Extended Summaries: 2nd Indian Rice Congress 2023

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An International Event on

Transforming Rice Research: Recent Scientific Developments and Global Food Crisis

February 11-14, 2023

ICAR-National Rice Research Institute
Cuttack 753006, Odisha, India

Organizer

Association of Rice Research Workers
Cuttack, Odisha, India

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SECOND INDIAN RICE CONGRESS

Transforming Rice Research :
Recent Scientific Developments and Global Food Crisis

February 11-14, 2023

Extended Summaries

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ASSOCIATION OF RICE RESEARCH WORKERS
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EXTENDED SUMMARIES

2nd Indian Rice Congress
Transforming Rice Research : Recent Scientific Developments and Global Food Crisis
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PREFACE

Rice is the mainstay global food and important source of livelihood for around 144 million rice-farming households and for millions of people working on rice farms as labourers. Rice production of India increased from 64.6 million tonnes in 1971 to 124.37 million tonnes in 2020-21 growing at an average annual rate of 2.68%. But the current research and development strategies appear to be inadequate to ensure food security in the present context of increasing food demand of the burgeoning population and the rising needs of international trade. New technologies are required to ensure more and better rice production to improve nutrition security and boost incomes. Moreover, focussed efforts are required to reduce vulnerability to biotic and abiotic risks and shocks; and improve resilience and adaptability to erratic weather patterns.

Keeping in mind those facts, the objective of this congress is to provide a platform for all rice stakeholders to interact and exchange ideas about recent advances in rice science as well as to sustain rice cultivation in India. The Congress is divided into four broad thematic areas 1. Enhancing the genetic potential of rice for stress tolerance and nutritional quality, 2. Ecological and sustainable management of rice-based production systems, 3. Biotic stress management in rice: recent scientific advances and 4. Socio-extension approaches in rice farming to address global food security issues.

We have received overwhelming responses from the rice researchers globally. A total of 264 extended summaries were accepted for the Congress. This compilation was not possible without the support from the scientists from different partner institutes and from ICAR-National Rice Research Institute, Cuttack. At the end, we thank all the participants of this Congress without whose handwork and dedication for rice research, it was not possible to document the present trend of rice science. The great enthusiasm shown by honourable delegates from all around the world is praiseworthy.

Chairman and Members
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Theme - I

Enhancing the genetic potential of rice for stress tolerance and nutritional quality

INVITED LECTURE

My tryst with rice plant for designer panicle architecture

Dr P K Mohapatra

Honorary Professor, School of Life Science, Sambalpur University, Jyoti Vihar, Sambalpur 768019

Among the cereals, rice is the most widely consumed staple food of mankind. Since the advent of dwarf statured varieties, which enabled a major breakthrough in rice yield and production, further raising the ceiling of genetically determined yield potential has been the breeding priority. The positive development in achieving a grain surplus was made possible because of improvement of the yield potential of irrigated rice. Food surplus in the developing nations of Asia was unperturbed until the end of the last century. However, population growth continued unabated thereafter, while the level of rice production stagnated. By the year 2030, there will be five billion rice consumers on earth and the demand for rice is projected to accentuate sharply. The level of rice production close to 700 million tons per annum in the recent years does not assure food security for rice consumers in the future. The level of demand is expected to rise up to 852 million tons in 2035. Increase of rice production up to this high level through field management practices is not possible because of several constraints like scarcity of water, land holdings, fertilizers and other commodities for the poor and marginal farmers. Trait development through innovative ideotype breeding efforts, however, holds promise for improvement of yield potential beyond 10 tons/ha of the IR8-parented high yielding semidwarf rice. In pursuance breeders focused attention on salient features of panicle morphology (spikelet number, primary and secondary branch number) and developed large panicle NPT rice bearing numerous spikelets per panicle. Most of the spikelets failed grain development because of improper structural design and the extra spikelets located mostly on secondary branches decimated owing to high ethylene production. This situation aggravates in stress-prone environments. It is plausible that the discovery of genetic control of organ formation in rice spikelet will provide the information to develop designer rice panicle bearing multi-floret spikelets. However, focusing attention on this issue has been wanting although an assortment of genotypes with varied panicle architecture widely differing in grain occurrence pattern are available naturally. Among the diverse genotypes rice breeders should consider number florets in each spikelet for increasing panicle grain number and potentially improving yield. Further, priority should be given for screening of rhizomatous rice landraces for improving ratooning ability and developing perennial rice. Opportunity for such diversity abounds but effort are lacking.

ARRW/SIRC/Theme I/01

Genetic divergence analysis in Rice(*Oryzasativa L.)*genotypes for yield and quality traits

Atul Kumar Pachauri[1] and Deepak Gauraha[1]

[1]*Department of Genetics and Plant Breeding, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattsgarh*
Correspondence author Email id: ***pachauriatul@yahoo.in***

Forty two rice genotypes excluding six checks comprising traditional landraces and released varieties from IGKV was evaluated for 18 quantitative and quality traits by principal component analysis and cluster analysis for determining the pattern of variation, relationship among individuals and their characteristics. Principal component analysis was utilized to examine the variation and to estimate the relative contribution of various traits for total variability. The uppermost numbers of genotypes were found in cluster VII, which consisted of 9 genotypes followed by Cluster V having 7 genotypes with cluster VI with 7 genotypes with one check TN1, cluster IV comprises of 4 genotypes, while cluster II and III contain each 3 genotype.

INTRODUCTION

Rice (Oryza sativa L.) (2n=24) is the staple food of more than three billion population in the world, mainly who lives in Asian countries. It is the beginning point of food anchorage and is systematically related with conventional traditions and customs. Rice is also known as 'Global grain' due to its wider adoptability and wider cultivation throughout the world and the production of rice is being decreasing annually due to the damage caused by several biotic stress factors

MATERIALS AND METHODS

Present study was carried out during 2020 at Instruction Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh. 42 Rice materials used in this study were obtained from NBPGR, New Delhi. The experiment was laid out in a RBD with three replications. Each block consisted of thirty one genotypes randomized and replicated within each block. Twenty seven days old seedlings were transplanted 20 cm apart between rows and 15 cm within the eighteen yield attributes of five randomly selected plants in each replication. Observations were also recorded to study grain quality characters.

RESULT AND DISCUSSION

Using principal component analysis, we found that kernel length after cooking, Decorticated grain l:b ratio, grain yield/plant, Decorticated length of grain, Decorticated breadth of grain, Head rice recovery percentage, hundred grain weight have the most substantial contribution Das et al 2013, . Six principal components exhibit in excess of 1 Eigen value and explain as a minimum 5% of disparity beside with 74.60% cumulative variability amongst the characters considered. However, the seven PCs were agreed due to its consequence for further explained. The PC1 was show 26.93% while PC2, PC3, PC4 PC5, PC6 and PC7 presented 16.26, 9.25, 8.74, 7.28 and 6.13% variability among the traits. PCA revealed principal discriminatory characteristics e.g. kernel length after cooking, Decorticated grain l:b ratio, grain yield/plant, Decorticated length of grain, Decorticated breadth of grain ,Head rice recovery percentage, hundred grain weight and Milling percentage respectively. Forty two rice accessions were used for UPGMA cluster analysis and these accessions were grouped in eight clusters.

CONCLUSION

The current study indicate that genotype from these clusters can be used to get utilized heterosis. Thus, in current study, the representative individuals (IC459148 X IR64) should be selected from cluster V and VIII respectively, as parents, for yielding superior hybrids. PCA shown principal discriminatory characteristics such as decorticated grain L/B ratio, decorticated grain breadth, elongation ratio, plant height, days to 50% flowering, gel consistency, grain yield per plant, Utilization of these characters in breeding programme to bring about rapid improvement for yield other associated traits which may be kept into consideration

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Standard heterosis and trait association of yield and therapeutic traits in rice (*Oryza sativa* .L)

Ananda Lekshmi. L[1], S. Geetha[1*], K. Amudha[1] and D. Uma[2]

[1]*Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore, 641003*

[2]*Department of Biochemistry, Centre for Plant Molecular Biology, Tamil Nadu Agricultural University, Coimbatore, 641003.*

[*]*Email of the corresponding author: geethagovind1@gmail.com*

Rice a staple food of millions of people worldwide and is branded as the grain of life and its significance had been appreciated throughout the history across civilizations and cultures. Rice feeds more than half of the population in India and provides 60 to 70% of calories and thus the so-called dal-vat-tarkari is an iconic menu seen across the entire Indian subcontinent. Landraces rice varieties have been demonstrated to possess anti inflammatory and antioxidant properties thus presenting rice as a potential candidate for neutraceutical and as functional food alternatives for the reduction of oxidative stress. The therapeutic properties of the red and black coloured whole grain rice varieties have been attributed to the presence of polyphenols such as phenolic acids, flavonoids and anthocyanins. The study was conducted to study the heterotic level in different cross combinations and inter-relationship among yield and therapeutic traits.

METHODOLOGY

Hybridization programme was carried out following a Line x Tester mating design, involving six lines and four testers at the Department of Rice, Centre for Plant Breeding and Genetics, Coimbatore, during 2019. The F_1 seeds of 24 hybrids along with ten parents and standard check CO (R) 50 and CO 51 were raised in two replications in a randomized block design. Single plant yield was recorded at maturity. Therapeutic traits viz., total flavonoids and anthocyanin content were estimated in the grains.

RESULTS

The extend of heterosis is the indication of genetic diversity among the parents involved in the cross combination. The estimate of heterosis over standard checks are more rational for practical applicability. Positive heterosis is considered for all traits studied including the therapeutic traits. Among 24 hybrids evaluated three hybrids exhibited high positive significant heterosis for therapeutic traits along with the foremost trait single plant yield. The best heterotic combinations identified were ADT 43 x IG6 (L_2 x T_2), ADT 37 x *Mikkuruvai* (L_1 x T_3) and Improved white ponni x *Nootripathu* (L_6 x T_1)over the standard checks CO (R) 50 and CO 51. A positive significant heterosis was exhibited by ADT 43 x IG6 for total flavonoid, anthocyanin, amylose content in addition to single plant yield and thousand grain weight. The cross combinations, ADT 37 x *Mikkuruvai* and Improved white ponni x *Nootripathu* recorded positive significant heterosis for total flavonoid, amylose content, thousand grain weight and single plant yield. In the current study, the hybrid ADT 43 x IG6, which was a cross between two high *gca* parents for the aforementioned qualities, was determined to be promising for total flavonoid content and single plant yield based on *per se* performance and standard heterosis. Among all the traits, a positive correlation with single plant yield was manifested by number of grains per panicle, number of productive tillers per plant and thousand grain weight. The anthocyanin and total flavonoid contents showed a positive association, however the single plant yield was not significantly correlated with these therapeutic traits.

Table.1 Estimates of standard heterosis for single plant yield and therapeutic traits

CROSS	Single plant yield		Total flavonoid		Anthocyanin		Amylose content	
	CO50	CO51	CO50	CO 51	CO50	CO51	CO50	CO 51
1 x 1	-28.23 **	-17.25 **	324.77 **	715.03 **	-16.67 **	11.11	8.33 **	9.36 **
1 x 2	-36.86 **	-27.20 **	296.78 **	661.32 **	108.61 **	178.15 **	-1.78	-0.85
1 x 3	44.20 **	66.28 **	254.84 **	580.84 **	-24.72 **	0.37	13.53 **	14.60 **
1 x 4	-84.77 **	-82.44 **	293.60 **	655.23 **	250.00 **	366.67 **	-12.55 **	-11.72 **
2 x 1	-36.09 **	-26.30 **	219.97 **	513.94 **	-75.00 **	-66.67 **	16.90 **	18.01 **
2 x 2	56.02 **	79.91 **	318.14 **	702.31 **	16.94 **	55.93 **	4.08 *	5.06 *
2 x 3	-34.97 **	-25.02 **	305.57 **	678.19 **	83.61 **	144.81 **	-2.15	-1.23
2 x 4	-82.05 **	-79.31 **	308.47 **	683.75 **	216.67 **	322.22 **	4.78 *	5.76 **
3 x 1	-36.36 **	-26.62 **	234.92 **	542.63 **	-25.00 **	0.12	11.57 **	12.62 **
3 x 2	-62.45 **	-56.70 **	334.11 **	732.94 **	133.33 **	211.11 **	8.76 **	9.78 **
3 x 3	-8.65 **	5.34 **	298.14 **	663.93 **	-49.72 **	-32.96 **	2.29	3.26
3 x 4	-68.13 **	-63.25 **	275.22 **	619.95 **	233.33 **	344.44 **	-11.28 **	-10.44 **
4 x 1	-14.50 **	-1.41	128.93 **	339.25 **	-66.67 **	-55.56 **	-8.80 **	-7.94 **
4 x 2	-15.93 **	-3.05	186.91 **	450.51 **	66.67 **	122.22 **	-2.01	-1.09
4 x 3	-82.79 **	-80.16 **	112.33 **	307.40 **	-8.33	22.22 **	1.69	2.65
4 x 4	-80.20 **	-77.17 **	336.49 **	737.52 **	233.33 **	344.44 **	-7.91 **	-7.04 **
5 x 1	-14.23 **	-1.10	271.37 **	612.57 **	0.00	33.33 **	7.91 **	8.93 **
5 x 2	-66.51 **	-61.38 **	259.34 **	589.49 **	66.39 **	121.85 **	5.06 *	6.05 **
5 x 3	-47.75 **	-39.75 **	222.89 **	519.55 **	-58.61 **	-44.81 **	9.97 **	11.01 **
5 x 4	-56.76 **	-50.14 **	142.46 **	365.22 **	208.33 **	311.11 **	-1.45	-0.52
6 x 1	21.78 **	40.43 **	234.56 **	541.94 **	-41.67 **	-22.22 **	8.10 **	9.12 **
6 x 2	-25.23 **	-13.78 **	277.82 **	624.94 **	50.00 **	100.00 **	3.28	4.25 *
6 x 3	-20.18 **	-7.96 **	249.94 **	571.45 **	-25.00 **	0.00	-13.34 **	-12.52 **
6 x 4	-54.05 **	-47.02 **	260.46 **	591.63 **	183.33 **	277.78 **	-4.68 *	-3.78

CONCLUSION

The hybrid combinations, ADT 43 x IG6, ADT 37 x *Mikkuruvai* and Improved white ponni x *Nootripathu* were found to be promising for therapeutic traits along with single plant yield in terms of standard heterosis. These genotypes may be evaluated for further confirmation of their superiority for exploiting them commercially. The correlation study serves as indexes to indirectly select breeding lines for high flavonoid and anthocyanin content. The study also offers a brand-new chance for rice breeders to advance the production of rice with improved therapeutic properties, which will eventually benefit commercial rice growers.

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ARRW/SIRC/Theme I/03

Study on Physicochemical and Cooking Properties of Farmers' Varieties of Rice (*Oryza sativa* L.)

Gadge Sushant Sundarrao[1*], Bidhan Roy[1] and Rajkumari Sarita Devi[2]

[1& 2]*Department of Seed Science and Technology, Faculty of Agriculture, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, 736165, West Bengal, India*

E-mail: sushantgadge4@gmail.com

Rice (*Oryza sativa* L. 2n = 24) is a member of *Poaceae* (old Gramineae) family, and it is the world most important cereal crop, which serve as a primary source of food for almost half of the world's population. China and India together accounts for more than half of the global rice consumption (Tripathy *et al.,* 2017). Rice provides essential nutrients, good amount of minerals, vitamins essential fatty acids and dietary fibres besides energy to large segment of world's population. Cooking and eating quality of rice is very important and is determinant of market price, consumer acceptance and end users. Physicochemical properties such as amylose content, gelatinization temperature and alkali spreading value determines the cooking and eating quality of rice. The demand of quality rice in market is increased with the improved living standard of peoples. For improvement of cooking and eating quality of rice, evaluation of physicochemical and cooking properties of traditional varieties of rice is preliminary step.Keeping these points in view the present investigation was undertaken with objectiveto evaluate the physicochemical traits, and cooking properties of 121 Farmers' Varieties of rice.

METHODOLOGY

In present investigation seeds of 121 Farmers' Varieties of rice were used which were collected from different states such as West Bengal, Assam, Manipur. The amylose content of all varieties was estimated as the method described by Sadasivam, 1996. The physicochemical properties such as gelatinization temperature was estimated through alkali spreading value of kernels as measured on a 7-point scale (Little *et al.,* 1958). The cooking quality traits of 121 FVs' of rice were assessed the method given by Oko*et al.,* 2012. The weighed sample of rice grain (2 g) was put into test tubes with 20 ml of boiling water and cooked in a water bath at 95°C. The data was recorded on observations such as weight of kernel after cooking, water uptake ratio, cooked kernel length, grain elongation (mm), grain elongation ratio, cooked kernel breadth, cooked kernel length breadth ratio, optimum cooking time and Aroma after cooking.

The data were analysed statistically by using absolute valuesAgRes Statistical Software, (c) 1994 Pascal Intl Software Solutions, Version 3.01 were used to the normal statistical procedures of analysis of variance (ANOVA). The principal component analysis was performed with the mean data of all variables and 121 FVs' of rice by using Rstudio-2022.2-576.exe software R version 4.2.1 (2022-06-23 ucrt).

RESULTS

It was found that the amylose content of all 121 rice varieties were varied from 9.36 % to 35.60 % with an average 24.96%. According to amylose content in rice cultivars, they were grouped into five groupswaxy (1-2%), very low amylose (3-9%), low (10-19%), intermediate (20-25%), and high (26-30%) and very high (> 30%). It was noted that 47 rice cultivars were have intermediate amylose content which is considered as desirable for country like India. In present study the twenty-eight rice cultivars showed low gelatinization temperature, 31 FVs had high or intermediate gelatinization temperature, 33 cultivars exhibited intermediate gelatinization temperature values and left over 29 FVs displayed high values for gelatinization temperature. Out of 121 FVs of rice 26 varieties were had aroma after cooking. The eleven rice varieties were had strong aroma whereas 6 rice varieties were had medium and 9 rice varieties had mild aroma after cooking.

All the cooking quality parameters of 121 farmers' varieties of rice exhibited high significant variation. Grain elongation (mm) after cooking without increase in girth is highly desirable cooking quality traits. The grain elongation of rice cultivars in present study were varied from 0.95-5.14 mm with a mean of 1.63 mm. The optimum cooking time of rice cultivars in present study was varied from 22 to 48 min with a mean of 28.60 min. The minimum value for cooking time was recorded for Agnisal (22 min). The results from PCA revealed that the genotypes falling under PC1, PC2, PC5 and PC6 can be utilised to improve the grain quality and cooking and eating quality parameters.

CONCLUSION

From the results of present study, it can be concluded that the rice cultivars such as Pusa Basmati 1121, Pakistani Basmati, JP-120, Deharadhun Gandheswari and Sadanunia can be utilised for overall rice quality improvement in terms of physiochemical and cooking quality traits. From the results of PCA it can be concluded that the genotypes contributing to different principal components in terms of a group of traits, and that they might be used in the genetic development programme for rice based on PC score for those characters.

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ARRW/SIRC/Theme I/04

Identification of Maintainers and restorers for the development of rice hybrids

P. Gonya Nayak, B. Srinivas, B. Laxmi Prasanna and P. Madhukar

Regional Agricultural Research Station, Polasa, Jagtial-505 529, PJTSAU, Telangana, India.
Corresponding author mail Id:pgonyanayak@gmail.com

In India rice is the most important staple food crop for more than two third of the population. The slogan 'Rice is life' is the most appropriate for India, as this crop plays a livelihood for millions of rural households. To meet the increasing demand for rice, several measures have to be envisaged. Hybrid rice is the proven technology for increasing rice production and productivity. With good management yield advantage of 1.0 to 1.5 t/ha can be obtained by cultivation of hybrids as compared to the high yielding varieties under the same set of growing conditions. Identification of restorer is important to develop high yielding hybrids. Maintainers play an important role in development of new female lines through back cross breeding.

METHODOLOGY

A total number of 291 hybrids were developed during *kharif* -2020 and *rabi* 2020-21 and were transplanted with a spacing of 20 x 15 cm during *kharif*, 2021 at Regional Agricultural Research Station, Polasa, Jagtial, Telangana, India to study the restorer / maintainer reaction. The following criteria was used for classifying the pollen parents as proposed by Virmani *et al.*, 1997.

Procedure for phenotypic analysis: At days to 50% flowering, the 5-8 spikelet's were collected randomly from indehiscent anthers of a panicle to study the spikelet fertility percentage and to prevent out crossing. Two panicles per plant were bagged with butter paper bag and pinned the bag to leaf sheath.

Pollen fertility percentage: Pollen fertility study was done from the collected anthers at 1 to 2 days before of anthesis. The anthers from each spikelet were smeared in a drop of 1% Iodine-potassium iodide (I-KI) solution on a glass slide, fertile and sterile pollens were counted in the three randomly selected microscopic fields. Stained, well filled and round pollen grains were counted as fertile, while unstained, shrivelled and empty pollen grains were considered as sterile. Pollen fertility was calculated and expressed in percentage as given below:

Pollen fertility (%) =

$$\frac{\text{Number of stained pollen grains}}{\text{Total number of pollen grains}} \times 100$$

Spikelet fertility: The panicles that emerged from the primary tiller were bagged before anthesis to avoid out crossing and the number of filled grains and chaffs in the panicle were counted at the time of maturity. The ratio of filled grains to the total number of spikelets was expressed as spikelet fertility percentage as given below:

Spikelet fertility (%) =

$$\frac{\text{No. of fertile spikelets in a panicle}}{\text{Total no. of spikelets in a panicle}} \times 100$$

Methodology for pollen fertility studies

Category	Pollen fertility (%)	Spikelet fertility (%)
Maintainers	0-1	0
Partial maintainers	1.1-50	0.1-50
Partial restorers	50.1-80	50.1-75
Restorers	>80	>75

RESULTS

About 291 test cross hybrids were produced crossing 17 cytoplasmic male sterile lines with stable lines from yield evaluation trials and stable segregating generations. Out of 291 hybrids, 56 were found to exhibit good restoration and 6 were found to exhibit maintainer reaction and remaining 229 were partial. Among the 56 restorers, duration of fifty per cent flowering difference ranged from 0 days (Test cross nursery 4350) to 15 days (TCN 4368 and TCN 4372), plant height ranged from 92 cm (4349) to 127.4 cm (4365). The highest panicle length was recorded in TCN 4579 (32.6 cm) and low in TCN 4351 (26 cm), spikelet fertility ranged from 76.00 per cent (TCN-4598) to 96.38 per cent (TCN-4527), test weight was recorded low in (TCN 4349)13.16 g and high in TCN 4391 (26.32 g) and highest yield was recorded in TCN 4379 (52.5g). In maintainers, spikelet sterility was ranged from 91 per cent (TCN-4346) to 100 per cent (TCN-4345). The concerned males of F1s exhibiting maintainer reaction could be converted to new CMS lines and males of F_1s with complete restoration will be used for new hybrid development.

CONCLUSION

Out of 56 hybrids exhibiting good restoration, based on fertility restoration and yield potential 18 hybrids combinations (JGLH – 471, JGLH - 472, JGLH – 473, JGLH – 474, JGLH – 475, JGLH – 476, JGLH – 477, JGLH – 478, JGLH – 479, JGLH – 480, JGLH – 481, JGLH – 482, JGLH – 483, JGLH – 484, JGLH – 485, JGLH – 486, JGLH – 487 and JGLH – 488) were selected for seed multiplication during *rabi* 2021-22 and further promoted for yield evaluation along with commercial hybrid checks during *kharif* 2022.

