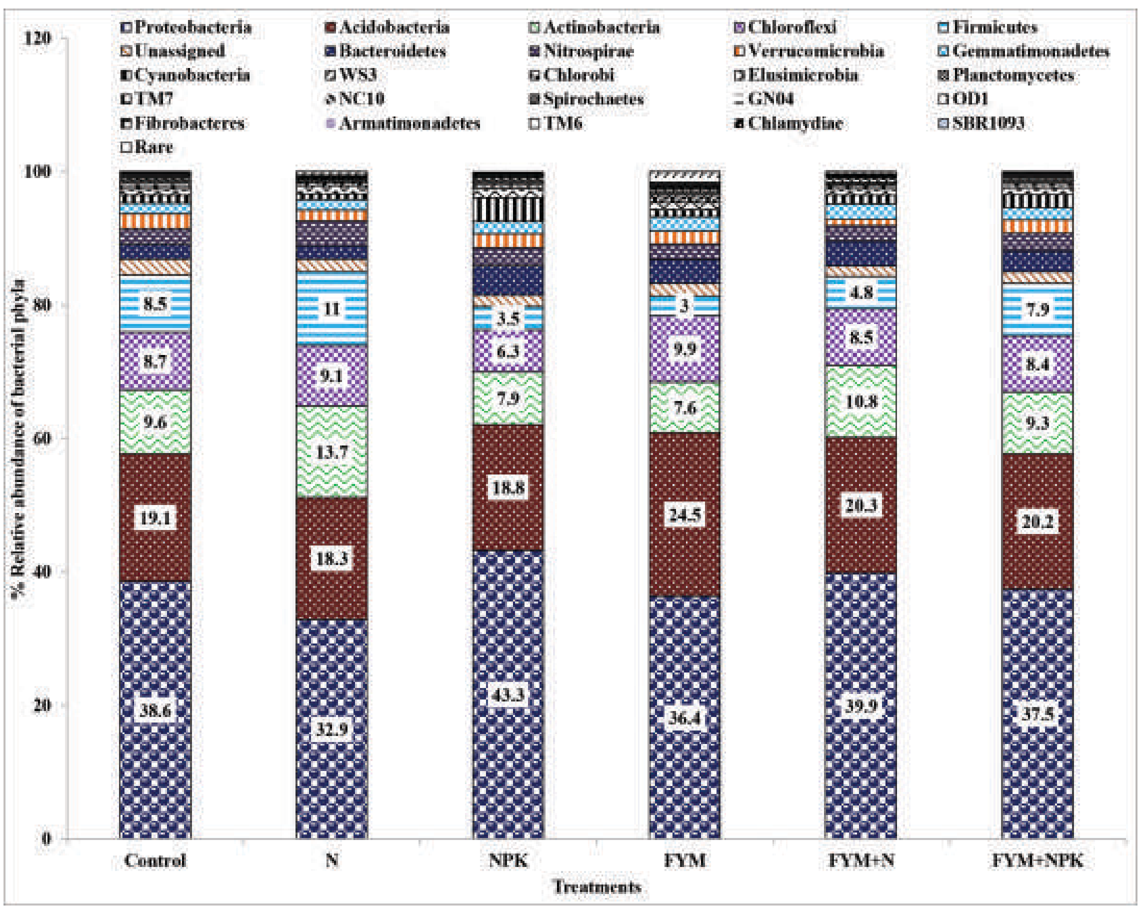
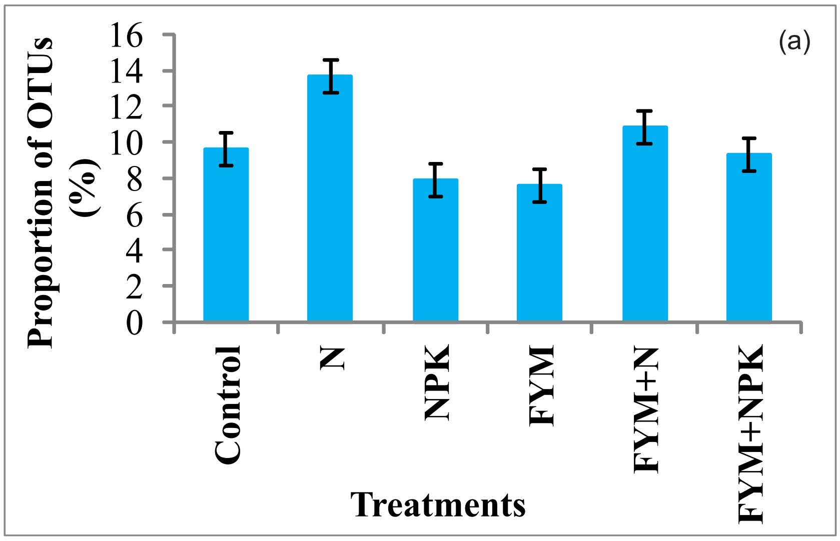
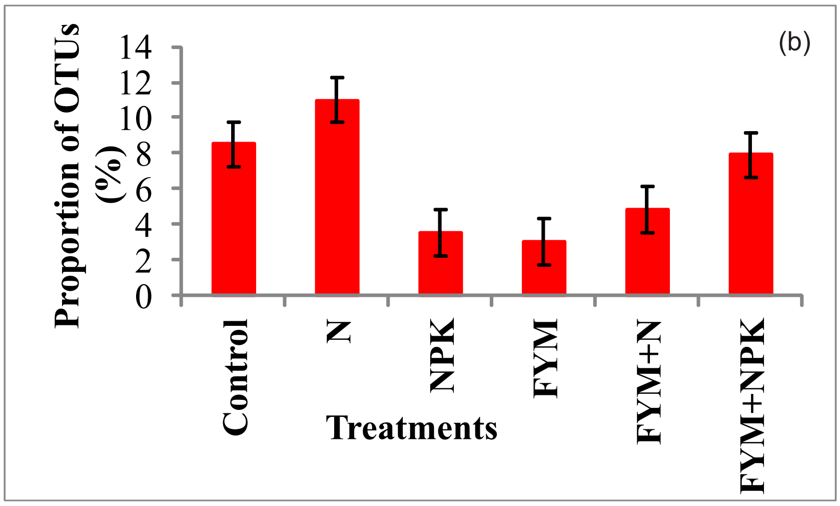


Fig. 2.5. The relative abundance of bacterial phyla in 47 years old long-term fertilizer experiment under rice-rice cropping system (% of total sequences). N: nitrogen; P: phosphorous; K: potassium; FYM: farm yard manure.





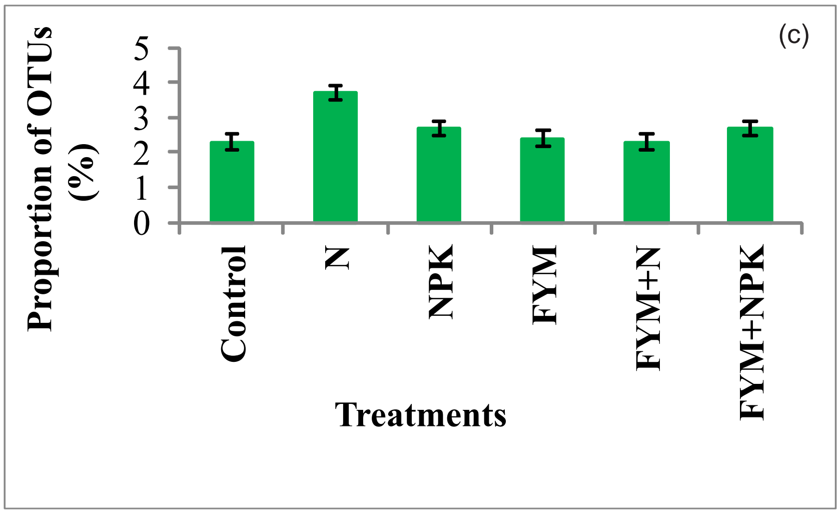
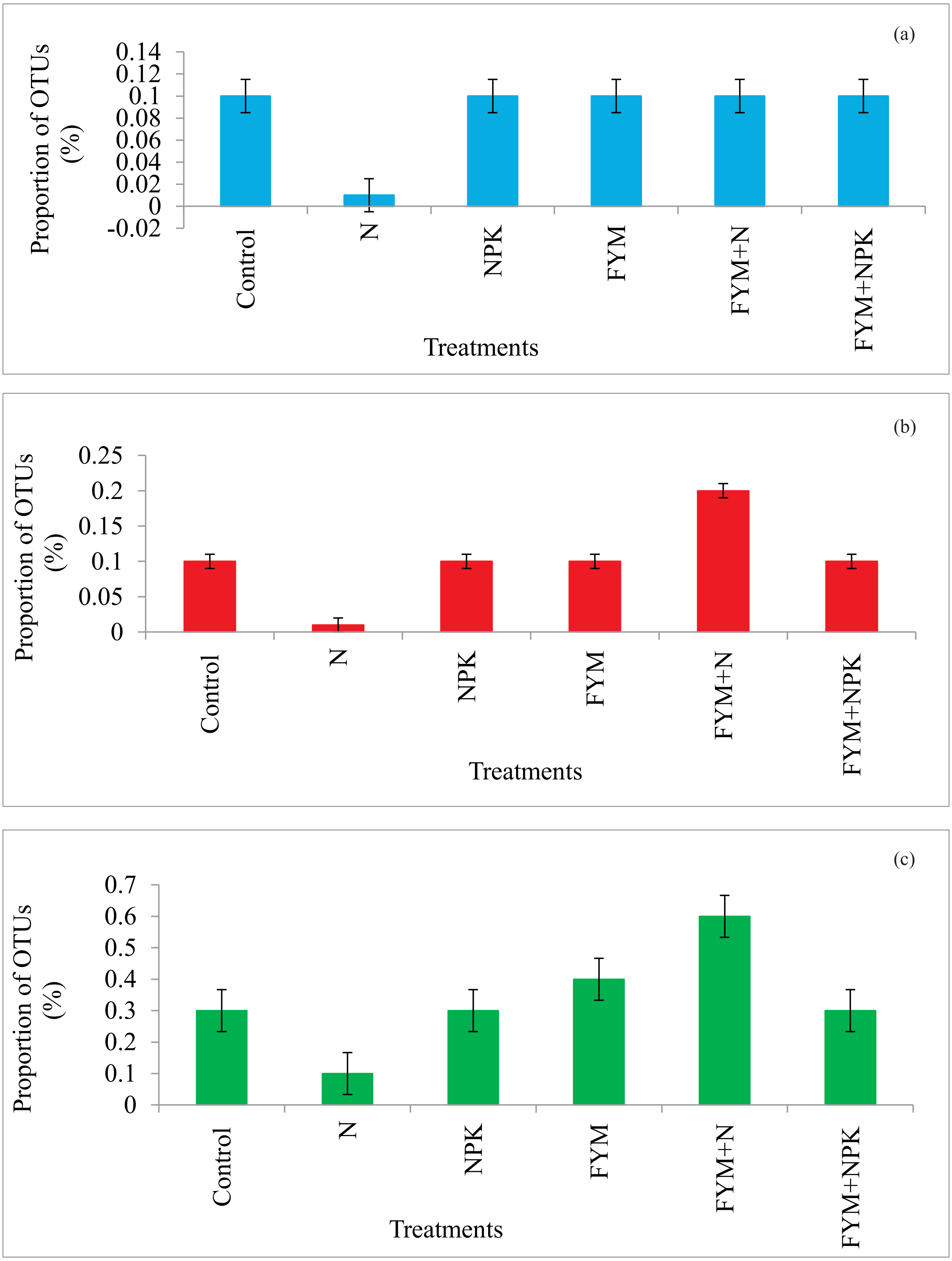


Fig. 2.6. Relative abundance of bacterial phyla such as Actinobacteria (a); Firmicutes (b) and Nitrospirae (c) in N treated plot compared to other treatments. N: nitrogen; P: phosphorous; K: potassium; FYM: farm yard manure) and OTUs: operational taxonomic units. Line on the bars represents standard error among the treatments.


(a)
Proportion of OTUs (%)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
Control
N
NPK
FYM
FYM+N
FYM+NPK
Treatments
(b)
Proportion of OTUs (%)
0.25
0.2
0.15
0.1
0.05
0
Control
N
NPK
FYM
FYM+N
FYM+NPK
Treatments
(c)
Proportion of OTUs (%)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Control
N
NPK
FYM
FYM+N
FYM+NPK
Treatments

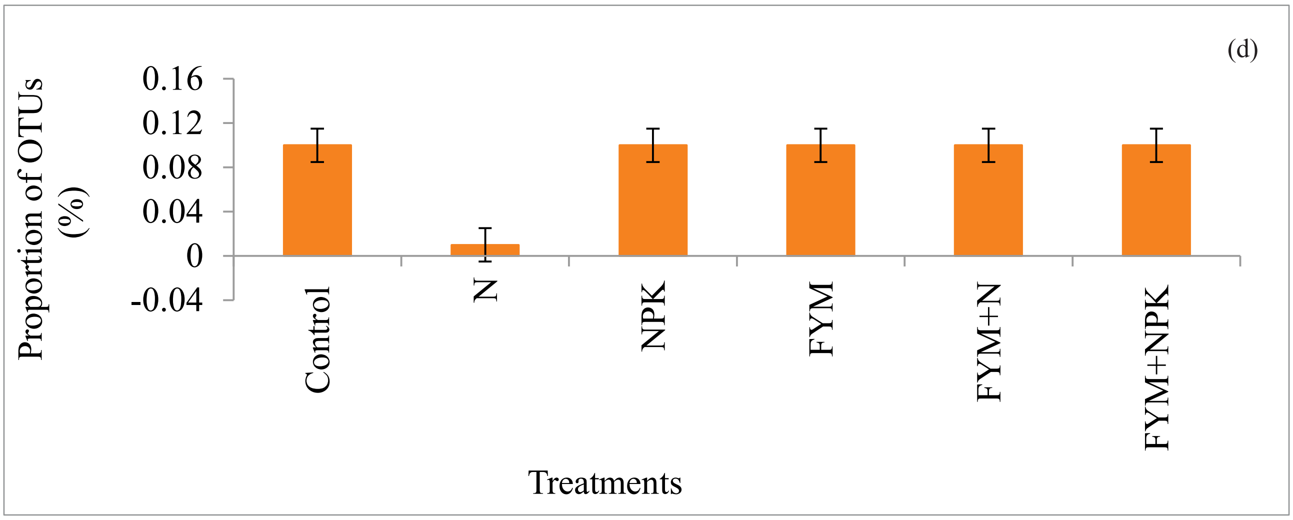


Fig. 2.7. Bacterial phyla such as Fibrobacteres (a); Spirochaetes (b); TM7 (c) and GNO4 (d) towards extinction in N treated plot compared to other treatments. N: nitrogen; P: phosphorous; K: potassium; FYM: farm yard manure and OTUs: operational taxonomic units. Line on the bars represents standard error among the treatments.

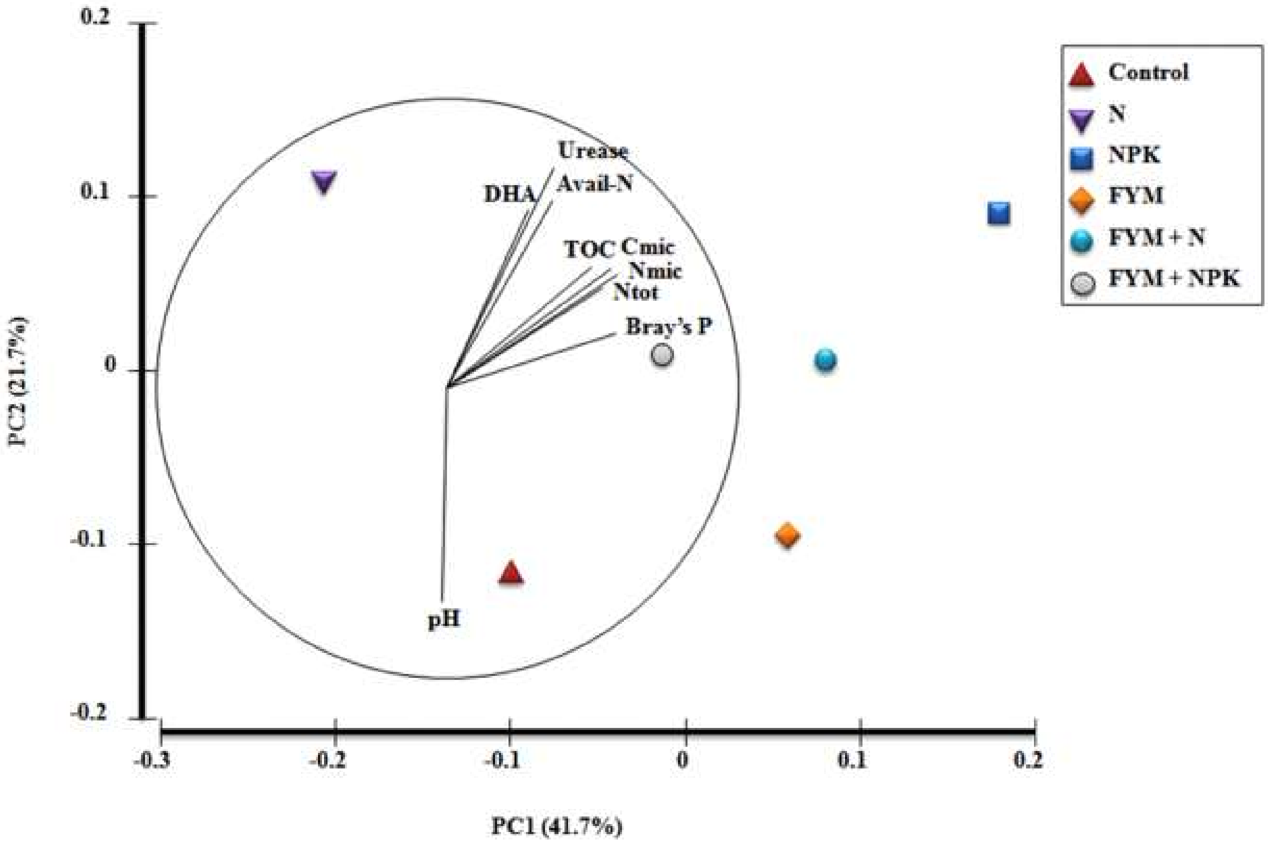


Fig. 2.8. Variation in soil bacterial community under 47 years old LTFE based on environmental variables at Pearson's correlation *(R = 0.6)*. (N: nitrogen; P: phosphorous; K: potassium; FYM: farm yard manure).TOC (%): total organic carbon; N_{tot}(%): total nitrogen; Avail-N (Kg ha^{-1}): available nitrogen; Bray's P (Kg ha^{-1}): Bray's phosphorus; C_{mic}(µg g^{-1}) and N_{mic}(µg g^{-1}):microbial biomass carbon and nitrogen; DHA (µg TPF g^{-1} h^{-1}): dehydrogenase activity; urease (µg NH_4^+ g^{-1}): urease activity.

Assessing energy and water footprints and increasing water productivity in rice-based systems

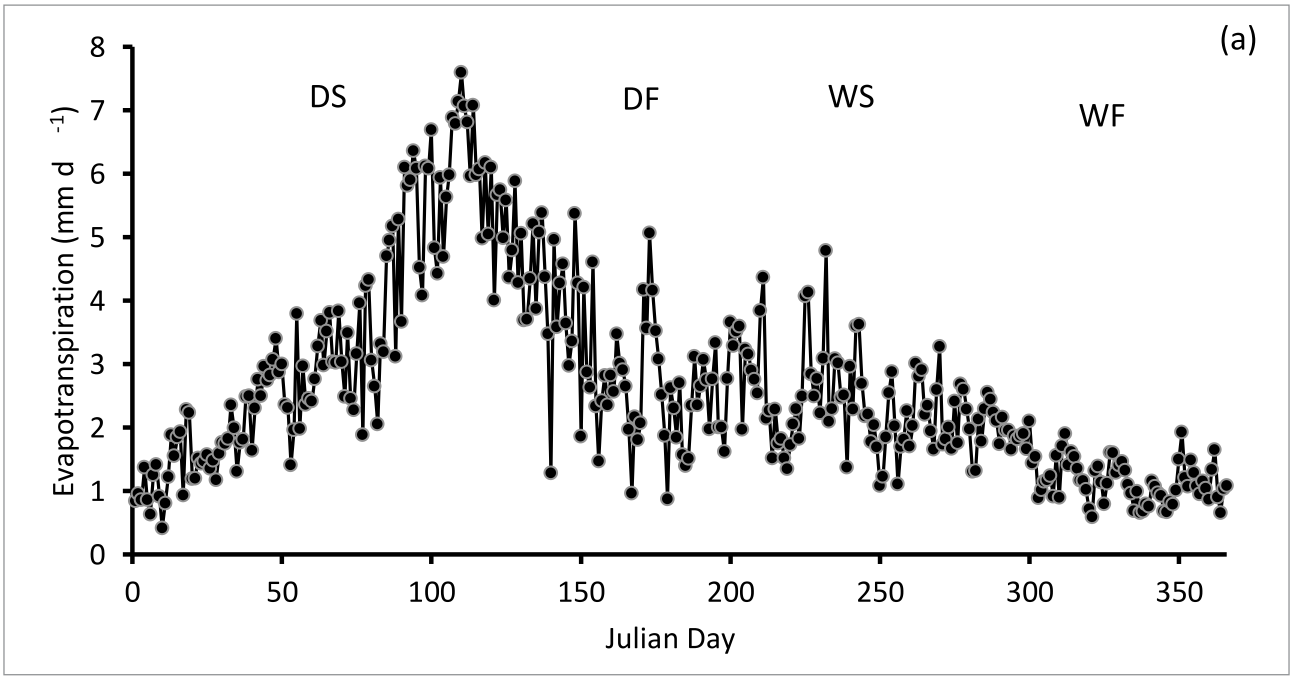
Estimation of actual and reference evapotranspiration for lowland rice paddy

Precise measurement of evapotranspiration (ET) is required for developing better irrigation scheduling. Currently, eddy covariance (EC) approach is worldwide used as direct method for measuring ET. The two year (2015 and 2016) data were used to study the evapotranspiration and crop coefficient of tropical lowland rice paddy in ICAR-NRRI, Cuttack. Daily weather data and energy balance components were taken from agro-meteorological weather station and an eddy covariance (EC) system in dry season (Dry Season (DS), 1-123 Julian days), dry fallow (Dry Fallow (DF), 124-187 Julian days), wet season (Wet Season (WS), 188-316 Julian days) and wet fallow (Wet Fallow (WF), 317-365 Julian days). Twenty-one days old seedlings of rice cultivar *viz.,* Naveen in DS and Swarna *Sub1* in WS were transplanted with a spacing of 20 cm × 15 cm during the month of January in DS and during the month of July in WS. Crop harvesting was done during month of May in DS and during November in WS. The crop was grown in dry season (January-May) and wet season (July-November) and in between the field was kept fallow. The magnitude of the actual evapotranspiration (ETa) and reference ET (ETo) during dry seasons were higher than the wet season in both the years of study. The average growing season ETa rate for dry season rice paddy was 2.86 and 3.32 mm d^{-1}, whereas, it was 2.31 and 2.24 mm d^{-1} during wet season of 2015 and 2016, respectively (Fig. 2.9). The magnitude of ETa increased with the progress of both cropping seasons and found minimum during the fallow periods. Out of all the four methods of estimating ETo, FAO-PM method was found to be better representative of ETo for this region. An overall good agreement was observed between FAO-PM and other three methods of ETo estimation during dry seasons of both the years as compared to wet season.

Agroecology-based intensification of rice based cropping system for enhancing productivity and profitability

Nutrient balance in zero tillage based rice – maize cropping system

A field experiment was carried out to study the effect of different nutrient management options on the rice-maize cropping system under conventional and zero tillage situations to develop conservation agriculture based nutrient management. The experiment was laid out in a split-split plot design with two tillage systems i.e. conventional and zero tillage in main plots and three residue management system i.e. RDF + no



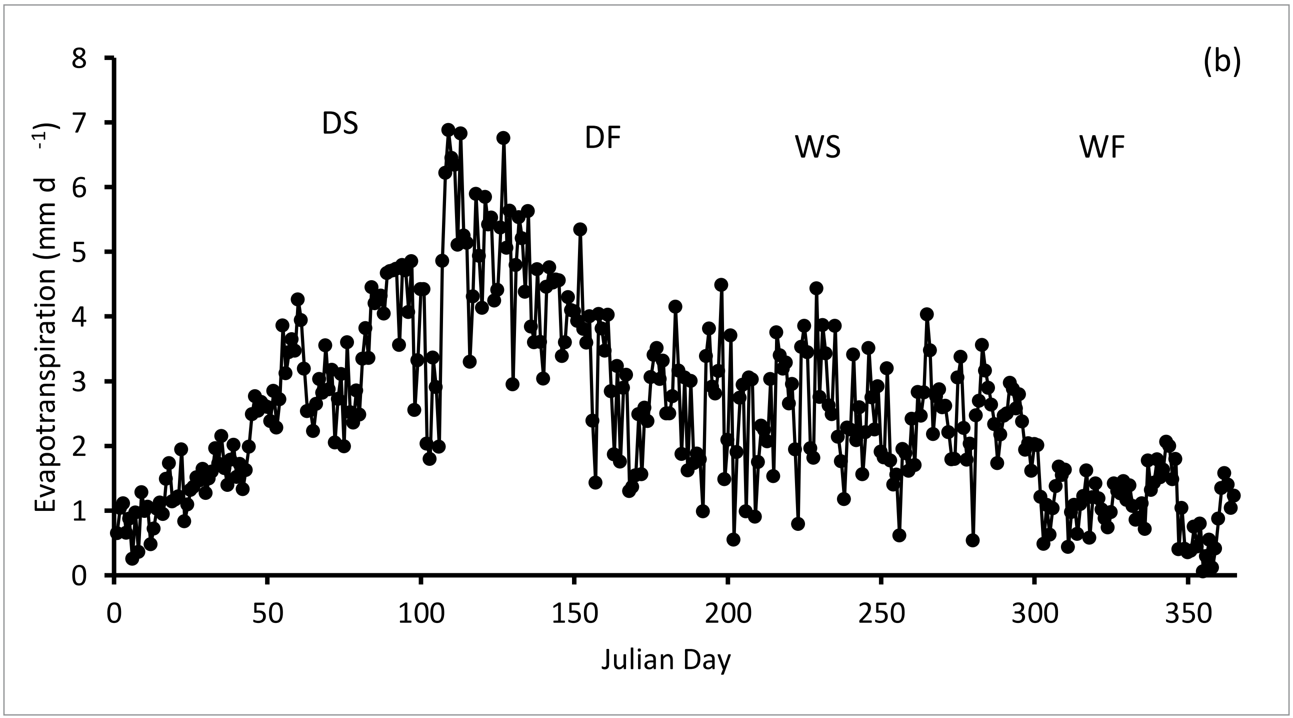


Fig 2.9: Daily variation of actual evapotranspiration (ETa) in (a) 2015 and (b) 2016.
DS= Dry season, DF= Dry fallow; WS= Wet season; WF= Wet fallow

residue, RDF + residue mulching (3 t ha^{-1}) and RDF + residue mulching (6 t ha^{-1}) to maize in subplots and two N levels to rice i.e. LCC based (75 % RDN) and LCC based (100 % RDN) replicated thrice. The variety Pooja (rice) and Super 36 (maize) were used in the experiment. The results indicated that significantly lower grain yield in rice when zero tillage was followed in rice compared to conventional tillage. The grain yield of rice was reduced by 13% in zero tillage compared to conventional tillage but was at par in maize. The system productivity of zero tillage was found to be at par with conventional tillage. The maize and rice grain yield was increased significantly with application of 6 t of rice residue as mulch in maize but application of 3 t of rice residue could not prove its superiority. The system productivity was found significantly higher by 12% with RDF + residue mulching (6 t ha^{-1}) over RDF + no residue. Application of 100% of recommended dose of N produced 8.81% and 13.13% higher grain yield in rice and maize, respectively, compared to 75% of RDN applied to rice. The system productivity of LCC based (100% RDN) was found to be 11% higher than LCC based (75% RDN).

The Partial Factor Productivity (PFP) and Partial Nutrient Balance (PNB) of nitrogen in rice under conventional tillage were found to be significantly higher than zero tillage where as in case of maize, zero tillage was found to be at par with conventional tillage. The PFP and PNB of nitrogen did not differ significantly with respect to residue levels applied to maize both in rice and maize crop. Application of 75% of recommended dose of N recorded 18% and 12% significantly higher PFP and PNB, respectively, compared to 100% of RDN applied to rice. However, in case of maize, application of 100% recommended dose of N registered 13% and 17% higher PFP and PNB, respectively, compared to 100 % of RDN. The Partial Factor Productivity (PFP) and Partial Nutrient Balance (PNB) of phosphorous in rice under conventional tillage was found to be significantly higher than zero tillage, whereas, in case of maize, zero tillage was found to be at par with conventional tillage. The PFP was increased 12% with application of 6 t of rice residue compared to RDF + no residue. Similarly, PNB was increased by 19% with application of 6 t of rice residue compared to RDF + no residue. The PFP and PNB of phosphorous in maize as well as system did not differ significantly with respect to tillage and residue mulching in maize.

Effect of stand establishment methods and hydrogel on productivity of rainfed rice - green gram cropping system

The effect of stand establishment methods and hydrogel on productivity of rainfed rice - green gram cropping system was studied. The experiment was laid out in a split plot design with two stand establishment methods in rice i.e. transplanted rice (TPR) and direct seeded rice (DSR) in main plots and seven stand establishment methods in green gram i.e. conventional, conventional + hydrogel, conservation agriculture, conservation agriculture + hydrogel, pyra cropping, pyra croppping + hydrogel and fallow in subplots, replicated thrice. The variety Sahbhagidhan of rice and IPM 2-3 of green gram were used in the experiment. The grain yield of rice under TPR was at par with DSR but significantly higher seed yield (11%) of green gram was produced in DSR plots compared to TPR. In green gram, conventional method of stand establishment (line sowing after tillage) with hydrogel application gave highest grain yield which was at par with conservation agriculture (zero till line sowing) + hydrogel but significantly higher compared to conservation agriculture without hydrogel and pyra cropping of green gram with or without hydrogel. From the economics point of view, DSR followed by conventional green gram + hydrogel treatment was found more profitable than other methods of stand establishment. The moisture content of the soil was comparatively higher in the DSR plots compared to TPR irrespective of depth of the soil and growth of green gram. Though, the pyra cropping of green gram recorded higher moisture content through out the crop growth period it could not be converted to yield due to lower plant population in the pyra cropping system. The cost of cultivation for TPR was Rs. 2950/- more than DSR, whereas, the gross return and net return of DSR was Rs. 6239/- and Rs. 9189/- more than TPR per hectare of land resulting in 22% higher B:C ratio than TPR.

Enhancing productivity and profitability of rice-rapeseed/ toria cropping system under rainfed situation

A field experiment was conducted during 2017-2018 to evaluate the different crop establishment methods and sulphur levels for enhancing productivity and profitability of rice-toria cropping system under rainfed situation. The experiment was laid out in split plot design and replicated thrice. The treatments consist of four crop establishment methods *i.e.*C_1: Rice- toria pyra cropping, C_2: Rice- toria broadcasting with tillage, C_3: Rice- toria line sowing with tillage and C_4: Rice- toria line sowing with no tillage in main plot and three sulphur levels *i.e.*S_1: S at 20 kg ha^{-1} to rice + S at 20 kg ha^{-1} to toria, S_2: S at 40 kg ha^{-1} to rice only and S_3: S at 40 kg ha^{-1} to toria only. Experimental result revealed that application of sulphur at 20 kg ha^{-1} to rice + sulphur at 20 kg ha^{-1} to toria crop increases system yield by 6.7% over application of S at 40 kg ha^{-1} to toria only but it remained at par with the treatment applied with S at 40 kg ha^{-1} to rice only. Similarly, application of sulphur at 20 kg ha^{-1} to rice + sulphur at 20 kg ha^{-1} to toria crop recorded higher net return and B:C ratio (1.70) as compared to application of S at 40 kg ha^{-1} to toria only. Among the crop establishment methods Rice-line sowing of toria with tillage recorded highest system productivity but it was at par with other treatments. Rice-toria pyra cropping sequence registered highest net return and B: C ratio (1.70) as compared to other treatments which could be attributed to lower cost involved in growing toria pyra cropping.

Integrated farming system under irrigated and deep water areas

Maintenance and evaluation of environmental impact of the existing rice based integrated farming system under irrigated and deep water areas

Multi-tier rice-fish-horticulture based integrated farming system with components of various crops and livestock was evaluated in deepwater ecology. The wet season rice cultivars, namely, Pooja, CR Dhan 500 and CR Dhan 501 were sown in Tier III during first week of June in *rainfed* medium-deep water in the upper part of the field those yielded 5.87 t, 5.32 t and 5.18 t per ha, respectively. In the Tier IV under deepwater situation with more than 50 cm water depth at lower end of the field, the grain yield in Jalmani, CR Dhan 505 and Varshadhan were 3.78 t, 6.76 t and 6.57 t per ha, respectively. Among the varieties CR Dhan 505 was performed better and found suitable for inclusion of rice-fish- duck system for its tall height and stiff straw.

Soil was collected under different components at three ft depths from the multitier rice-horticulture based farming system and analyzed for pH, organic carbon, phosphorus, available nitrogen. Result showed that with the increase of soil depth there was a decrease in nutrient content. Nutrient status of pond refuge enterprises was recorded to be higher with organic carbon (1.34%), available nitrogen (328.23 kg ha^{-1}) and phosphorus (41.96 kg ha^{-1}) content. However, where fish and other aquaculture were bred throughout the year, the soil nutrient status was lower in case of vegetable enterprise, may be due to intensive cultivation.

Evaluation of rice plant as a periphytic substrate in rice - fish system

The rice plant as a periphytic substrate under integrated rice-fish system was evaluated in 2017. In order to achieve the objectives, five treatments, *viz.* T_1-(Rice alone), T_2 (Rice +Rohu) and T_3 (Rice + Catla), T_4 (Rice + Mrigal) and T_5 (Rice + Polyculture) were imposed in field in randomized block design with four replications. The high dry matter (DM), ash content, and low ash free dry Matter (AFDM) content in T_1(Rice alone), T_3(Rice + Catla) and T_4 (Rice + Mrigal) might be corroborated to the shading effect as because of none grazing of peri-phyton. The high ash free dry matter (AFDM) and low ash content in T_2 (Rice +Rohu) and T_5 (Rice + Polyculture) might be due to grazing of peri-phyton by rohu – a potential grazer (Table 2.1)

Refinement and evaluation of rice based integrated farming systems for coastal saline areas

Rice based integrated farming system was developed successfully and validated at village-Gadakujanga, Block-Ersama, District-Jagatsinghpur. Kunjo Mullick (Farmer) converted his 4 acres of land into rice-fish with dyke system. Before shaping of the land the rice field usually remains submerged (up to 50 cm water depth) during *kharif* season with the tidal waves and back water flow from river. Only option with the farmer was to take the rice crop during the dry season with extra early rice variety having low productivity. The farmer could dig the pond (1 acre) at the edge of his rice field (3 acres) with the initial investment of Rs 52,000/-. Components included were rice, fish, ducks, poultry, vegetables and horticultural crops on the bunds. Farmer got net income of Rs. 1,50,290 ha^{-1} $year^{-1}$ from high yielding rice variety (3.56 t ha^{-1}), fish (yield was 750 kg ha^{-1}), poultry (200 kg 80 $chicks^{-1}$ $cycle^{-1}$), duckery (egg and 110 kg meat 50 ducklings $^{-1}year^{-1}$) fruits and vegetables on the bund during the second year.

Ecological mechanism and diversity in rice based integrated farming system

The dynamic and transitional characteristics of rice

Table 2.1. Effect of presence and absence of fish on the rice plant as a periphytic substrate in rice –fish system

Treatments	Rice	Rice + Rohu	Rice + Catla	Rice + Mrigal	Rice + CRM
	T_1	T_2	T_3	T_4	T_5
Survival (%)	-	90-96.7 (93.3 ± 2.7)	86.7-93.3 (90.8±3.2)	83.3-93.3 (87.5±5)	80-86.7 (82.5±3.2)
SGR (%BW/day)	-	3.38-3.65 (3.52±0.12)	2.93-3.02 (2.98±0.04)	4.07-4.19 (4.13±0.05)	--
NBW(kg/ha/80days)	-	444-540 (486±43)	478-535 (503±26)	381-406 (398±12)	388-432 (414±21)
DM(mg/m^2)	52-70 (63±5)	56-66 (61±3)	58-72 (65±5)	58-70 (63±4)	56-66 (61±3)
AFDM (mg/m^2)	27-38 (33±3)	36-58 (49±7)	32-42 (37±3)	31-40 (35±3)	35-47 (41±4)
Ash (%)	43-52 (47±2)	5.2-43.75 (21±13)	38-47 (43±2)	39-53 (45±4)	24-44 (33±6)

*SGR-Specific Growth Rate; NBW-Net Body Weight; DM- Dry matter; AFDM- Ash free dry matter.

field ecosystems provide an excellent environment for integration with compatible components such as fish and duck, which enhance the overall productivity through the effective nutrient recycling. The ecological mechanisms underlying the rice-fish-duck system sustainability have been studied in respect of soil and water chemistry, dynamics of plankton, microbe and benthic populations and their community compositions to understand the ecological significance and diversities of organisms in the processes of maintainace of soil health, nutrient recycling and sustainable productivity in different rice-based integrated farming systems. In the integrated system such as rice-fish (RF), rice-duck (RD), and rice-fish-duck (RFD); the physico-chemical parameters of water (dissolved oxygen, nitrate, ammonia, total alkalinity, dissolved organic matter, and total suspended solid) and soil nutrient levels were significantly higher compared to conventional system due to the continuous addition of fecal matters, scooping and churning of soil by fish and ducks in the paddy field ecology. The aquatic biological diversity including planktons (phyto- and zooplankton), soil benthic fauna and microbial populations were dynamic in integrated rice-based system, providing an indication of enhanced soil fertility and production sustainability. The observed decreasing trends of plankton and soil benthic populations in integrated systems (RF, RD and RFD) indicated that fish and ducks fed these materials in rice ecology. Higher productivity and profitability in term of rice equivalent yields (REY) and the ratio of output value and cost of cultivation (OV/CC) were achieved in integrated farming system as compared to conventional rice farming (CRF).

The PCA analysis among the significant water quality variables resulted the PC1 and PC2 accounted for 87.38% and 10.76% of the total variation, respectively, whereas, the PC loading factor indicated almost all water quality variables under different farming systems. PCA analysis of significant correlated soil quality variables along with REY under different farming management practices indicated that all the variables were clearly distinguished into two groups, one group comprising soil physical and chemical parameters (clay, TN, AK and SOC) and another group compriseing of macro-benthos parameters (Oli, Hir, SGA ad Ne). The PC1 accounted for 95.88% and PC2 explained 3.026% of total variation, whereas, the PC loading of each significant soil quality variables showed all the farming systems clearly distinguished and the effects of all variables in each farming system were attributed differently. The different year of sampling of soil and water variables did not register any significant variation.

Thus, the present study revealed that adoption of rice-fish-duck integrated farming system enhanced total farm production and income. Besides, the evaluation of different indicator indices (Fig 2.10) *viz.,* water quality index (WQI) and soil quality index (SQI) have shown a good prediction about ecological aspects of agro-ecosystems and will be helpful in farm management decisions making processes for improving farm productivity, profitability, and overcome any potential limiting factors in the rice-fish-duck integrated farming system. The rice-fish-duck integration utilises maximum ecological niches into potential production processes, which enhances farm production, farmer income and improves the soil health through the effective nutrient recycling in the rice ecologies.

Mechanization of rice-based cropping systems for higher productivity and energy use efficiency

Development and evaluation of deep placement urea briquette applicator attachment for mechanical rice transplanter

The four row urea briquette applicator attachment was developed to apply urea briquettes between the rows of rice transplanted by mechanical transplanter (Fig 2.11). The overall length x width x height of developed urea briquette applicator was 1150 x 1700 x 670 mm with overall weight of 40 kg. To design the metering unit of urea briquette applicator, physical properties of urea briquettes was measured i.e. size, shape, surface area, sphere type, weight, bulk density and angle of repose. The mean length, breadth and thickness of urea briquettes were found 16.59 mm, 14.54 mm and 9.30 mm, respectively. The mean size and sphericity of urea briquette were found 13.10 mm and 0.788, respectively. The mean weight and surface area of briquette were found 1.13 g and 470.44 mm^2, respectively. Based on the maximum length and thickness of urea briquette, the diameter and depth of

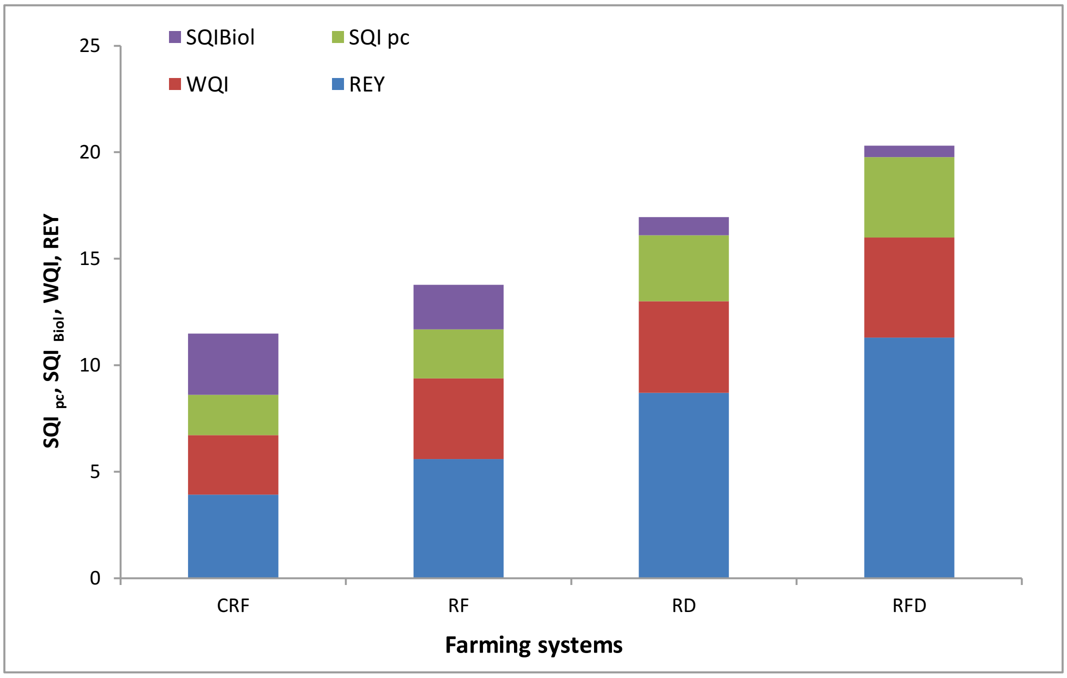


Fig. 2.10. Mean values for indicators of Water quality (WQI), indicators of soil quality (physicochemical) SQIpc, and indicators biological soil quality (macro benthos) SQIBiol, along with rice equivalent yields (REY) in four land management systems (CRF, RF, RD, RFD). WQI: water quality indicator (based on water physico-chemical properties, phyto and zooplankton and microbial population); SQIpc,: soil quality indicator (based on physical and chemical parameters of the soil), SQIBiol: soil quality biological indicator (based on abundance and diversity of macro benthos population observed in different farming system); CRF: conventional rice farming; RF: rice fish; RD: rice duck; RFD: rice fish duck integrated farming system.

cup were kept as 20 mm and 8 mm, respectively.

The developed urea briquette applicator attachment was tested in laboratory. The missing rate of 4.37% was observed in half-filling of hoppers. The over falling rate of 2.07% and 6.65% was observed in 3/4th and full filling of hoppers. The application rate of the urea briquette applicator was ranged between 89.2 to 92.13 kg ha^{-1}. At operating speed of 1.66 km h^{-1} the field capacity of the self-propelled transplanter with attachment of deep placement urea briquette applicator was 0.191 ha h^{-1} with field efficiency of 67.82%. The field machine index of self-propelled transplanter with attachment of deep placement urea briquette applicator was 84.10%. Total useful time was measured as 66.93% and remaining time loss due to turning (12.67%) and tray feeding (20.40%), respectively. The fuel consumption of self-propelled transplanter with attachment of deep placement urea briquette applicator was found 1.81 l h^{-1} or 9.44 l ha^{-1}. Further improvements in design are required to achieve the variable application rate of urea briquettes.

Development and evaluation of power operated two row wet land weeder for rice

Power operated two row wet land weeder for rice was developeod (Fig. 2.12). Weeder covers the two rows in one pass. Cutting blade was designed with width of 12 cm and the distance between blades was adjustable for different row spacing of paddy crop (row spacing of plant 20-25 cm). Power transmission system is designed to transmit the power from engine to blade with the use of belt, pulley, clutch, chain and chain sprocket. Brief specification of developed weeder is given in Table 2. 2.

The performance f developed weeder was evaluated. Different parameters were taken *viz*., depth of cut (4 cm, 5 cm , 6 cm), plant row spacing (20 cm, 22.5 cm and 25 cm) and speed of the blades (74 rpm, 80 rpm and 86 rpm) and effect of these parameters on weeding efficiency, plant damage, field capacity, field efficiency and fuel consumption was estimated. The fuel consumption was found in the range of 0.77-0.84 l h^{-1}. The fuel consumption was directly proportional to speed of blade and depth of cut. When we increase the depth of cut then power requirement was increased resulted in high fuel consumption. The maximum field capacity of weeder was observed 0.083 ha h^{-1} at row spacing of 25 cm and depth of cut was 4 cm with blade speed 86 rpm. Maximum fuel consumption was found at blade speed 86 rpm with depth of cut 6 cm. Field efficiency of the power weeder was ranged from 56.79 to 86.18%. Maximum field efficiency was observed at 6 cm depth of cut with blade speed 86 rpm at 20 cm row spacing between plants. The weeding efficiency of power weeder was found highest (77.5%) in plant spacing 20 cm with blade speed of 86 rpm. The width of blade was kept 12 cm, which enables the weeder to work properly in row without damaging the plants, resulted in less plant damage during the operation (Table 2.3). The field evaluation of developed weeder was done in comparison to finger weeder, cono weeder and manual weeding (Table 2.4). The cost of machine and cost of operation were found Rs. 23000/- ha^{-1}, and Rs. 1239/- ha^{-1}, respectively.

Table 2. 2 Specification of developed power operated weeder

Parameters	Values
Engine	1.03kW
Rated rpm	3600
Fuel type	Petrol+ kerosene
Fuel tank capacity	1.5 lit
Depth of work	4-8 cm
Power transmission	Chain & belt drive
Belt drive reduction	1:8.7
Chain drive reduction	1:3
No. of flange (Blades)	2
No of blades in each flange	16
Over all dimension (length, width, height)	165, 62, 110 cm
Ground wheel	Dia. 18 cm, width 10 cm
Float (length, width, height)	75, 12, 15cm
Total weight	46 kg

Table 2.3 Effect of different row spacing and speed of blade on performance of power weeder at depth of operation of 6 cm and 25 DAS

Speed of blade	20 cm row spacing			22.5 cm row spacing			25 cm row spacing		
	Field capacity, ha.h-1	Plant damage, %	Weed control, %	Field capacity, ha.h-1	Plant damage, %	Weed control, %	Field capacity, ha.h-1	Plant damage, %	Weed control, %
74	0.050	0.95	71.30	0.053	0.79	64.36	0.056	0.31	59.90
80	0.058	1.98	73.50	0.060	1.79	65.36	0.062	1.72	57.54
86	0.072	3.85	76.81	0.075	3.58	68.01	0.080	3.45	60.28

Table 2.4 Field evaluation of developed weeder in comparison to weeding implements/ methods in rice

Weeding methods	Field capacity, (ha.h^{-1})	Manpower required (man-h. ha^{-1})	Total cost, (Rs. ha^{-1})	Energy, (MJ.ha^{-1})
Finger weeder	0.010	100	3125	384.10
Cono Weeder	0.016	63	1954	310.60
Developed power weeder	0.076	14	1239	556.46
Hand weeding	0.004	250	7813	490.00

Fig. 2.11 Urea briquette applicator attachment for self-propelled rice transplanter

Fig. 2.12 Power operated two row wet land weeder for rice

Increasing productivity and input-use efficiency in rice-based production systems with resource conserving technologies

Assessment of ecosystem services

Ecosystem services (ES), are vital for the sustainable supply of food and fibre. The current trends of decline in the ability of agricultural ecosystems to provide ES pose great threat to food security worldwide. Ecosystem service valuation was done for five resource conservation technologies along with conventional control with and without application of nitrogen under direct seeded and transplanted conditions in a rice-green gram system taking into consideration the marketed ecosystem services (food and raw material) and non-marketed ecosystem services (soil formation, soil fertility, carbon accumulation, nitrogen fixation, biological control of pests, soil erosion and hydrological flow). It was found that use of green manuring resulted in higher values of both marketed and non-marketed ES (Fig. 2.13) under transplanted (TPR) and direct seeded rice (DSR).The ecosystem service under transplanted rice was higher as compared to the direct seeded rice due to higher productivity. Zero tillage under both TPR and DSR recorded higher ecosystem services as compared to conventional method due to higher soil fertility and carbon accumulation value.

Simulation on the effect of resource conserving technologies in transplanted rice through DSSAT modelling

Effect of resource conserving technologies (RCTs) on transplanted rice was studied using DSSAT model. The CERES-Rice model in DSSAT v 4.6 was used in this study. Six resource conservation techniques along with conventional package of practice as control were tested. The treatments included were, T_1: Conventional practice as control; T_2: Mechanical transplanting+ incorporation of paddy straw; T_3: Green manuring; T_4: Mechanical transplanting without residue; T_5: Mechnical transplanting + CLCC; T_6: Mechanical transplanting + Biochar. Weather file, soil file and crop management files were prepared

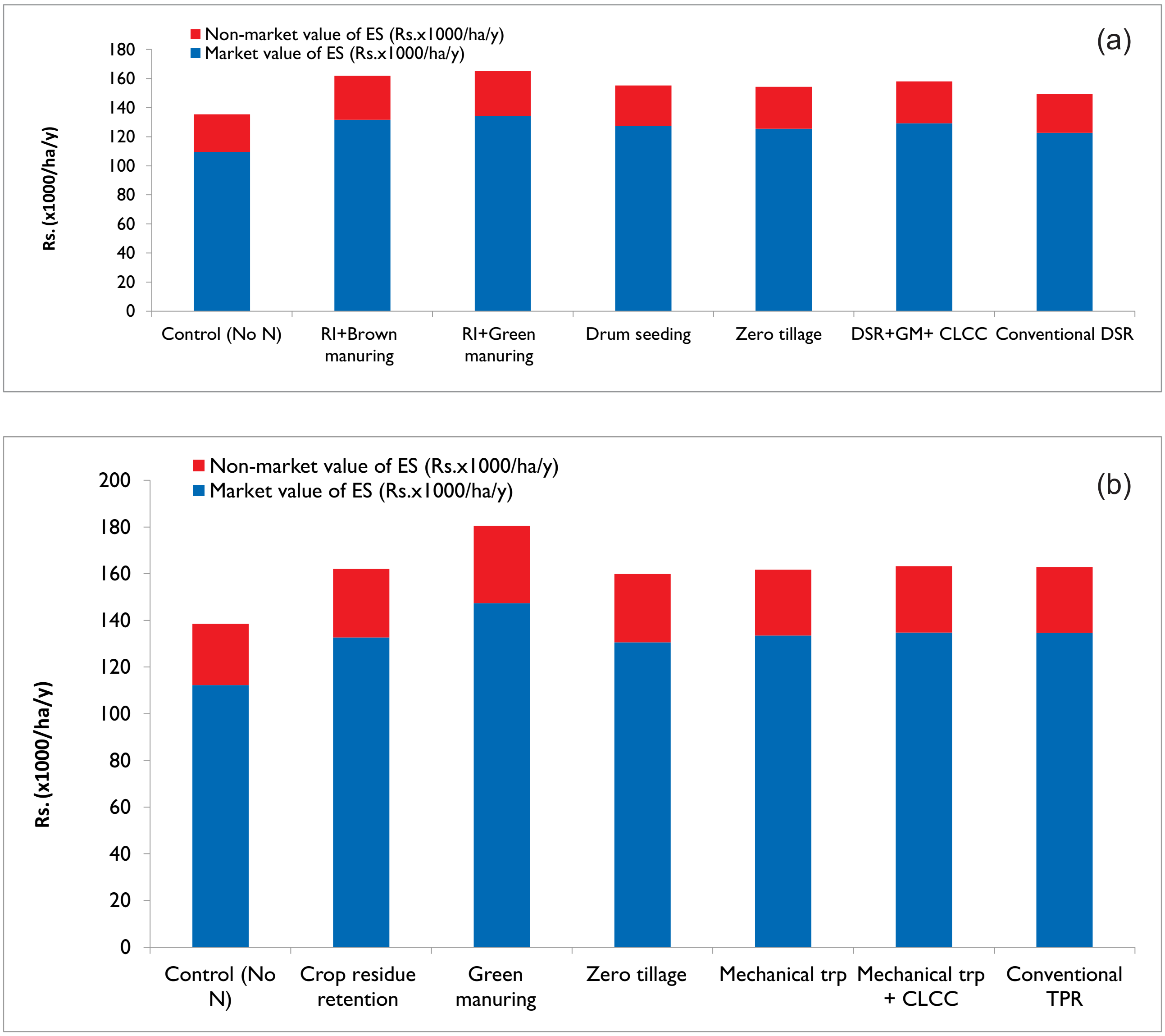


Fig. 2.13 Values of marketed, non-marketed and total ecosystem services generated in rice-green gram system under different RCTs for a) direct seeded rice b) transplanted rice.

using the weather, soil and crop management data collected from the experiment. Calibration of the DSSAT model was done using the data of 2015 experiment on RCT's. Genetic coefficients of Pooja variety of rice were developed using Gen Calc program. The 'trial and error" method was used in the calibration process to compare the best agreement, i.e., root mean square error (RMSE) was used to measure the minimum differences between the simulated and the measured yield by changing crop growth parameters. After calibration, the model accurately simulated the number of days to anthesis, maturity and grain yield in all the treatments for the year 2015 with NRMSE of 3.6% and d-stat value of 0.81 for grain yield indicating acceptable performance. The model simulated grain yield under various RCT's with high r^2 value (0.761).

The DSSAT model was validated using 2016 experimental data. The model predicted the phenological events of anthesis and maturity in rice accurately with low RMSE (1.0 and 0). There was a good agreement between observed and simulated values with low NRMSE (0.78 and 0%, respectively).

Yield and soil organic carbon assessment in rice-based system under organic nutrient management

Field experiment was conducted in rice (*kharif*)-groundnut (*rabi*-summer) system with eight organic nutrient treatments as follows: T_1-Control; T_2-FYM; T_3-Azolla; T_4-Green manure; T_5-Vermicompost; T_6- FYM + Azolla, T_7- FYM + green manure; T_8-FYM + Vermicompost. For groundnut (summer, 2017) variety Smruti (OG-52-1; Spanish bunchy habit group; duration: 110 days) was grown under irrigated condition with two treatments: R- with rhizobium-; NR- without rhizobium, while, residual N supplemented by organic manures applied in previous rice crop. The highest pod yield was recorded under FYM + green manure in both R and NR treatments. For rice, 'Padmini' and 'Ketekijoha' varieties had been grown in *kharif*, 2017. Results showed that both the cultivars were responsive towards organic sources of nutrients, while grain yield of 'Ketekijoha' was invariably better over 'Padmini' across the treatments and the highest was also observed under FYM + Green manure. Among the soil parameters SOC content was highest in FYM + Vermicompost treatment (Fig. 2.14, 2.15).

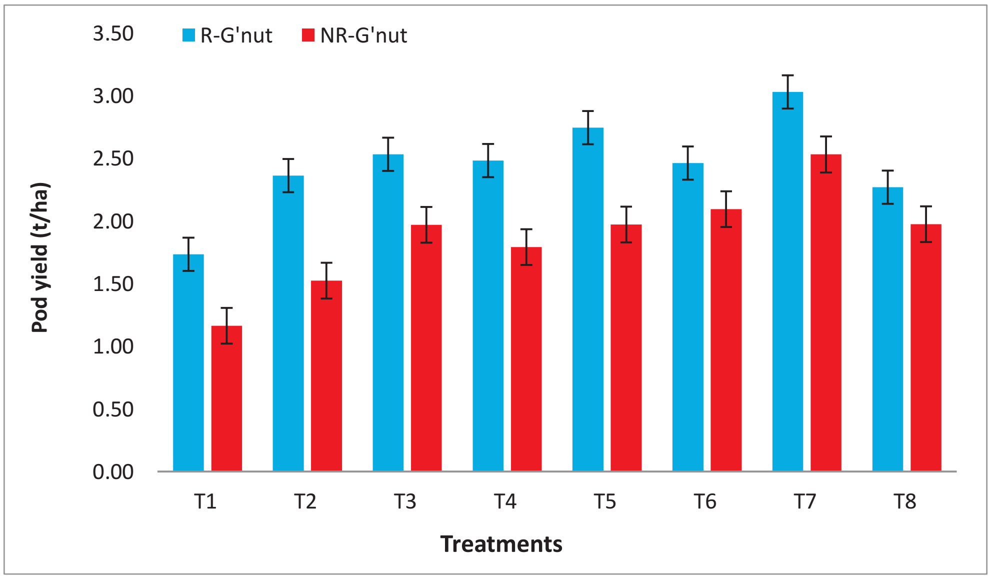


Fig. 2.14 Pod yield of groundnut during 2017

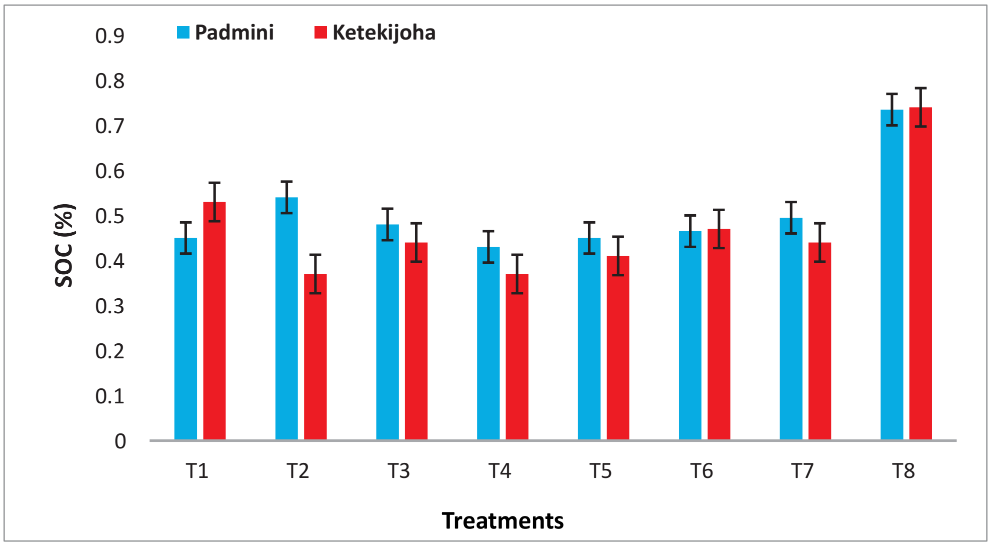
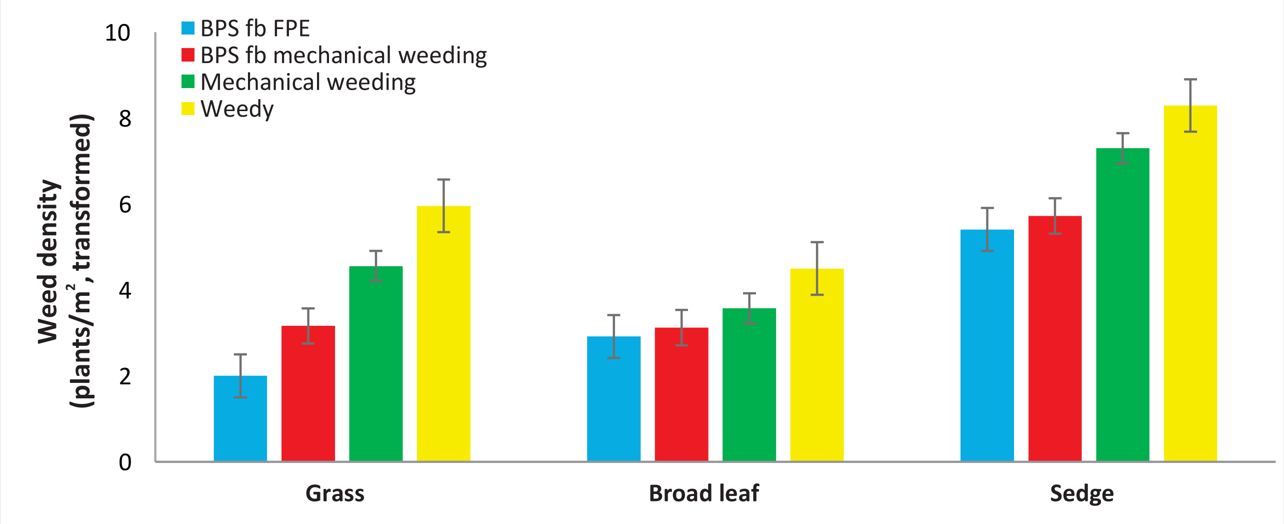


Fig.2.15 Soil organic C content under rice cultivation during *kharif* 2017

Weed management in rice production systems

Development of weed management strategy for zero tillage rice

The field efficacy of mechanical weeding in combination with chemical treatments in zero tillage transplanted rice was evaluated. The weed control treatments were, application of bispyribac sodium (BPS) at 5-7 DAT followed by fenoxop-p-ethyl at 25-30 DAT (T_1), application of BPS at 5-7 DAT followed by mechanical weeding at 25-30 DAT (T_2), mechanical weeding at 25-30 DAT (T_3) along with weedy check (T_4) and weed free (T_5). The results revealed that under zero tillage, the sedges constituted 61%, grasses constituted 26% and broad leaved weeds constituted 13% of total weeds. Among the weed management treatments, sequential application of BPS followed by fenoxop-p-ethyl (T_1) was most effective treatment and recorded lowest weed density and highest weeds control efficiency (70%). Combination of chemical and mechanical weeding (T_2) recorded significantly lower weed control efficiency (60%) compared to sequential application of herbicides (T_1). Mechanical weeding (T_3) was least effective in weed control and recorded lowest weed control efficiency (35%) and significantly higher weed density (Fig. 2.16).



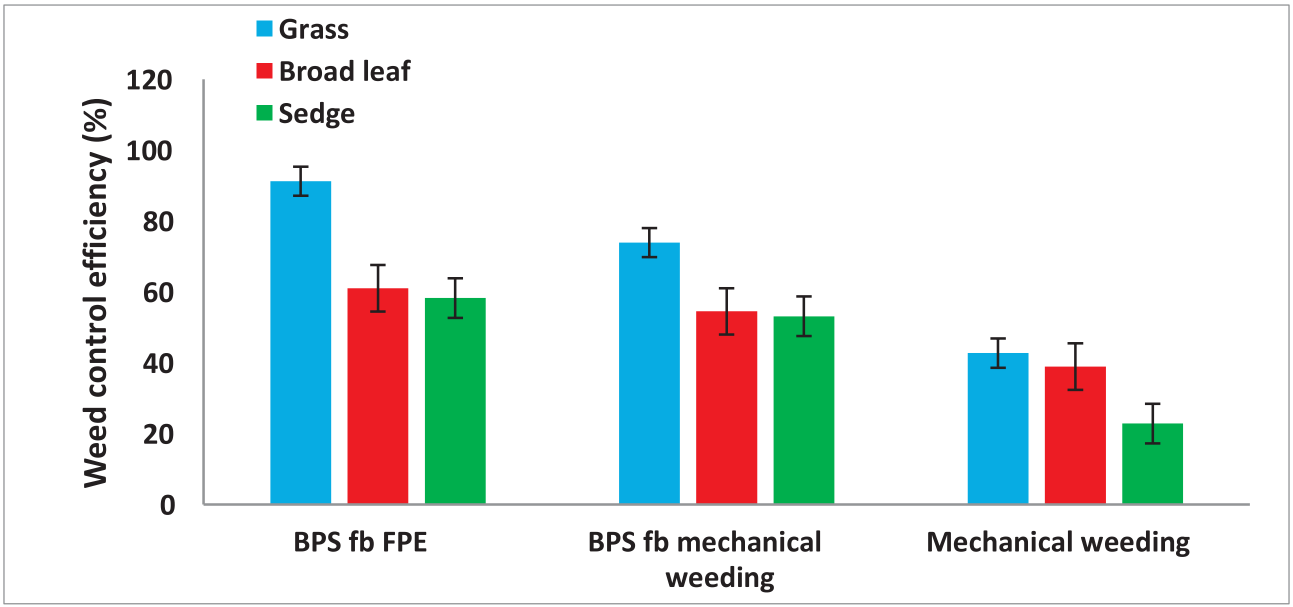


Fig. 2.16. Weed density (plants m^{-2}) and weed control efficiency (%) at 60 DAT

Assessing weed dynamics, management for improving productivity and production of rice

Development of species wise map showing weed distribution pattern in coastal Odisha

Field survey was conducted in three coastal district of Odisha *viz.* Cuttack, Jajpur and Puri during wet season, 2017 to detect the dominance of prevalent weeds in transplanted rice fields by following quantitative survey method using 0.5m x 0.5m size quadrate with 20 samples from each field. The weed samples were collected at 45 days after transplanting and counted species-wise for computing the density, relative density, frequency and relative frequency. Biomass of collected weed samples was recorded for computing relative dominance of weeds. Survey data revealed that there was a dominance of broadleaved weeds (49-51%) and sedges (34-37%) in *rainfed* lowland transplanted rice fields of these districts. The dominance of sedges and broadleaved weeds might be due to presence of continuous standing water (3-7 cm at early vegetative stage since transplanting during August). Among the weed species, *Ludwigia octovalvis* was the most dominant having highest density, relative frequency and relative importance value followed by *Cyperus iria* in all the three districts (Table 2.5).

Table 2.5. Density, Relative frequency and Relative importance of major weeds in coastal Odisha

Species	Density (no m^{-2})			Relative frequency (%)			Relative Importance (%)		
	Cuttack	Jajpur	Puri	Cuttack	Jajpur	Puri	Cuttack	Jajpur	Puri
Ludwigia octovalvis	24.5	20.2	11.8	29.5	39.9	24.5	38.1	50.7	25.3
Spenoclea zeylanica	2.6	1.5	5.5	5.4	5.6	12.9	6.8	5.2	12.3
Marsilia quadrifolia	-	-	5.5	-	-	9.5	-	-	8.9
Ipomoea aquatica	-	-	1.8	-	-	2.0	-	-	3.1
Alternantherase ssilis	2.7	0.8	-	8.8	5.6	-	7.0	3.6	-
Anagalis arvensis	3.3	-	-	5.8	-	-	5.3	-	-
Cyperus iria	4.8	6.6	9.5	16.1	15.7	12.2	11.6	14.1	13.4
Cyperus difformis	3.2	-	7.0	9.2	-	10.9	7.1	-	10.7
Cyperus haspan	4.5	1.7	2.5	6.9	4.5	3.4	6.1	3.9	3.4
Fimbristylis miliacea	3.7	5.8	2.5	4.6	14.6	8.2	4.8	11.8	6.3
Echinochloa crus-galli	1.6	1.3	3.9	4.6	6.7	8.2	4.8	5.3	9.5
Panicum repens	2.1	0.8	1.3	3.1	5.6	4.2	4.0	4.1	4.2
Other	2.3	0.5	1.0	6.0	1.8	4.0	4.4	1.3	3.0

Evaluation of cultivars for weed competitiveness under aerobic and wet direct-sown rice

Two field experiments were conducted to evaluate the weed competitiveness of promising rice varieties of aerobic and wet direct-sown rice (W-DSR) during wet season, 2017 in split plot design with weed competition (4 treatments) in the main plots and rice varieties (six) in subplots. The main plot treatments included weed free for 30, 45 and 60 days after emergence (DAE) with weedy check for aerobic rice and weed free for 15, 30 and 45 days after sowing (DAS) with weedy check for wet-DSR. The subplot treatments included rice varieties *viz.,* DRR Dhan41, DRR Dhan42, DRR Dhan44, DRR Dhan46, Sahbhagidhan and CR Dhan203 for aerobic rice and DRR Dhan44, DRR Dhan45, DRR Dhan46, RP Bio 226, Swarna *Shreya* and CR Dhan203 for wet DSR. Experimental results showed that CR Dhan203 produced significantly higher yield (4.15 t ha^{-1}) under aerobic condition while DRR Dhan44 recorded significantly higher yield (4.45 t ha^{-1}) under wet DSR. It was also found that weed free up to 30, 45, 60 DAE showed 25%, 63%, 90% yield advantages over the weedy check under aerobic condition while weed free up to 15, 30, 45 DAS showed 23%, 57%, 73% yield advantages over the weedy check under wet DSR.

Efficacy of herbicides and integration of chemical and mechanical weed control in dry direct-sown rice

The efficacy of herbicides and suitable weed control technology by integrating chemical and mechanical methods in dry direct-sown rice (D-DSR) with cv. CR Dhan 304 was evaluated during 2017 in field condition. The treatments included mechanical weed control twice by two row motorized weeder at 20 and 40 days after emergence (DAE), chemical weed control by pendimethalin *fb*bispyribac sodium (750 and 30 g ha^{-1} applied at 3 and 25 DAE), pendimethalin at 3 DAE *fb* mechanical weed control at 30 DAE, bispyribac sodium at 10 DAE *fb* mechanical weed control at 30 DAE, manual weeding (once at 30 DAE) at 25 cm row spacing, manual weeding (once at 30 DAE) at 20 cm row spacing, weed free at 25 cm row spacing, weed free at 20 cm row spacing, weedy at 25 cm row spacing and weedy at 20 cm row spacing. Altogether ten treatments were evaluated in randomized complete block design with three replications. Experimental results revealed that there was excellent control of complex weed flora in bispyribac sodium *fb* mechanical weeding (30 DAE) (at 25-cm row spacing) treated plots with WCE of 89.3%. Among the weed control treatments, the highest yield (5.23 t ha^{-1}) was recorded in bispyribac sodium *fb* mechanical weeding (30 DAE) at 25-cm row spacing and it was at par with weed free at 25-cm row spacing (5.44 t ha^{-1}). It showed 15% and 12% yield advantage over manual weeding once (30 DAE) at 25 and 20-cm row spacing, respectively. Thus, integration of chemical weed control by post-emergence application of bispyribac sodium (30 g ha^{-1}) at 2-3 leaf stage of weeds *fb* mechanical weed control by motorized weeder (30 DAE) may be recommended for dry-DSR.

Efficacy of sequential application of low dose herbicides for broad spectrum weed control in wet direct-sown rice

The weed spectrum and efficacy of sequential application of low dose herbicides for broad spectrum weed control in wet direct-sown rice (W-DSR) with cv. Naveen was investigated. The treatments included flucetosulfuron *fb*bispyribac sodium (25 and 25 g ha^{-1}at 7 and 25 days after sowing, DAS), cyhalofop butyl *fb*ethoxysulfuron (100 and 15 g ha^{-1} at 10 and 21 DAS), bispyribac sodium *fb*fenoxaprop-p-ethyl (25 and 60 g ha^{-1} at 8 and 30 DAS), flucetosulfuron*fb*ethoxysulfuron (25 and 15 g ha^{-1} at 7 and 21 DAS), bispyribac sodium *fb*ethoxysulfuron (25 and 15 g ha^{-1} at 8 and 30 DAS), cyhalofop butyl *fb*penoxsulam (100 and 22 g ha^{-1} at 10 and 21 DAS) with recommended herbicides of bispyribac sodium (30 g ha^{-1} at 10 DAS) and azimsulfuron (35 g ha^{-1} at 18 DAS) along with weed free and weedy check. Altogether ten treatments were evaluated in randomized complete block design with three replications. Experimental results revealed that there was excellent control of complex weed flora in bispyribac sodium *fb*ethoxysulfuron and cyhalofop butyl *fb*ethoxysulfuron treated plots with WCE of 87.0% and 86.0%, respectively. The highest yield (5.47 t ha^{-1}) was recorded in weed free check and it was comparable with bispyribac sodium *fb*ethoxy-sulfuron (5.23 t ha^{-1}). The treatment *viz.*, sequential application of bispyribac sodium *fb*ethoxy-sulfuron showed 8% and 13% yield advantage over the recommended herbicides of azimsulfuron and bispyribac sodium, respectively. The yield reduction due to weed competition in weedy plots was more than 48%.