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ARRW/SIRC/Theme I/06

α-Amylase Activity: A biochemical marker for breaking seed dormancy in rice

Kuntala Kisan, Preetam Kumar Senapati, Pramod Kumar Suna and Ekamber Kariali

School of Life Sciences, Sambalpur University, Sambalpur-768019, Odisha, India.
Email: kuntala.kuni@gmail.com

Seed dormancy is an agronomically important trait normally unsuitable for agriculture, but very much essential for preventing viviparous germination in rice when untimely rains frequent the crop fields (Barik et.al., 2017). Though seed dormancy is one of the important factors responsible for distribution of germination over time and required for plant survival under natural conditions, it is highly undesirable for a crop plant like rice because of its prevention in adequate germination and poor stand development. Hence, it is imperative to understand the timing of breaking seed dormancy and the underlying biochemical and molecular mechanisms governing seed dormancy and dormancy breaking needed for efficient agricultural practices. In this context, the plant hormones like GA and ABA, especially the balance between these two hormones play important role in breaking seed dormancy in rice. Though hormones are crucial for breaking seed dormancy, different paddy genotypes exhibit considerable variations in their dormancy periods and are largely influenced by soil moisture, land topology, salinity, day length and temperature etc. and traditional and wild rice genotypes are generally more dormant than that of the high-yielding rice cultivars. Considering this variations in dormancy periods among different rice genotypes, an experiment was conducted by taking few dormant, semi-dormant and non-dormant rice seeds for their artificial germination in Petri plates in a growth chamber to understand the role of α-amylase activity and whether it acts as a biomarker for breaking seed dormancy.

MATERIALS AND METHODS

Seeds of different traditional and wild rice cultivars were collected from different parts of Odisha and germination tests were conducted in 3 replicates in a growth chamber at 27 ^{0}C under 12h/12h light/dark cycle in Petri plates containing three layers of moist blotting paper. The experiment was conducted once in every two months during the entire period of 2021 from January to December. Germination %, soluble sugars and starch concentration (data not shown) and α-amylase activities were measured in the soaked seeds (Table 1) and experiments were terminated after 50 % seed germination or 48h of soaking, whichever was earlier.

RESULTS

The soluble sugar concentration in the dormant seeds was relatively lower compared to semi-dormant and was highest in non-dormant seeds whereas the starch concentration followed an opposite trend during the entire experimental period. The germination% was almost 100% in the non-dormant seeds during the entire period of experiment whereas in semi-dormant seeds, it was 100 % from January to June and reduced considerably thereafter and reached almost nil in November and December. On the other hand the G% in dormant seeds increased from March and attained a maximum value in June-July and germination ceased from August till December. α-amylase activity followed the same trend with that of G% and attained maximum value during Mar-April in coincidence with maximum seed germination (Table 1).

Table 1. Germination % and amylase activity (µmole of Maltose/min) of different dormant, semi-dormant and non-dormant rice seeds during January-December 2021.

Rice cultivars	Name		Jan-Feb	Mar-April	May-June	July-Aug	Sep-Oct	Nov-Dec
Dormant	*O. rufipogon*	Alpha-Amylase	16.69±1.29	169.04±3.48	158.57±1.49	19.74±0.93	1.67±0.10	5.91 ±9.38
		G%	0%	86%	74%	10%	0%	0%
	O. nivara	Alpha-Amylase	18.83±0.72	146.90±6.84	147.08±1.70	37.14±1.11	2.24±0.07	7.83±0.28
		G%	0%	79%	81%	35%	0%	0%
Semi-dormant	Pakhiraj	Alpha-Amylase	198.73±5.13	216.87±4.15	204.33±5.49	39.24±1.43	6.81±0.17	59.70±2.45
		G%	100%	100%	100%	15%	0%	25%
	Laisiring	Alpha-Amylase	216.39±1.95	232.34±3.73	223.59±6.75	47.18±2.21	3.13±0.77	64.51±2.94
		G%	100%	100%	100%	30%	0%	33%
Non-dormant	Sunakathi	Alpha-Amylase	251.35±2.87	263.36±6.01	260.26±7.80	258.45±9.47	228.83±1.92	256.01±5.80
		G%	100%	100%	100%	100%	100%	100%
	Karni	Alpha-Amylase	257.77±6.86	260.06±2.21	254.69±4.83	234.46±6.21	172.54±6.15	257.52±7.24
		G%	100%	100%	100%	100%	100%	100%

DISCUSSION AND CONCLUSION

Seed dormancy is a physiological trait where the seeds remain quiescent for a particular period of the year in spite of favourable environmental conditions required for seed germination. Though breaking seed dormancy is influenced by different environmental factors like temperature, available moisture, photoperiod, seasonal variations, the joint action of plant hormones and seasonal variations play a key role in seed germination and breaking seed dormancy in rice. In the present experiment, germination percentage was maximum during March-April in all categories of seeds in coincidence with increase in temperature and day length suitable for enhancement of α-amylase activity. Imbibitions of seeds by water might have signalled the embryo for synthesis of bioactive GA which in turn might have been responsible for activation of α- amylase gene and subsequently enhancement of its activity for starch degradation in the endosperm to produce soluble sugars for providing energy to germinating embryo (Mohapatra and Kariali, 2016) especially in dormant and semi-dormant seeds. On the other hand, the activity of the enzyme α- amylase was maintained at a high level during the entire period of experiment in parallel to germination percentage. α-amylase activity is positively and significantly correlated with germination percentage in all three groups of rice seeds (data not shown). Hence, α- amylase activity may be considered as a biomarker for breaking seed dormancy in rice and manipulation of its gene may be of high significance for cultivation of the crop especially under inclement weather conditions for prevention of viviparous germination.

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ARRW/SIRC/Theme I/07

Genetic characterisation of germplasm for grain quality traits in rice (*Oryza sativa* L.)

M. Hemalatha*, S. Geetha, R. Saraswathi, G. Hemalatha and A. Lakshmanan

Tamil Nadu Agricultural University, Coimbatore – 641 003, Tamil Nadu, India.

**Email – mhemalathavini@gmail.com*

Rice (*Oryza sativa* L.) is the staple food of almost half of the world's population. Food self-sufficiency for an increasing population was the major goal before green revolution. Green revolution led to the attainment of yield plateau in food grains by the process of introduction and improvement of cultivars. Grain quality in rice was initially surpassed by the need for higher yields and greater pest-resistance. However, as many traditional rice importing countries achieved self-sufficiency, real rice prices declined in many Asian countries and in the world market over the last two decades and grain quality played an important role in fetching better market price. There is a constant market for non-aromatic rice genotypes with high linear elongation ratio within the country and outside the country. But the present-day modern varieties have high yield but low linear elongation ratio. Grain size and shape largely determine the market acceptability of rice. Linear elongation without increase in breadth is considered a highly desirable trait for premium quality rice to fetch high market remuneration (Qiu *et al*., 2021). This renewed interest in rice grain quality has led to the formulation of this study in search of quality genotypes for the choice of parents in the hybridization programme for analysing the inheritance pattern of cooked rice elongation.

METHODOLOGY

A total of 51 genotypes comprising of pre-release cultures, released varieties, landraces and tropical *japonica* were taken up for the study. Randomized Block Design (RBD) was the experimental layout in two replications with a spacing of 20 x 20 cm. Biometrical traits including days to 50 per cent flowering, plant height, panicle length, number of productive tillers, number of filled grains per panicle, 1000 grain weight, single plant yield and physico-chemical traits including grain length, grain breadth, L/B ratio, Linear Elongation Ratio, Breadthwise Elongation Ratio, Gel consistency (Cagampang *et al*., 1973), Gelatinization temperature (Little *et al*., 1958) and Amylose content (Juliano *et al*., 1979). Mahalanobis D^2 method of diversity analysis was taken up using the TNAUSTAT software.

RESULTS AND DISCUSSION

The studied 51 genotypes were dissected into 14 clusters using Mahalanobis D^2 method. The trait

Table 1. Distribution of genotypes into various clusters

Cluster	Number of genotypes	List of genotypes
I	2	TRY3, TPS5
II	10	ADT37, AD18573, CO51, AD18538, AD18600, AD16024, TRY1, CB16605, CB15801, AD19224
III	12	ADT43, AD16028, AD19055, CB15714, CB15174, CB12122, ADT53, AD17020, AD18545, AD16052, CB13132, RNR15048
IV	7	ADT54, BPT5204, CB17528, CB16723, CB19132, AD17037, Improved White Ponni
V	2	ASD16, TN1
VI	1	VGD1
VII	1	CO52
VIII	1	CB15569
IX	2	Azucena, Palawan
X	2	TRY2, Khao Do Ngoi
XI	1	PB1
XII	1	PB1121
XIII	8	Gedumani, Kaatuyanam, Ottadai, Sivappumalli, Kavuni, Burma Kavuni, Thailand Kavuni, Karuppu Kavuni
XIV	1	Thirupathisaram

Linear Elongation Ratio trait contributed towards the maximum genetic divergence (38.19%). This implies that the germplasm studied contained a good amount of variation for this trait and selection of parents among these genotypes would be rewarding for enhancing the grain quality traits. The Cluster III have the highest number of genotypes (12) while, the clusters *viz.,* VI, VII, VIII, XI, XII and XIV were solitary clusters with one genotype in each (Table 1). Maximum inter cluster distance was found between the clusters IX and XII (247.72). Between the clusters I and XII (200.06), the next maximum inter cluster distance was found. Hence, hybridization involving the genotypes of these clusters would yield superior recombinants with good grain quality. Maximum intra cluster distance was found in cluster V followed by Cluster IX. Based on the *per se* performance, the genotype PB1121 had the highest Linear Elongation Ratio with intermediate amylose content, soft gel consistency and low to intermediate gelatinization temperature. Hence, parents contrasting to these characters could be selected based on the genetic distance between the clusters to effect hybridization to obtain notable segregants with elite grain quality aspects.

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ARRW/SIRC/Theme I/08

A note on ecology, taxonomy and genetic resource potential of *Oryza meyeriana* var. *indandamanica*, a rare wild relative of rice from Andaman islands

K Pradheep*, R Parimalan[1], K Joseph John, VA Muhammed Nissar[2], I Jaisankar[3], PP Thirumalaisamy and M Latha

ICAR-National Bureau of Plant Genetic Resources, Regional Station, Thrissur – 680656, Kerala
[1]ICAR-National Bureau of Plant Genetic Resources, New Delhi – 110 012
[2]ICAR-Indian Institute of Spices Research, Kozhikode – 673012, Kerala
[3]ICAR-Central Island Agricultural Research Institute, Port Blair-744 101, A&N Islands
**Presenting author & Corresponding author email: K.Pradheep@icar.gov.in*

During trekking for crop wild relatives' survey and their germplasm collection from Saddle Peak National Park (SPNP) of North Andaman Island in January 2020, the authors came across a dwarf but stiff bambusoid tuft-forming grass with erect culms and apparently unbranched spicate inflorescence with small, awnless spikelets, underneath the evergreen forest canopy at an altitudinal range of 330 to 590 m MSL for about two kilometres stretch (13.1637 - 13.1780° N, 93.0063 - 93.0125° E). This population with over 100 clumps/plants was spotted in highly shady steep-sloped stony terrain, having well-drained loamy soils with rich litter. It was identified as wild rice, *Oryza meyeriana* (Zoll. & Moritzi) Baill. var. *indandamanica* (J.L.Ellis) Veldkamp, based on the earlier floristic records from this park. The collected germplasm (IC641181) is maintained in the Field Genebank (FGB) at Thrissur, and also seeds were conserved in the National Genebank at NBPGR, New Delhi.

This taxon comes under the *Oryza meyeriana* complex (2n=24; GG genome) and is often considered as an ecotype/variant or subspecies of *O. granulata*, or variously treated/ synonymized under *O. meyeriana* var. *granulata* or often all the infraspecific taxa names were subsumed/kept under *O. meyeriana* only. A critical study of protologues, the type specimen(s) of var. *granulata*, var. *meyeriana* and var. *indandamanica* coupled with the study of the latter taxon at the natural field and FGB conditions revealed that the SPNP population of var. *indandamanica* falls well under the circumscription of var. *meyeriana*, instead of var. *granulata*. The observed key characters, *viz*., fruiting spikelets oblong, 3.7-5.1 times as long as wide, and caryopsis 4.60-5.94 mm long, readily differentiate from var. *granulata* (having an elliptic fruiting spikelet which is only 2.1-2.7 times as long as wide, and caryopsis 3.4-4.1 mm long) (vide

Fig. 1: ***Oryza meyeriana*** **var.** ***indandamanica*** **from SPNP. A. Plants in natural habitat; B. Ex-situ regeneration at Thrissur; C. Inflorescence at anthesis; D. Inflorescence at spikelet maturity; E. Physiologically mature (pale green) and mature dry seeds (inset: caryopsis)**

Duistermaat, 1987). The characters given in the diagnosis of var. *andamanica* (Ellis, 1985) fit well within the range of characters recognized for var. *meyeriana*, whereas some taxonomic characters of the SPNP population such as length of inflorescence (excl. peduncle) (7-9 vs 5 cm in var. *andamanica*) and floret (7.1-8.0 vs 5 mm) do not match with the protologue information indicating the role of environmental factors modifying the phenotypic expression of plants. Therefore, as JF Veldkamp suggested in Flora Malesiana Bulletin [10(1): 29-30; 1988], var. *indandamanica* is synonymized here under var. *meyeriana*. This synonymization would lead to a new distribution record for var. *meyeriana* westwards into the Andaman Islands (India), which was till now reported from Malesia and Peninsular Thailand.

The habitat ecology of the studied population indicates the potential for tolerance to shade (as thriving in almost full shade) and drought (as occurring on steep stony slopes, and blades roll inwards in response to stress). It takes only 16 days from anthesis to seed maturity (while rice takes about 30 days), and afterwards, colour of lemma and palea changes from pale green to straw yellow within a day and sheds immediately. For this reason, it is very difficult to find mature grains on culms and therefore needs white clothing underneath to collect seeds. At Thrissur, the plant produces abundant tillers (up to 40), and flowers year-round, and they open at 10 am throwing out far protruding white stigmas. Though the *meyeriana* group is a known source of bacterial leaf blight resistance, the studied population was susceptible to brown spot (*Biploris oryzae*) under Thrissur conditions. Understanding the physiological, genetic and molecular basis of stress tolerance and its application in rice improvement programme is the need of the hour.

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Genome-wide association studies (GWAS) of *Oryza sativa.* genotypes for drought stress tolerance

Sonali Sucharita Jena

Centurion University of technology and management, Andhra Pradesh, PIN-535005, India
Email: sonijena2016@gmail.com

Oryza sativa. or Rice is the important and major staple food for more than half of the global population. But drought is such an intolerable condition which reduces the productivity of the crop specially in rainfed ecosystem. Plant with drought tolerance capability only can overcome such condition. Now a days it is possible to produce genetically modified crops with superior qualities, in that way it is also possible to modify plants with desired character. GWAS(Genome wide association studies) is a excellent way to understand the genetic constitute of the plant which is associated with drought stress. Identifying the alleles and their interaction with genetic background with genotypes related to drought stress, the rice plant can be modified into a drought stress tolerant variety which would be the ultimate solution for getting increased productivity.

OBJECTIVE

- Phenotyping and genotypic Characterization of germplasms.
- Genome sequencing and identifying the associated SNPs with drought condition in Rice
- Analysis of the revealed genotypes.

METHODOLOGY

- Plant material collection and obtaining genotype data of all the population
- Phenotyping of population: managing the crops and then applying drought stress, measuring various traits after drought application. Analysis of phenotypic data for each trait
- Establishment of genetic structure and linkage disequilibrium using softwares.
- Identifying associations and candidate gene discovery.

RESULTS

The whole work will be conducted by using both dry and wet laboratory. The in-silico work constituents all the computational analysis of the corresponding genes and proteins responsible for the drought stress condition. The molecular expression studies of the corresponding genes are to be analyzed in wet laboratory which gives the complete idea about the genotype of rice plant responsible for drought tolerance. The results can be utilized for further studies and developing drought resistance rice plants.

CONCLUSION

Genome-wide association studies (GWAS) help in identifying genes associated with drought stress tolerance. This will be a combination work of in-silico and invivo. This work will be useful to develop new varieties of rice plant with drought tolerance capacity.

ARRW/SIRC/Theme I/10

Leaf pubescence and flavonoids confer UV-B resistance in rice

Preetam K Senapati[1], Kuntala Kisan[1], Sanjukta Mohapatra[2], Santanu K Tripathy[3] and EkamberKariali[1*]

School of Life Sciences, Sambalpur University, Sambalpur, 768019, Odisha, India.
2. RRTTS, Chipilima, Sambalpur, 768026, Odisha, India.
3. Department of Agronomy, OUAT, Bhubaneswar, 751003, Odisha, India
Email: preetamsenapati123@gmail.com

Depletion of stratospheric Ozone layer due to increased industrialization and environmental pollution is responsible for incidence of higher amount of UV-B radiations on earth surface and threatening life of crop plants like rice. Though animals can protect from UV-B radiation or run away temporarily to a microclimate, the sessile plants including rice are forced to suffer from UV-B induced injury. However, many traditional rice cultivars grown in the agro-ecosystems of Odisha since long time exhibit high degree of resistance against UV-B radiations. One such resistance mechanism is flavonoid mediated absorbance of UV-B radiations on leaf pubescent hairs or trichomes. Leaf pubescence is an important agronomic characteristic for rice morphology and influences crop growth and physiology. Pubescence is characterized by trichomes developed as unicellular or multi-cellular epidermal cell outgrowths. Trichomes may be glandular or non-grandular; the former is responsible for resistance against biotic stresses whereas the later contributes towards resistance against abiotic stresses including UV-B radiations. Experimental evidences suggest that leaf pubescent hairs can effectively absorb UV-B radiations and play a protective role against Photosystem-II damage. In *Arabidopsis*, exposure to UV-B radiations could stimulate trichome formation and resistance against UV-B radiation is due to accumulation of flavonoids in their trichomes. As flavonoids in the trichomes of epidermal cells can absorb UV-B radiations and can reduce the transmittance of such absorbed radiations in the epidermal layer, it could effectively reduce the amount of UV-B radiations reaching to the internal tissue and thus act as an 'internal filter'. In view of this, an experiment has been designed to understand the role of leaf pubescent hairs and accumulated flavonoids in leaf epidermis including hairs against UV-radiations in contrasting rice cultivars having high pubescence and no pubescence in their leaves.

MATERIALS AND METHODS

Experiments were performed at the Botanical Garden of the School of Life Sciences, Sambalpur University during the wet season of 2022 by taking two contrasting cultivars with more (Lalkain, a purple variety) and few (Swarnaprabha) trichomes in their flag leaves. Plants were cultivated in pot conditions with all recommended agronomic practices and supplemental UV-B radiation was applied for 5h/day (UVB_{BE} 14.4 $KJm^{-2}d^{-1}$) by UV-B emitting fluorescent tubes (TL20w/01). Treatments were given at booting stage and continued up to 30days. Morpho-physiological and biochemical parameters such as number of pubescent hairs (micro and macro) and concentrations of chlorophyll, carotenoids, anthocyanins, flavonoid and lipid peroxidations, were analysed during different days of treatment.

RESULTS

The results showed considerably higher number of pubescent hairs (micro and macro hairs, Fig.1) and more flavonoid contents (data not shown) in the abaxial surface of flag leaves in Lalkain cultivar than that of Swarnaprabha. In response to supplemental UV-B radiation, Lalkain cultivar

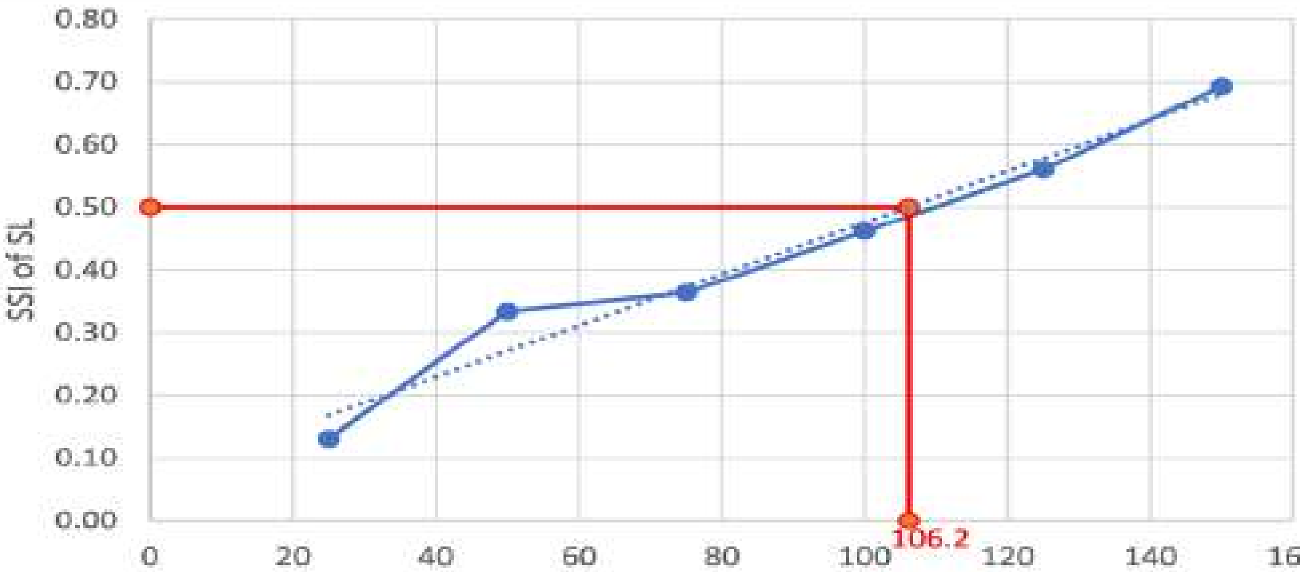

Fig. 1. Simple microscopic photograph (A&B) and SEM view (C&D) of abaxial surface of flag, leaf of Lalkain (left panel) Swarnaprabha (right panel) rice cultivars sowing leaf pubescence. Macro hair, Micro hair

accumulated more amounts of flavonoids and anthocyanins compared to Swarnaprabha whereas the decline in chlorophyll and carotenids due to UV-B treatment was quite higher in Swarnaprabha and was almost negligible in Lalkain. MDA contents in terms of lipid peroxidation after UV-B treatment was much more prominent in Swarnaprabha than that of Lalkain and these results were reflected in final grain yield (data not shown).

DISCUSSION AND CONCLUSION

Protective functions against UV-B radiation have been ascribed to leaf pubescence like trichomes due to accumulation of phenolic compounds in these structures which act as shields against harmful radiations (Karabourniotis et al., 2020). Leaf hairs not only reflects UV-B radiation from leaf surface, but also promotes the expression of UV-responsive genes like *UV RESISTANCE LOCUS* 8 (*UVR8*) and *ELONGATED HYPOCOTYL5* (*HY5*) (Li et.al., 2022) and mediate UV-B resistance. Our experiments also showed similar results and more pubescent hairs and pubescence-mediated accumulation of flavonoids and anthocyanins in flag leaves provided ample resistance against UV-B radiation in Lalkain, but not in Swarnaprabha. Identification of novel UV-B resistant genes will be largely helpful for their introgression in high yielding varieties for development of UV-B resistant rice genotypes in near future.

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ARRW/SIRC/Theme I/12

Phenology of rice under different dates of sowing and growth regulators in Hirakud command areas of Odisha

S.Mohapatra*, S. K. Tripathy, S. Tripathy, M.R.Mohanty, P.Sial, P.K.Senapati and E.Kariali

Regional Research and Technology Transfer Station, Odisha University of Agriculture and Technology, Chiplima, Sambalpur, Odisha

**Email: Sanjukta.mohapatra34@gmail.com*

In Hirakud Command areas of Odisha, sowing date of winter season rice plays a major role in rice-rice cropping system. The mean minimum temperature during sowing time (December and January) of *rabi* rice varies from 9-12^{0}C.The mean maximum temperature at reproductive phase varies from 38 - 41^{0}C. The yellowing of leaves starts when temperature falls below 12^{0}C for 3-4 days at seedling stage. Similarly, grains became chaffy when flowering period coincide with temperature more than 35^{0}C, resulting in significant yield loss (Moniruzzaman, 2009). So choosing optimum date of sowing in rice crop plays an important part of high production package. Brassinolide (stigma sterol and campesterol), a steroidal hormone of plant origin, is considered as new plant growth regulators and extensively used in agriculture for reducing environmental stress and improves crop yield (Elankavi *et al.* 2009). Keeping all these points in view, the present study was under taken to examine agrometeorological indices and phenology of rice under different dates of sowing and growh regulator in Hirakud Command areas of Odisha.

METHODOLOGY

The experiment was conducted during winter season of *rabi*2019-20 and 2020-2021at the Regional Research and Technology Transfer Station, Chiplima (21.3^0 N latitude and 83.9^0 E longitude), Odisha University of Agriculture and Technology. Sixteen treatment combinations of 4 sowing dates (December 10, December 20, December30, January 10) and 4 growth regulators (stigma sterol and campesterol 0.01% SL at 0.5 ml l^{-1}, gibberellic acid (GA_3) 50 ppm, salicylic acid 50 ppm and water spray) were tested in randomized split plot design with three replications. The plant growth regulators were sprayed at the time of panicle initiation (65 DAT) and flowering (85 DAT) with knapsack sprayer using 500 l water per hectare.

Table1. Mean minimum and maximum temperature (^{0}C) during various growth stages of rice.

Growth stages	Sowing dates			
	Dec.10	Dec.29	Dec.30	Jan.10
Seedling	9.4-26.9	9.4-27.3	9.5-28.0	10.5-28.7
Vegetative	18.0-32.8	18.8-33.2	19.3-33.9	19.6-33.9
Reproductive	22.9-38.8	23.0-39.6	23.0-39.7	23.1-40.6

RESULTS

Rice sown on 10th December utilized more thermal and heat units as compared to 30th December and

Table 2. Yield, grain heat use efficiency (GYHUE) and dry matter heat use efficiency (DMHUE) of rice as influenced by dates of sowing and growth regulators (Data pooled over 2 years).

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	GYHUE (kg ha^{-1}^{0}C day^{-1})	DMHUE (kg ha^{-1}^{0}C day^{-1})
Sowing dates				
Dec.10	6.3	6.8	2.7	5.6
Dec.20	6.9	7.9	2.9	6.3
Dec.30	7.2	8.1	3.2	6.6
Jan.10	5.8	6.7	2.7	5.7
CD (P=0.05)	0.9	1.0	0.2	0.5
Foliar sprays				
Salicylic Acid	6.3	7.1	2.8	5.9
GA3	6.5	7.4	2.8	6.0
SS and C	7.3	8.3	3.1	6.5
Water spray	6.1	6.6	2.7	5.7
CD (P=0.05)	0.9	1.0	0.2	0.4

10th January sown crop. On an average, 8.6 to 16% reduction in rice yield was obtained in case of sowing dates where temperature stress coincided with reproductive growth phase. The crop sown on 10th December took maximum thermal units to attain different phenological stages till physiological maturity. Rice yield increased with delay in sowing time up to 30th December, whereas there was a decrease in duration and tillers m^{-2}. December 30 sown rice registered the highest grain yield (7.3 t ha^{-1}), grain yield heat use efficiency (3.2 kg ha^{-1} ^{0}C day^{-1}) and dry matter heat use efficiency (6.6kg ha^{-1} ^{0}C day^{-1}). Foliar spray of stigmasterol and campesterol 0.01% SL (0.5 ml/l) recorded the higher dry matter heat use efficiency (6.5 kg ha^{-1} ^{0}C day^{-1}) and the highest grain yield (7.3 t ha^{-1}) followed by GA_3, salicylic acid and water spray (control).

CONCLUSION

Foliar spray of growth regulator stigmasterol and campesterol reduced the heat stress at flowering and produced economically higher grainyield, as well as grain heat use efficiency with sowing on 30th December during *rabi* in Hirakud command area of Odisha.

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ARRW/SIRC/Theme I/13

Rapid generation advancement (RGA) in paddy to enable speed breeding

Moushree Sarkar[1]*, Sagnik Chatterjee[2] and Jyotirmoy Guha[3]

R&D Unit, GMS Agritech Pvt.Ltd; Bahiri, Bolpur, Dist. Birbhum, West Bengal 731240, India

*Email: *moushreesarkar88@gmail.com, 9073324672; [2]gmsagro.rnd@gmail.com*

Rice is a staple food resource for over one-third of the world's population. So, we have to increase the rice production by 4 fold in next 10 years to reach the food security. After green revolution, hybrid rice has been a benefit for rice producers and consumers in the all rice growing regions. But standard conventional breeding method may take up to 7-8 years to establish one variety. So, there is an urgent need of speed breeding technique to reduce the time span. One of the straightforward techniques to enhance genetic gain is shortening the breeding cycle time (Quddus et al. 2019) and off season generation advancement is needed for reducing the length of the breeding cycle in rice. Rapid Generation Advance (RGA) is a part of breeding procedure where the segregating populations are facing different stresses like temperature, fertilizer and alterations in cultural practices to shorten growth duration, thus making possible several generations per year. The duration for advancing from F2 to F5 generally takes about 4 years which can be shortened by 2 years. Therefore, the present investigation was carried out to develop an RGA protocol for generation advancement among paddy genotypes.

METHODOLOGY

Genetic male sterility developed 8 accessions were selected for this experiment. Four seeds of each accession were planted in 15 cm deep pots filled with potting mixture composed of versitols,

Treatment	Fertilizer (N: P: K)	Temperature (°C)
Control	3:2:1	30-35
T1	1:1:1	40-42
T2	1:2:1	40-42
T3	1:2:2	40-42
T4	1:1:1	43-44
T5	1:2:1	43-44
T6	1:2:2	43-44
T7	1:1:1	45-46
T8	1:2:1	45-46
T9	1:2:2	45-46

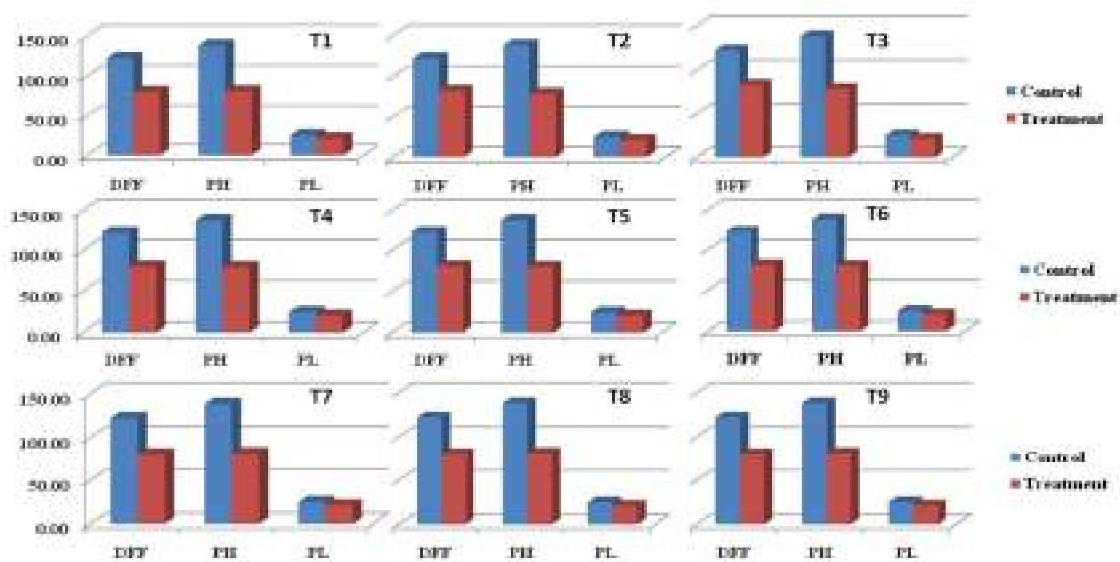

Fig.1. Effect of different treatments on various morpho-physiological parameters of eight accessions of Paddy

Table 1. Effect of different treatments on various paddy accessions to speed up the maturity duration

Sl No	Accession	C	T1	T2	T3	T4	T5	T6	T7	T8	T9
Days to Fifty percent (%) Flowering											
1	GMS 1	84.1	67.10	69.90	70.60	68.10	68.20	68.40	67.10	67.20	66.90
2	GMS 2	114.1	81.20	80.50	80.70	79.20	79.10	79.60	81.20	81.50	81.20
3	GMS 3	116.5	80.10	81.30	81.60	79.10	79.30	79.50	80.10	80.40	80.10
4	GMS 4	127.7	79.10	83.90	84.80	82.10	82.40	82.60	79.10	79.20	79.20
5	GMS 5	138.5	89.40	92.30	92.30	90.20	90.40	90.50	89.40	89.20	89.20
6	GMS 6	131.3	81.40	83.90	84.70	82.20	82.20	82.30	81.40	81.50	81.10
7	GMS 7	132.4	82.20	85.30	85.90	83.10	83.30	83.90	82.20	82.40	82.80
8	GMS 8	134.1	81.10	84.40	84.20	82.10	82.20	82.60	81.10	81.60	81.70
	Mean	122.3	80.20	82.69	83.10	80.76	80.89	81.18	80.20	80.38	80.28
Plant height (cm)											
1	GMS 1	116.4	68.10	65.10	65.70	66.20	66.40	66.50	68.10	68.20	68.30
2	GMS 2	102.2	64.20	61.20	60.70	62.10	61.90	62.20	64.20	64.30	64.50
3	GMS 3	123.6	69.10	67.50	67.50	68.20	68.30	68.30	69.10	68.90	69.40
4	GMS 4	125.4	69.10	67.90	68.40	68.50	68.50	68.50	69.10	69.40	69.20
5	GMS 5	140.3	90.30	87.40	87.50	88.10	87.90	88.10	90.30	90.50	90.10
6	GMS 6	155.1	93.20	91.70	91.60	92.20	91.90	92.70	93.20	92.90	93.30
7	GMS 7	170.5	96.40	95.10	94.50	95.30	95.30	95.50	96.40	96.10	96.40
8	GMS 8	172.3	99.10	96.10	96.10	98.20	97.90	98.70	99.10	99.40	99.30
	Mean	138.2	81.19	79.00	79.00	79.85	79.76	80.06	81.19	81.21	81.31
Panicle Length (cm)											
1	GMS 1	24.5	20.20	20.50	20.20	20.10	20.00	20.10	20.20	19.80	20.40
2	GMS 2	25.1	20.60	19.90	20.60	20.30	20.50	20.40	20.60	20.60	20.50
3	GMS 3	25.1	20.50	20.20	20.50	20.20	20.30	20.20	20.50	20.50	20.60
4	GMS 4	23.9	20.70	20.50	20.70	20.50	20.60	20.30	20.70	20.70	20.50
5	GMS 5	24.3	21.20	20.10	21.20	20.10	19.90	20.10	21.20	20.90	21.30
6	GMS 6	26.2	23.10	21.90	23.10	22.60	22.70	22.50	23.10	22.90	23.50
7	GMS 7	25.1	21.80	21.70	21.80	21.70	21.80	21.60	21.80	22.10	21.90
8	GMS 8	24.9	20.70	20.10	20.70	20.10	20.20	20.20	20.70	20.60	20.80
	Mean	24.89	21.10	20.61	21.10	20.70	20.75	20.68	21.10	21.01	21.19

vermicompost and sand in 6:2:1 ratio. 10 pots were planted for each accession (Ghosh et al 2018). The details of the treatments are as follows:

% reduction was calculated using the formula : $\%R = \dfrac{\text{Control} - \text{Treatment}}{\text{Control}} \times 100$

RESULTS

Table 1 and Figure 1 revealed that T1 and T7 followed by T9 and T8 showed lowest days to 50% flowering which indicate that these treatment doses are most suitable to reduce the maturity duration of these paddy accessions. Using T1 and T7 treatment the average maturity duration was reported to be reduced by 42 days than control. In West Bengal condition we can grow two generations of paddy per year. But using these treatments under RGA breeding program we can grow 4-5 generations of paddy per year.

CONCLUSION

Rapid generation advancement breeding could be an effective tool to reduce the operational requirement of time, expenses and save nearly couple of months in paddy breeding research.

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Genome-wide association studies (GWAS) of rice genotypes for Salinity stress tolerance

Shobhan Pradhan[1] and Pushpalatha Ganesh[1*]

Centurion University of Technology and Management, Andhra Pradesh, 535003 India.

Rice (***Oryza sativa***) a monocot, is often planted as an annual crop, however perennial in tropical climates. Rice cultivation is well with low labour expenses and heavy rainfall since it is labor-intensive and requires a lot of water. As a cereal grain, rice is the most extensively consumed staple food for more than half of the world's population, particularly in Asia and Africa. It is having 2n = 24, AA chromosomes belongs to Poaceae family. It has a total length of 430 Mb, a nucleotide length of 1000000 base pairs. Some advances have been made in developing rice varieties that can withstand stress conditions; one example is the hybrid generated by crossing the commercial rice variety IR56 with the wild rice species *Oryza coarctata*. *O. coarctata* may grow well on soils with double the salinity limit of typical types, but it cannot yield edible rice. The hybrid variety, developed by the IRRI, may use specialized leaf glands to remove salt from the atmosphere. Soil salinity is frequently expressed as the electric conductivity (EC) of a saturated soil paste extract (ECe). EC units are commonly expressed in decimil per metre (dS/m). The figure's crucial ECe value of 5.5 dS/m, calculated from measurements in farmers' fields, suggests that the rice crop is mildly salt sensitive.

OBJECTIVES

1. To evaluate rice genotypes for salinity stress.
2. To study the genome-wide association (GWAS) among the rice genotypes for salinity tolerance

CONCLUSION

The genotypes of rice whose whole-genome sequence is known would be evaluated phenotypically and further used for GWAS. Recent advancements in omics, like as genomics, transcriptomics, and proteomics, offer the potential to reveal the genetic components of plant genomes as well as the link between genotype and phenotype. Because of recent advancements in DNA sequence analysis, whole-genome sequence is now both technologically and commercially possible. This crop can be used for various molecular exploration. Thus, the present work is an effort to explore the genotypes to associate them with salinity tolerance and identify the superior genes.

ARRW/SIRC/Theme I/15

Creation of Repository, Maintenance, Protection and Successful Utilization of Farmer' Varieties for Rice Improvement

Bidhan Roy[1]*, Surje Dinesh Tulsiram[2], Swarnajit Debbarman[2], Gadge Sushant Sundarrao[1], Monish Roy[1], Pallabi Saha[1], Sagnik Poddar[1], H.A. Murali [1], Ranjeet Kumar[1]

[1]*Department of Seed Science and Technology;* [2]*Department of Seed Science and Technology, Faculty of Agriculture, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar 736165, West Bengal, India;*
**: Presenting author; E-mail: bcroy10@yahoo.com*

Gene pool is the basis of crop improvement programmes and collection and conservation of farmers' varieties (FVs) will act as reservoir for donors of desired traits. The collected FVs of rice possessed high probability of the useful genes for efficient application in the breeding programmes to develop high yielding varieties with grain quality, nutritional quality, accepted phenotype, productivity and resistance to biotic and abiotic stresses. In this endeavor, around 200 FVs have been collected, conserved, characterized and used in rice improvement programme.

METHODOLOGY

The FVs were primarily collected from West Bengal, Assam and Manipur. Every *Kharif* season, they are being cultivated and seeds are collected to conserve those FVs since 2008.

RESULTS

High variability has been observed among those varieties. Based on pre-breeding, important landraces were used as donor in rice improvement.

Eight desirable mutants were developed from Tulaipanji. Tulaipanji is aromatic FV of Dinajpur district of West Bengal. All those eight mutants induced from Tulpanji were photoperiod-insensitive, non-lodging, semi-dwarf with high yield potential and retained the aroma. Mutants TP3-2, TP3-4 and TP3-6 showed high increase in yield (>89%) over the control cultivar, Tulpanji (Roy *et al.*, 2018). Many recombinant inbred lines (RILs) have been developed using FV as one of the parent. A cross between *Nilachal* and *Swarna* resulted many RILs which are in different stages of yield trials. Some pure lines also have been isolated from *Kalo Nunia*, a traditional aromatic rice of northern part of West Bengal. One pure line, *Uttar Sugandhi* isolated from *Kalo Nunia* has been released for cultivation in West Bengal [Gazette Notification No. S.O. 4065(E), dated 31st August, 2022].

The traditional local aromatic rice cultivars are poor combiners. Hence, alternative tools may be used for improvement of the traditional aromatic rice. Here we report development of superior somaclones through plant tissue culture. The somaclones, TC 4/8 had the maximum yield followed by TC 5-1, TC 4/4, TC 4/5, and TC 4/7. Yield increase of TC 4/8, TC-5-1 was 54.75% and 50.33% more over the yield of parental cultivar, respectively (Roy, 2020). Effort is in progress to develop blast resistant improved Kalo Nunia and blast resistant RILs. There are further scope to utilize those FVs in rice improvement.

Distinctiveness of a genotype is compulsory for registration under PPV & FR Act (2001). Some special characters have been identified, which is not available in the descriptor of rice (PPV&FRA, 2007), such as, multi-kernelled rice, long sterile lemma, dark purple kernel (black rice), purple coloured leaf-blade and leaf-sheath and clustered panicle. In this study, we identified multiple kernel character (reference variety- *Jugal*) which may be included in the descriptors for rice as a novel trait. Occurrence of single, double and triple kernels per spikelet was 53.9, 42.2 and 3.9%, respectively. The length of sterile lemma has not been included in the descriptor of PPV&FRA. The average length of the sterile lemma in *Rami Gelee* was 9.09 mm, whereas the length of fertile lemma was 8.67 mm. *Thuri* has clustered panicle, *Khara Dhan*, *Kalawati* and *Nilachal* have purpled coloured leaf blade and leaf sheath, kernel of *Kalawati* and *Sadabhat Kalo* is dark purple.

Based on pre-breeding programme, 67 FVs have been registered under PPV&FRA. *Katarbhog*, a traditional aromatic rice variety has been registered under NBPGR (INGR21113).

CONCLUSION

Conservation of rice FVs has furthermost practical utility in rice improvement. We are conserving about 200 rice FVs collected from West Bengal and adjoining states. Those collected FVs have been characterized and 67 FVs have been registered under PPV&FRA. Based on the information derived from pre-breeding programme, FVs have been used as donor for development of high yielding varieties. Different breeding tools, like pure line selection, recombinant breeding, mutation and plant tissue culture technique have been implemented. In final conclusion, the FVs have great potentiality in rice improvement.

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ARRW/SIRC/Theme I/16

Marker Assisted Selection of Recombinant Inbred Lines of Aromatic Short Grain Rice (*Oryza sativa* L.) for Blast Resistance

Pallabi Saha[1*], Bidhan Roy[1], Gadge Sushant Sundarrao[1], Manish Kumar Agarawal[3], Prudveesh K[2], Nandita Sahana[2], Apurba Kumar Chowdhury[3], Somnath Mandal[2], Prateek Madhab Bhattacharya[3]

[1] Department of Seed Science and Technology; [2]Departmentof Biochemistry; [3]Department of Plant Pathology, Faculty of Agriculture, Uttar Banga Krishi Viswavidyalaya, Pundibari, Coochbehar-736165, West Bengal, India

**: Presenting author; E-mail: pallabisaha1904@gmail.com*

Rice is grown in almost all parts of India and experience diverse agro-climatic conditions which introduces a great number of biotic and abiotic stresses. Among the biotic stresses, blast caused by *Pyricularia oryzae* is one of the major fungal diseases of rice resulting 27-35% yield loss. Blast resistance in rice is of utmost importance to keep the diseases at bay and for boosting crop yields. In consequence, marker assisted selection for blast resistance and evaluation for yield and yield attributing characters of the Recombinant Inbred Lines were outlined as objectives.

METHODOLOGY

Kalo Nunia- an aromatic cultivar local to northern part of West Bengal grown in *Kharif* season was crossed with *Pusa Basmati 1637* possessing *Pi9* gene for blast resistance. Traditional varieties of rice exhibit a problem of blast incidence and are poor combiners. The most important character of the cultivar was the aroma which still retained when it was cultivated in *Boro* season. So, off-season flowering was used for crossing of *Kalo Nunia* with *Pusa Basmati 1637* to generate F1. The F1 seeds were space planted and harvested individually plant basis. In F2, half of the seeds space planted and harvested individually. From F3-F5 individual plant progenies were planted and superior plants were selected to isolate semi-dwarf, aromatic, photoperiod insensitive recombinant inbred lines.

For MAS selection at F5 generation, 55 RILs were selected from which 1000 samples were collected from individual plants at active tillering stage for screening for the presence of blast resistant genes using *Pi9* marker. The genomic DNA isolated using CTAB method (Murray and Thompson, 1980) from the excised plant tissues of RILs and both the positive and negative parents were loaded in the pre cast wells of the agarose gel along with *Pi9* primer. The RILs and the positive parent containing *Pi9* gene demonstrated bands (base pair of *Pi9* gene). At field level, RILs were planted and five plants from inner rows were randomly selected for taking observations on various yield and yield attributing characters. The parameters were taken following the based on the *Table of Characteristics* in the "Guidelines for Conduct of Test for Distinctiveness, Uniformity and Stability" published by PPV & FRA (2007).

RESULTS

In F5 generation, out of 55 RILs screened using MAS, 11 RILs had the *Pi9* gene and were considered as positive. In F6 generation, out of those 11 RILs, 4 RILs were positive and were also performing uniformly in the field. The 4 RILs namely are- Line no: C11; Plant number-3, Line no: C14; Plant number-7, Line no: C19 (Plant number-3) and Line no: G5 (Plant number-1, 2, 6, 7, 8 and 9). The plant height of almost all the lines were medium and hence were not lodging prone. The number of effective tillers ranged from 15-20 per plant. The mean panicle length ranged between 22.5 to 30 cm. Line No. C14-7 had awns present which were short in length; awns present in the upper half of the panicle only. The grains of C14-7 were medium slender, the decorticated grain length was 6.4 mm and breadth 1.59 mm. For the sensory test of leaf tissue (Sood &Siddiq, 1978), the presence of aroma in some plants from all 4 RILs were scored. Line No. C19-3 had medium length with dense foliage and medium bold grain and yield was 50 g/plant. By F6 generation, C19-3 was completely uniform in the field and all the plants individually planted from the seeds collected in F5 were positive. Every plant of the Line no. G5-2 was scored for the presence for aroma, height of the plant is short (93.1 cm), number of effective tillers were medium, length of the panicle being long (26.2 cm), yield was 15 g/plant, the grain was long slender. All the plants of the line no. G5 had long and narrow grain type.

CONCLUSION

4 RILs have shown promising yield attributing, agronomic as well as desirable characters in which the positive genes contributing resistance is considered to be fixed. At field level also, most of the agronomic and desirable characteristics have been uniform for 2 generations.

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ARRW/SIRC/Theme I/17

Association Pattern of Sterile Lemma of Rice (*Oryza sativa* L.) with Seed Yield and Its Attributing Characters

Sagnik Poddar*, Bidhan Roy

Department of Seed Science and Technology, Faculty of Agriculture, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar 736165, West Bengal, India;

**: Presenting author; E-mail: poddar.sagnik007@gmail.com*

Generally, rice is identified to have a pair of short sterile lemma with varying color. Some traditional rice cultivars, such as Ramigelee showed irregular long sterile lemma (Roy and Surje, 2016). Till now there is no report on contribution of sterile lemma towards seed yield. Considering the novelty of sterile lemma and taking into account the importance of sterile lemma as distinctive character, a study has been conducted find out the association of sterile lemma with seed yield and other yield attributing characters.

METHODS

The experiment was conducted to find the role of sterile lemma of spikelet and its contribution towards seed yield. In this study, 137 advanced lines derived from a cross between Nilachal (a traditional cultivar) and Swarna (MTU 7029) were included with a reference traditional cultivar-Ramigelee. In this endeavour, quantitative and qualitative characters were studied during *Kharif* 2019 and *Kharif* 2020.

Fig. 1. White coloured sterile lemma at maturity of different advanced lines

RESULTS

A sum of 21 quantitative characters were studied. High variability were observed among the RILs. Five quantitative such as, sterile lemma colour and length (Fig. 1), leaf blade colour, leaf sheath colour, chalkiness and grain types were studied in this endeavour.

High significant variability was observed in respect of all the quantitative and qualitative characters. Some lines showed high yield potential. Two lines, namely NS17-2 (9.71 t/ha) and NS1-2 (9.63 t/ha) had very high potential seed yield. Four lines exhibited yield ? 5.00 t/ha, such as, NS25-1 (6.87 t/ha), NS25-5 (6.07 t/ha), NS25-1-1S (5.67 t/ha) and NS7-1 (5.20 t/ha).