Efficacy of herbicide mixtures for broad spectrum weed control in wet direct-sown rice

A field experiment was conducted during the wet season, 2017 to study the weed spectrum and efficacy of herbicide mixtures for broad spectrum weed control in wet direct-sown rice with cv. CR Dhan 304. Total twelve treatments including eight newly standardized herbicide mixtures applied at 12 DAS *viz.*, bispyribac sodium + azimsulfuron (25+22 g ha^{-1}), flucetosulfuron + bispyribac sodium (25 +25 g ha^{-1}), penoxsulam + cyhalofop butyl (25 + 100 g ha^{-1}), fenoxaprop-p-ethyl + ethoxysulfuron (50+15 g ha^{-1}), bispyribac sodium + ethoxysulfuron (25 + 15 g ha^{-1}), cyhalofop butyl + ethoxysulfuron (100 +15 g ha^{-1}), XR 848 benzyl ester + cyhalofop butyl and flucetosulfuron + pretilachlor (25 +450 g ha^{-1}) were compared with recommended herbicides, bensulfuron methyl + pretilachlor (60+600 g ha^{-1}) and bispyribac sodium (30 g ha^{-1}) along with weed free and weedy check. The experiment was laid out in randomized complete block design with three replications. It was found that there was excellent control of complex weed flora in fenoxaprop-p-ethyl + ethoxy-sulfuron and penoxulam + cyhalofop butyl (WCE of 86.0% and 84.0%, respectively). There was 19% yield advantage in fenoxaprop-p-ethyl + ethoxy-sulfuron treatment plots over recommended herbicide mixtures of bensulfuron methyl + pretilachlor. The yield reduction due to weed competition in weedy plots was more than 46%.

Effect of herbicide mixtures on soil microbial properties in wet direct-sown rice

Nine herbicide mixtures *viz.*, bispyribac sodium + azimsulfuron (25+22 g ha^{-1}), fluceto sulfuron + bispyribac sodium (25 +25 g ha^{-1}), penoxsulam + cyhalofop butyl (25 + 100 g ha^{-1}), fenoxaprop-p-ethyl + ethoxysulfuron (50+15 g ha^{-1}), bispyribac sodium + ethoxysulfuron (25 + 15 g ha^{-1}), cyhalofop butyl + ethoxysulfuron (100 +15 g ha^{-1}), XR 848 benzyl ester + cyhalofop butyl (25 + 125 g ha^{-1}), flucetosulfuron + pretilachlor (25 +500 g ha^{-1}), bensulfuron methyl + pretilachlor (60+600 g ha^{-1}) were evaluated to study their effects on mycorrhizal association in rice (CR Dhan 304) under field condition. The results indicated that there was slight variation in AM fungal sporulation after one month of herbicides application, but none of the herbicide mixtures affected AM fungi root colonization and microbial biomass carbon (Table 2.6). Thus, all the herbicide mixtures might consider being safe so far soil microbial properties were concerned.

Modification of herbicide molecule for enhancing persistence and release in soil with higher efficacy

A study was conducted to evaluate low cost adsorbents viz., Farm yard manure (FYM), Charcoal and Biochar as carrier material of herbicide for improving efficacy and persistence to a longer period. The most widely used recommended herbicide viz., bispyribac sodium (BPS) was mixed with FYM, charcoal and biochar. Desorption experiment was conducted (Fig. 2.17). It was found that biochar strongly adsorbed BPS, so it cannot be used as slow release carrier. Whereas, FYM showed optimum adsorption capacity, thus could be used as carrier. When adsorbed BPS in FYM added to soil, BPS release was comparatively slow compared to non-amended BPS. So, use of FYM (dry) will save the loss of BPS. Rate of degradation of BPS was more when applied alone compared to BPS adsorbed in FYM (Fig. 2.17). This might save some quantity of BPS. In addition, it may help in reducing pollution.

Economic and environment friendly use of rice straw

Characterization of cellulose, hemicellulose and lignin content of different rice cultivars

Characterization of straw of nineteen rice cultivars was done on the basis of cellulose, hemicellulose and lignin content. The nineteen varieties studied were Sarala, Ratna, Abhishek, Kalajeera, Tapaswini, CR 310, Naveen, Swarna, Swarna *sub1*, Shatabdi, Varsha Dhan, Ketekijoha, Durga, Pooja, Geetanjali, Sahbhagidhan, Gayatri, MTU-1010 and IR-64. Lignin percentage varied from 6.2 to 12.6 (around 70-80% recovery by ultra sonicator method), whereas, cellulose and hemicellulose percentage ranged between 28.5 to 41.0 and 15.3 to 25.9, respectively (Table 2.7).

Table 2.6 Impact of herbicide mixtures on soil microbial properties in wet rice field

Treatments	AM sporulation (number / 100 g soil)	AMF root Colonization (%)	MBC (µg/g/soil h)
BPS + AZM	690.3 (26.27)[a]	41.0 (39.81)a	430.0[a]
FCS + BPS	687.0 (26.21)[ab]	39.7 (39.03)[a]	425.7[a]
PNX + CHB	676.7 (26.01)[c]	42.0 (40.39)[a]	426.3[a]
FPE + ES	676.0 (26.0)[c]	41.0 (39.81)[a]	429.0[a]
BPS + ES	676.3 (26.01)[c]	40.7 (39.61)[a]	428.0[a]
CHB + ES	684.3 (26.16)[b]	40.0 (39.22)[a]	432.0[a]
XR 848 + CHB	675.7 (25.99)c	40.3 (39.42)[a]	434.0[a]
FCS + Pretr.	683.0 (26.13)[b]	40.3 (39.42)[a]	433.7[a]
BSM + Pretr.	668.3 (25.85)[d]	40.7 (39.61)[a]	435.7[a]
BPS	676.7 (26.01)[c]	39.0 (38.64)[a]	434.7[a]
Weed free	687.0 (26.21)[ab]	39.0 (38.64)[a]	437.7[a]
Weedy	686.0 (26.19)[ab]	40.7 (39.62)[a]	431.3[a]

BPS = Bispyribac sodium; AZM =Azimsulfuron; FCS=Flucetosulfuron; PNX=Penoxsulam; CHB=Cyhalofop butyl; FPE=Fenoxoprop ethyl; ES=Ethoxysulfuron; XR 848= XR 848 benzyl ester; Pretr.=Pretilachlor; BSM=Bensulfuron methyl

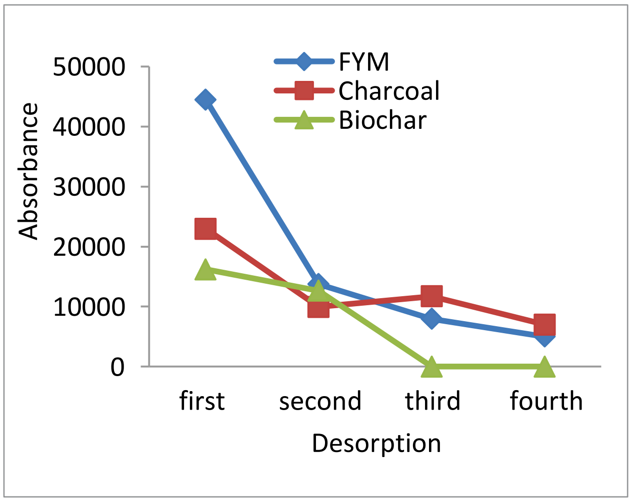


Fig 2.17. Desorption of Bispyribac sodium

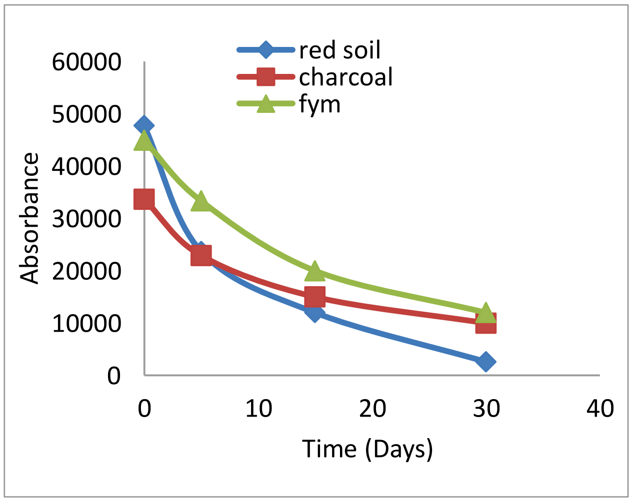
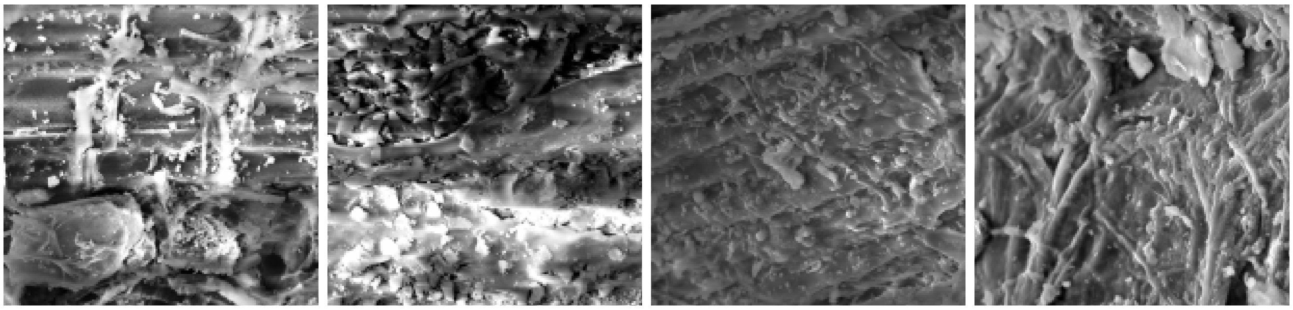


Fig 2.17. Persistence of Bispyribac sodium in soil

Scanning electron microscopy (SEM) imaging also done for nineteen varieties in order to understand the surface characteristics and pore size/ volume distribution (Fig. 2.18). Higher pore space signified higher surface area exposure which is expected to be more prime to decomposition when exposed to chemical and or microbial intervention. SEM images of some varieties in 4000x magnification presented in Fig. 2.18 (Naveen, Durga, Sarala and Pooja).

Table 2.7 Cellulose, hemicellulose, lignin content in rice varieties

Varieties	Cellulose (%)	Hemicellulose (%)	Lignin (%)
Sarala	39.0	19.0	6.2
Ratna	37.9	17.4	6.7
Abhishek	34.8	20.4	6.9
Kalajeera	38.8	22.1	7.7
Tapaswini	38.4	23.3	7.7
CR 310	32.4	22.1	8.2
Naveen	30.0	22.0	8.4
Swarna	40.3	20.2	8.4
Swarna *sub 1*	38.9	19.3	8.6
Shatabdi	35.0	25.9	8.6
Varshadhan	37.6	16.3	9.0
Ketekijoha	28.5	23.9	9.5
Durga	41.0	23.0	9.6
Pooja	41.0	21.0	10.7
Geetanjali	33.7	20.6	11.6
Sahbhagidhan	34.3	20.9	11.7
Gayatri	37.0	17.0	12.1
MTU 1010	31.1	22.8	12.3
IR 64	38.4	15.3	12.6



Naveen Durga Sarala Pooja

Figure 2.18 Scanning Electron Microscopic (SEM) views of rice cultivars

A large scale *ex-situ* composting was done in four tanks having 10 t dry rice straw each. Three microbial consortium namely, Consortium I; (*Aspergillus* + *Streptomyces* + Bacteria), Consortium II; (*Aspergillus* + *Streptomyces*), Consortium III (*Streptomyces* + *Trichoderma*) were evaluated along with un-inoculated control with urea (0.5%) and absolute control (un-inoculated and no urea). Microbial consortium was initially multiplied with 1% jaggerry solution for overnight for field use and was added at 1.0% v/w in each treatment. The water was sprinkled at regular intervals during composting. Lignin, cellulose and hemicellulose content were also measured at 15 days intervals during composting. Microbial biomass carbon (MBC) and enzyme activities were estimated at 30 days of composting at three depths (0-15, 15-30 and 30-45 cm) (Fig. 2.19, 2.20). Consortium-III looked to be promising based on the above mentioned parameters analysed.

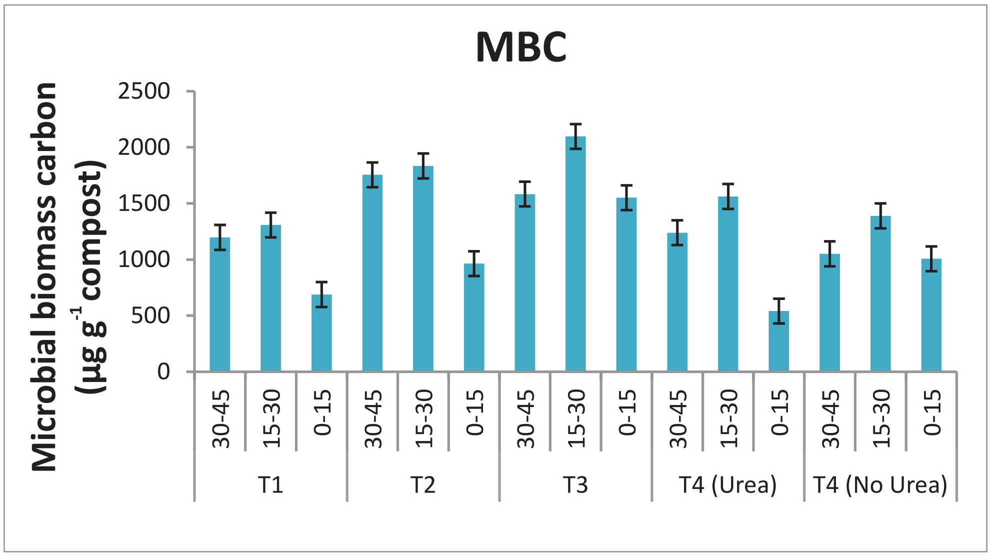
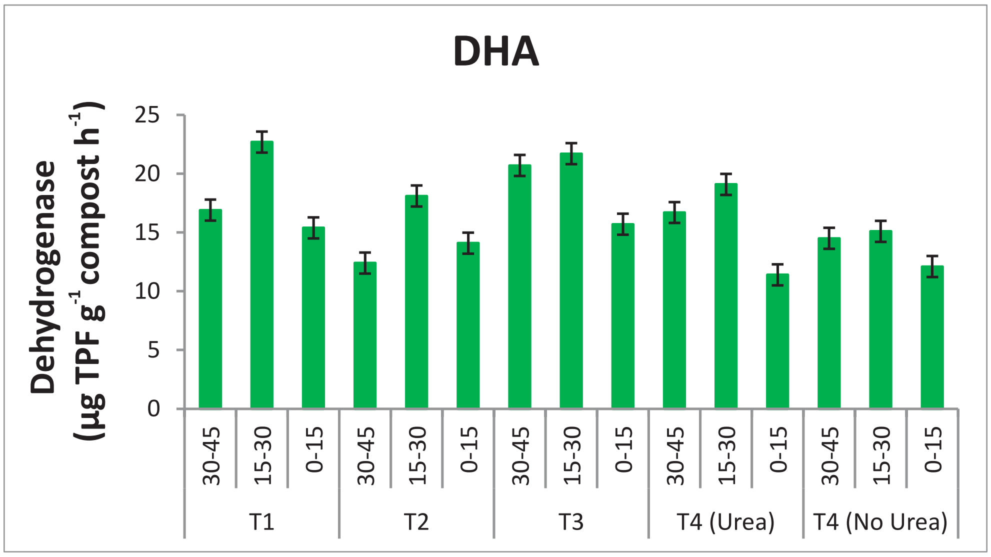


Fig. 2.19 MBC and Enzymatic activities at 30 days of composting



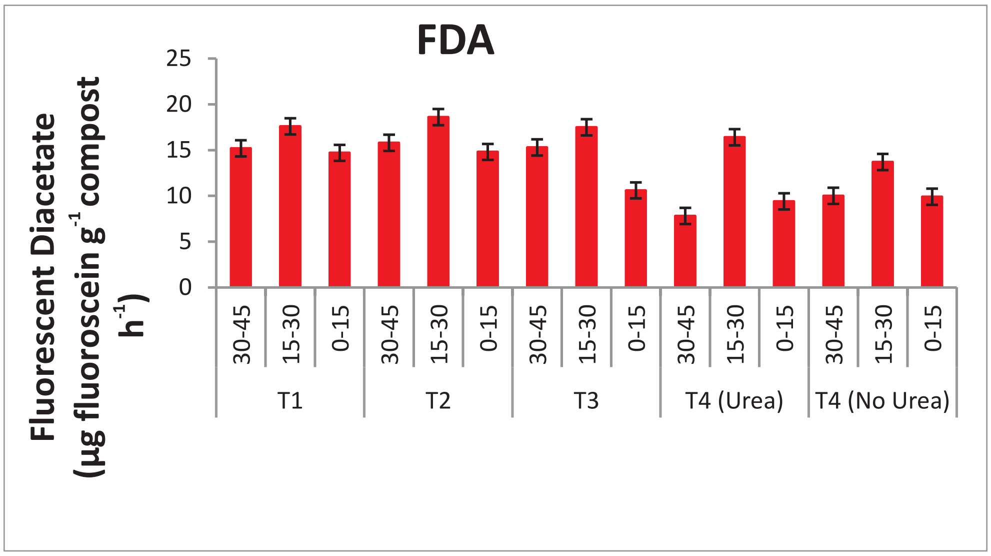


Fig. 2.20 Enzymatic activities at 30 days of composting

An attempt was made to produce biochar from rice straw by pyrolysis. Rice varieties namely Swarna, Swarna *sub1*, Ketekijoha, Shatabdi were tested. Among the rice varieties, higher recovery 52.5% was found in Ketekijoha at 300 ºC and 2 hours of pyrolysis. Temperature and time would be again tested with other varieties before getting definite conclusion of proper condition and recovery of biochar.

Harnessing microbial resources for alleviating abiotic and biotic stresses for improving soil health

Development of soil-based sporocarp formulation of *Azolla* for wet land rice

The aim of the present study was to develop sporocarp-based formulation of *Azolla* sp. Consequently, we identified 23 strains of sporocarp-producing *Azolla* (CRRI 1, CRRI 2, CRRI 3, CRRI 4, CRRI 5, CRRI 6, CRRI 7, CRRI 8, CRRI 9, CRRI 10, CRRI 11, CRRI 12, CRRI 14, CRRI 15, CRRI 16, GSMI 1, IEPI 1, IEPI 4, R 86, R 94, *P. assam*, *A. pinnata*, and *A. microphylla*) among 102 strains of *Azolla* available at ICAR-NRRI, Cuttack. One strain (CRRI-1) of *A. pinnata* was standardized for the development of soil-based sporocarp formulation with the count of 50 spores per 10 gm of soil (Fig. 2.21). The outcome of this study has given a novel sporocarp-based formulation of *Azolla* which considerably reduce the quantity of *Azolla* primary inoculums for wet land rice cultivation.

Fig. 2.21 Soil-based sporocarp formulation of *Azolla*

Evaluation of *Azolla* for diazotrophic efficiency under elevated CO_2 and different dose of nitrogen

Diazotrophs abundance was analyzed in two species of *Azolla* (*A. microphylla* and *A. pinnata*) subjected to elevated CO_2 (eCO_2) (550 ppm) and nitrogen (N) fertilizers (40 and 60 kg ha^{-1}). Results indicated that diazotrophs frequency was increased by almost double under elevated CO_2 of *A. microphylla,* whereas, 17.3% was increased in *A. pinnata*. However, diazotrophs frequency was gradually decreased under higher doses of N.

Enhancing the performance of diazotrophs under oxidative stress through intervention of antioxidants

Role of antioxidant (ascorbic acid) has been analyzed in nitrogen fixing bacterium (*Azotobacter chroococcum* AVi2) under oxidative stress (different concentration of H_2O_2). Result indicated that 1 ppm of ascorbic acid enhanced the life span of *Azotobacter chroococcum* (AVi2) and its PGP efficiencies under oxidative stress. Only 1 ppm ascorbic acid not only increased the life span of *A. chroococcum* AVi2, it also help in rice seed germination under stress condition. The findings of this experiment will help to enhance the performance of beneficial microbes under stress condition.

Assessment of variation of diazotrophs in different rice cultivars and nitrogen species

Diazotrophic frequency was assayed in four rice cultivars (IR64, MTU1010, CR Dhan 310 and Pusa44) subjected to different nitrogen sources (neem coated urea, FYM, BGA and combination of these three) as fertilizers. It was found that neem coated urea (NCU) along with FYM and BGA significantly increased the *nifH* copy no. in three cultivars IR64, MTU1010 and CR Dhan 310 compared to NCU alone.

Effect of different microbial consortium for *ex-situ* paddy straw degradation

Three groups of microbial consortia namely C_1 (*Aspergillus* + *Streptomyces* + Bacteria), C_2 (*Aspergillus* + *Streptomyces*) and C_3 (*Trichoderma* + *Streptomyces*) were evaluated in small scale (50 kg rice straw tank^{-1}) at net-house condition. The results indicated that the microbial biomass carbon and dehydrogenase activity were gradually increased in all the treatments after 20 days of compositing but decreased after 40 days of composting. The microbial consortia inoculated treatments recorded 19:1 to 22:1 CN ratio after 40 days of inoculation, whereas, it was 37:1 in un-inoculated control. Overall, all the consortia were able to decompose paddy straw rapidly under small scale.

Evaluation of *Skermanella* and *Serratia* as entomopathogens against rice leaf folder and stem borer

The entomopathogenic bacteria namely *Skermanella* and *Serratia* spp. were evaluated for its larvicidal potential against leaf folder and stem-borer and compared with *B. thuringiensis* under *in vitro* and potted plant. The results indicated that *Skermanella* sp. had higher larval mortalities of leaf folder and pink stem borer as compared to *Serratia* and *B. thuringiensis*.

PROGRAMME : 3

Rice Pests and Diseases-Emerging Problems and Their Management

Rice landraces were observed to be good source for resistance against different insect pests and diseases and are deployed for breeding program. Acc no. IC277274 IC346855, IC277338, IC334193, IC280502, IC346890, IC283249, IC346899, IC256547, IC256780, IC256515, IC346892, IC283226, IC256530, IC256545, IC346237, IC438639, IC426126, IC426139 and IC426148 showed high degrees of resistance against the most devastating insect of present era *i.e.* brown plant hopper (BPH). Aganni, INRC3021, ARC 5984, Kakai (K1417), ARC 6248, PTB 26, PTB 32, IC 332045, RP 6145GMK17-3, RP 6125 GMK17-3, WGL 1127, WGL 1131, WGL 32100 and RP 1 were highly resistant against gall midge. AC41772 showed moderately resistance against WBPH. ARC-5787, ARC-7083, ARC-6249, 7412, 10120, 10027 were observed to be resistant against yellow stem borer. Silica showed promise to be used for management of YSB. After screening 1450 lines 153 lines were identified to be promising against bacterial blight diseases. A total of 19 (20.2%) accessions of ARC, 23 (27.4%) DSN, 116 (33%) NSN1 and 39 (31.5%) NHSN entries were found non-infected to false smut pathogen (*U. virens*) but none of them could be considered to be promising due to low location severity index (0.4 to 0.8). The false smut infected grains were also showed lower nutrient quality. Out of the 80 NRVs, 19 were resistant, 21 found to be moderately resistant and 40 were highly susceptible against leaf blast disease. Insect pests' population remained below economic threshold level in IPM and ecological engineering-based pest management plots compared to conventional pest management regime. The harboured natural enemies were predators namely, spiders, odonata, coccinellids, carabids, staphylinids, and hymenopterans parasitoids. The insect pests *viz.*, yellow stem borer, BPH and GLH population was lower in rice than in vegetables. The genetic diversity and geographical distribution of *Xanthomonas oryzae pv oryzae* did not show any relation as revealed by molecular markers. The highest yield loss due to false smut varied from 5.14%(Moti) while the lowest yield loss was found in Swad (0.10%). The results showed that, the disease incidence was more during 2017 compared to 2016. This shows that, the disease is emerging as a major problem in Odisha. Among the five districts surveyed, significantly higher disease incidence was recorded from Cuttack district in both the years followed by Jajpur district. While searching for alternate host for *R. solani* it was observed that *Dactyloctenium aegyptium* showed highest severity followed by *Echinochloa colona* and *Digitaria ciliaris* while least was in *Cyperus esculentus.* Seven *Trichoderma* isolates (i.e. CRRIU-1, CRRIU-2, CRRIU-3, CRRIU-4, CRRIU-5, CRRIT-6, and CRRIT-7) were collected from bark of different trees or from parasitized wild mushrooms at Cuttack, Odisha and observed to be promising as biocontrol agent (BCA) and biofertilizer. *Bacillus* spp. have great potential to manage rice diseases as observed in the experiments conducted in NRRI field and net house. The *Bacillus* treated plants showed lower disease progress of bacterial blight and sheath rot in comparison to the control and also better growth promotion. The botanicals especially extracted from *Cleistanthus collinus* are having great potential to manage rice insect pests. Cent per cent mortality of *Rhyzopertha dominica* was observed at 24 hours after treatment with 100% nano emulsion formulation followed by 85 and 75 % nano emulsion formulation which registered 83.33 and 33.33% mortality, respectively. IPM practice was observed to fetch higher income to the farmers. Application of combined formulation of pesticide showed that DPX-RAB 55 + Baan @(0.48+0.6)ml/l resulted higher yield with less pest incidence.

Introduction

It is estimated that about 30% of yield loss is due to the pests and diseases at different stages of crop cycle including post harvest damage. So, to save the crop from pest and diseases the Crop Protection Division has taken a holistic approach combining ecological engineering to avoid pests and diseases, using biocontrol agents and botanicals, induced systemic resistance, nanotechnology and IPM for sustainable, eco-friendly, farmers' friendly and climate resilient management of rice pests and diseases at different stages.

For a sustainable eco-friendly and climate resilient management of insect pests and diseases of rice four pronged approaches have been under taken they are (i) Exploration of new sources of resistance for insect pests and diseases of rice where the resistance sources of rice against different biotic stresses and even genotypes with multiple biotic stresses are being identified for new source of donors; (ii) Bio-ecology and ecological engineering of rice insect pests and diseases for climate smart protection strategies (iii) Bio-intensive approaches for pest management in rice using holistic ecofriendly approaches for management of rice diseases and pests like different biocontrol agents, botanicals, induced systemic resistance using both bioagents and botanicals in biointensive IPM approaches and (iv) Optimization of chemical pesticide-use for management of rice pests in different eco-systems where testing of different new formulations for management of pests and diseases to avoid huge crop loss, testing the different formulations for post harvest management and testing the residue toxicity of different pesticides.

Exploration of new sources of resistance for insect pests and diseases of rice

Resistant donors identified against Insect pests Brown plant hopper, *Nilaparvata lugens* Stal (BPH)

A total of 1000 genotypes from National Gene Bank, NBPGR were screened against BPH in controlled condition as per the standard evaluation method. Twenty genotypes were found highly resistant with score 1 whereas 29 genotypes showed resistant reaction with score 3. They were as follows:

0 -1 Score (Below 10% plant mortality):

IC277274 IC346855, IC277338, IC334193, IC280502, IC346890, IC283249, IC346899, IC256547, IC256780, IC256515, IC346892, IC283226, IC256530, IC256545, IC346237, IC438639, IC426126, IC426139 and IC426148.

3 score (within 11-30% plant mortality):

Ic280550, IC256621, IC273558, IC256629, IC283251, IC256849, IC256842, IC282438, IC346230, IC346234, IC346248, IC346252, IC343499, IC337613, IC337584, IC280565, IC470442, IC447324, IC438643, IC426149, IC438540, IC426033, IC426092 . However, the genotypes will be again revalidated to confirm their resistant reaction.

Mass screening

Confirmation of resistance

The resistant donor Salkathi was registered at NBPGR and the identified resistant genotype CR 2711-149 (Tapaswini x Dhobanumberi) was reported to have multiple pest resistance in AICRIP trial. Highly resistant CR 2711-76 (Tapaswini x Dhoba numberi) and Salkathi introgressed genotype CR 3006-8-2 was multiplied in field condition to be tested at endemic pockets of Bargarh district through mini kit distribution.

Gall midge, *Orceolia oryzae*

Against gall midge, 187 genotypes were screened under controlled condition. Some of the genotypes such as Aganni, INRC3021, ARC 5984, Kakai (K1417), ARC 6248, PTB 26, PTB 32, IC 332045, RP 6145GMK17-3, RP 6125 GMK17-3, WGL 1127, WGL 1131, WGL 32100, RP 1 were highly resistant.

Net house evaluation of germplasm against WBPH

Out of one hundred and fifty one germplasm, AC41772 was found moderately resistant having damage score 3, eight were in damage score 5, thirty nine were in damage score 7 and rest were in damage score 9 (Table 3.1).

Table 3.1. Screening of genotypes against WBPH

Damage score	No. Of Genotypes	Genotypes
0		-
1	1	Ptb 33
3	1	AC41772
5	8	AC41777, AC452029, AC452035, AC452043, AC452084, AC452085, AC452089, AC452090,
7	39	Ac41723, AC41728, AC4173, Ac41733, AC41734, Ac41735, AC41740, AC41744, AC41745, AC41747, AC41748, AC41749, Ac41750, AC41753, Ac41754, AC41756, Ac41762, AC41775, AC41776, AC41779, AC41780, AC452030, AC452031, AC452032, AC452039, AC452042, AC452044, AC452047, AC452073, AC452074, AC452077, AC452081, AC452091, AC452094, AC452095, AC452096, AC452097, AC452107, AC452108,

Screening ARC germplasm against yellow stem borer of rice

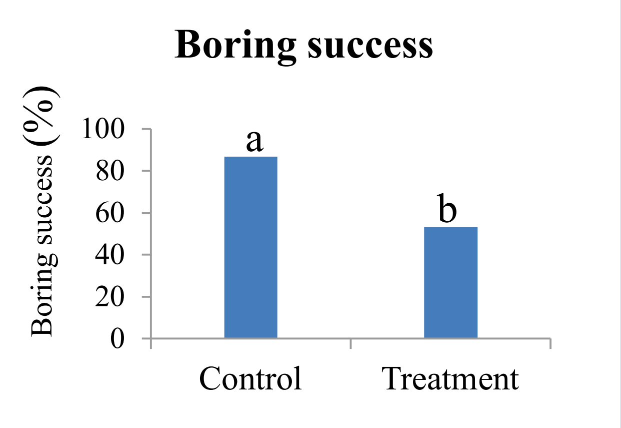
About 50 ARC germplasm were screened at field conditions for reproductive stage resistance (White ear head incidence) along with susceptible check TN1. Total number of tillers and white ear head incidence were counted and calculated white ear head per cent. Comparison was based on SES damage score and it was found that ARC-5787 with 8% white ear head incidence and ARC-7083 with 7% white ear head incidence fall under moderately resistant category of 3 damage score (Table 3.2).

Effect of synthetic plant bio-activators against yellow stem borer of rice

An experiment was conducted to see the induced resistance against yellow stem borer by silica amendment. Potassium silica as a silica source was amended to TN1 seedlings and tested the boring success, growth rate of yellow stem borer larvae. It was observed that potassium silica amendment reduced the boring success of yellow stem borer larva to the extent of 33 and 47% compared to untreated control in greenhouse and laboratory cut stem assays respectively (Fig. 3.1). The growth rate of larva was also affected by potassium silica amendment (Fig.3.2) where the relative growth rate in treatment was only 0.02g but in control it was 0.09g.

Table 3.2. Screening of ARC Germplasm against yellow stem borer

ARC accessions	Damage score	Category
ARC-5787, ARC-7083	3	Moderately resistant
ARC-6249, 7412, 10120, 10027	5	Moderately susceptible
ARC-5776, 5923, 5985, 6001, 6018, 6025, 6037, 6097, 6144, 6161, 6557, 6630, 7008, 7032, 7050, 7086, 7119, 7335, 7343, 7414, 7416, 7432, 10059, 10061, 10544	7	Susceptible
ARC-5784, 5791, 5795, 5906, 5956, 5972, 5976, 5982, 6102, 6551, 7080, 7093, 7210, 7220, 7255, 7259, 7308, 10062, TN1	9	Highly susceptible



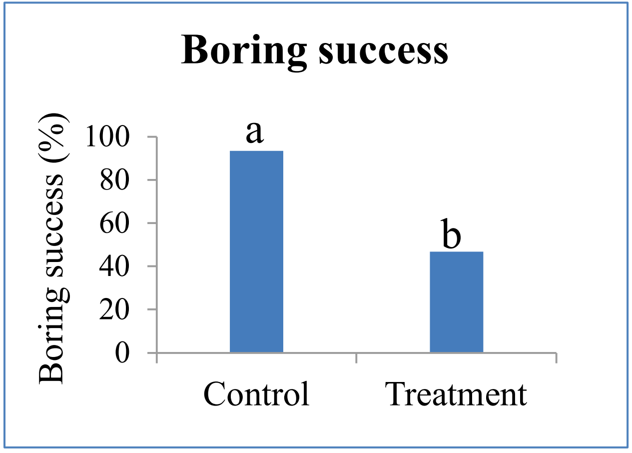


Fig. 3.1. Boring success of YSB larva at laboratory and greenhouse conditions

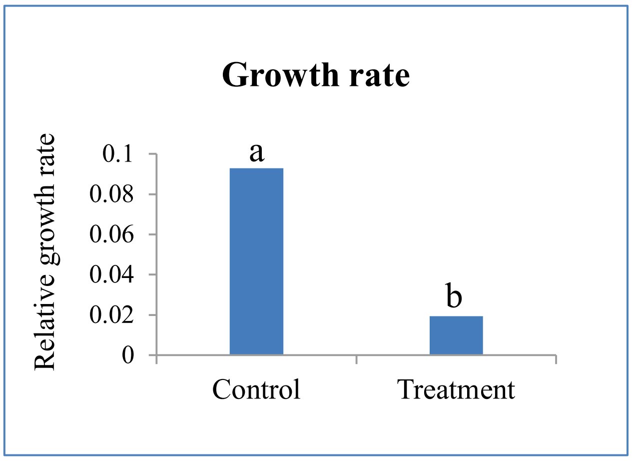


Fig. 3.2. Relative growth rate of YSB larva in treatment and control

An experiment was carried out to see the possible integrative effect of synthetic plant bio-activators (silica and salicylic acid) against yellow stem borer larva. Potassium silica and salicylic acid application significantly reduced the dead heart incidence compared to control. Salicylic acid application combination with silica has reduced dead heart incidence compared to salicylic acid application in alone. Soil amendment of K_2SiO_3 and spray of salicylic acid was found to be superior over all other treatments (Table 3.3). Thus there may exist a synergistic interaction among the synthetic plant bio-activators which need to be tested again.

Table 3.3. Effect of Silica on dead heart of rice

Treatment Details	Dead heart (%)
T_1- K_2SiO_3 (Soil)	20.9 (27.13 ^{C})
T_2 - K_2SiO_3 (Spray)	17.7 (24.91 ^{CD})
T_3 - Salicylic acid (SA)	32.8 (34.96 ^{B})
T_4 - K_2SiO_3 (Soil) + SA	10.6 (18.98 ^{D})
T_5 - K_2SiO_3 (Spray) + SA	24.9 (29.91 ^{BC})
T_6 - Control	46.3 (42.87 ^{A})
p-Value	<.0001
CV(%)	5.37
SE(d)	1.307

Fifteen diverse rice varieties were tested for physico-chemical parameters of grain and developmental parameters of weevil in governing the resistance of rice varieties. Among the different physical parameters evaluated, 100 grain weight was significantly and negatively correlated with weevil emergence (-0.53) and susceptibility index (-0.51) and found out to be an important physical characteristics of grain. Similarly, hardness of the grain delayed weevil emergence (-0.41) and reduced the grain loss (-0.245). Biochemical parameter of grain like protein was found positively associated with weevil emergence (0.741) and negatively associated with median developmental period (-0.537). Two principal component analyses (PCA's) each with two PC's were performed; one for physico-chemical and developmental parameters (PC1 explained 49.57 % and PC2 explained 17.88 % of variation; Fig. 3.3.) and other for rice varieties (PC1 explained 91.86 % and PC2 explained 5.06 % of variation; Fig. 3.4.). Variable response of *S. oryzae* to rice varieties was noted and according to susceptibility index, only Cross-12 was found to be moderately resistant compared to others. It was the only variety having long bold grain and recorded highest 100 seed weight indicating quantity and size of the substrate is not important for development of weevils. To date, breeding programmes conducted in India have concentrated more on field insect pest than storage pests, and very little attempt has been made on identification *S. oryzae* resistant lines. The resistant variety identified in the present study can also be used as a source of resistance in breeding programs to diversify the basis of resistance to this pest and also would offer sustainable, cost effective, and eco-friendly solution to management of rice weevil in longer terms.

Bacterial blight

A total of 2006 lines were screened artificially using clip inoculation technique for bacterial blight resistance (causal organism: *Xanthomonas oryzae pv oryzae*). Out of 1450 AICRIP lines 454 showed promising with 0 to 5 score and out of 232 lines selected from earlier screening 96 showed promising. Interestingly none of the ARC lines among 324 showed resistance to bacterial blight against the most virulent race of Xoo (Table 3.4).

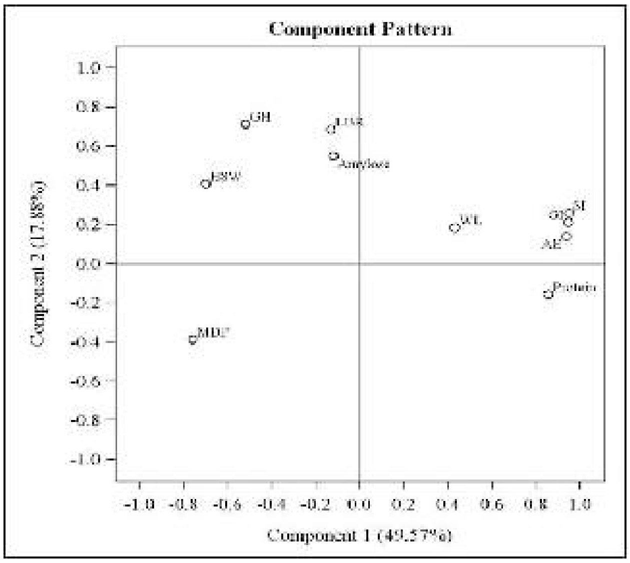


Fig. 3.3. 2-D plot of Principal Component Analysis Based on physico-chemical and developmental parameters

Note: AE-Adult emergence; MDP-Median Developmental Period; LBR-Length Breadth Ratio; HSW-Hundred seed weight; SI-Susceptibility Index; GI-Growth Index; GH-Grain hardness; WL-Weight loss

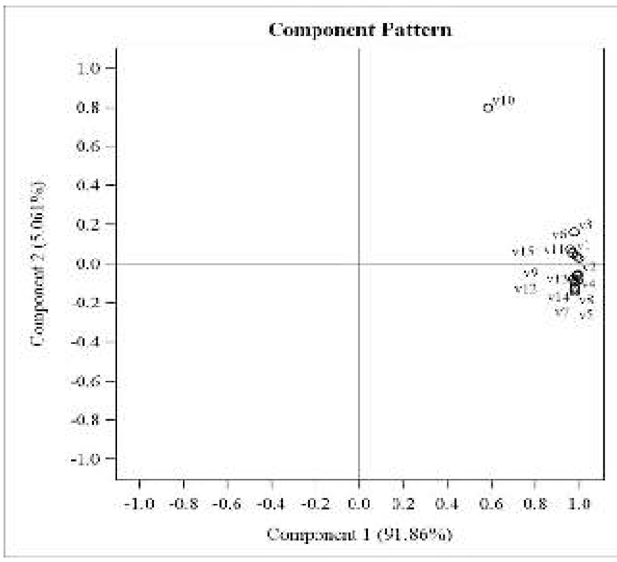


Fig. 3.4. 2-D plot of Principal Component Analysis based on varietal resistance against *S. oryzae*

Note: v1- Dhusara; v2-Chinikamini: v3- Kalajeera; v4: Geetanjali; v5: Satyabhama; v6- Naveen; v7- Swarna Sub 1; v8- Ketakijoha; v9- TN 1; v10- Cross 12; v11-Padmini; v12-Pyari; v13- Sarala; v14-Gayatri; v15-Satabdi

Screening against false smut

Altogether 653 accessions comprising 94 Assam Rice collection (ARC), 84 DSN, 124 NHSN, and 351 NSN1 were grown for screening against false smut pathogen (*U. virens*) under natural infection condition. Nineteen (20.2%) ARC, 23 (27.4%) DSN, 116 (33%) NSN1 and 39

Table 3.4. Screening of rice lines against bacterial blight

AICRIP		Earlier selected		ARC collections	
Score	Genotypes	Score	Genotypes	Score	Genotypes
0	0	0	0	0	NA
1	8	1	2	1	NA
3	145	3	46	3	NA
5	301	5	48	5	1
7	520	7	84	7	58
9	476	9	52	9	265
LSI	6.80827586	LSI	6.189655	LSI	8.62963

(31.5%) NHSN entries were found non-infected to false smut pathogen (*U. virens*). None of the entries was promising because of very low location severity index (LSI = 0.4 – 0.8) for false smut at NRRI experimental field (Table 3.5).

Table 3.5. Entries screened for identifying false smut pathogen resistant donor

Name of entries	Total No. of entries	No. of infected entries
ARC	94	19
DSN	84	23
NSN1	351	116
NHSN	124	39

Screening against sheath rot

Ninety fout Assam Rice collections (ARC) were grown for screening against sheath rot pathogen under natural infection condition. 74 entries scored ≤ 3. None of the entries was promising because of low location severity index (LSI = 1.4) for sheath rot at NRRI experimental field. (Table 3.6).

Effect of false smut on quality of grain

Analysis of nutritional quality data of 10 NRRI varieties, *viz*., Sarala, Utkalprabha, Padmini, Pooja, Ketekijoha, Phalguni, Nuachinikamini, Moudamani, Geetanjali and Swarna *Sub1*, revealed that antioxidant ($<p0.01$) was significantly high and amylose & total phenol ($p<0.05$) was significantly low in healthy grain over false smut diseased grain of rice whereas total soluble protein content was insignificantly low in diseased grain than healthy grain of rice (Fig.3.5).

Table 3.6. Reaction of ARC entries against Sheath rot pathogen

Score	No. of entries (% of entries)
0	63 (67%)
1	0 (0%)
3	13 (13.8%)
5	18 (19.1%)
7	0 (0%)

Candidate based genetic dissection of blast resistant genes in rice

Rice blast disease caused by *Magnaporthe oryzae* is one of the serious diseases causing enormous yield losses in different rice growing regions of the world. The use of resistant cultivars is the most preferred means to control the disease. In the present study, a set of 80 National Rice Research Institute released varieties (NRVs) was phenotyped and genotyped using thirty nine molecular markers linked to thirty nine blast

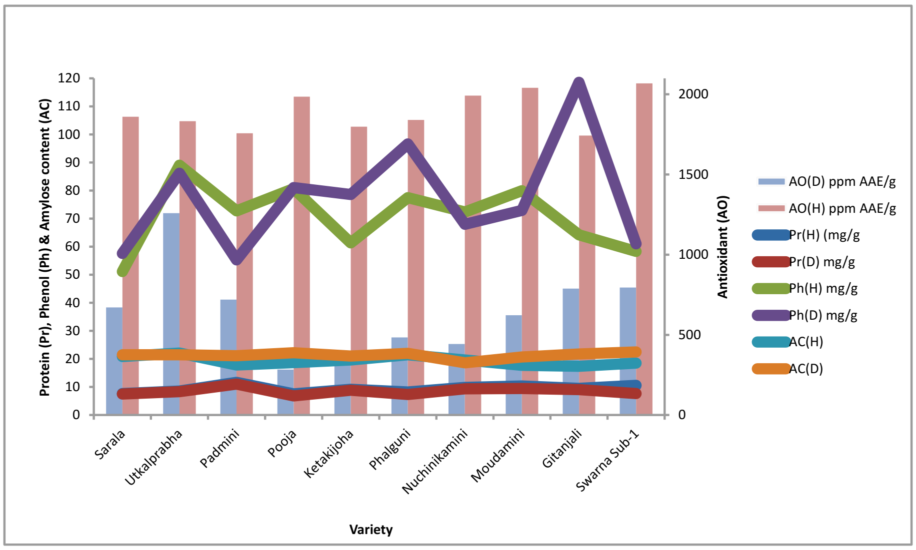


Fig. 3.5. Effect of false smut pathogen on quality of rice grain

resistance genes to investigate the genetic association between blast resistance and disease score. Out of the 80 NRVs, nineteen were resistant, twenty one found to be moderately resistant and forty were highly susceptible. The disease score varied from score 0 (Sarasa) to 9 (Ratna, Sonamani and Moti). The average gene diversity and major allele frequency of 39 markers were found to be 0.34 and 0.75, respectively. The polymorphism information content was used to measure the information content of a genetic marker. The PIC value of thirty nine markers had a mean value of 0.34 and varied from 0.11 to 0.37. Based on cluster analysis, eighty NRVs were categorized into three major clusters. Similarly, population structure classified the entire 80 NRVs into three sub-groups (Fig. 3.6). Genetic association was calculated using the generalized linear model (GLM) to detect the significant association of the blast disease. Through GLM, three markers (RM1233, RM7364 and pi21_79-3) corresponding to the three blast resistance genes (*Pi43(t)*, *Pi56(t)* and *pi21*) were found to be associated with the blast disease and explained phenotypic variance from 3.4% to 5.1%. The resistant NRVs could be good genetic resource for blast resistance and the associated markers can be used in marker-assisted selection for improving rice blast resistance in India and worldwide.

Screening farmers' varieties/Released varieties/ Super rice lines/ entries provided by AICRIP, 2017-18 for resistance against sheath blight (*Rhizoctonia solani* Kuhn)

During *kharif*, 2017, a total of 1605 entries including AICRIP entries were taken up for screening in evaluating their resistance/ tolerance against sheath blight pathogen, *R. solani*. They are farmers' varieties-211, selected released varieties-43, super rice lines-37 and AICRIP entries-1314 (NSN1-354, NSN2-743, NHSN-127 and DSN-90). Out of 211 farmers' varieties, 6 were found moderately resistant (at disease score of 1.1-3), 14 being tolerant (at disease score of 3.1-5). In case of 43 selected released varieties, 4 were moderately resistant, whereas, 7 showed tolerant reaction. Out of 37 selected super rice lines, 2

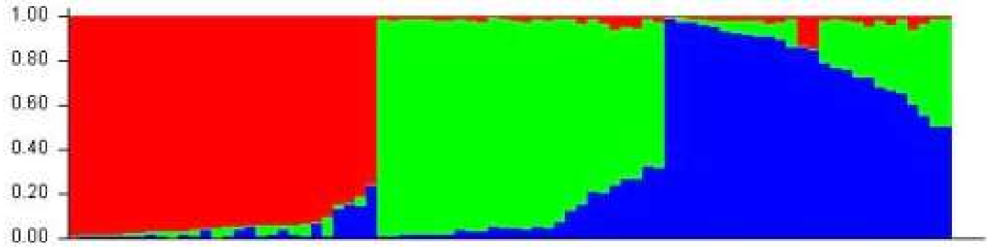


Fig. 3.6. Population structure representing the 80 NRVs in three subgroups based on K value

were resistant and 4 were tolerant. In case of AICRIP (2017-18 Trials), out of 354 NSN1 entries, 34 showed moderately resistant/tolerant reactions; of 743 entries, 59 were found moderately resistant/tolerant, but in 127 NHSN entries , 19 entries were moderately resistant/tolerant reactions.Taking into account of 90 DSN entries, 13 entries were found to be moderately resistant/tolerant.

Bio-ecology of rice insect pests and diseases for climate smart protection strategies

Assessment of insect parasitoid interaction under ecological engineering-based management regime

Ecological engineering for pest management mainly focuses on increasing the abundance, diversity and function of natural enemies in agricultural habitats by providing refuges and alternate or supplementary food resources. Ecological engineering is a component of agroecology that stresses precision (a feature of engineering) in the outcome of some intervention. Whereas the concept has been applied with some certainty of effect in ecosystem restoration and landscape productivity, using plants of function that often act as biofilters or to supply nutrients to the system; the concept is still in its infancy as regards pest management, particularly in rice. Looking to the importance of ecological engineering-based pest management, an experiment was laid in the NRRI Farm in lowland rice ecosystem during *rabi* 2018 where the rice crop was grown with least use of chemical pesticides to combat the insect pests and disease problems. The rice field has one-meter bunds in three sides and around three meters bund in one side. The rice crop (cv. Naveen) was raised in recommended agronomic practices. The bamboos tied with straw bundle in the top and charged with 5-6 spiders and yellow sticky traps were placed in the field to monitor the flying insects. Three vegetable crops were planted as 'bund crops'. These were bitter gourd (cv. VNR 22), ladyfinger (cv. VNR Super Green) and pumpkin (VNR 11) (Fig.3.7&3.8). About one month before rice transplanting seeds of ladyfinger, bitter gourd and pumpkin were sown directly in the wider bund. Roving survey was conducted to know the insect pest incidence and natural enemies in rice field as well as vegetables. Observations on natural enemies were undertaken fortnightly starting from seedling stage to ripening stage.

All three crops grew well on the bunds and produced fruits and harvested. About 18 kg of bitter gourd, 15 kg of ladyfinger and 62 kg of pumpkin were harvested from the bund. The patches attracted large number of pollinators and were used as perches and foraging sites for insectivorous birds. Weekly sweep net method collection in rice fields revealed that the insect pests' population remain below economic threshold level in ecological engineering-based pest management plots compared to conventional pest management regime. The harboured natural enemies were predators namely, spiders, odonata, coccinellids, carabids, staphylinids, and hymenopterans parasitoids. The insect pests *viz.*, yellow stem borer, BPH and GLH population was lower in rice where vegetables are grown as bund crop. Soil arthropod study revealed that dipluran population was more in 10cm soil depth whereas the earthworm population was higher in 20cm soil depth both in early tillering and maximum tillering stage (Fig. 3.9 & 3.10).

Fig. 3.7. View of Ecological engineering based pest management field

Fig. 3.8. Bund planting of vegetables in EE plot

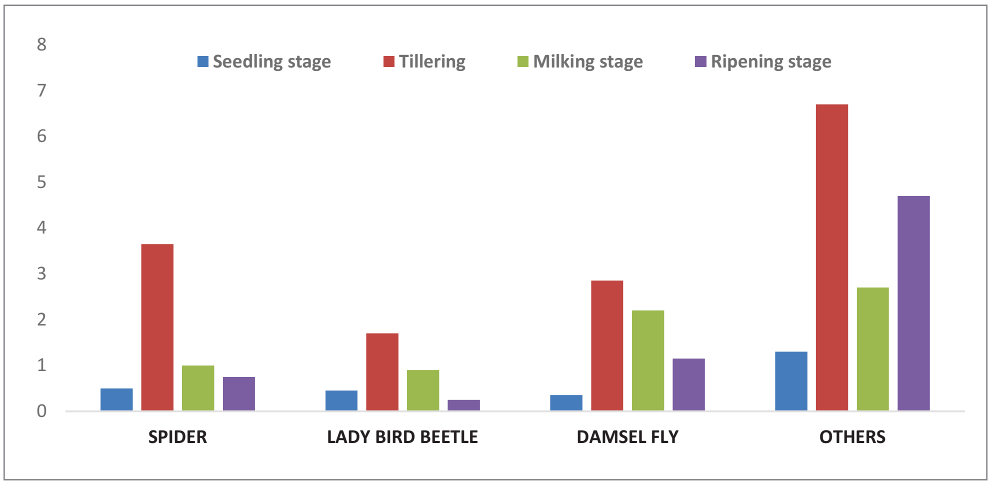
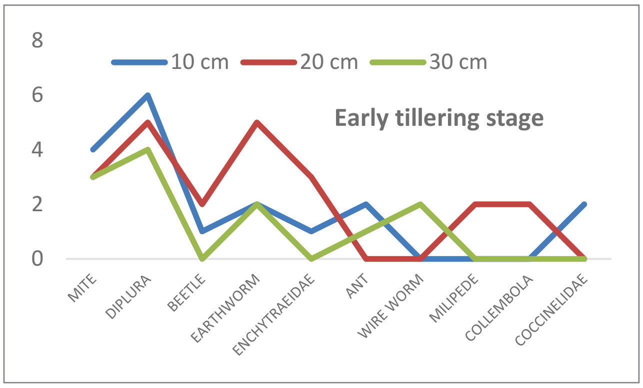


Fig. 3.9. Predator population (per sweep net) in different growth stages of rice in ecological engineering based pest management regime



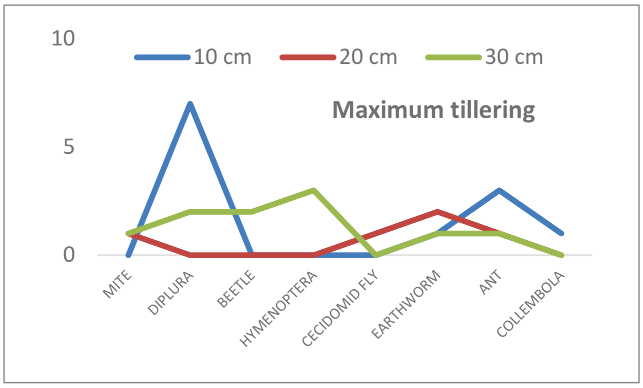


Fig. 3.10. Soil arthropods diversity in different growth stages of rice in ecological engineering-based pest management regime

Population structure of rice pathogens in different rice ecologies

Rice Blast

Twenty isolates of *M. oryzae* were collected from different places in Odisha. These isolates were categorized based on the variation in morphological characteristics *viz.,* colony color, surface appearance and type of growth. Twenty isolates of *M. oryzae* were categorized based on the variation in morphological characters (colony color, surface appearance and type of the mycelial growth). Various isolates produced little surface, downy, flat with little mycelium and submerged growth with smooth and rough margins on OMA media. The colony color varied from grey (1), greyish white (4), whitish black (1), black with cottony mass (6), white cottony mass (1), greyish black (2), white (1), black (2), greyish with white cottony mass (2). Most of the isolates (11) produced rough colonies and 11 were smooth in appearance. Only three isolates were found to display submerged type of growth (Table 3.7). The present study indicates subsistence variation in terms of mycelial colour and texture among the different isolates collected from Odisha. In phylogenetic tree analysis based on ITS region, overall two major groups were formed. OD-2 along with CG-2 and CG-43, KJ522979 (Indian isolate) and KJ766301 (Malaysian isolate) are in one group whereas other isolates from Kenya Japan, China are in a separate genotypic group.

Bacterial Blight

The variation in the bacterial blight pathogen *Xanthomonas oryzae pv. oryzae* is a major matter of

Table 3.7. Morphological characterization of *M. oryzae* from Odisha state

S.N.	Name of the isolate	Surface appearance	Colony color & texture
1.	ODL-1	Smooth	Whitish black
2.	ODL-3(2)	Rough	Black with cottony mass
3.	ODL-3(4)	Smooth	Black
4.	ODL-4	Smooth	Grey
5.	ODL-5	Rough	White cottony mass
6.	ODL-8	Rough	Greyish with cottony mass
7.	ODL-10	Rough	Greyish white
8.	ODL-11	Smooth	Black
9.	ODL-13	Smooth	Greyish white
10.	ODL-14	Rough	Black with white cottony mass
11.	ODL-15	Smooth	Greyish black
12.	ODL-16	Rough	Black with white cottony mass
13.	ODL-18	Rough	Black with white cottony mass
14.	ODL-19	Rough	Black with cottony mass
15.	ODL-20	Rough	Greyish black
16.	ODL-21(1)	Smooth	Greyish white
17.	ODL-21(3)	Smooth	Black with white cottony mass
18.	ODL-22	Smooth	White
19.	ODL-25	Rough	Greyish white
20.	ODL-26	Rough	Grey with white cottony mass

concern. So, in the present investigation we collected pathogen sample of Xoo from different eastern states of India like, Assam, Bihar, West Bengal and Tripura. The pathogens were tested for their pathogenicity in a highly susceptible check TN1 and then genetic diversity analysis was performed using JEL primers as reported earlier (Fig. 3.11). It was observed that the genetic diversity and geographical distribution of Xoo did not show any relation (Fig. 3.12).

Fig. 3.11. JEL banding pattern of representative isolates of Xoo

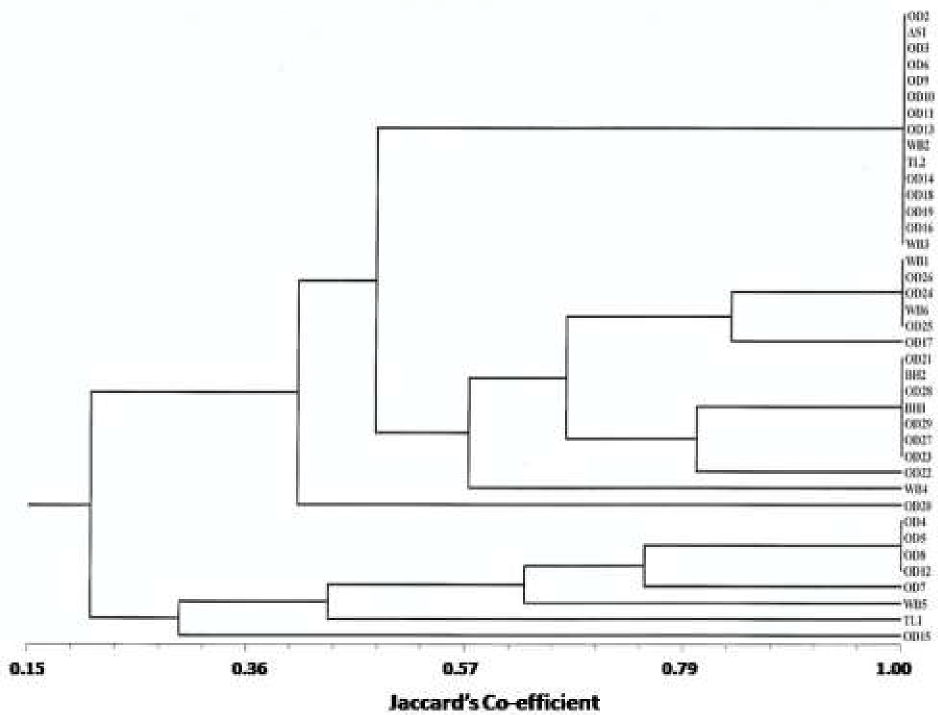


Fig. 3.12. Genetic Diversity of BLB isolates of Eastern States (OD=Odisha, WB= West Bengal, As=Assam, BH=Bihar, TL= Telangana)

False smut

Altogether 107 sample of false smut samples were collected from farmers' field of rice in different states of India particularly eastern India (Fig. 3.13). Out of these, 89 samples were isolated and morphological study of 7 to 28 days old cultures revealed remarkable variation in respect of size, shape, colour, textures and most importantly initiation of sporulating time (Fig. 3.14)

Experiment was conducted through staggered planting of three different rice varietyes (Pooja, Tapaswini and Ajay) on three different dates as early planting, normal planting and late planting in July. Last year non-significant low incidence of false smut disease was there at the experiment field during normal and late planting and no incidence in early planting date. Analysis of three years weather data (Temp, RH & RF) and experiment data revealed that combination of 24$\pm$2^{0}C temperature, 75$\pm$5 relative humidity and intermittent drizzling but not heavy rainfall was favourable for false smut disease appearance. But last year observation indicated micro-climate might have some role and should be taken care for identifying proper epidemiology of the

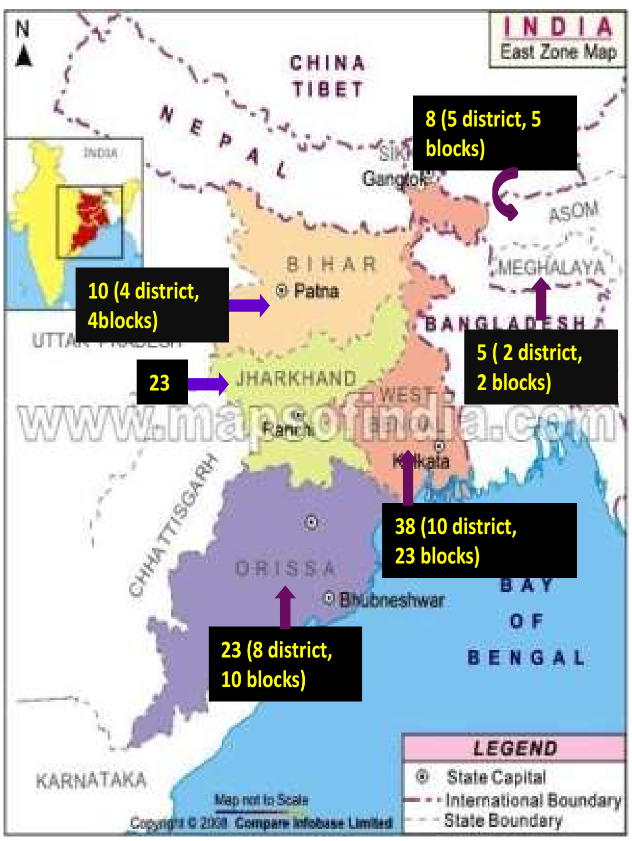


Fig. 3.13. Location of sample collection

Fig. 3.14. Morphological variation in different isolates of false smut culture

disease.

Yield loss assessment due to False smut

The disease incidence was 6-33% while the severity ranged from 3-575. The number of infected tillers varied from 1-5 while the number of smutted ball ranged from 1-22 ball/hill. The highest percentage of chaffy grains was found in Utkal Prava (70.59%) and least in Kala Champa (4.42%) for the infected panicle (Fig. 3.15). The yield loss of 0.10 to 5% was observed and average yield loss was 2.06% (Fig. 3.16).The highest yield loss occurred from Moti (5.14%) followed by Gayatri while the lowest yield loss was found in Swad (0.10%). Therefore, the yield loss is due to reduction of panicle weight, reduction in number of grains, grain weight and increase in number of chaffy grains in smutted panicles as evident from the observed data which is exacerbated by the favourable weather conditions during the latter stage of crop growth.

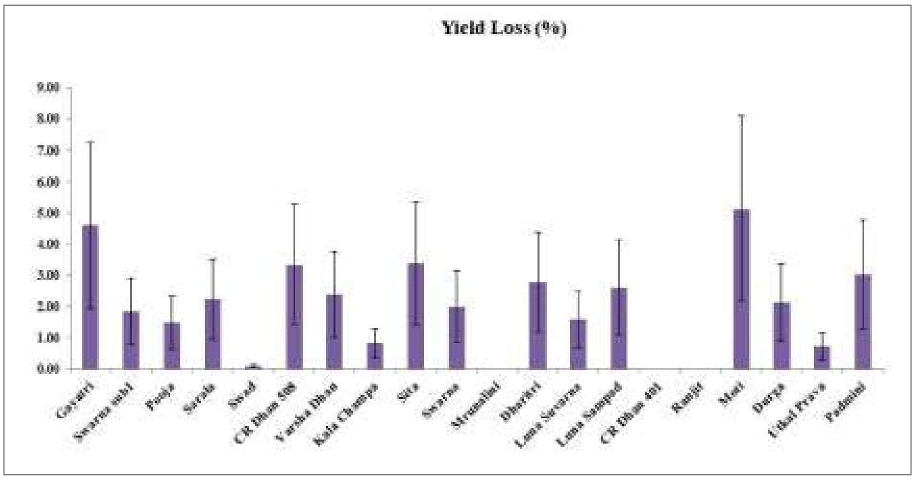


Fig. 3.15. Yield loss caused by false smut in different rice varieties

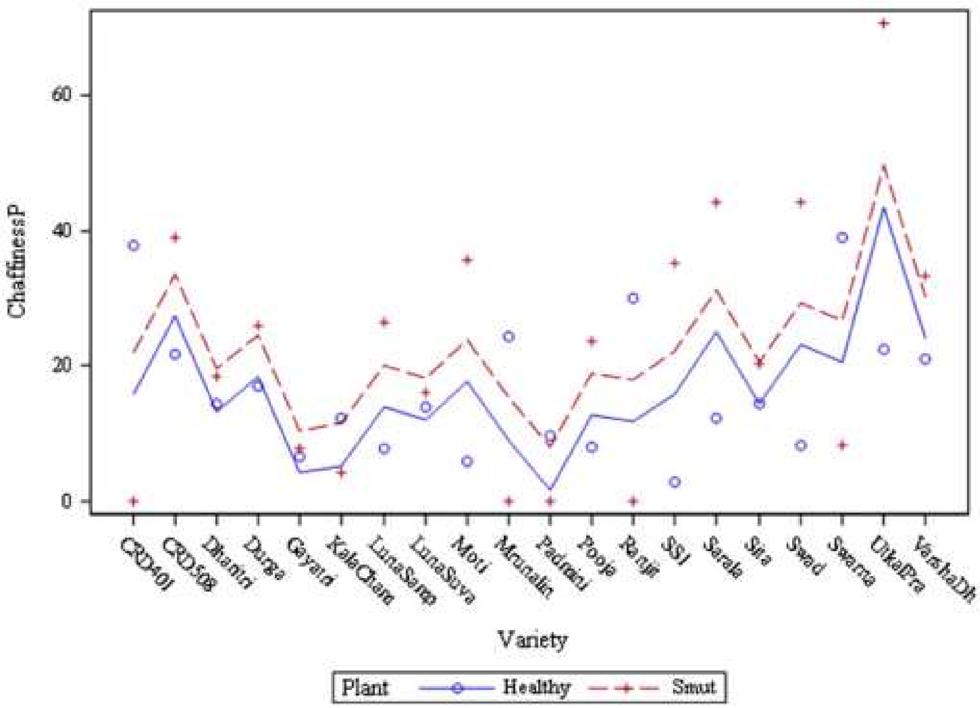


Fig. 3.16. Chaffiness between healthy and smut panicles

Bakanae

A roving survey was conducted during *kharif* 2017 in different villages of five districts of Odisha namely., Cuttack, Jajpur, Ganjam, Bargarh and Sambalpur. Typicalbakanae symptoms such as abnormal elongation, foot rot and death of the plants were noticed in different varieties of rice. The disease incidence was calculated by following formula.

$$\textbf{Per cent disease incidence (PDI)} = \frac{\textbf{Number of plants infected}}{\textbf{Total number of plants examined}} \times 100$$

The results showed that, the disease incidence was more during 2017 when compared to 2016. This shows that, the disease is emerging as a major problem in Odisha.Among the five districts surveyed, significantly higher disease incidence was recorded from Cuttack district in both the years followed by Jajpur district (Fig. 3.17). Among the popularly growing varieties of rice, Pooja recorded maximum disease incidence followed by Naveen and Swarna (Fig. 3.18).

Sheath blight

Nine different weed flora namely, *Digitaria ciliaris, Digitaria sanguinalis, Dactyloctenium aegyptium, Echinochloa colona, Echinochloa glabrescens,Cyperus rotundus, Cyperus esculentus, Cynodon dactylon and Commelina benghalensis* prevalent in and around rice fields of NRRI experimental farm were raised during *kharif,* 2017 in the earthen pots under net house condition to ascertain the role of weeds in perpetuation of rice sheath blight pathogen, *Rhizoctonia solani* Kuhn. These weed species were artificially inoculated with the virulent isolate of the sheath blight pathogen. The recording on disease incidence parameters namely, pathogenic reaction, time taken for disease symptoms appearance and lesion length were taken up during the study.

From the result findings (as may be seen from Table 3.8), it was observed that all the weed host species showed positive reaction of symptom production by a virulent isolate of *R. solani*. Highest lesion length (48.8 mm) was recorded in the weed host *Dactyloctenium aegyptium* followed by *Echinochloa colona* (42.7 mm) and *Digitaria ciliaris* (36.5mm), while least lesion length of 18.8 mm was found in *Cyperus esculentus.*

Time taken for the sheath blight symptom production

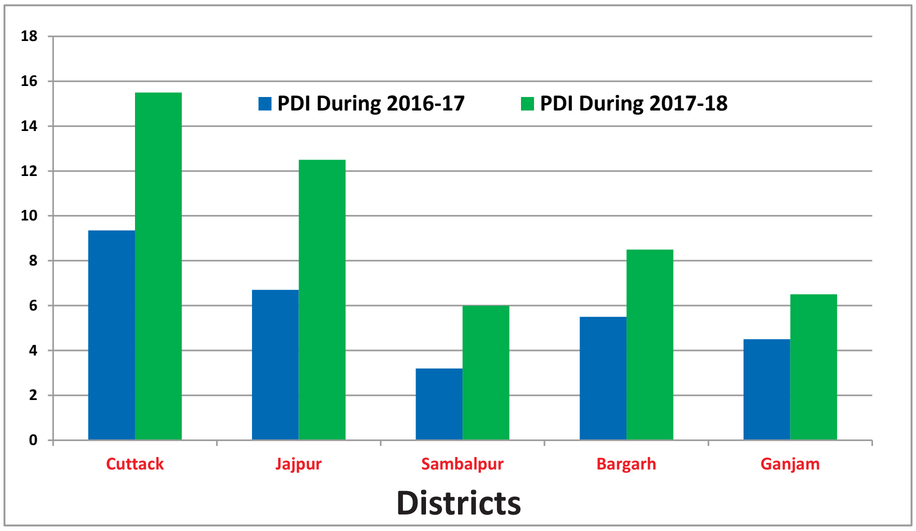


Fig. 3.17. Incidence of Bakanae disease of rice in five districts of Odisha

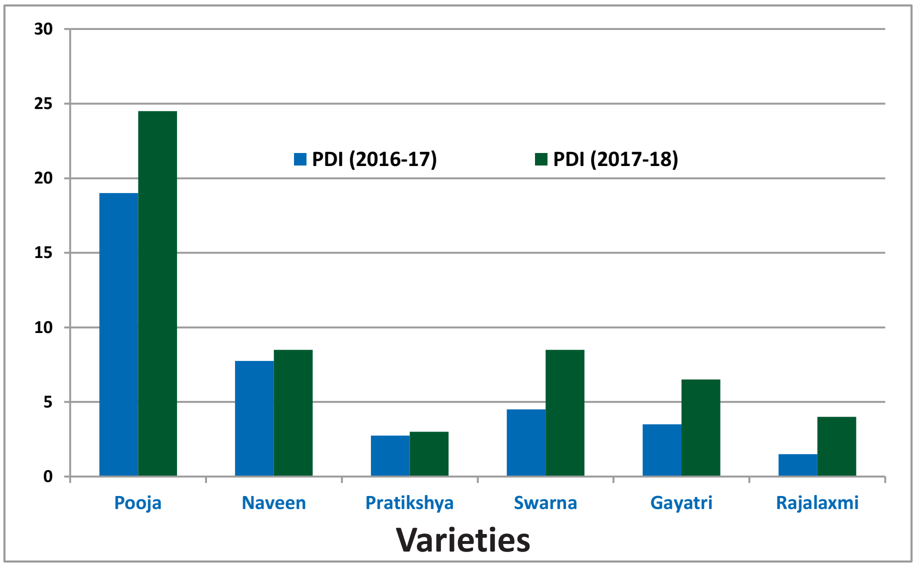


Fig. 3.18. Incidence of Bakanae disease in popular rice varieties

was observed to be different for the weed species taken for study ranging from 3 to 6 days.

The expression of symptoms in these weed hosts were observed to be more or less similar to that of rice plants.

Bio-intensive approaches for pest management in rice

Trichoderma as biocontrol agent & biofertilizer

Isolation of *Trichoderma* spp.