Grain type is a desirable character to attract the consumers. There are five classes of grains. Three of the lines were found long slender, 29 were medium slender, 70 were long bold, 35 were short bold and only one was categorized as Basmati type. None were found short slender and extra-long slender. Long slender and medium slender have good demand by the urban and semi-urban consumers. A good number of advanced lines in this investigation possessed long slender and medium slender grains. Those lines can be popularized for commercial cultivation.

Yield showed increasing trend with increase in length of sterile lemma and length of sterile lemma (palea-side), but it is not uniform across the advanced lines. It needs further statistical analysis to seed the effect of sterile lemma on yield. Considering this non-uniform graphical relationship between length of sterile lemma and yield, character associations was performed statistically in the later part of this chapter.

Length of sterile lemma showed significant positive correlation at genotypic and phenotypic levels with length of grain (0.338**; 0.293**), breadth of grain (0.286**; 0.279**), thickness of grain (0.282**; 0.228**), test weight (0.272**; 0.233**), kernel length (0.131*; 0.129*), kernel thickness (0.239**; 0.220**), 1000-kernel weight (0.252**; 0.244**), length of sterile lemma (palea-side) (1.015**; 0.975**), breadth of sterile lemma (0.721**; 0.652**) and seed yield (0.120*; 0.119*).

Length of sterile lemma (palea-side) displayed significant positive correlation at genotypic and phenotypic levels with length of grain (0.318**; 0.311**), grain breadth (0.318**; 0.274**), grain thickness (0.276**; 0.244**), test weight (0.276**; 0.248**), kernel length (0.143*; 0.127*), kernel thickness (0.228**; 0.213**), 1000-kernel weight (0.250**; 0.257**), length of sterile lemma (0.250**; 0.257**), breadth of sterile lemma (0.692**; 0.657**) and seed yield (0.129*; 0.126*).

Breadth of sterile lemma demonstrated significant positive correlation at genotypic and phenotypic levels with grain length (0.440**; 0.401**), grain thickness (0.265**; 0.249**), test weight (0.358**; 0.296**), kernel length (0.217**; 0.189*), kernel thickness (0.178*; 0.172*), 1000-kernel weight (0.350**; 0.323**), length of sterile lemma (0.721**; 0.652**) and length of sterile lemma (palea-side) (0.692**; 0.657**).

Seed yield demonstrated significant positive correlation with number of filled grains per panicle (0.188*; 0.151*), grain length (0.168*; 0.152*), kernel length (0.174*; 0.165*), kernel thickness (0.117*; 0.108*), 1000-kernel weight (0.123*; 0.122*), length of sterile lemma (0.120*; 0.119*) and length of sterile lemma (palea-side) (0.129*; 0.126*).

CONCLUSION

In nutshell, it can be concluded that length of sterile lemma (0.120*; 0.119*) and length of sterile lemma (palea-side) (0.129*; 0.126*) had significant positive correlation with seed yield of advanced lines derived from a cross between Nilachal and Swarna. Breadth of sterile lemma also showed positive but insignificant correlation with seed yield.

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ARRW/SIRC/Theme I/18

Callus mutagenesis and study of induced variability in M_4 generation of local aromatic rice landraces (*Oryza sativa* L.)

Subhashree Das[1], Banshidhar Pradhan[1], Rajesh Kar[1], Sanghamitra Samantaray[2]

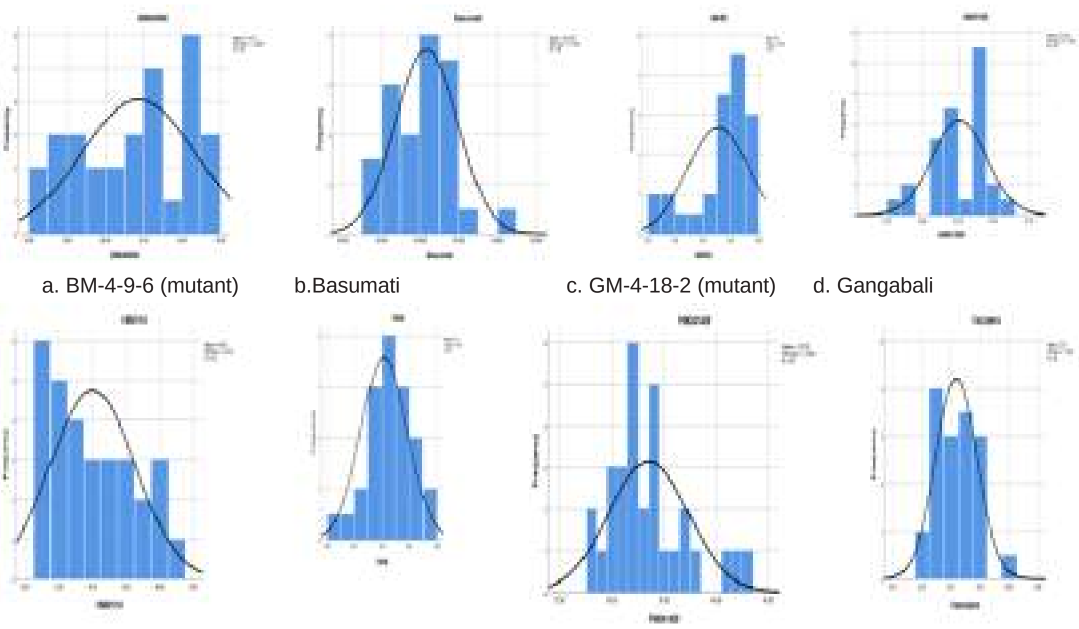
[1]*Department of Plant Breeding & Genetics, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India 751003*

[2]*Crop Improvement Division, ICAR-National Rice Research Institute, Cuttack, Odisha, India 753006.*

Mutagenesis using ethyl methanesulphonate (EMS) has been proved to have improved agronomically important traits in crop plants specially in rice as it was found to induce mutation rate of 1.4 to 2.9 mutations per Mb (Awais *et al*., 2019). Callus initiated from mature embryos of rice when treated with EMS at 0.2% for 2 hours was found to be effective in generating a whole rice mutant population with high mutation rate i.e., one mutation in every 451 Kb (Serrat *et al*., 2014). On the basis of these facts, this experiment was taken up to analyze EMS induced biological effects of *in vitro* mutagenesis and induced variability in M_4 generation of four local aromatic rice genotypes to identify the desirable mutants.

METHODOLOGY

MS medium with 125mg/l ascorbic acid, 125 mg/l citric acid, 0.5 mg/l NAA, 0.1 mg/l BAP,100 mg/l myo- inositol, sucrose at 3% (w/v) and EMS (0.2%) was used for *in vitro* mutagenesis. Twenty five calli (0.2mm size) from 4 aromatic rice landraces were treated for 2 hours, 4 hours and 6 hours each maintaining the control. Treated calli then transferred to regeneration medium and M_1 plantlets were obtained. In the M_2 seedlings the chlorophyll mutation spectrum was observed for determining mutation rate. Nine quantitative and three qualitative characters (aroma level, alkali spreading value and amylose content) were



a. BM-4-9-6 (mutant) b.Basumati c. GM-4-18-2 (mutant) d. Gangabali

e. KM-4-19-14 (mutant) f. Kalikati g. PM-4-14-9 (mutant) h. Karpurajeera

Fig. 1. Pattern of variation in the mutants and parents for single plant yield

subjected to statistical analyzes using RBD and CRBD respectively using ANOVA. The pattern of variation in the M_4 population was examined through frequency curves. Possible deviation from normality was examined through estimates of skewness and kurtosis for M_4 generation of the four aromatic rice genotypes.

RESULTS

The mutagenic frequency, effectiveness and efficiency was calculated on the basis of chlorophyll mutants observed in M_2 seedlings. Basumati (10.68) was found to be more responsive to mutation followed by Kalikati (10.25), Karpurajeera (4.45) and Gangabali (4.17) on the basis of mutation rate obtained in these genotypes in terms of effectiveness. Estimates of skewness and kurtosis which are the measure of deviation from normality for mutants and parents showed wide variations and improvement in terms of yield in the mutants compared to parents (Fig. 1).

CONCLUSION

EMS induced mutation in the *in vitro* technique in aromatic rice genotypes leads to more effective mutagenesis consuming less time and labour giving desirable mutants with reduced plant height upto 18.78%, increased tillers per plant by 134.4% and increased yield by 118.2%.

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ARRW/SIRC/Theme I/19

Drought Tolerance of qDTY QTL Introgressed Rice Genotypes Under Managed Water Stress Condition.

R Suresh[1*]., [3]Raveendran M, [2]Nithishkumar G, [1]Renuprasath P, [1]Shanmugam A, [2]Sassikumar D and [2]K. Subrahmaniyan

[1]Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore-641 003, Tamil nadu, India

[2]*Tamilnadu Rice Research Institute, Tamil Nadu Agricultural University, Aduthurai-612 101, Thanjavur, Tamil nadu, India*

[3]*Director of Research, Tamil Nadu Agricultural University, Coimbatore - 641 003*

**E-mail: sureshpbg@gmail.com*

Rice (*Oryza sativa* L.) is the one of the oldest cultivated and most widely consumed staple food crop to some 4 billion people throughout the world. It is grown in nearly 95 countries all over the world (IRRI, 2002). India, China and Indonesia are the top three nations that accounts for more than 50 per cent of global rice production (FAO, 2015). The demand for rice production is increasing day-by-day due to rapid increase in the world population. Drought is major limiting factor in rice production ecosystem and impacts world food security. According to climate change prediction models, impact of drought on rice production will be more in coming years and depends on severity of drought prevails during that year (Guo *et al*. 2021). Hence, there is a need to improve the rice production and productivity in wide range of environments including less favorable rainfed areas. Currently, there is no commercially viable way to increase rice yield under drought. However, developing drought-tolerant rice varieties is a promising strategy to help developing and underdeveloped nations to meet their rising food demands (Farooq *et al*., 2009). Direct selection for yield under drought stress in managed water stress environments is seen as a promising way to deal with drought tolerance in rice. Considering the above situations, the present research focuses on field screening of back crossed inbred lines (BILs) to identify high yielding drought tolerant genotypes.

METHODOLOGY

The present investigation was carried out using three sets of back crossed inbred lines (BILs) derived from three crosses *viz*., ADT (R) 45*3/Apo with QTLs *qDTY 1.1, qDTY 3.1*, ADT (R) 45*3/Way Rarem with QTL *qDTY 12.1* and ADT (R) 45*2/Apo//ADT (R) 45*2/Way Rarem with QTLs *qDTY 1.1, qDTY 3.1* and *qDTY 12.1*. The BILs along with the parental genotypes were evaluated for drought tolerance during dry season (Summer, 2022) under managed water stress conditions at Tamil Nadu Rice Research Institute, Aduthurai. by following the below mentioned protocol.

1. Each entry was direct seeded in two rows with a row length of 1.5 meter and spacing of 20 cm between rows. The seedlings were allowed to grow up to 65 days after sowing (DAS) with normal irrigation in 3 days interval with no standing water.
2. Irrigation was stopped 10 days before flowering *i.e.,* 70 days after sowing and the drought stress was imposed for a period of 15 days *i.e.,* up to 85 days after sowing.
3. Soil Moisture Content per cent (SMC %) was recorded before and after stress period and also during the stress period.
4. On 84th and 85th DAS, observations *viz.,* leaf rolling, leaf drying scores, relative water content, SPAD chlorophyll value and proline content were recorded.
5. Field was re-irrigated on 86th DAS to relieve the water stress and thereafter irrigation was continued for once in 3 days until maturity.

Table 1. Mean yield of genotypes with different QTL combinations

Genotypes with QTL combinations	Number of genotypes	Mean yield (g)	% increase in yield over ADT (R) 45
ADT (R) 45 (Recurrent Parent)	1	15.335	-
BILs with *qDTY 12.1*	73	16.590	8.18
BILs with *qDTY 1.1* + 3.1	31	23.720	54.68
BILs with *qDTY 1.1+ qDTY 12.1*	3	21.948	43.12
BILs with *qDTY 3.1+ qDTY 12.1*	3	28.998	89.10
BILs with *qDTY 1.1+ qDTY 3.1+ qDTY 12.1*	10	23.933	56.07

6. Post stress observations *viz.*, drought recovery per cent was recorded seven days after relieving the stress.
7. Biometric observations *viz.*, plant height, productive tillers per plant, flag leaf length, flag leaf breadth, panicle length were recorded at the time of harvest and traits such as grains per panicle, chaffs per panicle, spikelet fertility, thousand grain weight and yield under stress were recorded after harvesting the crop.

RESULTS

The mean yield of genotypes with different QTL combination (Table 1) showed that all QTL combinations recorded higher mean yield than the recipient parent ADT (R) 45. The results showed that BILs with 2 QTLs *viz., qDTY 3.1* and *qDTY 12.1* exhibited 89.10 per cent of increase in yield over ADT (R) 45. BILs with all the three QTLs *viz., qDTY 1.1*, *qDTY 3.1* and *qDTY 12.1* also exhibited 56.07 per cent of yield improvement than ADT (R) 45. Apo derived BILs with *qDTY 1.1* and *qDTY 3.1* recorded higher mean yield than the inter-mated BILs with *qDTY 1.1* and *qDTY 12.1*.

Three BILs (IM 33, IM 45 and IM 69) carrying *qDTY 3.1* and *qDTY 12.1*, two BILs (IM 5, IM 12) carrying *qDTY 1.1* and *qDTY 12.1*, seven BILs (IM 127, IM 140, IM 172, IM 32, IM 39, IM 71 and IM 85) carrying all the three QTLs, three BILs (A 24, A63, A80) carrying *qDTY 1.1* and *qDTY 3.1* and seven BILs (W 18-8-7, W 225, W 61, W 64, W 7-4-1, W 214 and W 216) carrying *qDTY 12.1* are best performing genotypes under drought tolerance for most of the traits under study. Out of 120 genotypes, 13 BILs *viz*., W 18-8-7, W 225, W 61, W 64, W 7-4-1, A 99, IM 33, IM 45, IM 69, IM 85, IM 127, IM 140 and IM 172 exhibited better performance for drought related traits such as leaf rolling, leaf drying, drought recovery, relative water content, SPAD value and proline content.

CONCLUSION

Evaluation of BILs under managed water stress conditions revealed that BILs with *qDTY 3.1* and *qDTY 12.1* exhibited maximum mean yield under drought stress followed by BILs with all three QTLs viz., *qDTY 1.1, qDTY 3.1* and *qDTY 12.1*. This indicates the additive effects of QTLs for drought tolerance. Five BILs carrying *qDTY 12.1 viz*., W 18-8-7, W 225, W 61, W 64, W 7-4-1, three BILs carrying *qDTY 3.1* and *qDTY 12.1 viz*., IM 33, IM 45, IM 69 and four BILs carrying *qDTY 1.1, qDTY 3.1* and *qDTY 12.1* are the most promising lines for drought tolerance. Hence, these lines can be considered for further testing in target production environments to release as drought tolerant varieties and also used as a potential donor parent for drought tolerance breeding.

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Genotypes with QTL combinations	Number of genotypes	Mean yield (g)	% increase in yield over ADT (R) 45
ADT (R) 45 (Recurrent Parent)	1	15.335	-

ARRW/SIRC/Theme I/20

Draft genome sequence for the allo-tetraploid wild rice *Oryza alta*.

Parimalan Rangan[1,*], Viswanathan Chinnusamy[2], Mirza Jaynul Baig[3], Rajkumar Subramani[1], Surendra Kumar Malik[1], Dhammaprakash P Wankhede[1], Kanagasabapathi Pradheep[4], Mahesh Chandra Yadav[1], S. Gopala Krishnan[2]

[1]*ICAR-National Bureau of Plant Genetic Resources, PUSA Campus, New Delhi-110012, India*
[2]*ICAR-Indian Agricultural Research Institute, PUSA Campus, New Delhi-110012, India*
[3]*ICAR-National Rice Research Institute, Cuttack-753006, India*
[4]*ICAR-National Bureau of Plant Genetic Resources-Regional Station, Thrissur-680656, India*

INTRODUCTION AND OBJECTIVES

Oryza alta is an allotetraploid wild rice carrying the CCDD genome. This species is an important member of the *Oryza officinalis* complex group comprising six diploids and six tetraploids. Our preliminary anatomical studies among the wild rice species had identified the potential in *O. alta* for various photosynthetic traits. An initiative in this regard had been taken to generate genomic resources for this species.

METHODOLOGY

Initially, we had generated short-read using an Illumina platform and long-read data using PacBio. These data were used to generate chloroplast assembly and the draft genome assembly and is much helpful in establishing species relationship using barcode markers. The contigs generated were scaffolded to chromosome-level draft genome using the recently reported genome sequence (Yu et al., 2021).

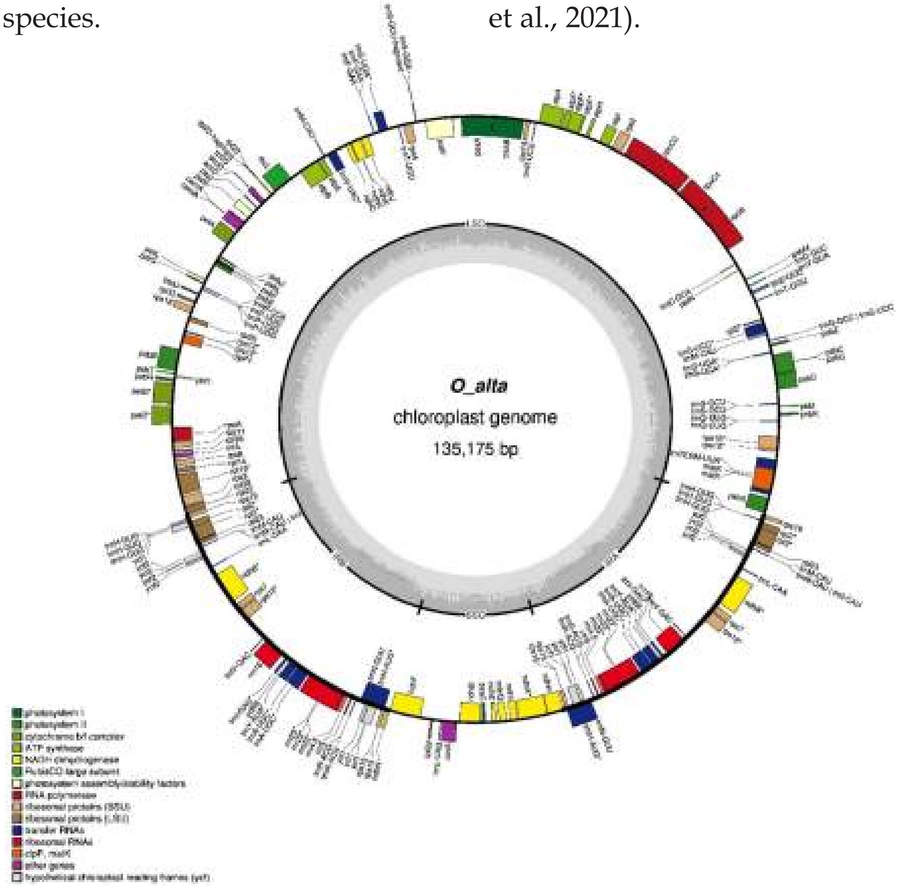

Fig. 1. chloroplast genome map of *Oryza alta*.

RESULTS AND CONCLUSION

The chloroplast assembly using short-read data gave a complete circular genome of size 135,175 bp (Fig. 1). The annotation of the chloroplast assembly had identified 173 mRNA, 34 tRNA and 4 rRNA genes. With reference to the nuclear genome, using the short read data, the genome size estimates were assessed and found that the genome contains an average of 29% repeats and the predicted genome size (corrected to accommodate repeats and heterozygosity values) was found to be 930.702294 Mbp. Previously the genome size for *O. alta* is reported to be 894.6 Mb (Yu et al., 2021). The short-read and long-read data generated were subjected through the hybrid assembler, MaSuRCA, and a first version draft genome assembly has been made and are scaffolded to chromosome level draft genome. This assembly size was 848.260214 Mbp in 6444 scaffolds. Around 86 per cent of the scaffolds (5548) were of more than 10 kb in length. The N50 contig and scaffolded length was estimated to be 0.23 and 35.65 Mb, respectively. The BUSCO score to estimate the annotation completeness of the genome is found to be 99.3%.

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ARRW/SIRC/Theme I/21

Genetic analysis and trait association in F_2 inter sub specific population in rice

R Rasitha, R Sangeetha* and R.Saraswathi

Department of Genetics and Plant Breeding, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore – 641 003

Email: rasitharahamath@gmail.com

Rice is the life and the prince among cereals as this distinctive grain helps to sustain two thirds of the world's population. To meet the indispensable demand of the constantly increasing population, improvement of the yield potential through genetic manipulation will be a key tool in rice breeding programs. Introduction of new favorable genetic material from genetically related groups of Asian rice is considered a promising approach. Rice yield can be further enhanced by exploiting the heterosis among the subspecies of rice which shows significant dissimilarities in stress resistance, quality and yield. Estimates indicate that about 30% higher yield can be obtained from the heterosis of *indica*/*japonica* varieties than those of *japonica* or *indica* cultivars (Guo *et al.*, 2016). The success of any plant breeding programme depends upon the existence of genetic variability present in a given crop species for the character under improvement which act as handy tools of a plant breeder for ensuring efficient selection. For selection, understanding the association of individual trait with the plant yield will be highly informative and useful along with genetic analysis.

MATERIALS AND METHOD

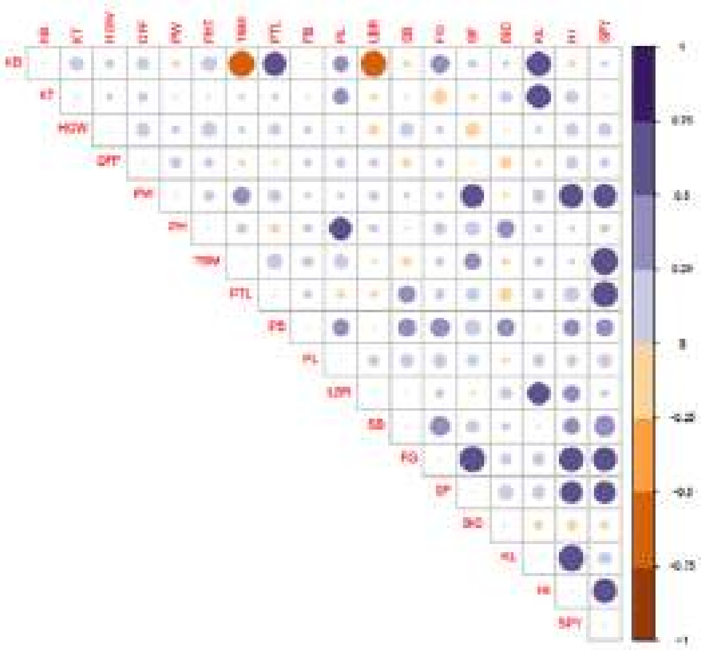
Totally 35 F_1 hybrid were synthesized by utilizing ten *japonica* and 14 *indica* genotypes. Based on standard heterosis, pollen fertility and seed set percent in all F_1's, Paiyur 1 x Nira (*indica* x tropical *japonica*) were forwarded to generation advancement. F_2 population were evaluated for the extent of variability and genetic parameters for 18 characters which includes, yield and yield attributing characters and physical grain quality parameters. Although it shows partial fertility, parents having desirable traits for further plants selection in segregation generation. The observations were recorded in an average of 400 plants in F_2 population.

RESULT

In the present study, values of phenotypic variance were greater than the genotypic variance for all the characters except for panicle weight, kernel length, and kernel breadth indicating the least/nil influence of environmental effects for these traits. High PCV and GCV coupled with high heritability and high genetic advance as per cent of mean were exhibited by spikelet fertility, hundred grain weight , basal internode diameter , number of primary branches, total biomass , panicle weight , number of productive tillers, number of secondary branches, single plant yield, harvest index and number of filled grains panicle^{-1} which indicated that these traits were controlled by additive type of gene action and there is a good chance for improvement through selection

In association studies, single plant yield was found to be determined by component traits like number of productive tillers, total biomass, harvest index, and panicle traits *viz.*, panicle length, number of primary branches, number of secondary branches, number of filled grain panicle^{-1}, panicle weight and spikelet fertility which is evident from their highly significant positive correlation(Figure 1). In path analysis, F_2 population were recorded high positive direct effect on single plant by the traits total biomass and harvest and indirect effect of traits on single plant yield, number of productive tillers showed a high positive indirect effect via

Traits	DFF	PHT	PTL	BID	PL	PB	SB	FG	PW	SF	HGW	TBM	HI	KL	KB	KT	LBR	SPY
DFF	1	0.07	-0.02	-0.13	0.08	0.05	-0.07	0.05	0.11	-0.01	0.04	-0.04	0.14	-0.04	-0.08	-0.23**	0.06	0.06
PH		1	-0.09	0.31**	0.53**	0.08	0.008	0.17*	0.23**	0.22**	0.19*	0.12	0.03	0.05	-0.03	0.08	0.07	0.07
PTL			1	-0.15	-0.06	0.06	0.29**	0.10	0.01	0.15	0.03	0.72**	0.22**	0.12	0.10	0.09	-0.04	0.70**
BID				1	0.19*	0.17*	0.04	-0.02	0.08	0.06	-0.03	0.03	-0.11	-0.09	-0.05	-0.06	-0.02	-0.06
PL					1	0.10	0.16*	0.20*	0.30**	0.11	0.31**	0.13	0.11	0.14	0.01	0.05	0.10	0.17*
PB						1	0.32**	0.37**	0.42**	0.24**	0.06	0.14	0.27**	-0.01	-0.001	-0.23**	-0.01	0.29**
SB							1	0.41**	0.40**	0.16*	0.10	0.36**	0.27**	0.006	0.08	0.02	-0.07	0.45**
FG								1	0.82**	0.70**	-0.02	0.30**	0.63**	0.16*	0.04	-0.01	0.07	0.60**
PW									1	0.56**	0.20*	0.31**	0.61**	0.18*	0.03	-0.04	0.08	0.59**
SF										1	-0.005	0.30**	0.52**	0.17*	0.05	-0.01	0.04	0.51**
HGW											1	0.04	0.16*	0.03	0.08	-0.01	-0.09	0.15
TBM												1	0.03	0.09	0.06	0.15	-0.02	0.74**
HI													1	0.17*	-0.01	-0.19*	0.12	0.61**
KL														1	0.35**	0.28**	0.38**	0.16*
KB															1	0.19*	-0.69**	0.03
KT																1	-0.04	0.002
LBR																	1	0.05
SPY																		1



total biomass and moderate positive indirect effect on single plant yield via harvest index. Hence these traits may be given importance in selection, since it will lead to increase in the yield plant^{-1} irrespective of whether it is inter/intra sub specific crosses.

CONCLUSION

Genetic studies for variability parameters and association studies in F_2 population (Paiyur 1 x Nira) is useful for identification of promising single plants with high mean values for different traits that can be advanced to next generation. The breeding lines to be developed from the harvested F_2 and F_3 of these inter sub specific crosses is expected to realize genetic gains for yield in future that can be exploited in both varietal development programmes and in hybrid breeding programmes

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ARRW/SIRC/Theme I/22

Morpho-physiological characters reveal optimum sodicity levels for rice varieties differing by their response to salt stress at seedling stage

M. Akilan, P. Jeyaprakash, P. Savitha and C. Vanniarajan

Department of Plant Breeding and Genetics, Anbil Dharmalingam Agricultural College and Research Institute, Tamil Nadu Agricultural University, Trichy, Tamil Nadu, India- 620 027

Rice is one of the most important cereal grains that meets the major calorie requirement of world community. However, rice production is hindered by various biotic and abiotic stresses. Comparative biochemical analysis of tolerant and susceptible cultivars augment the understanding of key proteins and metabolites and mechanisms underlying stress tolerance (Demirel *et al*. 2020). The current study aims to identify optimum sodicity concentration to screen these rice varieties for biochemical, proteomic and metabolomic studies.

METHODOLOGY

A set of four rice varieties *viz*., FL478, CSR36, Pusa44 and ASD19, differing by their response to salt stress were used in the present study. The seeds were subjected to different levels of sodicity stress *viz*., 0 mM, 25 mM, 50 mM, 75 mM, 100 mM, 125 mM and 150 mM, using roll paper towel method with 5 replications. The following morpho-physiological traits *viz*., shoot length, root length, seedling fresh weight and seedling dry weight, were measured and Salt Injury Index (SII) as per Wu *et al*., (2019) was calculated to identify the optimum sodicity level for each variety.

RESULTS

A graph was plot using salt injury index of each trait Vs the salt concentration for calculating the Growth rate inhibition 50 values (GR50), For instance, salt injury index Vs concentration for shoot length in FL478 was illustrated in Figure 1. The results indicate different levels of GR for all the traits observed in the study (Table 1). The mean value for each variety was calculated and identified as the optimum sodicity concentration of that variety. Clearly, FL478 showed higher mean GR50 value (105.39 mM) compared to other varieties, indicating it to be the most tolerant variety, while the most susceptible variety was found to be ASD19 (69.30 mM).

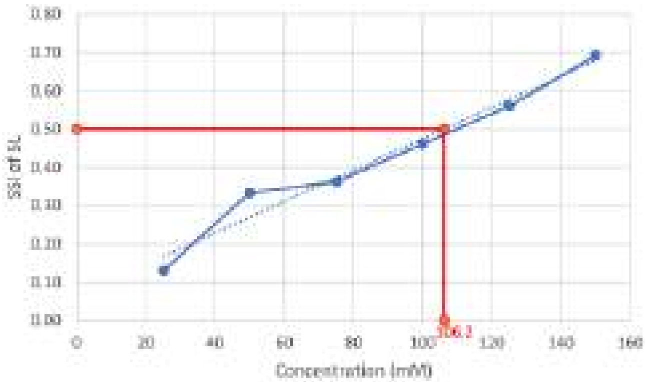

Fig. 1. **Salt injury index Vs Concentration for Shoot length of FL478**

Table 1. GR50 values of different traits at seedling stage

Varieties	SL	RL	SFW	SDW	Mean
FL478	106.21	97.44	134.51	83.39	105.39
CSR36	78.45	72.65	122.02	104.13	94.31
Pusa44	100.11	84.64	115.18	60.68	90.15
ASD19	71.57	64.33	78.88	62.44	69.30

CONCLUSION

Understanding the biochemical basis of salt stress tolerance is one of the prime steps for the development of tolerant varieties. Optimisation of salt concentration is the preliminary step for different biochemical, proteomic and metabolomic studies. The GR50 values for the varieties under study *viz*., FL478, CSR36, Pusa44 and ASD19 were

105.39 mM, 94.31 mM, 90.15 mM and 69.30 mM respectively. The results from the present study will be most useful for studying the biochemical basis of sodicity tolerance and further effective crop improvement.

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ARRW/SIRC/Theme I/23

Utilization of New Alleles through Pre-breeding to improve Yield and BPH resistance in cultivated rice

L. K. Bose, M. K. Kar, M. Chakraborti, , P.C. Rath, H. N. Subudhi, P. Sanghamitra, N. N. Jambhulkar and S.K. Dash

National Rice Research Institute, Cuttack-753006 (India)
Email : lotanrice@gmail.com

Rice is one of the most important cereal crops feeding more than half of the world population. The brown planthopper (BPH), *Nilaparvata lugens* (Stal) is one of the most serious rice pests worldwide. Growing resistant varieties is the most effective way to manage this insect, and wild rice species are valuable sources of resistance genes for developing resistant cultivars. New alleles can provide genetic variability for crop enhancement. The *Oryza* wild species represent a potential source of new alleles for improving the yield, quality and stress resistance of cultivated rice, therefore Pre-breeding is one the best options to address the problem of stagnating productivity by searching for new genes for tolerance to biotic stresses with yield, quality and tolerance to BPH. Common wild rice (*Oryza rufipogon* Griff.), known as the ancestor of Asian cultivated rice (*Oryza sativa* L.), is the most important germplasm for rice improvement. The objective of this study was to transfer BPH resistance gene with yield gene from wild rice (*Oryza rufipogon* Griff.) to cultivated rice (*Oryza sativa* L. cultivar Swarna) by backcrossing in combination with immature embryo culture. Brown plant hopper (BPH, *Nilaparvata lugens* Stål) is one of the most serious rice insect pests in India and the world and development of virulent BPH populations is becoming a serious threat for rice cultivation at present. In this study, more than 50 accessions of common AA genome wild rice (*Oryza rufipogon*, *Oryza nivara*) were evaluated for the resistance to BPH along with susceptible check TN1. Two resistant accession of *O. rufipogon* were identified and were used in hybridization programme. Lines were verified with markers linked to BPH resistance genes to detect whether that the resistance observed in *O. rufipogon* accession is due to existing resistant genes or new genes to avoid genetic uniformity of BPH resistance in cultivated rice in future. These resistant advanced genetic stocks set a solid foundation for breeding new resistance varieties. Wide hybridization in *Oryza* is normally difficult to achieve because many wild species of genus *Oryza* are difficult to cross with cultivated rice because of difference in chromosome number or genetic constitution. Wide hybridization and chromosome manipulation are the important techniques to transfer useful genes from wild to cultivated rice leading to rapid genomic changes like chromosomal rearrangements, genome expansion, differential gene expression and gene silencing.

METHODOLOGY

BPH tolerant accession of *O. rufipogon* was crossed with cultivars. All the F1s were backcrossed to the respective recurrent parents and embryo rescue were followed due to shattering of spikelets to get BC1 plants. BC1 progeny were back crossed to the same recurrent parent to obtain BC2 progeny.

RESULTS

The F1 hybrids were morphologically intermediate between two parents in some respect but showed preponderance of the traits of the wild species. They were robust and vigorous. All the F1 hybrids were semi-sterile. The seed set on back crossing the F1 hybrids with recurrent parents were extremely low. All the BC1F1 plants were completely male sterile. BC1F1 progeny were back crossed to same recurrent parents to obtain BC2F1 progeny. Disomic BC2F1 plants were grown for generation advance and selection for desirable plant type. All the derivatives of F1, BC1F1, BC2F1, BC2F2, BC2F3 and F2 were screened simultaneously against BPH.

CONCLUSION

The present investigation describes details of experimentation strategy to introgress BPH resistant genes from *O. rufipogon* to the cultivars.

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ARRW/SIRC/Theme I/24

Phenotypic Stability of Seed Characteristics in Rice (*Oryza sativa* (L).) is influenced by Source-Sink Imbalances

[1] M Dhandapani, [1] K Subrahmaniyan, [2] S Geethanjali, [1] A Shanmugam, [3] M Sangeetha

[1]*Tamil Nadu Rice Research Institute, Tamil Nadu Agricultural University, Aduthurai-612 101*
[2] *Department of Plant Biotechnology, Tamil Nadu Agricultural University, Coimbatore-641003*
[3] *Regional Research Station, Tamil Nadu Agricultural University, Paiyur-635112*

INTRODUCTION

Rice is cultivated in an area of 14 lakh ha in Cauvery Delta Zone of Tamil Nadu, a special agricultural zone, as per the TN Govt GO. Short duration rice varieties with a duration of 100-110 days are being cultivated during summer season (April-July) and Kuruvai season (June-September) viz., ADT36, ADT37, ADT43, ASD16, CO51, TPS5, and ADT53. The popular paddy variety ADT53 often shows objectionable percentages of off types viz., bold grains, long slender grains and tall plants in seed production plots. The proposed study was formulated with the following objectives.

1. Studying the cause of phenotypic stabilities of grain types in the paddy variety ADT53
2. Modified nutrients dose and application method to prevent the source sink imbalances

Table 1. Treatment Details

S No	Treatment Details
1.	T_1- SA: NPK (100: 50 :50 kg/ha) + Zinc sulphate, 25 kg/ha
2.	T_1+ (FA- 0.5% water soluble macro nutrients + 0.2% micro nutrients on 15th DAP)- T_2
3.	T_2 + (FA on 25th DAP)- T_3
4.	T3+ (FA on 45th DAP)- T_4
5.	T4 + (FA on 60th DAP)-T_5
6.	Rescheduling Nitrogen and Potassium (N-40 kg/ha, No phosphorous, K- 75 kg/ha + FA- 15th, 25th, 45th, 60th DAP- T_6

(SA: Soil application-Nitrogen- Urea, phosphorous- Di ammonium phosphate K- Muriate of Potash, **FA**: Foliar application: MN mixture: 0.2% (MN-Chelated mixture of Fe 2.5%, Mn 1.0%, Zn 3.0%, Cu 1.0%, Mo 0.1% and B 0.5%), Water soluble: 19:19:19 (NPK)

MATERIALS AND METHODS

- Confirmation of genetic purity of nucleus seeds by paired row method of Seth et al., 2022.
- Raised bed nursery, 14 days old seedlings for transplanting, spacing 30 x 30 cm and Planting of single seedling per hill

Statistical analysis

Six treatments with three replications, each replication with 20 cents as one plot, total number of plants: 8888 / plot. Duncan multiple range test was performed to study the significance of the treatments imposed on each plot with replications using R statistical packages. Removal of off types was carried out as per the DUS characteristics and guidelines.

RESULTS AND DISCUSSION

Totally six treatments were imposed on each plots consisting of 20 cents. The first treatment as soil application of zinc sulphate with recommended dose of NPK, showed (T_1) showed increased number of off types of 147 bold grain (1.6%), long slender grains and elongated stem plants with excess foliage (taller types) viz., 147, 37, 16 with respective percentages to the total population of 1.6%, 0.4% and 0.2%. The second treatment (SA + FA: 15ht DAP) reduced the off types 72 (0.8%), 17(0.2%) and 5(0.06%) with almost 50% reductions. The third treatment showed further reduction of off types viz., 53 bold types (0.6%), 5 long slender types (0.06%), 3 tall plants (0.04%). The fourth treatment showed 38 bold types (0.4%), 3 long

Table 2. Effect of dose modifications and application on grain phenotypic stabilities of ADT-53 during summer (April-July)-2022 and Kuruvai (May-August)-2022

Summer-2022 (April-July)				
SNo	Treatments	Bold grain type	Long slender grain type	Tall plant type
1.	T_1	147.0[a] (1.6%)	37.0[a] (0.4%)	16.0[a] (0.2%)
2.	T_2	72.0 [b] (0.8%)	17.0[b] (0.2%)	5.0[b] (0.06%)
3.	T_3	53.0 [c] (0.6%)	5.00[c] (0.06%)	3.0[b] (0.04%)
4.	T_4	38.00 [cd] (0.4%)	3.0[c] (0.04%)	2.0[b] (0.03%)
5.	T_5	22.0 [d] (0.2%)	4.00[c] (0.05%)	1.0[b] (0.02%)
6.	T_6	5.00 [e] (0.06%)	2.0[c] (0.03%)	2.0[b] (0.03%)
Kuruvai-2022 (May-August)				
S No	Treatments	Bold grain type	Long slender grain type	Tall plant type
1.	T_1	100.0[a] (1.0%)	24.0 [a] (0.3%)	0
2.	T_6	4.0[b] (0.05%)	3.0 [a] (0.04%)	0

slender types (0.04%), 2 tall plant types (0.03%). Fifth treatment with additional fourth foliar application on 60th DAP (70 days old plants), showed 22 bold types (0.2%), 4 long slender types (0.05%) and 2 tall plant types (0.02%). Sixth treatment (Nutrients rescheduling and foliar applications) effectively reduced the bold types to 0.06% (Table 2). Recommended dose showed 1.0 %, 0.3% off types respectively during kuruvai-2022.

Table 3. Influence of nutrients rescheduling and foliar sprays of macro and micro nutrients on seed yield of the paddy variety, ADT53 during kuruvai-2022

S No	Treatments	Seed yield (kg/ha)
1.	T_1	3966.67[b]
2.	T_6	5641.67[a]

Modified protocol showed drastic reduction as 0.05% and 0.04% respectively along with yield increase of 42.2 % over control (T_6:5641.67, T_1:3966.67 kg/ha) respectively.

CONCLUSION

1. Nutrients imbalance causing grain phenotypic stabilities of rice mainly attributed to deficiencies of Phosphorous and Zinc

2. Prevention of formation of off types by modified nutrients dosage and application results in yield increase.

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Evaluation of morphological traits for salt tolerance in rice Tamil Nadu landraces

Mathankumar P[1] and S Geetha [2]

[1] *Ph.D. scholar, Department of Genetics and Plant Breeding, CPBG, TNAU, Coimbatore 641 003, Tamil Nadu, India.*
[2] *Professor & Head, Department of Pulses, CPBG, TNAU, Coimbatore 641 003*
Corresponding author: Email: geethagovind1@gmail.com

Over the years, abiotic stresses have severely constrained rice production, especially salinity. Rice is sensitive to salinity at seedling and reproductive stages, leading to a yield loss of 45% around the globe. In Tamil Nadu (TN), rice is cultivated in an area of 17.58 Lakh hectares with a production of 63.30 Lakh metric tons. Wide genetic variations are available in Tamil Nadu landraces for salinity tolerance at the seedling stage. In this study, therefore, we evaluated 31 landraces along with 2 checks (Pokkali and IR29) for salt tolerance at the early seedling stage.

MATERIALS AND METHODS

The experiment material of 31 landraces was collected from Paddy Breeding Station, TNAU, Coimbatore. Pre-germinated seeds were grown in Yoshida solution for 14 days then salinity (12 dS/m) was imposed and readings were taken from the 7th day after salt treatment. A total of ten morphological traits were recorded. Salt tolerance index (STI) values and Membership function values (MFV) were calculated for each trait. The salt tolerance grading was based on average MFV values, When, $X_i > \overline{X} + 1.64$ SD, the plant was highly saline tolerant; when + 1 SD < X_i < - 1.64 SD, the plant was saline tolerant; when - 1 SD < X_i < + 1 SD, the plant was moderately saline tolerant; when - 1.64 SD < X_i < - 1 SD, the plant was saline susceptible and when X_i < - 1.64 SD, the plant was highly saline susceptible (Chen *et al* (2020)). Further, a mathematical model was developed from multiple regression analysis using unstandardized coefficients (β) and constant (μ) (Li *et al.,* (2020)). The formula is given below

$$Y = \beta_{STI\,SL} * STI_{SL} + \beta_{STI} RL*STI_{RL} + \beta_{STI\,SFW}*STI_{SFW} + \beta_{STI\,RFW}*STI_{RFW} + \beta_{STI\,RDW}*STI_{RDW} + \beta_{STI\,SDW}*STI_{SDW} + \beta_{STI\,TFW}* STI_{TFW} + \beta_{STI\,TDW}*STI_{TDW} + \beta_{STI\,MC}*STI_{MC} + \mu$$

RESULTS

In the present study, recorded traits showed significant differences among genotypes. Salt stress caused a reduction in the growth parameters of rice seedlings in all landraces. The STI and MFV values vary widely between genotypes for all traits.

Table 1. Salt tolerance evaluation of Average MFV and Y value of two genotypes from each salt tolerance grades

Genotypes	STISL	STIRL	STISFW	STISDW	STIRFW	STIRDW	STITFW	STITDW	STIWC	STISES	AVGMFV	Y	Diff
Pokkali	0.75	0.96	0.81	0.82	0.56	0.88	0.70	0.83	0.94	8.50	0.86(HT)	0.86	0.00
A. kuruvai	0.78	0.85	0.83	0.83	0.44	0.90	0.66	0.84	0.92	6.20	0.78(HT)	0.78	0.00
Sarapillai	0.81	0.85	0.57	0.50	0.60	0.73	0.58	0.59	1.00	6.80	0.68(T)	0.68	0.00
Manavari	0.70	0.76	0.64	0.63	0.58	0.71	0.61	0.65	0.98	6.20	0.67(T)	0.67	0.00
Poongar	0.67	0.74	0.53	0.44	0.55	0.69	0.54	0.48	1.04	5.00	0.56(MT)	0.56	0.00
Senthooram	0.51	0.45	0.55	0.31	0.29	0.53	0.42	0.35	1.04	2.80	0.30(MT)	0.30	0.00
Kavuni	0.62	0.55	0.41	0.32	0.30	0.60	0.35	0.37	0.99	2.00	0.27(S)	0.27	0.00
IR29	0.47	0.44	0.43	0.39	0.30	0.21	0.37	0.34	1.02	2.83	0.22(S)	0.22	0.00

SL- shoot length, RL-Root Length; SFW-Shoot Fresh Weight, RFW-Root Fresh Weight, RDW-Root Dry Weight, TFW-Total Fresh Weight, TDW- Total Dry Weight, WC- Water content, SES- Standard Evaluation Fees

The average MFV which indicates comprehensive tolerance ranged from 0.21(IR29) to 0.86 (Pokkali). Based on Chen et al (2012) salt tolerance grading, the 31 genotypes and 2 checks were classified into four categories *viz.,* Highly tolerant (3), Tolerant (2), moderately tolerant (24), and susceptible (4). Based on multiple regression, a quantitative evaluation model was established using unstandardized coefficients and STI. The reliability of the quantitative evaluation model for predicting the salt tolerance of rice germplasms were assessed by calculating Y values and comparing it with average MFV. The Y values and average MFV of random 3 landraces from each salt tolerant grades were given in table 1. The average difference between Y and the average MFV is 0.0001. This indicates the mathematical model can be used to predict the salt tolerance of rice germplasms.

CONCLUSION

The identified highly tolerant genotypes (Pokkali, A. kuruvai and Varakkal) and tolerant (sarapillai and manavari) landraces can be used in breeding programmes for improving seedling stage salt tolerance in rice. Further, this mathematical model is a reliable method for evaluating rice landraces for salt tolerance.

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Rooting and physiological traits of rice genotypes under contrasting water regimes and biofertilizer

Shahana Begum[1] and Shalini Pillai P.[2]

[1,2]*College of agriculture, Vellayani, Kerala Agricultural University, Thiruvananthapuram, Kerala – 695522, India*

Rice is the most important cereal crop in the world but requires an enormous quantity of water for its production. Conventional cultivation of rice requires special operations like nursery establishment, pudding, transplanting, *etc*. which makes it labor-intensive. Under present scenario, where climate change has adversely affected the rainfall distribution leading to water shortage, shifting from conventional to alternate water-saving rice production technologies like aerobic rice system and saturated irrigation of rice holds great significance. In aerobic rice production system, rice is directly seeded in non-puddled and non-saturated soil with fertilizer application and supplemental irrigation during insufficient rainfall (Bouman et al., 2006). The role of biofertilizer *Azospirillum lipoferum* in promoting plant growth is well established. Thus, this study was undertaken to compare the characteristics of rice genotypes under contrasting water regimes with the inoculation of *A. lipoferum*.

METHODOLOGY

During summer 2021, the seeds of 3 rice genotypes *viz*., Prathyasa (MO 21), KAU Manu Rathna (HS 16) and Sharada (MAS 946-1) were dibbled in the PVC tubes of 8" diameter and subjected to 3 different water regimes, W_1-flooded condition (5 cm standing water), W_2-saturated condition (irrigating to 1 cm depth one day after the disappearance of standing water column) and W_3-aerobic condition (irrigation to obtain 2.5 cm depth of irrigation and subsequent irrigation once in five days), with and without *A. lipoferum*. The rooting traits at harvest and physiological parameters at panicle initiation stage were recorded.

RESULT

The genotype, Sharada recorded significantly higher root traits *viz*., rooting depth, root dry weight, root volume, root: shoot and physiological parameters *viz*., root oxidizing activity (ROA), relative water content (RWC), proline accumulation, total soluble protein (TSP), membrane stability index (MSI) and chlorophyll stability index (CSI) while number of crown roots, stomatal frequency (SF), stomatal conductance (SC) and transpiration rate (TR) were significantly reduced under Sharada. Among the water regimes, aerobic condition significantly increased the rooting depth, root dry weight, root volume, root : shoot, ROA and proline accumulation while the number of crown roots, root density, nitrate reductase activity (NRA), chlorophyll content, RWC, TSP, SF, SC, TR, MSI and CSI were greatly reduced as compared to flooded condition. The root density, NRA, chlorophyll content and CSI under flooded and saturated conditions were comparable. Further, the RWC and MSI under saturated and aerobic conditions were at par. Inoculation with *A. lipoferum* significantly increased the rooting depth, root dry weight, root volume and root: shoot ratio. Sharada recorded an increment in the grain yield by 8.36% over Prathyasa and 11.87% over KAU Manu Rathna. Saturated and aerobic condition resulted in 12.65% and 16.98% yield reduction over flooded rice, respectively.