Seven *Trichoderma* isolates (i.e. CRRIU-1, CRRIU-2, CRRIU-3, CRRIU-4, CRRIU-5, CRRIT-6, and CRRIT-7) were collected from bark of different trees or from parasitized wild mushrooms at Cuttack, Odisha (Fig. 3.19).

The fungi were collected with a sterile cotton swab and the conidial suspension was prepared in sterile double distilled water. The suspension was poured on Potato Dextrose Agar (PDA) plates after serial dilution and the isolated colonies were further purified by repeated serial dilution and plating.

Morphological & Molecular Characterization

Morphological identification of *Trichoderma* spp. was done based on colony and microscopic characteristics

Table 3.8. Reaction of weed species against sheath blight disease

Sl. No.	Weeds	Family	Pathogenic reaction	Time taken for appearance of disease symptoms (in days)	Lesion length (in mm)
1	*Digitaria ciliaris*	Poaceae	+	4	36.5
2	*Digitaria sanguinalis*	Poaceae	+	4	33.8
3	*Dactyloctenium aegyptium*	Poaceae	+	3	48.8
4	*Echinochloa colona*	Poaceae	+	4	42.7
5	*Echinochloaglabrescens*	Poaceae	+	5	31.6
6	*Cyperusrotundus*	Cyperaceae	+	4	27.4
7	*Cyperuses culentus*	Cyperaceae	+	5	18.8
8	*Cynodon dactylon*	Poaceae	+	4	25.2
9	*Commelina benghalensis*	Commelinaceae	+	6	28.0

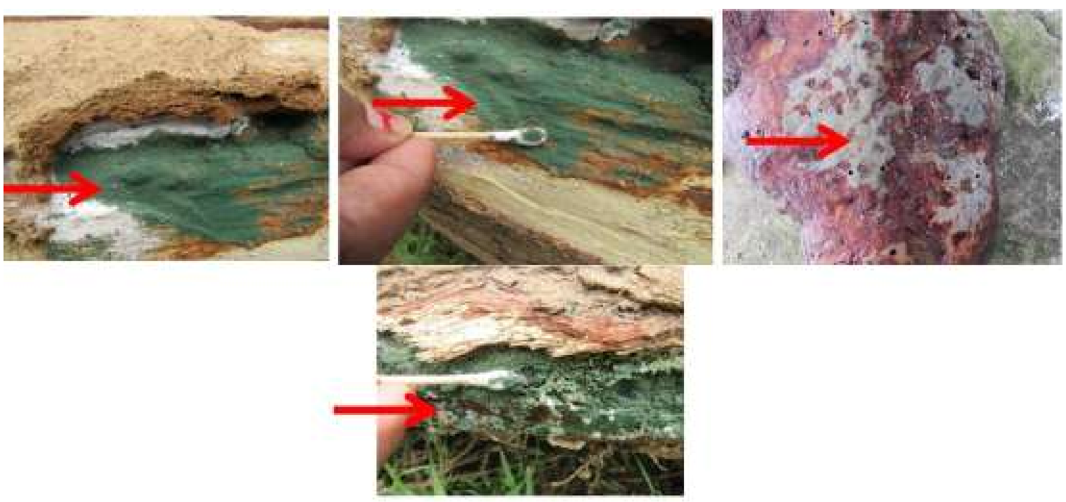


Fig. 3.19. Collection of *Trichoderma* isolates from tree barks

(Gams and Bissett, 1998) according to ISTH (International Sub-commission on *Trichoderma* and *Hypocera*) after incubation for four days at 27 °C on PDA medium (Fig. 3.20). Total genomic DNA from the mycelia was isolated by using standard method. The molecular characterization of all the fungal isolates were based on the sequences of Internal Transcribed Spacer (ITS) regions, Translation Elongation Factor 1 (TEF1) regions and RNA Polymerase B-larger subunit-II (RPBII) regions as per standard methods (http://www.isth. info/ tools/ blast/ markers.php).

Confrontation assays

Ability of the *Trichoderma* isolates to antagonize the isolated pathogens were assessed by using confrontation assay on PDA plates by simultaneous inoculation of both *Trichoderma* and the pathogen near the edge of the plate, placed opposite to each other. Plates inoculated with pathogens only were used as control. The percentage of mycelia growth inhibition was calculated according to Hajieghrari (2010) (Fig. 3.21)

Fig. 3.20. Growth pattern (5days after inoculation) on PDA medium shows Morphological variations in different isolates of *Trichoderma* spp.

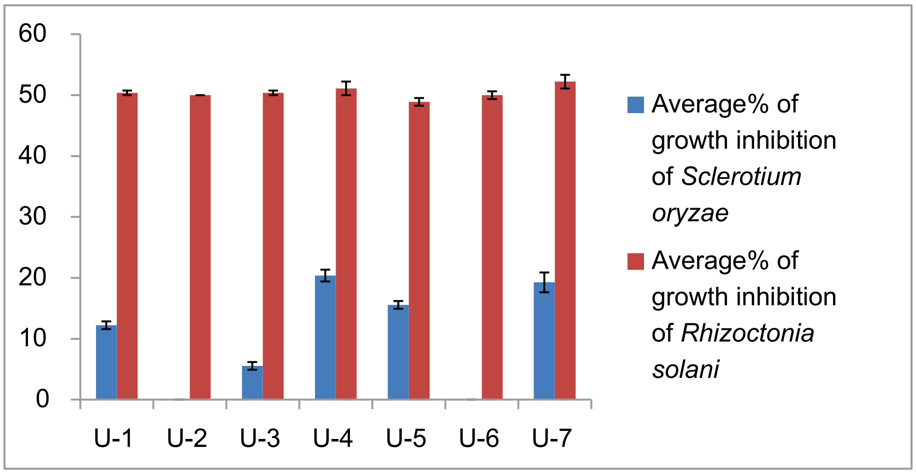


Fig. 3.21. Average % of growth inhibition of Pathogens against *Trichoderma* spp.

Evaluation of bioagents against False smut disease

Evaluation of bio-agents in *in vitro* condition revealed *Trichoderma harzianum, Trichoderma atroviride* and *Dendryphiella sp* as the most promising control of *Ustilaginoidea virens* with inhibition percentage of 68.82%, 54.04% and 44.94% respectively (Fig. 3.22 and Table 3.9).

Fig. 3.22. Growth inhibition of U. virens by *Trichoderma harzianum*

Preparation of floating granule formulations of *Trichoderma* sp

Floating granules were prepared by different proportions of Hydrogenated Vegetable oil, PVP, water, *Trichoderma* spores and using either wheat flour/maize flour/oat flour. Ingredients of the formulations have been standardized. The granules were dried under room temperature as well as in hot air oven and more viable colonies of *Trichoderma* were found in room temperature dried formulation. The granules from wheat formulation were completely dispersed after 24 hrs where in other two (maize and oat) it took more than 72 hrs. The value (CFU/g) of viable fungi was more than 10^8 cfu/g. All the three formulations showed antagonistic responses against *Rhizoctonia solani*. Rice stem was inoculated with *R. solani* at 60 days after rice transplanting. The formulations were applied @ 0.15 and 0.30 g per plot by extrapolating the doses of 15 kg/ha and 30 kg/ha formulation. The application of granule formulation significantly reduced the development of sheath blight lesions (Fig. 3.23). After 15 days of application, the severity of the sheath blight using formulations

Table 3.9. Efficacy of bio-agents against *U. virens* at 20 days after inoculation

Sl. No.	Bioagents	Accession no.	Growth diameter (mm)	Inhibition (%)
1.	*Pseudomonas aeruginosa*		69.63	18.09
2.	*Bacillus amyloliquefaciens*	MH257581	50.75	40.29
3.	*Bacillus sp*		52.63	38.09
4.	*Bacillus sp*		73.00	14.12
5.	*Bacillus amyloliquefaciens*	MH251872	50.88	40.15
6.	*Bacillus subtilis*	MH251913	77.50	8.82
7.	*Trichoderma harzianum*		26.5	68.82
8.	*Trichoderma atroviride*		39.07	54.04
9.	*Dendryphiella sp*	JQ039898	46.8	44.94
Control			85	00.00

was less than that of control. Further tests and development of these fungal spore formulations are needed to find out the appropriate amount and frequency of application to get the most effective biocontrol treatment against sheath blight disease.

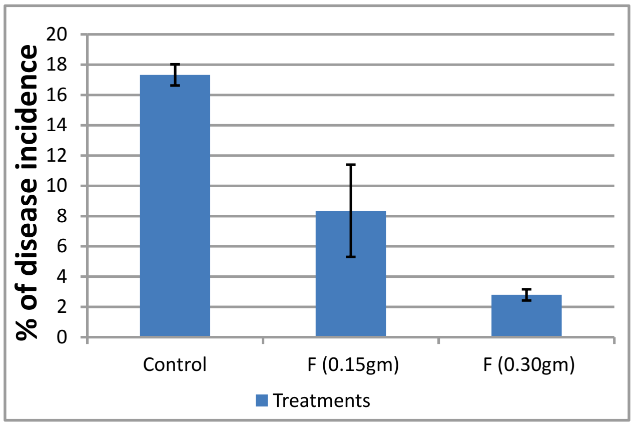


Fig. 3.23. Floating Granules against sheath blight disease in rice plant (F= formulation)

Induction of resistance against Bacterial Leaf Blight in rice (*Oryza sativa* L.) using *Bacillus* Spp

Bacterial leaf blight (BLB), caused by *Xanthomonas oryzae* pv *oryzae (Xoo)*, is a serious threat to rice yield resulting in about 70 % reduction in grain yield. Crop rotation, use of antibiotics are insufficient to control BLB and to meet global food demand. So, there is a need for alternative strategies and use of Biocontrol agent like *Bacillus* spp. is one such strategy. Seeds of TN1 (susceptible to BLB) were treated with 3 spp of *Bacillus* (NRRI-Bac1, Bac2, Bac3) and inoculated with Xoo after 45 Days of transplanting. There were 8 treatments: i) C- Control (no *Bacillus* treatment, no *Xoo* inoculation, ii) D- Disease control (no *Bacillus* strains treatment, + *Xoo*), iii) B1 (+ NRRI Bac 1, no *Xoo* inoculation), iv) B1D (+ NRRI Bac 1 + *Xoo* inoculation), v) B2 (+ NRRI Bac 2, no *Xoo* inoculation, vi) B2D (+ NRRI Bac 2, + *Xoo* inoculation), vii) B3 (+ NRRI Bac 3, no *Xoo* inoculation, viii) B3D (+ NRRI Bac 3, + *Xoo* inoculation). Disease progression, yield and chlorophyll content data has been taken. In comparison to diseased (D) plants, the plants treated with *Bacillus* spp and inoculated with *Xoo* showed slower disease progression percentage (Fig. 3.24) even on 20 DAI, high chlorophyll content (Table 3.10) on 15 DAI and higher yield (mean grain weight per pot in grams) (Fig. 3.25).

Characterization of *Bacillus* spp. for management of sheath rot diseases in rice

The antagonistic effect of *Bacillus* isolates were calculated as inhibition of mycelial growth by dual culture method and presented in Fig. 3.26. A total of ten isolates of *Bacillus* spp. were evaluated for their

Table 3.10. Effect of *Bacillus* spp. treatment on chlorophyll content before and after pathogen inoculation

Treatment	Days after inoculation			
	0	5	10	15
C	45.86[c]	47.42[cd]	48.54[a]	40.53[c]
D	45.71[d]	44.73[de]	28.57[c]	10.10[g]
B1	48.12[a]	50.79[ab]	48.68[a]	48.76[a]
B1D	47.67[b]	52.36[a]	48.28[a]	38.77[d]
B2	42.07[f]	45.61[de]	41.63[b]	42.61[b]
B2D	41.96[g]	48.97[bc]	41.45[b]	32.67[e]
B3	45.71[d]	44.11[e]	48.05[a]	38.83[d]
B3D	45.40[e]	46.15[cde]	44.27[ab]	28.61[f]
Tukey HSD at 5%	0.08	1.56	4.34	2.86

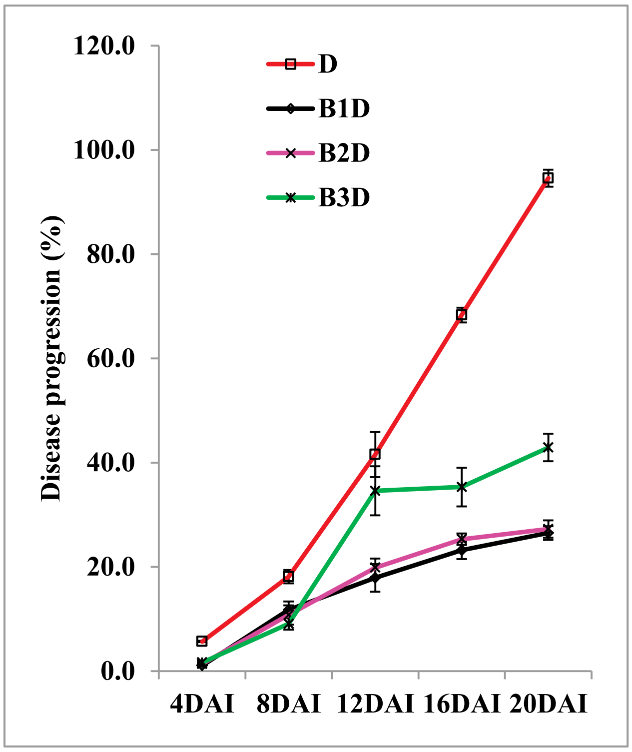


Fig. 3.24. Effect of *Bacillus* spp. treatment on disease progress (D= diseasesd control, B1D to B3D= Treated with different species of *Bacillus* and inoculated with *Xanthomonas oryzae pv oryzae*)

antagonistic performance against *Sarocladium oryzae* under *in vitro* conditions. Among the isolates RB1 showed the greater mycelial growth inhibition against the pathogen, followed by the isolates RB5 and RB6 (Fig. 3.26). Furthermore, all the isolates were tested for their growth promoting attributes. Results of the *in vitro* growth promotion assay revealed that isolates RB1, RB5, RB6 and RB10 promotes the plant growth than other isolates. The maximum vigor index of 2850 was observed in rice treated with RB1 suspension and less vigor index of 1584 was recorded from untreated control (Fig. 3.27).

To know the presence of antibiotic biosynthetic genes, the gene specific region of *bacD*, *bacAB*, *fenB*, *ituC*, *ituD*, *ituA*, *albf*, *alba*, *srfA* and *bamC* were amplified with the antibiotic specific primers. Among the isolates RB3 possesses the maximum number (10) of antibiotic genes followed by RB1 (9). Biochemical and molecular characterization revealed that RB1, RB5 and RB6 were found to be *B. amyloliquefaciens* (MG490146), *B. subtilis* (MG490145) and *B. subtilis* (MG490144), respectively.

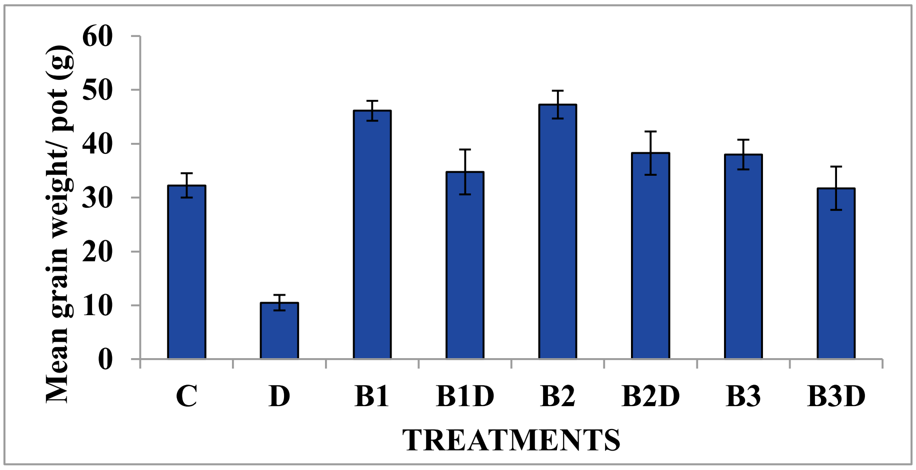


Fig. 3.25. Effect of *Bacillus* spp. treatment on yield data (C= absolute control, D= Disease control, B1 to B3 =treated with different Bacillus spp.; B1D to B3D= Treated with with different species of Bacillus and inoculated with *Xanthomonas oryzae pv oryzae)*

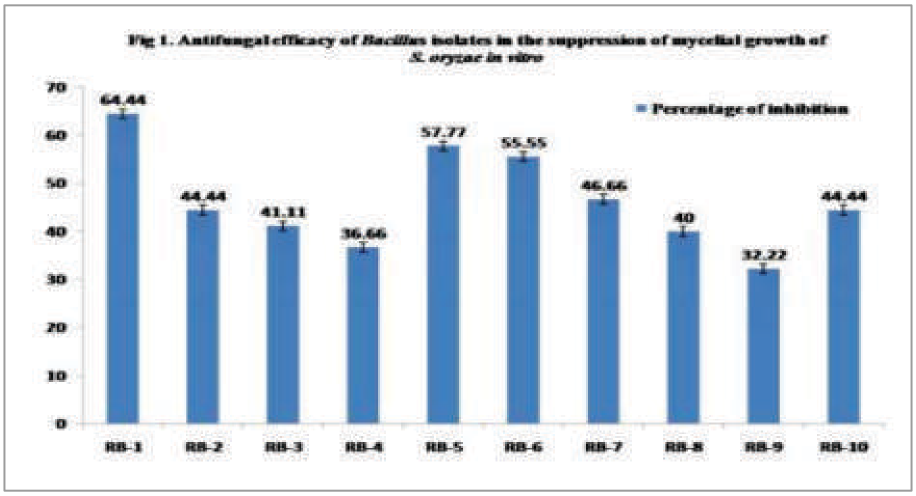


Fig. 3.26. Antifungal efficacy of different *Bacillus* spp. *in vitro*.

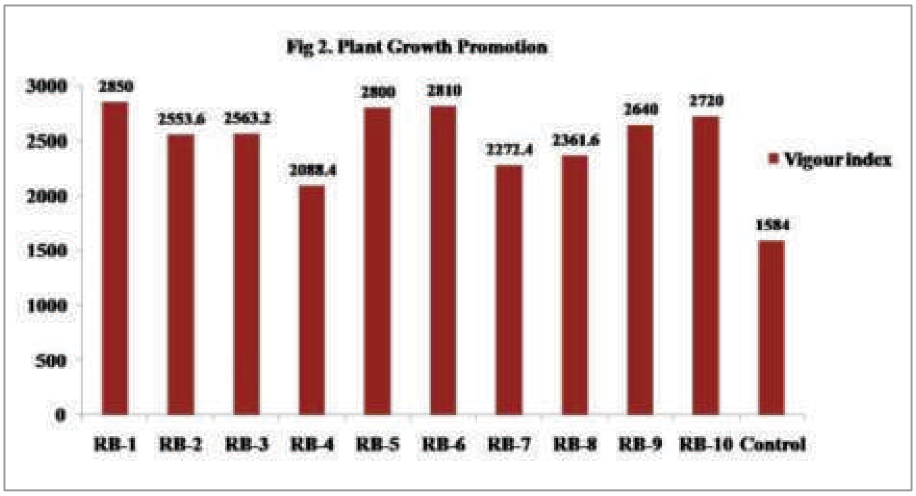


Fig. 3.27. Plant growth promotion in *Bacillus* spp treated seedlings as indicated by seedling vigour index

Evaluation of botanical extract against yellow stem borer of rice

Cleistanthus collinus extract produced a significant result against brown planthopper and gall midge raised the curiosity to conduct a pot experiment to evaluate the effect of *C. collinus* extract on dead heart incidence caused by rice yellow stem borer (YSB). *C. collinus* extract was sprayed at desired concentrations and released 30 first instar YSB larvae and covered with Mylar sheet. Then observed total number of tillers and dead hearts and calculated dead heart per cent. The result showed that all the five sprayed concentrations of *Cleistanthus collinus* extract produced significantly less dead heart compared to control. Highest concentrations of 1000 and 2000 ppm were found to be significantly superior over other concentrations tested. The possibility of using this plant extract against yellow stem borer need to be done exhaustively.

Nano-emulsion formulation of eucalyptus oil (EO) for stored grain pest management

Nano emulsion formulation was prepared and treated at different concentrations *viz.*, 100, 85, 75 and 50% on cement arena and tested for their efficacy against *Rhyzopertha* and *Oryzaephilus*.

Rhyzopertha dominica

Results showed that 24 hours after treatment cent per cent mortality was observed with 100% nano emulsion formulation followed by 85 and 75 % nano emulsion formulation which registered 83.33 and 33.33% mortality, respectively (Table 3.11). Significantly lowest mortality was registered at 50% nano emulsion formulation (20.00%). As the time lapsed and concentration increased mortality also increased in all the treatments.

Oryzaephilus surinamensis

Results of our experiment showed that 24 hours after treatment 36.60% mortality was observed with 100 % nano emulsion formulation followed by 85 and 75 % nano emulsion formulation which registered 30.00 and 16.67% mortality, respectively (Table 3.12). Significantly lowest mortality was registered at 50% nano emulsion formulation (6.67%). As the time lapsed and concentration increased mortality also increased in all the treatments.

Table 3.11. Efficacy of nano emulsion formulation of eucalyptus oils against *Rhyzopertha dominica*

Sl no	Treatments	Per cent mortality				
		1 DAT	3 DAT	5 DAT	7 DAT	10 DAT
1	Non formulated EO @ 0.75 µl/cm^2	30.00 (33.21)	40.00 (39.23)	60.00 (50.77)	73.33 (58.91)	80.00 (63.43)
2	Formulated EO 50 %	20.00 (26.57)	26.67 (31.09)	30.00 (33.21)	36.67 (37.27)	46.67 (43.09)
3	Formulated EO 75 %	33.33 (35.26)	33.33 (35.26)	43.33 (41.17)	56.67 (48.83)	60.00 (50.77)
4	Formulated EO 85 %	83.33 (65.91)	86.67 (68.58)	90.00 (71.57)	93.33 (75.04)	96.67 (79.48)
5	Formulated EO 100 %	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)	100.00 (90.00)
6	Control (Water)	3.33 (10.52)	3.33 (10.52)	3.33 (10.52)	3.33 (10.52)	3.33 (10.52)
	SEm ±	3.67	5.60	5.01	5.01	5.72
	CD (@1%)	15.85	24.21	21.67	21.65	24.73

Table 3.12. Efficacy of nano emulsion formulation of eucalyptus oils against *Oryzaephilus surinamensis*

Sl no	Treatments	Per cent mortality				
		1 DAT	3 DAT	5 DAT	7 DAT	10 DAT
1	Non formulated EO @ 0.75 µl/cm^2	20.00 (26.57)	26.67 (31.09)	40.00 (39.23)	46.67 (43.09)	56.67 (48.83)
2	Formulated EO 50 %	6.67 (14.96)	13.33 (21.42)	23.33 (28.88)	30.00 (33.21)	36.67 (37.27)
3	Formulated EO 75 %	16.67 (24.09)	23.33 (28.88)	33.33 (35.26)	40.00 (39.23)	46.67 (43.09)
4	Formulated EO 85 %	30.00 (33.21)	33.33 (35.26)	36.67 (37.27)	46.67 (43.09)	53.33 (46.91)
5	Formulated EO 100 %	36.67 (37.27)	43.33 (41.17)	50.00 (45.00)	60.00 (50.77)	70.00 (56.79)
6	Control (Water)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	SEm ±	3.67	3.94	3.19	3.03	2.59
	CD (@1%)	15.85	17.03	13.80	13.08	11.19

Isolation of semiochemicals from rice stink bugs

In the gundhibugs (*Leptocorisa oratorius* and *L. acuta*) only males were attracted to abdominal extracts (semiochemicals) that are produced and emitted by both males and females. When handled or disturbed *L. oratorius*, adults of both sexes and nymphs secreted a defensive chemical from scent glands on the 5th abdominal segment. These compounds were defensive, alarming to predators and an aggregation pheromone for juvenile stage of its con-specifics. *L. acuta* females detected the hexane extracts of males, but they did not elicit any attraction. The chemical odor is similar to that of stink bugs such as *Nezara viridula* and probably has a role in repelling predators. When not feeding on rice, the abdominal secretion of *L. oratorius* was different and not as powerful as that produced during feeding on the rice crop. Available information suggest that (E)-2-octenal, hexyl acetate, 3-octenal, octan-1-ol, (Z)-3-octenyl acetate, octyl acetate are pheromone (alarm) compounds for *L. oratorius*.

Effect of rice grain volatiles on Angoumois grain moth, *Sitotroga cerealella*

Rice grain volatiles were collected from susceptible variety through customized headspace. Dual choice oviposition assay was conducted using this extracted volatile against Angoumois grain moth, *Sitotroga cerealella* attraction. There was higher mean number of eggs laid (Fig. 3.28) at volatile side (219.75±17.72) than control side (26.25±5.12) which was significant at 0.01 per cent. Comparisons were performed by paired samples t test.

Fig. 3.28. Eggs of *Sitotroga cerealella* found towards volatile side in Dual choice oviposition assay

Validation and promotion of IPM module in farmer's fields under shallow low land ecosystem (*w.r.t* rice diseases)

Twenty acres in a compact block was taken for conducting the experiment in the farmer's fields in the village Bodhpur of Cuttack Sadar involving 24 farmers during *kharif*, 2017 with taking of Swarna and Pooja varieties under IPM.

In IPM practice, seed treatment was performed with carbendazim 50WP @ 2.0g/kg seed before sowing in nursery bed. Need based application of pesticides were undertaken by the farmers in the affected areas only. The fungicide carbendazim 50WP@1.0g/litre against brown spot, sheath blight, sheath rot diseases, Cartap hydrochloride @1kg ai/ha against YSB, leaf folder, BPH and need based foliar application of another insecticide chlorpyriphos 20%EC @ 0.5kg ai/ha against gundhi bug were applied during the experimentation. Periodical monitoring and recording of disease incidences along with grain/straw yield parameters from the experimented farmers' fields were undertaken in the presence of the participating farmers.

In case of treatment with Swarna IPM (Need based), least incidences of brown spot-3.6%, sheath blight-5.36%,sheath rot-3.9%, false smut-2.96% with maximum grain yield of 7.36t/ha, straw yield of 5.5t/ha, B:C ratio-2.45 were found followed by Swarna IPM (Schedule based) over Swarna (Farmers' practice).

Treatment with Pooja IPM (Need based), least incidences of 3.52% brown spot, 3.86% sheath blight, 2.96% sheath rot, 4.48% false smut with maximum grain yield- 7.36t/ha, straw yield- 6.36t/ha, B:C ratio-2.18 were found followed by Swarna IPM (Schedule based) over Swarna (Farmers' practice).

There was significant reduction in disease incidences like brown spot, sheath blight, sheath rot, false smut and increased yield parameters (grain/ straw yield) in Need based Swarna and Pooja IPM followed by Schedule based Swarna/Pooja IPM over Farmers' practices.

Low cost IPM technology for rice pests in favourable lowland ecology

In the on-farm IPM plots at Bianpur village of Mahanga block, Cuttack, the biotic stresses during *kharif*, 2017 consisted of case worm at 3rd week of August, leaf folder at 2nd week of September and yellow stem borer at 1st week of October. Proper surveillance could enable to identify pest problems at the initiation of infestation. Since sheath blight had been identified as an upcoming disease in the area for last 5 years, pre-sowing seed treatment with carbendazim @ 2gm/Kg of seeds was made. Timely management options reduced pest incidence to minimum without any endemic situation. Seed treatment with carbendazim kept the fungal diseases low though sheath blight, sheath rot and false smut were more in farmers' practice in terms of area as well as severity. Farmers applied only neem oil instead of chemical pesticides to control surface feeders like case worm, leaf folder and to their assessment, disease infection(ShB) also went down. Area-wise, pests occurred in about 12 acres of field which were made completely free by applying proper treatments at proper timing so that there was no economic loss. The protection cost was only 9% as compared to the initial 100% cost during the year 2012. The average yield was 5.8 t/ha against 3.7 t/ha during 2012.

Validation of IPM module in farmaer's field

IPM module was validated in farmer's field during *kharif* 2017 using variety Pooja and Swarna with three integrated pest management practices i.e. need based, schedule based and farmer practices in village Bodhapur, Cuttack Sadar. The result revealed as follows :

In farmers field, higher grain yield was obtained in need based IPM practice plot (7.36 & 6.3 t/ha) over schedule based IPM practice (6.5 & 5.2 t/ha) and farmer practice plot (4.3 & 3.8 t/ha) in both the tested varieties Swarna and Pooja, respectively. Higher grain yield was obtained in schedule based IPM practice as compared to farmer practice in both the tested varieties Swarna and Pooja. Natural enemies population is more in farmer practice plot (6.3 and 6.6) followed by need based IPM practice plot (4.0 and 4.3) and schedule based IPM practice plot (2.0 and 2.3), in both the tested varieties, respectively (Table 3.13).

Table 3.13. Result of IPM in *kharif* 2017

S.N.	Treatment	%DH	%WEH	%LF	% Gbug	NE	G-yield	S-yield	B:C ratio
1	Swarna IPM need based	2.5 (9.08)d	3.5 (10.83)d	2.4 (8.97)d	4.5 (12.24)c	4.00b	7.36a	5.50bc	2.4
2	Swarna IPM schedule based	3.5 (10.87)c	4.4 (12.19)c	2.8 (9.68)c	5.5 (13.64)b	2.00c	6.50b	5.33c	1.9
3	Swarna farmer practice	5.5 (13.60)b	5.7 (13.89)b	6.2 (14.40)a	7.2 (15.56)a	6.33a	4.30d	3.53e	1.6
4	Pooja IPM need based	3.6 (11.01)c	3.9 (11.37)d	3.3 (10.51)b	4.3 (12.01)c	4.33b	6.30b	6.36a	2.1
5	Pooja IPM schedule based	4.9 (12.82)b	4.6 (12.37)c	3.6 (10.93)b	5.2 (13.26)b	2.33c	5.26c	6.16ab	1.6
6	Pooja farmer practice	6.5 (14.84)a	6.6 (14.96)a	6.0 (14.21)a	7.2 (15.59)a	6.66a	3.83d	4.43d	1.5
CD at 5%		1.16	0.75	0.65	0.57	1.22	0.80	0.80	-

Need based application of pesticide in IPM is economical (Rs.52000=00) as compared to schedule based IPM practice (Rs.57500=00).

Optimization of chemical pesticide-use for management of rice pests in different eco-systems

Efficacy of pesticides against insect and diseases of rice in *kharif*

Eight pesticides including insecticides and fungicides and combination products were evaluated against insect and diseases of rice during *kharif* 2017 and the results revealed that Spinetoram 6%+Methoxy fenozide 30% @ 0.75ml/l recorded least dead heart(3.6%) at 30DAT and leaf folder damage 2.3% and gundhi bug damage 2.3% where as DPX-RAB 55+ Contaf @(0.48+2.0)ml/l recorded least dead heart 3.4% at 50DAT, white ear head 4.6% at harvest and higher grain yield of 4.33t/ha (Table 3.14).

Efficacy of pesticides against insect and diseases of rice in *rabi*

Eight pesticides including insecticides, fungicides, antibiotic and combination products were evaluated against insect and diseases of rice during *rabi* 2017 and the results revealed that Coragen+CM75 (0.3+2ml/l)recorded least dead heart (2.1%), leaf folder damage 2.0% and gundhi bug damage 2.3%, blast 1.2%, white ear head 2.4%, natural enemies 1.66 and higher grain yield of 7.6 t/ha where as in untreated control the corresponding values were 6.1%, 5.2%, 5.4%, 5.1% 6.4%, 5.66% and 4.3 t/ha, respectively (Table 3.15)

In long term pesticide trial, two insecticides *i.e.* cartap and chlorpyriphos, one fungicide *i.e.* carbendazim and one herbicide *i.e.* pretilachlor along with untreated control were tested against insect pest of rice during *rabi* and *kharif* season of 2017-18. The result revealed that in cartap @1kg ai/haleast incidence of deadheart 2.5%, white ear head 3.5% leaf folder damage 2.2%, gundhi bug damage 4.2%, natural enemies 1.2 were observed along with higher grain yield of 4.8 t/ha during *kharif* 2017 (Table 3.16). Similar result was also obtained during *rabi* 2018 (Table 3.17).

Table 3.14. Evaluation of combination of pesticides against insect and disease of rice in *kharif*-2017

Treatment with dose	%DH at 30DAT	%DH at 60DAT	%WEH at Harvest	%LF	% G.Bug	%Blast	NE	Yield t/ha
Spinetoram6%+Methoxyfenozide30% @0.75ml/l	3.6 (10.99)b	3.6 (10.97)c	5.6 (13.17)cd	2.3 (8.78)f	2.3 (8.78)h	3.6 (10.98)b	3bc	4.00a
DPX-RAB55 (Triflumezopyrim 106%%0.48ml/l)	3.9 (11.47)b	3.4 (10.71)c	5.3 (13.27)cd	2.9 (9.89)ef	2.6 (9.33)g	3.8 (11.24)b	4b	4.13a
Contaf plus (hexaconazole5%@2 ml/l)	8 (16.40)a	8.5 (16.93)b	11.8 (20.09)ab	6.7 (15.00)b	7.5 (15.63)c	1.7 (7.63)d	6a	3.73a
Mantis 75WP(Baan) (Tricyclazole @0.6ml/l)	8.6 (17.06)a	9.1 (17.55)b	11 (19.38)b	6.9 (15.29)b	7.6 (15.85)b	1.8 (7.70)d	5.6a	3.80a
Spinetoram6%+Methoxy fenozide30% +Contaf @(0.75+2.0)ml/ha	4.1 (11.70)b	3.6 (10.92)c	9 (12.74)cd	3.3 (10.56)de	2.8 (9.74)f	2.5 (9.14)c	2c	4.03a
Spinetoram6%+Meyhoxy fenozide30%+ Baan @ (0.75+0.6)ml/l	5 (12.78)b	4 (11.61)c	5.4 (13.36)cd	4.2 (11.87)c	3.3 (10.57)e	2.2 (8.59)c	2.3c	4.06a
DPX-RAB 55+ Contaf @(0.48+2.0)ml/l	4 (11.50)b	3.7 (11.13)c	6.1 (14.29)c	4.1 (11.66)cd	3.5 (10.88)d	2.3 (8.84)c	2.3c	4.10a
DPX-RAB 55 + Baan @(0.48+0.6)ml/l	4.5 (12.33)b	3.4 (10.64)c	4.6 (12.45)d	3.6 (11.02)cde	3.6 (11.08)d	2.4 (9.03)c	2.3c	4.33a
Untreated Control	10.3 (18.71)a	10.6 (18.99)a	13.1 (21.26)a	8.1 (16.58)a	8.4 (16.77)a	4.5 (12.24)a	6.6a	2.60b
CD at 5%		1.25	1.20	0.51	0.48	0.70	0.71	0.99

Data in parentheses are angular transformed values

Application method of chlorantraniliprole for better efficacy against yellow stem borer(YSB), *Scirpophaga incertulus* Walk., the major pest in dry season rice

Pheromone trap catch of yellow stem borer during the year 2017 started after 2nd week of January in *rabi*. Though there was only one peak (4-6 SMW), moths prevailed upto 1st week of March (9 SMW) causing more than 50% dead heart in untreated control. During *kharif*, the population started appearing towards 3rd week of September (38 SMW) with peak during October 2nd to 1st week of November (41-44 SMW). But there was drastic reduction in number during 3rd week of October, perhaps due to rain and wind during the time. Afterwards, it was gradually reduced without causing significant level of white earhead in medium duration test varieties like Pooja and Ketekijoha (Fig. 3.29).

Table 3.15: Evaluation of pesticides against insect and disease of rice in *rabi* 2018

Sl. No.	Treatment	Dose	%DH	%WEH	%LF	%G bug	%blast	%blight	NE	Yield
1	Coragen	0.3ml/ lit	2.5 (9.05)de	3.1 (10.25)c	2.2 (8.59)de	2.6 (9.39)d	3.6 (11.03) bc	3.7 (11.18)b	2.33cd	6.40c
2	Token	0.4ml/ lit	3.0 (9.96)cd	3.6 (10.98)c	2.5 (9.09)cd	3.0 (10.08)c	3.8 (11.34)b	4.0 (11.63)b	2.66c	6.13cd
3	CM75	2ml/lit	5.0 (12.91)b	5.3 (13.35)b	3.7 (11.13)b	3.9 (11.48)b	1.3 (6.52)d	3.9 (11.48)b	4.66b	5.03e
4	V3	2.5ml/ lit	5.2 (13.18) ab	5.4 (13.43)b	3.9 (11.43)b	4.2 (11.82)b	3.8 (11.31)b	1.2 (6.28)d	5.00ab	5.30e
5	Coragen+ Cm75	0.3+2ml /lit	2.1 (8.32)e	2.4 (8.96)d	2.0 (8.26)e	2.3 (8.71)e	1.2 (6.28)d	3.2 (10.30)c	1.66d	7.60a
6	Coragen+V3	0.3+2.5 ml/lit	2.9 (9.78)cd	3.2 (10.35)c	2.2 (8.65)de	2.3 (8.72)e	3.3 (10.46)c	1.3 (6.54)d	2.66c	7.13ab
7	Token+ CM75	0.4+2ml /lit	3.3 (10.46)c	3.6 (10.96)c	2.5 (9.21)c	2.7 (9.45)d	1.3 (6.54)d	3.6 (10.97) bc	3.00c	6.83bc
8	Token+ V3	0.4+2.5 ml/lit	3.2 (10.24) cd	3.5 (10.80)c	2.3 (8.71) cde	2.4 (8.97)de	3.7 (11.18)b	1.4 (6.84)d	2.66c	5.66de
9	Control	500lit water/ ha	6.1 (14.29)a	6.4 (14.69)a	5.2 (13.22)a	5.4 (13.43)a	5.1 (13.05)a	5.0 (12.96)a	5.66a	4.30f
CD at 5%			1.25	1.20	0.51	0.48	0.70	0.71	0.99	0.71
Data in parentheses are angular transformed values										

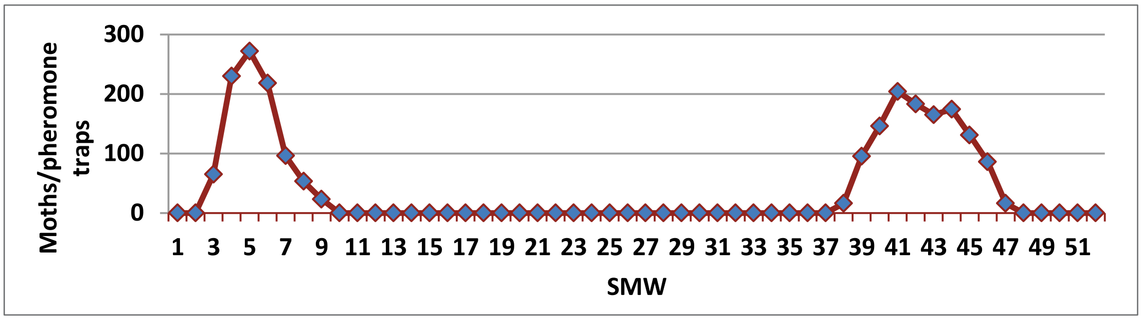


Fig. 3.29. Pheromone trap catches of YSB during the year 2017

Table 3.16. Effect of pesticides on insect pest of rice during *kharif*-2017

Treatment	dose	%DH	%WEH	%LF	%G.bug	%Blast	NE	Yield
Cartap	1kg ai/ha	2.5 (9.22)b	3.5 (10.89)c	2.2 (8.62)d	4.2 (11.89)	2.8 (9.62)d	1.2c	4.82a
Cholrpyriphos	0.5kg ai/ha	2.8 (9.69)b	3.6 (10.93)c	2.8 (9.66)c	5.0 (13.01)	3.3 (10.45)c	1.5c	4.60a
Carbendazim	0.1%	5.5 (13.62)a	5.6 (13.74)b	4.5 (12.34)b	6.5 (14.85)	1.3 (6.52)e	3.5b	3.80b
Pretilachlor	0.75kg ai/ha	5.6 (13.70)a	5.6 (13.68)b	4.7 (12.62)b	6.5 (14.79)	3.8 (11.34)b	3.7b	3.65b
Control	Water 500l/ha	6.1 (14.37)a	6.2 (14.49)a	6.1 (14.35)a	7.4 (15.78)	5.2 (13.21)a	4.7a	3.17c
CD at 5%		0.91	0.51	0.49	0.39	0.38	0.7	0.42
Data in parenthesis are angular transformed values								

Table 3.17. Effect of pesticides on insect pest of rice during *rabi*-2017

treatment	dose	%DH	%WEH	%LF	%G.bug	%Blast	NE	Yield
Cartap	1kg ai/ha	2.8 (9.71)d	3.1 (10.22)e	2.2 (8.62)d	3.4 (10.66)e	2.6 (9.36)d	1.5c	6.40a
Cholpyriphos	0.5kg ai/ha	3.0 (10.01)c	3.4 (10.62)d	2.6 (9.40)c	3.8 (11.31)d	3.0 (10.05)c	2.0c	5.77a
Carbendazim	0.1%	5.0 (12.98)b	5.3 (13.34)c	4.6 (12.36)b	6.2 (14.47)c	1.1 (6.14)e	3.7b	4.97b
Pretilachlor	0.75kg ai/ha	5.1 (13.11)b	5.5 (13.56)b	5.0 (12.98)ab	6.4 (14.71)b	3.3 (10.54)b	4.2b	4.67bc
Control	Water 500l/ha	5.8 (13.99)a	6.2 (14.44)a	5.4 (13.50)a	7.3 (15.67)a	4.6 (12.45)a	5.2a	4.07c
CD at 5%		0.28	0.21	0.68	0.08	0.38	0.9	0.75
Data in parentheses are angular transformed values								

But the pest was effectively managed during *rabi* by standing water application of chlorantraniliprole (Ferterra) coinciding with high brood emergence. Dead heart formation was about 0.41% at 30 DAT and 1.31 at 50 DAT against 26.78% and 52.59%, respectively in untreated control . It also resulted in 67.25% more yield. Carbofuran and cartap hydrochloride, though were superior to untreated control, were significantly inferior to chlorantraniliprole (Table 3.18). The reduction of yield was observed to be due to the dead heart formation directly and also its indirect impact in terms of nil or small panicles or chaffy panicles in compensatory tillers, immature panicles at harvesting and less grain weight. Severe pest infestation at early stage of the crop resulted in complete damage of some hills, therby decreasing plant population in the field which contributed to low yield. It also gave rise to unsynchronized flowering and maturity in compensatory tillers of the YSB infested plants leading to yield reduction.

Table 3.18. Efficacy of insecticides against YSB in rabi rice

Treatments	% Dead heart		% WEH	Grain Yield(t/ha)
	30 DAT	50 DAT		
Carbofuran 3G	6.96 (15.24)	10.85 (19.21)	1.01	5.47
Cartap hydrochloride 4G	9.08 (17.51)	18.64 (25.57)	2.33	4.95
Chlorantraniliprole 0.4GR	0.42 (4.38)	1.64 (7.36)	0.0	6.71
Untreated control	27.56 (31.62)	52.59 (46.49)	3.52	3.47
CD at 5%	3.73	1.59		0.49

DAT: Days after transplanting, WEH: White ear head

Bioassay of fungicides against *Usilaginoidea virens*

Three broad spectrum systemic fungicides of different modes of action, *viz.*, Azoxystrobin 25% (strobilurin group-mitochondrial respiration inhibitor) and Thifluzamide 25% (carboxamides group-succinate dehydrogenase inhibitors) and Difenconazole 25% (Triazole group -a sterol demethylation inhibitor) were assayed against the *U. virens* culture of native isolate following poisoned food technique under ideal laboratory condition. Azoxystrobin 25% and Difenconazole 25% inhibit ~100% fungal growth at 20 ppm while Thifluzamide 24% require 40 ppm concentration. First two fungicides were found more toxic at half of the active ingredient of the later one (Fig. 3.29).

Phosphine fumigation for quarantine and long term stored grain pest management

An experiment was conducted at CWC godown, Cuttack (Odisha) to evaluate the efficacy of phosphine (PH_3) fumigant with improved granular formulation against major stored grain pests of rice followed by residue analysis for traces of phosphine in fumigated rice samples (Fig. 3.31 & 3.32). About 30 stacks each of 5 tonnes (100 bags) milled rice consisting of 10 treatments, each replicated thrice under CRD design were subjected to fumigation. The treatments included two Aluminium Phosphide formulations *viz.*, 77.5% G (Granule) & 56 % (Tablet), each with two doses and two exposure periods against adults of major stored grain pests of rice *viz.*, lesser grain borer, *Rhyzopertha dominica*, rice weevil, *Sitophilus oryzae* rust-red flour beetle, *Tribolium castaneum* and grubs of Khapra beetle, *Trogoderma granarium*. Fumigation was done with the help of UPL Pvt. Ltd. and Pest Control India Pvt. Ltd and the observations were recorded on grain moisture, insect mortality, phosphine gas concentration (Fig. 3.33), pre and post fumigation insect count. The phosphine residue in milled rice samples was quantified after 7 days of degassing.

Results indicated that the total pre-treatment insect count ranged from 1.33 to 9.67 insects per 500 g of sample drawn and moisture content ranged from 12.47 to 13.57, whereas there was reduction in post fumigation insect count and moisture content which ranged from 0.33 to 7.33 and 10.70 to 12.93, respectively. Among the insects observed in post fumigation samples *Tribolium* count was highest whereas *Oryzaephilus* and *Rhyzopertha* count was negligible. Cent per cent mortality of all the test insects kept in boxes at all the treatments was observed which indicates that efficacy of both formulations was on par with each other. Granular formulation reached peak concentration of PH_3 immediately at both the doses which reduced gradually, compared to tablet formulation. Lower PH_3 residue was detected in rice samples of 10 days exposure period compared to 7 days. The residue concentration correlates with the PH_3 concentration of the stack ($r=0.82$, $p<0.0127$). None of the samples indicated PH_3 residue more than MRL value fixed by WHO and FAO (Fig. 3.34). The present study revealed phosphine formulations are effective against stored grain pests of rice at both the exposure periods. Seven days degassing period is safe and can be recommended in fumigation practice.

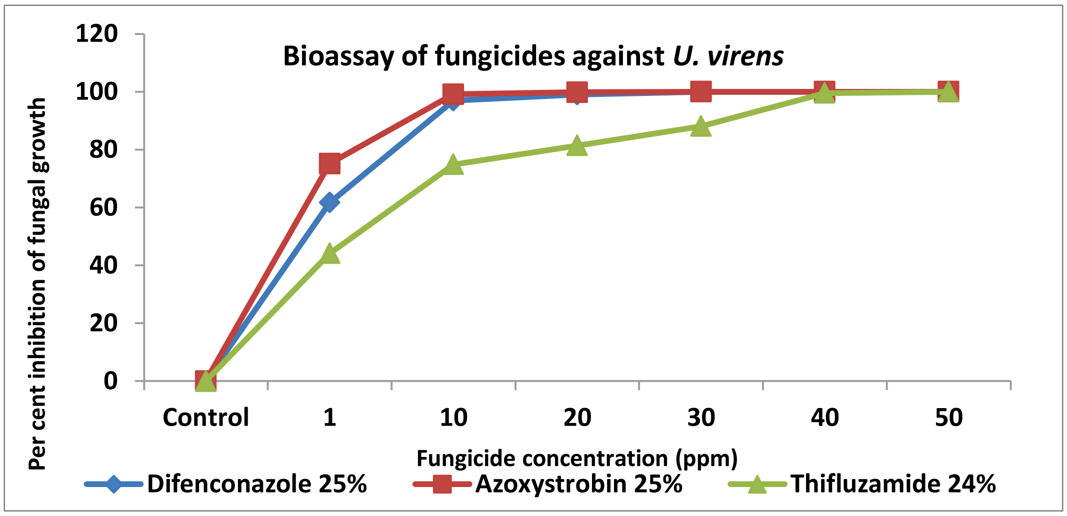


Fig. 3.30. Bioassay of fungicides against *U. virens*

Fig. 3.31. Initial preparations with PH3 gas generator

Fig. 3.32. Overall view after complete fumigation

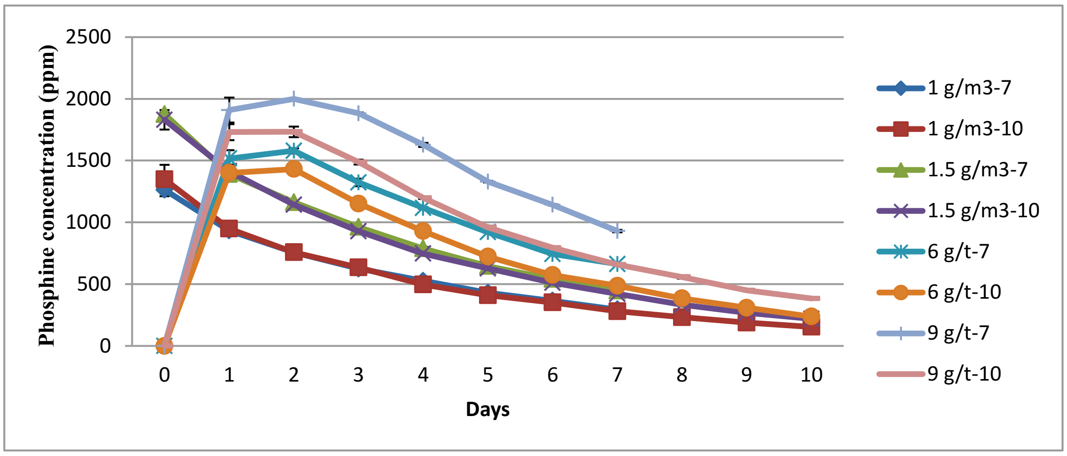


Fig. 3.33. Temporal variation in Phosphine gas concentration with different dosage and exposure periods (error bars represent variation in phosphine concentration at three different levels; top, bottom, middle).

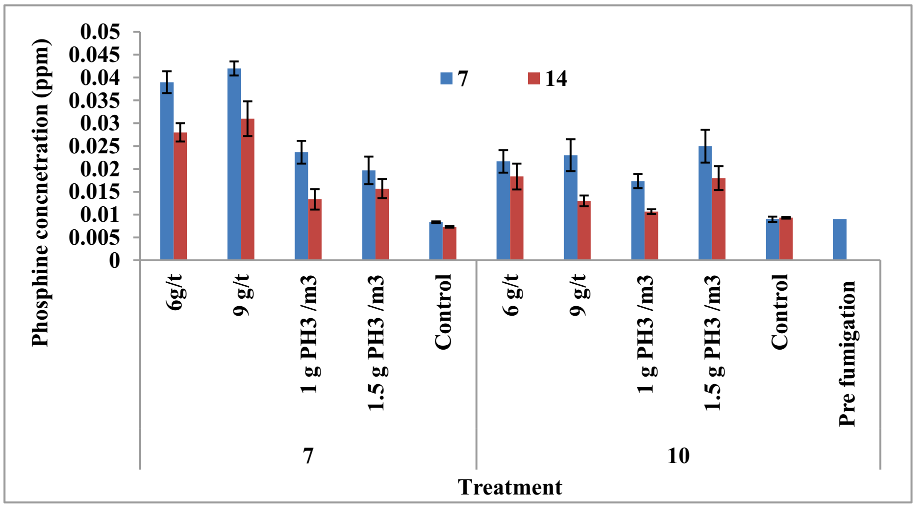


Fig. 3.34. Phosphine residue in rice samples after 7 and 14 days of degassing (error bars represent standard error of three replicates)

Screening of antibiotics against *Xanthomonas oryzae pv oryzae*

In a quest for finding an alternative Streptomycin, 14 antibiotics were screened against *Xanthomonas oryzae pv oryzae* and observed that Ofloxacin is the best under *in-vitro* condition (Fig. 3.35). However, for confirmation we need to test in the field and standardize the dose.

Bacterial diversity in 7 years old long-term pesticide treatments

Alternation of bacterial community was observed under long term application of pesticides (Fig. 3.36). Cyanobacteria and verrucomicrobia phyla were found to be affected by pesticide applications.

Chemical insecticide treatment and rice varieties response

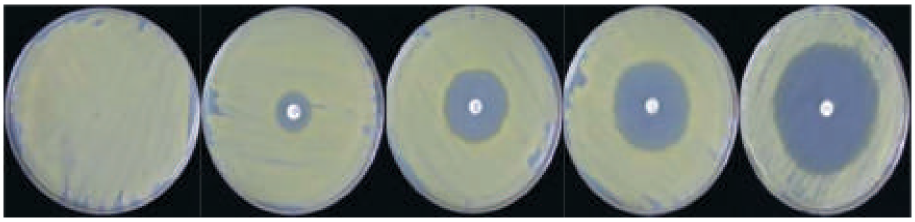
In recent years, neonicotinoids and diamides have been the fastest-growing class of insecticides used in modern crop protection. This provides room for more innovative technology to be developed in application of newer molecule pesticides. Of such the technologies are 1) Employing pesticides as seed treatment to provide protection to seedlings against insect pests, and 2) Using insecticide mixtures having independent mode of action. Not much work is done on use of this relatively new insecticidal active ingredient as a seed treatment in rice against yellow stem borer of rice raised the curiosity.

Seed treatment with thiamethoxam @ 0.5, 1.0 and 2.0 g/L concentrations had a positive effect on emergence percentage, root and shoot characters and biomass accumulation.

In pipeline of the previous result to verify the possible use of chlorantraniliprole the newer insecticide molecule showing better field control against yellow stem borer as a seed treatment chemical an experiment was carried out.

Seed treatment with chlorantraniliprole had no negative effect on emergence percentage at laboratory conditions in turn had a slight increased emergence percentage (Fig.3.37-3.40).

Zone of Inhibition exhibited by different antibiotics



A1 (10ug/disc) A2 (30ug/disc) Streptomycin 10ug/disc A3 (5mcg/disc)

Fig. 3.35. Zone of inhibition exhibited by antibiotics

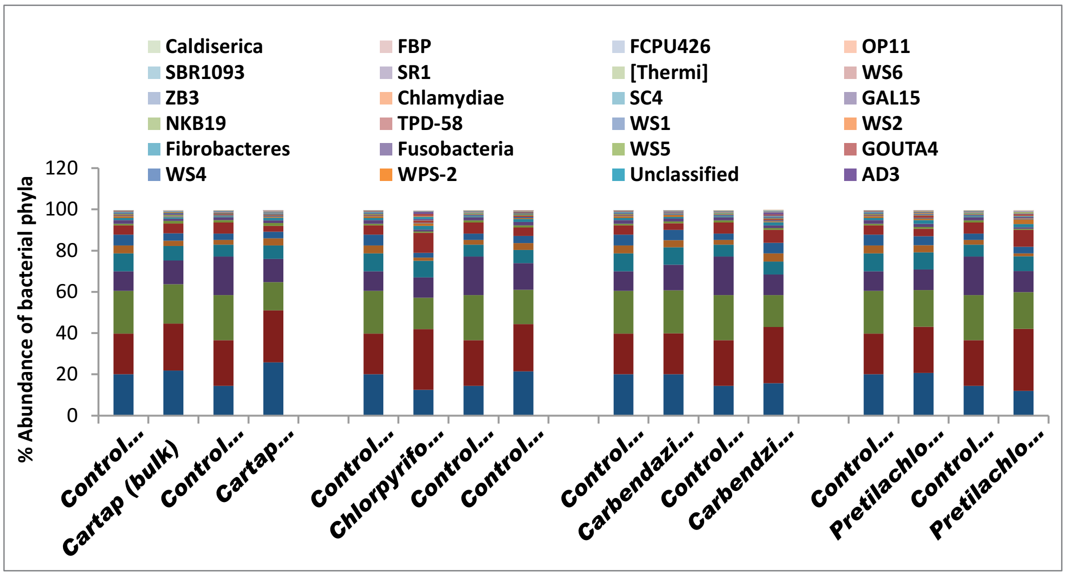


Fig .3.36. Abundance of bacterial phyla under long term pesticide treatments

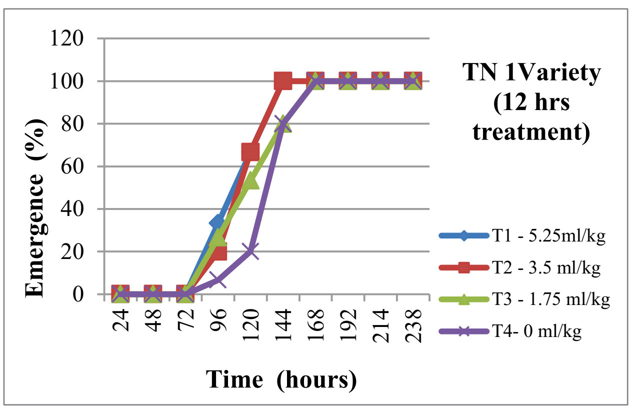


Fig. 3.37. Emergence percentage of TN1 seeds after 12 hrs treatment with Chlorantraniliprole at laboratory conditions

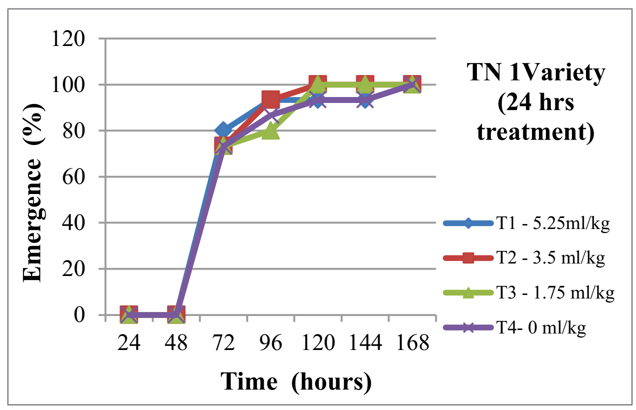


Fig. 3.38. Emergence percentage of TN1 seeds after 24 hrs treatment with Chlorantraniliprole at laboratory conditions

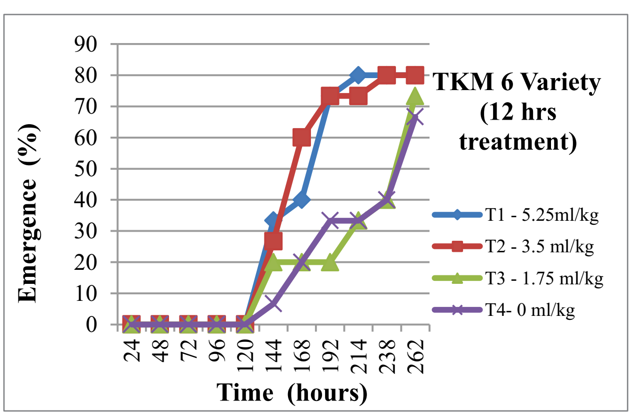


Fig. 3.39. Emergence percentage of TKM6 seeds after 12 hrs treatment with Chlorantraniliprole at laboratory conditions

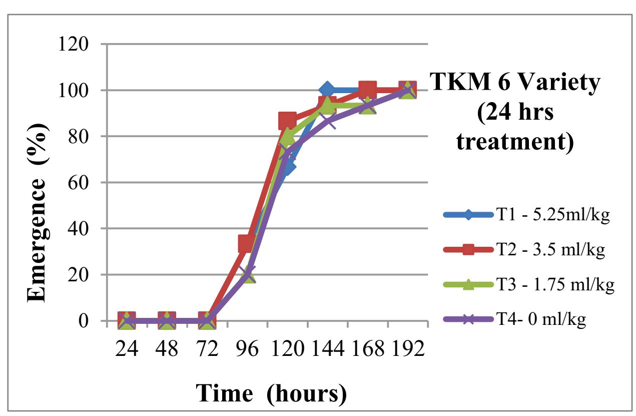


Fig. 3.40. Emergence percentage of TKM6 seeds after 24 hrs treatment with Chlorantraniliprole at laboratory conditions

Four treatment concentrations of chlorantraniliprole (0, 1.75, 3.5, 5.25 ml/kg of seeds) at two treatment time intervals (12 hrs and 24 hrs) against two varieties (TN1, TKM6) were tested. The result showed that chlorantraniliprole seed treatment did not affect the seed emergence percentage both in TN1 and TKM6 varieties at both the treatment time intervals tested at both laboratory (Fig. 3.37 to 3.40) and greenhouse conditions (Fig. 3.41 to 3.44). In turn there was slightly increased seed emergence and also pronounced early increased seed emergence compared to control.

Seed treatment with chlorantraniliprole also had no negative effect on shoot length and root shoot length (Fig.3.45-3.48). In turn slightly increased mean root and shoot length was observed both in TN1 and TKM6 varieties. Among the tested concentrations both the higher concentrations (3.5 and 5.25 ml/kg of seed) had a better effect. With this preliminary background further experiment will be carried out to see the efficacy of this chemical employed as a seed treatment and seedling dip against insect pest.

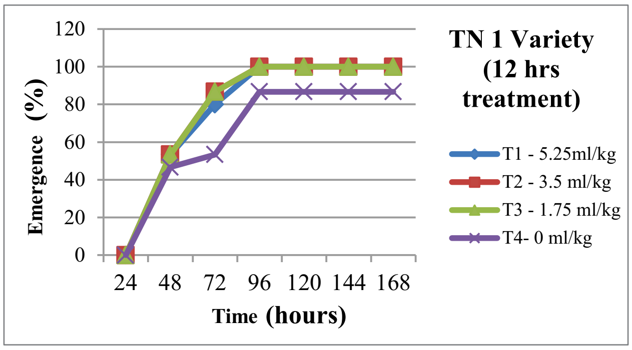


Fig. 3.41. Emergence percentage of TN1 seeds after 12 hrs treatment with Chlorantraniliprole at greenhouse conditions

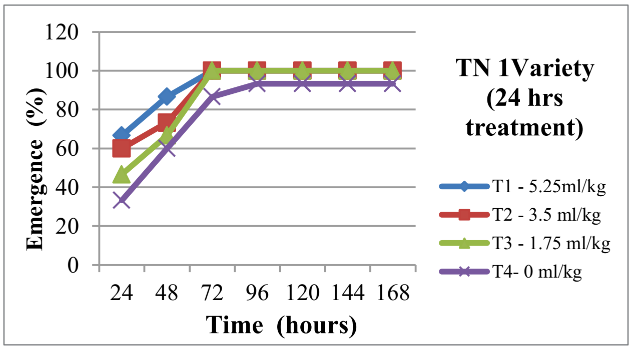


Fig. 3.42. Emergence percentage of TN1 seeds after 24 hrs treatment with Chlorantraniliprole at greenhouse conditions

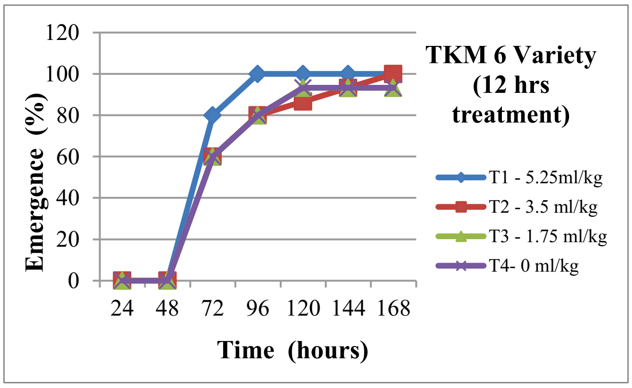


Fig. 3.43. Emergence percentage of TKM6 seeds after 12 hrs treatment with Chlorantraniliprole at greenhouse conditions

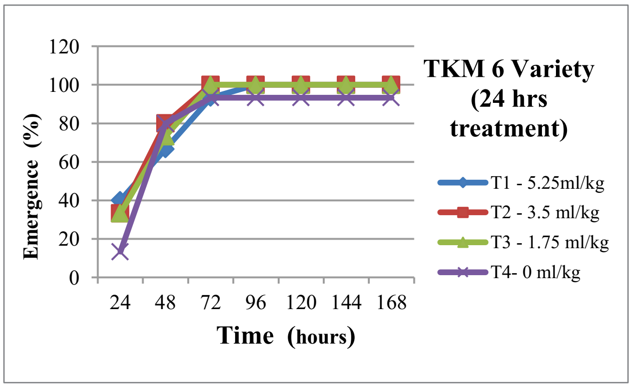


Fig. 3.44. Emergence percentage of TKM6 seeds after 24 hrs treatment with Chlorantraniliprole at greenhouse conditions

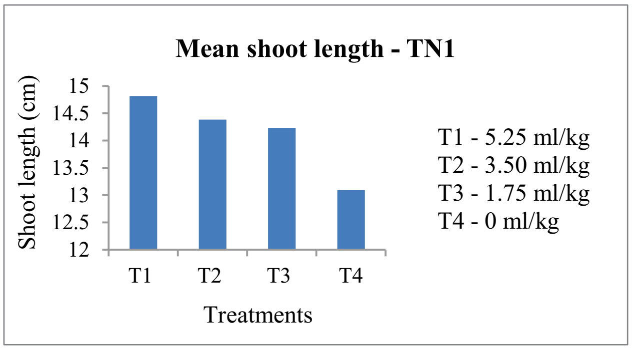


Fig. 3.45. Mean shoot length of TN1 seeds after treatment with Chlorantraniliprole

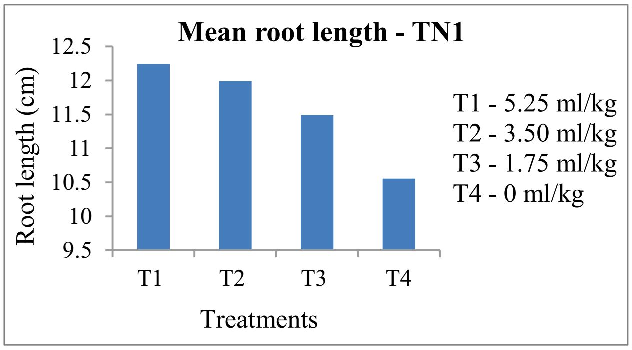


Fig. 3.46. Mean root length of TN1 seeds after treatment with Chlorantraniliprole

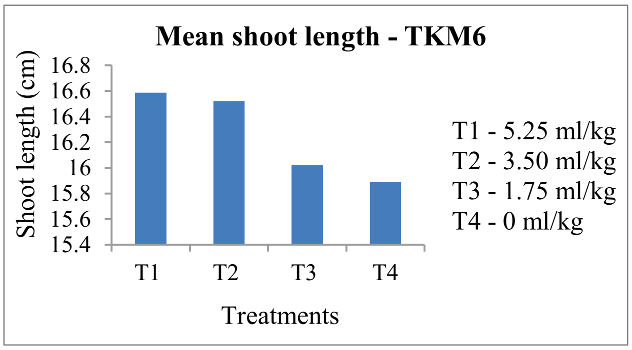


Fig. 3.47. Mean shoot length of TKM6 seeds after treatment with Chlorantraniliprole

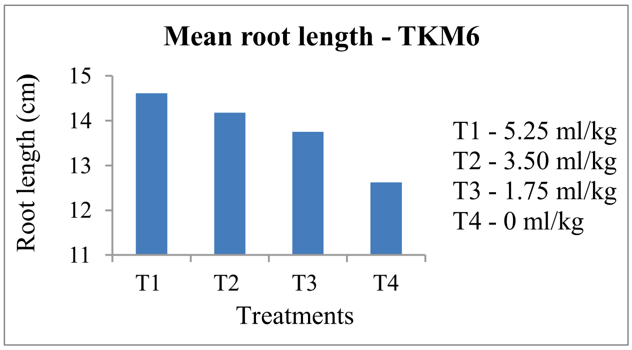


Fig. 3.48. Mean root length of TKM6 seeds after treatment with Chlorantraniliprole

Evaluating the *in vivo* efficacy of new combination fungicides against sheath blight disease under artificial inoculation, *kharif*, 2017

The trial was conducted with following information: Susceptible variety Tapaswini: Treatments-9, Replications-4, Design-RBD, T1-Flusilazole 12.5%+carbendazim 25%SC @ 1.0ml/litre, T2-Azoxystrobin 18.2%w/w+ difenoconazole 11.4% w/w SC @ 1.0ml/litre, T3- Azoxystrobin 11%+ tebuconazole 18.3% w/w SC @ 1.5ml/litre,T4-Tricyclazole 18%+mancozeb 62% WP @ 2.5g/litre, T5-Zineb 68%+hexaconazole 4% WP @ 2.5g/litre, T6-Trifloxystrobin 25%+tebuconazole 50% WG @ 0.4g/litre,T7- Mancozeb 50%+carbendazim 25%WS @2.5g/litre , T8- Fluxapyroxad 62.5g/l +epoxiconazole 62.5g/l EC @1.5ml/litre ,T9- Control. The result (Table 3.20) reveals that best treatment was T2-Azoxystrobin 18.2%w/w+difenoconazole 11.4% w/w SC @ 1.0ml/litre by showing 16.8% disease severity, 76.8% reduction in disease severity over control; 22.4% disease incidence, 71.5% reduction in disease incidence over control; grain yield- 5.58t/ha & 70.1% increase in grain yield over control. Second significant treatment was T1-Flusilazole 12.5%+ carbendazim 25%SC @ 1.0ml/litre by showing 23.7% disease severity, 67.3% reduction in disease severity over control; 27.6% disease incidence, 64.9% reduction in disease incidence over control; grain yield-5.348 t/ha & 62.8% increase in grain yield over control (Table 3.19).

Evaluated the *in vitro* efficacy of two proven efficient fungicides, azoxystrobin 23%SC and validamycin 3%L each in six concentrations of 50ppm, 100ppm, 200ppm, 500ppm, 750ppm, 1000ppm of *w.r.t* per cent mycelial growth inhibition and sclerotial formation. The result revealed that the fungicide validamycin 3%L was found relatively more efficient than azoxystrobin 23% SC.

Evaluation of fungicides against *Fusarium proliferatum* and *Sclerotium oryzae-*

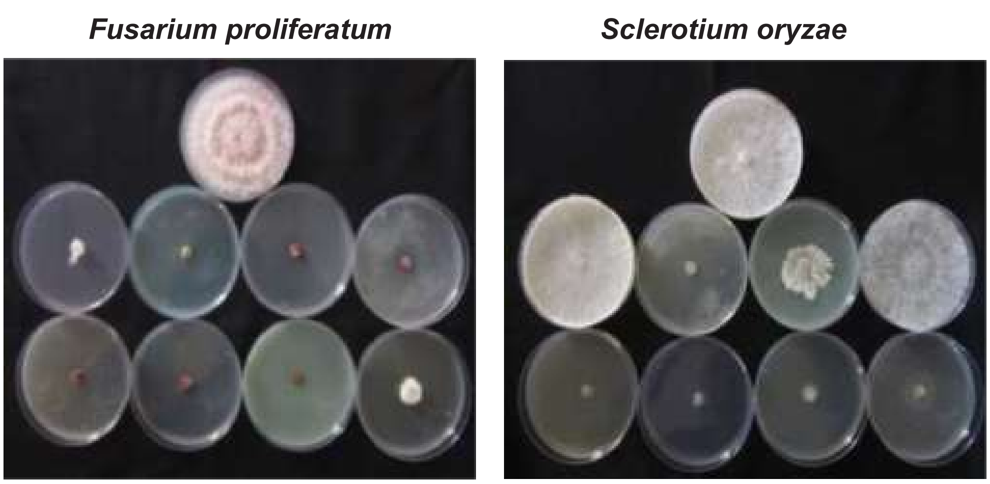
A total of eight fungicides were tested against two different pathogens *viz*., *Fusarium proliferatum* and *Sclerotium oryzae* under *in vitro* conditions. All the chemicals showed100% mycelial growth inhibition to *F. proliferatum* @ 0.1%.The mycelial growth of *S. oryzae* was reduced completely by the chemicals *viz*., Biltox, Nativo, Bavistin and Saff @ 0.1%.(Fig. 3.49).

Indigenous "biobed" to prevent point pollution at farm level

Efficacy of biobed to degrade imidacloprid was tested by using crop residues (rice straw) and farm yield manures (cow dung compost). The experiment was conducted in poly vinyl chloride pipes (PVC). Biomixture was prepared by mixing rice straw, FYM and top soil at the volumetric ratio of 50:25:25. The bottom of the column was filled with 3cm layer of biochar (35g) and 900 mL of water was added to simulate the washing volume. In this study, imidacloprid was dissipated at faster rate in biobed (Fig 3.50). Less than 10% pesticide residue was recovered after 90 days of experiment. Most of the residues was recovered from the top 10 cm of biobed. Degradation was faster at the top of the biobed column (0-10 cm) although imidacloprid might have been leached down to bottom layer but rate of degradation was high due to active microbial interaction. Less than 2% of the pesticide was recovered from leachate. Dissipation rate was high till day 15 and it was gradually decreased with time. The rate of degradation corroborates with the total

Table 3.19. Evaluating the in vivo efficacy of new combination fungicides against sheath blight disease under artificial inoculation, *kharif*, 2017, Susceptible variety Tapaswini

Treatments	Dosage per litre	Disease Severity			Disease Incidence			Grain yield (t/ha)	% increase in grain yield over control
		After 1st spray(%)	After 2nd spray(%)	%reduction over control (after final spray)	After 1st spray (%)	After 2nd spray (%)	%reduction over control after final spray)		
T1	1.0ml	29.3	23.7	67.3	32.3	27.6	64.9	5.34	62.8
T2	1.0ml	23.1	16.8	76.8	28.6	22.4	71.5	5.58	70.1
T3	1.5ml	27.6	19.4	73.2	37.0	31.5	59.9	4.97	51.5
T4	2.5g	58.7	51.6	28.7	59.4	54.2	31.0	3.78	15.2
T5	2.5g	45.2	39.0	46.1	50.2	47.4	39.7	4.02	22.6
T6	0.4g	42.4	36.6	49.4	42.6	39.2	50.1	4.16	26.8
T7	2.5g	49.3	42.2	41.7	55.3	51.8	34.1	3.90	18.9
T8	1.5ml	38.0	32.3	55.4	45.7	42.0	46.6	4.55	38.7
T9	-	70.3	72.4	-	77.4	78.6	-	3.28	-
CD (at 5%)		8.65	7.72		5.96	5.92		5.92	



1. Vitatax (Carboxin+Thiram)
2. Biltox (Copper Oxy Chloride)
3. Tilt (Propiconazole)
4. Folicur (Tebuconazole)
5. Nativo (Tebuconazole+Trifloxystrobin)
6. Bavistin (Carbendazim)
7. Saff (Carbendazim + Mancozeb)
8. Thiram 75

Fig. 3.49. Effect of fungicides against *Fusarium proliferatum* and *Sclerotium oryzae*

microbial biomass data. The total biomass carbon was highest on 7[th] day after treatment where as it was lowest on 60[th] day. Initially DHA activity was more on the top half layer of the bio-column. Later on DHA activity was increased in lower half of the bio-column. The FDA activity was declined up to 75 days. The mixture of straw, top soil and cow dung compost provided a good surface for microbial growth which helped to degrade the imidacloprid in a significant manner (Fig. 3.51). It was found that high amount of imidacloprid application reduced the microbial activities as well as other soil enzymes. Further research is needed to evaluate the efficacy of biobed system with different pesticides application and to find out the microorganisms which are responsible for pesticide degradation.

Susceptibility of Imidacloprid at different populations of BPH

Field populations of *N. lugens* were collected from various rice growing areas of India, *viz.*, Bargarh (Odisha), Karnal, Kerala, Raipur, Punjab between March to December, 2017. Laboratory reared and field collected BPH populations were subjected to toxicological bioassays (rice-stem dipping method) to assess their resistance levels to commonly used insecticides in the sampled areas, Imidacloprid. The mortality data from the insecticide bioassays were subjected to probit analysis for the determination of lethal concentration values (LC_{50}) and presented in (Table 3.20). Interestingly, Bargarh population from Odisha also falls with Karnal and Punjab population and found to have lesser susceptibility against Imidacloprid compared to Kerala, Raipur and laboratory populations. Resistance factors (RF) were estimated at the LC_{50} level as RF = LC_{50} of field population / LC_{50} of laboratory reared susceptible population. The classification of resistance levels was done based on the RF as RF value <10- fold as low resistance, RF = 10–40-folds as moderate resistance, RF = 40–160-folds as high resistance and >160-fold as extremely high resistance. The field populations were found to exhibit low to moderate levels of resistance against Imidacloprid.

Effect of different systemic and combination fungicides on the growth of *Fusarium fujikuroi* under *in-vitro* and *in vivo*

Ten selected fungicides were evaluated for the second consecutive year for their efficacy against *Fusarium fujikuroi* both under *in vitro* and pot experiments. All tested fungicides showed variation in per cent inhibition of radial growth of the pathogen (Fig. 3.52). The results showed that minimum complete inhibitory concentration (MIC) was found by Carbendazim, Tebuconazole and Carboxin 37.5 % +Thiram 37.5 % (Vitavax Power) (5 ppm). Next to MIC were Trifloxistrobin + Tebuconazole (Nativo), Carbendazim + Mancozeb and Propiconazole (10 ppm) followed by Merger, Campanion, ICF-110 and Azoxystrobin (50 ppm). Seed treatment with three fungicides such as Carbendazime 50% WP, Tebuconazole and Carboxin 37.5 % +Thiram 37.5 % (Vitavax Power) @ 0.1% had significantly increased germination and vigor index and reduced disease incidence in three test varieties such as Pooja, Naveen and Pusa Basmati 1121, compared to control (Fig. 3.53).

Table 3.20. Comparative susceptibility of BPH against Imidacloprid 17.8SL

Population	Heterogeneity		b±SE	Lc50 (ml ai/1)	Fiducial Limit	Resistance factors (RF)
	Df	X^2				
Odisha (Laboratory)	4	2.789	2.781±0.456	0.06[a]	0.030 to 0.080	-
Odisha (Bargarh)	4	2.183	3.397±0.383	0.58[c]	0.510 to 0.650	9.67
Karnal	4	6.196	2.931±0.336	0.69[c]	0.510 to 0.860	11.5
Kerala	4	2.514	2.239±0.309	0.23[b]	0.190 to 0.270	3.83
Raipur	4	5.798	3.044±0.339	0.25[b]	0.190 to 0.300	4.17
Punjab	4	9.257	2.962±0.338	0.73[c]	0.500 to 0.950	12.16

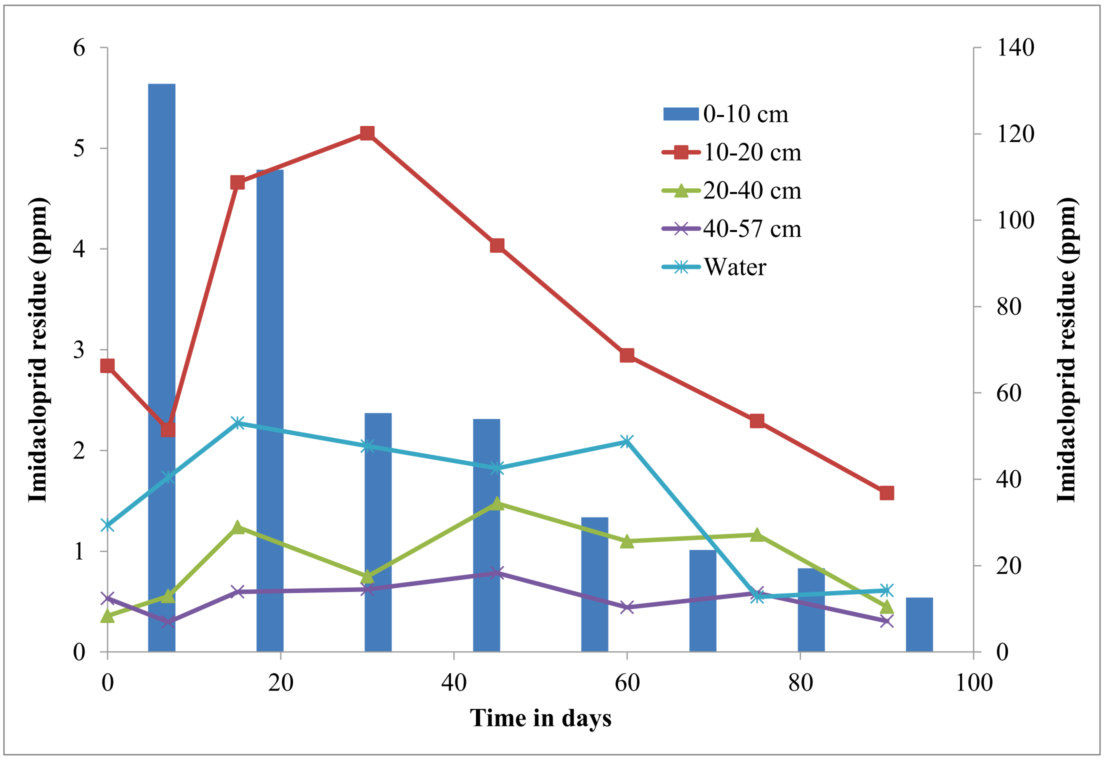


Fig. 3.50. Imidacloprid persistence in different layers of biobed

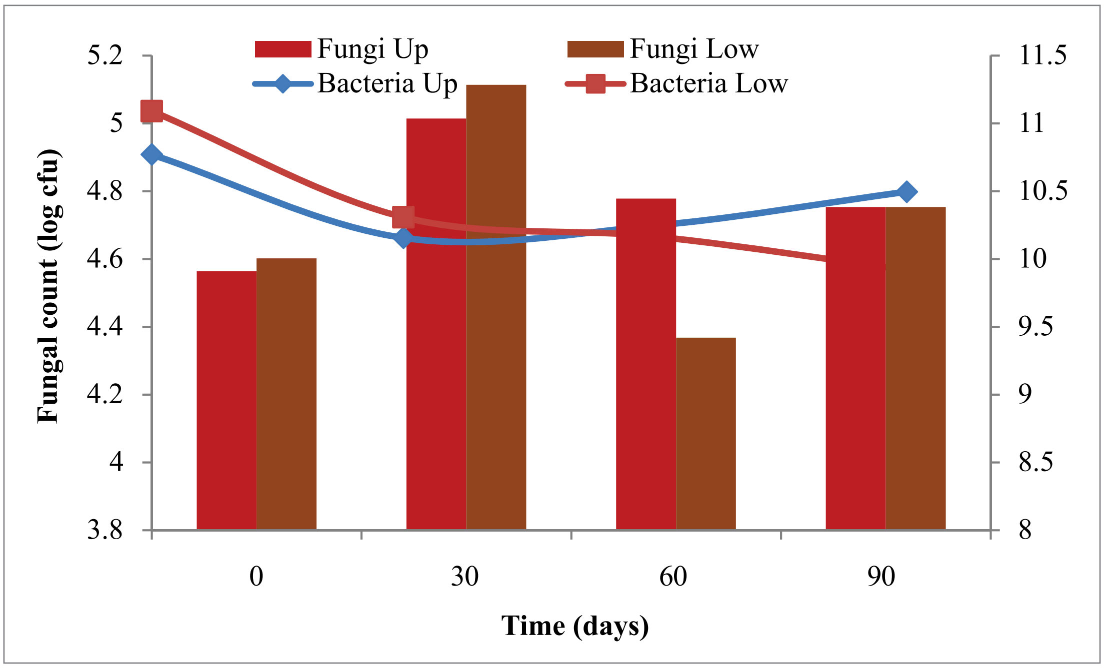


Fig 3.51. Microbial counts in different layers of biobed

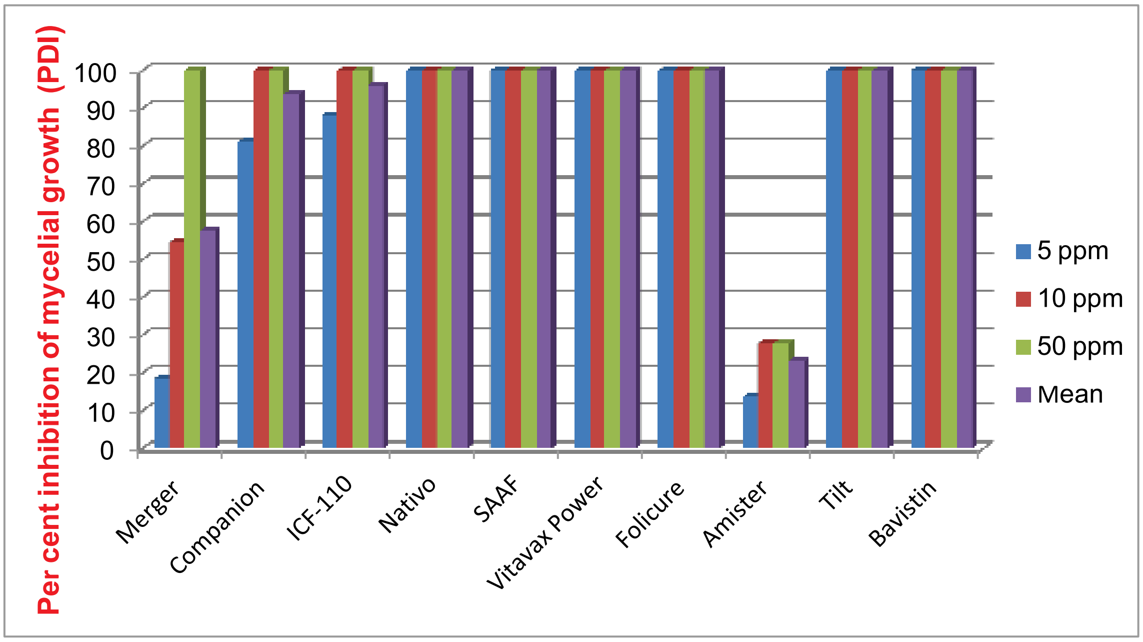


Fig. 3.52. Effect of different systemic and combination fungicides on the growth of *Fusarium fujikuroi in-vitro*

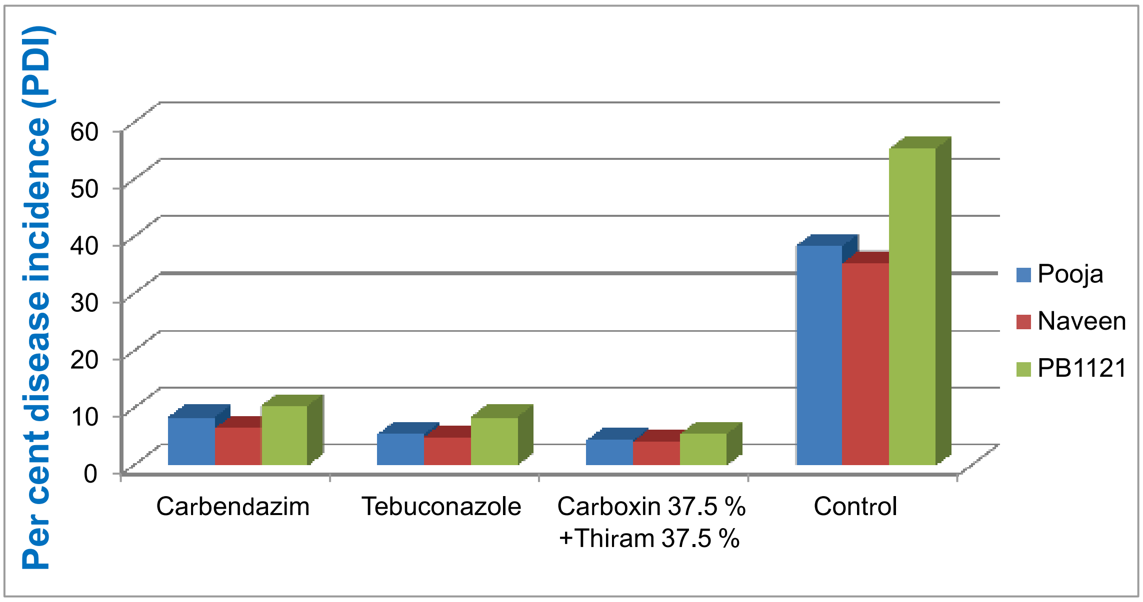


Fig. 3.53. Effect of Seed treatments with fungicides on the incidence of bakanae disease of rice

PROGRAMME : 4

Biochemistry and Physiology of Rice for Grain Quality, Abiotic Stress Tolerance and Improving Photosynthetic Efficiency

This research programme has three major thrust areas namely (i) rice grain and nutritional quality, (ii) abiotic stress physiology and enhancing photosynthetic efficiency with major objectives to study on low glycemic index (GI) rice, micronutrient (Fe/Zn) dense rice and high protein rice, to identify donors for different abiotic stress tolerance and understand physiological and molecular mechanism of stress tolerance and (iii) to enhance photosynthetic efficiency by introduction of C4 pathway and minimizing photorespiration. To accomplish these objectives, in the present study, under rice grain quality in relation to GI, mineral bioavailability and protein content, an improved and reproducible *in vitro* method for determination of Glycemic Index in rice was developed. Effect of differential N-dose on cooking and eating quality of contrasting varieties, estimation of GI, Resistant starch (RS) and Amylose content (AC) in rice genotypes from different ecologies/traits and the level of lipid peroxidation in brown rice at three months interval for ageing in rice grain were studied.

Under abiotic stress physiology, 192 genotypes with SES score "1" for drought tolerance, Annapurna and N-22 for high temperature tolerance having minimum yield reduction (19.3 to 21.5%), Pyari with highest grain yield of 3.93 t ha^{-1} followed by Panindra, Bihari Sali, Nalini Sali and Pabitra which were at par with the tolerant check Swarnaprabha as low light tolerant genotypes were identified. For salinity tolerance Pokkali was identified as a good Na^+ excluder, while Sabita, the salt sensitive genotype, showed poor Na^+ exclusion at root zone. Under submergence, FR 13A, Kalaputia & Swarna sub-1 had highest volume of air layer on both the leaf surfaces and removal of gas film by Triton X-100 treatment resulted in loss of quiescence ability and increased mortality in submergence tolerant genotypes. However, under anaerobic germination (AG), a robust gene regulatory mechanism involving key physiological processes like C-metabolism, N-metabolism and cellular redox handling under anaerobic condition were identified as key strategies for better AG potential in AC41620 compared to sensitive check Naveen.

For high photosynthetic efficiency, BAM 8296, BAM 247, BAM 8315 and CR 262-4 were observed to have both high crop growth rate (CGR) and panicle growth rate (PGR) indicating their better biomass partitioning efficiency leading to higher yield. For enhancing photosynthetic efficiency by introduction of C4 pathway and minimizing photorespiration, cloning & transformation of foxtail millet PPDK enzyme in rice, designing of constructs encoding *glycolate dehydrogenase* (*glc*) gene tagged with RuBisCO smaller subunit transit peptide for chloroplastic transformation and amplified glycolate catabolic enzymes encoded genes from *E. coli* and cloned into pGEMT-Easy vector was done.

Based on these results, grain quality in relation to glycemic index, mineral bioavailability, ageing and protein content in rice varieties, trait specific donors for different abiotic stresses, physiological adaptation and molecular mechanism of individual stress as well as intrinsic mechanism of multiple stress tolerance, expression analysis of important light regulated proteins in popular rice varieties, cloning and transformation of sorghum *Carbonic anhydrase* and foxtail millet PEPC enzyme in rice and designing of gene constructs tagged with RuBisCO were carried out.

Rice grain quality in relation to GI, mineral bioavailability and protein content

Variability of Glycemic index with Resistant starch in rice

Rice is generally considered a high glycemic index (GI) food. With diabetes rates increasing alarmingly in Asia, there is an urgent need to find methods of reducing the glycemic impact of rice. The resistant starch (RS) which normally comprises <3% of cooked rice escapes digestion and therefore, its calories are unavailable for use by cells. Rice contains type 5 RS, wherein amylose forms complex with lipids making it thermally more stable. The more the RS, the slower the digestion of rice and the lower is the GI, which is indicative of the ability of food to raise the blood sugar level.

In the present study, 102 rice genotypes of different ecologies possessing specialty traits, including high yielding varieties, high protein rice, pigmented rice, double haploid lines, scented rice, weedy rice and wild rice were tested to determine the GI, RS and amylose content (AC) in brown rice. GI was derived from Hydrolysis index (HI).

Large variation in the value of GI (57.91-75.91), RS (0.43-2.72%) and AC (04.08-26.54%) was observed. Among the genotypes studied, PB177 showed lowest GI (57.91) and high RS (1.97%). The highest value for GI (75.91) was found for *O. ridleyi* with relatively low RS (0.43%) (Fig. 4.1). The data indicate that there was no direct relationship between GI and AC or GI and RS content in all rice genotypes. The only unambiguous conclusion from the study was that, where ever the RS was more than 1%, the GI value was less than or equal to 61. Therefore, screening the available germplasm for high RS (>1%) may be one approach to identify a low GI rice. These findings emphasize upon the need to identify and develop rice genotypes with high RS, amylose and low GI which may be suitable for consumption by people suffering from diabetes, obesity and colon diseases.

Determining the age of stored rice grains in terms of biochemical parameters

Ageing of rice is one of the important steps in post-harvest processing of paddy. During storage, rice undergoes numerous changes in physicochemical properties that can be identified after three months of storage. Although the mechanism of rice ageing is not fully understood, study on the biochemical changes during storage is important in the evaluation of cooking and eating quality. In the present study, Malondialdehyde (MDA) estimation which is considered to be an indicator of membrane lipid peroxidation for determining storage periods was done in 15 different rice varieties grouped in three classes as mentioned in Table 4.1.

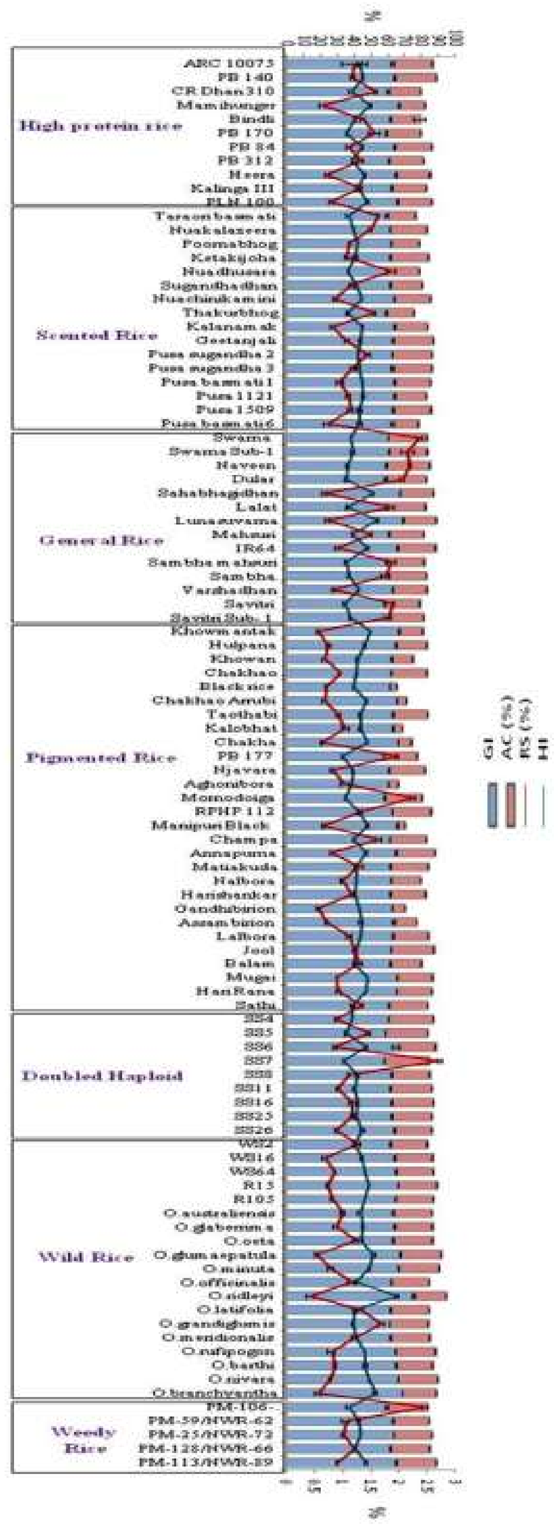


Fig. 4.1. GI, RS and AC values of different rice genotypes (High protein, Scented, general rice, Pigmented, DH, Wild and Weedy rice). Values are expressed as mean of triplicate determination ±standard deviation.

Table 4.1. Rice varieties used for Malondialdehyde (MDA) estimation

Colored	Other	Scented
1. Chakhao	1. Sahbhagidhan	1. Taraori basmati
2. Kalabiroin	2. Kalinga 3	2. Sugandha Dhan
3. Kalabhat	3. Bindli	3. Ketekijoha
4. Manipuri black	4. Lalat	
5. Mamihunger	5. CR Dhan 310	
6. Annapurna	6. IR64	

The Malondialdehyde estimation was done in brown rice in all the fifteen varieties (Fig. 4.2, 4.3 and 4.4) at every three months interval for nine months.

Among the colored varieties, Kalabiroin shows the minimum synthesis of MDA (0.889 µM g^{-1}) where as Annapurna produces maximum amount of MDA (1.142 µM g^{-1}) after 3 months of ageing. MDA content was found to be almost doubled in all the colored varieties after nine months of ageing, the value being minimum in Manipuri black (1.638 µM g^{-1}) and maximum in Chakhao (1.775 µM g^{-1}).

Among the non-colored and non-scented varieties higher level of MDA was estimated as compared to colored varieties after three months as well as nine months of ageing. The MDA values ranges from 1.356 (Sahbhagidhan) to 1.633 µM g^{-1} (Lalat) in three months old rice. More than two fold increase was observed in MDA content after nine months of ageing in all the non colored varieties. Like three months old rice Sahbhagidhan showed minimum accumulation of MDA (2.437 µM g^{-1}) where as IR64 showed maximum (2.794 µM g^{-1}) accumulation of MDA after nine months of ageing.

Non-colored and scented rice varieties showed similar pattern like non-colored non-scented varieties where MDA content varied from 1.282 µM g^{-1} in Taraori basmati to 1.44 µM g^{-1} in Ketekijoha. After nine months of ageing, the MDA content was found to be maximum in Taraori basmati (2.461 µM g^{-1}) and minimum in Sugandha dhan (2.289 µM g^{-1}). As compared to colored varieties higher level (2 fold) of MDA generation was observed in both scented and non scented, non colored varieties. This could be due to the presence of more amount of antioxidant in colored varieties which inhibit the lipid peroxidation and hence leads to less generation of MDA.

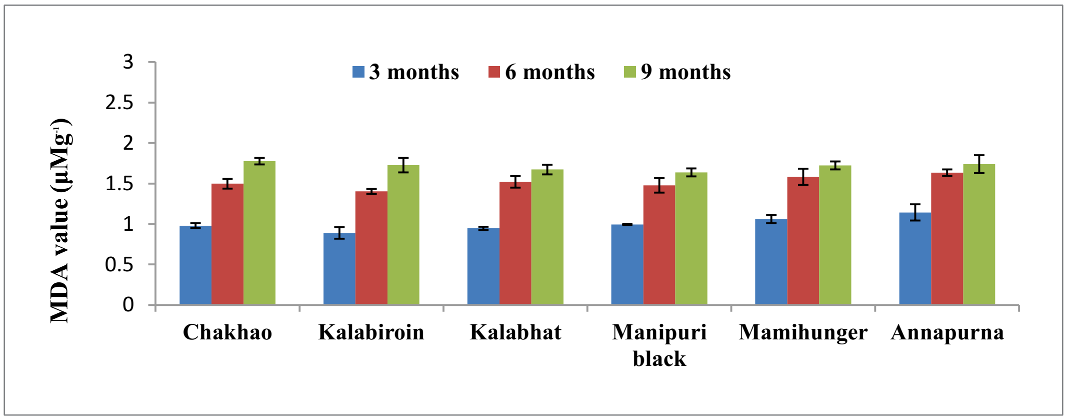


Fig. 4.2. Level of Malondialdehyde in colored varieties for 3, 6 and 9 months aged rice grains

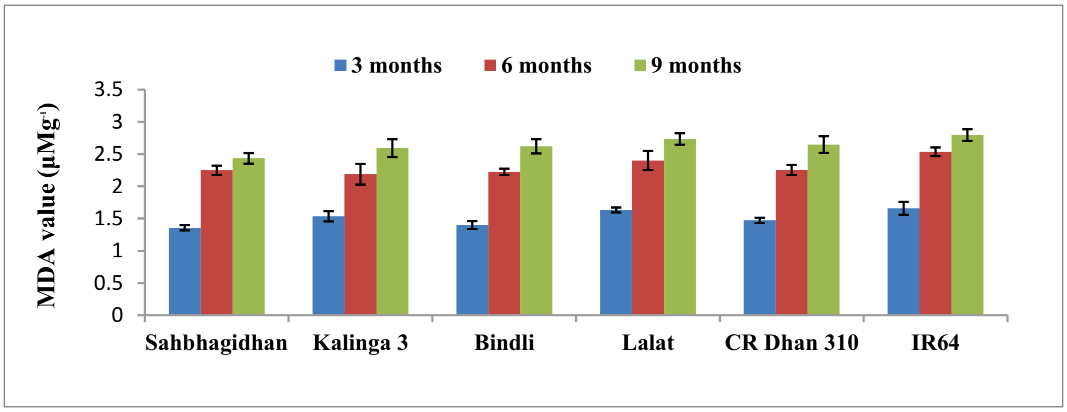


Fig. 4.3. Level of Malondialdehyde in non-colored and non-scented varieties for 3, 6 and 9 months aged rice grains

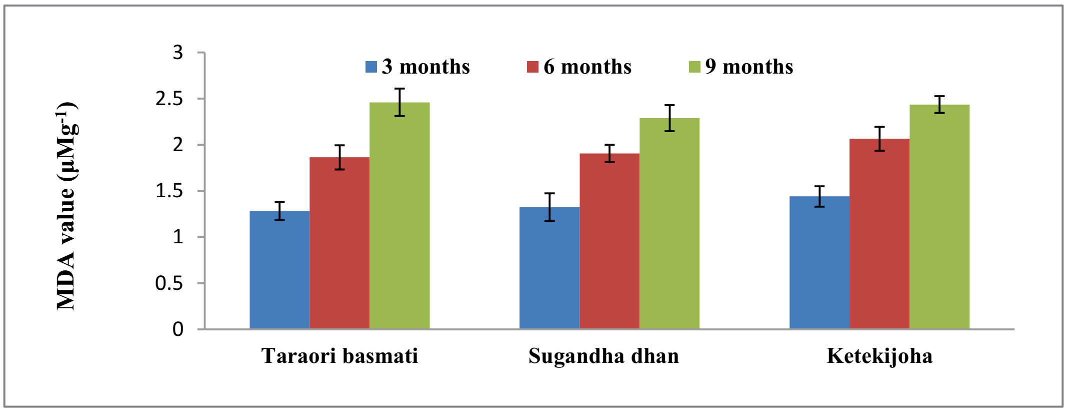


Fig. 4.4 Level of Malondialdehyde in other non-colored scented varieties for 3, 6 and 9 months aged rice grains

Study on the effect of differential N-dose on cooking quality of contrasting varieties

Three rice varieties showing contrasting grain protein content (Heera- high protein variety, CR Dhan 310- high protein variety released by ICAR-NRRI, Naveen- low protein variety) have been selected and subjected to three different doses of nitrogen fertilization (T_1: N:P:K @ 50:50:50; T_2: N:P:K @ 100:50:50; T_3: N:P:K @ 150:50:50). The data suggest that quality parameters particularly HRR% and water uptake (WU) vary significantly on varying N-application dose (Table 4.2).

A Rapid Method to distinguish between low and high protein rice grains

ICAR-NRRI recently developed a high protein (10.3%) rice CR Dhan-310 in the background of the rice Naveen. As protein content is not a phenotypic trait, it is desirable to suggest a simple and rapid method to differentiate between the parent Naveen (7.5% protein) and its high protein version CR Dhan 310 and CR Dhan 311 (another high protein rice, 10.2% protein). It was found that the xanthoproteic test, which is the qualitative test used for confirming the presence of protein in a sample could easily distinguish among the three varieties. The procedure involves change in colour intensity finally from yellow to orange, the high protein rice samples exhibiting a more intense orange color than its low counterpart Naveen. The photograph depicts the colors developed in brown rice samples of Naveen, CR Dhan 310 and CR Dhan 311. Thus the high protein rice varieties can be easily distinguished from the low protein rice with the help of the xanthoproteic test as the former gives more intense yellow / orange color than the latter (Fig. 4.5).

Table 4.2: Quality analysis of rice varieties under differential N_2 doses

Name of Variety / Treatment	Hulling (%)	Milling (%)	Head Rice Recovery (%)	Moisture content (%)	Kernel Length (mm)	Kernel Breadth (mm)	Length/ Breadth Ratio	Alkali Spreading Value	Water Uptake (ml/ 100g)	Volume Expansion Ratio	Kernel Length After Cooking (mm)	Elongation Ratio	Amylose Content (%)	Gel Consistency
HEERA T_1	74.0	62.0	40.0	12.2	6.47	2.12	3.05	3	65	3.75	10.0	1.54	26.92	39
HEERA T_2	75.5	65.0	42.0	12.5	6.25	2.06	3.03	3	80	3.75	10.0	1.60	27.60	37
HEERA T_3	74.5	67.0	45.5	12.5	6.43	2.42	2.65	3	80	3.75	10.0	1.55	27.60	40
CR DHAN 310 T_1	76.0	66.0	60.0	13.4	5.44	2.18	2.49	3	70	3.75	10.0	1.83	24.60	42
CR DHAN 310 T_2	76.5	66.5	62.5	13.5	5.45	2.04	2.67	3	90	3.75	10.0	1.83	25.27	45
CR DHAN 310 T_3	77.0	66.0	61.0	13.4	5.49	2.22	2.47	3	105	3.75	10.0	1.82	26.47	41
NAVEEN T_1	76.0	61.0	58.0	13.7	5.32	1.87	2.84	3	95	4.00	10.0	1.87	24.07	47
NAVEEN T_2	77.0	64.0	60	13.4	5.20	1.90	2.73	3	105	3.75	10.0	1.92	24.75	49
NAVEEN T_3	77.5	65.0	61.0	13.3	5.17	1.92	2.69	3	115	3.75	10.0	1.93	24.90	51

T_1= N:P:K @ 50: 50: 50 T_2= N:P:K @ 100 : 50 : 50 T_3= N:P:K @ 150 : 50 : 50

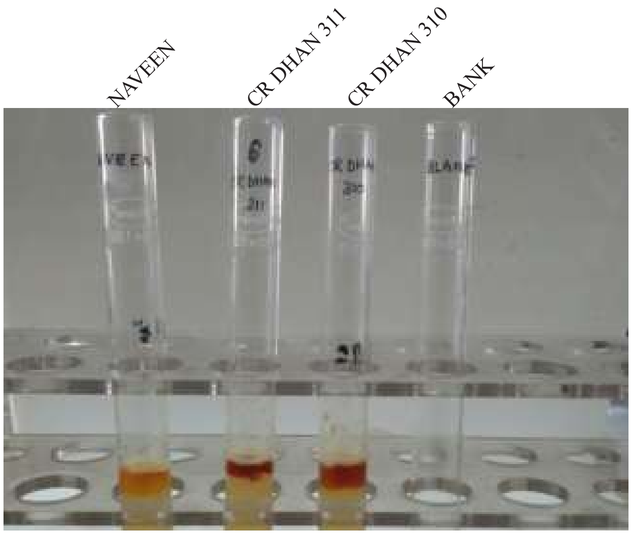


Fig. 4. 5. A Rapid Method to distinguish between low and high protein rice grains

Physiology of rice for individual and multiple abiotic stress tolerance

Screening and evaluation of ARC (Assam Rice Collection) accessions and released high yielding varieties for vegetative stage drought tolerance

Screening of 507 ARC germplasm lines and 599 released high yielding rice varieties was done for vegetative stage drought tolerance under field condition during dry season 2017. Twenty eight days old seedlings were exposed to moisture stress and during the period of stress, soil moisture content was 9.44 to 12.62%, soil metric potential was -35 to -48kPa at 30cm soil depth and water table depth was below 75cm (Fig. 4.6). Out of 1106 genotypes, 192 genotypes were observed to be tolerant with SES score "1", 467 & 225 were moderately tolerant (SES '3' and '5'), 213 were susceptible (SES '7') and 09 ARC lines were found to be highly susceptible (SES '9') (Fig. 4.7).

Selective genotyping of mapping population for identification of linked markers for vegetative drought stress tolerance in rice

RILs population for 350 F7 lines of IR20 x Mahulata was developed. Polymorphic survey was carried out among IR 20 and Mahulata using 1010 STMS markers. 109 (10.7%) STMS markers were informative. Based on phenotypic score, ten extreme RILs (10 each of tolerance and susceptible) were selected. RM3473 was identified as a putative linked marker based on selective genotyping.

Effect of high temperature on grain yield and yield traits

Under 4 staggered sowings (S_1, S_2, S_3 and S_4) in 10 days interval during dry season 2017, with maximum temperature ranging from 34.5°C to 37.0°C and minimum temp from 25.0°C to 27.0°C during anthesis period, grain yield reduced by 11.1, 21.8 and 32.9 % under S_2, S_3 and S_4. Grain yield was recorded high in Lalat under both S_1 and S_2 (> 6.0 t ha^{-1}) while it reduced by 25 to 33 % under S_3 and S_4. Naveen and Shatabdi showed maximum reduction in grain yield (> 42.0%). Annapurna and N-22 showed minimum reduction in grain yield (19.3 to 21.5%) followed by IR 72 (25%) with range of 3.75 – 4.38 t ha^{-1} indicating their tolerance to high temperature stress (Fig.4.8).

Understanding the role of leaf gas film in submergence tolerance

Submergence substantially decreases the rate of gas diffusion, limiting oxygen uptake and compelling carbon inefficient anaerobic metabolism. Super hydrophobic, self-cleansing leaf surfaces of cereals is known to retain a thin gas film when immersed in water. Among the cultivated cereal crops, rice has the highest thickness of leaf gas film in its adaxial and

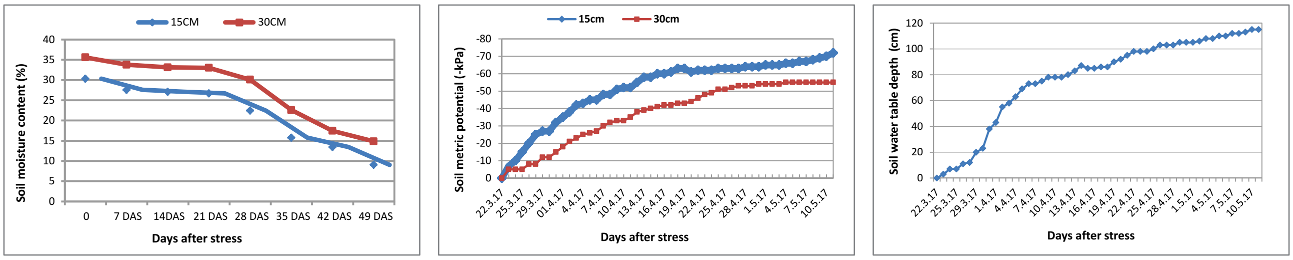


Fig. 4.6. Soil moisture content (%), soil metric potential (-kPa) and soil water table depth (cm) recorded under moisture stress period

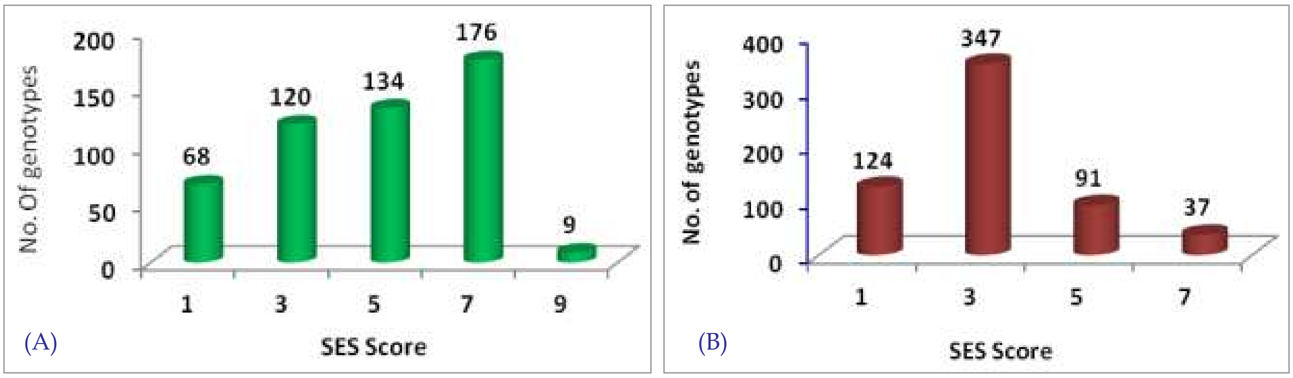


Fig. 4.7. Performance of ARC accessions (A) and High yielding rice varieties (B) under vegetative stage drought based on drought reaction score

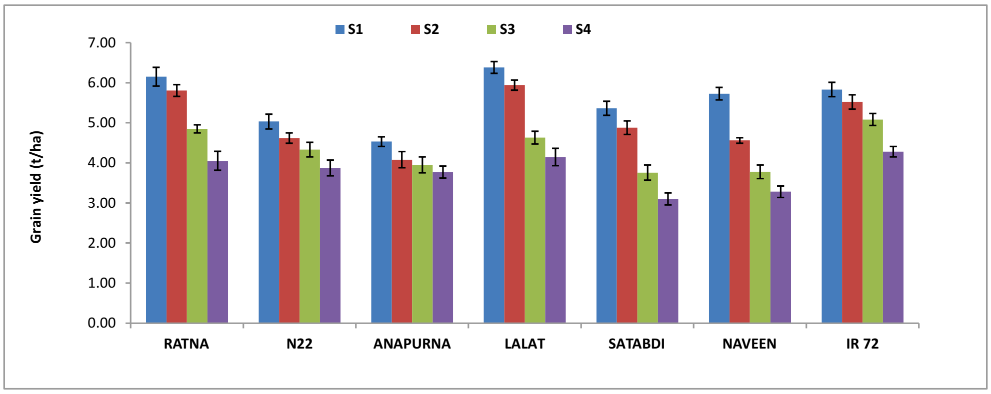


Fig. 4. 8. Effect of high temperature on grain yield (S1- 1st sowing, S2- 2nd sowing, S3= 3rd sowing, S4= 4th sowing)

abaxial leaf surfaces. Interestingly, among these cereals, rice possesses highest level of tolerance to partial and complete submergence. Hence, the impact of presence and absence of leaf gas film on submergence tolerance was studied in 10 rice genotypes. Among the studied genotypes, FR13A possessed the highest thickness of leaf gas film in both adaxial and abaxial (32.8 and 31.1 µm, respectively) leaf surfaces (Fig. 4.9), followed by Kalaputia (31.5 and 24.7 µm, respectively), whereas the genotype IC450292 was found to have least leaf gas film thickness (9.8 and 6.1 31.1 µm, respectively) under control condition.

Removal of this leaf gas film by application of Triton X-100 (0.1%) resulted in loss of submergence tolerance to some extent in most of the genotypes. The survival percentage of FR13A dropped from 94% in submergence with intact leaf gas film to ~80% in case of submergence without leaf gas film. The extent of reduction was even greater in the genotype IC450292, which was having least volume of air layer in its leaf surfaces. Similarly, significant increase in elongation ability was also observed with removal of leaf gas film. More than 2.5-fold increase in elongation ability was observed in both the tolerant cultivars FR13A and Swarna sub-1 (Fig. 4.10).

Studies on role of Na^+- and K^+-transporters in reproductive stage salt tolerance

Rice is sensitive to salinity (>4 dS m^{-1}) at both seedling and reproductive stages and the mechanism of tolerance is thought to vary considerably at each stage, probably with different set of genes governing the tolerance level. It was reported that the *Saltol* QTL contributes ~43 % of variation in shoot Na^+/K^+ ratio at seedling stage, but don't act as efficiently at reproductive stage. Pot experiment with 4 differentially sensitive rice genotypes showed Pokkali, a good Na^+ excluder at root zone is also

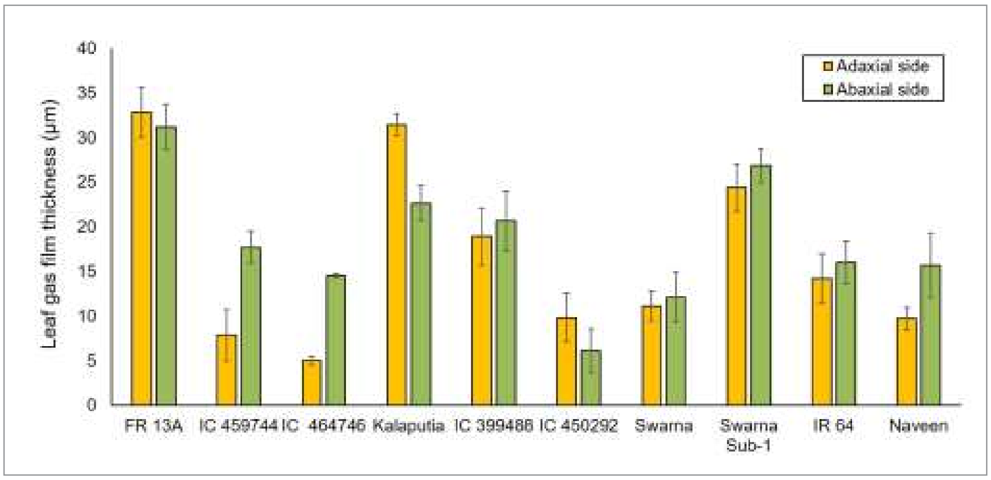


Fig. 4. 9. Variation in leaf gas film thickness in adaxial and abaxial leaf surfaces of rice genotypes

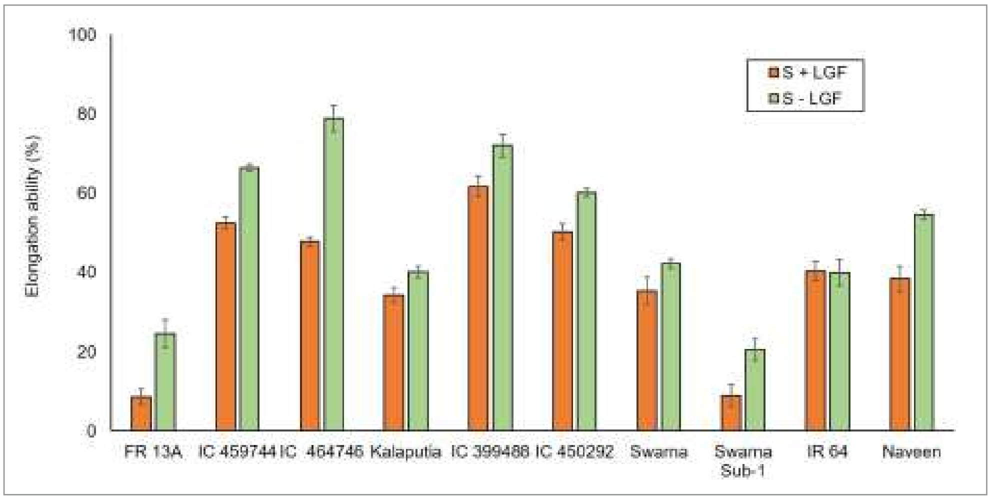


Fig. 4.10. Effect of presence and absence of leaf gas film in elongation ability of rice under submergence stress

having the capacity to sequester excess Na^+ in mesophyll tissue through the action of NHX1. Besides, it regulates Na^+ movement in different plant tissue by controlling the xylem loading of Na^+. Lunidhan & Chettivirippu, both were moderately tolerant but had different ion balancing strategies. Sabita, the salt sensitive genotype, showed poor Na^+-exclusion at root zone along with inefficient selective transport of Na^+ into the upper leaf tissue, but possessed better Na^+ partitioning in flag leaf (Fig. 4.11 and Fig. 4.12).

Differential response of rice genotypes to Germination Stage Oxygen Deficiency (GSOD) Stress

Stagnation of water during the germination process imposes Germination Stage Oxygen Deficiency (GSOD) in rice. Present study was performed to understand differential responses of two rice cultivars, Naveen and AC41620 (already identified as sensitive and tolerant to GSOD, respectively) subjecting them to continuous submergence during germination. Biochemical changes related to carbohydrate metabolism (Fig. 4.13), anaerobic respiration and oxidative stress tolerance were more significant in AC41620, than Naveen. The time-course enzyme assays suggested greater activities of α-amylase, pyruvate decarboxylase and alcohol dehydrogenase, while gene expression data confirmed the upregulation of respective transcripts under continuous submergence in AC41620.

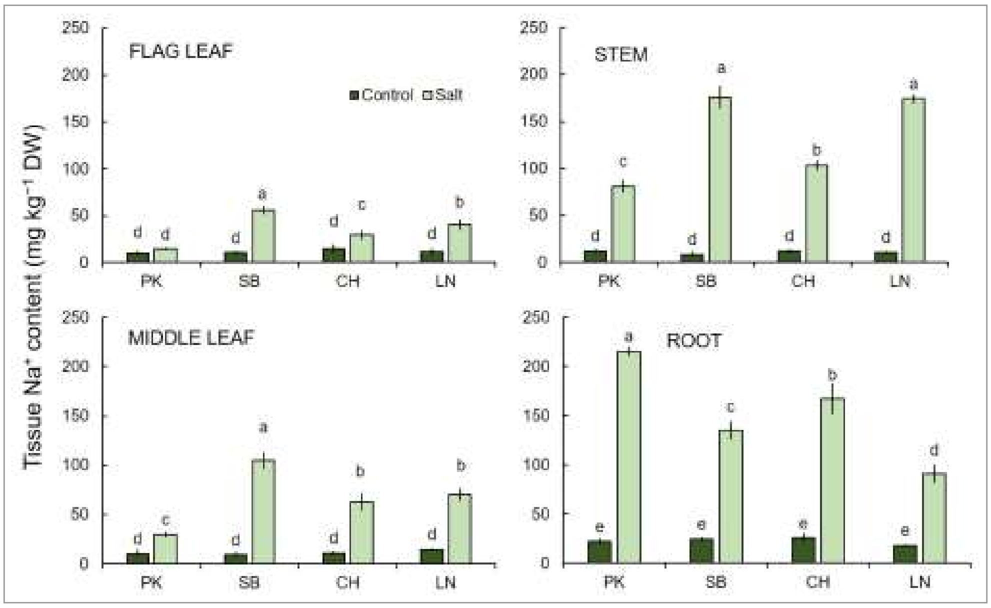


Fig. 4.11. Tissue transport of Na+ in different rice genotypes subjected to reproductive stage salt stress

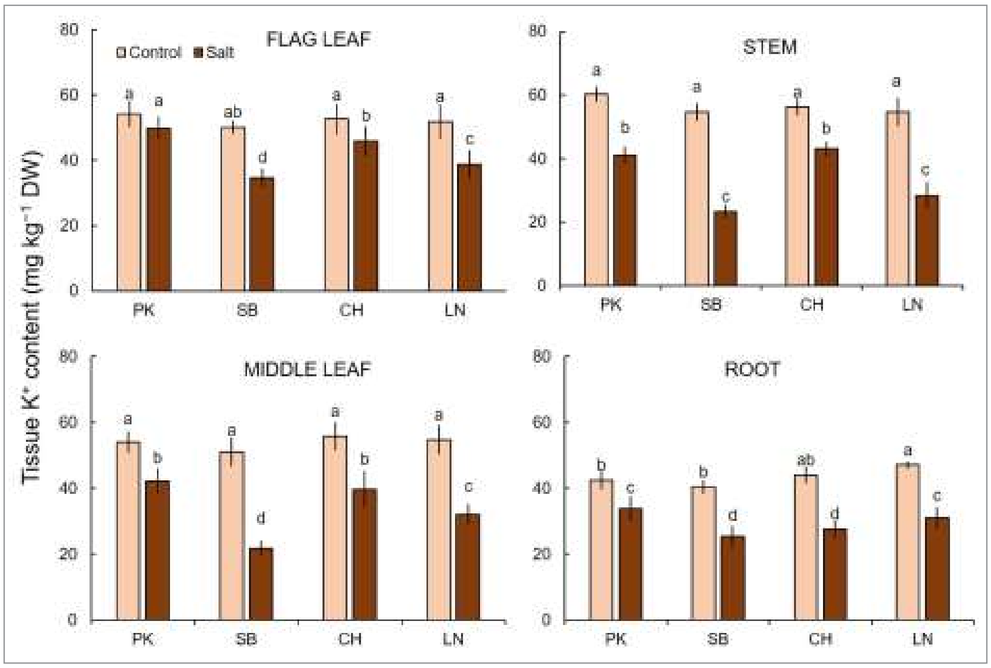


Fig. 4.12. Tissue transport of K+ in different rice genotypes subjected to reproductive stage salt stress

AICRIP Trials: Following three All India Coordinated Trials were conducted in wet season 2017.

1. Influence of silicon solubilizers on induced stress tolerance in rice genotypes :

Silicon solubilizer - Silixol has positive effect on grain yield and also mitigate the effect of moisture stress. PA 6129 followed by KRH 2 performed better under drought and drought with silixol treatment indicating their tolerance to both the treatments. Under silixol spray at tillering, PI, 50% flowering and milky grain stages, KRH 4 recorded highest yield (6.67 t ha^{-1}) followed by PHB 71 (6.22 t ha^{-1}), while under moisture stress and moisture stress with silixol, PA 6129 had highest grain yield of 3.61 and 4.79 t ha^{-1} respectively

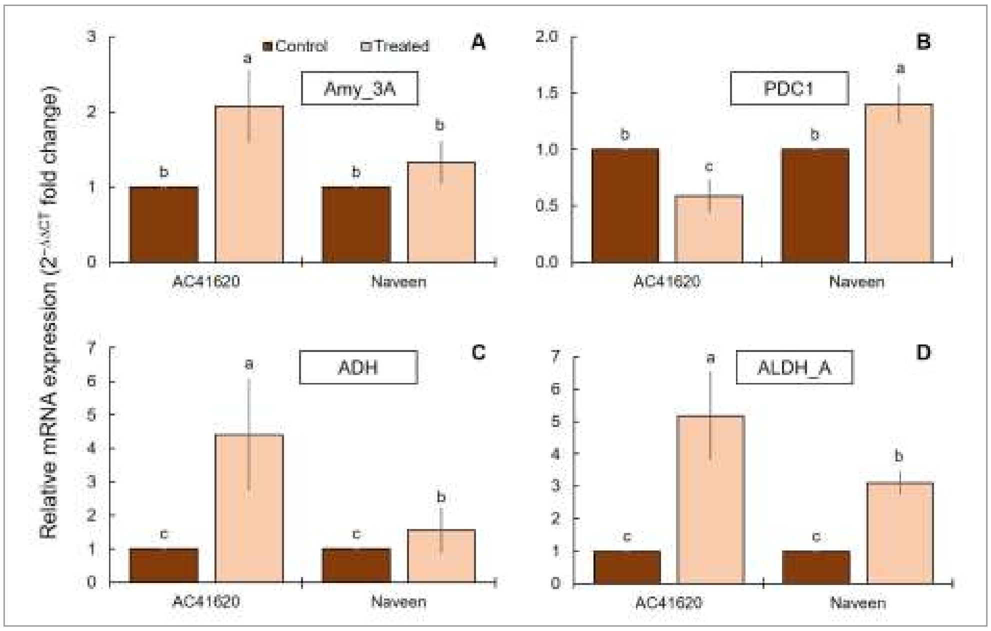


Fig. 4.13. Differential expression of C-metabolizing enzymes in AC41620 and Naveen subjected to 48 h of continuous submergence during germination stage

followed by KRH 2 indicating their tolereance to drought as well as response to silixol application as mitigation option for induced drought stress tolerance.

2. Screening of rice varieties for tolerance to low-light stress

Twenty one entries were tested for low light (LL) stress tolerance and 50% normal light (NL) was induced to 45 days old seedling. Out of 21 entries tested, under NL condition, highest grain yield was observed in LLS 2506 (6.51 t ha^{-1}) followed by LLS 2514 (6.47 t ha^{-1}) and LLS 2502 (6.43 t ha^{-1}), while under low light condition, highest grain yield was observed in LLS 2519 (4.49 t ha^{-1}) followed by LLS 2508 (4.22 t ha^{-1}) and LLS 2510 (4.11 t ha^{-1}). In general, grain yield was reduced by 50.15% under low light condition and lowest yield reduction was observed in LLS 2511 (24.96%), LLS 2519 (27.16%) and LLS 2508 (30.98%). LLS 2519 and LLS 2508 are identified as lowlight tolerant with higher grain yield (4.0 t ha^{-1}) and lower yield reduction 24 - 31%.

3. Physiological characterization of selected genotypes for multiple abiotic stress tolerance

Nineteen entries were tested for multiple abiotic stress tolerance grown in solution culture separately for each salinity, anaerobic germination, drought and low temperature stress to identify any culture tolerant to more than one stress. Under saline condition (200 mM NaCl), MAS 306 and MAS 309 (2 entries) showed 14.2% survival after 7 days of NaCl treatment, under anaerobic condition, MAS 301, MAS 302, MAS 303, MAS 305, MAS 309, MAS 310, MAS 313, MAS 317 and MAS 318 (8 entries) showed more than 60% germination after 25 days of treatments, under water stress (1% and 2% mannitol) MAS 301, MAS 304, MAS 306, MAS 309, MAS 302 and MAS 303 (6 entries) had SES score '1' and '3' and none of the genotypes survived under low temperature (8°C) after 10 days of treatment. From this experiment it could be inferred that 4 entries MAS 301, MAS 302 and MAS 303 and MAS 309 are tolerant to both anaerobic germination and drought, two entries MAS 306 and MAS 309 are tolerant to both salinity and drought and only one entry MAS 309 was tolerant to salinity, drought and anaerobic germination.

Improvement of Photosynthetic efficiency of rice

Identification and characterization of rice genotypes for high photosynthesis and biomass production

Seventy five rice germplasm lines were evaluated based on leaf traits, biomass accumulation and partitioning during grain filling. Specific leaf weight (SLW) varied in the range of 200-500 mg dm^{-2} and nine entries (BAM 491, Abhishek, Gotrabi, MTU 1010, BAM 4168, Ganga, NERICA L-42, Dular, IR 83388-B-108-3) had higher values of 450-500 mg dm^{-2}, while three entries (BAM 8305, IR 87707-446-B-B and Moroberekan) had lowest values (200-300 mg dm^{-2}). Maximum no. of entries was in the range of 350-400 mg dm^{-2}. Some entries BAM 328, Abhishek, CR 262-4 and Ganga consistently had higher values of specific leaf weight (> 450 mg dm^{-2}) at all the growth stages (Fig. 4.14).

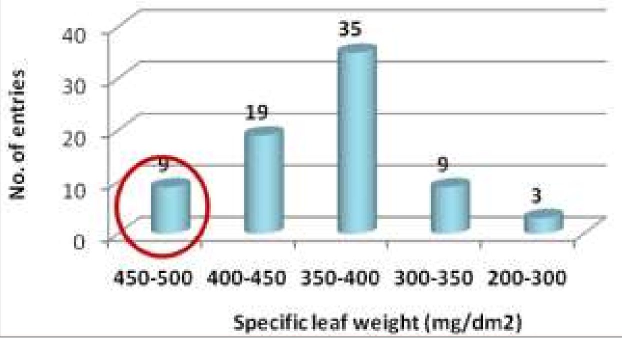


Fig. 4.14: Variation in Specific leaf weight among the entries

In general, total biomass increased from stage I (30 days after transplanting) to stage IV (maturity) in a linear fashion. Crop growth rate (CGR) increased during initial stages and decreased during grain filling stage. However, maximum rate was observed during milk white stage (CGR 2). Four entries had crop growth rate > 8.0 g day^{-1} and 5 entries had 7.0-8.0 g day^{-1}. Maximum entries were in the range of 3.0- 4.0 g day^{-1}. High crop growth rate (>7.0 g day^{-1}) was recorded in BAM 8296, BAM 4797, BAM 247, BAM 4009, BAM 8315, BAM 326, BAM 328, Abhishek, CR 262-4, while low crop growth rate (<1.0 g day^{-1}) was recorded in BAM 4510, Bakal, BAM 6924, Moroberekan, BAM 3154, BAM 1057, BAM 1689. BAM 8296, BAM 247, BAM 8315 and CR 262-4 commonly have both high crop growth rate and panicle growth rate indicating the better biomass partitioning efficiency leading to higher yield. BAM 1689 commonly had low crop growth rate and panicle growth rate. However, entries BAM 6921, BAM 4797, BAM 4009, Nagina 22, BAM 4234, BAM 328, Abhishek, CR 262-4, Ganga had higher SLW at either of the stages, which also had high crop growth rate and panicle growth rate values indicating the possibility of higher photosynthesis in these entries as SLW and Photosynthetic rate are positively related.

Cloning and transformation of foxtail millet Pyruvate, Phosphate Dikinase-PPDK (SiPPDK) enzyme in rice: RT-PCR amplification and cloning of *SiPPDK* gene

The full length *SiPPDK* gene was amplified from C-DNA of *Setaria italica* by using gene specific forward and reverse primers. The gene was amplified using NEB Q5 high fidelity taq polymerase. The purified PCR product was cloned in the pBS-SK+ vector and sub cloned in pCAMBIA-1301 at the downstream of *ZmPPDK* green tissue specific promoter and upstream of *nos* terminator (Fig. 4. 15).

Generation of Transgenic rice plant expressing SiPPDK photosynthetic gene

In order to produce transgenic rice (Naveen) plants expressing *SiPPDK* gene construct in the pCAMBIA-1301 binary vector, the embryogenic calli were infected with agro containing gene construct and grown on Co-cultivation media (CCM) and transformed calli were transferred to the selection media (SM) containing hygromycin for selection. The embryogenic calli were tested for gus histochemical staining and found positively stained. Selected calli were transferred to regeneration media for caulogenesis (Shoot development) and subsequently transferred to rooting media for root development (Fig. 4.16).

Screening of transgenic plants

The transgenic plants carrying *SiPPDK* gene were obtained by infecting embryogenic calli with a mixture of the transformation cassette along with the selectable marker genes *hygromycin phosphotransferase* (*hpt*) and *β-glucuronidase* (*gus*). Twenty-five putative transgenic plants were obtained from the transformation experiments. Primary screening of positive plants was performed by using the *gus and hpt.* Clear amplified PCR bands were observed in the lane corresponding to transgenic plants where as non-transgenic control plants did not show any band at specific position (Fig. 4.17).

Expression analysis of *SiPPDK* gene in transgenic plants

Over expression of *SiPPDK* genes in transgenic plants was analyzed by real time PCR using gene specific primers. *SiPPDK* gene was expressed in three different plants obtained from genetic transformation.

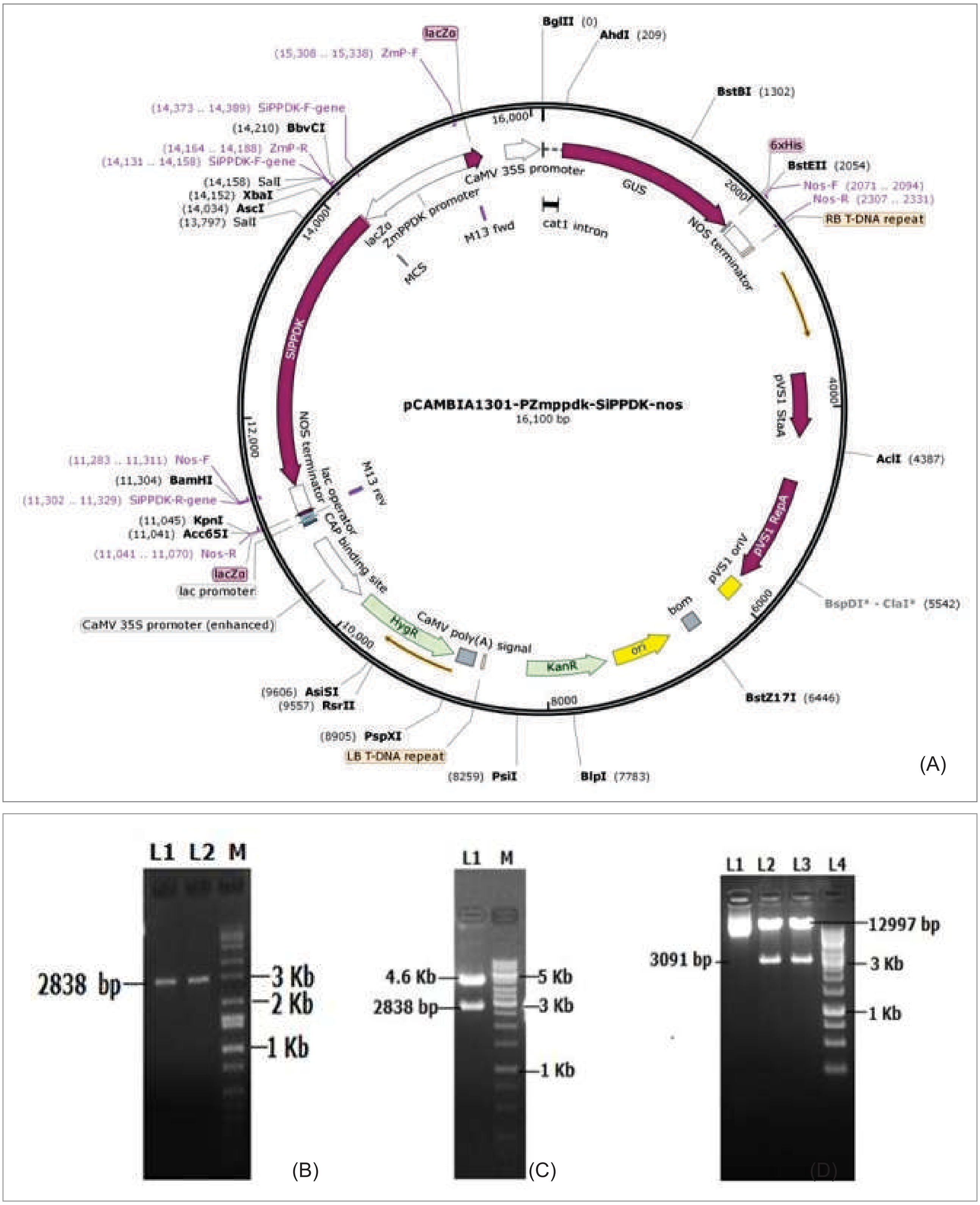


Fig. 4.15 A : Vector map of the construct pCAMBIA1301-P_{ZmPPDK}-$_{SiPPDK}$G-$_{nos}$ B- L1, L2- *SiPPDK* gene amplified from cDNA. M- 1 Kb DNA ladder. C- digestion of cloned *SiPPDK* gene in the pBS-SK+ vector downstream the promoter fragment. D- Digestion of pCAMBIA1301-P_{ZmPPDK}-*SiPPDK-nos* gene with *BamHI* and *KpnI* to release gene along with terminator fragment. L1- Uncut plasmid, L2 and L3 digested product and L4 - 1 Kb DNA ladder.

All transgenic plants showed variable fold induction of the mRNA level as compared to the control and pCAMBIA empty vector control plant (Fig. 4.18).

Physiological response of the transgenic plants

The net photosynthetic rate (*A*) under a controlled environment condition was found to exhibit 29.8% higher in the transgenic plants as compared to the non-transgenic and empty vector control plants. PS II photochemical quenching (*Fv/Fm*) declined in transgenic plants as compared to non-transgenic and empty vector control plants (Fig. 4.19).

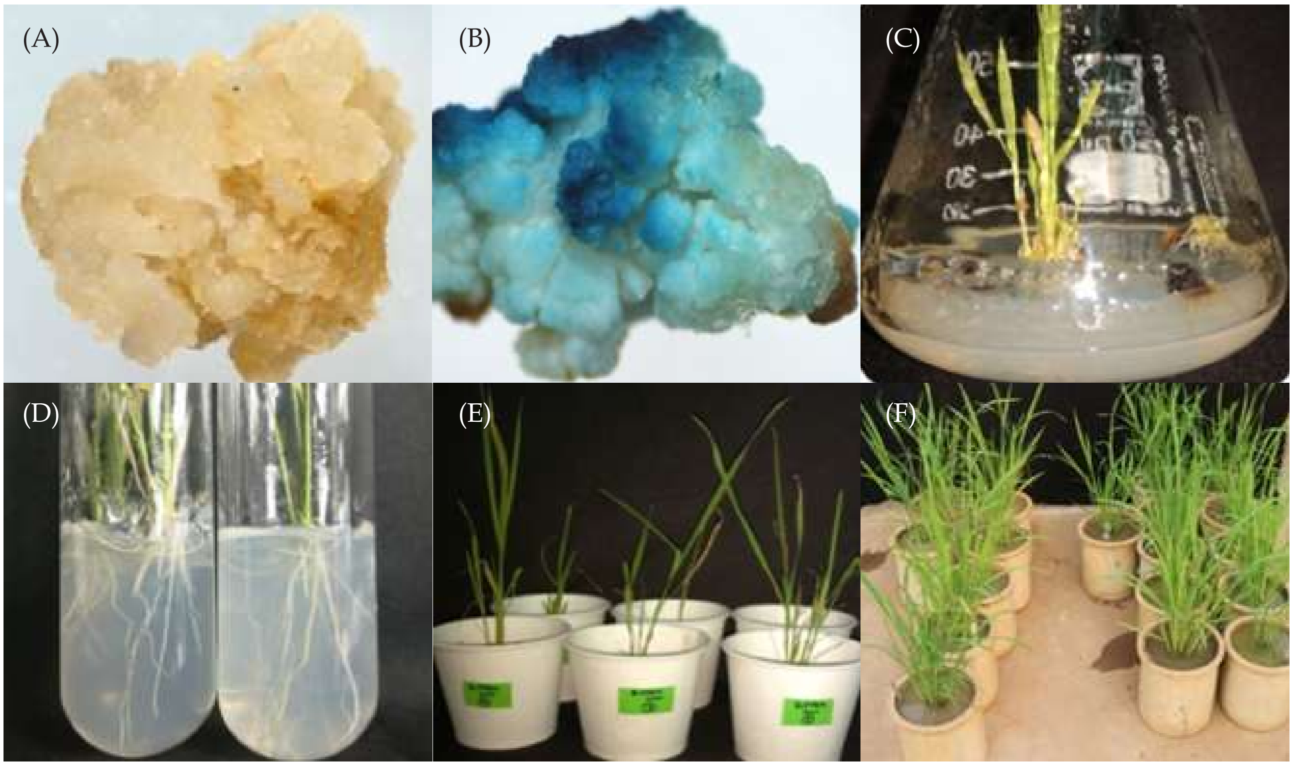


Fig . 4.16: Genetic transformation of rice with pCAMBIA-1301- Zm*PPDK*P-*SiPPDK* g-*Nos* Construct: [A] control calli after GUS histochemical staining [B] Positive GUS staining of transformed calli. [C] Regenerated plantlet in the regeneration media.[D] Rooting of the plantlets.[E] Rooted plantlets transferred to the soilrite.[F] Putative transgenic plant grown in pot.

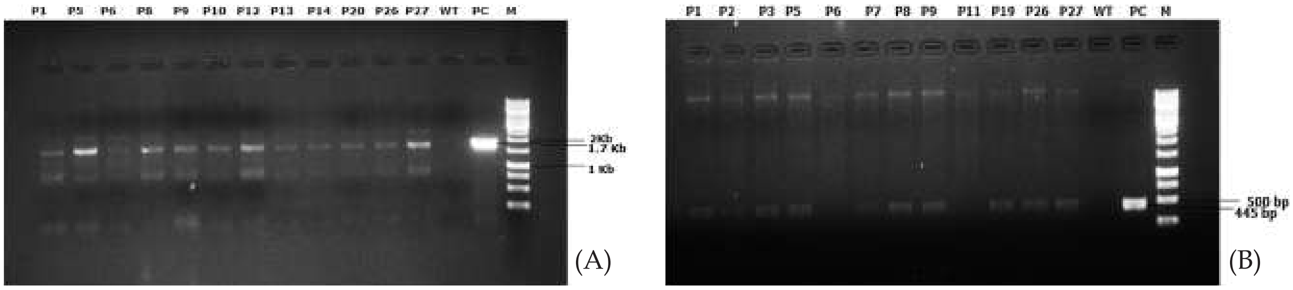


Fig. 4.17: PCR amplification of putative transgenic plants: [A] PCR amplification of putative transgenic plant for *gus* gene. **[B]** PCR amplification of putative transgenic plant for *hpt* gene.