CONCLUSION

The increased rooting traits are critically associated with aerobic adaptation and inoculation with *A. lipoferum*. The genotype, Sharada performed better under aerobic condition with respect to rooting and physiological traits and produced higher yield. Since the yield reduction was only about 12-17%, under water deficit situation, saturated and aerobic rice production can be considered as an alternate system over flooded rice cultivation based on the severity of water shortage.

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Bound phenolic acids profile and antioxidant activity of pigmented and non-pigmented rice

Gosangi Avinash, Neerja Sharma & Rupinder Kaur

Department of Biochemistry, Punjab Agricultural University,141004, India

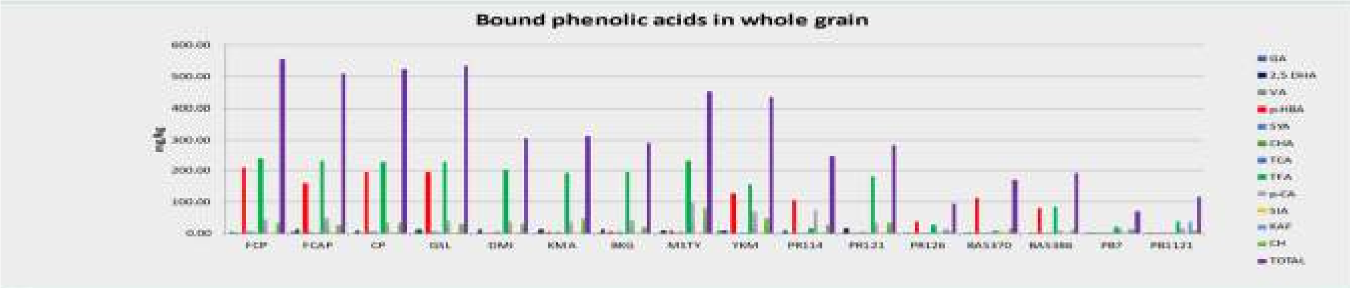
Rice (*Oryza sativa* L.) is an essential cereal crop consumed by millions of people both as a staple food as well as processed products. Recently, pigmented rice varieties have received increased attention from consumers for their high bioactive compounds, presenting antioxidant, anti-inflammatory, and other health benefits. Pigmented rice is characterized by having red, black, or dark purple color in its aleurone layer due to the presence of flavonoids especially anthocyanins and proanthocyanidins located mostly in the aleurone layers of rice kernels are especially a mixture of anthocyanin compounds that belong to the family of flavonoids.The distribution of phenolic acids exhibits varietal differences and predominantly exist in insoluble bound form.Two groups of phenolic acids are present in rice grain *viz*., derivatives of hydroxybenzoic acids (gallic acid; GA, 2,5-dihydroxybenzoic acid; 2,5-DHA, *p*-hydroxybenzoic acid; *p*-HA, vanillic acid; VA, syringic acid; SYA, *p*-coumaric acid; *p*-CA), and derivates of hydroxycinnamic acids (chlorogenic acid; CHA, *trans*-cinnamic acid; *trans*-CA, *trans*-ferulic acid; *trans*-FA, *p*-coumaric acid; *p*-CA, and sinapic acid; SIA), and flavonoids such as Kaempferol; KAM, (±) Catechin hydrate; CH.The objectives of the present investigation were (1) to identify and quantify the bound phenolic acids present in pigmented and non-pigmented rices and (2) to determine the total bound phenolic content and its antioxidant activities in pigmented and non-pigmented rice.

MATERIALS AND METHODS

The phenolic acid content was analyzed by an HPLC system that consisted of a binary pump (Waters 2695), an autosampler (Waters 2707), and a PDA detector (Waters W2998). A C18 column of dimensions 250 mm ×4.6 mm with 5 µm pore size (XBridge, Waters) was used for separation. The mobile phase consisted of A (87:3:10 Water: ACN: Formic acid) and B (40:50:1 Water: ACN: Formic acid). The flow rate was 1 mL/min. A 33 min gradient was set according to the method of Shao et al. (2014a) with few modifications. The injection volume was 10 µL. The phenolic acids were detected at wavelengths of 280nm and quantified using the external calibration curves according to the retention time of phenolic acid standards. Free phenolics were extracted according to the method of Shao et al. (2014a). The solid residue after the extraction of free phenolics was washed with distilled water and then digested with 4 M NaOH (20 mL) at room temperature on a shaker for 2 h. The mixture was then adjusted to pH 1.5-2.0 with concentrated HCl and extracted thrice with 60 mL of ethyl acetate. The combined ethyl acetate fractions were concentrated and dissolved in 5 mL of 50% methanol. The extracts were used as bound phenolic extracts for quantification of phenolic acids, antioxidant activity.

RESULTS AND DISCUSSION

Trans-FA was the major phenolic acid detected in black, red, and NP rice genotypes with its content ranging from 229.06-239.35; 169.8-230.4; and 10.6-182.38 mg/kg, respectively. The content of *p*-CA in black, red, and NP rice genotypes varied from 35.21-49.65; 38.49-98.44; and 5.77-75.54 mg/kg, respectively.GA could not be detected in NP rice genotype Basmati 386 while 2,5-DHA could not be detected in red rice genotype DMI and NP rice



Gallic acid; (GA), 2,5 -dihydroxybenzoic acid; (2,5 -DHA), *p*-hydroxybenzoic acid; (*p*-HA),vanillic acid; (VA), syringic acid; (SYA), *p*-coumaric acid; (*p*-CA), (chlorogenic acid; (CHA), *trans*-cinnamic acid; (*trans*-CA), *trans*-ferulic acid; *trans*-FA, *p*-coumaric acid; (*p*-CA), and sinapic acid; (SIA), and flavonoids such as Kaempferol; (KAM), (±) Catechin hydrate; (CH)

genotypes Basmati 370, Punjab Basmati 7, and Basmati 386.We detected less amount of VA compared to most of the earlier reports. The differences may be due to the prevailing environmental conditions. Its content was found in the range of 0.2-6.09; 0.34 - 5.89; and 0.29 - 5.3 mg/kg, in black, red, and NP rice genotypes, respectively. The significant content of SYA existed inblack, red, and white rice genotypes with its content ranging from 18.81-261.and 0.75-156.6; and 2.95-182.39 mg/kg, respectively. CHA existed in considerable amounts in black rice genotypes (1.21-7.73 mg/kg). KAFexisted in significant amount in NP genotypes (0.53-156.82 mg/kg).A considerable amount of CH existed in black, red, and white rice genotypes with their content ranging from 26.35 - 35.73;4.21.94-82.29; 6.07-33.68 mg/kg, respectively.Significant TPC was present in the black rice genotype FCAP (436 mg GAE/100g), red rice genotype KMA (439 mg GAE/100g),and non-pigmented rice PB1121 (120 mg GAE/ 100g.)Among the three colour groups red rice YKM, black rice FCP, and NPrice genotype PR114 displayed higher DPPH activity of 79.98%, 75.14%, and 70.98% respectively. Black rice genotype CP, red rice genotype BKG,and NP rice genotype PR126,displayed significant ABTS activity of 12, 3.1, and 2.2 µM TEAC/g respectively.

CONCLUSION

This study quantified individual phenolic acids using HPLC, present in the bound form in the whole grain of 16 rice genotypes possessing three different bran colours, along with bound phenolic content and antioxidant capacity. *trans*-ferulic acid was found to be the predominant phenolic acid in both pigmented and non-pigmented (NP) rice. In black rice genotypes, the content of *p*-hydroxybenzoic acid was found to be significantly higher compared to red and NP rice genotypes. The highest antioxidant activities were observed in black, The main bound phenolic acids present in pigmented rice genotypes were *p*-hydroxybenzoic acid, *p*-CA, and *trans*-ferulic acid while *p*-HA and*trans*-ferulic acid were present in NP rices. In both pigmented and NP rice genotypes 2,5-DHAwas also detected in bound form.It is noteworthy that the presence of 2,5-DHA has been rarely reported in rice grains.

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ARRW/SIRC/Theme I/29

Phenotypic characterization and molecular screening of *OsPSTOL1* introgressed rice lines

Kiruba G[1], N Aananthi[2], S Vellaikumar[3], S Thiyageshwari[4] and J Ramalingam[2*]

[1]*Department of Genetics and Plant Breeding, CPBG, TNAU, Coimbatore 641 003, Tamil Nadu, India.*
[2]*Dept. of Genetics and Plant Breeding, AC&RI, Madurai 625 104*
[3]*Dept. of Plant Biotechnology, CPMB&B, TNAU, Coimbatore 641 003*
[4]*Dept. of Soils Science and Agricultural Chemistry, TNAU, Coimbatore 641 003*
Email: kirubaganesan111@gmail.com

Rice (*Oryza sativa L.*), the most dynamic crop and holds a unique position among cereals, serves as the staple food for the world population. Among the abiotic and biotic stresses, Phosphorus deficiency are of primary importance in southern India and phosphorus (P) one of the important macronutrients required for normal growth and development of all crop plants. Rice is very sensitive to P starvation as most cultivated genotypes have poor tolerance levels to P deficiency and consequently the grain yield is severely affected by starvation (Chithrameenal *et al* 2018). About 50% of the rice fields are experiencing a deficiency of P in Asia requiring many applications of P fertilizer to produce the desired yields. However, P fertilizer harms the environment and is already beyond of reach for small-scale farmers. This justifies creating rice varieties that are P-efficient and use less P to achieve the desired yield (Prodhan *et al* 2022). Hence it is essential to determine phosphorus deficiency tolerance in rice.

MATERIALS AND METHODS

The experimental material consists of thirty-three advanced backcross lines (derived from parents ASD16/ADT43 which are pyramided with bacterial blight and blast resistance genes and IR64 containing *Pup1* gene). These lines along with parents were raised in Randomized Block Design with two replications under phosphorus sufficient and deficient conditions. The molecular screening was carried out to identify the plants with *OsPSTOL1* gene using the functional markers, K29-3 (co- dominant) and K46-1 (dominant). The genotypes were also screened for bacterial blight and blast resistance genes using functional markers. Introgressed lines were evaluated for various morphological traits including shoot and grain phosphorus content.

RESULTS

The experimental results revealed that growth and yield parameters were higher in +P condition than in –P situation in field level (Fig 1). Molecular screening shows all genotypes carrying *OsPSTOL1* gene and bacterial blight and blast resistance genes. There were significant differences in DFF, PH, PL, NFP, 100 GW and GY for the introgressed population between the 2 conditions, whereas there were no significant differences in NT, NPT, SP and GP. This result indicted that DFF, PH, PL, NFP, 100 GW and GY were more easily influenced by phosphorus deficiency than NT, NPT, SP and GP. Under phosphorus sufficient condition, high GCV and PCV were observed for the traits viz., height of plant, shoot P content, grain P content and grain yield. In P shortage situation, plant height alone showed high variability and this indicates that there was adequate scope for selection based upon these characters. Higher heritability and high genetic advance were observed for the traits *viz.*, plant height, number of productive tillers and number of filled grains per panicle, 100 grain weight, shoot phosphorus content and grain yield in P sufficient conditions. Under –P regimes, except shoot phosphorus and grain phosphorus content exhibits low heritability

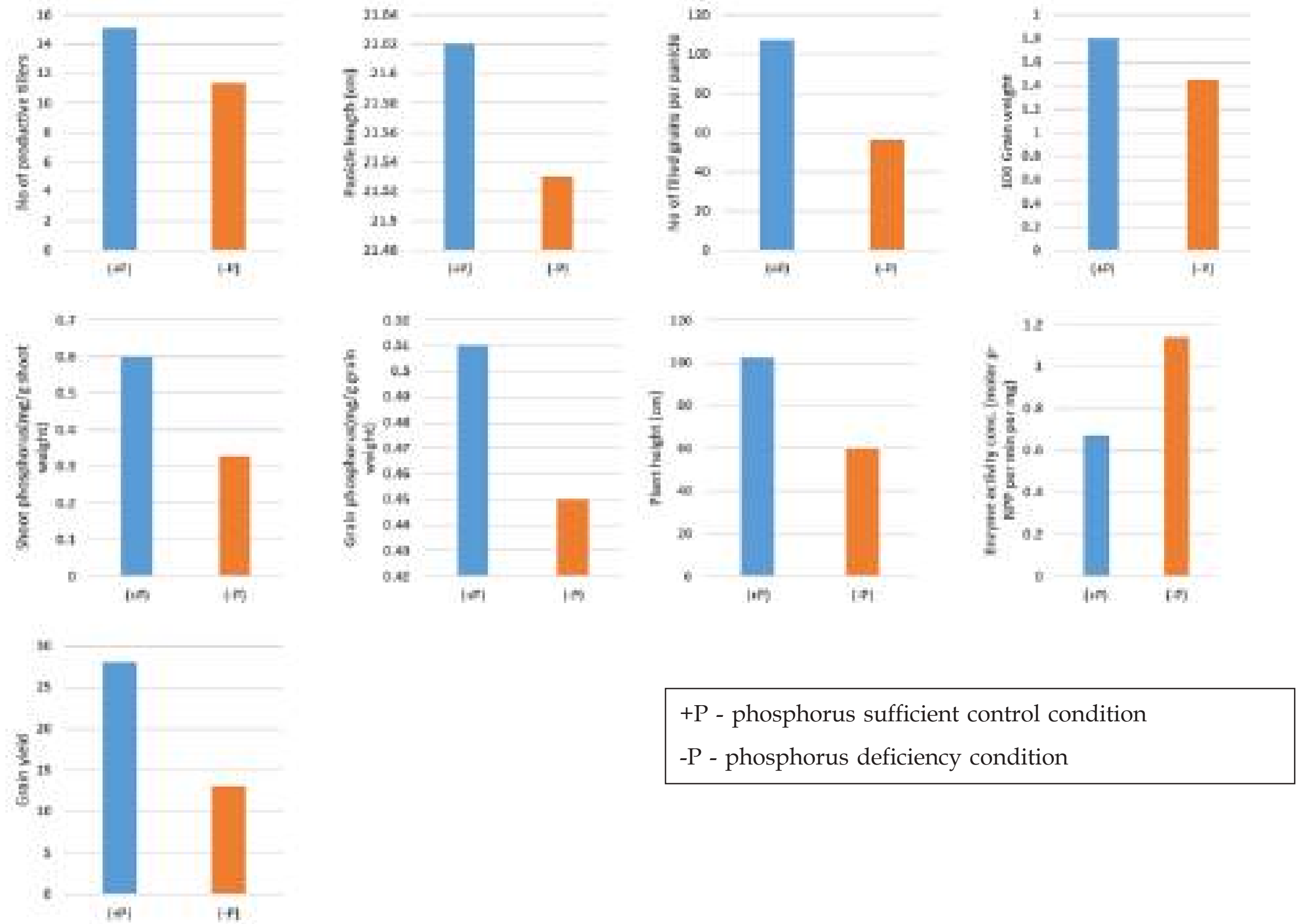

Fig. 1. Changes in parameters of rice genotypes grown under P and - P conditions

and genetic advance, indicates lesser influence of environment in expression of these characters and these characters are controlled by the additive gene effect. In both +P and -P conditions, positively significant correlation was found in 100 grain weight, productive tillers and filled grains per panicle with yield of the plant and the direct effect of hundred grain weight on grain yield was higher. The lines IL2, IL10, IL11, IL16, IL28, IL31, IL39, IL62-2, IL62-4, IL63, IL66, IL70, IL 85 and IL92 were significantly superior to that of parent in grain P content under phosphorus deficient condition.

CONCLUSION

The lines IL2, IL7, IL11, IL16, IL28, IL52, IL62-2, IL62-4, IL63, IL69 were promising under both the field and hydroponics conditions as they have good root and shoot characters, high P content in root, shoot and grain coupled with good yield. Hence these lines may be exploited as pre breeding line for further breeding work or can be tested under multilocation trial for stable performance.

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Early germination stage morphometric evaluation of rice genotypes (*Oryza sativa* L.) for moisture stress tolerance

Pravin Kumar. K[1*], R. Pushpam[1], S. Manonmani[1], M. Raveendran[2] and A. Senthil[3]

[1]*Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore, 641003*
[2]*Directorate of Research, Tamil Nadu Agricultural University, Coimbatore, 641003.*
[3]*Directorate of Crop Management, Tamil Nadu Agricultural University, Coimbatore, 641003*
[*]*Email : pravinagri378@gmail.com*

Rice (Oryza sativa L.) is one of the major staple food of over a billion population in the world. In a climate-changing scenario, abiotic stresses are the prime limiting factors in crop productivity. In India, 42 mha area is affected by drought stress gradually yields a loss of up to 12-30 %. Cultivable lands facing water deficit conditions, recognize the potential genotypes that are tolerant to drought stress with minimum yield loss (Valarmathi *et al.*, 2019). The aim of this study is to assess the rice genotypes based on varying osmotic potential levels through effective screening techniques, which in the future may be helpful for selecting rice genotypes with better performance to varying degrees of drought.

METHODOLOGY

To evaluate 35 rice genotypes for drought tolerance during the germination stage, the genotypes were tested against four levels of drought stress imposed by Polyethylene glycol 6000 (PEG-6000) @ 0, -4 bar, -6 bar, and -8 bar. The experiment was laid out in a completely randomized design with two replications. Healthy seeds of 35 genotypes were initially checked for their viability, treated with 5% NaOCl solution (10%) for 5 min, rinsed with distilled water, and then air dried for 1h before sowing. Ten sterilized seeds of each genotype were sown in each Petri-plates and subjected to 12 mL of -4 bar, -6 bar, and -8 bar PEG-6000 solution for osmotic stress and distilled deionized water for control under laboratory conditions. Each Petri plate containing ten seeds was incubated in the darkness (30°C) at 60% relative humidity. Observations *viz.,* Root Length, Shoot Length, Root: Shoot ratio, and Vigor Index were recorded on 14th days after sowing. Mean data were subjected to DMRT analysis using R software.

RESULTS

Thirty-five genotypes were screened with different osmotic potentials at early germination stage. Almost all the genotypes withstand -4 bars of osmotic stress. In contrast, in -6 bars and -8 bars, only 7 genotypes have germinated and a drastic reduction in the growth of shoot and root was observed. The significant difference was shown based on the mean value followed by different letters (a,b,c) in each column between different PEG-6000 MW (Table 1). A significant difference was found among moisture stress of -4 bars and -6 bars, whereas there was no significant difference among -6 bars and -8 bars. Hence, -6 bars can be considered as an optimum concentration for screening of rice genotypes.

Genotypes with a high R/S ratio under moisture stress are much preferred. High R/S has been reported as a component trait for drought avoidance. Based on the root-shoot ratio genotype

Table 1. Mean comparison of different drought stress levels using Duncan's multiple range test (DMRT)

Treatment	Germination percentage	Root length	Shoot length	Root/ Shoot ratio	Seedling Vigor
Control	99.04 a	7.88 a	6.13 a	3.28 a	1384.62 a
- 4 bar	63.70 b	7.42 a	3.02 b	1.31 b	684.88 b
- 6 bar	12.45 c	0.69 b	0.314 c	0.511 c	59.08 c
- 8 bar	10.77 c	0.44 b	0.299 c	0.44 c	34.06 c

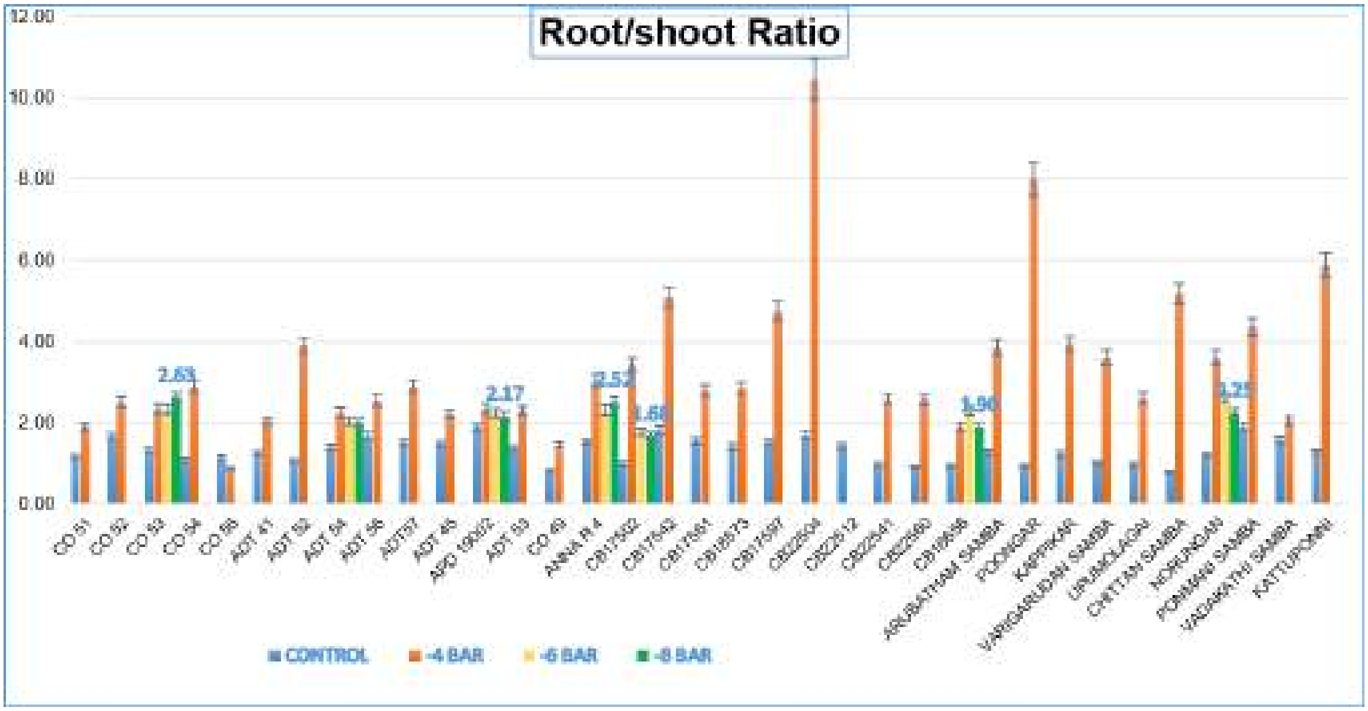

Fig 1. Mean performance of different drought stress levels of rice genotypes based on the root-shoot ratio

CO 53 followed by Anna (R) 4, Norungan, APD19002, ADT 54, CB 16656, and CB17502 (Fig 1.) proved their tolerant performance in stress condition.

CONCLUSION

The tolerant genotypes with better source-sink relationship, can be used as a potential donor candidate towards genetic improvement of drought tolerance in rice.

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Generating genomic resources for the wild relatives of rice – a treasure trove to transform rice research for sustained yield in the changing climate scenario.

Parimalan Rangan[1,*] and Kanakasabapathi Pradheep[2]

[1]*ICAR-National Bureau of Plant Genetic Resources, PUSA Campus, New Delhi-110012, India*
[2]*ICAR-National Bureau of Plant Genetic Resources-Regional Station, Thrissur-680656, India*

INTRODUCTION AND OBJECTIVES

Rice – Asian rice (*Oryza sativa*) and African rice (*O. glaberrima*) – is domesticated for cultivation around ten thousand years ago and has an important role in human civilization. Nearly half of the global population meet out their energy requirements through rice consumption. Rice domestication events had led to the development of the present-day high yielding cultivars carrying key domestication traits. On the parallel but converse, the genetic base has been considerably narrowed to an extent the rice cultivars are prone to various biotic and abiotic stress factors, in addition to erratic climate patterns resulting in significant yield loss. Domestication events are associatively one-way process and less probable

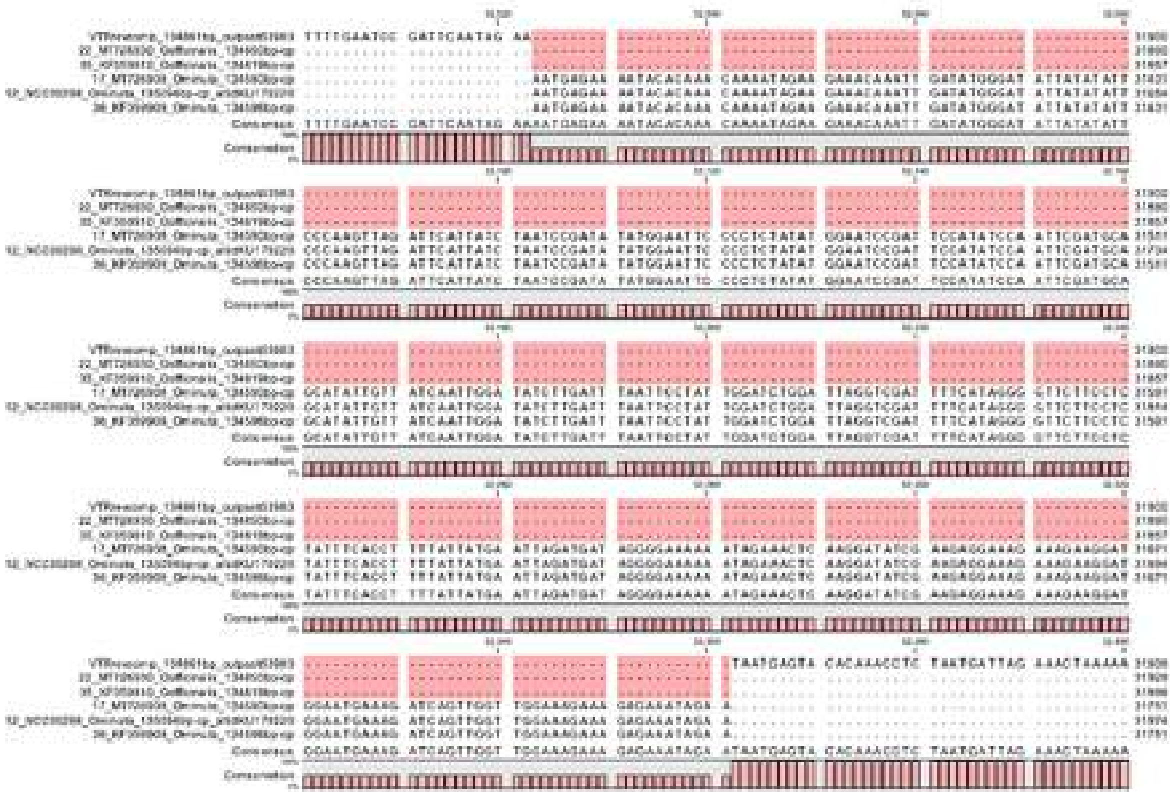

Fig. 1: Sequence alignment regions of the chloroplast genome sequence distinguishing the *Oryza officinalis* accession collected from the Valmiki Tiger reserve, Bihar from the publicly available *O. minuta* accessions with a continuous 339 bp deletion (highlighted) in all three *O. officinalis* when compared to three *O. minuta*.

to reverse the domestication events to our desire. Wild relatives of the domesticated rice play a key role in being the source of tolerance and resilience traits that would potentially address the key agricultural challenges, besides broadening the genetic base that were narrowed down during domestication events. Comparative genomics and physical mapping strategies are the major paths to identify the genes underlying tolerance and resilience traits in the wild relatives. With next generation sequencing technologies, generation of genome-scale information with special focus to wild relatives is advantageous in identification and isolation of genetic principles associated with the desirable traits. Long-grained rice being native to India, generating genomic resources for the augmented wild rice germplasm were prioritized.

METHODOLOGY

Short read data for the wild rice, *Oryza officinalis* (collected from the Valmiki Tiger Reserve area), were subjected to chloroplast assembly using GetOrganelle software tool. Hence obtained single contig circular assembly was used to analyze and establish the distinctness between *O. officinalis* and *O. minuta* at chloroplast genome level.

RESULTS AND CONCLUSION:

Here, we report the chloroplast genome assembly generated for the wild rice (*Oryza officinalis*) accession collected from the Valmiki Tiger Reserve, West Champaran Dt., Bihar using the short-read data generated using Illumina-based NGS platform. This is compared with the available *O. officinalis* and *O. minuta* chloroplast genome and established its distinctness between the two taxa (Fig. 1). These organelle genome sequences are much informative in establishing or fine-tuning the species relationships in *Oryza* genus, especially the *officinalis* complex taxa.

Bivariate analysis in for yield component traits in Rice (*Oryza sativa* L.)

V. Sumithra, K. Palaniraja and S. Vennila

Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, 641 003, India.

About 6.73 million ha productive area is constituted by salty lands for the entire country, while in Tamil Nadu 13 thousand ha area is covered by coastal salinity (CSSRI, Karnal). Therefore, the major focus of rice research in the next decade must be the development of high-yielding and early maturing varieties in order to ensure food scarcity and efficient use of natural resources. Development of salt tolerant varieties considered to be practical solution to overcome the problem of salinity. Parents with high *per se* performance is very much essential for the development of hybrids or varieties by combining the desirable characters of parents involved in hybridization. Hence, the selection of parents is the pre-requisite for further breeding program (Kabir *et al.*, 2015). However, the traits that are in positive association with grain yield per plant, were the major contributors to the grain yield.

MATERIALS AND METHODS

Ten genotypes, based on genetic diversity analysis were selected as parents for hybridization programme. These parents were crossed in line x tester mating design, out of which seven varieties were taken as lines (ADT 43, ASD 16, ADT 48, MTU 1010, IR 20, CO 51 and CO 49) and three well adopted varieties as testers (TRY 3, ADT 36 and CO 43). Crosses were made between seven female and three male parents in line x tester design by adopting hand emasculation and desired artificial pollination. The experimental materials consisted of twenty-one hybrids with their ten parents were transplanted in rows with spacing of 30 cm between rows and 20 cm between plants during October 2018 – January 2019.

RESULT

The present study was carried out to assess the breeding potentiality of seven lines and three testers through Line x Tester analysis in rice (*Oryza sativa* L.). The parents include, ADT 43, ASD 16, ADT 48, MTU 1010, IR 20, CO 51 and CO 49 and the testers includes TRY 3, ADT 36 and CO 43.

Based on the per se performance of different traits of the parents, ADT 48, ADT 43, CO 51 and CO 49 among the lines and among the

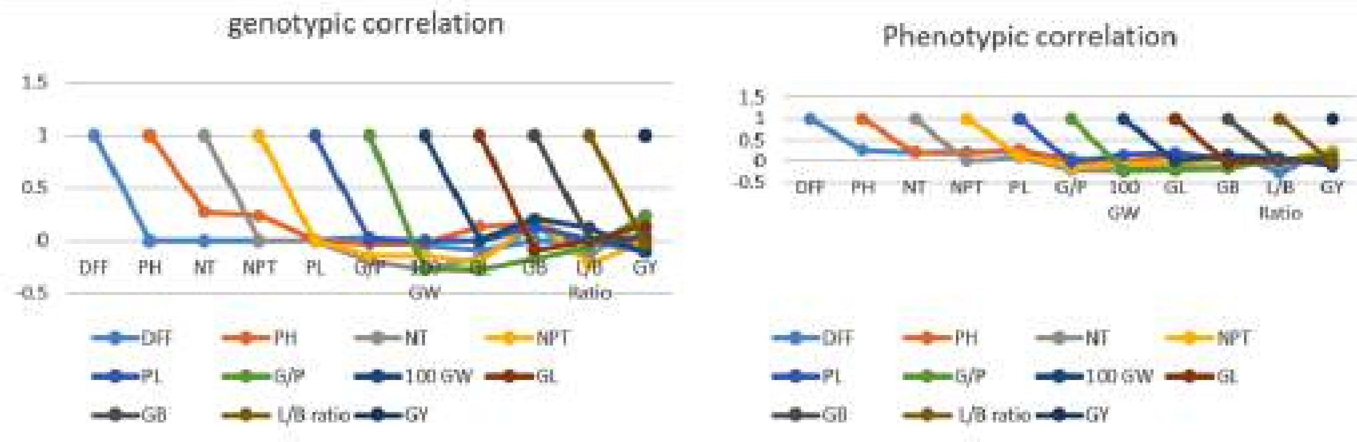

Fig 1. Genotypic and phenotypic correlation among various characters in rice genotypes

testers, ADT 36 and TRY 3 were found to be the best performers for grain yield and its component traits. Correlation studies revealed that number of tillers/plant, 100 grain weight and grain length registered, positive correlation with grain yield per plant.

CONCLUSION

Apart from the values of gca and sca, high mean values for grain yield and yield contributing traits are the pre-requisite for selection of parents for further hybridization program. Based on the results, these parents showing best performance with significant mean values for grain yield and most of the other yield attributing characters. Hence, the superiority of hybrids can be attained from combination of these parents in which both the parents of a cross had higher mean values when compared to others for most of the traits studied. And also, the positive association of traits with the dependent character grain yield contributes more for the increased grain yield per plant.

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Wild introgression lines from *Oryza nivara* as donors for seedling vigour related QTLs

Magudeeswari P, Divya Balakrishnan*, Pranay G, Krishnam Raju A, Sai Theja D, Senguttuvel P, Sarla N, LV SubbaRao

ICAR-Indian Institute of Rice Research, Hyderabad-500030, Telangana, India
**Email : dbiirr23@gmail.com*

Seedling vigour is an important trait in direct-seeded rice and has a direct impact on rice productivity. Vigorous plants will have the advantage of germination under adverse climatic conditions, weed competitive and uniform growth. Wild introgression lines are important genetic stocks that have been utilized in the past for biotic and abiotic stress tolerance/ resistance in rice. Although wild species are known for better seedling vigour and growth, studies in this direction are limited. Wild introgression lines from *Oryza nivara* was used for evaluation for seedling vigour and related QTLs.

MATERIALS AND METHODS

A set of 90 advanced backcross introgression lines derived from a cross between indica rice variety Swarna (*Oryza sativa*) with wild introgression line *O. nivara* (IRGC81832) (Balkrishnan *et al.,* 2020) were used for studying the seedling vigour traits at BC_2F_{10} stage. The study was carried out at the Indian Institute of Rice Research (IIRR), Hyderabad on freshly harvested rice seeds. Fifty matured seeds each were used for evaluating seedling vigour related traits (Addanki *et al.,* 2019). QTL analysis was conducted using QTL IciMapping v4.2 (www.isbreeding.net) in a stepwise regression model.

RESULTS

Significant phenotypic variation was observed for seedling vigour traits. Seedling vigour index1 observed a positive significant correlation with germination percentage, seedling vigour index 2, root length, shoot length, total fresh weight, shoot fresh weight. Seed vigour index 2 observed a positive significant association with shoot dry weight, root dry weight, total dry weight and germination percentage. Based on the QTL mapping study, 10 QTLs were detected for seedling vigour traits on chromosomes 3,6,7 and 8. Among the identified QTLs eight QTLs were reported with LOD score >3 and explaining the phenotypic variation (PV) ranging from 7.92 % to 26.38%. *qSDW3.1*, *qTDW3.1* and *qSVI2-3.1* are the major QTLs for shoot dry weight, total dry weight and seedling vigour index2 explaining 24.71%, 26.38% and 26.38% of PV respectively. The major QTL for seedling vigour index1 *qSVI1-6.1* explained 19.68% of PV. There were two chromosomal regions (chromosome 3 and 6) reported for more than two QTLs co located for different seedling vigour traits. Additive effects showed the favourable allele for shoot dry weight, total dry weight, root dry weight, plant length, shoot length, total length were contributed by the donor parent *O.nivara*. It indicates the effective use of wild introgression lines for seedling vigour studies

CONCLUSION

A significant variation was observed for different morphological traits associated with seedling vigour. The QTL mapping studies identified eight major QTLs for different seedling vigour associated traits and explained the presence of additive effect. For all the QTLs the trait enhancing allele for all the traits are derived from wild species *O.nivara*. It indicates that the introgression of QTLs/genes from *O.nivara* into the elite genetic background will be beneficial in improving the seedling vigour traits in rice.

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Assessment of drought tolerance in rice landraces (*Oryza sativa* L.) at the early seedling stage

Santhiya S*, Subramanian A, Pushpam R, John Joel A, Senthil A and Manonmani S

Tamil Nadu Agricultural University, Coimbatore – 641003
**E.Mail: santhiyamullaiventhan@gmail.com*

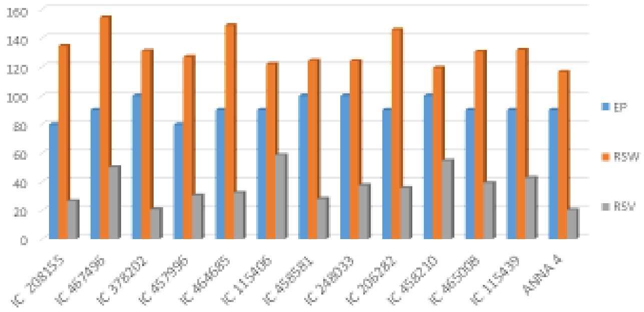
Rice is the staple food for more than half of the world's population. Rice production is often constrained by several abiotic and biotic stresses. Drought is one of the most important limiting factor for agricultural productivity and has a negative impact on global food security. Drought is the major abiotic stress which will affect 50% of the arable land across the globe by 2050. In many Asian countries, the production of rice drastically decreases every year due to drought stress. Yield loss mainly depends on the stage, duration and severity of drought. Germination and early seedling growth are considered one of the most critical stages that are drastically affected by drought stress. Among the low molecular osmotica, PEG mimics a way that is similar to the soil under moisture stress situations. Hence, it can be used to select drought tolerant genotypes at the early seedling stage under in vitro conditions. In this context, the present study was formulated to characterize the relative performance of rice landraces based on germination and seedling characteristics under in vitro conditions using polyethylene glycol and also to identify the landraces with better drought response.

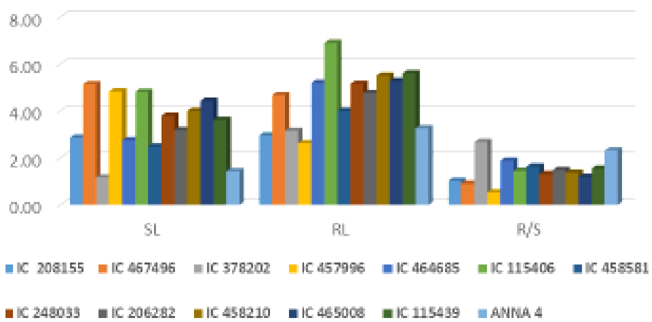
METHODOLOGY

Standardization of PEG concentration was carried out using two drought tolerant entries (ANNA R4 and CO 53) and five drought susceptible entries (IR 64, Swarna, Jaya, Pusa 44 and P-1850). Distilled water was used as control (0 bars) and osmotic potentials -1 to -10 bars were created. Twelve rice landraces were screened for drought tolerance at the early seedling stage under CRD with two replications for both control and drought (-7 bars). Seeds were surface sterilized using 1% sodium hypochlorite for five minutes. The seeds were washed three times with sterile distilled water. Ten seeds were evenly distributed in a sterile petri dish. Observations like emergence percentage, shoot length, root length, root-to-shoot ratio, seedling fresh weight, seedling dry weight, relative seedling height, relative seedling vigor and relative seedling weight were taken on the 14th day. The data were collected and subjected to analysis of variance and DMRT using R software.

RESULTS

Based on the performance of drought tolerant entries (ANNA R4 and CO 53) at different concentrations of moisture stress, -7 bars were fixed as the optimum concentration for screening of accessions. The mean performance of accessions for germination and seedling characters at -7 bar was presented in Fig.1. Emergence percentage was considered as a criterion for selecting better performing accessions in terms of drought tolerance as it might reflect the potentiality of the crop at remaining growth stages. Four accessions *i.e.,* IC 378202, IC 458581, IC 248033 and IC 458210 recorded 100% emergence, similar to control. Similar findings were obtained by Manonmani *et al* (2020). Relative seedling weight varies with seedling length and number of roots. Almost all the accessions had higher seedling weight than ANNA R4 with the highest in IC 467496, followed by IC 464685 and IC 206282. Genotypes with high initial seedling weight might possess high biomass and it may tend to have a higher value for most of the yield-attributing characters. Relative seedling vigor was high for accessions *viz.,* IC 467496, IC 115406 and IC 458210.





EP - emergence percentage, RSW - relative seedling weight, RSV - relative seedling vigor, SL -shoot length, RL - root length and R/S - root-to-shoot ratio

Fig.1. Mean performance of accessions for germination and seedling characters at -7 Bar

Initial root length can be considered a good selection criterion for identifying accessions with altered drought response at early seedling stage. Nearly 75% of the accessions had higher root length than ANNA R4. High root length was found in IC 115406, IC 458210 and IC 115439 which could help the plants to absorb water from deeper layers of soil and can help the plants to survive under moisture stress. The root to shoot ratio was high for IC 378202 when compared with ANNA R4, followed by IC 464685 and IC 458581. Accessions with a high root to shoot ratio under moisture stress are preferred in selecting drought tolerant accessions.

CONCLUSION

Selection of accessions with altered drought response based on emergence percentage, root length, seedling vigor and seedling weight will be highly effective. Thus, accessions *viz.*, IC 464685 and IC 458210 recorded the highest value for all these characters than ANNA R4. Hence, these accessions could be further evaluated under natural drought stress conditions for further reliable and accurate results.

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ARRW/SIRC/Theme I/36

Marker Assisted Introgression of QTL's tolerance to drought and salinity in rice (*Oryza sativa L.*)

Pushpam R*, Nanditha R S, Raveendran M, Geetha S and Manonmani S

Tamil Nadu Agricultural University, Coimbatore – 641003
**E.Mail: pushpamtnau@gmail.com*

Rice is a major staple food crop among Asian countries being widely cultivated in different ecological conditions across the world. It is the second-most widely grown cereal crop in the world next to wheat and serves more than 60-70% of the energy source for the human diet making a vast majority of nations rely more heavily on rice for their daily diets. Rice had always been particularly vulnerable to biotic and abiotic stress conditions, which leads to a crop loss of more than 50%. Drought and salinity have a detrimental effect on rice production and pose a significant risk to food security. Drought solely seems to have an impact on more than 50% of the world's rice cultivating area and induces critical losses in crop yield. It is expected to cause a yield loss of about 90% when occurred at critical stages of crop growth such as grain filling and reproductive stages. Salinity particularly impacts the cultivation of rice and has a significant negative impact on rice grain yield, leading to a decrease in the total grain yield production of about 45%. With the recent advancement in the utility of a marker system, incorporation of the discovered significant chromosomal genomic regions (QTLs) underlying drought and salinity into contemporary high-yielding popular varieties through MABC lead to breakthroughs toward breeding climate-adaptive cultivars (Muthu *et al.*, 2020). With this background, the current study was initiated for developing drought and salinity tolerant version of popular rice cultivar of Tamil Nadu namely CO 52 by introgressing the QTLs *viz.*, $qDTY_{1.1}$, $qDTY_{2.1}$ and *Saltol*.

METHODOLOGY

The present study was undertaken to develop drought and salinity tolerant version of a popular high yielding medium duration variety of Tamil Nadu *viz.*, CO 52 through Marker assisted backcross breeding approach. In the recurrent parent CO 52, three QTLs *viz.*, $qDTY_{1.1}$, $qDTY_{2.1}$ (drought) and *Saltol* (salinity) were introgressed from the backcrossed inbred line 3-11-11-2. F_1s were developed and the true F_1's identified using trait linked SSR markers were further backcrossed to CO 52 (Recurrent parent) to obtain BC_1F_1. Total of 62 BC_1F_1 plants were raised during *Kharif* 2021.

Table 1. FGS in BC_1F_1 plants

Sl No.	QTLs	Tolerance	Total number of BC_1F_1 plants screened	Number of positive plants
Three QTLs				
1	$qDTY_{1.1}$+ $qDTY_{2.1}$ + *Saltol*	Drought & salinity	62	6
Two QTLs				
2	$qDTY_{1.1}$+ *Saltol*	Drought & salinity	62	16
3	$qDTY_{2.1}$ + *Saltol*	Drought & salinity	62	13
4	$qDTY_{1.1}$+ $qDTY_{2.1}$	Drought	62	15
Single QTL				
5	$qDTY_{1.1}$	Drought	62	32
6	$qDTY_{2.1}$	Drought	62	27
7	*Saltol*	Salinity	62	28

Further BC_1F_1 were subjected to molecular marker-based screening to obtain the plants with all the three target QTLs *viz.,qDTY*$_{1.1}$, *qDTY*$_{2.1}$ and *Saltol* correspondingly for drought and salinity along with highest recurrent parent genome recovery through Foreground selection and Background selection.

RESULTS

Parental polymorphism between recurrent parent (CO 52) and donor parent (3-11-11-2) unveiled that, out of 624 SSR markers analysed, 84 markers were polymorphic accounting for 13.46 per cent of polymorphism. Foreground selection in BC_1F_1 plants revealed that, 6 plants (22, 32, 33, 44, 47 and 54) were heterozygous for all the three QTLs (Drought - *qDTY*$_{1.1}$, *qDTY*$_{2.1}$; Salinity - *Saltol*). Background selection was carried out using 84 polymorphic SSR markers in six BC_1F_1 plants containing target genes. Genome recovery in the introgressed lines were observed from 63.69 to 80.35 per cent. Plant 33 expressed the highest genome recovery of 80.35 per cent, followed by the plants 32, 44, 54 and 47 with the genome recovery of 76.19, 73.21, 70.23 and 67.85 per cent respectively.

The four BC_1F_1 plants with more than 70 per cent recurrent parent genome identified were utilized for further backcrossing in order to get the maximum genome recovery.

CONCLUSION

In the present study, for the introgression of drought and salinity tolerant QTL's in the fine grain, blast tolerant mega rice variety CO 52, the four BC_1F_1 plants with more than 70 per cent recurrent parent genome identified was forwarded to next backcross generation and the work is under progress. After the attainment of higher recovery of the recurrent parent genome and will be further evaluated for superior agronomic performance with high yield and quality characters coupled with drought and salinity tolerance.

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Effect of elevated temperature on seed germination and vigour in rice

Priyadarsini Sanghamitra[1*], Jyotirmayee Mishra[1], Swastideepa Sahoo[1], S Sabarinathan[1], Nabaneeta Basak[2], Gaurav Kumar[2], Sutapa Sarkar[1], Reshmi Raj KR[1]

[1]*Crop Improvement Division,*[2] *Crop Physiology and Biochemistry Division, ICAR-NRRI, Cuttack, 753006*
**Corresponding author: p.sanghamitra1@gmail.com*

High temperature stress can be considered as a serious threat to rice production in tropical and subtropical countries (Pradhan et al., 2016, Zhu et al., 2017). Breeding rice varieties resistant to high temperature is required for sustaining the production in rice. Though some genotypes that can withstand high temperature during vegetative and reproductive stage have been identified (Chen et al., 2021), genotypes tolerant to high temperature at germination stage is limited. So the present research work is undertaken to identify promising genotypes that can withstand high temperature at germination stage.

METHODOOLOGY

Germination assays was performed by evenly distributing the 50 seeds in four replication in a 10-cm-diameter sterilized petri dish with two layers of Whatman No. 1 filter paper. The experiment was laid out in a complete randomized design (CRD) with four replications. The experiment was conducted in a growth chamber maintained at temperature of 30±0.5°C and 40±0.5°C with relative humidity of 100 %. The final germination percentage and seedling length (5 per replication) were recorded on 10th day. Seed quality traits such as germination percentage (GP), root length (cm), shoot length (cm), seedling length (cm), seed vigour index-I (SVI-I), were estimated. For the analysis of variance (ANOVA), Cropstat software version 7.0 was used.