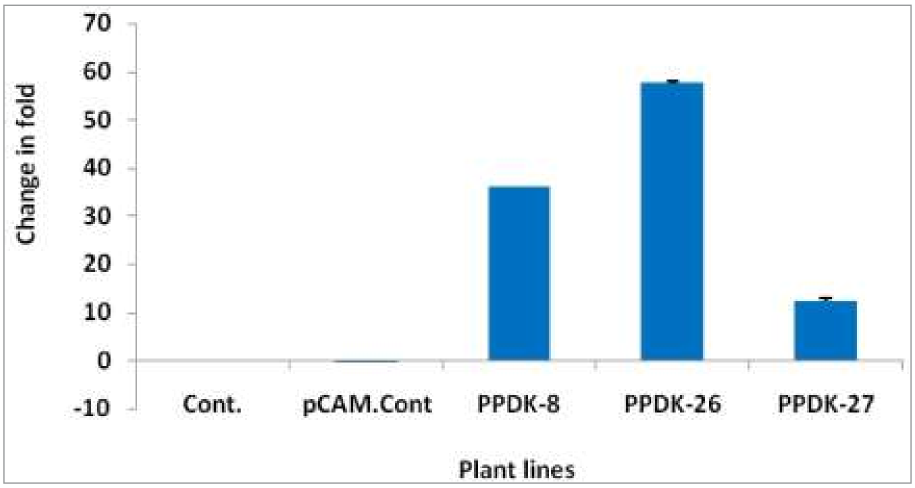


Fig. 4.18 : Normalised transcript level of *SiPPDK* overexpressing transgenic plant lines (PPDK-8, PPDK-26 and PPDK-27) and wild type control plant (Cont.) and empty vector control plant (pCAM.Cont) as determined by quantitative real time polymerase chain reaction (qRT PCR). Result are the ± SE of three independent biological replicates.

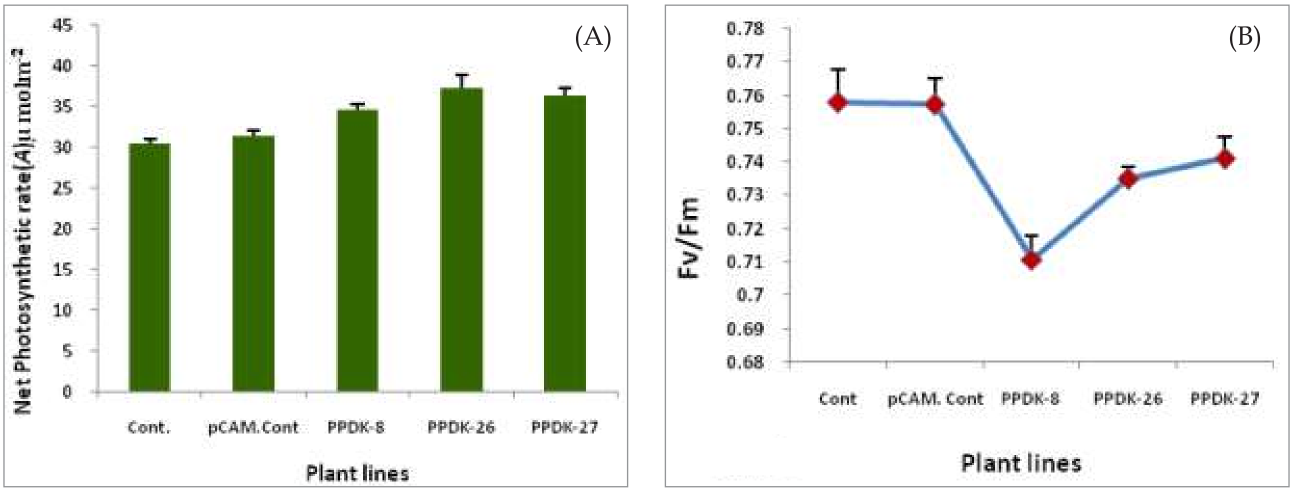


Fig. 4.19: Variation in net photosynthetic rate (A) and chlorophyll fluorescence among the transgenic plant lines and control plants in the vegetative stage. (A) Represents the net photosynthetic rate at the vegetative state. (B) represents the Fv/Fm among the plant lines.

PROGRAMME : 5

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

The technology generation research cycle is completed only when it is aided by sound socio-economic research for its effective dissemination. Accordingly, programme 5 aims to develop extension approaches, methodologies and models that would take into consideration factors affecting dissemination of the technology in the farming community. In line with the objective of the programme, two-factor RBD experiments comparing NRRI variety and the most popular variety of the state were undertaken in four eastern Indian states namely, Odisha, Jharkhand, West Bengal and Assam during *kharif* 2017. The results were encouraging with maximum yield gain advantage of 30.76 per cent, whereas out of 23 NRRI varieties, 20 varieties outperformed popular varieties by a margin of more than five per cent grain yield advantage. Under the activity, testing and validating the 'Self-sufficient Sustainable Seed System for Rice' (4S4R) model of NRRI, three Farmer Producer Companies (FPC) situated at Mahanga, Niali and Athagarh were registered under Company Act 2013. Under FPC of Mahanga, 134 quintals of foundation seed was produced and certified which has been given to all five FPCs for further multiplication to certified seed. Besides, decade wise compound growth rate of area, yield and production of rice calculated for four Southern Indian states (Kerala, Tamil Nadu, Andhra Pradesh and Karnataka) revealed negative growth of area for most of the periods. Detailed cost of cultivation data of rice for 18 states of India has been updated up to the year 2014-15 and growth rate was calculated with respect to various indicators. The analysis revealed that cost of cultivation (Cost C_2 as well as Cost A_2+FL) has increased at faster rate than profit. Next year two new states viz. Bihar and Chhattisgarh would be included for spread of NRRI varieties; Rice Value Chain for CR Dhan 310 and 311 will be established; under 4S4R model certified seed will be produced and marketed and two remaining FPCs will be registered under project 5.1. As part of Project 5.2, updation and analysis of cost of cultivation/ trade data of rice; analysis of information on rice area, yield and productivity for 10 states and district wise analysis of four states will be undertaken. The results of varietal experiment-cum-demonstration provided insight into its potential to replace popular variety in different states. These varieties can be recommended for inclusion in the seed chain of the country. The 4S4R model is showing signs of success as an alternate to formal seed system. Once established, it can be replicated in other parts of the country.

Developing Extension Approaches to enhance Rice Farmers' Income

Developing extension approaches for spread of rice varieties in different states

It is seen that a new rice variety takes about 6-8 years to become popular among farmers. But as per the existing government policy, all the subsidies cease for any variety which is older than 10 years and those cannot be demonstrated through any government scheme with exception from case to case basis. Major reasons for slow spread and adoption of new rice varieties by farmers were reported to be (i) non-inclusion in state seed chains, (ii) lack of breeder seed indents, (iii) unavailability of quality seeds, (iv) lack of publicity and awareness effort, (v) insufficient minikit trials and demonstration programmes, and (vi) absence of suitable seed production and distribution policy. In order to develop extension mechanisms to narrow down the gap between varietal development and its spread, demonstration-cum-experiment activities were undertaken in four eastern Indian states namely, Odisha, Jharkhand, West Bengal and Assam during *kharif* 2017-18.

Primary as well as secondary data were collected from various reports and through interactions with the state officials and farmers to identify existing popular varieties and farmers' preference in these selected states for testing new and comparable improved NRRI varieties in the targeted areas. Taking all criteria like ecology, duration and farmers' preference into consideration, a 'Varietal Matrix' was prepared for all 'popular but low yielding varieties' vis-a-vis 'new and higher yielding NRRI varieties' for replacement with better alternatives. Ecology wise district clusters were selected comprising about 15-20 farmers per cluster in consultation with state agriculture department officials and other stakeholders. Varietal demonstrations-cum-experiments were conducted by providing only 5 kg seed minikits to participating farmers as critical inputs (Table-5.1) without altering farmers' own crop management practices. It has been planned to cover almost all the districts in each selected states in 2-3 years in rotation.

These small scale on-farm demonstrations were conducted for participatory varietal evaluation in consultation and collaboration with all stakeholders like, state departments of agriculture (SDAs), state seed corporations (SSCs), state seed certification agencies (SSCAs), Krishi Vigyan Kendras (KVKs), state agricultural universities (SAUs), regional research institutes, farmers interest groups (FIGs), private seed companies and dealers, non-governmental organizations (NGOs) working in agriculture sector, media representatives and both demonstrating and non-demonstrating farmers. Big size and clearly visible road side field boards were placed on the demonstration sites with details of varietal characteristics in local language.

Capacity building programmes were conducted for various stakeholders through organizing village meetings and package demonstrations in each cluster, and providing regular technical backstopping through field visits/ telephonic advisory/ mobile social groups. During pre-harvesting stage, crop cutting experiments -cum- field days were organized in each state with the principle of 'Seeing is Believing', involving all the stakeholders including non-demonstrating farmers to showcase the superiority of the new varieties over existing popular varieties. Table-5.1 depicts the comparable results of crop cutting experiments. It is clearly evident that almost all the new varieties have outperformed the existing locally popular varieties with about 15-25 percent grain yield advantage, highest being for CR Dhan 307 (popularly known as Maudamani) - 30.77%, followed by CR Dhan 311 (Mukul - a high protein rice variety) - 27.50% and CR Dhan 206 (Gopinath) - 25.63%, respectively.

During the field days, participating farmers were encouraged to share their experiences to motivate fellow stakeholders. Best performing new varieties would be upscaled through creating demand for breeder seed indents, efforts to incorporate in state seed chain, promotion of local seed production by government and private agencies for making timely seed availability to farmers, and creating an institutional mechanism for planning and production of adequate quantity of seed for minikit distribution.

Fig 5.1 Field monitoring of cluster demonstration and experimental plots in Jharkhand

Fig 5.2 Field monitoring of cluster demonstration and experimental plots in West Bengal

Table 5.1. Details of crop cutting results of the cluster demonstrations-cum-experiments conducted during *Kharif* 2017-18 under varietal popularization programme

State	Selected District Clusters	No. of participating farmers	New NRRI Varieties demonstrated	Fresh Grain Yield (t/h)	Locally popular check varieties	Fresh Grain Yield (t/h)	Grain Yield Advantage (%)
Jharkhand	Ranchi, Gumla, Garwah, Palamu	60	CR Dhan 202	4.80	Sahbhagidhan	4.00	20.00
			CR Dhan 305	5.00	Sahbhagidhan	4.20	19.05
West Bengal	Burdwan	22	CR Dhan 201	4.24	Shatabdi	4.00	6.00
			CR Dhan 203	4.48	Shatabdi	4.00	12.00
			CR Dhan 304	5.60	Swarna	4.80	16.67
Odisha	Cuttack, Kendrapara, Jajpur, Dhenkanal, Boudh	100	CR Dhan 200	4.28	Lalat	3.84	11.46
			CR Dhan 202	4.80	Sahbhagidhan	4.12	16.50
			CR Dhan 203	4.64	Sahbhagidhan	4.24	9.43
			CR Dhan 204	4.84	Sahbhagidhan	4.24	14.15
			CR Dhan 205	4.50	Lalat	3.88	15.98
			CR Dhan 206	5.00	Lalat	3.98	25.63
			CR Dhan 303	6.20	Swarna	5.60	10.71
			CR Dhan 304	6.16	Swarna	5.20	18.46
			CR Dhan 306	5.52	Swarna	5.20	6.15
			CR Dhan 307	6.80	Swarna	5.20	30.77
			CR Dhan 310	5.00	Naveen	4.48	11.61
			CR Dhan 311	5.10	Lalat	4.00	27.50
			CR Dhan 408	4.92	Sarala	4.24	16.04
			CR Dhan 409	5.96	Pooja	5.20	14.62
			CR Dhan-500	4.50	Sarala	3.80	18.42
			CR Dhan-505	4.88	Sarala	4.00	22.00
			CR Dhan 508	5.24	Pooja	5.20	0.77
Assam	Darrang	4	CR Dhan 909	4.72	Ketekijoha	3.84	22.92

An overview of standing crops of CR Dhan 202 and CR Dhan 305 in Jharkhand

Crop Cutting experiment in Jharkhand

Crop Cutting experiment in Odisha

Fig 5.3 Field days and Experience sharing being organized in Jharkhand and Odisha

Improving Gender Equity in rice with emphasis on Value addition and Market linkage

The ICAR-NRRI which has been mandated to increase production and productivity of rice-based farming systems in India took up a project on 'Gender Mainstreaming in Rice' during 12th plan period (2012-2017). Under this approach, intense gender sensitization was a pre-requisite which followed capacity building of women rice growers through trainings, workshops, demonstrations, group discussions, counseling and exposure programmes. Both men and women got equal opportunity to exchange their experiences and feelings to garner community support to women rice growers in many critical areas of gender gap. A group of 50 women farmers were formally registered in the name of 'Ananaya Mahila Bikash Samiti' in Sankilo village of Nischintakoili, Cuttack for supporting and accelerating their all round development. During the project implementation process, the participating farm women showcased their traditional skills and displayed over hundred rice-based value-added products (VAPs) in a village workshop, many of which were found having very good commercial value and market potential, and could generate additional income and employment if linked to any value chain.

On the basis of the above findings, this new activity was undertaken with a broad objective of testing an innovative extension approach on gender sensitivity with emphasis on i) Partnership, ii) Group approach and iii) Market led extension. The data relating to existing knowledge and skills on post-harvest processing and value addition was collected from all fifty members of the women development group. A village level meeting was organized with the women group members (Fig. 5.4) to shortlist few suitable VAPs having market demand and preservation quality and to identify few local vendors/ outlets for regular marketing. Initially few value added products were selected, namely rice bran cake, rice bran biscuits, rice noodles and rice cake, apart from regular rice-based consumer products. They were given training on processing and packaging with the help of a renowned local NGO-NIGAM. The group members have started preparing and marketing these VAPs through the identified local vendors as well as fairs (Fig. 5.5). The initial enthusiasm and reactions of the group members have been very encouraging and motivating. A thorough socio-economic analysis of the group would be taken up after a gap of one year to see the impact.

Fig. 5.4 Village Meeting with the members of the Women Development Group

Fig. 5.5 DG and DDG (Hort. & CS), ICAR visiting the stall of the women group showcasing various rice based VAPs

Development, Evaluation and Upscale of a 'Rice Value Chain' approach for enhancing farmers' income

Rice Value Chain (RVC) as an approach to increase farm income and promote entrepreneurship was first conceived and operationalized at NRRI during 2014-15. The main objective was to promote large scale cultivation of high quality and specialty rice varieties of the institute in contiguous patches, and to undertake it's processing and trading, so that farmers get fair price for their produce and the consumers have access to premium quality rice and all the parties/ actors involved in the value chain are benefitted. Accordingly, a formal RVC through signing MOU was developed by NRRI, Cuttack in public-private-partnership (PPP) mode with the involvement of five parties including ICAR-NRRI, Cuttack (Fig-5.6) for growing and marketing of a long slender NRRI developed aromatic rice variety 'Geetanjali'. A bulletin on the RVC success story has been published and also has been uploaded in the ICAR and NRRI websites. From next *kharif* 2018 onwards, apart from Geetanjali, two more varieties, namely, CR Dhan 310 - a high protein rice variety with 10.3% grain protein content and CR Dhan 409 (Pradhan Dhan) - purple base with long slender grains have been identified for large scale production and marketing through discussion with other stakeholders. The various functions and activities have been given in the Fig 5.7.

The major benefits of this RVC were found to be: (i) farmers get doorstep procurement facility; (ii) fair price with minimum 20% more over MSP; (iii) quick spread of NRRI variety with less investment in extension; (iv) business to the seed companies; (v) additional income to the farmers groups towards coordination; and (vi) business and profit to the rice processors and traders.

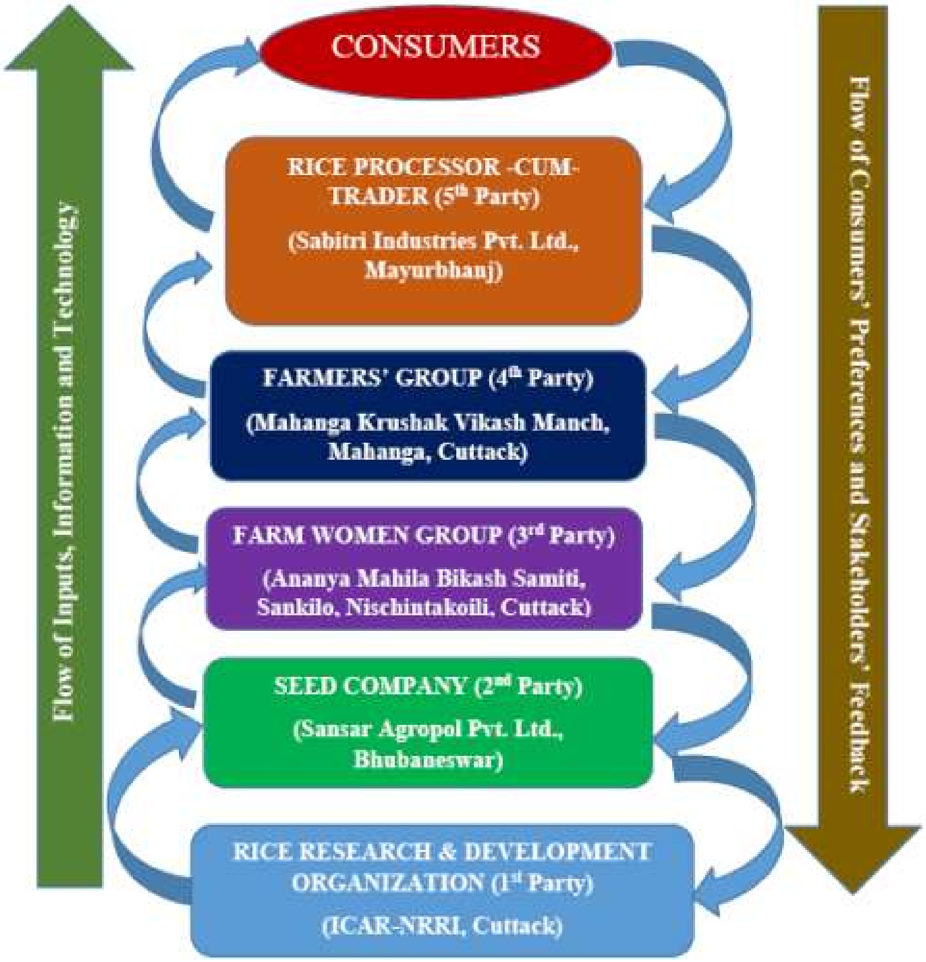


Fig. 5.6. Schematic representation of the RVC Model of NRRI

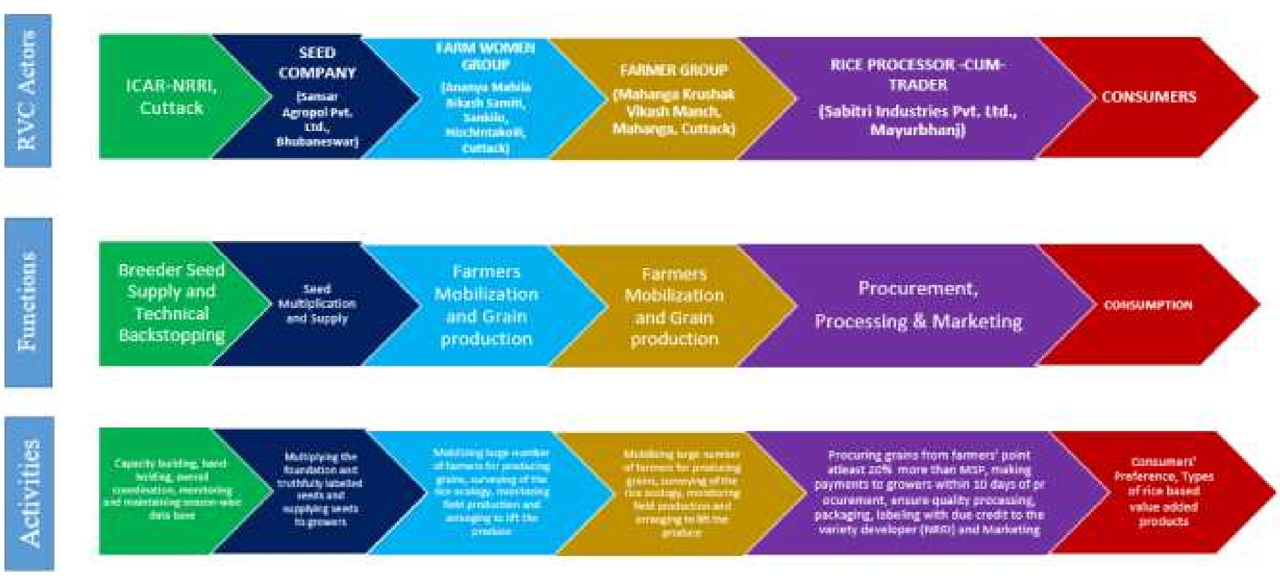


Fig. 5.7. Functions and Activities of RVC Actors

Testing and validating the 'Self-sufficient Sustainable Seed System for Rice' (4S4R) model of NRRI

The two top most problems in agriculture faced by the nation are water and seed. The formal seed system, though the best in South-East Asia, has inherent problems related to quality, quantity, timeliness, choice of variety and cost of production. In order to solve these problems, a local seed system, Self-sufficient Sustainable Seed System for Rice (4S4R) was conceptualized (Fig 5.8) and implemented in five blocks in Cuttack with the aim to make the district self-sufficient in paddy seed. During 2017-18, three out of five Farmer Producer Companies (FPCs) were registered under Company Registration Act, 2013, namely, Cuttack 4S4R Seed Farmer Producer Company Limited, Mahanga; Niali 4S4R Farmer Producer Company Limited, Niali; and Athgarh 4S4R Farmer Producer Company Limited, Athgarh.

During *Kharif* 2017, 134 quintals of foundation seed of three popular varieties was produced by Mahanga FPC under the technical guidance of ICAR-NRRI which was also certified through OSSCA. Besides, guidance for management, capacity building and entrepreneurship development was also provided as per the details given below in Table-5.2. The foundation seeds of Pooja, Swarna *Sub1* and Sarala were produced, which were processed at NRRI on cost basis. Although the foundation seed was produced by Mahanga FPC, it will be purchased by all other FPCs to produce certified seed during *kharif* 2018, thus advancing other FPCs in seed production of certified seed by one year.

As per the details given in table-5.3, the cost of production of 134 quintal foundation seed was Rs. 4.02 lakhs, while it was sold for Rs. 5.36 lakhs resulting into B:C ratio of 1.33 and net profit of Rs. 1.34 lakhs to the company. Besides, the seed growers received Rs. 2.68 lakhs as selling price while their cost of seed production was 1.34 lakhs with B:C ratio being 2.00. Since it was the first year of seed production, the quantity of foundation seed produced was less. Next year, the estimated total seed production including foundation and certified seeds would be around 2150 quintals for all five FPCs.

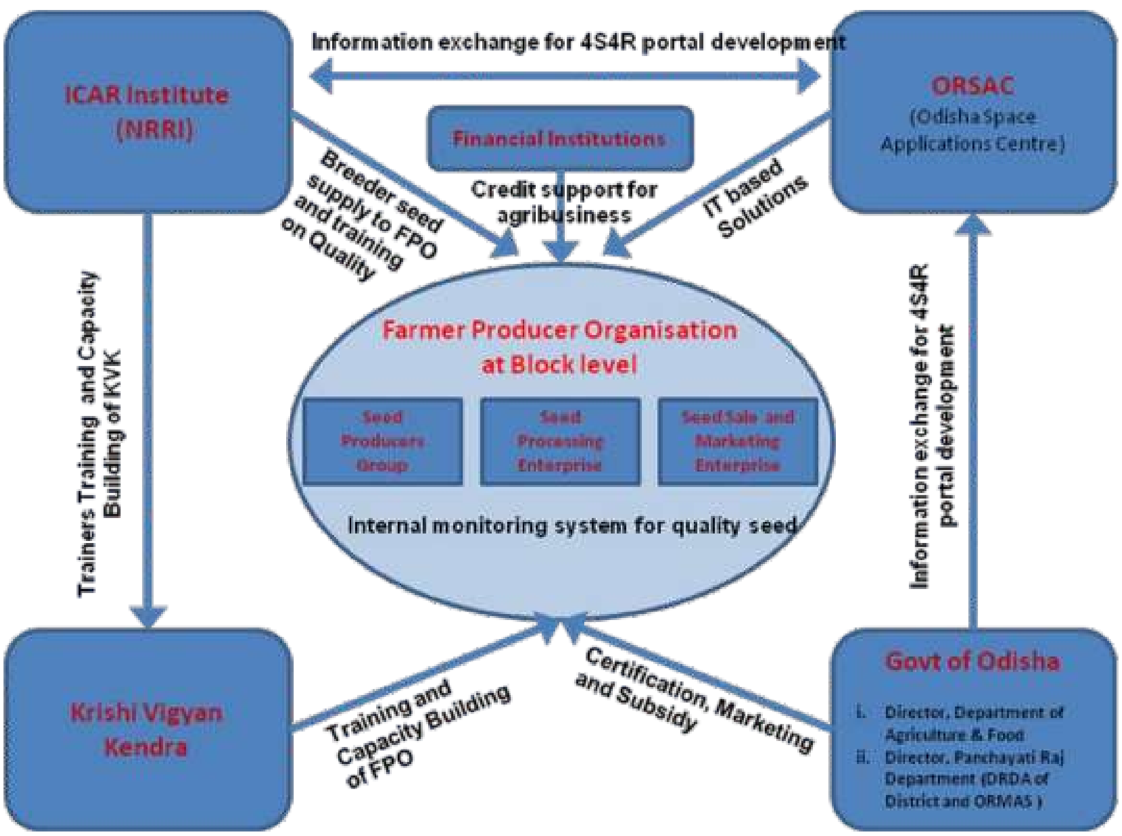


Fig. 5.8. Self-sufficient Sustainable Seed System for Rice (4S4R) model

Table 5.2. Training on management, capacity building and entrepreneurship development to progressive farmers of different blocks under 4S4R model

Name of Training Programme	Date	Categories of Participants	No. of Participants
1. Capacity building program on FPO Management (CBP)	11 Sep 2017	Progressive Farmers of Mahanga block	15
2. Awareness program on FPO Formation at Athgarh	21 Sep 2017	Progressive Farmers of Athgarh block	67
3. Awareness program on FPO Formation at Badamba	21 Sep 2017	Progressive Farmers of Badamba block	44
4. Capacity building program on FPO Management CBP)	15 Nov 2017	Progressive Farmers of Mahanga block	12
5. Capacity building program on FPO Management CBP)	14 Dec 2017	Progressive Farmers of Athgarh block	12
6. Awareness program on FPO Formation at Niali	11 Jan 2018	Progressive Farmers of Niali block	23
7. Awareness program on FPO Formation at Niali-Jhalarpur	24 Feb 2018	Progressive Farmers of Niali block	72

Fig. 5.9. Awareness programme cum workshop on FPO Formation at Badamba block, Cuttack

Fig. 5.10. Capacity Building Programme of Farmers of Cuttack 4S4R Seed Farmer Producer Company Limited, Mahanga

Fig. 5.11. Rouging of off-type plants in Mahanga, Cuttack

Fig. 5.12. Field Monitoring by Seed Certification Officer (SCO), Cuttack in Mahanga

Fig. 5.13. 4S4R Seed Processing and Sale by FPC, Mahanga

Table 5.3. Cost of foundation seed production per kg

Parameters	Costing in Rs.
1. Procurement of 1 kg from farmer	20
2. Processing Charge	5
3. Bag (20 kg)	2
4. Thiram	1
5. Transport	1
6. Misc.	1
7. Total cost/kg	**30**
8. Selling price/kg	**40**

Showcasing and Maintenance of On-station Varietal Cafeteria suitable for various ecologies

The newly released and popular rice varieties of NRRI suitable for various ecologies were transplanted and maintained in the Varietal Cafeteria for on-station demonstration during *Kharif 2017-18* and *Rabi 2017-18*. The main objective of this demonstration was to showcase the varietal characteristics as well as their performance to different categories of visitors to the institute. The yield and other yield attributes were recorded.

During *Rabi 2017-18*, 26 different rice varieties were demonstrated. The yield (t/ha) were: Rajalaxmi (7.2), Ajay (7.0), CR Dhan 701 (6.7), CR Dhan 206 (5.3), CR Dhan 205 (4.8), CR Dhan 203 (4.7), CR Dhan 204 (4.6), CR Dhan 202 (4.6), Satyabhama (4.7), Sahbhagidhan (4.3), CR Dhan 101 (4.3), Annada (4.2), CR Dhan 304 (5.9), CR Dhan 305 (5.8), CR Dhan 306 (5.5), CR Dhan 310 (5.5), CR Dhan 303 (5.4), CR Dhan 311 (5.4), Satyakrishna (5.4), Phalguni (5.3), Naveen (5.1), Bina Dhan 10 (5.0), Bina Dhan 11 (4.7), Pyari (4.7), Luna Sankhi (4.3) and Shatabdi (4.1)

During *Kharif 2017-18*, 26 different rice varieties were demonstrated. The yield (t/ha) were: Rajalaxmi (7.0), Ajay (6.8), CR Dhan -701 (6.6), Ketekijoha (4.3), CR Dhan 202 (5.3), CR Dhan 206 (4.9), CR Dhan 304 (5.8), CR Dhan 307/Maudamani (5.8), CR Dhan 305 (5.6), CR Dhan 306 (5.4), CR Dhan 303 (5.3), CR Dhan 300 (5.2), Chakaakhi (5.8), CR 1018 (5.8), Pradhan Dhan (5.8), CR Dhan 508 (5.7), Reeta (5.6), Pooja (5.5), CR

Dhan 501 (5.5), CR Dhan 506 (5.5), CR Dhan 500 (5.4), CR Dhan 505 (5.2), Sarala (5.2), Prasanta (5.1), Sumit (4.8) and Luna Suvarna (4.2)

Trainers' Training Programmes organized

Capacity development through enhanced knowledge, skill, attitude and other personal attributes of farmers and farmwomen has always been instrumental in bearing a direct and positive relationship with their farm productivity and family income. Therefore, efforts were made to impart skill-based training programmes to selected farmers, farmwomen and subject matter specialists (as mentioned in Training and Capacity Building section) to prepare them as key change agents in rice production technologies and para-extension professionals in their respective vicinities. The course curricula were planned and executed in such a way that more than half of the total time was earmarked for skill-based field demonstrations, practical sessions and field visits. Well experienced resource persons imparted the training through two-way interactive discussions, experiential sharing and simulation exercises. All the participants were provided with manuals and reading materials for future reference. Pre and post-training evaluations were done to assess the immediate impact of the training programmes on change in knowledge on subjects taught and to know the feedbacks of the participants about the effectiveness of the programme, which in turn help in future improvements.

Participation of NRRI, Cuttack in various Exhibitions

General awareness creation and wider publicity of latest rice production and protection technologies with emphasis on improved high yielding and hybrid varieties suitable for various ecologies, coping strategies to mitigate recent climate change effects and multiple biotic and abiotic stresses, agri-preneurship opportunities in rice sector, rice value addition to attract fair market price, drudgery reduction technologies for farm women, rice mechanization to reduce cost of cultivation and after all adding income to rice growers' family has been an integral mandate of the institute. Accordingly, the institute organizes agriculture fairs and exhibitions from time to time as well as participates in various national and international agricultural events (as mentioned in Events and Activities section) by displaying various technologies, products and varieties.

Mera Gaon Mera Gaurav (MGMG) Activities

The MGMG programme was initiated at ICAR-NRRI, Cuttack during Sept, 2015 with 21 multi-disciplinary teams (four scientists/team) in 21clusters of villages (five villages/cluster, 105 villages in total) covering eight districts of Odisha (Cuttack, Dhenkanal, Jagatsinghpur, Jajpur, Kendrapara, Khurda, Nayagarh and Puri). As per the Benchmark Survey, (1) non-availability of quality inputs like seeds and pesticides, (2) drought coupled with un-timely release of canal water in irrigated area, (3) marketing and storage problems, and (4) lack of institutional credit etc were identified as major problems in most of the clusters. Supports were provided through training, village meeting, providing paddy seed minikits, extension literature in local language, exposure visits, focus-group discussions and mobile advisory services. More than 300 farmers from selected clusters were also invited during Screening of Pusa Krishi Unnati Mela and Farmers-Scientists Interaction at ICAR-NRRI, Cuttack on 17 March 2018.

Yield gap analysis and impact assessment to aid rice research and policies

Estimation of yield gaps and identification of yield influencing factors

Assessment of yield gap between modern rice varieties and existing popular varieties in rainfed shallow lowland and irrigated ecologies, diagnosis of factors and constraints that contribute to the gap are necessary to bridge it for enhancing the productivity and efficiency of rice production. Aiming at quantification of average on-farm yield and yield gaps as well as to understand the influencing factors, experiments were conducted in four clusters from four districts of Jharkhand state and two clusters in Odisha state. Varietal demonstrations-cum-experiments were conducted by providing 5 kg seed kits of recently released varieties of the Institute to 15 farmers at each cluster as critical inputs without altering farmers' own crop management practices. Apart from above, about 15 neighboring farmers in each cluster were chosen as control. Data

Fig. 5.14 Participation of ICAR-NRRI in various Exhibitions during 2017-18

collected on all aspects of rice cultivation and the analysis indicated 19% to 31% of yield advantage for test varieties over existing popular varieties at the above locations (Fig. 5.16). The gap in yield from the potential yields of respective varieties were ranged between 20% and 40% (Fig. 5.17). Availability of improved varieties of seeds, extension services (training and exposure visits), irrigation and mechanization are perceived to be yield influencing factors.

District wise trend of rice area, yield and production and identification of low producing districts

Decade wise compound growth rate (CGR) of area, yield and production of rice calculated for four Southern Indian states (Kerala, Tamil Nadu, Andhra Pradesh and Karnataka) revealed negative growth of area for most of the periods (Table 5.4). For Kerala, area declined during all the periods, increase in yield could not compensate the negative growth which results into negative growth of production. For Karnataka, area growth was positive during 1990-91 to 2009-10 but during current decade it was negative, which rendered production growth also negative. For Andhra Pradesh, area growth was positive since last decade; while for Tamil Nadu, area growth was negative during recent period. We have calculated also the growth rate for whole period from 1980-81 to 2015-16 which indicated that for Kerala, area declined over the periods which led to decrease in total rice production, inspite of a reasonable yield growth. For Andhra Pradesh, though area declined for few districts, for some other districts area increased which resulted into increase in area for the state as a whole. For Karnataka also similar trend was observed. Again for Tamil Nadu, area declined and interestingly, CGR for yield during the period of 1996-97 to 2014-15 also declined. Further, decomposition of production growth into area and

Fig. 5.15 Mera Gaon Mera Gaurav activities during 2017-18

yield effect was made for four states and revealed negative contribution from area for Kerala and Tamil Nadu; positive contribution of area for Karnataka and Andhra Pradesh and positive effect of yield for all the states (Table 5.5). An exercise was also made to identify 100 number of districts of India based on the criterion of rice area > 25000 ha and rice yield < 2 t ha^{-1} (average of 201-11 to 2014-15). It is being noted from the results that for Assam (11), Bihar (18), Chhatishgarh (16), Madhya Pradesh (15) and Odisha (16), number of districts under this category is high (Table 5.6).

Updation of state-wise cost of cultivation and country wise export-import of rice

Detailed cost of cultivation data of rice for 18 states of India has been updated up to the year 2014-15 and growth rate calculated with respect to various indicators. The analysis revealed that cost of cultivation (Cost C_2 as well as Cost A_2+FL) has increased at faster rate than profit (Table 5.7). The profit per ha in irrigated states were greater than rainfed states. Further analysis indicated that the share of human labour contributed 54% to the total cost of cultivation considering only operational expenses and if cost C_2 is considered, it reduced to 37%.

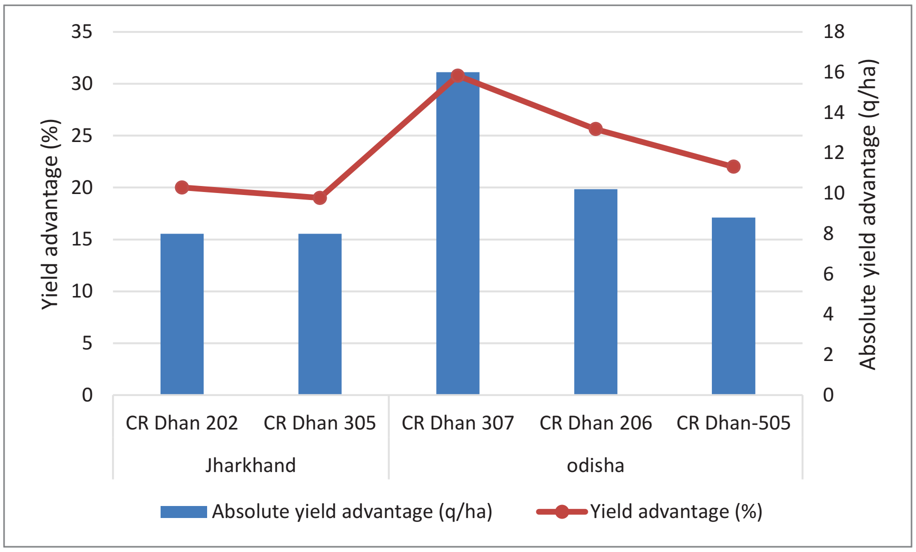


Fig. 5.16: Yield advantage of test varieties over existing popular varieties in Jharkhand and Odisha state

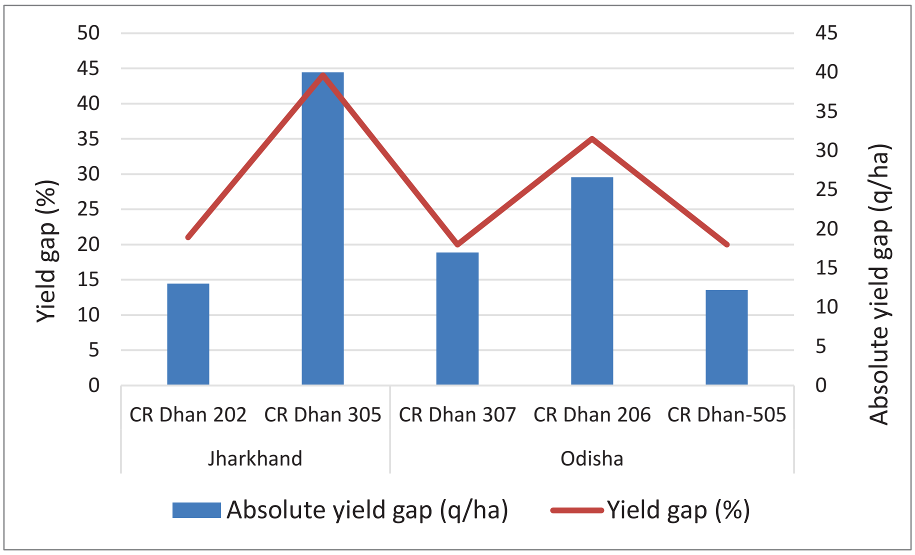


Fig. 5.17: Yield gap of test varieties from potential yields in Jharkhand and Odisha state

Table 5.4. Cumulative growth rate of area, yield and production of rice in Southern Indian states

(in per cent)

Particulars	1980-81 to 1989-90	1990-91 to 1999-2000	2000-01 to 2009-10	2010-11 to 2014-15	1980-81 to 2014-15
Kerala					
Area	-3.44	-4.86	-4.46	-3.45	-4.44
Yield	0.60	1.05	1.55	1.29	1.58
Production	-2.9	-3.9	-3.0	-2.2	-2.92

Karnataka					
Area	-0.05	1.69	0.55	-3.71	0.87
Yield	-0.37	2.14	0.97	0.78	1.09
Production	-0.42	3.86	1.52	-2.96	1.96
Andhra Pradesh					
Area	-0.64	-0.51	0.40	0.53	0.35
Yield	2.70	0.55	1.67	1.14	1.58
Production	2.04	0.04	2.07	1.67	1.93
Tamil Nadu					
Area	NA	0.95	-1.01	-3.43	-1.34
Yield	NA	14.43	-2.94	0.44	-0.34
Production	NA	15.51	-3.92	-3.01	-1.68

Note: NA: Data not available

Table 5.5. Decomposition of rice production growth into area and yield component ***(in per cent)***

Particulars	1980-81 to 1989-90	1990-91 to 1999-2000	2000-01 to 2009-10	2010-11 to 2014-15	1980-81 to 2014-15
Kerala					
Area	-60.5	-1805.2	-104.8	208.2	-128.26
Yield	144.1	1211.5	170.7	-93.5	132.38
Interaction	16.4	693.8	34.0	-14.7	95.88
Karnataka					
Area	37.64	41.58	133.40	11.67	60.77
Yield	60.60	48.43	-33.92	89.95	28.69
Interaction	1.77	9.99	0.52	-1.62	10.54
Andhra Pradesh					
Area	55.93	77.04	-56.28	-126.58	88.62
Yield	35.03	21.25	145.89	201.49	6.40
Interaction	9.04	1.71	10.39	25.09	4.97
Tamil Nadu					
Area	NA	99.16	47.02	-446.91	-7197.82
Yield	NA	0.64	58.94	520.95	6083.53
Interaction	NA	0.20	-5.96	25.96	1214.29

Note: NA: Data not available

Table 5.6. The most lowest producing 100 districts of India [with rice area >25000 ha and yield<2 t ha^{-1}]

States	No. of districts	No. and Name of districts with above criteria
Andhra Pradesh	13	**1** (Visakhapatnam)
Arunachal Pradesh	17	**1** (West Siang)
Assam	26	**11** (Chiraag, Bongaigaon, Tinsukia, Dibrugarh, Dhemaji, Jorhat, Udalgiri, Baksa, Kokrajhar, KarbiAnglong, Lakhimpur)
Bihar	38	**18** (Shivar, Begusarai, Vaishali, Jamui, Madhepura, Darbhanga, Saran, Kishanganj, Gopalganj, Purnea, Samastipur, Saharsa, Siwan, Supal, Sitamarhi, Muzaffarpur, East Champaran, Madhubani)
Chhattisgarh	27	**16** (Narayanpur, Beejapur, Koriya, Balrampur, Dantewara, Kabirdham (Kawardha), Kondagaon, Surajapur, Mungeli, Korba, Gariya Band, Sarguja, Bastar (includes Jagdalpur), Bemetara, Balod, Jashpur)
Gujarat	26	**3** (Dahod, Vadodara / Panchmahals)
Haryana	21	**1** (Rohtak)
Himachal Pradesh	11	**1** (Kangra)
Jharkhand	24	**6** (Sahibganj, Pakur, Jamtara, Khunti, Gumla, West Singhbhum)
Madhya Pradesh	51	**15** (Umariya, Singrauli, Damoh, Raisen, Panna, Sidhi, Jabalpur, Dindori, Satna, Katni, Annupur, Sahadol, Rewa, Mandla, Seoni)
Maharashtra	34	**6** (Satara, Nasik, Pune, Nagpur, Chandrapur, Gadchiroli)
Manipur	9	**1** (Churchandapur)
Odisha	30	**16** (Gajapati, Phulbani (Kandhamal), Deoghar, Jharsuguda, Rayagada, Boudh, Angul, Jagatsingpur, Malkangiri, Nayagarh, Dhenkanal, Khurda, Nawapara, Koraput, Jajpur, Puri)
Rajasthan	33	**1** (Banswara)
Uttar Pradesh	75	**3** (Sonbhadra, Banda, Unnao)
Total	435	**100**

Table 5.7. Growth trends in cost of cultivation & profit in rice cultivation in different states (1980-81 to 2014-15)

(in per cent)

State	Cost C_2 per ha	Cost A_2 + FL per ha	Profit per ha over Cost C_2	Profit per ha over Cost A_2+FL	Irrigated rice area
Andhra Pradesh	1.66	1.55	2.00 (9.99)	2.58	97.3
Assam	2.54	3.27	# (-10.15)	0.41	11.0
Bihar	2.62	1.87	# (-1.42)	-2.37	63.0
Jharkhand	0.97	0.88	# (-3.20)	#	5.3
Haryana	2.16	1.52	7.76 (44.06)	4.20	100.0
Punjab	0.90	2.70	3.66 (32.32)	2.81	99.6
Karnataka	2.10	2.54	-0.92 (20.33)	0.19	75.3
Madhya Pradesh	2.35	2.67	#(4.30)	0.39	29.6
Chhattisgarh	2.16	2.71	1.96 (3.86)	1.27	35.3
Maharashtra	-0.01	-0.70	# (-3.99)	#	26.1
Odisha	3.07	3.28	# (-8.13)	-1.03	33.0
Tamil Nadu	1.06	1.24	# (8.73)	-0.51	93.4
Uttar Pradesh	1.60	1.62	# (5.25)	1.83	83.4
West Bengal	2.27	2.67	# (-8.26)	-2.03	46.9

Note: FL: Family labour; Figures in parentheses indicate average profit (in '000 Rs.) for the period 2012-13 to 2014-15; # Growth rate cannot be computed due to negative profit for some years.

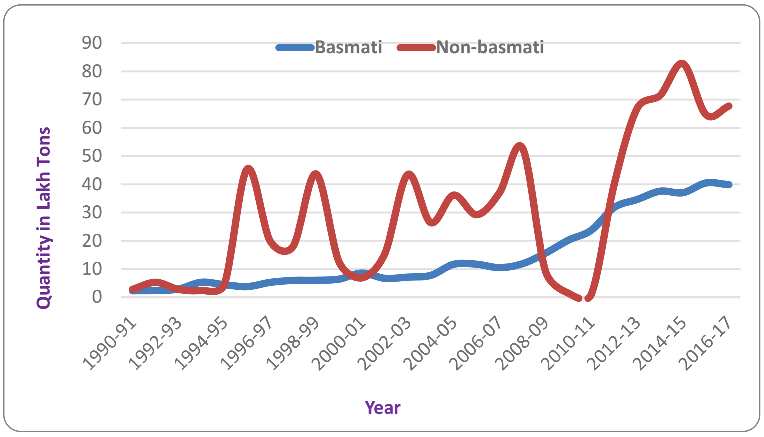


Fig. 5.18: Trends in Basmati & Non-basmati Rice Export from India (1990-2016)

Rice export data from India for seven grades of rice for 215 countries/custom territories have been updated up to the year 2016-17 and trend in export of basmati and non-basmati rice export indicated a consistent rise in export of basmati rice (Fig. 5.18). Export of non-basmati rice also grown tremendously since its opening during September 2011 after lifting of three-year ban period.

PROGRAMME : 6

CRURRS, Hazaribag

Upland rice in India accounts for about 13% of total rice growing area which is mostly distributed in eastern parts of the country. It is grown under diverse topography, climatic and soil conditions, mostly as direct seeded, rainfed crop. Due to adverse topography with gently rolling (0-8% slope) to highly sloppy (30% slope) lands, poor soil conditions with low water holding capacity and absolute rain dependence, it often suffers from drought at several growth phases. The situation has got further worsened during recent years with more uncertainty of monsoon rainfall distribution as results of climate change. Moreover, poor soil nutrient status (very low organic matter content, higher phosphorus fixation etc.), biotic stresses like weeds, diseases (blast, brown spot etc.) and insects (termites, stink bug, yellow stem borer etc.) which also are accentuated by drought, are major challenges for improving upland rice productivity. Improving productivity of rice in the upland ecosystem is essential to meet food security needs of impoverished upland farming communities leading to address the set national targets of (i) Bringing Green Revolution to Eastern India (BGREI) and (ii) doubling farmers' income. The project, thus, aims at addressing the following objectives and operative at Central Rainfed Upland Rice Research Station situated in Hazaribag, a unit if ICAR-NRRI.

1. To breed resilient high yielding rice varieties suitable for drought-prone rainfed uplands
2. To strategize management options for sustainable rice production under direct seeded rainfed ecology
3. To evolve rice based farming systems for drought prone rainfed ecology
4. To develop biotic stress management strategies for rainfed upland rice

Development of resilient production technologies for rainfed upland rice systems

Breeding resilient rice varieties for rainfed upland ecosystem

Augmentation and maintenance of upland rice germplasm

A total of 354 rice germplasm, comprising 70 upland rice from Arunachal Pradesh, Manipur and Sikkim, and 284 rice accessions from Assam, West Bengal and other eastern and northeastern Indian states, were acquired, characterized in the field and maintained for use as donor in breeding programmes.

Evaluation of rice germplasm for drought tolerance

Two hundred and fifty one (251) rice germplasm, received from NBPGR, were screened for drought tolerance under rainfed direct seeded upland field during 2017 *kharif* season. There was 15 days of dry spell at 45 to 60 days after seeding (45-60 DAS) mostly corresponding to the vegetative stage of the crop (Fig. 6.1). During the stress period, genotypes were scored for vegetative stage drought tolerance following SES (IRRI) and canopy temperature was measured. Later on, observations were recorded on days to flower, plant height and grain yield. Distribution of the genotypes for drought tolerance score followed a normal distribution (Fig. 6.2). Among the germplasm, drought tolerance score ranged from 1 to 9. About 43% of the germplasm had good drought tolerance with score 1 to 3, and 21 genotypes were found to have very good drought tolerance with a score of '1'. Most promising top five genotypes identified were IC-576054, RO-46, SKY-67, IC-389895 and IC-568239. All the promising genotypes will be screened for reproductive stage drought tolerance in the *kharif* season 2018.

Fig. 6.1. Genotypes showing tolerance to vegetative stage drought stress

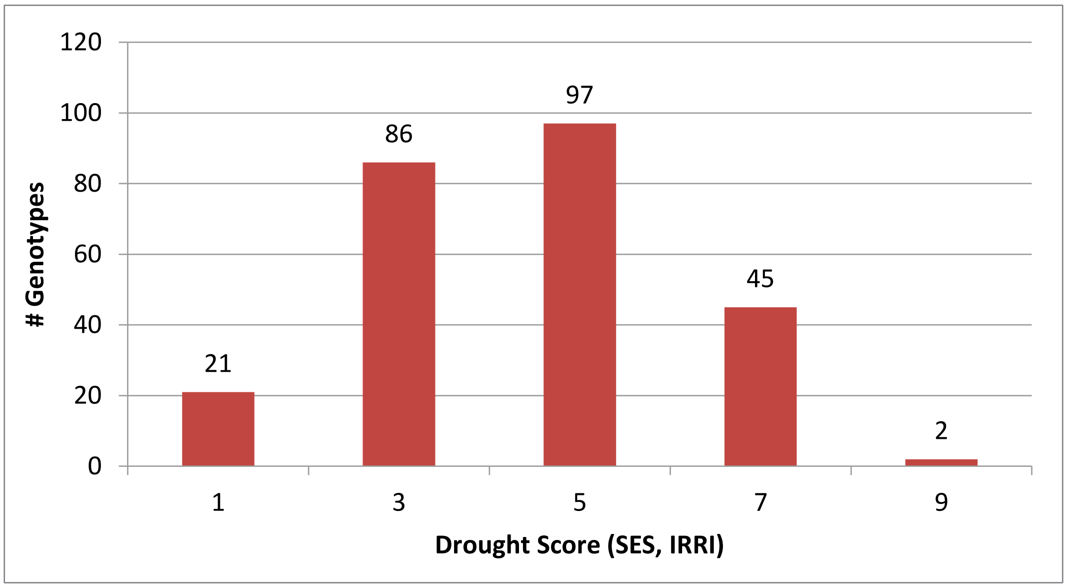


Fig. 6.2. Distribution of genotypes based on drought score

Molecular screening of rice germplasm from eastern and northeastern India for bacterial leaf blight resistance

Bacterial blight (BB) or bacterial leaf blight of rice, caused by *Xanthomonas oryzae* pv. *Oryzae* (*Xoo*), occurs worldwide and can reduce rice yield as much as 60-70%. Development of resistant varieties carrying major resistance (*R*) gene(s) has been the effective way for controlling BB, however, the pathogen frequently evolves to break the varietal resistance. Identification of the *R* genes present in rice germplasm is a vital exercise. Phenotyping for BB resistance was carried out in 210 rice germplasm comprised of released varieties and landraces from eastern and northeastern India. Based on disease reaction, 95 released varieties being categorized into 29 resistant, 42 moderately resistant and 24 susceptible, while, 115 landraces were grouped into 8 resistant, 38 moderately resistant and 69 susceptible accessions (Fig. 6.3a). Molecular screening for the presence and frequency of 10 BB resistance genes was made from a sub set of 70 genotypes, comprising of 35 resistant, 21 moderately resistant and 14 susceptible entries. The frequency of *R* genes varied from 0 to 5 per genotype. The most frequent gene was *Xa1* followed by *Xa7*>*Xa4*>*Xa10* >*Xa11* (Fig. 6.3b).A few entries such as Nua Kalajeera, Kalinga III, Naveen, CR Dhan 701, Swarna *Sub1*, Kalajeera, and ARC5791 possessed 3-5 genes. The findings indicated that *Xa1*, *Xa7*, and *Xa11* had been frequently selected in breeding programmes, and the frequency of *xa5*, *Xa8*, *xa13* and *Xa21* should be increased in the elite lines/released varieties in different combinations to achieve durable resistance.

Agro-morphological and molecular characterization of 'gora' rice germplasm of Jharkhand under rainfed upland condition

The traditional *gora* rice cultivars grown in the uplands (*tanr*) of the state of Jharkhand possess many agronomically important traits such as drought tolerance, earliness, low input responsiveness, weed smothering ability etc., besides some medicinal properties. A total of 49 *gora* rice germplasm, comprising of black gora (10), brown gora (12), white gora (8) and other gora cultivars (19), earlier collected from different parts of Chotanagpur plateau and maintained at CRURRS has been characterized for 26 agro-morphological traits, drought tolerance related traits (leaf rolling score, leaf drying score) and leaf blast severity in the drought screening plots following randomized block design along with six check varieties *viz.*, N22, Kalinga III, Vandana, Anjali, Apo and IR64 *Drt1*.

Highest average grain yield under stress was as follows: check > other gora> black gora> white gora> brown gora. Majority of gora accessions showed drought tolerance at vegetative stage in terms of low leaf rolling and drying scores at 10-15% soil moisture levels. However, moderate to high blast infestation (score 3-5) was recorded for most of the accessions. Factor analysis of mixed data (FAMD) using 28 phenotypic traits revealed that lemma palea colour, apiculus colour, seed coat colour, awning, awn colour, leaf rolling score, grain length and early plant vigor were the most important traits in differentiating the germplasm. In the biplot (Fig. 6.4a) the black gora accessions being morphologically distinct for grain appearance, formed separate group from the rest of the accessions. The popular drought check varieties along with the white gora accessions also separated from the brown gora and other gora and check varieties.

Genetic diversity at nine *qDTY* (QTLs for grain yield under drought stress) regions was assessed using 12 QTL-linked SSR markers. Highest frequency of allele specific to *qDTY*-positive check was recorded for RM3212 (*qDTY2.3*), followed by RM204 (*qDTY6.1*) and RM60 (*qDTY3.2*). Clustering of rice accessions using the allelic diversity at nine *qDTY* regions revealed that some commonly used drought donors (Apo, Moroberekon and Way Rarem) formed separate group from the rest of the accessions which mostly formed a close group with N22, Kali aus and Vandana. Some of the white gora accessions also differentially grouped along with IR64 *Drt1*. Molecular screening of blast resistance genes (*Pi2*, *Pib*, *Pi9*, *Piz* and *Pita2*) was carried out using linked/specific markers. Almost all *gora* accessions were found to be negative for the surveyed *Pi* genes except *Pib* for which all accessions were positive. One black gora accession was found to be positive for *Pi2* and *Piz* and *Pita2*. Genetic diversity analysis using 23 SSR markers, distributed throughout rice genome, revealed that white gora accessions are genetically associated with *indica*., while brown gora, black gora and other gora rice accessions are genetically close to the *aus* group (Fig. 6.4b). The characterized *gora* rice germplasm may serve as a valuable resource for upland rice breeding program.

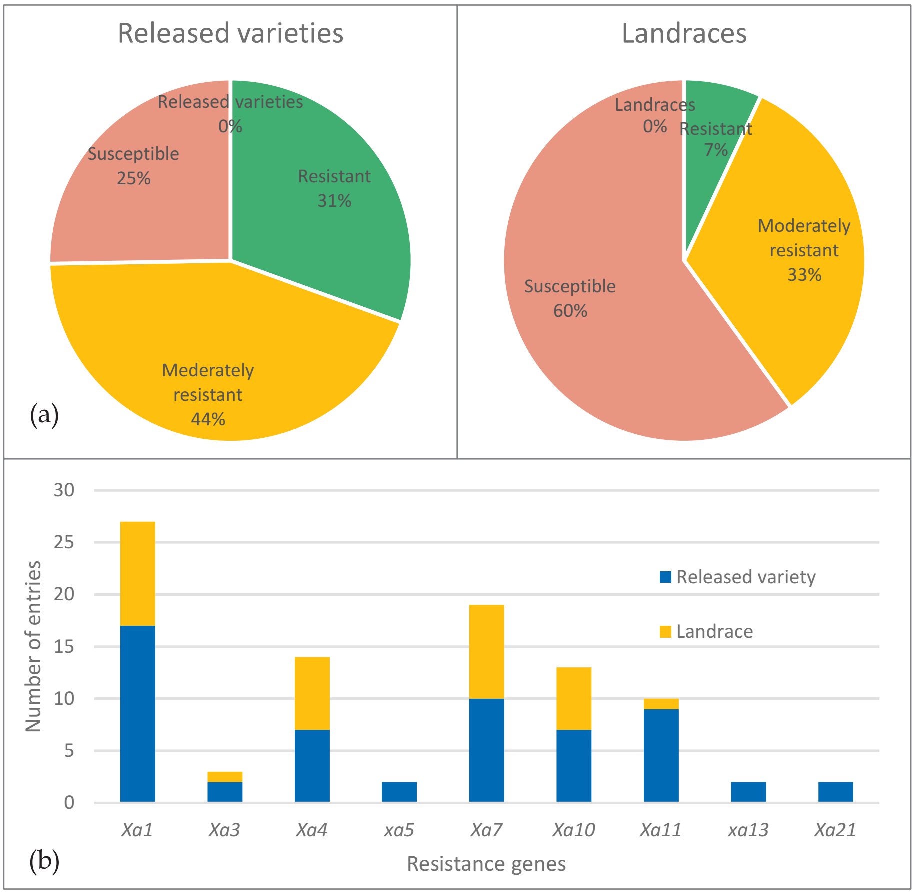


Fig. 6.3a.Percentage of bacterial blight resistant, moderately resistant and susceptible genotypes under 95 varieties and 115 landraces; (6.3b) Frequency of released varieties and landraces under each category of bacterial blight resistance genes

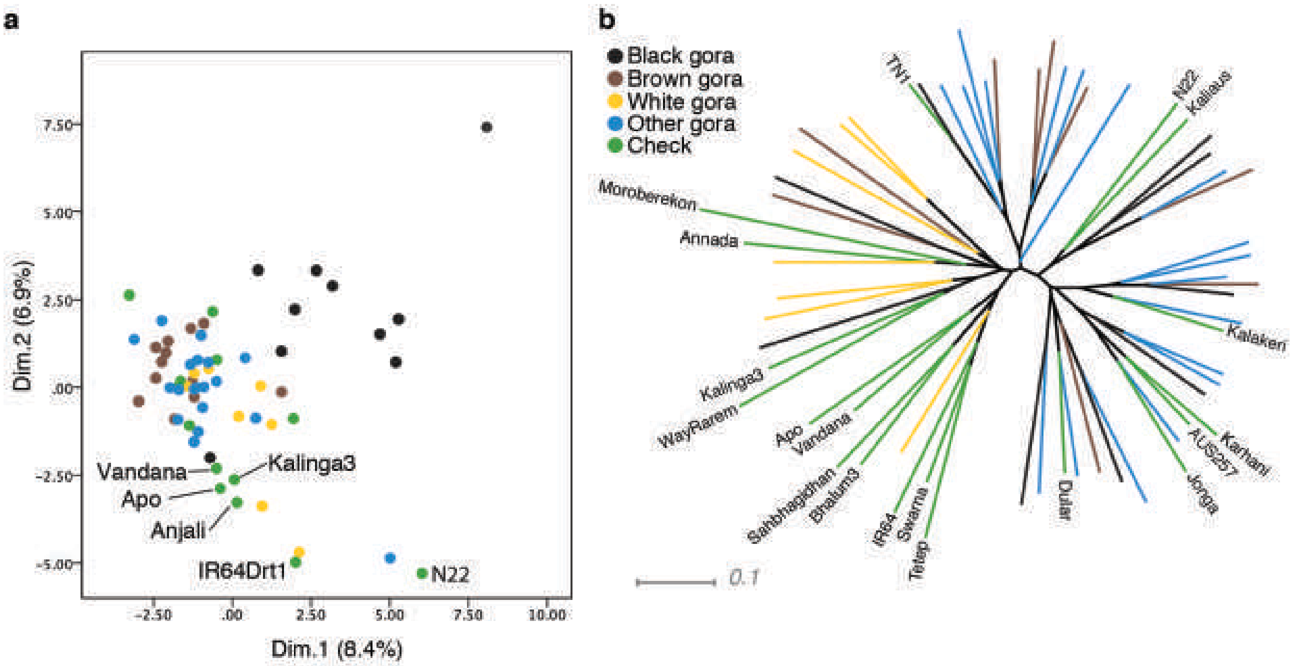


Fig. 6.4a. Distributing of gora rice germplasm based on 28 agro-morphological traits;
Fig. 6.4b. Genetic clustering of gora rice germplasm using 23 SSR marker.

Hybridization and generation of breeding lines

Six crosses, e.g., KalingaIII x Brown gora, Brown gora x IR64/CG-425, Geetanjali x Moroberekon, Moroberekon x Saket4, Anjali x Ngahongma (cold tolerant landrace of Manipur), Sahbhagidhan x IR64/CG-425 and Heera x Brown gora, were made to generate breeding lines and mapping populations involving drought tolerant and good grain quality varieties.

During 2017 *kharif* season, about 936 breeding lines from 33 crosses in F_4 generation were evaluated in the pedigree nursery and 299 single plant selections were made based on duration, plant type, grain type disease and pest reactions besides grain yield. Similarly, 218 advance (F_6 to F_7 generations) breeding lines from 55 crosses were evaluated and observations were recorded on days to flower, plant height, panicle length, grain yield, grain type and disease and pest reaction. Based on these characters, 50 progenies were selected as bulks for further evaluation under preliminary yield trial during 2018 *kharif* season.

Marker assisted selection combined with phenotyping for drought and blast resistance

One population has been developed involving Sahbhagidhan and IR87707-446-B-B as parents to combine the favourable alleles of both the parents using single large-scale marker-assisted selection (SLS-MAS) at an early generation. Sahbhagidhan is an widely adapted drought tolerant variety, possess large effect grain yield under drought stress QTLs *qDTY*12.1, whereas the other parent IR87707-446-B-B possess two major *DTY* QTLs (*qDTY*2.2 & 4.1) along with blast resistance gene *Pita2*. One hundred and twenty eight recombinant inbred lines of the population in F_2 generation were genotyped with the linked SSR markers of the above mentioned three *DTY* QTLs and blast resistance gene Pita2 (Table 6.1).

Different combinations of DTY QTLs and blast R gene were observed among the recombinant lines and only two lines with positive alleles of all QTLs and genes were obtained. To assess the agronomic performance these lines in F_5 generation were phenotyped under non-stress, rain-out shelter managed stress and rainfed conditions. Several recombinant lines out-performed both the parents under both stress and non-stress conditions. Two lines with all four positive alleles of the targeted QTLs/gene are certainly not the best performer but one of the lines out-yielded the parents. This is the preliminary results of first year of testing and will be validated with more number of trials in the coming season.

Table 6.1. Performance of the selected Sahbhagidhan x IR87707 lines under preliminary testing

Entries	Days to flower	Plant ht. (cm)	Grain yield (kg/ha)			*DTY* 2.2	*DTY* 4.1	*DTY* 12.1	*Pita2*
			Non-stress	RoS Stress	Rainfed				
CRR759-B-19-B-1	96	115	4524	4114	1920	B	B	B	B
CRR759-B-20-B-1	89	115	5567	3051	1643	B	B	A	A
CRR759-B-17-B-1	87	112	5527	2893	3107	B	B	A	A
CRR759-B-26-B-1	87	124	5204	2478	2775	B	B	A	B
CRR759-B-12-B-1	83	111	5115	2038	1761	B	B	A	B
Sahbhagidhan	90	99	4172	2082	1770	A	A	A	A
IR87707-446-B-B	92	91	5527	1891	2101	B	B	B	B
CD (5%)	5.5	19.5	923.5	862.3	831.1				

Development of isogenic lines with major blast resistance genes in rice cv. Vandana

Vandana has been popular among farmers in the eastern Indian states as an upland rice cultivar because of its moderate tolerance to drought and suitability to grow under direct seeded conditions. Since Vandana has the potentiality to serve as donor for drought tolerance traits in breeding programmes but susceptible to blast, an introgression programme was initiated to incorporate five major blast resistance genes, *Pi1, Pi2, Pita2, Pi9* and *Pi54*, into the genetic background of Vandana. The crosses were made between Vandana X IRBL-1-LA[CO], IRBL-ta2-IR64[CO], IRBL-z5-CA[CO], IRBL-9-W[LT] and Pi54NIL. The successful crosses were selected for backcrossing.

Preliminary yield trial

Forty promising advance breeding lines along with five checks were evaluated in upper bunded field under rainfed transplanted conditions. The design used was alpha-lattice with three replications and recommend package of practices was followed. The trial was sown on 28th July 2017 in the nursery and transplanted on 18th August 2017 in the main field. Because of late seeding the genotypes experienced moisture stress during grain filling stage. Out of forty only eight entries gave significantly higher yield than best check variety Vandana (Table 6.2). The top yielding entry CRR618-19-1 produced a grain yield of 3200 kg/ha followed by CRR588-18-1-1 (3199 kg/ha) and CRR586-9-1-1-1 (3098 kg/ha) as compared to best check Vandana (2511 kg/ha). The yield advantage in these elite breeding lines ranged from 27.4 to 17.3 per cent.

Entries promoted and new nominations in AICRIP trials

CRR 356-29 (IET 18654): Derived from the cross-Annada x RR 151-3, is one of the early cultures developed at CRURRS, Hazaribag, matures in 90 days, highly drought tolerant with short bold grains. It is moderately resistant to leaf blast and brown spot and also moderately resistant to stem borer and leaf folder. This elite line was tested in AICRIP trial during 2004 under direct seeded very early trial (IVT-VE). In the year 2017 this culture was released through SVRC as Purna for the uplands of Gujarat by the Navsari Agricultural University, Vyara, Gujarat.

Considering yield advantage over best check, IET 26337 (CRR747-12-3-B) has been promoted to 3rd year of testing in AVT 2-E DS trial of AICRIP. Similarly, two other entries IET26351 (CRR708-1-B-2-B-B-1) and IET26635 (CRR754-1) were promoted from IVT-E-DS to AVT1-E-DS, IET26866 from IVT-IME to AVT1-IME trial. Ten new entries developed at the station have been nominated for initial varietal testing under AICRIP trials during 2018 *kharif* season.

Table 6.2. Performance of selected entries in preliminary yield trial *kharif* 2017

Genotypes	Days to 50% flow.	Plant height (cm)	No. of Panicles/m^2	Grain yield (kg/ha)	% superiority over BC Vandana
CRR618-19-1	64	113.0	298	3200	27.4
CRR588-18-1-1	70	123.5	286	3199	27.4
CRR586-9-1-1-1	70	133.0	254	3098	23.4
CRR422-B	71	115.8	313	3077	22.5
CRR619-43-1	70	111.0	289	3075	22.4
CRR553-39-1-2	70	123.7	287	3069	22.2
CRR798-14	75	125.8	267	2991	19.1
CRR627-3-2	72	112.2	323	2946	17.3
CR Dhan 103	73	130.3	328	3118	
Vandana	70	107.8	267	2511	
Anjali	71	112.2	354	2411	
CD (5%)	2.4	11.7	62.3	417.3	

Evaluation of elite lines under AICRIP trials

AVT-1E-DS: Twelve entries and five checks were evaluated in randomized block design under rainfed upland direct seeded condition. The seeding was done during mid July and there was no moisture stress during the cropping season because of evenly distributed rainfall. The highest grain yield obtained was from the hybrid entry YRH 909 (3517 kg/ha) followed by CB 13 805 (3500 kg/ha) as compared to the best check Vandana (3317 kg/ha), which are statistically at par.

IVT-E-DS: Thirty six entries and five checks were evaluated in IVT-E-DS under rainfed direct seeded condition. This trial also was sown during mid July and didn't experience any drought as there was continuous rain during crop growth season. The top yielding entries in this trial were CRR 523-2-2-1-1 (3789 kg/ha), CRR 752-3-1 (3438 kg/ha) but not significantly better than the best check Vandana (3398 kg/ha).

IVT-E-TP: In this trial 60 entries along with four checks were evaluated in RBD in two replications under transplanting condition during *kharif* 2017. The entry NVSR 2120 (7200 kg/ha) was found top yielder among the test entries followed by NK-17508 (7000 kg/ha) and CR 4007-547-11-2-1-2-3 (6800 kg/ha) as compared to CO-51(NC)/ Sahbhagidhan (ZC) which yielded 4600 kg/ha.

AVT2 NIL-DRT: Two NIL entries in the background of Varalu were tested along with RP, donor parent Vandana+*qDTY*12.1 and drought checks Anjali (sensitive), DRR Dhan 42 & DRR Dhan 44 (tolerant) both under stress and control conditions during 2017 *kharif* season. The trial experienced moderate stress during grain filling stage (from 90 DAS to maturity). One NIL (IET26753) was inferior to RP and other NIL (IET26754) performed at par with the RP, both under control and stress conditions. Both the NILs performed very poorly as compared to tolerant check, DRRdhan 44.

INGER Nursery IURON: The 43rd IURON trial with 30 test entries and 10 checks were evaluated in two replications during 2017 *kharif* season following recommended protocols and plot size of 2 m^2. The promising entries identified from the nursery were TP30251 (690 g/plot), TP30596 (675 g/plot), TP30531 (655 g/plot) and TP 30257 (650 g/plot).

Seed production of upland rice varieties at CRURRS, Hazaribag

The breeder seeds of nine varieties developed at CRURRS, Hazaribag were produced to fulfill the requirement of DAC indent and local needs (Table 6.3). The nucleus seeds of these varieties were also produced as required for breeder seed production.

Management of direct seeded rice for sustainable crop production

Effect of seed and fertilizer management on productivity of upland rice

With an objective to study the effect of PSB and AM in enhancing the fertilizer use efficiency of phosphorus application through SSP and interaction with priming agents for improving productivity of rainfed upland rice, a trial was initiated during 2017 wet season. Trial was laid out in split plot design and treatments were replicated thrice. Main plot treatments included combination of P levels *viz.*, 0 kg & 30 kg P_2O_5/ha, PSB @ 4.0 kg/ha, and AM @1.5 t/ha. Seed priming with *Syzygium cumini*@ 1.7%, GA3@100 ppm, and three strains of *Trichoderma* were the priming agents

Table 6.3. Quantity of breeder seed produced at CRURRS, Hazaribag during 2017 WS

Sl. No.	Varieties	Quantity of B.S. allotted as per BSP I	Quantity of B.S. actually produced (Qtls)
1.	Abhishek	40.00	40.00
2.	Anjali	2.00	5.70
3.	Hazaridhan	3.50	5.40
4.	Sadabahar	1.00	1.60
5.	Sahbhagidhan	206.00	280.00
6.	Vandana	8.00	8.00
7.	IR64 *Drt1*	-	7.90
8.	CR Dhan 40	-	1.00
9.	Virendra	-	1.50
10	Total		351.10

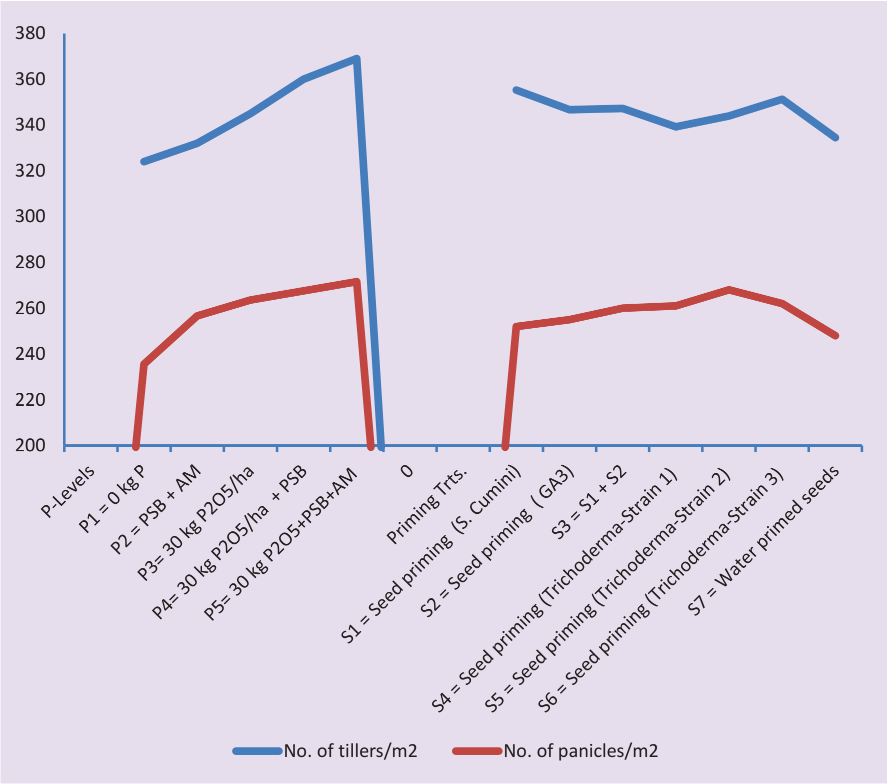


Fig. 6.5. Effect of fertilizer and priming techniques on tillering

Nutrient management using green manuring (AICRIP)

A trial was initiated during 2017 wet season to study the effect of green manuring and nutrient management on productivity of rainfed upland rice. Application of lime and foliar spray of zinc was coupled with different combinations of N and P. Sunhemp was used as green manure crop and rice crop was grown either as sole crop or intercropped with sunhemp. Analysis of results showed that incorporation of sunhemp (rice + green manure intercropping) could not enhance rice grain yield over sole rice cropping. Nutrient management (NPK) showed its influence more on crop biomass than the economic yield irrespective of foliar Zinc and lime application.

Crop establishment methods (AICRIP)

Rice cv. DRR Dhan 44 was used as test variety for evaluation of effect of various crop establishment methods on its productivity. Crop establishment methods viz., Conventional transplanting, wet-DSR, aerobic cultivation and semi dry direct seeded rice under puddled conditions were used and treatments were replicated four times in randomized complete block design. Rice cultivar DRR Dhan 44 took about 10 days more time for 50% flowering in comparison to other methods. Differences among various DSR methods were statistically non-significant in respect to 50% flowering. Wet-DSR method produced yields at par with conventional method of transplanting irrespective of its sowing method (broadcast/drum seeder) etc. Aerobic rice produced yields comparable to wet DSR rice cultivation using broadcast technique but proved inferior to wet DSR with drum seeder.

Crop and fertilizer management for high yielding varieties/hybrids (EC-IFAD)

The DSR offers farmers a choice of crop establishment methods to cope with climate induced changes, save the labor costs and reduces the amount of water required for subsequent crop growth. Direct seeded rice cultivation is, therefore, gaining popularity among farmers in Eastern India and elsewhere. Information on relative performance of high yielding rice varieties and hybrids under wet-DSR is scarce. Hence, this study aimed on comparison of HYVs and hybrids under different fertilizer application rates and crop establishment methods was initiated during 2016

Table 6.4. Effect of seed and fertilizer management on growth, yield and yield attributes of upland rice (2017, wet season).

Treatments	Grain yield (t/ha)	Panicles (no./m^2)	Wt./ panicle (g)	1000 - Gr. Wt (g)	Filled grains/panicle (no.)	Chaffs/ panicle (no.)	Spikelet Fertility (%)	Plant dry weight (g/m^2)	No. of tillers/m^2
P-Levels*									
P1 = 0 kg P	1.70	236	2.79	20.4	72.9	26.0	73.7	259.5	324
P2 = PSB + AM	1.82	257	2.95	20.6	74.0	25.6	74.3	280.5	332
P3= 30 kg P_2O_5/ha	2.26	264	3.15	20.9	76.2	24.4	75.7	297.5	345
P4= 30 kg P_2O_5/ha + PSB	2.41	268	3.25	21.2	77.0	24.5	75.8	309.5	360
P5= 30 kg P2O5+PSB+AM	2.45	272	3.29	21.9	78.0	23.5	76.8	321.5	369
CD (0.05)	0.36	24	0.3	ns	4.0	ns	-	29.4	36
CV%	16.4	18.0	6.4	2.3	5.0	7.0	-	9.8	16.5
Priming Treatments**									
S1 = Seed priming (*S. cumini*)	2.24	252	3.21	21.2	78.2	18.4	80.9	301.0	355
S2 = Seed priming (GA3)	2.04	255	3.15	21.0	77.7	22.8	77.3	291.0	347
S3 = S1 + S2	2.31	260	3.26	21.5	77.9	24.9	75.8	306.0	347
S4 = Seed priming (*Trichoderma*-Strain 1)	2.12	261	3.15	20.9	74.2	25.7	74.2	302.0	339
S5 = Seed priming (*Trichoderma*-Strain 2)	2.13	268	3.18	21.2	72.9	23.7	75.5	301.0	344
S6 = Seed priming (*Trichoderma*-Strain 3)	1.94	262	3.02	20.8	75.6	30.0	71.6	284.0	351
S7 = Water primed seeds	1.89	248	2.98	20.4	72.6	28.2	72.1	271.0	335
CD(0.05)	0.18	ns	0.14	0.7	4.6	3.7	-	24.2	ns
CV%	18.4	16.0	8.85	3.6	2.6	6.0	-	7.6	18.8

*P source was SSP, PSB @4 kg/ha, AM @ 1.5 t/ha; ** *S. cumini* @1.7%, GA3@100 ppm, *Trichoderma* @ 10 g/kg seed wet season and continued in 2017. Combinations of two crop establishment methods *viz.*, 1) Transplanting, 2) Wet Direct Seeding, and two fertilizer application rates *viz.*, 1) N80:P40:K30, 2) N120:P60:K30 comprised the main plot treatment while four high yielding varieties (Hazaridhan, Sadabahar, Sahbhagidhan and DRR Dhan 44) and two hybrids (PAC 801 and PA 6444 Gold) formed the subplot treatments.

Experiment was carried out under shallow lowland situation in a field having clay loam soil with 0.65% soil organic carbon, 19.7 kg available P and 428 kg available potassium per hectare. Soil pH was 6.6 and EC was 8.2. During both the years, number of days taken to 50% flowering varied significantly due to interaction effects between varieties, methods of crop establishment and fertilizer application rates. On an average, DRR Dhan 44 took 10 days less uniformly to flower under DSR method compared to TPR, whereas yearly variations were noted in case of other varieties. Wet DSR method of crop establishment produced comparable yields to transplanted method as evident from a mean change of 0.4 t/ha due to switching from DSR to TPR. When averaged over fertilizer application rates, a decrease of 15.1 per cent in the grain yield of hybrids and 2.6 per cent in the HYVs was noted due to switching of crop establishment method from TPR to DSR over two years. Among the different fertilizer application rates, remarkable response of HYVs was noted under DSR for high dose of fertilizer application (N120:P60:K30). Based on the results, it may be inferred that HYVs should be preferred for cultivation under DSR than hybrids since yield reductions are relatively less due to switching impact from TPR to DSR in comparison with hybrids.

Assessment of residual effect of inoculation in previous year on AMF population

In fixed plot study (since wet seasons of 2010), AMF inoculums in respective treatments of two rice based cropping rotations *viz.*, (i) pigeon pea (1st year) and rice (2nd year) and (ii) maize relay cropped by horse gram (1st year) and rice (2nd year) under most AM-supportive P fertilization form of 50% Purulia rock phosphate (PRP) and 50% DAP were added every year except for 2016 and 2017 to assess residual AMF population in June (beginning of rice season) which is important for beneficial effects on crop.

In previous years of 2011 to 2016, AMF inoculums were added and in June, 83.6 to 89.5% increase in AMF population (over that of June population in 2010) after obvious offseason (fallow winter and summer) decline was observed during the years (2011 to 2016). Further decline rate in June population of 2017 (Fig. 6.6) was observed after no inoculation in 2016, though it maintained sufficiently higher (77.3%) population as compared to that of June 2010. Final population (end of wet season; October) followed a gradual increase (population build up) over years (2011 to 2016) over that of October 2010 attaining 53.5% increase (October 2016) from 18.2% (October 2011) as compared to that of the initial year (2010). No inoculation in 2016 still supported steady growth at the end of the season. The steady trend of increment of October population though reduced to 37% in 2017 but still maintained sufficiently higher population (Fig. 6.7) despite two years of no inoculation. The June population of 2018, will indicate whether two years of no inoculation (after 6 years of continuous inoculation) still support higher June population over initial.

Effects of different forms of off-season tillage on native AMF population in soil

Previous results indicated that, though off-season tillage reduces native AMF population in soil by disrupting mycelia network, less finer till at 12-14 weeks interval produces least deleterious effect. Since off-season tillage is agronomic recommendation for upland rice grown as direct seeded crop, several forms of one summer tillage (using Mold board plough, cultivator, Disc harrow and rotovator) were evaluated. Pre sowing ploughing, however, was done using cultivator in all plots. One summer plough with MB plough recorded least deleterious effect on soil AMF population with concomitant significantly higher grain yield of upland rice (CR Dhan 40) (Fig. 6.8).

Biotic stress management in Upland Rice

Screening of rice lines for resistant donors

A total of 2491 rice germplasm (NSN1, NSN2, DSN, OYT, AYT, IRBN, RILs, Vandana NILs, Anjali NILs, BPT NILs, V x A NILs, etc. were screened under UBN against leaf blast during wet season 2017 (Fig. 6.9). The results indicated that 20.5% (93/454) of NSN1, 28.8%

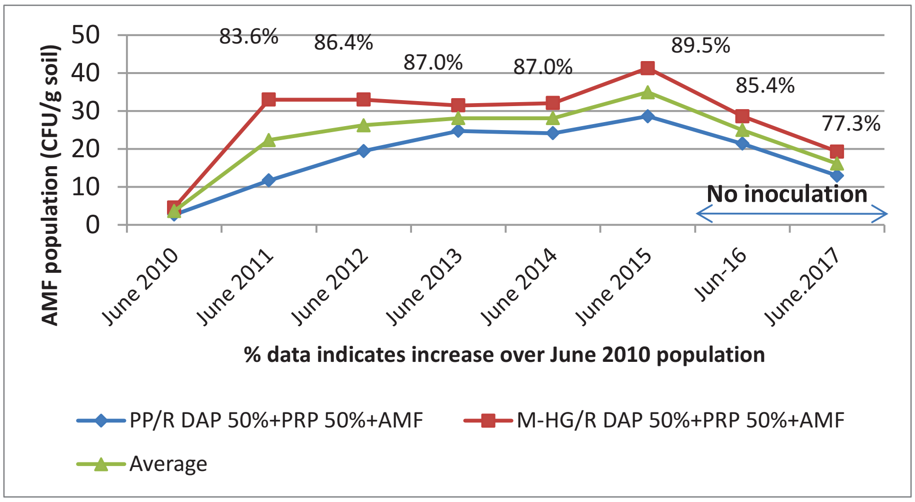


Fig. 6.6. Population dynamics of AMF during June (2010 to 2017) as influenced by inoculation

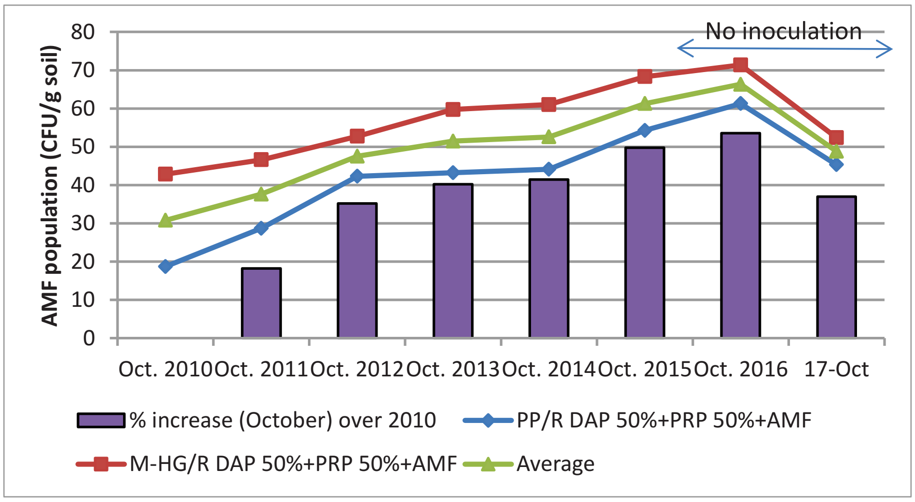


Fig. 6.7. Population dynamics of AMF during October (2010 to 2017) as influenced by inoculation

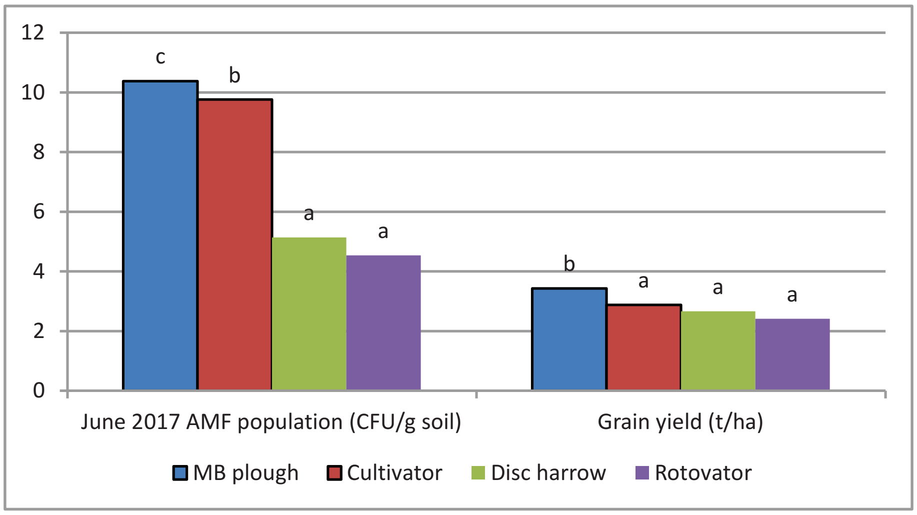


Fig. 6.8. Effect of tillage on AMF population and grain yield of upland rice

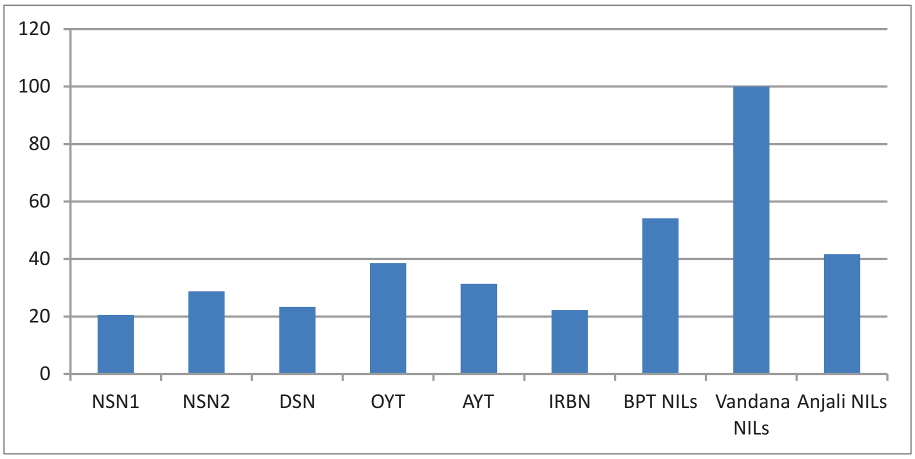


Fig. 6.9. Percentage of resistant rice entries in Wet Season 2017 under UBN

Fig. 6.10. View of blast disease screening nursery

(214/743) of NSN2, 23.33(21/90) of DSN, 38.6% (110/285) of OYT, 31.42% (33/105) of AYT (STRASA), 22.22 % (10/45) of IRBN, 54.2% (13/24) of BPT 5204 NIILs, 100% (12/12) of Vandana NILs & 41.7% (5/12) of Anjali NILs were found resistant (0-2 SES Scale) (Fig. 6.10).

Screening and validation of resistant donors for brown spot diseases

Two thousand two hundred and twenty nine (2229) lines comprising of entries of the national screening nurseries [NSN 1 (351) and NSN 2 (743)], Donor Screening Nursery [DSN (90)], and NSN-Hills - 89); entries of advanced yield trial [AYT (105)] and observational yield trial [OYT (286)]; landraces from north-east India (43), ARC (389), weedy rice (129) and NRRI released varieties (94) were screened for their reaction to brown spot disease in a UBN at Hazaribag during *kharif* 2017 (Fig. 6.11). First visible disease symptom appeared during first week of August on few NE accessions *viz.*, Sarpung, Phung Phama, Ngahongmaa. Each entry was scored on a scale of 0-9 (SES, 1996) and brown gora was used as susceptible check.

Fig. 6.11. View of brown spot disease screening nursery

Based on the scoring data, out of 351 NSN1 entries, only three entries were found resistant, rests showed moderately resistant (30), susceptible (39) and highly susceptible (277) reaction against brown spot disease. All entries under NSN2, DSN, AYT, OYT and all the NE Indian landraces were highly susceptible to brown spot. While out of 389 ARCs, only one line was resistant and rests were moderately resistant (173), susceptible (191) and highly susceptible (17). Out of 129 weedy rice accessions, 49 were moderately resistant, 68 were susceptible and three were highly susceptible. None of the NRRI released varieties was resistant to brown spot. Only 25 varieties showed moderately resistant reaction, whereas 59 varieties were identified as susceptible and three varieties were highly susceptible. Overall, out of 2229 screened materials, only four lines were resistant and 277 lines were moderately resistant to brown spot disease.

IDM modules in rice under unfavorable uplands

A field experiment was conducted to evaluate the

IDM modules for their effectiveness in reducing leaf blast and brown spot of rice under unfavorable upland condition. A total of five IDM modules were formulated involving use of local strain of *Trichoderma harzianum* (Th-CRURRS-9), biocontrol agent and intercropping of rice with pigeonpea. The details of IPM modules were:

Control: No Seed Treatment + Late Hand weeding (40 DAS) + N: 15 + 30 +15 (kg/ha).

IPM module 1: MSS with Brine Solution + ST with *Trichoderma* @5g/kg seed + Pre-emergence application of Pendimethaline + need based PE Weedicide application (40 DAS) + N: 15 + 30 + 15 (kg/ha).

IPM module 2: MSS with Brine Soln. + + ST with *Trichoderma* @5g/kg seed + Pre-emg. Appl. of Pendimethaline + need based PE Weedicide appl. (40 DAS) + Intercropping with pigeonpea (4:1) + N: 15 + 30 + 15 (kg/ha).

IPM module 3: MSS with Brine Soln. + ST with *Trichoderma* @5g/kg seed + Pre-emg. Appl. of Pendimethaline + need based PE Weedicide appli. (40

Fig. 6.12. Field view of IDM plot under unfavorable upland

DAS) + I C with pigeonpea (8:1) + N: 15 + 30 + 15 (kg/ha).

IPM module 4: MSS with Brine Soln. + + ST with

Table 6.5. Evaluation of IPM modules in Rice under unfavorable uplands

IPM Modules	% Leaf blast incidence 75 DAS	% RDI	% Brown spot incidence 75 DAS	% RDI	Weed biomass (g/m^2)	% reduction in weed biomass	Yield (q/ha)	% increase in yield
Control	10.9 e	0.00	8.8 e	0.00	60.86 b	0.00	17.5 c	0.00
IPM 1	6.2 d	43.1	5.1 d	42.0	13.3 a	78.15	21.9 b	18.4
IPM 2	4.9 b	55.0	3.5 b	60.2	12.6 a	79.30	24.4 b	31.9
IPM 3	5.1 bc	53.2	4.2 c	52.3	13.0 a	78.64	22.5 b	22.2
IPM 4	3.1 a	71.5	2.7 a	69.3	10.5 a	82.75	31.9 a	72.4
IPM 5	3.5 a	67.9	3.1 a	64.8	11.1 a	81.80	29.3 a	58.4
LSD (5%)	0.61	-	0.51	-	19.41	-	3.46	-

IPM of paddy under favourable upland

The details of IPM modules were:

Control: No seed treatment + Hand weeding (40 DAE)+ N application = 20 (basal) : 40 (40 DAE) : 20 (65 DAE).

IPM module 1: Seed treatment (MSS) + Pre-emergence weedicide (Butachlor at 2 DAG) application + Post-emergence weedicide application (Bispyribac Na: 21 DAG) + N application = 20 (basal) : 40 (25 DAE) : 10 (45 DAE) : 10 (65 DAE).

IPM module 2: Seed treatment (MSS) + Pre-emergence weedicide (Butachlor at 2 DAG) application + N application = 20 (basal) : 40 (25 DAE) : 10 (45 DAE) : 10 (65 DAE); and

IPM Module 3: Seed treatment (MSS) + Only post emergence weedicide application + N application = 20 (basal) : 40 (25 DAE) : 10 (45 DAE) : 10 (65 DAE). The experiment was laid out in RBD design and replicated four times. The pest incidence was periodically closely monitored and the data on disease incidence was recorded at 25 DAE, 40 DAE, 55 DAE & 70 DAE whereas false smut was recorded at 75 DAE, 90 DAE and 100 DAE. Weed biomass was recorded at 40 DAS (before application of post emergence weedicide/late hand weeding).

Fig. 6.13. Field view of IDM plot under favorable upland

All the IPM modules were significantly effective in suppressing pest infestation in Shahbhagidhan as compared to untreated control. However, the comparative evaluation of IPM modules in Favorable uplands revealed that IPM module 1 (Seed treatment (MSS) + Pre-emergence weedicide (Butachlor at 2 DAG) application + Post-emergence weedicide application (Bispyribac Na: 21 DAG) + N application = 20 (basal) : 40 (25 DAE) : 10 (45 DAE) : 10 (65 DAE) was most effective in reduction of plant diseases and weed infestation, followed by IPM module 3 and 2. Lowest weed biomass and highest yield was also recorded with IPM module 1 (Table 6.6).

Integrated Disease Management (IDM) for False Smut of Rice

Field experiment was conducted at CRURRS, Hazaribag for IDM of false smut of hybrid rice. The IDM modules involved adjustment of transplanting date, chemical fungicides and fertilization level. The experiment was laid out in RBD design with four replications. The rice hybrid PHB 71 used in this experiment. The results presented in (Table 6.7) revealed that early transplanting (latest by 20th July) with moderate level of fertilization and preventive sprays of Hexaconazole had resulted into lowest false smut incidence. However, highest yield of rice was recorded with early transplanting, high level of fertilization and preventive sprays of Hexaconazole.

Table 6.6. Comparative efficacy of IPM modules in rice under favorable uplands

Treatments	Disease score on SES scale*			Weed dry biomass	Rice grain yield (q/ha)
	Brown leaf spot	Leaf blast	False smut		
Control	6.80 d	7.29 b	5.3 c	79.68 c	18.1 b
IPM module 1	3.69 a	2.1 a	1.1 a	13.56 a	35.1 a
IPM module 2	4.55 ab	2.51 a	2.8 b	16.43 a	31.6 a
IPM module 3	4.78 bc	1.99 a	1.6 a	20.95 b	33.2 a
LSD (5%)	0.99	0.81	0.67	4.41	5.10

*Mean of five replications; SES -Standard Evaluation System for Rice (IRRI); Blanket need based application of PP chemicals at action threshold (only onlyMonocrotophos for G Bug at flowering was applied)

Table 6.7. Interactive effect of date of transplanting, fertilizer dose and chemical fungicides) for false smut of Rice (PHB 71)

Date of transplanting	NPK	False smut (% panicle infection)					Grain yield (t/ha)				
		Chemicals (Fungicides)			Mean (DT x F)	Mean (DT)	Chemicals (Fungicides)			Mean (DT x F)	Mean (DT)
		C 1	C 2	C 3 (control)			C 1	C 2	C 3 (control)		
DT 1	F1	1.1 a	1.67 a	4.5 a	2.42	2.50	6.25 a	6.65 a	6.15 a	6.35	6.54
	F2	1.7 a	1.96 a	5.1 a	2.92		7.41 b	6.94 a	6.25 a	6.9	
DT 2	F1	2.2 b	3.5 b	6.4 b	4.03	3.98	6.93 a	6.15 b	5.9 b	6.33	6.86
	F2	2.9 b	4.31 bc	7.2 bc	4.80		7.2 b	6.29 bc	6.21 b	6.6	
Mean (Fung.)		3.16	2.9	5.8			6.94	6.50 a	6.13		
LSD (5%) Fung.				0.75					0.52		
LSD (5%) DT						0.91					0.44
LSD (5%) F						NS					NS
LSD (5%) DT x F					1.14					0.49	
Mean DT x C	DT 1	0.95	0.67	0.98			6.34	6.87	6.51		
	DT 2	0.139	1.14	2.57			6.89	6.29	6.75		
LSD (5%) DT x C				1.53					0.71		
LSD (5%) F x C						NS					NS
LSD (5%) DT x F x C						1.93					1.04

DT (Date of transplanting): D/T 1= 16 July 2017, D/T 2= 26 July 2017
F (Fertilizer dose): F 1= 80:40:40 (NPK), F 2= 100:60:40 (NPK)
C (Chemicals (fungicides) application): C 1= Hexaconazole (Contaf 5 EC) @ 2ml a.i./L, C 2= Mancozeb (Indofil) @2.5 g a.i./L, C 3 Control

Fig. 6.14. Difference in False smut infection in Hybrid Rice in different dates of transplanting

PROGRAMME : 7

RRLRRS, Gerua

Rice (*Oryza sativa* L.) is the principal food crop of Assam and dependence on rainfall have resulted three distinct rice growing seasons *viz.*, *ahu* or autumn rice (March/April to June/July), *sali* or winter rice (June/July to November/December) and *boro* or summer rice (November/December to May/June). Low temperature at early vegetative stage in *boro* season prolonged the crop harvest and recurrent pre-monsoon flood caused heavy crop loss to *boro* and early *ahu* paddy cultivated in lowlands of Assam. Development of *boro* rice varieties of 145-160 days duration having low temperature tolerance at early vegetative stage and early *ahu* varieties of 100-120 day duration with quick vegetative growth will escape pre-monsoon flood. Similarly, winter rice varieties of 130-140 days duration having medium slender grains and submergence tolerance will perform better in rainfed lowlands of Assam. Insect-pests and diseases are important constraints to rice production in rainfed lowland ecosystem. Exploration of geographical distribution of these biotic factors and development of pest management strategies are important to schedule pest management operation in rainfed lowlands of Assam.

By utilizing local genetics resources development of suitable medium duration photo insensitive cold tolerant new rice varieties for *boro* and *ahu* season will be the major thrust area of the project. For sali/ winter season, Speciality rice of aromatic, glutinous, soft rice, medicinal rice etc needs to be developed with higher production and productivity potentials with tolerance to biotic and abiotic stress condition and expecting some new agrotechniques on Integrated Farming/ Cropping system research and to identify stress tolerant climate change resilient products for future benefit of the farming community of rainfed lowland agro ecosystem of the state.

Genetic improvement and management of rice for rainfed lowlands

Maintenance of rice germplasm

A total of 783 accessions of rice germplasm were maintained during *kharif* 2017. Observation on days to 50% flowering, plant height, number of effective tillers, panicle length and grain yield were recorded. Fifty two indigenous rice germplasm including *bao* rice, *soft* rice, aromatic (*joha*) were collected from different parts of Assam *viz.,* Morigaon, Sonitpur, Tezpur, Lakhimpur, Mazuli and Anjaw (Arunachal Pradesh).

Generation advance of segregating materials

Pedigree nursery of 124 F_7 progenies of four crosses were raised during *sali* season for development of lowland rice and F_8 seeds were advanced for further selection and evaluation. The range of yield performance of 124 breeding lines were 1008.33 kg/ha to 7441.67 kg/ha and the lines performed better than check Swarna sub-1 (6635.33 kg/ha) and CR Dhan 909 (6366.67 kg/ha) are as follows; CRL 145-34-2 (7441.67 kg/ha), CRL 145-28-1 (7358.33 kg/ha), CRL 146-35-1 (7283.33 kg/ha), CRL 145-7-1(7083.3 kg/ha), CRL 145-19-1 (7066.67 kg/ha), CRL 145-12-2 (6941.56 kg/ha), CRL 145-21-1 (6925 kg/ha), CRL 145-29-1 (6816.67 kg/ha) and CRL 145-20-1 (6743.1 kg/ha).

BC_1F_6 of 31 crosses raised for improvement of rainfed shallow lowland rice and plants were bulked for BC_1F_7.

For development of *boro* rice, 59 single plant progenies selected from 28 crosses were grown in F_8 nursery during *rabi* 2017-18, single panicle selection was performed to purify the mixture/off types and F_9 seeds were advanced for next generation.

For the development of pre-flood *ahu* rice, F_7 nursery of five crosses were raised during *ahu/autumn* 2017-18 and F_8 seeds were bulked for selection in the next generation.

Maintenance of elite breeding materials

During *sali/kharif* 2017, 27 elite breeding lines for rainfed shallow lowlands were maintained. These breeding materials were full of mixture of other lines hence single panicle selection was done and advanced for next generation.

Generation advance of segregating materials

Pedigree nursery of 258 F_3 progenies of a cross between Swarna *Sub1* x CR 1014 were raised during *sali/kharif* 2017, out of 258 lines, 61 lines were selected and advanced for the next generations. Similarly F_1

seed of seven crosses *viz.*, CR 1014/Jasmine 85, CR Dhan 310/Kalinga III, Swarna *Sub1*/Tetep, Swarna *Sub1*/Chinikamini, CR 1014/Tetep, Pusa Basmati-1/Jasmine 85 and CR Dhan/IET 23814 were raised and advanced for next generations.

Performance of CR Dhan 909 in the farmers field

CR Dhan 909 developed from the cross between Pankaj and Padumoni is a promising variety under aromatic medium slender grain category developed at RRLRRS, NRRI, Gerua (Assam). The variety was tested for the 3rd year in Darrang district of Assam during *sali/kharif* 2017. The location was village -2 No. Mazgaon. Aromatic rice variety "Ketekijoha" was used as the local check. CR Dhan 909 yielded 5.013 t/ha as gainst 4.306 t/ha of local check. This variety was also tested at ICAR-NEH Tripura centre and its performance was better than the local check.

Evaluation of breeding materials in National (AICRIP) Trials

A total of 290 entries in the following categories were tested and evaluated in RRLRRS, Gerua situation during *sali*2017-18:

Table 7.1. Evaluation of breeding materials in AICRIP trials

Sl. No.	AICRIP Trials	No. of entries	Replications	Check (Local)
1.	AVT-1	17	3	Ranjit
2.	AVT-1 ASG	9	4	Ketekijoha
3.	AVT-1 MS	26	3	Mahsuri
4.	AVT-2 IME	24	3	Naveen
5.	IVT-RSL	56	2	Chandrama
6.	AVT-1 SDW	13	3	Varshadhan
7.	NSDWSN	45	2	Varshadhan
8.	IVT-SDW	15	3	Varshadhan
9.	AVT-1 IME	26	3	Naveen
10.	IVT-DW	16	3	Kekoa bao
11.	IVT-DW	22	3	Kunkuni joha
12.	AVT-1 NIL	21	3	--

Table 7.2. Breeder and Foundation Seed production of high yielding varieties at RRLRRS, Gerua

Variety Name	Indent (in qtls)			Actual Seed Production-Shortfalls if any (in qtls)		
	DAC	StateGovt agencies	NGO, KVK, Seed Farm etc.	DAC	StateGovt agencies	NGO, KVK, Seed Farm etc.
Chandrama	30	----	---	36	---	---
Naveen	---	64	---		45	---
Abhishek	---	16	---		8	---
Sahbhagidhan	---	---	3			4
CR Dhan 310	---	---	2			4
CR Dhan 909	---	2	1			5

Survey on the incidence of major insect-pests and diseases of rice in rainfed lowlands of Assam

Survey was conducted in rainfed lowland of Kamrup, Darrang, Marigaon and Nagaon districts of Assam for recording the incidence of insect-pests and diseases on rice during *kharif* 2017. Rice leaf folder (*Cnaphalocrosis medinalis*), stem borers (*Scirpophaga incertulas* and *S. innotata*) and gundhi bug were found to be the major insect pests in surveyed areas. Brown plant hopper affected 56 ha of winter paddy in Marigaon district of Assam. Major diseases observed in farmer's field were blast, brown spot, bacterial leaf blight and sheath blight. Sporadic appearance of false smut and *bakanae* were also observed in farmer's fields in Assam.

Population dynamics of rice insect-pests in Assam

Adult stage of rice insect-pests were captured through installing three light traps in the experimental farm of RRLRRS, Gerua, Hajo, Assam during *kharif* 2017. Moth activity of rice stem borer and leaf folder started at the second week of October. Daily catches of rice stem borer reached its first peak (16 nos. of moth/trap) on 27-10-2017 and then moth population gradually declined up to 0.67 nos. of moth/trap in the second week of November before reaching its second peak 16.33 nos. of moth/trap on 24-11-2017 (Fig. 7.1). Thereafter stem borer moth population declined and maintained a low population level upto the third week of December. Daily catches of leaf folder moth in light trap found to gradually increase in the second fortnight of October and reached its peak of 4.67 moths per trap on 17-11-2017. Thereafter leaf folder moth population gradually declined till the third week of December. Daily catch of green leafhopper was fluctuating during second fortnight of October to second fortnight of November and the highest catch (9.33 per light trap) was recorded on 17-11-2017.

Date of transplanting and pest infestation in post flood situation in Assam

Rice variety Naveen was transplanted late during *kharif* 2017 from first fortnight of August to first fortnight of September in three different dates at fifteen days intervals. Rice stem borer infestation was lowest in the crop transplanted in first fortnight of August (0.49% DH) as compared to second fortnight (0.96%) and first fortnight of September (1.22%) crop (Table 7.3). Rice crop transplanted in first fortnight of September recorded the highest percentage of leaf folder folded leaves (4.75%) as compared to first (2.78%) and second fortnight of August (3.19%). Crop transplanted on first fortnight of August recorded 5.34 t/ha of yield as compared to crop transplanted on second fortnight of August(4.81 t/ha) and first fortnight of September (4.54 t/ha).

Management of rice stem borer, leaf folder and gundhi bug

Spraying of chlorantraniliprole 18.5% @ 150 ml/ha recorded the lowest 0.49 and 0.66 per cent dead heart as compared to 2.77 and 3.25 per cent in control at 45 and 60 days after treatment (DAT), respectively (Table 7.4). Application of cartap hydrochloride 4% granule @ 20kg/ha recorded the lowest 0.59 and 0.70 per cent leaf folder folded leaves at 45 and 60 DAT, respectively in comparison to 1.13 and 1.73 per cent in control plot. Use of crab trap @ 20/ha was found to be superior over all other treatments. Spraying of chlorantraniliprole 18.5% @ 150 ml/ha recorded the highest yield of 5.36 t/ha as compared to control (3.77 t/ha).

Integrated disease management

Out of seven treatments evaluated against bacterial leaf blight, application of DAP 108 g and MOP 85 g/10 m^2 nursery area before sowing, application of FYM in main field @ 1kg/m^2 and application of fertilizers @ 120 kg N/ha, 60kg P_2O_5/ha, 40 kg K_2O/ha and 25 kg $ZnSO_4$/ha recorded the lowest 30.43 per cent disease index as compared to control 36.45. Incorporation of FYM @ 1 kg/m^2 in the nursery, seed treatment with carbendazim (2g/kg), application of DAP 108 g and MOP 85 g/10 m^2 nursery area before sowing, application of FYM in main field @ 1kg/m^2, application of fertilizers @ 120 kg N/ha, 60 kg P_2O_5/ha, 40 kg K_2O/ha and 25 kg $ZnSO_4$/ha and spraying of propiconazole at booting stage recorded the lowest 26.60 per cent brown spot disease incidence as compared to 37.88% in control (Table 7.5).

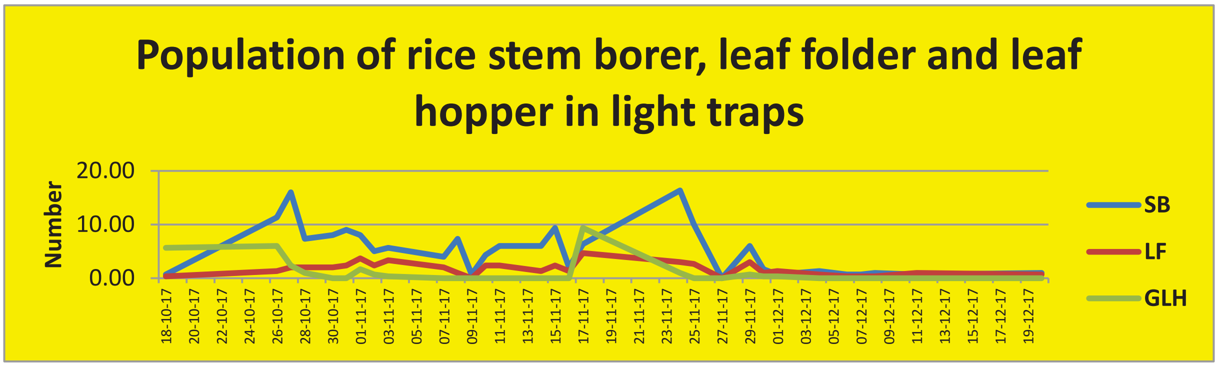


Fig. 7.1. Population of rice stem borer, leaf folder and green leaf hopper in light traps

Table 7.3. Date of transplanting and pest infestation

Date of transplanting	Per cent DH	Per cent LFFL	Yield (t/ha)
02-08-2017	0.49	2.78	5.34
16-08-2017	0.96	3.19	4.81
01-09-2018	1.22	4.75	4.54
SEd ±	0.95	0.93	0.93
CD (p = 0.05)	2.65	2.58*	2.57

Table 7.4. Management of stem borer, leaf folder and gundhi bug in rainfed lowland rice

Treatment	DH (%)		LF (%)		GB	Yield (t/ha)
	45 DAT	60 DAT	45 DAT	60 DAT		
Cartap Hydrochloride 4% granule @ 20 kg/ha	0.93	1.79	0.59	0.70	0.10	4.53
Chlorantraniliprole 18.5% @ 150 ml/ha	0.49	0.66	0.68	0.95	0.20	5.36
Scorpolure @ 20 nos./ha	0.98	1.48	0.68	1.27	0.20	4.50
Azadirechtin 0.03% @ 2 lit/ha	1.15	1.95	0.59	0.80	0.10	4.31
Cypermethrin @2 ml/lit	2.36	2.57	0.67	0.82	0.15	4.37
Malathion dust @ 20 kg/ha	2.31	2.62	0.78	1.37	0.05	4.01
Crab trap @ 20/ha	2.35	2.45	0.78	1.51	0.00	4.07
Control	2.77	3.25	1.13	1.73	0.40	3.77
SEd	0.88	0.96	0.80	0.86	0.91	0.86
CD at p = 0.05	1.82*	2.01*	1.67*	1.78*	1.89*	1.79*

Screening for Bacterial blight resistance

Out of 1019 entries screened against bacterial leaf blight during *kharif* 2017, 682 entries showed tolerant reaction and 289 were found to be susceptible and 48 were highly susceptible to Bacterial leaf blight.

Monitoring field virulence in *Xanthomonas oryzae pv. oryzae*

Twenty four entries were artificially inoculated with virulent Gerua isolate of *Xanthomonas oryzae pv. oryzae* during *kharif* 2017. Four entries were found to be tolerant, 17 were susceptible and three were highly susceptible to Gerua isolate of *Xanthomonas oryzae pv. oryzae.*

Bacterial Leaf Blight and Brown Spot disease on paddy sown on different dates

Rice variety Naveen was sown in three different dates during *kharif* 2017. Per cent disease index (PDI) of bacterial leaf blight and brown spot were the highest in late planting crops as compared to early and normal sown crop (Table 7.6).

Table 7.5. Management of bacterial leaf blight and brown spot

Treatment	Per cent disease incidence	
	Bacteria leaf blight	Brown spot
Incorporation of FYM @ 1 kg/m^2 in the nursery, application of FYM during land preparation of main field @ 1kg/m^2 + *Tricoderma* (2g/kg of FYM) and spraying of neem @ 3ml/lt at tillering and booting stage.	32.98	35.48
Application of DAP 108 g and MOP 85 g/10 m^2 nursery area before sowing, application of FYM in main field @ 1kg/m^2 and application of fertilizers @ 120 kg N/ha, 60kg P_2O_5/ha, 40 kg K_2O/ha and 25 kg $ZnSO_4$/ha.	30.43	36.38
Seed treatment with carbendazim (2g/kg), application of DAP 108 g and MOP 85 g/10 m^2 nursery area before sowing, application of fertilizers @ 120 kg N/ha, 60kg P_2O_5/ha, 40 kg K_2O/ha and 25 kg $ZnSO_4$/ha, application of cartap hydrochloride at 15 DAT and spraying of propiconazole at booting stage	33.55	27.98
Incorporation of FYM @ 1 kg/m^2 in the nursery, seed treatment with carbendazim (2g/kg), Application of DAP 108 g and MOP 85 g/10 m^2 nursery area before sowing, application of FYM in main field @ 1kg/m^2, application of fertilizers @ 120 kg N/ha, 60kg P_2O_5/ha, 40 kg K_2O/ha and 25 kg $ZnSO_4$/ha and spraying of propiconazole at booting stage	36.35	26.60
Incorporation of FYM @ 1 kg/m^2 in the nursery, seed treatment with carbendazim (2g/kg), Application of DAP 108 g and MOP 85 g/10 m^2 nursery area before sowing, application of FYM during land preparation of main field @ 1kg/m^2 + *Tricoderma* (2g/kg of FYM), application of fertilizers @ 120 kg N/ha, 60kg P_2O_5/ha, 40 kg K_2O/ha and 25 kg $ZnSO_4$/ha, application of cartap hydrochloride at 15 DAT and spraying of propiconazole at booting stage.	31.70	32.75
Incorporation of FYM @ 1 kg/m^2 in the nursery, seed treatment with carbendazim (2g/kg), Application of DAP 108 g and MOP 85 g/10 m^2 nursery area before sowing, application of FYM during land preparation of main field @ 1kg/m^2 + *Tricoderma* (2g/kg of FYM), application of fertilizers @ 120 kg N/ha, 60kg P_2O_5/ha, 40 kg K_2O/ha and 25 kg $ZnSO_4$/ha, cleaning of bunds, application of fertilizers @ 90 kg N/ha, 45kg P_2O_5/ha, 30 kg K_2O/ha and 18 kg $ZnSO_4$/ha, application of cartap hydrochloride at 15 DAT and spraying of propiconazole at booting stage.	32.18	27.58
Control	36.45	37.88

Table 7.6. Per cent disease index of BLB and Brown Spot on paddy sown on different dates

Date of observation	Crop stage	Per cent disease index					
		Early sowing		Normal sowing		Late sowing	
		BLB	BS	BLB	BS	BLB	BS
08-09-2017	Vegetative	0.00	11.11	0.00	0.00	0.00	0.00
18-09-2017	Vegetative	0.00	16.12	0.00	11.67	0.00	0.00
12-10-2017	Flowering	10.56	17.23	0.00	12.78	0.00	6.12
25-10-2017	Flowering	36.11	30.00	0.00	28.34	25.55	20.56
09-11-2017	Grain formation	36.11	31.11	31.11	28.89	40.30	35.00
22-11-2017	Maturity	0.00	0.00	35.56	31.67	42.22	36.67

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Gautam Priyanka, Lal B, Nayak AK, Tripathi R, Shahid M, Baig MJ, Maharana S, Raja R, Panda BB, Mohanty S, Chatterjee D, Guru PK and Kumar U. 2017. Nutrient Management for Enhancing Submergence Tolerance in Rice. NRRI Research Bulletin No. 13, Cuttack, India.

Radio/TV talks

Dr. P Samal delivered a radio talk on '*How to get better price in rice marketing*' (ଧାନ ଚାଷରେ ଉପଯୁକ୍ତ ବଜାର ମୂଲ୍ୟ ପାଇବେ କିପରି ?)broadcasted by AIR, Cuttack on 29 May 2017.

Dr. Yogesh Kumar delivered live TV talk on 'Direct seeding Rice and nursery preparation in Jharkhand' on 25 May 2017 which was telecasted through Krishidarshan programme, Doordarshan Ranchi, Jharkhand.

Dr. Bibhash Verma delivered a radio talk at Akashvani, Hazaribagh on the topic "Importance of soil testing and soil health card".

Dr. SK Mishra delivered a talk on the topic "ମାତ୍ରାଧିକ କୀଟନାଶକ ପ୍ରୟୋଗର ଅପକାରିତା" (Demerits of Excessive use of Pesticides) which was broadcasted by All India Radio, Cuttack on 29 November 2017.

Dr. RK Mohanta delivered a radio talk on "ଗୋରୁଗାଈଙ୍କ ପାଇଁ ଖଣିଜ ଲବଣ ଓ ଲୁଣର ଆବଶ୍ୟକତା" (Importance of mineral mixture and common salt for dairy animals) which was broadcasted by AIR, Cuttack on 28 December 2017.

Dr. Sudhanshu Shekhar delivered a TV talk on "Care and management of milch cattle in winter season" on 3 February 2018.

Mrs. Chanchila Kumari gave a TV talk on "Nutrional Kitchen Garden" on 3 February 2018.

Shri Manish Kumar delivered a TV talk on "Scientific cultivation of chick pea" on 3 February 2018.

Shri Rupesh Ranjan delivered a TV talk on the topic "Poly mulching in winter vegetable" on 3 February 2018.

Events and Activities

IJSC, IMC, IRC, RAC and SAC Meetings

Institute Joint Staff Council

3rd IJSC Meeting

The 3rd Institute Joint Staff Council Meeting was held on 30 October 2017 at NRRI, Cuttack under the chairmanship of Dr. H Pathak, Director. The members present during the meeting were Dr. ON Singh, Head, Crop Improvement Division, Dr. (Mrs.) S Samantaray, PS, Crop Improvement Division, Dr. SD Mohapatra, PS, Crop Protection Division, Shri SK Das, F&AO, Shri NC Parija, AAO (Technical & Secretary official side); Shri RC Pradhan, CJSC Member; Shri SK Sahoo, Secretary staff side; Shri P Moharana, STA; Shri DR Sahoo, STA; Shri B Pradhan, Technician; Shri KC Ram, SSS and Shri MC Nayak, SSS. Various administrative and financial issues were discussed and modalities to solve them were planned.

Institute Management Committee

IMC Meeting

The 30th Institute Management Committee (IMC) meeting of the NNRI was held on 30 January 2018 at Cuttack under the chairmanship of Dr. Himanshu Pathak, Director, NRRI. The members present were Dr. LM Gadanayak, Dean of Agriculture, OUAT, Bhubaneswar, Dr. SG Sharma, PS & Head, Crop Physiology & Biochemistry Division, NRRI, Dr. (Mrs.) Mayabini Jena, PS & Head, Crop Protection Division, NRRI, Cuttack, Dr. CS Kar, PS, CRIJAF, Barrackpore, Kolkata, Dr. Shiv Sewak, PS, IIPR, Kanpur, Dr. AK Nayak, PS & Head, Crop Production Division, NRRI, Cuttack, Dr. ON Singh, PS & Head, Crop Improvement Division, NRRI, Cuttack, Dr. P Samal, PS & Head, Social Science Division, NRRI, Cuttack, Shri SK Das, FAO, NRRI, Cuttack, Shri SK Mathur, AO, NRRI, Cuttack, Shri BK Sahoo, AO, NRRI, Cuttack and Shri KC Joshi, CAO, NRRI, Cuttack as Member Secretary also attended the meeting. Matters related to infrastructure development and budgetary provisions for construction works were discussed.

Research Advisory Committee

23rd RAC Meeting

Dr. H Pathak, Director, NRRI presenting the highlights of the research achievements and infrastructural developments of the institute before RAC

The 23rd Meeting of the Research Advisory Committee (RAC) of NRRI was held at NRRI, Cuttack from 13 to 14 October 2017 under the chairmanship of Prof. SK Datta. Other members who attended the meeting were Dr. DK Mishra, Dr. AR Sharma, Dr. JS Bentur, Dr. PK Mohapatra, Dr. RP Singh 'Ratan' and Dr. IS Solanki, ADG (FFC). Dr. SR Voleti, Principal Scientist, IIRR attended the meeting as Special Invitee. The Chairman along with the members conducted a pre-meeting briefing with the Director and Heads of Division followed by an open session. Dr. H Pathak, Director, NRRI presented the highlights of the research achievements and infrastructural developments for the last one year. Dr. JN Reddy, Member Secretary presented the details of the action taken report (ATR) on the recommendations of the 22nd RAC. Research and extension achievements made between November 2016 and September 2017 were presented by different Program Coordinators (Dr. ON Singh, Dr. AK Nayak, Dr. (Mrs.) M Jena, Dr. (Mrs.) P Swain and Dr. P Samal). This was followed by brief presentations by Dr. D Maiti, Officer-in-Charge, NRRI Regional Station, Hazaribagh, Jharkhand, Dr. R Bhagawati, Officer-in-Charge, NRRI Regional Station, Gerua, Assam and Dr. KR Rao, Officer-in-Charge, NRRI Regional Station, Naira, Andhra Pradesh on overall activities of the respective regional stations. Mr. SK Das, Finance and Accounts Officer presented details of budget and administration related issues before the RAC. The RAC members visited different experimental fields and facilities in the divisions and had discussion with the scientists of concerned disciplines.

Institute Research Council

36th IRC Meeting

The 36th meeting of the Institute Research Council (IRC) was held at NRRI, Cuttack from 19 to 23 June 2017 for presentation of results of 2016-17 and work plan for 2017-2020 under the chairmanship of Dr. H Pathak, Director and Chairman, IRC. In the opening session, Dr. (Mrs.) Mayabini Jena, the secretary, IRC welcomed the Director and the other members of the house including all newly joined scientists. The house greatly acknowledged the cooperation and contribution of Dr. BN Sadangi, Dr. RK Sarkar and Dr. SP Patel to rice research. The Director, NRRI extended a warm welcome to the external expert members, Dr. JK Roy, Dr. D Panda, Dr. LK Rath, Shri SK Nayak and Dr. C Satpathy. Project-wise presentation of results of all 40 projects for the year 2016-17 was made by the concerned PIs. The IRC as well as the expert members evaluated the projects programme-wise through minute observations and active interaction. The meeting was completed with a business session at the end.

SAC Meeting of Krishi Vigyan Kendras

KVK, Cuttack

The 19th Scientific Advisory Committee meeting of Krishi Vigyan Kendra Cuttack at Santhapur was held on 20 April 2018 at its campus under the Chairmanship of Dr. H Pathak, Director, ICAR-NRRI, Cuttack. The meeting was attended by the members, invited guests, and SMSs of KVK Cuttack.

Dr. DR Sarangi, SMS (Soil Sc.) & OIC, KVK Cuttack welcomed the chairman and the members. The OIC presented the Action Taken Report of last SAC meeting along with a brief presentation of report on achievements of KVK Cuttack. The activities namely, trainings, OFTs, FLDs etc., taken up during 2017-18 and proposed activities of 2018-19 in the area of Soil Science, Plant Protection, Horticulture and Animal Science were presented by the concerned Subject Matter Specialists of the KVK. After presentation discussion was held and suggestions for improvement were sought.

Director, NRRI addressing during SAC Meeting of KVK, Cuttack

The chairman made his critical observations after listening to each member present in the meeting. The important suggestions that emerged during the proceeding were recorded. At the end of the meeting, Dr. TR Sahoo, SMS (Horticulture) proposed vote of thanks.

KVK, Koderma

The Scientific Advisory Committee (SAC) meeting of Krishi Vigyan Kendra, Koderma, Jharkhand was held at KVK, Koderma on 27 February 2018 and presided over by Dr. H Pathak, Director, ICAR-NRRI. The meeting was attended by Scientists from ICAR-CRURRS, (Hazaribagh), ICAR-IINRG (Ranchi), progressive farmers, bank, line departments and NGO representatives. The meeting started with welcome address by Dr. Dipankar Maiti, OIC, CRURRS, Hazaribagh who also highlighted the salient achievements of the KVK, Koderma. Dr. H Pathak, Director, ICAR-NRRI advised that the KVK should give emphasis on documentation of the various KVK activities, validation of research on local technology and transfer of technologies of local importance to the block and district administration for further dissemination. In the technical session, Smt. Chanchila Kumari, (I/c) PC, KVK, Koderma presented Annual Progress report and Action Plan (2018-19) of KVK and Dr. S. Shekhar, PI, NICRA presented salient achievements of NICRA project. SAC meeting was preceded by Scientist-farmer interaction and an exhibition which was attended by more than two hundred farmers and dozens of experts from scientific community and line department.

Director, NRRI addressing during SAC Meeting of KVK, Koderma

Participation in Symposia/ Seminars/ Conferences/ Trainings/ Visits/ Workshops

Sl. No.	Particulars	Date	Participants
1.	52nd Annual Rice Group Meeting at Assam Agricultural University, Jorhat, Assam	8 to 11 April 2017	Drs. H Pathak, Mayabini Jena, PC Rath, AK Mukherjee, S Lenka D Maiti, NP Mandal, CV Singh, SSC Patnaik and S Bhagat
2.	Zonal Research and Extension Advisory Council Meeting at RRTTS, Dhenkanal, Mahisapat	13 April 2017	Smt. Sujata Sethy and Dr. DR Sarangi
3.	Zonal Workshop of KVKs of Zone II at ICAR-CIARI Port Blair, Andaman & Nicobar Islands	14 to 16 April 2017	Mrs. Chanchila Kumari
4.	Krishi Mela at Motihari, Bihar	13 to 19 April 2017	Shri Rupesh Ranjan
5.	Kisan Mela organized by ICAR-RCER, Patna at Motihari, Bihar	15 to 17 April 2017	Dr. Yogesh Kumar
6.	As DST team member to ICRISAT, Hyderabad	17 April 2017	Dr. H Pathak
7.	Review meeting on KVK functioning at OUAT, Bhubneswar	17 April 2017	Dr. DR Sarangi
8.	Stakeholders meet on Pilot project Krishak Samridhi-Cuttack district	18 April 2017	Dr. DR Sarangi
9.	INSA meeting at New Delhi	24 to 25 April 2017	Dr. H Pathak
10.	ICAR Review Committee meeting at IARI, New Delhi	29 April 2017	Dr. H Pathak
11.	STRASA meeting at New Delhi	30 April 2017	Dr. H Pathak
12.	Phase 3 Year 3 Review and Annual Planning Workshop for South Asia of STRASA at NASC Complex, Pusa, New Delhi	30 April to 2 May 2017	Drs. D Maiti and NP Mandal
13.	Review & Planning Workshop of ICAR-IRRI collaborative EC-IFAD funded project on 'Improved crop management and strengthened seed supply system for drought prone rainfed lowlands in South Asia' at New Delhi	3 May 2017	Drs. Sanjoy Saha and CV Singh
14.	International Conference on “Climate change and Adaptation: Empowering small holders and ensuring food security” at TNAU, Chennai	11 May 2017	Dr. H Pathak
15.	National Conference on “Sustainable Development Goals: Preparedness and Role of Indian Agriculture” at NASC Complex, New Delhi	12 May 2017	Dr. H Pathak

16.	Basmati Export Development Foundation at Modipuram, Uttar Pradesh	18 May 2017	Dr. H Pathak
17.	1st meeting of Global Technology Watch Group (GTWG)-Sustainable Agriculture Sector at TIFAC, New Delhi	19 May 2017	Dr. H Pathak
18.	National Workshop on 'Rice Varietal Diffusion in India: Estimation, Problems & Prospects' at MANAGE, Hyderabad	19 May 2017	Dr. SK Mishra
19.	'Review & Planning Workshop' of Odisha-IRRI collaborative project on 'Increasing productivity of rice-based cropping systems and farmers' income in Odisha' at Bhubaneswar	23 May 2017	Dr. Sanjoy Saha
20.	State Level National Food Security Mission (NFSM) working committee meeting at Project Bhawan, Dhurwa, Ranchi	26 May 2017	Dr. NP Mandal
21.	DLRAC RSETI Koderma meeting at conference hall of DC office Koderma on 8 May 2017 and KVK, review meeting at BAU, Ranchi	30 May 2017	Mrs. Chanchila Kumari
22.	Workshop of NICRA and presented annual report 2016-2017 and annual action plan-2017-18 at KVK, Coochbihar, West Bengal	1 June 2017	Dr. S Shekher
23.	World environment Day celebration organized by Orissa Environmental Society, Bhubaneswar	5 June 2017	Dr. BC Patra
24.	Rural Advisory Committee (RAC) meeting of Doordarshan Kendra at Bhubaneswar	7 June 2017	Dr. SK Mishra
25.	One day review-cum-project formulation meeting for KVKs of Odisha for ARYA Project at OUAT, Bhubaneswar organized by ATARI, Kolkata	8 June 2017	Dr. DR Sarangi
26.	National Seminar on "Nutrients and pollutants in soil-plant-animal-human continuum for sustaining food and nutritional security-way forward" at BCKV, Kalyani, West Bengal	9 to 10 June 2017	Dr. H Pathak
27.	Second meeting of the National Steering Committee of the GTWG project at Technology Bhavan, New Delhi	12 June 2017	Dr. H Pathak
28.	RAC meeting at IIRR, Hyderabad	13 June 2017	Dr. H Pathak
29.	State level review workshop for KVKs of Odisha at OUAT, Bhubaneswar	12 to 13 June 2017	Smt. Sujata Sethy and Dr. M Chourasia
30.	Visited KVK Cuttack and reviewed the on campus activities and chalked out the plan for 2017-18	15 June 2017	Dr. H Pathak

31.	State Steering Committee meeting of Department of Agriculture, Govt. of West Bengal for BGREI Program at Kolkata	27 June 2017	Dr. Sanjoy Saha
32.	Meeting on ICAR-IRRI Work-Plan at IIRR, Hyderabad	28 June 2017	Dr. H Pathak
33.	Institute Management Committee (IMC) meeting of ICAR-CRIJAF at Barrackpore as an external member	6 July 2017	Dr. SK Mishra
34.	Final viva voce examination and evaluated of Ph.D. thesis at North Cap University, Gurgaon	10 July 2017	Dr. H Pathak
35.	Stakeholder Consultation Workshop and 2nd meeting of GTWG-Sustainable Agriculture (GTWG-SA) at ICAR-NAARM, Hyderabad	13 to 14 July 2017	Dr. H Pathak
36.	30th 'Extension Education Council Meeting' at BAU, Ranchi	14 July 2017	Dr. CV Singh
37.	ICAR Foundation Day, Award Ceremony-2017 and Directors' Conference at Pusa, New Delhi	16 July 2017	Dr. H Pathak
38.	Meeting at Nepal House, Doranda with Secretary, Jharkhand Government	17 July 2017	Smt. Chanchila Kumari
39.	TAC/DCSW meeting of Biological Sciences Division at Indian Statistical Institute, Kolkata	21 July 2017	Dr. H Pathak
40.	Sectional Committee-XII meeting of INSA at New Delhi	24 to 25 July 2017	Dr. H Pathak
41.	Visited Mayurbhanj district of Odisha and reviewed various activities under BGREI programme	24 to 25 July 2017	Dr. SK Mishra
42.	CSISA workshop on ML&E at ATARI, Kanpur	26 to 27 July 2017	Dr. DR Sarangi
43.	Assessment committee on CAS as an Expert member at ICAR-CRIJAF, Kolkata	27 July 2017	Dr. (Mrs.) Mayabini Jena
44.	AGRI UDAAN launching programme at New Delhi	4 August 2017	Dr. H Pathak
45.	Visited to NRRI Regional Station RRLRRS, Gerua at , Assam	11 August 2017	Dr. H Pathak
46.	Visited four districts of Jharkhand, namely, Ranchi, Gumla, Palamau and Garhwa in connection with monitoring and technical backstopping of cluster demonstrations under varietal popularization activity of the institute	8 to 11 August 2017	Dr. SK Mishra and Dr. B Mondal
47.	Oral Defense Evaluation of Ms. Ashmita Bharali at Tezpur University, Assam	12 August 2017	Dr. H Pathak

48.	Workshop on Soil Testing Kit at WBUAFS, Kolkata	12 August 2017	Dr. DR Sarangi
49.	Workshop on 'Farmers FIRST Project' at ATARI, Kolkata	21 August 2017	Dr. Lipi Das
50.	EFC/SFC meeting of Rice, Wheat, and Barley Improvement Scheme (2017-2019) at ICAR, Krishi Bhawan, New Delhi	22 August 2017	Dr. H Pathak
51.	Workshop on "Transformative Rice Breeding (TRB)" jointly organized by NRRI, Cuttack and IRRI, Philippines at NRRI, Cuttack	23 August 2017	Dr. NP Mandal and Dr. Somnath Roy
52.	National Workshop on "Gender Budgeting in Rural Development" at National Institute of Rural Development & Panchayati Raj (NIRD&PR), Hyderabad	29 to 31 August 2017	Dr. Lipi Das
53.	State Level Review and Planning Workshop of Stakeholders on '*Key SI Technologies in Odisha*' organized by CSISA, Bhubaneswar	30 August 2017	Dr. DR Sarangi
54.	Ever Greening India meeting conducted by CGIAR-ICRAF (World Agro forestry Center) at NASC complex, New Delhi as special invitee	31 August to 1 September 2017	Dr. D Maiti
55.	A Think Tank meeting on the topic "Sustainable Agriculture and Climate Change" at Raj Bhavan, Bhubaneswar	5 September 2017	Dr. H Pathak
56.	National Seminar on "Climate Change: Impact on aquatic environment and fish health at CIFA, Bhubaneswar	6 September 2017	Dr. H Pathak
57.	Selection Committee meeting at ASRB, New Delhi	8 September 2017	Dr. H Pathak
58.	NRRI Farmer FIRST programme Training-cum-Workshop at Satyabhamapur, Cuttack	8 September 2017	Drs. SK Mishra and Lipi Das
59.	Assessment committee (ASRB) for promotion of Sr. Scientist to Pr. Scientist (Entomology) as the DG's Nominee	12 to 13 September 2017	Dr. (Mrs.) Mayabini Jena
60.	SFC/EFC meetings for consideration of Schemes of DARE/ICAR for the period (2017-2020) at ICAR, Krishi Bhawan, New Delhi	14 September 2017	Dr. H Pathak
61.	Final viva voce examination of Ph.D. student at IARI, New Delhi	18 September 2017	Dr. H Pathak
62.	CEC meeting of Animal Nutrition Society of India at NDRI, Karnal	18 September 2017	Dr. RK Mohanta

63.	District level convergence meeting on implementation of Mission Antodaya Gram Samridhi Evam Swachata Pakwada	21 September 2017	Dr. DR Sarangi
64.	Workshop on cluster frontline demonstration on oilseeds and pulses at OUAT, Bhubaneswar	22 September 2017	Dr. DR Sarangi
65.	Institute Management Committee (IMC) meeting of ATARI at Kolkata as an external member	26 September 2017	Dr. SK Mishra
66.	Indo-UK NEWS project meeting on 'increasing N use efficiency in rice-wheat cropping systems' at NASC Complex, New Delhi	3 to 4 October 2017	Dr. H Pathak
67.	Selection Committee Meeting at ASRB, New Delhi	5 October 2017	Dr. H Pathak
68.	3rd meeting of reconstituted DST Expert Committee (EC) under CCP-SPLICE Division at IIT Delhi, New Delhi	4 to 6 October 2017	Dr. AK Nayak
69.	State Coordination Committee Meeting on "Doubling Farmers Income" at Krishi Bhawan, New Delhi	10 October 2017	Dr. H Pathak
70.	"World Food Day" celebration organized by Orissa Krushak Samaj at Bhubaneswar	16 October 2017	Dr. SK Mishra
71.	Selection Committee Meeting at ASRB, New Delhi	17 October 2017	Dr. H Pathak
72.	Consultation workshop on "Building NRAA as a knowledge platform for the rainfed systems in the country" at NASC Complex, Pusa New Delhi	25 October 2017	Dr. R Tripathi
73.	Training-cum-workshop for FFT partner at IARI, New Delhi	23 to 26 October 2017	Dr. Lipi Das
74.	Review meeting at Sikkim University, Gangtok related to twinning mode DBT project	25 to 28 October 2017	Drs. P Panneerselvam and U Kumar
75.	National Consultation Meet on "Faster reach of innovations from aquaculture research through media: A science communication perspective" organized by ICAR-CIFA at Bhubaneswar	27 October 2017	Dr. SK Mishra
76.	Goal Oriented Project Planning Workshop for the Pilot Project Krishak Samridhi in Hotel Promad, Cuttack	27 October 2017	Dr. DR Sarangi
77.	Tuber Crops Technology Conclave & Agri-startup Meet 2017 and Centre-State Interface Meet" to enhance productivity of rice and horticultural crops at Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram	27 to 28 October 2017	Dr. BC Patra
78.	Field demonstration on use of microbial consortium for nutrient and pest management for creation of awareness on farming community at Namin village, East Sikkim	28 October 2017	Dr. P Panneerselvam

79.	RASSA National Convention-cum-Seminar on "Doubling Farmers' income & Farm Profitability by 2022" at Babasaheb Bhimrao Ambedkar University (BBAU), Lucknow, U.P.	28 to 29 October 2017	Mrs. Chanchila Kumari
80.	Workshop on Preventing Grain Losses along with 60 farmers at OUAT, Bhubaneswar	29 October 2017	Dr. M Chourasia and Dr. RK Mohanta
81.	Journal Score Committee Meeting as Member Secretary at NASC Complex, New Delhi	2 November 2017	Dr. H Pathak
82.	State Level Coordination Committees Meeting for Doubling Farmers' Income at NASC Complex, New Delhi	3 November 2017	Dr. H Pathak
83.	Crop Cutting -cum- Field Day on Rice programme in Chundri village of Ghaghra block in Gumla district of Jharkhand	3 November 2017	Drs. GAK Kumar, SK Mishra, CV Singh, SM Prasad, NN Jambhulkar, and Somnath Roy
84.	Meeting of Agri Cabinet as a Committee of Cabinet at Secretariat, Bhubaneswar	6 November 2017	Dr. H Pathak
85.	Review-cum-Planning Workshop on Pulse Seed Hub Programme at IIPR, Kanpur	7 November 2017	Dr. M Chourasia
86.	Stakeholders meeting under DEVIL project at Coimbatore and nearby villages	7 to 8 November 2017	Dr. Md Shahid and R Tripathi
87.	Review meeting on NASF project, TNAU, Coimbatore	7 to 9 November	Drs. P Bhattacharyya and U Kumar
88.	Short course on 'Tools on Monitoring, Evaluation and Impact Assessment of Rainfed Technologies and Agricultural Development Programmes' at ICAR-CRIDA, Hyderabad	1 to 10 November 2017	Dr. Biswajit Mondal
89.	8th National Seminar on "Potential, Prospects and Strategies for Doubling Farmer's Income: Multi-stakeholder Convergence" Organized by Mobilization at College of Veterinary Science, Assam	9 to 11 November 2017	Mr. Rupesh Ranjan
90.	58th AMI conference held at Baba sahib Bhimrao Ambedkar University, Lukhnow	16 to 19 November 2017	Dr. P Panneerselvam and U Kumar
91.	NFSM meeting at Project Bhawan, Dhurwa, Ranchi	20 November 2017	Dr. SM Prasad
92.	'India Rice Conclave 2017' at Vijayawada, Andhra Pradesh	22 to 23 November 2017	Dr. Biswajit Mondal
93.	31st National Conference on Agricultural Marketing at NCDS, Bhubaneswar	23 to 24 November 2017	Dr. P Samal

94.	National Conference of Plant Physiology-2017 on "Emerging role of plant Physiology for food security and climate resilient Agriculture" at IGKV, Raipur	23 to 25 November 2017	Drs. P Swain, MJ Baig, K Chakraborty and D Bhaduri
95.	Delivered a lecture on "Science and Technology for Environmental Security" at KIIT University, Bhubaneswar	26 November 2017	Dr. H Pathak
96.	19th Odisha Bigyan O Paribesh Congress at KIIT, Bhubaneswar	25 to 26 November 2017	Dr. DR Sarangi and Dr. RK Mohanta
97.	Crop Cutting-cum-Field Day on Rice programme in Anuapada village of Derabis block in Kendrapara district of Odisha	6 December 2017	Drs. P Samal, NC Rath SK Mishra and B Mondal
98.	Interactive Seminar on the Foresight Agrimonde-Terra for 2050 at NASC Complex, New Delhi	7 December 2017	Dr. H Pathak
99.	National Level Symposium on "Climate Smart Agriculture-A Key to Livelihood Security" at Institute of Agricultural Science, University of Calcutta, Hazra Road, Kolkata	9 to 11 December 2017	Dr. H Pathak
100.	Special Symposium on "Soil and Water Management Innovations towards Doubling the Farmers' Income" at ISSS, Kolkata	12 December 2017	Dr. H Pathak
101.	44th Junior National Kabaddi Championship as Guest of Honour accompanied by Dr. RK Sahu, Chairman, Sports and Shri SK Das, F&AO at Jawaharlal Nehru Indoor Stadium, Cuttack	13 December 2017	Dr. AK Nayak
102.	NAAS meeting at NASC Complex, New Delhi	13 to 14 December 2017	Dr. H Pathak
103.	Conservation agriculture, nutrient and energy management-inn ovative water and nutrient management technologies for reducing GHG emissions in paddy at Mahatma Gandhi Mission College Complex, Aurangabad	15 December 2017	Dr. H Pathak
104.	DPC meeting of scientists as DG'S nominee at ICAR Research Complex for NEH Region, Barapani, Shillong	15 December 2017	Dr. BC Patra
105.	Participated and delivered a talk on the topic "Scientific methods of rice cultivation for higher income" to over thousand farmers/ farmwomen during the Silver Jubilee celebration of Balasore Social Service Society (BSSS) at Balasore, Odisha	27 December 2017	Dr. SK Mishra
106.	Centenary Conference of the Indian Economic Association at Acharya Nagarjuna University, Guntur, A.P.	27 to 30 December 2017	Dr. P Samal

107.	'First National Conference of Society of Krishi Vigyan' at ICAR-CIFA, Bhubaneswar	5 to 7 January 2018	Drs. TR Sahoo and M Chourasia
108.	Review meeting for CFLD on Oilseeds and Pulses at CPRS Campus Patna	8 to 9 January 2018	Smt. Chanchila Kumari
109.	National conference on "Dairy symposium–Feed the Rumen microbes First" at Kolkata on 10 January 2018 and Review workshop of NICRA (2017-18) at Nimpith KVK, W.B.	13 to 15 January 2018	Dr. Sudhanshu Shekhar
110.	4th meeting of GTWG-Sustainable Agriculture at New Delhi	19 January 2018	Dr. H Pathak
111.	CAFT training programme on "Soil management approaches for climate mitigation in sustainable agriculture system" at JNKVV, Jabalpur	9 to 29 January 2018	Dr. DR Sarangi
112.	National conference on Livelihood and Food Security (LFS-2018) organized by Society for Agriculture Innovation and Development Ranchi, held at Bihar Animal Science University, Patna, Bihar	27 to 28 January 2018	Dr. Sudhanshu Shekhar
113.	"1st International Extension Congress-2018" organized by Orissa Society of Extension Education at ICAR-CIWA, Bhubaneswar	1 to 3 February 2018	All scientists of Social Science Division attended
114.	40th Annual Central Sri Ramakrishna Kisan Mela and participated in the Kisan Gosthi at KVK Demonstration Farm Getalsud, Angara, Ranchi	1 February 2018	Dr. BC Verma
115.	Capacity building programme for respective SMSs at WBUA&FS, Kolkata	1 to 6 February 2018	Drs. TR Sahoo, M Chourasia and RK Mohanta
116.	"3rd ARRW International Symposisum-2018" organized by Association of Rice Research Workers at ICAR-NRRI, Cuttack	6 to 9 February 2018	All scientists attended and presented paper
117.	Stakeholders Consultation Workshop for sustainable agriculture in NE Region under Global Technology Watch Group project on Climate Change at Guwahati	15 to 17 February 2018	Scientist of RRLRRS Gerua
118.	Interface Programme on "Doubling the Farmers Income" at ICAR-CPCRI Research Centre, Kahikuchi, wherein NRRI varieties suitable for Assam were demonstrated	19 February 2018	Dr. K Saikia and Dr. SK Ghritlahre
119.	training program on "Analysis of experimental data" organized by ICAR-National Academy of Agriculture Research Management, Rajendranagar, at Hyderabad	19 to 24 February 2018	Shri Rupesh Ranjan

120.	National Agronomy Congress-2018 on "Redesigning agronomy for nature conservation and Economic Empowerment" held at G.B.P.U.A.T, Pantnagar	20 to 22 February 2018	Dr. Sudhanshu Shekhar
121.	National Annual Review Workshop of Farmers FIRST programme at IARI, New Delhi	21 to 22 February 2018	Dr. Lipi Das
122.	Review Workshop on CFLD for KVKs of Odisha at SAMETI, RK Mission, Narendrapur, West Bengal	24 February 2018	Dr. TR Sahoo
123.	11th Institute Management Committee (IMC) meeting of ICAR-ATARI, Kolkata as a member	26 February 2018	Dr. SK Mishra
124.	Meeting for GCRF South Asia Nitrogen Hub at IARI, New Delhi	7 March 2018	Dr. H Pathak
125.	AICRIP data analysis work at ICAR-IIRR, Hyderabad	5 to 9 March 2018	Dr. NN Jambhulkar
126.	Director's Conference at ICAR, Krishi Bhawan, New Delhi	8 to 9 March 2018	Dr. H Pathak
127.	Krishi Unnati Mela along with ten farmers and farm women at IARI, New Delhi	15 to 18 March 2018	Dr. Lipi Das
128.	'Biennial National Conference of KVKs' at IARI, New Delhi	15 to 17 March 2018	Dr. DR Sarangi and Smt. Chanchila Kumari
129.	Indian Science Congress at Manipur University, Imphal	18 to 19 March 2018	Dr. H Pathak
130.	An International Conference on "Novel Application of Biotechnology in Agriculture Sector: Towards Achieving Sustainable Development Goal-2018" organized by BHU-IAS Varanasi	20 to 21 March 2018	Dr. SK Ghritlahre
131.	National Seminar on Water and Soil Management Approaches for Climate Smart Agriculture at BHU, Varanasi	23 March 2018	Dr. H Pathak
132.	A Policy Dialogue on 'Innovations in Ensuring Remunerative Prices (MSP) to Farmers: Challenges & Strategies' at NASC Complex, Pusa, New Delhi which was organized by IFPRI, South Asia and presented a paper *viz.,* 'Ensuring Remunerative Price to Rice Farmers of India'	23 March 2018	Dr. P Samal

Participation in Exhibition

The institute participated and displayed its exhibits in the following events for showcasing the NRRI technologies.

Inaugural function of the state of the art 'International Research Centre for Foot and Mouth Disease', at Arugul, Bhubaneswar on 1 April 2017. Dr. SK Mishra, PS, Dr. SD Mohapatra, PS, Dr. AK Mukherjee, PS, Shri P Jana, ACTO, Shri B Behera, TO, Shri BD Ojha, STA and Shri AK Parida, STA presented the institute.

Odisha State Level Agriculture Fair 'Odisha Krushi Mahotsav- 2017' at Bijupatnaik Ground, Baramunda, Bhubaneswar from 10 to 13 April 2017. Dr. SK Mishra, PS, Shri P Jana, ACTO, Shri BD Ojha, STA, Shri DR Sahoo, STA, Shri AK Parida, STA and Smt. Gayatri Sinha, STA presented the institute.

71st Foundation Day and Dhan Diwas at NRRI, Cuttack on 23 April 2017. Shri P Jana, ACTO, Shri AK Parida, STA and Smt. Gayatri Sinha, STA presented the institute.

World Food Day organized by the Orissa Krushak Samaj (OKS) in the premises of the Institute of Engineers, Sachivalaya Marg, Bhubaneswar on 16 October 2017. Dr. SK Mishra, PS; Shri DR Sahoo, STA; Smt. Gayatri Sinha, STA and Shri SK Tripathy, TA represented the institute.

Mahila Kisan Diwas and World Food Day organized by ICAR-CIWA, Bhubaneswar on 16 October 2017. Dr. Lipi Das, PS; Shri P Jana, ACTO; Shri B Behera, TO; Shri BD Ojha, STA and Shri AK Parida, STA represented the institute.

Parliamentary Standing Committee on Agriculture visited NRRI, Cuttack on 8 November 2017. Dr. SK Pradhan, PS, CID, Dr. RL Verma, Scientist, CID, Dr. SD Mohapatra, PS, CPtD, Dr. AK Mukherjee, PS, CPtD, Dr. Sangita Mohanty, Scientist, CPD, Dr. Upendra Kumar, Scientist, CPD, Dr. Nabneeta Basak, Scientist, CP&B, Dr. SK Mishra, PS, SSD, Dr. Lipi Das, PS, SSD, Shri P Jana, ACTO, Smt. Gayatri Sinha, STA and Shri AK Parida, STA represented the institute.

Regional Workshop on Farmers Right and Exhibition on Agro-Biodiversity at NRRI, Cuttack on 17 November 2017. Dr. SK Mishra, PS; Shri P Jana, ACTO; Smt. Gayatri Sinha, STA and Shri AK Panda, TA presented the institute.

Agriculture Education Day at NRRI, Cuttack on 3 December 2017. Shri P Jana, ACTO; Smt. Gayatri Sinha, STA and Shri AK Parida, STA and Shri AK Panda, TA presented the institute.

82nd Annual Convention and National Seminar on Developments in Soil Science-2017 organized by Indian Society of Soil Science, Kolkata at Amity University, Kolkata from 11 to 14 December 2017. Shri P Jana, ACTO and Shri DR Sahoo, STA presented the institute.

1st International Extension Congress-2018 at CIWA, Bhubaneswar from 1 to 3 February 2018. Dr. P Samal, Head, SSD; Dr. SK Mishra, PS; Shri P Jana, ACTO; Shri B Behera, TO, Smt. Gayatri Sinha, TO, Shri AK Parida, STA and Shri BD Ojha, STA represented the institute.

3rd ARRW International Rice Symposium-2018 at NRRI, Cuttack from 6 to 9 February 2018. Dr. SK Mishra, PS; Shri P Jana, ACTO; Smt. Gayatri Sinha, TO, Shri AK Parida, STA and Shri BD Ojha, STA represented the institute.

'Foundation Day Celebration of ICAR-CIWA and Technology Demonstration Mela' at CIWA, Bhubaneswar on 5 March 2018. Dr. Lipi Das, PS, Shri B Behera, TO, Smt. Gayatri Sinha, TO and Shri DR Sahoo, STA represented the institute.

Odisha State Level Agricultural Exhibition and Krushak Pathshala 'Krushi Odisha-2018' at Baramunda Ground, Bhubaneswar from 6 to 9 March 2018. Dr. P Samal, Head, SSD, Dr. SK Dash, PS, CID, Dr. S Saha, PS, CPD, Dr. SD Mohapatra, PS, CPtD, Dr. SK Pradhan, PS, CID, Dr. S Lenka, Sr. Scientist, CPtD, Dr. SK Mishra, PS, SSD, Dr. PC Rath, PS, CPtD, Shri P Jana, ACTO; Shri B Behera, TO, Smt. Gayatri Sinha, TO, Shri AK Parida, STA, Shri DR Sahoo, STA, Shri BD Ojha, STA and Shri A Panda, TA represented the institute.

Pusa Krishi Unnati Mela cum Biennial National Conference of KVKs-2018 at NRRI, Cuttack on 17 March 2018. Dr. SK Mishra, PS; Shri P Jana, ACTO; Smt. Gayatri Sinha, TO, Shri AK Parida, STA and Shri BD Ojha, STA represented the institute.

Organization of Events, Workshops, Seminars and Farmers' Day

71st Foundation Day and Dhan Diwas

The National Rice Research Institute, Cuttack celebrated its "71st Foundation Day and Dhan Diwas" on 23 April 2017. Inaugurating the function as chief guest, Dr. Trilochan Mohapatra, Secretary, DARE and DG, ICAR, New Delhi congratulated the farming and scientific communities for record production of rice as well as food grains during 2016-17 despite vagaries of weather. However, he highlighted on the goal set by Hon'ble Prime Minister of India for 'Doubling Farmers Income by 2022'. To achieve this, he emphasized on integration of suitable technologies in different farming situations, crop diversification, linking all farmers with the market, exploring all options for value addition to agricultural produces, women empowerment and encouraging participation of youths in agriculture, especially in post-harvest activities. He acknowledged the contributions of the institute in bringing green revolution to the country during mid 1960s and now becoming a rice exporter.

Attending the function as the guest of honour, Padma Shree Dr. Ajay Parida, Director of the Institute of Life Sciences, Bhubaneswar appreciated the contributions of NRRI in bringing national food and nutritional security through high quality research outputs. He also delivered the Foundation Day Lecture for the benefit of scientific fraternity and shared his vast experiences of closely working with farming communities for over two decades.

In the beginning of the programme, Dr. H Pathak, Director and Chairman highlighted the significant achievements of the institute, like eleven recently released varieties including two high protein rice namely, CR Dhan-310 & 311, rice value chain an riceXpert mobile App in Odia and English.

On this occasion, the chief guest inaugurated an Agricultural Exhibition showcasing technologies of NRRI, its regional stations, all other ICAR institutes and centres of the state, KVKs and state line departments. He felicitated seven distinguished retired staff, the best workers of the institute, Swachhta awardees among campus residents and seventeen rice farmers/farmwomen from Odisha, Jharkhand, Assam and Meghalaya for their innovative practices in rice-based farming. Six research and technology bulletins and Odia version of the riceXpert mobile App were released by the dignitaries. The chief guest also inaugurated 238 KW Roof Top Solar Power system, which will cater to nearly fifty per cent of electrical energy requirement of the institute.

Guests visiting the Agricultural Exhibition stalls

Dignitaries releasing some NRRI publications cleaning of Patnaikia tank, fencing and beautification of Dispensary, cleaning of residential area and weeding out the old and zero garbage materials in the Institute were conducted.

As part of the Swachhta Pakhwada, a Village Awareness Programme regarding 'disposal of insecticide containers, agricultural and household wastes' was organized on 24 May 2017 at Paramahans village of Cuttack. Director along with Heads of Divisions, Scientists and other staff participated in the programme to generate consciousness about the necessity of keeping the surroundings clean among the villagers. On 29 May 2017, a lecture was delivered by Dr. AK Nayak, Head, Crop Production Division, NRRI on 'Agricultural Waste Management' to create awareness among the staff of the Institute. Organic waste management programme was organized near Institute Compost pit on 31 May 2017.

Dr. Trilochan Mohapatra, Secretary, DARE & DG, ICAR graced the closing function of the Pakhwada as the Chief guest on 3 June 2017. The Chief guest garlanded the statues of Mahatma Gandhi and Pt. Jawaharlal Nehru and planted sapling in Dispensary

Prof. S Pasupalak, Vice Chancellor, OUAT addressing the gathering

Dr. H Pathak, Director, NRRI addressing the gathering

campus to mark the occasion.

Speaking on the occasion, he emphasized that cleanliness/swachhta is required in all facets–individual, family, village, office and region for all-round development of the nation. Keeping 'swachh' is not only important from aesthetic point of view, but also imperative for healthy and disease-free society, he remarked. He also stressed upon sensitization of the children, who will further persuade the rural as well as urban masses. The programme was coordinated by the Institute Swachh Bharat Committee (ISBC).

High protein and high yielding rice variety CR Dhan 310 released by Shri Radha Mohan Singh, Union Minister of Agriculture & Farmers Welfare

Shri Radha Mohan Singh, Union Minister of Agriculture & Farmers Welfare, Government of India released NRRI's high protein and high yielding rice variety 'CR Dhan 310' on the occasion of 89^{th} Foundation Day-cum-Award ceremony of Indian Council of Agricultural Research at AP Shinde Symposium Hall, NASC Complex, New Delhi on 16 July 2017. The high protein rice variety, CR Dhan 310 is first of its kind in the world containing about 10.3% protein in milled rice.

Regional Workshop on 'Farmers' Rights and Exhibition on Agro-Biodiversity'

NRRI, Cuttack organized "Regional Workshop on Farmers' Rights and Exhibition on Agro-Biodiversity" on 17 November 2017. The event was sponsored by the Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA), Department of Agriculture and Co-operation (DAC), Ministry of Agriculture & Farmers Welfare, Govt. of India, New Delhi.

Shri SK Pattanayak, IAS, Secretary (Agriculture), Ministry of Agriculture & Farmers Welfare, Govt. of India inaugurated the programme and congratulated the farmers of Odisha for submitting maximum number of rice varieties for registration. He encouraged them to submit other crop varieties for registration with the PPV&FRA and take advantage from the plant genome savior community award under benefit sharing.

Dr. Trilochan Mohapatra, Secretary (DARE) & Director General (ICAR) spoke about the importance

Chief Guest planting sapling in the NRRI-Dispensary Campus

A section of audience

of the wild and weedy rices apart from native landraces/varieties in developing new varieties in the context of adverse climatic fluctuations causing severe damage to the crop.

Shri GK Dhal, IAS, Agriculture Production Commissioner, Govt. of Odisha complimented the scientists of NRRI and State Agriculture Department in arranging several awareness programmes among the farmers about the Act, which resulted in collection, conservation and submission of more than 950 rice varieties to the PPV&FR Authority for registration. The Chairperson of PPV&FRA and Jt. Secy (Seeds) Dr. B Rajinder, IAS highlighted the importance of Farmers' Rights in the PPV&FR Act. Dr. H Pathak, Director of the Institute welcomed all the dignitaries, scientists from different Institutes/SAUs/Government Departments and farmers from all the states. Dr. RC Agrawal, Registrar General of PPV&FRA had proposed vote of thanks on behalf of the Authority for making the programme a grand success.

The technical session on "Mainstreaming of Farmers' Varieties in Seed Chain" was held under the

CR Dhan 310

chairmanship of. Dr. Ajay Parida, Director, Institute of Life Sciences, Bhubaneswar and the lead speakers

Mohapatra said extension is not technology transfer and it is beyond that of working on other domains like marketing and facilitating agricultural development in all ways and means. Extension has to be the base for research which will be the key for agricultural development in the country, he added. Dr. Mohapatra emphasized that the teaching must ensure development of quality professionals through changed of modified syllabus.

Dr. AK Singh, DDG (Agril. Extension), Prof. S Pasupalak, Vice Chancellor, OUAT and Shri Saurabh Garg, IAS Principal Secretary (Agriculture), Govt. of Odisha were Guests of Honour.

Dr. AK Singh, DDG (Agril. Extension) and President of the Congress remarked that the National Demonstration programme was crucial in making Green Revolution a success. He said presently, extension researchers need to develop methods and models to address the issues before agriculture development.

The valedictory session of the congress was chaired by Prof. (Dr) AK Srivastava, Chairman, ASRB, ICAR, New Delhi and presided by Dr. AK Singh, DDG (Agril. Extension), ICAR, New Delhi in the presence of Dr. DP Ray, Former VC of OUAT and others.

Dr. Srivastava briefed about the conversing about the significance of Extension in achieving green revolution in India and also informed some of the key messages that extension has to do for the promotion of dairy and livestock sector.

Dr. GAK Kumar, Organizing Secretary of the congress presented the recommendations of congress.

The valedictory session was also graced by Dr.

Dignitaries releasing Research Bulletin during the regional workshop

Himanshu Pathak, Director, NRRI and Dr. SK Srivastava, Director, ICAR-CIWA.

The congress comprised of ten technical sessions in which emerging challenges and innovative approaches in Extension, advancements and futuristic assessment of core areas of extension, envisioning extension in changing context of agriculture and society, professionalism and ethics in extension to several other themes were discussed through interactive presentations and panel discussions.

The congress was attended by several professionals including scientists, policy makers, extension personnel and students from the country as well as abroad. On the eve of congress, 20 exhibition stalls were arranged to display the newly emerging extension technologies of ICAR/SAUs.

International Rice Symposium

The 3rd ARRW International Symposium on the topic "Frontiers of Rice Research for Improving Productivity, Profitability and Climate Resilience" was inaugurated by Padma Bhusan Prof. VL Chopra, Former Secretary, DARE and DG, ICAR on 6 February 2018 at National Rice Research Institute, Cuttack, Odisha. The four-day long Symposium was organized by NRRI, Cuttack and Association of Rice Research Workers (ARRW) in association with other national and international organizations like, ICAR, New Delhi; NAAS, New Delhi; IRRI, Philippines and ICAR-IIRR, Hyderabad from 6 to 9 February 2018. Gracing the inaugural function as the Chief Guest, Prof. Chopra mentioned that the global demand of milled rice will cross 550 million ton by 2030. He recalled that over 40% of the total rice growing areas in India are rainfed, which are severely affected by the vagaries of climate like drought, submergence and flood. In addition, farmers also face several challenges like labour shortage, rising cost of cultivation, emergence of new pests & diseases, deteriorated soil health, and changing food habit of consumers. He emphasized that solutions to majority of these problems could be resolved by advanced biotechnological interventions in rice research like multiple gene pyramiding, whole genome sequencing and pollen magneto facture. He advised that scientists, especially biotechnologists, must test their laboratory inventions in farmers' fields for solving their multitude problems. Guest of Honour of the function Dr. Trilochan Mohapatra, Secretary, DARE and DG, ICAR said, 'this is the occasion to celebrate Rice for serving humanity, alleviating hunger, malnutrition and poverty from the world'. He reiterated and advised the participants to work hard to achieve the target set by Hon'ble Prime Minister of India to Double the Farmers' Income by 2022. He also advocated working more in fields rather than in labs. Later, he delivered the plenary lecture on the topic "Indian Agriculture: A Perspective".

Dr. Himanshu Pathak, Director of Institute and Convener of the event briefed about the objectives and expected outputs of symposium and highlighted the significant achievements and crop management techniques of the institute particularly the recently released nutrient rich high protein rice varieties (CR Dhan 310 & CR Dhan 311 with over 10.2% grain protein content, which are 1st of its kind in the world), climate resilient and climate smart varieties, and other biotic and abiotic stress tolerant varieties, riceXpert

Chief Guest Dr. T Mohapatra, Secretary, DARE & DG, ICAR addressing to the participants

Guest of Honour Dr. AK Srivastava, Chairman, ASRB, ICAR, New Delhi addressing the participants

mobile app, and the contributions of the institute in bringing green revolution in India during late 1960s held on 1 June 2017 at NRRI, Cuttack. Dr. H Pathak, Director, NRRI and Chairman of TOLIC, Cuttack presided over the meeting. Shri Nirmal Kumar Dubey, Head, Regional Implementation Office (East), Ministry of Home Affairs, Government of India, Kolkata was the Chief guest.

There are 86 Central government offices located in Cuttack city who have registered as members under TOLIC, Cuttack. A total of 51 representatives from various member offices participated in this meeting. Addressing the gathering, Dr. H Pathak emphasized on the unity and interactive communication among all the member offices. He said that working together can pave the way for the better implementation of official language. In this context, Dr. Pathak assured of NRRI's cooperation for organizing all forthcoming workshops and seminars.

The Chief guest Shri Dubey discussed in detail with the representatives of the member offices for the achievement of the goals set in the annual program for 2017-18 by the Department of Official Language. Shri Dubey said that "TOLIC have a major role in the smooth implementation of the Official Language Policy of the Union". He deliberated upon the issues related to the implementation of official language with the representatives of various member offices.

Mr. Ashutosh Kumar Tiwari, Member Secretary of TOLIC and Assistant Director (OL), NRRI welcomed the guests and representatives of the member offices and discussed the key points of the minutes of the 47th meeting of TOLIC and presented the agenda of the 48th TOLIC meeting. The member secretary offered vote of thanks in the end.

49th Meeting of TOLIC

The 49th meeting of Town Official Language Implementation Committee (TOLIC), Cuttack was held on 27 October 2017 at the National Rice Research Institute, Cuttack and on this occasion a Hindi Sammelan was held for the member offices of TOLIC. Dr. Himanshu Pathak, Director NRRI and Chairman of TOLIC, Cuttack presided over the meeting. Shri Nirmal Kumar Dubey, Head, Regional Implementation Office (East), Ministry of Home Affairs, Government of India, Kolkata was the Chief Guest. Dr. Himanshu Pathak in his keynote address emphasized on the compliance with Official Language Rules for the member offices. He asked to

Chief Guest Prof. VL Chopra addressing to the participants

A section of the participating delegates during the inauguration

ensure the progressive use of official language, and all the member offices must be technically skilled. Shri Ashutosh Kumar Tiwari, Member Secretary of TOLIC and Assistant Director (OL), NRRI welcomed the guests and representatives of the members present in the meeting. He discussed the ATR points of the minutes of the 48th meeting of TOLIC and presented the agenda of the 49th TOLIC meeting and also discussed the recommendations approved by the President of India on the ninth part of the report of the Committee of Parliament on Official Language. In the meeting, 29 delegates from different offices and banks of the Government of India, located in Cuttack, Shri Sudarshan Rai, Overall-Officer-In-Charge of the Hindi Teaching Scheme, Department of Official Language, Cuttack center also participated in the meeting. On the occasion of 49th TOLIC meeting, the Chairman of TOLIC, Cuttack, Dr. Himanshu Pathak honored the National Disaster Response Force (NDRF), Mundli with the Official Language Shield as the best performer for compliance of Official Language

Director, NRRI addressing the gatherings

Dignitaries on the dais discussing with the participants

rules among the member offices of TOLIC, Cuttack during the year 2016-17. Mr. Jacob Kispota, Senior Commandant received the shield on behalf of NDRF.

International Day of Yoga

The International Day of Yoga (IDY) was observed at NRRI, Cuttack on 21 June 2017 with the participation of staff members. Dr. H Pathak, Director of the institute highlighted the importance of Yoga and Pranayam in leading a healthy life. Various types of Yogasans were demonstrated by trained Yogacharyas from Regional Center of Art of Living Organization, Cuttack. The staff thoroughly enjoyed the programme and suggested to set up regular practice camp at the institute for the benefit of the employees.

National Integration Week

The National Rice Research Institute, Cuttack observed National Integration Week from 19 to 25 November 2017 to foster and reinforce the spirit of Communal Harmony, National Integration, secularism and pride in our vibrant composite culture & nationhood. The celebration of the week started with the National Integration Pledge. During whole week of celebration, various programmes were held in relation to the specific theme. Some of the programs like meetings, quizzes, creating awareness through video clips, open-forum discussion were held to highlight the themes of National Integration Week. Women's Day as a theme was observed in the institute premises. On this occasion, Dr. H Pathak, Director of the Institute greeted all the women employees of the institute. Speaking on this occasion, Dr. Pathak highlighted the importance of Women in Indian Society and their role in development of nation-building. Staff of the institute actively participated in quizzes, discussions and also committed to maintain

TOLIC Meeting in progress

Dr. H Pathak, Director, NRRI addressing the yoga participants

Cuttack. Dr. (Mrs.) Lipi Das, Organizing Secretary briefed about the objectives of observing the day and highlighted on the overwhelming responses received from the past six years. At the end she proposed the vote of thanks. The day-long celebration was highly exciting with special events for the participating students like Debate on "Can Current Agricultural Education Cater the Needs of Farmers?"and Quiz competition on "General Agriculture" apart from the Exhibition, which showcased the innovative ideas of the students in the form of models, charts, graphs and live materials. Through an outlet on Career Counseling in Agriculture, the students were sensitized and provided counseling on the scope and opportunities in the subject. Also an interaction session between NAAS fellows and students was conducted. In the evening during closing function, the winners of the various competitions along with all the participating students were awarded with trophies and certificates by the Director.

26th Dr. Gopinath Sahu Memorial Lecture

The Association of Rice Research Workers (ARRW), NRRI, Cuttack organized a memorial lecture in memory of Dr. Gopinath Sahu, the founder member of the society and renowned rice physiologist. Dr. H Pathak, Director, NRRI, Cuttack delivered the lecture on "Chemistry of Carbon: Controlling, Crop, Climate, Calorie and Commerce" on 5 December 2017. Dr. PK Mohapatra, President, Dr. Gopinath Sahu Memorial Trust graced the occasion as Guest of Honour. Dr. SR Das, President, ARRW presided over the function.

Stakeholder's Workshop on Climate Change Issues

A stakeholder's workshop on "Technological options to address the climate change issues" and 3rd meeting of Global Technology Watch Group (GTWG): Sustainable Agriculture was held at NRRI, Cuttack, from 24 to 25 October 2017. This was organized by Technology Information, Forecasting & Assessment Council, Department of Science & Technology, Govt. of India. Dr. H Pathak, Director, NRRI, Cuttack; Dr. Goutam Goswami, Scientist F and Principal Investigator, TIFAC, New Delhi; Dr. KK Singh, Deputy DG (Agromet), IMD, New Delhi; Dr. TK Adhya, Professor, KIIT, Bhubaneswar; Dr. RC Upadhyay, Head, NDRI (Ex), Karnal; Dr. MK Das, CIFRI (Ex), Kolkata; Dr. TK Behera, IARI, New Delhi; Dr. SK Roy, NBSSLUP, Jorhat, Assam; Dr. PS Tiwari, CIAE, Bhopal; Dr. T Chakradhar, Scientist C and Co-PI TIFAC, New Delhi; Dr. AK Nayak, Head CPD, NRRI, Cuttack; Dr. P Bhattacharyya, ICAR-National Fellow, NRRI, Cuttack; Dr. MJ Baig, Principal Scientist, NRRI, Cuttack; Dr. D Bhaduri, Scientist, NRRI, Dr. N Basak Scientist, NRRI, Cuttack and other Heads of the divisions of NRRI, Cuttack, Scientists, students, technical staff and farmers participated in the workshop. The topics delivered and discussed were, climate change scenario in Eastern India, its impact on field crops, livestock, fisheries, horticulture and soil water conservation. DDA/DDO of different agro-climatic zones of Odisha also participated in the workshop along with progressive farmers. Government official of State Department and Universities actively participated. The GTWG meeting– sustainable agriculture were conducted on 25 October 2017, where all the members actively participated and discussed about weightage scoring process of technologies to cope up with climate change issues.

Director with the Women Employees of the Institute on Women's Day

Brain Storming Session on Use of Rice Straw

Brain storming session on economic and environment friendly use of rice straw was organized on 26 October 2017 at NRRI, Cuttack. Dr. JS Mahal, Dean, Agriculture Engineering, PAU, Ludhiana delivered lecture on 'Use of rice straw on conservation agriculture and use of machineries to handle the straw'. Dr. Indra Mani Mishra, Head, Agriculture Engineering, IARI, New Delhi and Dr. PK Sahoo, Principal Scientist, Agriculture Engineering, IARI, New Delhi gave deliberations on use of rice straw as feed blocks to animals. Dr. BK Pani, OIC, CTM, OUAT elaborated the use of rice straw as the substrate of mushroom production. Dr. Rintu Banerjee, Professor, IIT, Kharagpur gave lecture on use of rice straw as bio-ethanol/bio-diesel production with the intervention of enzymes. Presentations were also made on the rice breeding aspect by Dr. SK Pradhan, on Biochar by Dr. D Bhaduri and pathological/microbial aspects by Dr. AK Mukherjee on the eco-friendly use of rice straw. The brain storming sessions and group discussions were coordinated by Dr. H Pathak, Director, NRRI, Cuttack, Dr. AK Nayak, Head, CPD, NRRI and Dr. Pratap Bhattacharyya, ICAR-National Fellow, NRRI, Cuttack.

Release of an educational bulletin during the occasion

Professor, School of Law, KIIT University, Bhubaneswar spoke on legal rights and benefit thereof for registering under Geographical Indications (GI) of Goods Act, 1999 of IPR. Both the talks aroused several queries and clarifications were made by the resource persons. Dr. BC Patra, Member Secretary, ITMU, also highlighted the activities of ITMU at NRRI with reference to management and protection of IPR with respect to number of Patents filed/granted, New/Extant Plant Varieties filed/granted, MoUs signed and revenue generated, unique germplasm identified and registered. Dr. M Naresh Reddy, Business Manager of the ITMU proposed a vote of thanks.

Workshop on "Future action plan on coordination of different AICRIP activities for Zone III and IV"

One day workshop on "Future action plan on coordination of different AICRIP activities for Zone III and IV" was organized at NRRI, Cuttack on 22 August 2017. It was chaired by Dr. AK Nayak, Director (I/c), NRRI, Cuttack. Dr. LV Subba Rao P.I. of AICRIP, IIRR, Hyderabad was the chief guest in the workshop. Sixty two delegates participated in the workshop including representatives from Assam, Bihar, West Bengal, Odisha, Meghalaya, Jharkhand, Sikkim, Nagaland and Manipur along with scientists of NRRI, where achievements and problems of different centers were discussed. It was suggested to conduct monitoring of different AICRIP trials in appropriate time and exchange germplasm for screening against biotic and abiotic stresses.

Kharif Workshop under Farmer FIRST Programme

A "Training Programme-cum-*Kharif* Workshop" was organized by the NRRI, Cuttack under the Farmer FIRST Programme (FFP) on 8 September 2017 at village Satyabhamapur in Salipur block of Cuttack district - the birthplace of Utkal Gaurav Madhusudan Das. Over two hundred fifty farmers/farmwomen from four adopted villages, *viz.*, Satyabhamapur, Biswanathpur, Laxminarayanpur and Ganeswarpur and over thirty scientists from NRRI, CARI, CIWA and senior officials from state line departments, *viz.*, agriculture, animal husbandry and fishery participated in the event. As per the *kharif* 2017 plan of FFP, rice varietal demonstrations were undertaken on 200 acres with twenty new varieties involving over 400 farmers; and backyard poultry and duckery involving 60 farmwomen apart from rice mechanization activities, need-based plant protection and capacity building programmes in the cluster. Inaugurating the workshop, Dr. AK Nayak, Director (I/c), NRRI complemented the multidisciplinary interventions adopted through the project in a rice-based production system to achieve the national goal as well as a challenging task of Doubling the Farmers Income (DFI) of 2022. He advised the project personnel to evaluate the impact on the socio-economic implications of the project interventions and bring out a suitable document at the end of the project. A field visit to demonstration plots was also organized for participating farmers/farmwomen and officials. The programme was covered by various mass media including DDK, Bhubaneswar. At the outset of the programme, Dr. Lipi Das, PI, NRRI-FFP briefed about the objectives, achievements & future plans of the project, while, Dr. SK Mishra, Co-PI coordinated the programme.

Eastern India Rainfed Lowland Shuttle Breeding Network (EIRLSBN) Selection Activity and TRB Workshop

Under ICAR-IRRI collaborative STRASA project, breeders involved in Eastern India Rainfed Lowland Shuttle Breeding Network (EIRLSBN) *viz.*, Dr. T Ahmed, RARS, Titabar, AAU, Assam; Dr. D Chowdhary, North Lakhimpur, AAU, Assam; Dr. NK Singh and Dr. Rajesh Kumar, RAU, Pusa, Bihar; Dr. Ananda Kumar, BAU, Sabour, Bihar; Mr. Monoranhan Jana, RRS, Chinusrah, West Bengal; Dr. DN Bastia, OUAT, Bhubaneswar, Odisha; and Dr. JN Reddy, and

Mr. SSC Patnaik, NRRI, Cuttack participated in the selection activity at NRRI, Cuttack from 13 to 14 November 2017. During the selection activity, single plant selections were made by the breeders from the segregating populations grown at NRRI, Cuttack as per their location specific requirements.

On the occasion of 25 years of Eastern India Rainfed Lowland Shuttle Breeding Network (EIRLSBN), all the participants including IRRI, Philippines were honored in a function held on 14 November 2017. On 15^{th} November a workshop on 'Transformative Rice Breeding' was organized and were participated by all the members of EIRLSBN besides Dr. SK Katiyar and Dr. Shalabh Dixit, Scientists from IRRI, Philippines.

"Seed Day" observed on Participatory Seed Production

A "Seed Day" on Participatory Seed Production in Rice was organized by ICAR-NRRI, Cuttack, Odisha at Goudgop, Mahanga on 20 December 2017. The programme was addressed by Dr. H Pathak, Director of the Institute; Dr. AK Nayak, Head, Crop Production; Dr. M Jena, Head, Crop Protection; Dr. P Samal, Head, Social Science and Mr. RK Sahu, Nodal Officer, Seed of ICAR-NRRI. The training was attended by more than 100 farmers of near by villages involved in rice production.

Field Day on Rice in Odisha

A "Field Day on Rice" including crop cutting experiments was organized by the institute at Anuapada village of Derabis block in Kendrapara district, Odisha on 6 December 2017 to highlight the varietal performance of newly released NRRI varieties. The field day was followed by a Farmers' Meet. Over one hundred farmers, senior officers of the

Dr. H Pathak, Director, NRRI felicitating Dr. G Kotch, HOD, Plant Breeding, IRRI, Philippines

Dr. H Pathak, Director, NRRI speaking on the occasion

The crop cutting results showed about 20 per cent grain yield advantage in both the varieties over the most popular rice variety of the area 'Sahbhagidhan' under farmers' practice.

Later, a Farmers-Scientists-Officers Interaction Meet was organized. In the beginning, Dr. SK Mishra, PS & Principal Investigator of the project briefed about the *kharif* 2017 cluster demonstrations of these two varieties (CR Dhan 202 & CR Dhan 305) in four selected districts, *viz.,* Ranchi, Gumla, Palamau and Garhwa of Jharkhand with the participation of sixty rice farmers (15 from each district) by providing 5 kg seed minikits to each farmer. Invited guests, officers, scientists and participating farmers present on the occasion appreciated the efforts by NRRI to demonstrate new varieties in the state and gave their valuable remarks. The state officials assured to take necessary steps at their respective capacities to popularize and accelerate fast spread of these two varieties in the state by bringing into state seed chain at the earliest and local production of sufficient quantity of foundation and certified seeds. Chief Guest of the function, Dr. Subash Singh, Director, SAMETI advised all the beneficiary farmers not to consume the produces of these two varieties, rather use as seeds and to supply surplus quantity to neighboring farmers as seeds to replace the low

Participants of the AICRIP workshop

biodiversity and also to ensure *Parthenium*-free NRRI campus. Eradication of *Parthenium* from the campus was taken up at the Institute by spraying non-selective herbicides and uprooting the newly emerged *Parthenium* plants from the campus. In this juncture, an 'Awareness Meeting' was held at institute on 18 August 2017. The scientists, technical staff, KVK staff, research scholars and students were present in the meeting. Dr. Sanjoy Saha, Principal Scientist delivered

Dr. AK Nayak, Director (I/c), NRRI addressing the participants

a lecture on 'Impact of *Parthenium* and its management' in this meeting.

Meeting of newly constituted Women Cell

The first meeting of women cell was held on 6 March 2018. The meeting was attended by Dr. Sanghamitra Samantaray, Chairperson, Women cell along with all the members of Women cell, Dr. MK Kar, Dr. MJ Baig, Dr. A Poonam, Smt. Manasi Das, Smt. Chandmuni Tudu, Smt. Surubali Hembram, Shri NC Parija and Dr. Sushmita Munda (Member Secretary). Dr. H Pathak, Director, ICAR-NRRI attended the meeting as special invitee. At the outset, Dr. H Pathak, Director, welcomed Dr. Meena Senapati, Third party member and all the members of women cell. As per the agenda, all the members introduced themselves especially with the third party member. Thereafter, Dr. S Samantaray, chairperson, briefed about the aims, objectives and guidelines of women cell. As per suggestion of Dr. M. Senapati, it was decided that an awareness programme will be conducted for the

Interaction of EIRLSBN members with Dr. H Pathak, Director, NRRI, Cuttack

Seed Day on 'Participatory Seed Production in Rice' in progress

welfare of the women workers in which health related issues like nutrition requirements, sanitation issues etc. will be highlighted. Besides, some other points were discussed for the welfare of the women working at NRRI. The meeting was ended with vote of thanks by Dr. Sushmita Munda, Member Secretary, Women Cell.

Hindi Workshop-cum-Training Programme

Under the aegis of NRRI, a one day Workshop-cum-training program of Town Official Language Implementation Committee (TOLIC), Cuttack was organized at NRRI on 27 June 2017. The training programme was held in two sessions. The topic of the first session was -"Online Dispatch of Quarterly Progress Report" and the topic of the second session was "Application of Unicode for Computer Typing in Hindi". A total of 35 officers from various offices of TOLIC, Cuttack participated in the program. Dr. AK Nayak, (I/c) Director, NRRI, Cuttack presided over the programme. Dr. Banbihari Sahu, Manager (Official Language), State Bank of India was the Chief guest and instructor of this training programme. At the end, the Secretary, TOLIC thanked all the people and called upon the officials to make best use of the information received from the training in their day to day office work.

Hindi Workshop

A Hindi workshop was organized on 29 August 2017 for the compliance of Section 3 (3) of the Official Language Act, 1963 for the AAOs and FAO of NRRI, Cuttack. Dr. Banbihari Sahu, Manager, (Official Language), State Bank of India, Bhubaneswar was the Guest lecturer of this workshop. Inaugurating the workshop, Assistant Director (OL) Shri AK Tiwari welcomed the members. In light of the provisions of

Dr. P Samal, Head, Social Science addressing the farmers

highlighted the activities of the project and presented the work plan for the forthcoming *kharif* season. All the scientists of the station including Dr(s). NP Mandal, SM Prasad, CV Singh, BC Verma, Somnath Roy and Amrita Banerjee addressed the farmers to help them understand pest management in upland rice cultivation. The meeting was attended by fifty five farmers from Binkarva and Chalchalaiya villages.

Observance of Swachhata Pakhwada

RRLRRS, Gerua observed Swachhata Pakhwada from 16 to 31 May 2017. On 20 May 2017, a day-long awareness camp on cleanliness was organized at village Mazgaon in Darrang district wherein 75 farmers, farmwomen and villagers participated. The meeting was presided by Mr. Jayanta Deka, President, Darrang district unit of Assam Jatiyatabadi Yuva Chhatra Parishad (AJYCP). Shri Kulen Deka, Headmaster, Mazgaon L.P. School and Mr. Bhabesh Kakati, Advisor, Darrang district unit of AJYCP were the Guests of Honour.

Monitoring of BGREI Summer Rice Block Demonstrations

Dr. KB Pun, Dr. R Bhagawati and Dr. T Singh along with Shri P Mahanta, Deputy Director (Agriculture) & Nodal Officer (BGREI), Directorate of Agriculture (Assam), Officers and field functionaries from district agricultural office and Programme Coordinator, KVKs undertook technical monitoring of BGREI summer rice block demonstrations in Dhubri district of Assam on 23 and 24 May 2017. Block demonstrations at villages – Kazipara, Baronitara, Lalkura, Rishipara and Koimari in Bilasipara Sub-Division & village – Madhu Soulmari Part II in Dhubri Sub-Division were monitored. HYV 'Abhishek' and the hybrid 'NPH 924-1' were grown in the demonstrations. The crop was in dough to maturity stage. The farmers applied fertilizers in the demonstrations on their own. The farmers noticed the shorter duration of Abhishek and higher yield and slender grain type of NPH 924-1 in comparison to their own varieties. The farmers requested for the supply of inputs well ahead of the cropping season. The team also visited a power tiller beneficiary group in the village – Madhu Soulmari Part I.

"New India Manthan-Sankalp Se Siddhi" Programme

KVK Cuttack organized "*New India Manthan-Sankalp se Siddhi*" programme at KVK campus, Santhapur on 19 August 2017. About 250 farmers, farmwomen and rural youth from different corners of Cuttack district like Baramba, Narsinghpur, Niali, Tigiria, Nischintakoili, Tangi Choudwar and Cuttack Sadar blocks along with officials of line departments and media persons attended this programme. Shri PK Swain, Joint Secretary, Dept. of Agriculture, Cooperation & Farmers Welfare and Chief Guest of this function emphasized on the importance of proper implementation of the Seven Sutras underlined by Government of India for doubling farmer's income by 2022. Dr. H Pathak, Director, NRRI, Cuttack drew attention on different strategies to improve income from agriculture particularly climate smart technologies. Dr. P Samal, Head, Social Science Division emphasized on various extension strategies to achieve the target. In the technical session, Heads of Divisions and Scientists from NRRI, Cuttack - Dr. (Smt.) M Jena, Head, Crop Protection Division, Dr. S Saha, PS, Crop Production Division, Dr. (Smt.) M Kar, PS, Crop Improvement Division along with district

Invited guests addressing the gathering at Chundri, Jharkhand line department officials - Dr. K Jena, Dy. Director Horticulture; Dr. H Nayak, Chief District Veterinary Officer, Cuttack, representatives from GeM portal, Orissa Livelihood Mission Officials interacted with the farmers for improving their income by discussing about adoption of sustainable and proven technologies in their fields. There was extensive discussion on this aspect with inputs from both experts and farmers. Dr. DR Sarangi, Officer-in-Charge, KVK Cuttack welcomed the dignitaries and programme ended with vote of thanks by Dr. RK Mohanta. Dr. TR Sahoo moderated the programme and it was facilitated by Dr. M Chourasia. In this occasion, an extension literature on this mass movement was distributed among the participants in Odia language after the inspiring film show. The participants took the pledge and energetically went home with a mission to double Farmers' Income by 2022.

Dr. Sanjoy Saha, PS (Agronomy) delivering lecture in Awareness meeting

emphasized on the importance of awareness of women friendly agricultural technologies and realizes their own potential to empower themselves. Dr. AK Nayak, Director (I/c), NRRI, Cuttack drew attention on different strategies to improve income from agriculture using climate smart technologies and ensure their nutritional security. Dr. P Samal, Head, Social Science Division emphasized on implementation of proper extension strategies for empowering women. Women Scientists from NRRI, Cuttack (Dr. (Mrs.) M Kar, PS, Crop Improvement Division, Dr. (Mrs.) Lipi Das, PS, Social Science Division) along with Dr. A Mishra, DDA, Cuttack addressed the farmwomen for improving their income by discussing about adoption of sustainable and proven women friendly technologies in their respective fields. Dr. DR Sarangi, Officer-in-Charge, KVK Cuttack welcomed the dignitaries and the programme ended with vote of thanks by Dr. TR Sahoo, and facilitated by Dr. RK Mohanta. On this cultivation. A field visit was arranged to the demonstration plots where crop cutting was done in Chaturbhuj Nayak's field and harvested for getting the yield estimates. The farmers cultivating the crop shared their experiences and the other participants shared their views on this crop. The experts addressed to the queries raised by the farmers about the crop husbandry practices and emphasized its role in ensuring the nutritional security and economic enhancement. Different recipes of broccoli were prepared by the farmers led by Chandamani Pradhan and Chaitanya Muduli which the participants relished.

Field Day on Groundnut

To promote oilseed cultivation through area expansion and productivity enhancement, KVK Cuttack has chosen 30 ha area in 134 farmer's field in two clusters, Regedapada in Athagarh block and Kharibila in Niali block under CFLD oilseed programme for 2017-18. PRA and other surveys were conducted to identify the problem and prioritization thereof on groundnut cultivation. The farmers' use promising variety AK-12-24 and due to imbalanced fertilizer use and lack of basic fertilizer schedule the harvested groundnut are small, with hollow pods and yield is low. To alleviate this problem, KVK Cuttack provided “Sulphur”, the secondary fertilizer in the form of sulphur mills and micronutrients zinc and boron in the form of “Agromin gold” to the farmers as technological intervention.

A field day was organized at Regedapada on 28 March 2018 with participation of hundred farmers for comparing demonstration plots with other fields. Dr. P Samal, Head, Social Sciences Division, reiterated the importance on seed treatment, soil test based nutrient application and crop husbandry practices for getting optimal production. Dr. TR Sahoo, SMS (Horticulture) briefed about the importance of the intervention. Dr. DR Sarangi, Officer-in-charge, KVK Cuttack discussed about the role of soil testing and nutrient management in groundnut, whereas the pest and disease management practices were elaborately discussed by Dr. M Chourasia. Dr. RK Mohanta, SMS (Animal Science) offered vote of thanks. The farmers using the technology shared their experiences and the other participants shared their views on this intervention.

Animal Health Camp

In Mangarajpur, an adopted village of KVK Cuttack blood protozoan disease like Theileriosis and Trypanosomiasis outbreak occurred in the high yielding cows purchased from Jagatsinghpur. To tackle the situation Dr. RK Mohanta, KVK expert on Animal science was deputed to Mangarajpur for 3 days, i.e. 14-16 March 2018. An animal health camp was organised in the village along with two group discussion and awareness meetings. About one hundred livestock sheds were cleaned and disinfected using lime and bleaching powder along with phenyl. To control the tick population, spraying of anti-ticks was made in the disinfected shed and applied on the animals in proper dosage. The affected animals were examined and line of treatment was suggested. More than 200 livestock were examined. The most common problems were found to be ticks and internal parasites, followed by underfeeding, repeat breeding, and infertility, whereas blood protozoan diseases was found only in high yielding cows. Most of the livestock sheds were not having pucca floor and is also partially responsible for negative health condition and productivity status of the animals. The

Chief Guest giving away prize to the winner

Swachhata Pakhwada at Mazgaon village

pranimitras of Mangarajpur (Sri Balabhadra Rana) and Gopapur (Sri Prakash Chandra Panda) along with Sri Chaitanya Muduli helped in effective execution of the programme.

World Soil Day cum Kisan Gosthi

KVK Koderma organized World Soil Day cum Kisan Gosthi program in which total 227 farmers participated. The program was chaired by District Board Chairperson Mrs. Shalini Gupta and 206 soil health cards were distributed to farmers in this program held on 5 December 2017. Dr. SM Prasad, PS, delivered a lecture on "Importance of Soil Health card" on the occasion of World Soil Day. Two programs namely "*Parthenium* Awareness Week" and "Sankalp Se Sidhi" were organized during 16-22 August 2017 at KVK, Koderma and Jamu village of Markacho block on 25 August 2017, respectively. A total of 950 participants were present in these programs.

Exposure Visits

Seven thousand nine hundred and fifty eight (7958) visitors including farmers, farmwomen, students, agriculture officers and scientists from Odisha, West Bengal, Jharkhand, Assam, Bihar, Tamil Nadu, Jammu and Kashmir, Chhattisgarh, Madhya Pradesh, Karnataka, Maharashtra and New Delhi visited NRRI experimental plots, demonstrations, agricultural implement workshops, net houses and *Oryza* museum and were addressed by the rice experts of the institute.

Distinguished Visitors

Parliamentary Standing Committee on Agriculture visited NRRI, Cuttack

Parliamentary Standing Committee on Agriculture headed by Shri Hukumdev Narayan Yadav, Hon'ble MP including ten members *viz.,* Shri S Dhotre, Prof. RV Gaikwad, Shri S Karadi, Md. B Khan, Dr. T Mandal, Shri D Patel, Shri AC Sethi, M Ali Khan, Shri KK Ragesh and Shri Shankarbhai paid a visit to this institute on 8 November 2017. The Director and Heads of the Divisions/Sections of the institute extended warm welcome to them. In the beginning Director, NRRI, Dr. H Pathak made a presentation on "Contribution of ICAR Institutes in Development of High Yielding Varieties of Rice". The Chairman appreciated the research achievements of NRRI,

Dignitaries taking '*Sankalp*' during the '*Sankalp Se sidhi*' programme

Cuttack and recalled the days of late 1960s, when variety Jaya was first cultivated in his field. He

Felicitating the innovator farmwomen

in the "Seventh Annual Global Research Alliance on Agricultural Greenhouse Gases (GRA) Council Meeting" at Tsukuba, Japan from 29 August 2017 to 1 September 2017.

- Dr. H Pathak, Director, NRRI, Cuttack participated in the "21st Annual Meeting of Council for Partnerships on "Rice Research in Asia (CORRA)" at Hangzhou, China from 19 to 22 September 2017.
- Dr. H Pathak, Director, NRRI, Cuttack participated in the Second Lead Author Meeting (LAM2) "for the elaboration of the 2019 Refine to the 2006 IPCC Guidelines for National Greenhouse Inventories (2019 Refinement)" at Zimbabwe from 25 to 28 September 2017.
- Dr. SD Mohapatra, Principal Scientist attended the training on "Ecological management of rodents, insects and weeds in rice agro-ecosystems" at IRRI, Philippines from 25 September 2017 to 6 October 2017.
- Dr. Kutubuddin Ali Molla, Scientist was awarded the *Fullbright-Nehru* Post-doctoral Research Fellowship for conducting research on rice genome editing at Pennsylvania State University, USA for a period of 24 months from 26 September 2017 to 25 September 2019.
- Dr. AK Nayak, Head, Dr. Rahul Tripathi, Scientist, Crop Production Division participated in the annual project meeting on 'Delivering Food Security on Limited Land (DEVIL) (EAP-220)' at Wits Rural Facility, Hoedspruit, South Africa from 29 November to 2 December 2017.
- Dr. Himanshu Pathak, Director, NRRI attended as a resource person to a course entitled 'Principles and Practices of Climate-Smart Agriculture (CSAg 6111)' to Ph.D. and M.Sc. students of climate smart agriculture and biodiversity conservation programme for academic year 2017-18 at Haramaya University, Ethiopia from 9 to 13 February 2018.
- Dr. ON Singh attended the International Hybrid Rice Symposium (IHRS) 2018, organized by IRRI and Indonesian Agency for Agriculture Research and Development at Indonesia from 27 February to 1 March 2018.

Institute Seminar

- Dr. Debarati Bhaduri delivered her deputation seminar on 12 April 2017 at NRRI, Cuttack sharing her postdoctoral research experience about 'Restoration of soil carbon and microbial processes in degraded soil by influence of biochar to mitigate the climate change' under Endeavour Research Fellowship-2016 (funded by Australia Awards, Department of Education & Training, Australian Govt.) carried out at University of New England, Armidale (NSW), Australia.
- Dr. D Maiti delivered a lecture on 'Enhancing ecosystem services rendered by native arbuscular mycorrhiza fungal (AMF) community to improve phosphorous nutrition of rainfed upland rice' at CRURRS, Hazaribagh on 22 April 2017.
- Dr. S Bhagat delivered a lecture on 'Benefits and hazards of using pesticides in field crops' at CRURRS, Hazaribagh on 5 June 2017.
- Dr. RD Gautam, Former Professor, ICAR-IARI, New Delhi delivered a lecture on "Recent

Release of technical bulletin on Soil health and its management advances in concept & implications of IPM" at CRURRS, Hazaribagh on 12 June 2017.

- Dr. P Samal delivered a lecture on 'Future Technological needs for rice crop in India' on 6 July 2017.
- Dr. KR Rao delivered a lecture on 'Insect Plant Chemical Interaction' on 7 July 2017.
- Dr. Abey CP, Sr. Application Specialist, M/s-Jeol India Pvt. Ltd., delivered a lecture on 'Transmission Electron Microscope jFM1400 Plus-the difference parts and its application' on 13 July 2017.
- Dr. Raju Venugopal, Director, Sciheman, Research Foundation Chemical delivered a lecture on 'Next Generations Sequencing Biology, Bio informatics and Technologies (NGBT)' on 17 July 2017.
- Dr. R Pushkar, IRRI, Phillipines delivered a lecture on 'Rice Research for Development: Imperative for effective gender integration' on 18 July 2017.
- Shri SK Das delivered a lecture on 'Administrative and Financial aspects for functioning of EAPs' on 19 July 2017.
- Shri SK Das delivered a lecture on 'Orientation on Goods & Service Tax' (GST) on 25 August 2017.
- Dr. H Pathak delivered a lecture on 'How to write Research Papers' on 20 January 2018.

Dignitaries of Parliamentary Standing Committee on Agriculture

Shri Hukumdev Narayan Yadav, Hon'ble MP distributed seed kit to the progressive farmers

Shri SK Das delivered a lecture on GST

Awards/Recognition

ICAR-NRRI received Best Annual Report Award

ICAR-National Rice Research Institute, Cuttack, Odisha received the 'Best Annual Report Award 2016-17 for Large Institutes'. This prestigious award instituted by ICAR was conferred to the Director, ICAR-NRRI Dr. Himanshu Pathak by Hon'ble Union Minister of Agriculture and Farmers Welfare, Govt. of India Shri Radha Mohan Singh in presence of Hon'ble Union Minister of State of Agriculture and Farmers Welfare, Govt. of India Shri Gajendra Singh Shekhawat; Dr. Trilochan Mohapatra, DG, ICAR and Secretary, DARE; Shri Chhabilendra Roul, Special Secretary, DARE and Secretary, ICAR; Dr. Ramesh Chand, Member, NITI Ayog; Dr. Panjab Singh, President, National Academy of Agricultural Sciences; Dr. AK Srivastava, Chairman, ASRB and other dignitaries. The award was given on the occasion of Vice-Chancellors of Agricultural Universities and ICAR Directors Conference on 8 March 2018 at AP Shinde Hall, the National Agricultural Science Complex, Pusa, New Delhi. The Annual Report 2016-17 highlighted the most significant research, education and extension activities of the Institute.

Director, NRRI receiving the prestigious award from Hon'ble Union Minister of Agriculture and Farmers Welfare Shri Radha Mohan Singh

NRRI, Cuttack bagged the 2nd Prize for the prestigious "Ganesh Shankar Vidyarthi Hindi Patrika Puraskar"

NRRI, Cuttack bagged the 2nd Prize for the prestigious "Ganesh Shankar Vidyarthi Hindi Patrika Puraskar" for institute's annual Rajbhasa Patrika "Dhan" for the year 2015-16. Dr. H Pathak, Director NRRI and Shri AK Tiwari, Assistant Director (OL), NRRI have received the Plaque and Certificate from Shri Sudarshan Bhagat, Minister of State for Agriculture and Farmers Welfare, Govternment of India in presence of Shri Radha Mohan Singh and the DG, ICAR, Dr. Trilochan Mohapatra.

Individual Award/Recognition

Dr. Kutubuddin Molla, Scientist, Crop Improvement Division, NRRI has received the prestigious "Jawaharlal Nehru Award for P.G. Outstanding Doctoral Thesis research in Agricultural and Allied Sciences-2016". The award has been bestowed on Dr. Molla in the area of Crop protection for his Ph.D. research work on the development of transgenic rice expressing defense genes from rice and non rice sources for enhanced sheath blight resistance in the University of Calcutta, Kolkata. The award was presented to Dr. Molla by Shri Radha Mohan Singh, Union Minister of Agriculture and Farmers Welfare, Govt. of India.

Shri Radha Mohan Singh presenting Jawaharlal Nehru Award to Dr. Kutubuddin Molla

Dr Pratap Bhattacharyya, Principal Scientist, Crop Production Division was awarded ICAR-National Fellow and got appointed on 25 May 2017.

Dr. Sudhanshu Shekhar, SMS (Veterinary Science), KVK, Koderma received 'Young Scientist Award' by Society for Agriculture Innovation and Development at International conference on Advance in agricultural and applied sciences for promoting food security at Hotel Mirage Lords Inn, Battishputli, Kathmandu, Nepal from 13 to 15 May 2017.

Dr. Vallabhaneni Damodar Naidu, who worked for his doctoral degree in the Plant Pathology department of NRRI during 1975-79 period, joined as the Vice Chancellor of Acharya NG Ranga Agricultural University, Guntur, Andhra Pradesh in the first week of June 2017.

Dr. Lipi Das has been nominated as the Convener of Broad Subject Matter Area (BSMA), ICAR for Social Science (Agril Extension, Economics and Agri-Business Management).

Dr. Lipi Das was nominated as an Expert of AICRP (Community Science) Review meeting at ICAR-CIWA, Bhubaneswar during 8-9 April, 2018.

Dr. S Shekhar received Excellence in Extension Award (Animal Science) in the International Conference of Society for Bioinformatics and Biological sciences (SBSS) on "Recent trends in bioinformatics and biotechnology for sustainable development" at Faculty of Veterinary sciences and Animal Husbandry, R. S. Pura, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, J&K from 12 to 13 October 2017.

Dr. AK Nayak received Endeavour Executive Fellowship-2018 (Department of Education & Training, Australian Govt.).

Dr. AK Nayak acted as Research Advisory Committee of the ICAR-National Bureau of Soil Science and Land Use Planning, Nagpur for a period of three years since November, 2016.

Dr. AK Nayak acted as member of Institute Management Committee of ICAR-CIFA and ICAR-IIWM, Bhubaneswar from the year 2017-18.

Dr. AK Nayak acted as Member of the Institute Biosafety Committee of Institute of Life Sciences, Bhubaneswar for the year 2017-18.

Drs. Sangita Mohanty & Dibyendu Chatterjee received NEWS India-UK senior fellowship in 2017-18.

Dr. Debarati Bhaduri received Pran Vohra Award 2017-18 by Indian Science Congress Association, Ministry of Science & Technology, Govt. of India for her significant research work in the field of Agriculture & Forestry Sciences at 105th Indian Science Congress held at Manipur University, Imphal during 16-20 March 2018.

Dr. P Bhattacharyya received Mosaic Company Foundation Scientist Award on Plant Nutrition for the year 2017-18 in the area of Plant Nutrition for his significant contribution in Plant Nutrition, Climate Change and Soil Science research on 27 March 2018.

Drs. P Panneerselvam received Dr. B Vasantharaj David Award for the year 2018 from Applied Zoologists Research association (AZRA)

Dr. U Kumar received AZRA Fellowship Award, 2018

Dr. U Kumar recognized as excellent contribution to Bioscience, Biotechnology Research Asia as Reviewer for the year 2017-2018.

Dr. A Anandan received NEWS India-UK Research Fellowship for the year 2017-18 under Senior category.

Dr. SK Pradhan, Principal Scientist, Crop Improvement Division was awarded NAAS Fellow-2018, Crop Science.

Dr. SK Pradhan was awarded AB Joshi Award-2017

(ISGPB, New Delhi).

Dr. SK Pradhan was awarded Samanta Chandra Sekhar Award, DST, Govt. of Odisha, 2015 (conferred in Sept. 2017).

Dr. SK Pradhan was awarded Outstanding achievement award 2017, awarded by Society for agricultural Innovations & Development (SAID), Ranchi, Jharkhand, India.

Dr. RL Verma received Emerging Scientist Award-2017 of Biologix Research and Innovation Centre (BRICPL), New Delhi, India.

Sports Activities

Tournament of Eastern Zone Sports Meet

NRRI sports contingent of 57 players participated in the ICAR Zonal Tournament for Eastern Zone from 13 to 16 November 2017 at Patliputra Sports Complex, Patna organized by ICAR-RCER. In team events NRRI became Champions in Kabaddi, Football, Volley Shooting and 4 x 100 mt Relay race and Runner Up in Basketball.

In individual events, Shri PK Parida became the winner in 100, 200, 400 and 800 mt race and awarded the Best Athlete (Men) of Eastern Zone for 2017. In women section, Smt. Rosalia Kido was placed first position in Discuss throw. Dr. Susmita Munda and Shiva Sankari secured first position in Badminton doubles and Dr. Susmita Munda and Ms. Sabita Sahoo secured first position in Table Tennis doubles. NRRI scored highest points of 101 and awarded ICAR Zonal Tournament Champion for Eastern Zone, 2017. Shri RK Sahu, Senior Scientist was the *Chief-d-Mission* and Shri BK Sahoo, Administrative Officer was the Manager of the sports contingent.

Best Worker Award

Name	Category
Dr. MJ Baig and Dr. MK Kar	Principal Scientist
Dr. Yogesh Kumar (CRURRS, Hazaribagh)	Senior Scientist
Dr. Upendra Kumar and Dr. RL Verma	Scientist
Dr. Dilip Ranjan Sadangi, KVK, Cuttack	Technical (T6-T9)
Shri Arun Kumar Parida	Technical (T4-T5)
Shri Janardan Nayak, PS	Administrative-II (upto UDCs including Stenos)
Shri Pradeep Kumar Parida	Best Sports Person

NRRI Kabaddi team with Championship trophy

List of Plant Varieties/Unique Germplasms filed

IPRs	Name of Institute	Application/ Registration No.	Name of Innovation/ Technology/ Product/ Variety	Date of Filing/ Registration	Application Granted/ Registered**
Plant Variety	ICAR-National Rice Research Institute, Cuttack	1) REG/2018/6 CR Dhan 502 (IET 20706) 2) REG/2018/7 Satyabhama (CR Dhan 100; IET 20148) 3) REG/2018/8 CR Dhan 200 (IET 21214) 4) REG/2018/9 CR Dhan 503 (IET 20214) 5) REG/2018/10 CR Dhan 404 (Sumit; IET 19913)	Extant Paddy Varieties	19th January, 2018	Applications under Progress
Biological Material/ Strains/ Resources	ICAR-National Rice Research Institute, Cuttack	Unique Rice Germ Plasm CR-143-2-2 (IC0513420)	Rice breeding line tolerant to both vegetative as well as reproductive stage drought stress	Submitted on 17th September, 2016	INGR 17019 Registered in July, 2017
		Unique Rice Germ Plasm SALKATHI Appl.No. 14016; IC0256801	BPH Resistant Rice Germplasm	Submitted on 19th August, 2017	INGR17069 Registered in October, 2017

Commercialization of ICAR-NRRI Technologies (MoUs Signed)

Name of Institute	Name of Technology/ Know-How	IP Protection (Yes/ No)*	Name of Contracting Party	Mode of Partnership**	Date of Licensing
ICAR-National Rice Research Institute, Cuttack	Contract Research MoU on Bio-efficacy evaluation of Agri-Booster ™ KSi against major insect pests and disease of rice	No	Noble Alchem Private Limited, Indore	MoU for Contract Research	03.08.2017
	Memorandum of Understanding (MoU) for commercial seed production of popular paddy inbred high yielding Inbred-Variety POOJA	Yes Reg.No.67 of 2012 with PPV & FRA, New Delhi	Agraza seeds and Biotech Private Limited, Bargarh	MoU	01.09.2017
	MoU of Hybrid Rice Rajalaxmi, CRHR-5	Yes Reg.No.206 of 2014 with PPV & FRA, New Delhi	Bharat Nursery Pvt. Ltd., Kolkata	MoU	08.01.2018
	MoU of 5 panel Customized Leaf Colour Chart (CLCC) with folder	-	Nitrogen Parameters, Chennai	MoU	26.02.2018

Training and Capacity Building

Physical targets and achievements

Sl. No.	Category	Total No. of employees	No. of training planned for 2017-18 as per Annual Training Plan	No. of employees undergone training during 2017-18	% realization of trainings planned during 2017-18
1.	Scientist	97	26	21	80.76
2.	Technical	89	19	12	63.15
3.	Administrative & Finance	65	17	92	541.17
4.	SSS	53	1	Nil	Nil

Category wise training attended by employees

Category: Scientific

Professional attachment training

Sl. No.	Name of the Scientist	Period	Institution
1.	Ms. Rubina Khanam	22 May to 22 August 2017	ICAR-IISS, Bhopal
2.	Dr. Sivashankari .M	24 November 2017 to 24 February 2018	IIFPT, Thanjavur
3.	Dr. B. Raghavendra Goud	20 November 2017 to 20 February 2018	ICAR-CRIDA, Hyderabad
4.	Dr. S. Vijayakumar	27 November 2017 to 27 February 2018	TNAU, Tamilnadu
5.	Dr. Devanna BN	21 October 2017 to 21 February 2018	UAS, Dharwad (IABT)
6.	Dr. Shankari Meena	24 November 2017 to 23 February 2018	TNAU, Tamilnadu

National Training

Sl. No.	Name of the Scientist	Period	Name of Training Programme	Institution
1.	Dr. Nabaneeta Basak	20 February to 12 March 2018	Improved nutritional outcomes through Integrated approach of processing	ICAR-CIAE, Bhopal
2.	Dr. Gaurav Kumar	23 January to 12 February 2018	Recent techniques & tools for Nutritional quality assessment & enhancement of good crop	ICAR-IARI, New Delhi
3.	Dr. Prashant Kumar S. Hanjagi	08 to 28 November 2017	Advanced statistical Tools Techniques for modeling of forecasting Agricultural Data	ICAR-IASRI, New Delhi
4.	Dr. Basana Gowda	7 to 12 August 2017	Introduction to molecular entomology	Agri-biotech foundation (ABF), Hyderabad

5.	Dr. Guruprasanna. Pandi. G	5 to 25 September 2017	Current techniques and advances in mass culturing of microbials for the production of biopesticides	ICAR-NBAIR, Bengaluru
6.	Dr. Guruprasanna. Pandi.G	30 November to 10 December 2017	Innovative approaches and methods in Insect biodiversity conservation	TNAU, Coimbatore
7.	Dr. Prabhukarthikeyan S.R	5 to 25 September 2017	Winter school on Current Techniques and advances in mass culturing of micribials for the production of biopesticides	ICAR-NBAIR, Bengaluru
8.	Dr. Mathew S. Baite	3 to 23 March 2018	Statistical advances for agricultural data analysis	ICAR-IASRI, New Delhi
9.	Dr. Prabhat K Guru	06 to 26 November 2017	Winter school on climate smart machinery for conservation agriculture	ICAR-CIAE, Bhopal
10	Dr. Sumanta Chatterjee	16 November to 06 December 2017	Winter school on simulation modeling	ICAR-IARI, New Delhi
11.	Dr. Manish Debnath	16 November to 06 December 2017	Winter school on simulation modeling	ICAR-IARI, New Delhi
12.	Dr. Lipi Das	22 to 26 October 2017	Training cum workshop for FFP partners	ICAR-IARI, New Delhi
13.	Dr. B Mondal	1to 10 November 2017	Tools on Monitoring , Evaluation and Impact Assessment of Rainfed Techchnologies and Agricultural Development Programmes	ICAR-CRIDA, Hyderabad

International Training

Sl. No.	Name of the Scientist	Period	Name of Training Programme	Institution
1.	Dr. Totan Adak	14 August to 01September 2017	Rice research to production	IRRI, Phillipines
2.	Dr. S.D. Mohapatra	25 September to 06 October 2017	Ecological management of rodents, insects and weeds in rice agro-ecosystems	IRRI, Phillipines

Category: Technical

Sl. No.	Name of the Employee	Period	Name of Training Programme	Institution
1.	Mr. Srikrushna Pradhan	3 to 12 October 2017	Layout and maintenance of field experiments and recording observations	ICAR-IARI, New Delhi
2.	Mr. Prahallad Moharana	3 to 12 October 2017	Layout and maintenance of field experiments and recording observations	ICAR-IARI, New Delhi

3.	Mr. Prahallad Moharana	15 to 24 June 2017	Competence enhancement programme on soft skills and personality development	ICAR-NARM, Hyderabad
4.	Mr. A.K. Maharana	15-24 June 2017	Competence Enhancement Programme on soft skills & personality development	ICAR-NARM, Hyderabad
5.	Mr. Bhakta Charan Behera	03-12 October 2017	Layout and maintenance of field experiments and recording observations	ICAR-IARI, New Delhi
6.	Mr. Santosh Ku Sethi	4 to 8 September 2017	Networking: Basics & Management	ICAR-IASRI, New Delhi
7.	Mr. Dipti Ranjan Sahoo	15 to 24 June 2017	Competence Enhancement Programme on soft skills & personality development	ICAR-NARM, Hydrabad
8.	Mr. K.C. Palwar	06 to 10 March 2017	Automobile Maintenance Road Safety and Behavioural skill	ICAR-CIAE, Bhopal
9.	Mr. P.K. Jena	18 to 22 July 2017	Automobile Maintenance Road Safety and Behavioural skill	ICAR-CIAE, Bhopal
10.	Mr. S.K. Rout	22 to 27 September 2017	Computer Application	ICAR-IASRI, New Delhi
11.	Mr. Ugan Saw	19 to 23 September 2017	Automobile maintenance, road safety & behavioral skill	ICAR-IISS, Bhopal
12.	Mr. Bibhash Medhi	17 to 22 July 2017	ICAR ERP System	ICAR- IASRI, New Delhi

Category: Administrative

Sl. No.	Name of the Employee	Period	Name of Training Programme	Institution
1.	Mr. Sunil Kumar Das	06 to 07 July 2017	Workshop on Public Procurement under GRR-2017	ICAR-ISTM, New Delhi
2.	Mr. Sunil Kumar Das	9 to12 August 2017	Training on Public Financial Management System (PFMS)	ICAR-IASRI, New Delhi
3.	Mr. Basant Ku. Sahoo	20 to 24 August 2017	General Financial Rule 2017	ICAR-ISTM , New Delhi
4.	Mr. R Paswan	5 to 11 January 2018	Enhancing efficacy & behavioral skill	NBSSLUP, Kolkata
5.	61 Administrative staff	11 to 12 September 2017	GST, PFMS & GFR 2017	ICAR-NRRI, Cuttack
6.	22 Administrative staff	24 to 25 October 2017	Training Programme on Public Financial Management System (PFMS)	ICAR-NRRI, Cuttack
7.	5 Administrative staff	27 to 28 November 2017	Training Programme on Public Financial Management System (PFMS)	ICAR-NRRI, Cuttack

Category: Progressive Farmers and Govt. Officials

Sl. No.	Title of the Training/ Short-term Training-cum-Exposure visit Programme	Period	Sponsored by	Target group with number
1.	KRISHI	10 to 15 April 2017	NRRI, Cuttack	Scientific staff of the Institute
2.	Improved rice production and protection technologies	21 to 22 August 2017	CARD, New Delhi	50 farmers from Gumla district of Jharkhand
3.	Backyard poultry production and Kitchen gardening	6 September 2017	Tribal Sub-Plan (TSP)	100 tribal farmers and farmwomen in Ramthenga village of Kalinga Nagar, Jajpur
4.	FPO Management	11 September 2017	ABI Centre, NRRI, Cuttack	15 progressive farmers
5.	Public Financial Management System (PFMS), General Financial Rules (GFR) and Goods & Services Tax (GST)	11 to 12 September 2017	NRRI, Cuttack	101 participants of the ICAR institutes located at Cuttack, Bhubaneswar, Kolkata, Ranchi, Patna, Guwahati and Port Blair
6.	Quality Parameters and Varieties of Rice	19 September 2017	Trade E-Commerce Startup	Seven Marketing executives
7.	Awareness program on FPO formation at Atgarh	21 September 2017	ABI Centre, NRRI, Cuttack	67 progressive farmers of Atgarh
8.	Awareness program on FPO formation at Badamba	21 September 2017	ABI Centre, NRRI, Cuttack	44 progressive farmers of Badamba
9.	Quality Seed Production and Storage in Rice	23 to 24 and 25 to 26 September 2017		21 Assistant Agriculture Officers, 25 Seed growers, and 28 representatives of various NGOs involved in seed production in Odisha
10.	Public Financial Management System (PFMS)	24 to 25 October 2017	NRRI, Cuttack	Administrative personnel of the institute and its regional stations
11.	Comprehensive Agribusiness Incubation Program (CAIP)	06 to 11, 20 to 25 November 2017 04 to 09 December 2017	ABI Centre, NRRI, Cuttack	20 farmers, entrepreneurs, ex-serviceman, educated rural and urban youth

12.	Improved Rice Production and Protection Technologies	14 to 16 November 2017	ATMA, Raghunathganj-II, Murshidabad, West Bengal	40 farmers from Murshidabad, West Bengal
13.	Mushroom cultivation-a profitable enterprise and source of additional income for the farmwomen	21 November 2017	Farmer's FIRST Programme of NRRI, Cuttack	Farmwomen of Satyabhamapur, Biswanathpur, Laxminarayanpur and Ganeswarpur villages
14.	Public Financial Management System (PFMS)	27 to 28 November 2017	NRRI, Cuttack	41 participants of the ICAR institutes located at Cuttack, Bhubaneswar, Kolkata, Ranchi and Port Blair and personnel from other organizations like BCKV, West Bengal, CSIR-CIMAP, Lucknow and CDB, Bhubaneswar
15.	Application of pesticides in rice	6 December 2017	ATMA, Bargarh and NRRI, Cuttack	Thirty progressive farmers and Krushak Sathi from different blocks of Bargarh district, Odisha
16.	FPO Management	14 December 2017	ABI Centre, NRRI, Cuttack	12 progressive farmers of Atgarh block, Cuttack Dist, Odisha
17.	Technology based Entrepreneurship Development Program (TEDP)	18 to 23 December 2017	ABI Centre, NRRI, Cuttack	17 participants from different districts of Odisha
18.	Awareness program on FPO formation at Niali	11 January 2018	ABI Centre, NRRI, Cuttack	23 Progressive Farmers of Niali-Eranch
19.	Improved Rice Production and Protection Technologies	14 to 15 February 2018	SISU (NGO), Ranchi, Jharkhand	23 Progressive Farmers
20.	Awareness program on FPO formation at Niali-Jhalarpur	24 February 2018	ABI Centre, NRRI, Cuttack	72 Progressive Farmers of Niali-Jhalarpur
21.	Winter school on 'Innovative Approaches and ICT Applications in Extension Research, Teaching and Work'	14 February to 6 March 2018	ICAR, New Delhi	16 participants from ten different states

22.	Friends of Coconut Tree	12 to 17 March 2018	Coconut Development Board, Regional Centre, Bhubaneswar	36 rural youth and progressive coconut growers from six different blocks of Cuttack and Puri district
23.	Improved Package of Practices for Enhancing Rice Productivity and Profitability	20 to 24 March 2018	ATMA, Madhepura	21 kisan sathis, progressive farmers and officers from Madhepura district of Bihar
24.	One-day Workshop cum Exposure visit and Awareness Programme on Climate Change	21 March 2018	NICRA Project, NRRI, Cuttack	35 farmers from seven villages of Biridi Block of Jagatsinghpur district, Odisha

Financial targets and achievements for 2017-18 of all NRRI employees

Sl. No.	RE 2017-18 for HRD			Actual Expenditure 2017-18 for HRD	% Utilization
	Plan	Non-Plan	Total		
	(Lakh Rs.)			(Lakh Rs.)	2017-18
1.	5.00		5.00	5.00	100%

In-charge and Members of Different Cells

Research Advisory Committee

Prof. SK Datta, VC, Visva Bharati University, Shantiniketan, West Bengal, Chairman

Dr. DK Mishra, Director Farms, JN Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, Member

Dr. AR Sharma, Ex-Director, Weed Science, Directorate of Weed Research, Jabalpur, Member

Dr. JS Bentur, Ex-Principal Scientist, ICAR-IIRR, Hyderabad, Member

Dr. PK Mohapatra, Ex-Professor, Life Sciences, Sambalpur University, Odisha, Member

Dr. RP Singh 'Ratan', Dean, Extension, BAU, Ranchi, Member

Dr. H Pathak, Director, NRRI, Cuttack, Member

Dr. IS Solanki, ADG (FFC), ICAR, New Delhi, Member

Dr. SR Voleti, Principal Scientist, IIRR attended the meeting as a Special Invitee

Dr. JN Reddy, Principal Scientist, NRRI, Cuttack, Member Secretary

Institute Management Committee

Dr. H Pathak, Director, NRRI, Cuttack, Chairman

Director of Agriculture & Food Production, Govt. of Odisha, Member

Director of Agriculture, Govt. of West Bengal, Kolkata, Member

Dr. LM Gadanayak, Dean of Research, OUAT, Bhubaneswar, Member

Dr. SG Sharma, PS & Head, NRRI, Cuttack, Member

Dr. (Mrs.) Mayabini Jena, PS & Head, NRRI, Cuttack, Member

Dr. Shiv Sewak, Principal Scientist, IIPR, Kanpur, Member

Dr. CS Kar, Principal Scientist, CRIJAF, Barrackpore, Kolkata, Member

Dr. IS Solanki, ADG (FFC), ICAR, New Delhi, Member

Shri SK Pathak, DD (F)-III, ICAR, New Delhi, Member

Shri Sukanta Kumar Panigrahi, Patanda, Nayagarh, Odisha (Non-Official)

Shri Amareswar Mishra, Bhubaneswar, Odisha, Member (Non-Official)

Shri KC Joshi, Joint Director Admn-cum-Registrar, NRRI, Cuttack, Member Secretary

Institute Technology Management Committee (ITMC)

Director, NRRI, Cuttack, Chairman

Dr. P Swain, CIFA, External Member

Dr. ON Singh, Member

Dr. SG Sharma, Member

Dr.(Mrs.) Mayabini Jena, Member

Dr. GAK Kumar, Member

Dr. BC Patra, Member Secretary

Institute Joint Staff Council (IJSC)

Director, NRRI, Cuttack, Chairman

Dr. ON Singh, Member

Dr.(Mrs) S Samantaray, Member

Dr. SD Mohapatra, Member

Shri SK Das, Member

Shri NC Parija, AAO (Technical Section), Secretary (Official side)

Shri Sanjaya Kumar Sahoo, (Administrative Staff Side), Member & Secretary (Staff side)

Shri Rama Chandra Pradhan, (Administrative Staff Side), CJSC Member

Shri Dipti Ranjan Sahoo, (Technical Staff Side), Member

Shri Prahallad Moharana, (Technical Staff Side), Member

Shri Bhagyadhar Pradhan, (Technical Staff Side), Member

Shri KC Ram, (Supporting Staff side), Member

Shri Meru Sahoo, (Supporting Staff Side), Member

Shri Markand Charan Nayak, (Supporting Staff side), Member

Central Public Information Officer

Shri CP Murmu

PME Cell

Dr. (Mrs.) Mayabini Jena

Dr. (Mrs.) Padmini Swain

Dr. JN Reddy

Dr. (Mrs.) MK Kar

Dr. B Mondal

Dr. NN Jambhulkar

Dr. T Adak

Shri SK Sinha

Human Resource Development (HRD) Committee

Nodal Officer-Dr. (Mrs.) S Samantaray

Co-Nodal Officer-Dr. SD Mohapatra

Women Cell

Dr. (Mrs.) S. Samantray, Chairperson

Dr. Meena Senapati, 3rd Party Member, Director, Centre for Plant Tissue Culture & Biotechnology, Bhubaneswar

Dr. (Mrs.) MK Kar, Member

Dr. MJ Baig, Member

Dr. (Mrs.) A Poonam, Member

Mrs. Manasi Das, Member

Mrs. Chandmuni Tudu, Member

Mrs. Surubali Hembram, Member

Mrs. Sushmita Munda, Member Secretary

Institute Grievance Cell

Director, NRRI, Cuttack, Chairman

***Dr.(Mrs.) Padmini Swain,** Member

***Chief Administrative Officer,** Member

***Finance & Accounts Officer,** Member

Shri J Meher, Member

Shri Santosh Kumar Sethi, Member

Shri Abhaya Kumar Pradhan, Member

Shri Bichitrananda Khatua, Member

Asstt. Administrative Officer (Tech), Member Secretary

(*Subject to nomination by the Institute Management Committee)

Institutional Bio-Safety Committee

Director, NRRI, Cuttack, Chairman

Dr. BP Shaw, Scientist-F, Institute of Life Sciences (ILS), Bhubaneswar, DBT Nominee

Dr. MJ Baig, Member Secretary

Dr. PK Chand, Professor (Botany), Department of Botany, Utkal University, Bhubaneswar, Outside Experts

Dr. Kishore CS Panigrahi, Reader-F, NISER, Bhubaneswar, Outside Experts

Dr. Luna Samanta, Professor & Head, Department of Zoology, Ravenshaw University, Cuttack, Outside Experts

Dr. Jogeswar Pani, Medical Officer, NRRI, Cuttack, Biosafety Officer

Dr. ON Singh, Member

Dr. SG Sharma, Member

Dr. (Mrs.) S Samantaray, Member

Personnel

(From April, 2017 to March, 2018)

Dr. Himanshu Pathak, Director

Crop Improvement Division

Name of the Scientist	Designation
Dr. Onkar Nath Singh	I/c Head
Dr. J.N.Reddy	Pr.Scientist
Dr. B.C.Patra	Pr.Scientist
Dr. (Mrs.) S.Samantaray	Pr.Scientist
Dr. (Mrs.) MeeraKumari Kar	Pr.Scientist
Dr.Sarat Kumar Pradhan	Pr.Scientist
Dr.Lamobodar Behera	Pr.Scientist
Dr.Hatanath Subudhi	Pr.Scientist
Dr.Lotan Bose	Pr.Scientist
Dr.K.Chattopadhyay	Pr.Scientist
Dr.Sushant Kumar Dash	Pr.Scientist
Dr.A.Anandan	Pr.Scientist
Shri R.K.Sahu	Scientist
Shri S.S.C.Patnaik	Scientist
Shri B.C.Marndi	Scientist
Shri J.Meher	Scientist
Shri Mridul Chakraborti	Scientist
Dr.Jawahar Lal Katara	Scientist
Dr.Ramlakhan Verma	Scientist
Dr.Rameswar Prasad Sah	Scientist
Dr.(Mrs.) P.Sanghamitra	Scientist
Dr.N.Umakant	Scientist
Dr. Kutubuddin Ali Molla	Scientist
Dr.(Mrs.)Sutapa Sarkar	Scientist
Md. Azharudeen T.P.	Scientist
Dr.Soham Ray	Scientist
Shri Parameswaran, C	Scientist
Dr.Devanna	Scientist

Crop Production Division

Name of the Scientist	Designation
Dr.A.K.Nayak	Head
Dr.P.K.Nayak	Pr.Scientist
Sri S.P.Patel	Pr.Scientist
Dr.T.K.Dangar	Pr.Scientist
Dr.Sanjay Saha	Pr.Scientist
Dr.Pratap Bhattacharyya	Pr.Scientist
Dr.B.B.Panda	Pr.Scientist
Dr.(Mrs.)Annie Poonam	Pr.Scientist
Dr.P.Panneerselvam	Sr.Scientist
Dr.Rahul Tripathi	Scientist
Dr.Banwari Lal	Scientist
Dr.(Mrs.)Sangita Mohanty	Scientist
Dr.Mohammad Shahid	Scientist
Dr.Debarati Bhaduri	Scientist
Dr.Upendra Kumar	Scientist
Shri B.S. Satapathy	Scientist
Shri Anjani Kumar	Scientist
Dr.(Mrs.)Sushmita Munda	Scientist
Dr.(Mrs.) Priyanka Goutam	Scientist
Dr.Dibyendu Chatterjee	Scientist
Shri Prabhat Kumar Guru	Scientist
Shri B.N.Totaram	Scientist
Shri Sumanta Chaterjee	Scientist
Er.Manish Debanath	Scientist
Mrs. Rubina Khanam	Scientist
Dr.(Ms.) M.Sivashankari	Scientist
Sri B.Raghavendra Goud	Scientist
Dr.Vijayakumar S.	Scientist

Crop Protection Division

Name of the Scientist	Designation
Dr.(Mrs.)Mayabini Jena	Head
Dr.P.C.Rath	Pr.Scientist
Dr.K.R.Rao	Pr.Scientist
Dr.S.D.Mohapatra	Pr.Scientist
Dr.A.K.Mukherjee	Pr.Scientist
Dr.Manas Kumar Bag	Pr.Scientist
Dr.Srikanta Lenka	Sr.Scientist
Dr.Totan Adak	Scientist
Shri Somnath Suresh Pokhare	Scientist
Shri Manoj Kumar Yadav	Scientist
Shri Aravindan S.	Scientist
Dr.Naveenkumara B.Patil	Scientist
Dr.Raghu S.	Scientist
Dr.Guruprasanna Pandi, G	Scientist

Dr.Basana Gowda, G ....Scientist
Dr.Prabhukarthikeyan, SR ....Scientist
Dr.Mathew Saikholen Bite....................Scientist
Shri M.Annamalai ....Scientist
Ms.Golive Prasanthi....................Scientist
Dr.(Mrs.) Sankari Meena K. ....Scientist

Crop Physiology and Biochemistry Division

Name of the Scientist....................Designation

Dr.S.G.Sharma ....Head
Dr.(Mrs.) Padmini Swain....................Pr.Scientist
Dr.M.J.Baig....................Pr.Scientist
Dr.Koushik Chakraborty....................Scientist
Shri Torit Baran Bagchi....................Scientist
Dr.Awadhesh Kumar....................Scientist
Dr.P.S.Hanjagi ....Scientist
Mrs. Nabaneeta Basak....................Scientist
Sri Gaurav Kumar....................Scientist

Social Science Division

Name of the Scientist....................Designation

Dr.P.Samal....................Pr.Scientist
Dr.N.C.Rath ....Pr.Scientist
Dr.G.A.K.Kumar ....Pr.Scientist
Dr.S.K.Mishra ....Pr.Scientist
Dr.(Mrs.) Lipi Das....................Pr.Scientist
Dr.Biswajit Mandal ....Pr.Scientist
Dr. N.N.Jambhulkar....................Scientist

Central Rainfed Upland Rice Research Station, Hazaribagh, Jharkhand

Name of the Scientist....................Designation

Dr.D.Maiti ....Head
Dr.N.P.Mandal ....Pr.Scientist
Dr.Shiv Mangal Prasad ....Pr.Scientist
Dr.Someshwar Bhagat ....Pr.Scientist
Dr.C.V.Singh ....Sr.Scientist
Dr.Yogesh Kumar ....Sr.Scientist
Dr.B.C.Verma....................Scientist
Dr.Somnath Roy ....Scientist
Dr.(Mrs.) Amrita Banerjee ....Scientist

Resgional Rainfed Low Land Rice Research Station, Gerua, Assam

Name of the Scientist....................Designation

Dr.K.B.Pun....................OIC
Dr.Rupankar Bhagwati....................Pr.Scientist
Dr.Kanchan Saikia....................Pr.Scientist
Dr.Teekam Singh ....Sr.Scientist
Shri S.K.Ghritlahre ....Scientist

Technical Staff, NRRI, Cuttack

Category-III

Name ....Designation

Sri K.K. Swain ....Chief Technical Officer (Mechanical)
Dr. Jogeswar Pani ....Medical Officer (On deputation)

Category-II

Name ....Designation

Dr. Ramesh ChandraChief Technical Officer (Sr.Farm Assistant)
Sri Prakash Kar ....Chief Technical Officer (Photography)
Sri P. Jana.Chief Technical Officer (Rice Production Training)
Dr. Pradeep Ku. SahooAsst. Chief Technical Officer (Fishery)
Sri A.K. Dalai..........Asstt. Chief Technical Officer (Electrical)
Sri B.K. Mohanty.......Sr.Technical Officer (Hindi Translator)
Sri Sunil Kumar Sinha ....Technical Officer (Computer Asst.)
Sri Manoj Kumar Nayak...........Technical Officer (Lib. Asst.)
Sri J. Sai Anand ....Technical Officer (Farm Asst.)
Sri Santosh Kumar Sethi .Technical Officer (Computer Asst.)
Sri Padma Lochan Dehury ......Technical Officer (Farm Asst.)
Sri Brundaban Das ....Technical Officer (Farm Asst.)
Sri Prempal Kumar ....Technical Officer (Farm Asst.)
Smt. Sandhya Rani Dalal ....Technical Officer (Editor)
Smt. Rosalin Swain ....Technical Officer (Farm Asst.)
Smt. Gayatri Sinha ....Technical Officer (Farm Asst.)
Sri Smruti Kanta Rout.....Technical Officer (Computer Asst.)
Smt. Chandamuni Tudu ....Technical Officer (Farm Asst.)
Sri Lalan Kumar Singh ......Technical Officer (Training Asst.)
Smt. Baijayanti Nayak ....Technical Officer (Farm Asst.)

Category-I

Name ....Designation

Sri Bhagaban Behera ....Technical Officer (Photography)
Sri K. C. Bhoi ....Technical Officer (Blacksmith)
Sri Srikrishna Pradhan...Technical Officer (Field Assistance)
Sri J.C.Hansda................Technical Officer (Field Assistance)
Sri Aparti Sahoo.............Technical Officer (Field Assistance)
Sri K.K. Suman...............Technical Officer (Field Assistance)

Sri A.K. Mishra ....Technical Officer (Field Assistance)
Sri Arun Panda ....Technical Officer (Library Asst.)
Sri K.C. Palaur ....Technical Officer (Driver)
Sri J.P. Behura................Technical Officer (Supervisor-Civil)
Sri Santosh Kumar Ojha ....Technical Officer (Electrician)
Mrs. Nibedita Biswal .....Technical Officer (Lab. Technician)
Sri Ramrai Jamunda ....Sr.Technical Assistant (Fitter)
Sri Arun Kumar Parida ....Sr.Technical Assistant (Painter)
Sri Prahallad Moharana .Sr.Technical Assistant (Field Asst.)
Sri D.R. Sahoo ....Sr.Technical Assistant (Projectionist)
Sri A.K. Moharana ....Sr.Technical Assistant (Field Asst.)
Sri Prasanta Kumar Jena ....Sr.Technical Assistant (Driver)
Sri Bansidhar Ojha ....Sr.Technical Assistant (Welder)
Mrs. Chintamani Majhi...Sr.Technical Assistant (Field Asst.)
Sri Charan Naik ....Sr.Technical Assistant (Field Asst.)
Sri Kailash Ch. Mallick ...Sr.Technical Assistant (Field Asst.)
Sri Srinibas Panda ....Sr.Technical Assistant (Electrician)
Sri Parimal Behera ....Sr.Technical Assistant (Field Asst.)
Sri Bhakta Ch. Behera .....Sr.Technical Assistant (Field Asst.)
Sri Nakula Barik ....Sr.Technical Assistant (Field Asst.)
Sri Charan Naik ....Sr.Technical Assistant (Field Asst.)
Sri Gouranga Ch. Sahoo ...Sr.Technical Assistant (Mechanic)
Sri Mansingh Soren ....Sr.Technical Assistant (Field Asst.)
Sri A. C. Moharana ....Technical Assistant (Field Asst.)
Sri Jogeswar Bhoi ....Technical Assistant (Field Asst.)
Sri Pradeep Kumar Parida ....Technical Assistant (Driver)
Sri Debasis Parida..........Technical Assistant (Tractor Driver)
Sri Pramod Kumar OjhaTechnical Assistant (Tractor Driver)
Sri Debaprakash Behera ....Technical Assistant (Driver)
Sri Gyanaranjan Bihari ....Technical Assistant (Driver)
Sri Ajaya Kumar Nayak ....Sr.Technician (Pharmacist)
Sri Surendra Biswal ....Sr.Technician (Field Asst.)
Sri Susanta Ku. Tripathy ....Sr.Technician (Field Asst.)
Sri Baidyanath Hembram ....Sr.Technician (Field Asst.)
Sri Dularam Majhi........................Sr.Technician (Field Asst.)
Sri Sesadev Pradhan ....Sr.Technician (Field Asst.)
Sri Chandan Kumar Ojha ....Sr.Technician (Field Asst.)
Sri Ramudev Beshra ....Sr.Technician (Farm Mechanic)
Sri Pramod Ku. Sahoo ......Sr.Technician (Machine Operator)
Sri Bhagyadhar Pradhan ......Sr.Technician (Farm Mechanic)
Sri Keshab Chandra Das ..Sr.Technician (Machine Operator)
Sri Alok Kumar Panda ....Technician (Extension Asst.)
Sri Ajaya Kumar Naik ....Technician (Field Asst.)

CRURRS, Hazaribag (Jharkhand)

Category-I

Name ....Designation

Sri Ranjit Tirky ....Technical Officer (Field Assistance)
Sri A. N. Singh ....Technical Officer (Field Assistance)
Sri Sawan Oran ....Sr.Technical Assistant (Field Asst.)
Sri Ugan Saw ....Technical Assistant (Driver)
Sri Jitendra Prasad.....................Technician (Extension Asst.)

RRLRRS, Gerua (Assam)

Category-I

Name ....Designation

Sri Haladhar Thakuria...........Technical Officer (Field Asstt.)
Sri Bhupen Kalita ....Technician (Field Asst.)

Category-II

Name ....Designation

Sri Bibhash Medhi ....Sr.Technical Assistant (Farm Asst.)

K.V.K., Santhpur, Cuttack

Category-III

Name ....Designation

Mrs. Sujata Sethy ....Asstt.Chief Technical Officer, SMS (Home Sci.)
Sri Dillip Ranjan Sarangi..........Asstt.Chief Technical Officer, SMS (Soil Science)
Dr.Manish Chourasia ....Asstt.Chief Technical Officer, SMS (Plant Protection)
Sri Tusar Ranjan Sahoo ....Sr. Technical Officer, SMS (Horticulture)
Dr.Ranjan Kumar Mohanta...................Sr. Technical Officer, SMS (Animal Science)

Category-I

Name ....Designation

Sri Makardhar Behera..Sr.Technical Asstt. (T-4) (Tractor Driver)
Sri Arabinda Bisoi ....Sr.Technician (T-2) (Driver)

K.V.K., Jainagar, Koderma, Jharkhand

Category-III

Name ....Designation

Mrs. Chanchila Kumari ....Asstt. Chief Technical Officer, STA (Home Science)
Dr. Shudhanshu Sekhar ....Asstt. Chief Technical Officer, STA (Veterinary Science)

Sri Bhoopendra Singh ....Sr. Technical Officer, SMS (Horticulture)

Category-II

Name ....**Designation**

Sri Rupesh Ranjan...............Technical Officer, Training Asst.

Sri Manish Kumar ....Technical Officer, Training Asst.

Category-I

Name ....**Designation**

Sri Sanjay Kumar.........................Technical Assistant (Driver)

ADMINISTRATIVE STAFF

NRRI, Cuttack

Name ....**Designation**

Sri K.C.Joshi ....Joint Director (Admn.-cum-Registrar

Sri S.R.Khuntia ....Chief F & AcO.

Sri B.K.Sinha ....Sr.Administrative Officer

Sri Sunil Kumar Das....................Finance & Accounts Officer

Sri A.K.Tiwari ....Assistant Director (Official Language)

Sri Nabakishore Das ....Security Officer

Sri S.K.Mathur....................................Administrative Officer

Sri B.K. Sahoo ....Administrative Officer

Sri B.K.Moharana...............Assistant Administrative Officer

Sri Sunil Kumar Sahoo ....Assistant Administrative Officer

Sri S.K.Das ....Assistant Administrative Officer

Sri N.C.Parija......................Assistant Administrative Officer

Sri N.K.Swain ....Assistant Administrative Officer

Sri C.P.Murmu ....Assistant Administrative Officer

Sri G.K.Sahoo ....Private Secretary

Sri N.N.Mohanty ....Private Secretary

Sri Janardan Nayak......................................Private Secretary

Sri Narayan Mahavoi ....Private Secretary

Sri Trilochan Ram.......................................Personal Assistant

Sri A.Kullu ....Personal Assistant

Smt. Belarani Mahana ....Personal Assistant

Sri Daniel Khuntia ....Personal Assistant

Smt. Nirmala Jena..Personal Assistant

Sri Manas Ballav Swain..............................Personal Assistant

Smt. Snehaprava Sahoo ....Personal Assistant

Miss Sabita Sahoo ....Personal Assistant

Sri Manoranjan Swain................................Personal Assistant

Sri B.C.Tudu ....Assistant

Sri K.K.Sarangi ....Assistant

Sri S.K. Behera ....Assistant

Sri Satyabrata Nayak ....Assistant

Sri Subodh Kumar Sahu ....Assistant

Sri R.K. Behera ....Assistant

Sri Ramesh Ch. Das ....Assistant

Smt. Rosalia Kido ....Assistant

Sri N.P.Behura ....Assistant

Sri Sanjaya Kr. Sahoo ....Assistant

Sri Munael Mohanty ....Assistant

Sri Saroj Kumar Nayak ....Assistant

Sri Dillip Kumar Parida ....Assistant

Sri S.K. Satapathy ....Assistant

Sri Manoj Kumar Sethi..Assistant

Sri K.C. Behera ....Assistant

Sri P.C. Das...Assistant

Sri A.K. Pradhan..Assistant

Sri R.C. Pradhan ....Assistant

Sri Vishal Kumar ....Assistant

Smt. Gourimani Dei ....Assistant

Sri Rajdip Dutta ....Assistant

Sri Samir Kumar Lenka ....Upper Division Clerk

Sri Sanjeeb Kr. Sahoo............................Upper Division Clerk

Smt. Manasi Das ....Upper Division Clerk

Sri Ramesh Ch. Nayak ....Upper Division Clerk

Sri Sunil Pradhan..................................Upper Division Clerk

Smt. Ambika Sethi................................Upper Division Clerk

Sri Ranjan Sahoo..................................Upper Division Clerk

Sri Maheswar Sahoo ....Upper Division Clerk

Sri Amit Kumar Sinha..........................Lower Division Clerk

Sri B.K.Gochhayat................................Lower Division Clerk

Sri Harihar Marandi ....Lower Division Clerk

Sri Santosh Kr. Bhoi.............................Lower Division Clerk

Sri Dhaneswar Muduli ....Lower Division Clerk

CRURRS, Hazaribag (Jharkhand)

Name ....**Designation**

Sri S.K.Jena ....Assistant Administrative Officer

Sri R.Paswan ....Personal Assistant

Sri Sanjeev Kumar ....Assistant

Sri C.R.Dangi ....Upper Division Clerk

Sri Arbinda Kumar Das ....Lower Division Clerk

Sri Satish Kr. Pandey ....Lower Division Clerk

RRLRRS, Gerua (Assam)

Name .... **Designation**

Sri D.K.Mohanty .... Assistant Administrative Officer
Smt. Jali Das .... Upper Division Clerk

KVK, Santhpur, Cuttack

Name .... **Designation**

Sri Bibhuti Bhusan Polai .... Stenographer

Others (Canteen Staff), NRRI, Cuttack

Name .... **Designation**

Sri Arabinda Jena .... Canteen Manager
Sri Meru Sahu .... Bearer
Sri Markanda Nayak .... Bearer
Sri Madhaba Pradhan .... Bearer
Sri Nityananda Naik .... Wash Boy

SKILLED SUPPORT STAFF

ICAR-NRRI, Cuttack

Name .... **Designation**

Sri Sundara Marandi .... Skilled Support Staff
Sri Duryodhan Naik .... Skilled Support Staff
Smt. Hadi Dei .... Skilled Support Staff
Sri K.C.Ram .... Skilled Support Staff
Sri Sahadev Naik .... Skilled Support Staff
Smt. Gurubari Dei .... Skilled Support Staff
Sri Dambarudhar Das .... Skilled Support Staff
Sri Fakira Charan Sahu .... Skilled Support Staff
Sri Jogendra Biswal .... Skilled Support Staff
Smt. Snehalata Biswal .... Skilled Support Staff
Smt. Namasi Singh .... Skilled Support Staff
Sri Lawa Murmu .... Skilled Support Staff
Smt. Surubali Hembram .... Skilled Support Staff
Smt. Mukta Hembram .... Skilled Support Staff
Smt. Basanti Marandi .... Skilled Support Staff
Sri Dasia Naik .... Skilled Support Staff
Sri Krushna Naik .... Skilled Support Staff
Sri Ganesh Chandra Sahoo .... Skilled Support Staff
Sri Bichitrananda Khatua .... Skilled Support Staff
Smt.Santi Dei .... Skilled Support Staff
Smt. Deba Dei .... Skilled Support Staff
Sri Dharmananda Bhoi .... Skilled Support Staff
Sri Kirtan Bhoi .... Skilled Support Staff
Sri Sarat Chandra Bhoi .... Skilled Support Staff
Sri Narayan Das (B) .... Skilled Support Staff
Sri Sudhir Kuamar Bhoi .... Skilled Support Staff
Sri Gokuli Majhi .... Skilled Support Staff
Smt. Mini .... Skilled Support Staff
Smt. Kuni Dei .... Skilled Support Staff
Sri Duruja Naik .... Skilled Support Staff
Smt. Pramila Dei .... Skilled Support Staff
Smt. Ramani Dei .... Skilled Support Staff
Sri Biranchi Bhoi .... Skilled Support Staff
Sri Pradeep Kumar Das .... Skilled Support Staff
Sri Sadananda Naik .... Skilled Support Staff
Sri Jagu Marandi .... Skilled Support Staff
Smt.Jayanti Dei .... Skilled Support Staff
Sri Rabi Naik .... Skilled Support Staff
Sri Bijay Naik .... Skilled Support Staff
Sri Pandab Naik .... Skilled Support Staff
Sri Debaraj Naik .... Skilled Support Staff
Sri Bansidhar Naik .... Skilled Support Staff

CRURRS, Hazaribag, Jharkhand

Name .... **Designation**

Sri Rameswar Ram .... Skilled Support Staff
Sri Liladhar Mahato .... Skilled Support Staff
Smt. Sita Devi .... Skilled Support Staff
Smt. Nagiya Devi .... Skilled Support Staff
Sri Bhuneswar Oran .... Skilled Support Staff
Smt. Panwa Devi .... Skilled Support Staff
Smt. Karmi Devi .... Skilled Support Staff
Smt. Dhanwa Devi .... Skilled Support Staff
Sri Tirath Ram .... Skilled Support Staff
Sri Shambhu Gope .... Skilled Support Staff
Sri Gopal Gope .... Skilled Support Staff
Sri Megh Narayan Prasad .... Skilled Support Staff
Sri Harish Chandra Bando .... Skilled Support Staff

RRLRRS, Gerua, Assam

Name .... **Designation**

Sri Manoranjan Das .... Skilled Support Staff

KVK, Santhpur, Cuttack

Name .... **Designation**

Sri Rama Pradhan .... Skilled Support Staff

KVK, Koderma, Jharkhand

Name .... **Designation**

Sri Mukesh Ram .... Skilled Support Staff

Financial Statement for 2017-18

(As on 31 March 2018)

Plan

(Rs. in Lakh)

Head of Account	R.E.	Expenditure
Establishment Charges	2850.00	2850.00
O.T.A.	0.08	0.08
T.A.	75.00	75.00
HRD	5.00	5.00
Pension	4200.00	4200.00
REPAIR & MAINTENANCE		
Equipment	20.00	20.00
Office Buiilding	27.50	27.50
Residential Building	15.00	15.00
Minor Works	21.00	21.00
Contingencies	883.00	883.00
CAPITAL		
Equipment	150.28	150.28
Works	1315.65	1315.65
Furniture	2.07	2.07
TOTAL	**9564.58**	**9564.58**

Work Plan 2017-18

Programme 1. Genetic improvement of rice for enhancing yield, quality and climate resilience

Programme Leader: ON Singh/JN Reddy

Exploration, characterization and conservation of genetic resources for rice improvement

Principal Investigator: BC Patra

Co-Principal Investigator: BC Marndi, P Sanghamitra, S Samantaray, JL Katara, N Umakanta, N Jambhulkar, Somnath Roy & NP Mandal

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

Principal Investigator: RK Sahu

Co-Principal Investigator: RP Sah, P Sanghamitra, ON Singh, RL Verma, M Jena, AK Mukherjee, MK Bag, NKB Patil & Azharudheen TP

Utilization of wild and cultivated gene pool of rice for resistance to biotic stresses

Principal Investigator : MK Kar

Co-Principal Investigator : LK Bose, M Chakraborti, Soham Ray, Sutapa Sarkar, M Azharudheen, SK Dash, JN Reddy, NN Jambulker, AK Mukherjee, S Lenka, SD Mohapatra & DR Pani

Associate : M Jena

Genetic improvement of rice for enhancing input use efficiency

Principal Investigator : A Anandan

Co-Principal Investigator : J Meher, C Parameswaran, RP Sah, S Samantaray, Anjani Kumar, Sangita Mohanty, P Panneerselvam, SKDash, P Swain, Gaurav kumar and Devanna BN

Genetic improvement of rice for aroma, nutrition and grain quality

Principal Investigator: Sutapa Sarkar

Co-Principal Investigator: SSC Pattanaik, K Chattopadhay, P Sanghamitra, A Anandan, S Samantaray, HN Subudhi, M Chakraborti, N Basak, J Meher & MK Kar

Genetic improvement of rice for climate resilience in rainfed shallow lowland

Principal Investigator: SK Pradhan

Co-Principal Investigator: JN Reddy, M Chakraborti, L Behera, K Chakraborty, Prashant KH, N Basak, P Guru, A Kumar, NN Jambulkar, J Meher, HN Subudhi, P S Hanjagi & SK Mishra

Genetic improvement of rice for multiple stress tolerance in unfavorable rainfed ecology

Principal Investigator: Krishnendu Chattopadhyay

Co-Principal Investigator: JN Reddy, SK Pradhan, BC Marndi, SSC Patnaik, A Anandan, K Chakraborty, LK Bose, JL Katara, A Poonam, SK Mishra, C Parameswaran, SD Mohapatra, AK Nayak, P Swain & AK Mukherjee

Harnessing heterosis for enhancing yield and quality of rice

Principal Investigator: ON Singh

Co-Principal Investigator: RL Verma, JL Katara, RP Sah, Muhammed Azharudeen TP, S Samantaray, S Sarkar, LK Bose, BC Patra,

Anandan A, RK Sahu, BB Satpathy, AK Mukherjee, SD Mohapatra, Somnath Roy & Amrita Banerjee

Development of new generation rice for breaking yield ceiling

Principal Investigator: SK Dash

Co-Principal Investigator: SK Pradhan, M. Kar, P Swain, HN Subudhi, J Meher, N Umakanta, R P Sah, S Sarkar, M Azaruddin, SD Mohapatra, Somnath Roy, N Mandal, S Bhagat L Behera, A Anandan, AK Mukherjee, & ON Singh

Biotechnological strategies for genetic improvement of rice

Principal Investigator: S Samantaray

Co-Principal Investigator: N Umakanta, RL Verma, JL Katara, Awadhesh Kumar, H.N. Subudhi, Somanath Roy, K Molla, C Parameswaran, Sanjay Saha & M Shahid

Development of Genomic Resources for Rice Improvement

Principal Investigator: L Behera

Co-Principal Investigator: C Parameswaran, SK Pradhan, M Jena, RK Sahu, SK Dash, Devenna, N Umakanta, KA Molla, Awadhesh Kumar, P Sangamitra, K Chattopdhyaya, HN Subudhi , J Meher, A Anandan , Guru P Pandi G, P Swain

Programme 2: Enhancing the productivity, sustainability and resilience of rice based production system

Programme Leader: AK Nayak/S Saha

Nutrient management for enhancing productivity and resource use efficiency in rice

Principal Investigator: AK Nayak

Co-Principal Investigator: H Pathak, P Bhatacharya, PK Nayak, Annie Poonam, BB Panda, R. Tripathy, M Shahid, S Mohanty, A Kumar, U Kumar, D Chatterjee, S Munda, D Bhaduri, M Debnath, S Chatterjee, Rubina Khanam, P Panneerselvam, CV Singh, BC Verma, SK Dash, A Anandan, N Umakanta,

Assessing energy and water footprints and increasing water productivity in rice-based systems

Principal Investigator: Rahul Tripathi

Co-Principal Investigator: Manish Debnath, Anjani Kumar, S Chatterjee, D Chatterjee, BB Panda, D Bhaduri, PK Nayak, Annie Poonam, AK Nayak

Associate: M Shahid and BS Satpathy

Agroecology-based intensification of rice-based cropping system for enhancing productivity and profitability

Principal Investigator: BB Panda

Co-Principal Investigator: BS Satpathy, D Bhaduri, PK Nayak, R Tripathi, S Mohanty and R Khanam

Integrated rice-based farming systems for enhancing climate resilience and profitability in eastern India

Principal Investigator: A Poonam

Co-Principal Investigator: AK Nayak, PK Nayak, M Shahid, NN Jambhulkar, R Tripathy, BS Sathpaty, GAK Kumar, B Mondal, PK Sahu, SC Giri (RC of CARI), M Nedunchezhian (RC of CTCRI), Govind Acharya (RC of CHES)

Associates: Drs. S Saha, U Kumar SK Lenka and SD Mahapatra

Increasing productivity and input-use efficiency in rice-based production systems with resource conserving technologies

Principal Investigator: M Shahid

Co-Principal Investigator: AK Nayak, D Chatterjee, D Bhaduri, S Munda, R Tripathi, A Kumar, PK Guru, PK Nayak, S Mohanty, P Bhattacharyya, BB Panda, U Kumar, S Saha, R Khanam, B Mondal

Assessing weed dynamics, management for improving productivity and production of rice

Principal Investigator: S Saha

Co-Principal Investigator: S Munda, BC Patra, P Panneerselvam, BS Satapathy, T Adak, PK Guru, S Chatterjee

Economic and environment-friendly use of rice straw

Principal Investigator: P Bhattacharrya

Co-Principal Investigator: H Pathak, AK Nayak, P Paneerselvam, MJ Baig, S Munda, D Bhaduri, BS Satapathy, M Chakrabarty, NT Borkar

Mechanization of rice-based cropping systems for higher productivity and energy use efficiency

Principal Investigator: P Guru

Co-Principal Investigator: N T Borkar, M Debnath, S Saha, BB Panda, D Chatterjee

Harnessing microbial resources for alleviating abiotic and biotic stresses for improving soil health

Principal Investigator: U Kumar

Co-Principal Investigator: P Paneerselvam, Anjani Kumar, D Chatterjee, Koushik Charaborty, C Parmeswaran

(**Associate:** AK Nayak, TK Dangar, SD Mahapatra, Prasanti G, P Swain

Programme 3: Management of biotic stress of rice with genetic, ecological and chemical approaches

Programme Leader: M Jena/ PC Rath

Exploration of new sources of resistance for insect pests and diseases of rice

Principal Investigator: Mayabini Jena

Co-Principal Investigator: PC Rath, Guru P Pandi G, SD Mohapatra, AK Mukherjee, MK Bag, S Lenka, MK Yadav, Arvindan S, Raghu S, Naveen KB Patil, Basana Gowda G, Prabhukarthikeyan SR, Mathew Baite, M. Annamalai, G Prasanthi, R R Korada, K Sankari Meena & N Umakanta

Bio-ecology of rice insect pests and diseases for climate smart protection strategies

Principal Investigator: SD Mohapatra

Co-Principal Investigator: AK Mukherjee, MK Bag, S Lenka, MK Yadav, Arvindan S, Raghu S, Prabhukarthikeyan SR, Mathew Baite, M. Jena, R R Korada, Guru P Pandi G, Basana Gowda G, G Prasanthi, M Annamalai, Amrita Banerjee, K Sankari Meena & Naveen KB Patil

Bio-intensive approaches for pest management in rice

Principal Investigator: AK Mukherjee

Co-Principal Investigator: M Jena, R R Korada, SD Mohapatra, MK Bag, S Lenka, Raghu S, M Baite, Prabhu Kartikeyan SR, Naveen KB Patil, Guru P Pandi G, Basana Gowda G, G. Prasanthi, M Annamalai, S Bhagat, T Adak, R Bhagavati, U Kumar, Nabaneeta Basak, K Sankari Meena & PC Rath

Optimization of chemical pesticide-use for management of rice pests in different eco-systems

Principal Investigator: PC Rath

Co-Principal Investigator: Annamalai M, G Prasanthi, AK Mukherjee, MK Bag, S Lenka, MK Yadav, Arvindan S, Raghu S, Prabhukarthikeyan SR, Mathew Baite, M Jena, T Adak, Guru P Pandi G, SD Mohapatra, Naveen KB Patil, U Kumar, P Panneerselvam & K Sankari Meena

Programme 4. Biochemistry and physiology of rice for grain quality, abiotic stress tolerance and improving photosynthetic efficiency

Programme Leader: SG Sharma/P Swain

Biochemistry of rice in relation to grain quality and nutritional improvement

Principal Investigator: Awadhesh Kumar

Co-Principal Investigator: SG Sharma, Nabaneeta Basak, Gaurav Kumar, LK Bose, P Sanghamitra & N Umakant

Physiology of rice for individual and multiple abiotic stress tolerance

Principal Investigator: P Swain

Co-Principal Investigator: MJ Baig, NP Mandal, K Chakraborty, P S Hanjagi, K Chattopadhyaya, Nabaneeta Basak, Gaurav Kumar & A Anandan

Improvement of photosynthetic efficiency of rice

Principal Investigator: MJ Baig

Co-Principal Investigator: P Swain, K Chakraborty, Awadhesh Kumar, KA Molla, Gaurav Kumar

Associates: A Kumar, JL Katara, SK Pradhan, J Meher

Programme 5: Socio-economic Research to aid Rice Stakeholders in enhancing Farm Income

Programme Leader: P Samal

Developing Extension Approaches to Enhance Rice Farmers' Income

Principal Investigator: SK Mishra

Co-Principal Investigator: Lipi Das, GAK Kumar, NC Rath, P Samal, B Mondal, NN Jambhulkar, SK Pradhan, S Saha, PK Guru, PC Rath, AK Mukherjee, RK Sahu, SM Prasad, CV Singh, Someshwar Bhagat, Somnath Roy, R Bhagabati, K Saikia and SK Ghritlahre

Associate: Meera Kar, K. Chattopadhyay, S.K. Dash, N.P. Mondal, M. Chakraborti, BB Panda, Annie Poonam, M Shahid, MK Bag, S Lenka, Nabaneeta Basak, SSC Patnaik, BC Patra, HN Subudhi, T Adak

Yield gap analysis and impact assessment to aid rice research and policies

Principal Investigator: Biswajit Mondal

Co-Principal Investigator: Co-Principal Investigator: P Samal, NC Rath, GAK Kumar, SK Mishra, Lipi Das, NN Jambhulkar, PK Guru, MK Bag, SM Prasad, Somnath Roy & K Saikia

Programme 6: CRURRS, Hazaribag

Programme Leader: D. Maiti

Development of resilient production technologies for rainfed upland rice systems

Principal Investigator: D Maiti

Co-Principal Investigator: NP Mandal, SM Prasad, CV Singh, S Bhagat, S Roy, A Banerjee, BC Verma, P Swain, S Saha, BS Sathpathy, MK Bag, MK Yadav, Aravindan S, M Annamalai, Guru P Pandi G, S Sekhar (SMS)

Programme 7: RRLRRS, Gerua

Programme Leader: Rupankar Bhagawati

Genetic improvement and management of rice for rainfed lowlands

Principal Investigator: Rupankar Bhagawati

Co-Principal Investigator: Kanchan Saikia, SK Ghritlahre, SK Pradhan, AK Mukherjee & S Lenka

Ongoing Externally Aided Projects (EAPs)

Project No.	Title of the Project	Principal Investigator	Source of Funding
EAP27	Revolving fund scheme for seed production of upland rice varieties at CRURRS, Hazaribagh	NP Mandal	AP Cess
EAP36	National Seed Project (Crops)	RK Sahu RP Sah P Sanghamitra	NSP
EAP49	Revolving fund scheme for breeder seed production	RK Sahu RP Sah P Sanghamitra	NSP/Mega seed
EAP60	Front line Demonstration under Macro-Management scheme of Ministry of Agriculture -New High Yielding Varieties	Y Kumar	DAC
EAP100	Seed Production in Agricultural Crops	RK Sahu RP Sah P Sanghamitra	ICAR
EAP125	Stress tolerant rice for poor farmers of Africa and South Asia-Drought prone rain-fed rice areas of South Asia-Hazaribagh Centre	NP Mandal	ICAR - IRRI (B&MGF)
EAP126	Stress tolerant rice for poor farmers of Africa and South Asia- Drought prone areas- CRRI Centre	ON Singh P Swain A Anandan	ICAR - IRRI-(B&MGF)
EAP127	Stress tolerant rice for poor farmers of Africa and South Asia - Submergence and Flood prone areas (STRASA)	JN Reddy SSC Patnaik K Chakraborty K Chattopadhyay	ICAR-IRRI (B&MGF)
EAP128	Stress tolerant rice for poor farmers of Africa and South Asia – Salt affected areas (STRASA)	B Marandi A Nayak A Poonam K Chattopadhyay K Chakraborty	ICAR-IRRI (B&MGF)
EAP130	All India Network Project on Soil Biodiversity - Biofertilizers	D Maiti	ICAR
EAP139	AICRP on energy in agriculture and agro-based industries	PK Guru NT Borkar	AICRP (DRET-SET/DRET-BCT)
EAP140	Intellectual Property Management and Transfer/ commercialization of agricultural technology under National Agricultural Innovation Fund (NAIF)	BC Patra	ICAR
EAP141	DUS Testing of Rice and documentation	BC Patra	PPV&FRA
EAP161	Monitoring of the new initiative of "Bringing Green Revolution to Eastern India (BGREI) under the Rashtriya Krishi Vikas Yojana"	H Pathak BB Panda	DAC, GOI
EAP163	Stress tolerant rice for poor farmers of Africa and South Asia – Sub grant, Seed (CRRI, Cuttack)	RK Sahu P Sanghamitra RP Sah	IRRI-ICAR (STRASA)

EAP173	Crop Pest Surveillance and Advisory Project (CROPSAP-Paddy)	M Jena T Adak	Govt. of Maharashtra
EAP176	Using wild ancestor plants to make rice more resilient to increasingly unpredictable water availability	SK Das P Swain L Behera B Sadangi (up to 31.11.16) P. Samal (w.e.f.01.12.16)	DBT-BBSRC (DFI, UK)
EAP178	National Initiative on Climate Resilient Agriculture	Sudhansu Sekhar	NICRA (ICAR)
EAP183	Characterization of toxins of *Bacillus thuringiensis* isolated from rice genotypes and their virulence assessment against leaf folder (*Cnaphalocrocismedinalis* Guenee)	Sonali Acharya (TK Dangar)	DST Inspire
EAP184	Utilization of fly ash on amelioration and source of nutrients to rice-based cropping system in eastern India	Sanghamitra Maharana (AK Nayak)	DST Inspire
EAP185	Development of crop and nutrient management practices in rice for Odisha state	S Saha BC Patra S Munda	ICAR-IRRI STRASSA
EAP186	Use of microbes for management of abiotic stresses in rice	AK Mukherjee	ICAR-IRRI
EAP189	Front Line Demonstrations under NFSM	NC Rath	DAC-DRR (NFSM)
EAP190	Multi location evaluation of rice germplasm (CRP on Ag. Bio)	NP Mandal	CRP-ICAR
EAP192	DNA marker based pyramiding and study of interactions among QTLs for higher grain number in rice (*Oryza sativa* L.)	Gayatri Gouda (T Mohapatra)	DST Inspire
EAP193	Future rainfed lowland rice systems in Eastern India 15 (T3) (Development of crop and nutrient management practices in rice)	AK Nayak P Gautam B Lal M Shahid R Tripathi D Bhaduri K Chakraborty	STRASSA South Asia
EAP195	Artificial induction of chlamydospore in *Trichoderma* sp. and identification of genes expressed during the process	HK Swain (AK Mukherjee)	DST Inspire
EAP197	Consortia research platform (CRP) on bifortification	K Chattopadhyay S Samantaray M Chakraborty A Kumar N Basak LK Bose A Poonam N Umakant	ICAR Plan-CRP
EAP198	Incentivizing Research in Agriculture: Study of rice yield under low light intensity using genomic approaches	L Behera MJ Baig A Kumar SK Pradhan S Samantaray N Umakant	ICAR Plan

EAP199	Incentivizing Research in Agriculture: Towards understanding the C3-C4 intermediate pathway in Poaceae and functionality of C4 genes in rice	MJ Baig P Swain L Behera S Ray A Kumar K Alimolla	ICAR Plan
EAP200	Incentivizing Research in Agriculture: Genetic modifications to improve biological nitrogen fixation for augmenting nitrogen needs of cereals	U Kumar P Panneerselvam	ICAR Plan
EAP201	Incentivizing Research in Agriculture: Molecular genetic analysis of resistance/tolerance to different stresses in rice, wheat, chickpea and mustard including sheath blight complex genomics	M K Kar L Behera A Mukherjee S Aravindan NP Mandal S Samantaray S Ray M Azharudheen	ICAR Plan
EAP202	Associated mapping of genes/QTLs for yield under reproductive stage drought stress in rice (*Oryza sativa* l.)	L Behera P Swain SK Dash SK Pradhan BC Patra ON Singh	BIRAC
EAP203	Strategic development of water utilization in rice production system for higher crop and water productivity and profitability	BB Panda P Swain SK Pradhan L Behera R Tripathi	CRP-water (ICAR)
EAP204	CRP on Agro biodiversity: PGR Management and Use of Rice (Component & II)	BC Patra M Jena AK Mukherjee K Chakraborty	CRP-Agrobiodiversity (ICAR)
EAP205	Nutrient cycle in agricultural system at field and regional scales	AK Nayak S Mohanty R Tripathi M Shahid A Kumar P Goutam	ISRO-EOAM
EAP206	Eliciting soil microbiome responses of rice for enhanced water and nutrient use efficiency under anticipated climate changes	AK Nayak P Bhattacharyya MJ Baig Md. Shahid S Raj A Kumar T Adak S Roy U Kumar	NASF - ICAR

EAP207	Conservation agriculture for enhancing the productivity of rice based cropping system in Eastern India	AK Nayak R Tripathi B Lal BB Panda M Shahid P. Gautam S Munda S Saha SK Mishra SD Mohapatra P Guru R Khanam	CAP - ICAR
EAP208	Evaluation of efficiency of zinc metalosate and boron metalosate foliar supplements for maximizing yield through balanced nutrition of important crops grown in India	M Shahid AK Nayak A Kumar B Lal	AICRP (Contract)
EAP209	CRP on hybrid technology	RL Verma ON Singh JL Katara	CRP - ICAR
EAP210	Fine mapping and identification of candidate gene/QTL for brown plant hopper resistance in rice cultivar, Salkathi	P Patnaik (L Behera)	DST Inspire
EAP211	CRP on molecular breeding	M K Kar L Behera M Jena A Mukherjee S Ray N Umakanta S Aravindan	CRP - ICAR
EAP212	Multilocational monitoring of Rynaxypyr 20SC against *Scirpophagaincertulas* in rice and rice hopper susceptibility survey in India for DPH-RAB55 106SC against *Nilaparvatalugens*and *Sogatellafurcifera*	SD Mohapatra M Jena B Gowda	Du Pont
EAP213	Maintenance, characterization and use of EMS of upland variety Nagina 22 for functional genomics in rice – Phase II	M K Kar P Swain AK Mukherjee S Ray	DBT
EAP215	Agri-Business Incubation Centre	GAK Kumar M Jena BC Patra SG Sharma NC Rath S Saha RK Sahu BB Panda B Mondal AK Mukherjee PK Guru	NAIF, IP&TM – ICAR

EAP217	Development of high yielding, water and labor saving rice varieties for dry direct seeded aerobic conditions utilizing recent discoveries on traits, QTLs, genes and genomic technologies	ON Singh A Anandan S Sarkar SK Dash	DBT
EAP218	Evaluation of XR-848 benzyl ester alone; XR-848 Benzy ester + cyhalofop-butyl and penoxulam + cyhalofop-butyl for broad-spectrum weed control in wet direct-sown rice under shallow lowland and irrigated ecology	S Saha S Munda	Dow agro sciences India Pvt. Ltd.
EAP219	Genetic enhancement of rice for low moisture stress tolerance	NP Mandal Y Kumar	ICAR
EAP220	Delivering food security on limited land (DEVIL)	AK Nayak M Shahid R Tripathi B Mondal SD Mohapatra H Pathak P Bhattacharyya	Min. Earth Science, GOI
EAP222	Earth observation application mission	AK Nayak S Mohanty R Tripathi M Shahid A Kumar P Gautam	ISRO
EAP223	Marker-assisted introgression of yield-enhancing genes to increase yield potential in rice	L Behera M Kar SK Dash SK Pradhan N Umakanta	DBT
EAP224	Understanding mechanism of tolerance to low light intensity in rice	MJ Baig P Swain SK Pradhan	NASF -ICAR
EAP225	Forewarning of major crop pests on special scale for their integrated management	SD Mohapatra MK Yadav G Pandi S Bhagat	SAC-ISRO
EAP226	Study of host induced gene silencing (HIGS) and its utility in rice-*R. solani* pathosystem to controlsheath blight disease	KA Molla A Mukherjee	DST
EAP227	Creation of seed hub for increasing indigenous production of pulses in India	DR Sarangi T R Sahoo M Chourasia RK Mohanta	DAC &FW

EAP228	Increasing productivity and sustaining the rice-based production system through farmer FIRST approach	L Das SK Mishra SSC Patnaik S Saha PK Nayak SD Mohapatra S Lenka R Tripathi P Guru SC Giri M Kumari SK Pradhan GC Acharya	ICAR-Farmer FIRST
EAP229	Phenomics of moisture deficit stress tolerance and nitrogen use efficiency in rice and wheat – Phase II	P Swain SK Das J Meher	NASH-ICAR
EAP230	Developing microbial consortium for horticultural crops in rice based cropping system to promote growth, nutrient uptake and disease management in organic farming in Sikkim	P Paneerselvam U Kumar	DBT (NER-BPMC)
EAP231	Evaluation of bio efficacy and phytotoxicity of NN1-1501 on rice BPH + WBPH	M Jena T Adak GP Pandi	Hyderabad Chem Pvt. Ltd.
EAP232	Double herbicide tolerant transgenic rice: weed management	C Parameswaran KA Molla N Umakant S Samantaray S Saha	NASF
EAP233	Accelerated decomposition of rice straw using novel Trichoderma strain and its mutant s	A Mukherjee T Adak	BRNS – DAE
EAP234	Gene staking for submergence tolerance, bacterial blight resistance and yield potential in rice variety Swarna through classical and molecular breeding approaches	SK Pradhan S Mohapatra	DST, Gov. Odisha
EAP235	Study and investigation of major QTLs associated with panicle compactness, ethylene receptor expression and grain filling in rice	S Sekhar (L Behera)	DST, SERB
EAP236	ICAR-CSISA collaborative project (phase III)-Research to quantify near and long term effects of sustainable intensification technologies at National Rice Research Institute (NRRI)	R TripathI AK Nayak BB Panda M Shahid B Lal D Chatterjee	CSISA
EAP237	Effect of time of application and maintaining water level on bio-efficacy of flucetosulfuron (10% WG) against weed complex of direct-sown and transplanted rice	S Saha S Munda	Indofil Industries Limited

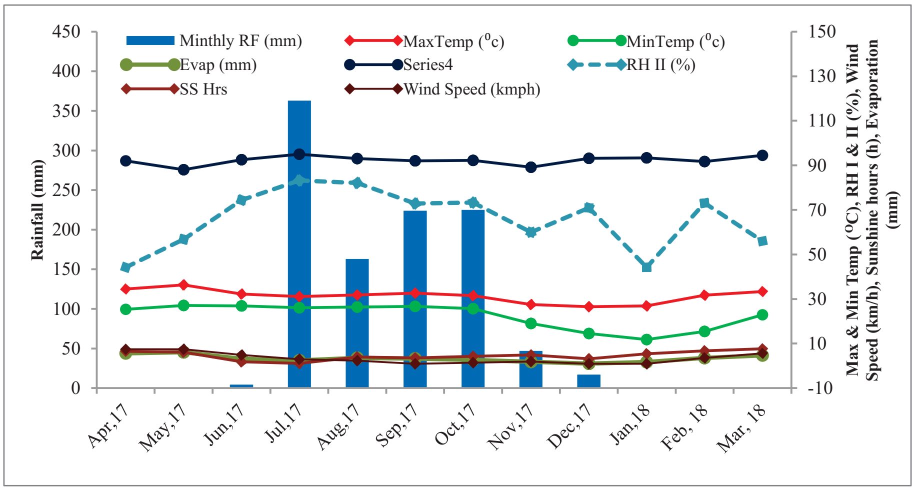
EAP238	Efficacy of phosphine fumigant against storage pests of pulses, wheat, rice and coffee beans and residue analysis for quarantine and long term storage purpose	M Jena NKB Patil T Adak	DAC
EAP239	Pyramiding and understanding the interaction of QTLs for deeper rooting and phosphorous uptake in rice (*Oryza sativa* L.)	E Pandit (SK Pradhan)	DST (WOS-A)
EAP240	Potential gene mining from salt tolerant grasses for improvement of stress tolerance in crops	C Parameswaran	NASF-ICAR
EAP241	Genetic improvement of hybrid rice parental lines for enhancing yield heterosis	ON Singh RL Verma RP Sah JL Katara LK Bose S Samantaray	ASEAN
EAP242	Targeting rice- fallows: a cropping system based extrapolation domain approach	BB Panda R TripathI AK Nayak H Pathak	STRASSA Phase III
EAP243	Phenotyping based on chlorophyll fluorescence imaging under salinity-stagnant flooding stress and identification of quantitative trait loci of chlorophyll fluorescence traits in rice	RK Sarkar	ICAR Emeritus scheme
EAP244	Validation and promotion of IPM in Rice in Tribal Region of Jharkhand	S Bhagat A Banerjee D Maiti	ICAR-NCIPM
EAP245	Strategic research component of national innovation in climate resilient agriculture (NICRA)	P Swain A K Nayak P Bhattacharyya K Chattopadhyay A Anandan S Mohanty D Chatterjee K Chakraborty H Pathak	ICAR Net work
EAP246	Raising productivity and profitability of rice-based cropping system in Odisha through rice crop manager	S Saha S Munda BS Satapathy	IRRI
EAP247	Bio-efficacy evaluation of 'Agri-Booster™KSi' against major insect pests and diseases of rice	M Jena M Annamalai T Adak GP Pandi B Gowda MK Yadav	Noble Alchem Pvt. Ltd., Indore

EAP248	Accounting green house gases (GHGs) emission and carbon flow in temporal shift of tropical mangrove to agriculture	P Bhattacharyya	ICAR- National Fellow
EAP249	Strengthening seed system of STRVs through innovative demonstrations and extension approaches in Odisha	RK Sahu RP Sah P Sanghamitra	IRRI-Odisha
EAP250	Validation and promotion of IPM in rice based cropping system	SD Mohapatra S Lenka U Kumar BS Satapathy S Raghu G Prasanthi S Bhagat D Maiti A Banerjee SM Prasad	NRRI-NCIPM
EAP 251	IT-enabled Self- sufficient Sustainable Seed System for Rice	G A K Kumar R K Sahu B C Patra B Mondal M Jena AK Mukherjee P Sanghamitra RP Sah	RKVY, Odisha
EAP252	Development and demonstration of Rice based integrated farming system for livelihood security of small and marginal farmers in coastal Odisha	A Poonam AK Nayak S Saha BS Satpathy GAK Kumar PK Sahu K Chattopadhyay	RKVY, Odisha
EAP253	Genomics-assisted breeding for increasing yield potential and durable resistance to major biotic stresses (BPH, Blast, BB, Sheath blight) of Indian elite cultivars	MK KAR L Behera SK Pradhan SK Dash LK Bose M Jena AK Mukherjee	IRR I
EAP254	Cereal Systems Initiative for South Asia (CSISA)- KVK, Cuttack	DR Sarangi TR Sahoo M Chourasia RK Mohanta	IRRI- CSISA Project
EAP255	To evaluate the bio-efficacy of PII 1721 60% WG against sucking pests of rice	G P Pandi G M Jena T Adak G Prasanthi	PI Industries Pvt. Ltd.

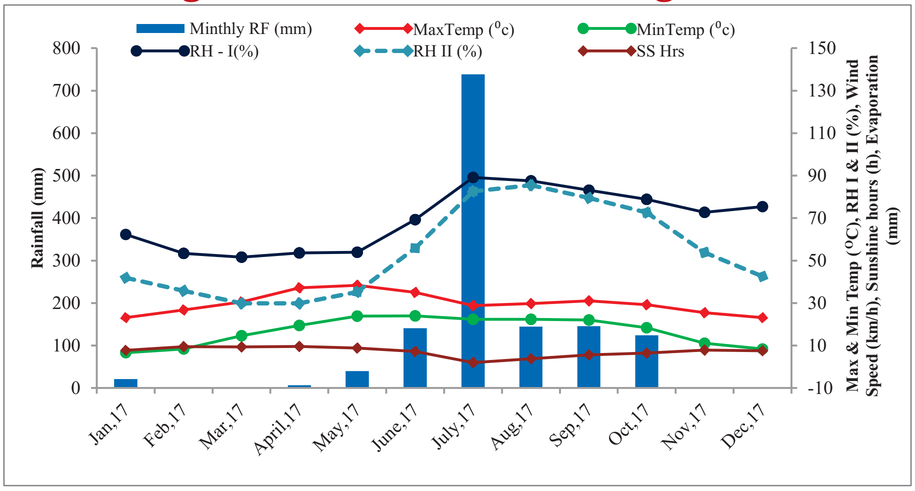
EAP256	Utilization and refinement of haploid / doubled Haploid induction systems in rice, wheat and maize involving molecular and in-vitro strategies	S Samantray N Umakanta J L Katara Parameswaran C RL Verma A Anandan K Chattopadhaya K Awadhesh	NASF
EAP257	Genetic improvement of rice for yield, NUE, WUE, abiotic and biotic stress tolerance through RNA guided genome editing (CRISPR-cas 9/ Cpf 1)	N Umakanta S Samantray K Awadhesh Parameswaran C	NASF
EAP258	Evaluation of different formulations of Penoxsulam alone and Penoxsulam+ Cyhalofop butyl for broad spectrum weed control in rice	S Saha B S Satapathy S Munda D Bhaduri	Dow Agro Sciences India Pvt. Ltd.
EAP259	Bio-efficacy, phytotoxicity and effects of Spinetoram 0.8% GR insecticide on natural enemies and rice pests	M Jena M Annamalai P Golivi B Gowda	Dow Agro Sciences India Pvt. Ltd.
EAP260	Development of climate smart practices for climate resilient varieties	H Pathak A K Nayak Anjani Kumar	IRRI
EAP261	Establishment of State of Art of Pesticide Residue Analysis in Odisha for its Optimum and Safe Use	T Adak M Jena Guru Pirasanna Pandi G Naveenkumar Patil Basana Gowda Raghu S S Munda	RKVY
EAP262	Enhancing resilience of rice based production system to climate change	AK Nayak SK Pradhan P Bhattacharya MK Bag GAK Kumar K Chakraborty	DST
EAP263	From QTL to variety: Genomics-Assisted Introgression and field evaluation of rice varieties with genes/ QTLs for yield under drought, flood and salt stress	JN Reddy ON Singh BC Marandi P Swain JL Katara	DBT
EAP264	From QTL to variety: Genomics-Assisted Introgression and field evaluation of rice varieties with genes/ QTLs for yield under drought, flood and salt stress	NP Mandal	DBT

Weather

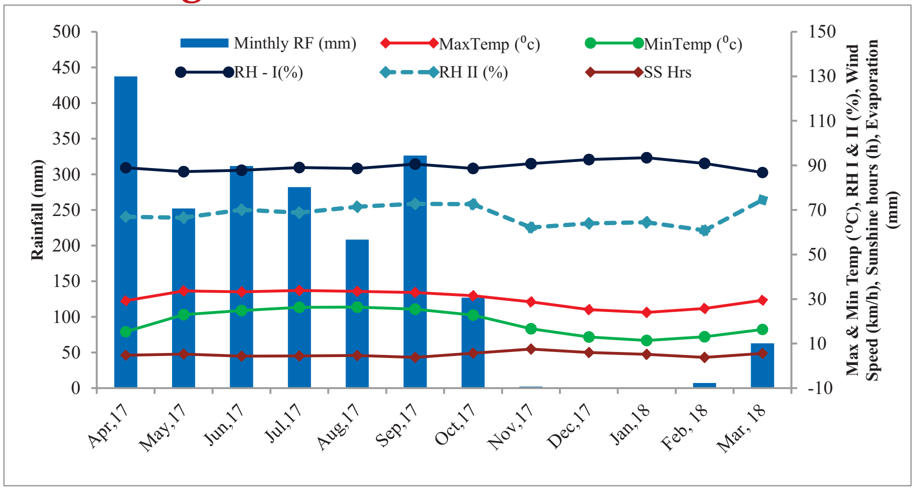
NRRI, Cuttack



NRRI Regional Station, Hazaribag



NRRI Regional Station, Gerua



Acronyms

ADG	:	Assistant Director-General
AICRIP	:	All India Coordinated Rice Improvement Project
AIR	:	All India Radio
AMAAS	:	Application of Microorganisms in Agriculture and Allied Sectors
ANGRAU	:	Acharya N.G. Ranga Agricultural University, Hyderabad
ARIS	:	Agricultural Research Information Service
ASG	:	Aromatic-Short Grain
ASGON	:	Aromatic Short Grain Observation Nursery
ASRB	:	Agricultural Scientists Recruitment Board, New Delhi
ASV	:	Alkali Spreading Value
ATMA	:	Agricultural Technology Management Agency
AVT	:	Advanced Varietal Trial
AWD	:	Alternate Wetting and Drying
AYT	:	Advance Yield Trial
BB/BLB	:	Bacterial Leaf Blight
BMGF	:	Belinda and Bill Gates Foundation
BPH	:	Brown Planthopper
Bt	:	Bacillus thuringiensis
CAC	:	Consortium Advisory Committee
CIAE	:	Central Institute of Agricultural Engineering, Bhopal
CIC	:	Consortium Implementation Committee
CIFA	:	Central Institute of Freshwater Aquaculture, Bhubaneswar
CMS	:	Cytoplasmic Male Sterile/Sterility
CRIDA	:	Central Research Institute for Dryland Agriculture, Hyderabad
CRIJAF	:	Central Research Institute for Jute and Allied Fibres, Barrackpore
CRRI	:	Central Rice Research Institute, Cuttack
CRRURS	:	Central Rainfed Upland Rice Research Station, Hazaribag
CSIR	:	Council of Scientific and Industrial Research
CURE	:	Consortium for Unfavourable Rice Environment
DAC	:	Department of Agriculture and Cooperation
DAF	:	Days after Flowering
DAH	:	Days after Harvest
DAO	:	District Agricultural Officer
DARE	:	Department of Agriculture Research and Education, Government of India
DAS	:	Days after Sowing
DBN	:	Drought Breeding Network
DBT	:	Department of Biotechnology, New Delhi
DFF	:	Days to 50 % Flowering
DH	:	Dead Hearts
DNA	:	Deoxyribonucleic Acid
DRR	:	Directorate of Rice Research, Hyderabad
DRWA	:	Directorate of Research for Women in Agriculture
DS	:	Dry Season
DSN	:	Dry Season Nursery
DSR	:	Directorate of Seed Research, Mau
DST	:	Department of Science and Technology, New Delhi
EAP	:	Externally Aided Projects
EC/ECe	:	Electrical Conductivity
EIRLSBN	:	Eastern India Rainfed Lowland Shuttle Breeding Network
FLD	:	Frontline Demonstration

FYM	:	Farmyard Manure
g	:	Gram
GLH	:	Green Leafhopper
GM	:	Green Manuring / Gall Midge
h	:	Hour
ha	:	Hectare
HI	:	Harvest Index
HRR	:	Head Rice Recovery
HYV	:	High-yielding variety
IARI	:	Indian Agricultural Research Institute, New Delhi
IASRI	:	Indian Agricultural Statistics Research Institute, New Delhi
ICAR	:	Indian Council of Agricultural Research
ICRISAT	:	International Crops Research Institute for the Semi-Arid Tropics
IDM	:	Integrated Disease Management
IET	:	Initial Evaluation Trial
IFAD	:	International Fund for Agricultural Development
IGAU	:	Indira Gandhi Agricultural University, Raipur
IGKVV	:	Indira Gandhi Krishi Vishwavidyalaya
IINRG	:	Indian Institute of Natural Resins and Gums, Ranchi
IISS	:	Indian Institute of Soil Science, Bhopal
IIVR	:	Indian Institute of Vegetable Research, Varanasi
IJSC	:	Institute Joint Staff Council
IMC	:	Institute Management Committee
INGER	:	International Network for Genetic Evaluation of Rice
INM	:	Integrated Nutrient Management
INSA	:	Indian National Science Academy
IPM	:	Integrated Pest Management
IPR	:	Intellectual Property Rights
IPS	:	Indian Police Service
IRRI	:	International Rice Research Institute, Philippines
IVRI	:	Indian Veterinary Research Institute, Izatnagar
IVT	:	Initial Varietal Trial
Kg	:	Kilogram
KVK	:	Krishi Vigyan Kendra
L	:	Litre
LB	:	Long-bold
LCC	:	Leaf Colour Chart
LF	:	Leaf Folder
LS	:	Long-slender
LSI	:	Location Severity Index
MAS	:	Marker-assisted Selection
MB	:	Medium Bold
MLT	:	Multilocation Trial
MS	:	Medium-slender
NAARM	:	National Academy of Agricultural Research Management, Hyderabad
NAAS	:	National Academy of Agricultural Sciences
NAIP	:	National Agricultural Innovation Project
NARES	:	National Agricultural Research and Extension Research
NARS	:	National Agricultural Research System
NASC	:	National Agricultural Science Complex, New Delhi
NBAIM	:	National Bureau of Agriculturally Important Microorganisms
NBPGR	:	National Bureau of Plant Genetic Resources, New Delhi
NDRI	:	National Diary Research Institute, Karnal
NDUAT	:	Narendra Dev University of Agriculture and Technology

NFSM	:	National Food Security Mission
NGO	:	Non-governmental Organization
NHSN	:	National Hybrid Screening Nursery
NIL	:	Near-isogenic Lines
NIPGR	:	National Institute for Plant Genome Research, New Delhi
NIWS	:	National Invasive Weed Surveillance
NPK	:	Nitrogen, Phosphorous, Potassium
NPT	:	New Plant Type
NRC	:	National Research Centre
NRCPB	:	National Research Centre for Plant Bio-technology, New Delhi
NSN	:	National Screening Nursery
NSP	:	National Seed Project
OFT	:	On-farm Trials
OUAT	:	Orissa University of Agriculture and Technology, Bhubaneswar
OYT	:	Observational Yield Trial
PAU	:	Panjab Agricultural University, Ludhiana
PDCSR	:	Project Directorate for Cropping System Research, Meerut
PE	:	Panicle Emergence
PI	:	Panicle Initiation
PMYT	:	Preliminary Multilocational Yield Trial
PVS	:	Participatory Varietal Selection
PYT	:	Preliminary Yield Trial
Q	:	Quintal
QTL	:	Quantitative Trait Loci
RAC	:	Research Advisory Committee
RAPD	:	Random Amplification of Polymorphic DNA
RARS	:	Regional Agricultural Research Station
RBC	:	Rice-based Cropping System
RBD	:	Randomized Bock Design
RCC	:	Reinforced Cement Concrete
RFLP	:	Restriction Fragment Length Polymorphism
RH	:	Relative Humidity
RIL	:	Recombinant Inbred Line
RRLRRS	:	Regional Rainfed Lowland Rice Research Station, Gerua
RTV/RTD	:	Rice Tungro Virus/ Disease
SAC	:	Scientific Advisory Committee
SATVT	:	Saline Alkaline Tolerant Varietal Trial
SAU	:	State Agricultural University
SB	:	Short-bold
SBN	:	Salinity Breeding Network
SES	:	Standard Evaluation System
SRI	:	System of Rice Intensification
STRASA	:	Stress Tolerant Rice for Poor Farmers in Africa and South Asia
t	:	Tonne
UBN	:	Uniform Blast Nursery
URSBN	:	Upland Rice Shuttle Breeding Network
WBPH	:	White-backed Plant Hopper
WCE	:	Weed Control Efficiency
WEH	:	White Ear Heads
WS	:	Wet Season
WTCER	:	Water Technology Centre for Eastern Region, Bhubaneswar
WTO	:	World Trade Organization
WUE	:	Water-use Efficiency
YMV	:	Yellow Mosaic Virus
YSB	:	Yellow Stem Borer
ZPD	:	Zonal Project Directorate

Note

ICAR-National Rice Research Institute
(Formerly Central Rice Research Institute)
An ISO 9001:2008 Certified Institute
Cuttack-753 006, Odisha, India, Phone: 0671-2367757, Fax: 91-671-2367663
Email: director.nrri@icar.gov.in, directorcrricuttack@gmail.com, Website: http://www.crri.nic.in

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