RESULT

20 rice genotypes were subjected to germinate under high temperature (45°C) and control (30°C) condition. Seed quality traits such as seed

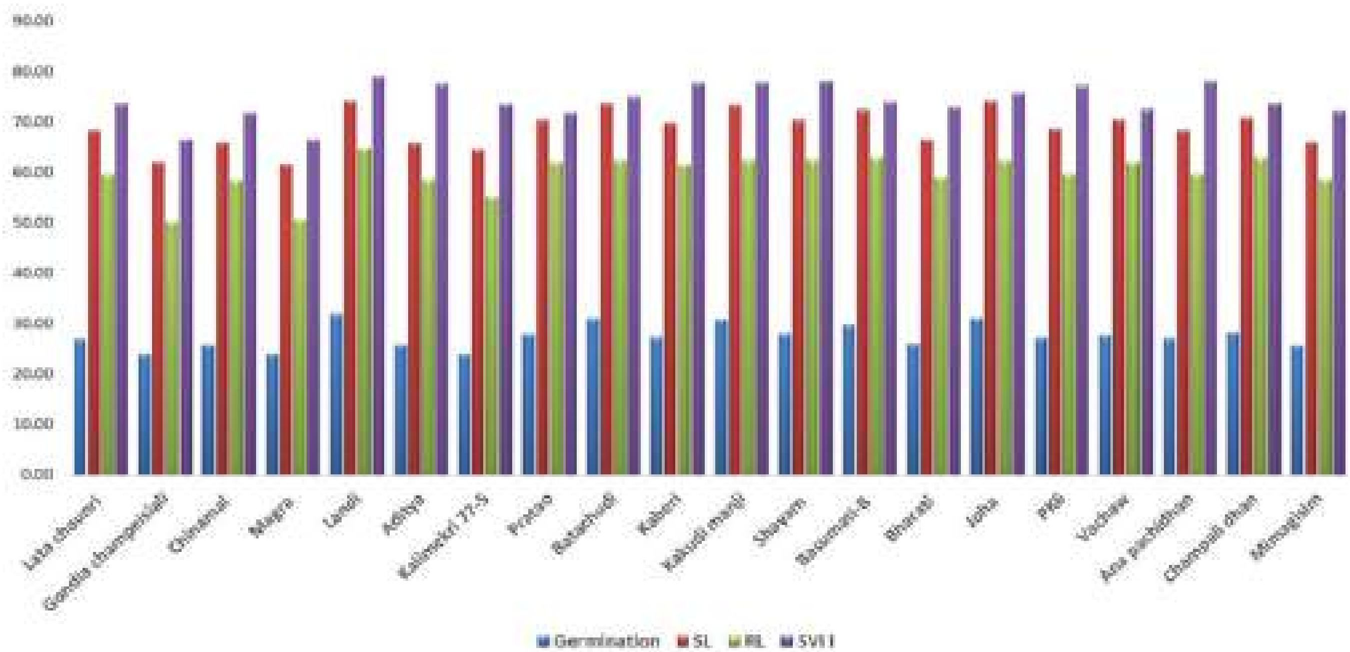

Fig.1 Percentage reduction in seed quality traits subjected to high temperature

germination, shoot length, root length and seed vigour index I were estimated. For all the traits, genotypes and temperature effect were significant. However interaction effect was significant for all the traits except germination value. In control condition, all the genotypes had more than 80% germination that ranged from 89.0(Landi)-98.54 % (Gondia champeisiali and Magra). At 45°C, germination value ranged from 60-67% (Landi) to 75.00% (Gondia champeisiali and Magra). Average 25% reduction in germination value was observed among the genotypes subjected to high temperature condition. Shoot length, root length and seed vigour index I was ranged from 10.29(Landi)-123.24cm (Gondia champeisiali and Magra), 10.72 (Landi)- 12.74cm (Magra), 1869.85(Landi)-2461.57cm (Magra) respectively under control condition. At 45°C, shoot length, root length and seed vigour index was reduced that ranged from 2.65 (landi)-4.70 cm (Magra), 3.76 (Landi)-6.28cm (Magra), 388.86(Landi)-823.51cm (Magra) respectively. Reduction of 65%, 55% and 71% in shoot length, root length and seed vigour index respectively. Was observed among the genotypes subjected to high temperature condition (Fig.1).

CONCLUSION

Gondia chanpeisiali and Magra were observed as superior genotypes for higher value of all the traits under high temperature condition. These two rice genotypes could suitably be used for breeding varieties that can withstand high temperature at germination stage.

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ARRW/SIRC/Theme I/39

Development of semi-dwarf and early maturing aromatic rice cultivars from landraces of Bihar through marker assisted breeding

Mankesh Kumar[1], Neha Kashyap, Rabiya Parween, Sweta Sinha, Satyendra, Anand Kumar and S P Singh

Department of Plant Breeding and Genetics, Bihar Agricultural University, Sabour, Bhagalpur – 813210, Bihar
Corresponding author E-mail: drmankeshkumar@gmail.com

Bihar is very rich genetic reservoir of both aromatic and non-aromatic rice gene pool. Most of the aromatic rice landraces are non-basmati type with excellent cooking and eating qualities. However, farmers are not preferring to cultivate these genotypes because of their tendency to lodge at the time of maturity and very late maturity making them unsuitable for prevalent rice-wheat cropping system in the state. The present study was undertaken to develop non-lodging, early maturing, and semi-dwarf aromatic genotypes from the landraces of Bihar through marker assisted forward breeding approach.

MATERIALS AND METHODS

F_2 population was developed by crossing aromatic local landraces like Hafsal, Malbhog, Shyamjira, Karibank, Kishanganj Basmati, Jasua, Sonachur, Champaran Basmati and Burma Bhusi with semi dwarf and early maturing mega varieties Rajendra Sweta and BPT5204. Parental polymorphism was checked through SSR markers and gene specific markers for fragrance (*badh2*) and semi-dwarfing (*sd1*) gene in rice as suggested by Bradbury *et al.*, 2005 and Speilmeyer, 2002 *et al.*, respectively.

RESULTS AND DISCUSSION

Parental polymorphism was surveyed through 20 SSR markers. Out of 24 F_1 plants of Hafsal x BPT5204, 18 were validated through RM21. Through RM248, 20 and 17 F_{1s} of Malbhog x BPT5204 and Shymajira x Rajendra Sweta, respectively were validated whereas RM161 validated 23 and 20 F_1 plants, respectively in Karibank x BPT5204 and Kishanganj Basmati x BPT5204 in year 2019. Through RM519 20 F_{1s} of Jasua x BPT5204 were validated.

In F_2 generation of all cross combination, the plant height and days to 50% flowering of selected plants ranged between 118 to 122 days and 115 to 120 cm, respectively. The selected F_2 plants were first screened for the presence of *badh2* (for aroma). Plants with *badh2*-specific amplification of 257bp were selected for further screening through *sd1 (*for semi-dwarfism*)* genes in PCR. However, the heterozygous F_2 plants with fragrant-specific257bp band and non-fragrant-specific 370bp band were also selfed in F_3 generation to isolate fragrant segregants. The plants with 350bp amplification of *sd1* gene specific primer were selected as semi-dwarf segregants and after PCR 4, 2, 8, 2, 4 and 3 F_2 plants in Hafsal x BPT5204, Malbhog x BPT5204, Shyamjira x Rajendra Sweta, Karibank x BPT5204, Kishanganj Basmati x BPT5204 and Jasua x BPT5204 had positive amplification of *sd1* gene. In 2021, 98 F_3 of all cross combinations were grown and 48 homogeneous families were selected based on semi-dwarf and early maturing phenotype. In PCR, presence of both *sd1* and *badh2* gene was confirmed in 25 F_3 families which are being evaluated during Kharif 2022. Like *sd1* gene, *fgr* or *badh2* gene is recessive in nature hence can't be distinguished phenotypically unless in homozygous state. The availability of a molecular marker for *sd1* and *badh2* gene has helped in the present breeding programme to test the presence of dwarf or tall genotypes with fragrance gene rapidly at early generations of the different cross combinations of aromatic landrace with BPT5204 and Rajendra Sweta.

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ARRW/SIRC/Theme I/40

Phenotypic and Genotypic Evaluation of Rice Landraces of Jharkhand for Tolerance to Multiple Abiotic Stresses

Priyamedha*[1], Somnath Roy[1], Koushik Chakraborty[2], A. Banerjee[1], J. Kumar[1], P. Sar[1], B.C. Verma[1] and N.P. Mandal[1]

[1]*Central Rainfed Upland Rice Research Station, ICAR-National Rice Research Station, Hazaribag, Jharkhand 825301, India*
[2]*Crop Physiology and Biochemistry Division, ICAR-National Rice Research Institute, Cuttack, Odisha 753006, India*

Rice (*Oryza sativa* L.) is the most important staple food for more than half of the world population. Increasing rice production to meet global food needs in the future is heavily affected by abiotic stresses like drought and flooding due to climate change. These stresses are also threat to rice cultivation and its sustainability in rainfed lowland areas in South and Southeast Asia. Exploitation of abiotic stress tolerant germplasms for the development of climate resilient varieties is very much important. Therefore, present study was undertaken to evaluate rice landraces of rainfed ecologies of Jharkhand for drought, submergence and germination stage oxygen deficiency (GSOD) tolerance to identify promising multiple abiotic stress tolerant genotypes.

METHODOLOGY

A total fifty rice landraces that include 38 *gora* rices and 12 traditional cultivars along with respective check varieties were evaluated under drought and submergence, both at germination and seedling stages of the crop. Screening for drought tolerance were conducted at CRURRS, Hazaribag, Jharkhand for two consecutive wet season (2019-20) in rainout shelter following the phenotyping protocol described by Verulkar et al. (2010). Whereas trials for submergence tolerance and anaerobic germination potential were carried out at ICAR-NRRI, Cuttack, Odisha. The submergence stress was calculated as described in Chakraborty et al. (2021) and the hypoxic stress experiment was conducted following Vijayan et al. (2018) for germination stage oxygen deficiency. The genotyping of the rice germplasm accessions was carried out using 24 SSR markers representing nine DTY QTLs for grain yield under drought and three markers (AEX1, SC3, and Sub1BC2) linked to *SUB1* locus for submergence tolerance. Positive checks/ donors for QTLs were included in all the assays.

RESULTS

ANOVA conducted on the nine morpho-physiological traits recorded under drought revealed highly significant differences ($P < 0.01$) among the cultivars. Under drought, highest grain yield was recorded in Dular followed by N22. It was observed that cultivars with higher grain yield predominantly showed lower leaf rolling and drying, in addition to lower spikelet sterility and higher RWC. The marker survey identified seventeen genotypes to carry one or more DTY QTLs. Kalakeri possessed five DTY QTLs ($qDTY_{1.2}$, $qDTY_{2.2}$, $qDTY_{2.3}$, $qDTY_{3.2}$ and $qDTY_{6.1}$). Most of the genotypes were found to carry the *SUB1A-1* gene, however their survival rate under 14 days of complete submergence varied widely (0.58-92.4%).

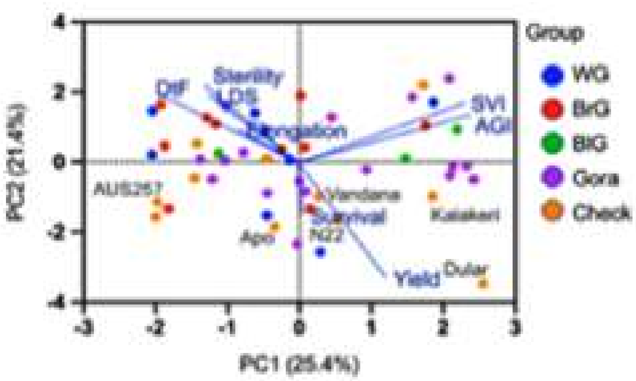

Fig.1. Genotype-by-trait biplot with important traits measured under drought, submergence and GSOD.

Multivariate analysis using important traits of abiotic stress conditions, identified promising genotypes (Dular, Kalakeri, IC0640869, IC-0640884, IC-0640896, IC-0640897 and Vandana) for tolerance to drought, submergence and GSOD (Fig. 1).

CONCLUSION

The substantial genetic variation that can be exploited to develop climate resilient rice varieties was identified in this study. Dular and Kalakeri were identified as the most promising genotypes along with a few *gora* cultivars. The promising genotypes identified in this study would be utilized for developing climate resilient rice varieties as well as for understanding the molecular basis of adaptation to multiple abiotic stresses.

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Characterization of MTU1010/ *Oryza rufipogon* CSSLs for Fe and Zn content and identification of related QTLs

Pranay G, YV Rao, Divya Balakrishnan*, Magudeeswari P, G Padmavathi, Sarla N, LV Subba Rao

ICAR-Indian Institute of Rice Research, Hyderabad-500030, Telangana, India

Email : dbiirr23@gmail.com

Rice is an important staple food crop across the globe ensuring the food security. It belongs to *Poaceae* family and deficient in essential micronutrients viz., Fe and Zn resulting in nutritional deficiency disorders among the consumers. Iron and Zinc are essential nutrients being major component in haemoglobin and cofactor in many enzymatic processes respectively (Swamy *et al*., 2018). For the nutritional security, recently major attention has been given to improve rice grain Fe and Zn contents, as wide genetic variability have been reported in natural rice germplasms. The present study was designed to detect genetic variation of Fe and Zn content in a set of chromosome segment substitution lines (CSSLs) developed in the background of popular rice variety MTU1010 with *Oryza rufipogon* as the donor parent.

METHODOLOGY

The Experimental material included 270 chromosome segment substitution lines of MTU1010 / *Oryza rufipogon* IC 309814 (BC_4F_4) (Rao *et al*., 2018) along with parent MTU1010. The materials were raised in Randomized Complete Bock design with two replications at IIRR, Hyderabad. Standard agronomics practices and plant protection measures were followed. Freshly harvested seeds of 5 grams each (dehusked whole grains) were used for Fe and Zn content estimation using energy-dispersive X-ray ûuorescence spectrometry (EDXRF) instrument (model X-Supreme 8000; Oxford Instruments plc, Abingdon, UK). QTL mapping using 160 polymorphic SSRs were carried out using composite interval mapping method.

RESULTS

Significant variation for Fe and Zn content was observed among the CSSLs. The grain Fe content ranged from 5.1 to 11.3 ppm with a mean of 8.2 and Zn content ranged between 3 to 20.9ppm. The QTL mapping studies detected thirteen QTLs for Fe content and four QTLs for Zn content on the chromosomes 1, 3, 4, 6, 9, 10 and 12. Among the identified QTLs for Fe, all the QTLs reported >3 LOD score except *qFe1.6* and explained the phenotypic variation ranging from 0.57 to 24.29%. The major QTLs for Fe was reported in chromosome 1 i.e., *qFe1.3.* and *qFe1.4* which explained 24.29% and 19.28% respectively. For Zn content the four QTLs explained phenotypic variation ranging from 2.23% to 4.78%. For both Fe and Zn content QTLs the favourable allele was derived from wild accession *O. rufipogon* except for *qFe1.4* and *qFe 1.6*. The two major QTLs for iron content *qFe1.3* and *qFe1.4* were observed between the marker interval of RM5310-RM1 and RM1329-RM8068 respectively. Among the 270 lines evaluated 15 lines were observed to have significantly high Fe and Zn content than MTU1010.

CONCLUSION

There is wide variation for Fe and Zn content among the wild introgression lines derived from *O. rufipogon* was observed. Fifteen lines were having more than 15ppm of Zinc content and 6-8 ppm of Fe content. Therefore, these introgression lines can be used in improving the Fe and Zn content in future breeding programs.

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ARRW/SIRC/Theme I/42

Assessment of genetic variability and association analysis in rice genotypes for rice bran oil and other quality traits

Arunkumar. M*, Geetha. S and Ariharasutharsan. G

Department of Genetics and Plant Breeding, CPBG, Tamil Nadu Agricultural University, Coimbatore- Tamil Nadu- 641 003.
**E mail: arunajithmak10@gmail.com*

Rice bran is the brown outer layer of the rice kernel, mainly composed of the pericarp, aleurone, seed coat, and germ. It is an important by product after the polishing of rice grains.Rice bran contains 12 to 23 per cent lipid, which upon extraction becomes rice-bran oil (RBO).Rice bran oil is a healthy edible oil that have a balanced source of unsaturated and saturated fatty acid.Bran has sufficient amount of antioxidant (γ-oryzanol) and nutritionally important components such as minerals, vitamin E (tocopherols and tocotrienols), phytosterols and phenolic components. It also help to reduce LDL cholesterol, protect cardiovascular diseases and have anticancer effects (Awad-Allah, M.M.A*et al*. 2022). Hence, the present study was conductedto explore the diverse rice bran genotypes and to identify the suitable donor for high rice bran oil content and quality traits.

METHODOLOGY

The experimental material comprisedof 35 genotypes including landraces and improved cultivars. Rice bran was extracted from all the genotypes with laboratory miller and was kept immediately at 4°C to control the growth of rice bran free fatty acid (FFA).The rice bran oil content was determined using soxhlet apparatus and standardized in thenear infra-red spectroscopy (NIR) instrument (M/s ZEUTEC, Germany; Model: SPA 1.0) calibrated with the oil content of rice bran ranging from 12 – 23%. The analysis of unknown oil content samples of each genotypewas recorded by scanning samples in a wave number range of 1400 – 2400 wavelength/nm.

Table 1. Genetic variability parameters for quality traits

	Range	Mean	PCV%	GCV%	h^2	GAM%
Hulling %	60.20-79.80	73.55	5.77	5.62	94.90	11.29
Milling%	58.10-73.00	66.38	5.46	5.32	95.03	10.69
HRR %	50.00-69.60	60.64	6.38	6.21	94.84	12.47
Bran yield%	4.30-8.10	5.72	13.85	13.77	98.56	28.21
Bran Oil%	12.10-20.37	16.81	12.33	12.30	99.01	25.27

RESULTS

Rice quality parameters *viz*., hulling percentage, milling percentage, head rice recovery, bran yield% and bran oil content was recorded and given in Table 1.The mean for hullingpercentage was 73.55 % with a range of 60.20 to 79.80. Among the genotypes, the highest hulling percentage was observed in CO (R) 49 and ADT 50 (79.80 %). The PCV and GCV were found to be low with their estimates 5.77 and 5.62 per cent respectively. High heritability (94.90 %) with moderate GAM (11.29 %) was observed for this trait. The average value recorded for milling percentage was 66.38 per cent with a range of 58.10 to 73.00. Highest and lowest milling percentage was recorded in ADT 50 (73.00 %) and ASD16 (58.1 %)respectively. The PCV and GCV were found to be low with their estimates 5.46 % and 5.32 % respectively. High heritability (95.03 %) accompanied with moderate GAM (10.69 %) were found for this trait. The mean for head rice recovery was 60.64 per cent. It ranged from 50.00 to 69.60 per cent. Low PCV (6.38 %) and low GCV (6.21%) were recorded. High heritability (94.84 %) and moderate GAM (12.47 %) were recorded for this trait. The trait bran yield recorded an overall mean of 5.72 %. The range was between 4.30 % to 8.10 %. The highest bran yield was recorded in CR 1009 (8.10%) and lowest was observed in ADT 51(4.30%). Moderate PCV (13.85 %) and Moderate GCV (13.77 %) were recorded. High heritability (98.56%) coupled with high GAM (28.21%) were found for bran yield. The trait bran oil content exhibited an overall mean of 16.81 give

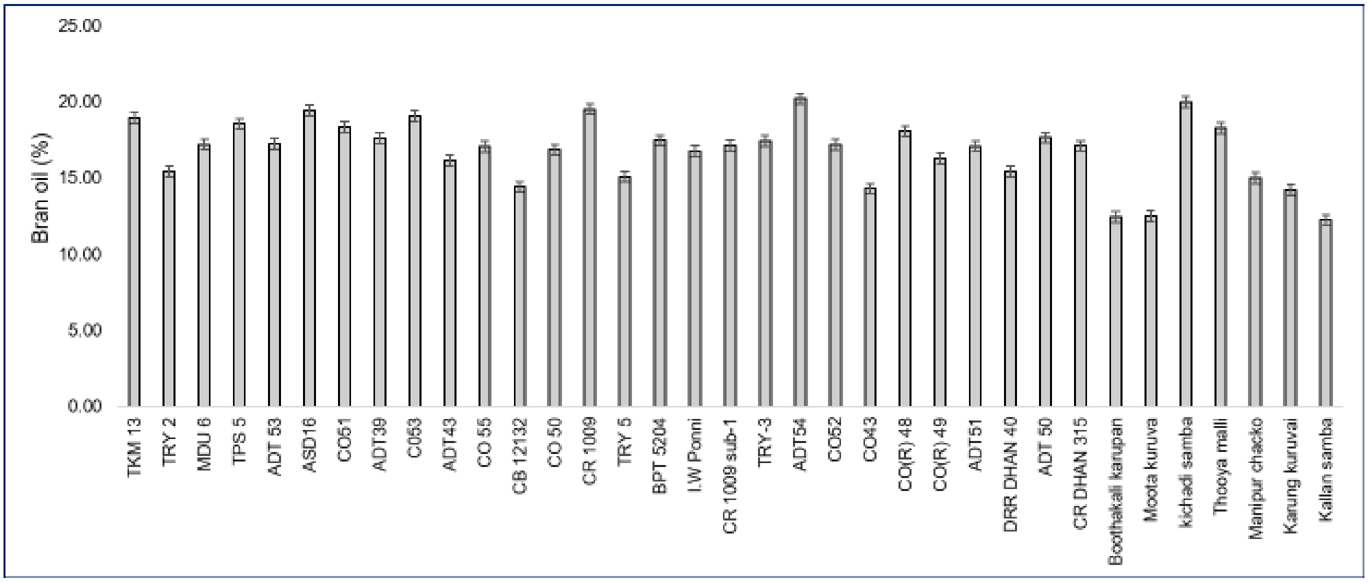

Fig 1. Bran oil content in rice genotypes

in Figure 1.It range from 12.10 to 20.37. Among the genotypes, the highest oil content was recorded in ADT 54 (20.37 %) and lowest was observed in *kallan samba* (12.10%). Moderate PCV (12.33%) and moderate GCV (12.30%) were recorded. High heritability (99.01%) along with high GAM (25.27%) was observed for this trait. Among all the traits, significant and positive correlation with bran oil content was manifested by hulling percentage and milling percentage. Negative and significant association of bran yield was witnessed with hulling percentage and milling percentage. Head rice recovery had a positive correlation with hulling percentage and milling percentage (Fig 2).

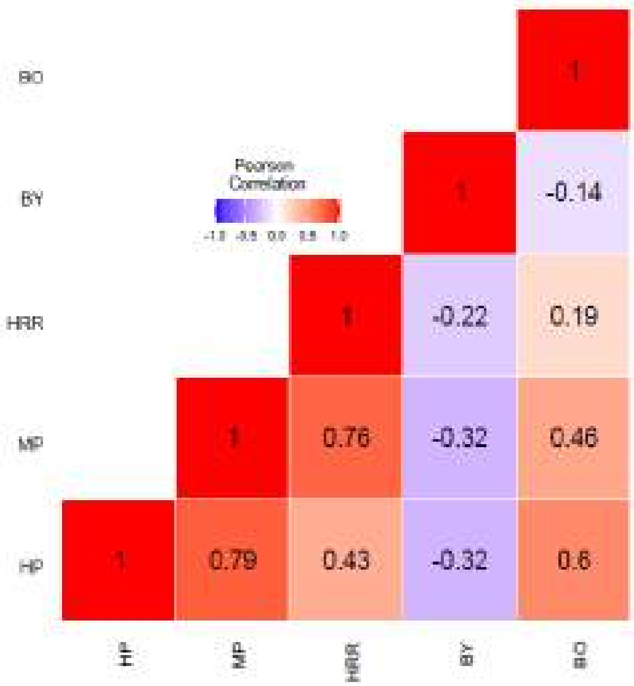

Fig 2. Correlation coefficient between traits

CONCLUSION

Bran oiland bran yield percentage were observed high heritability coupled with genetic advance as percent of mean which implies additive gene action, Hence improvement of these traits would be achieved through simple selection. Based on *per se* performance, the genotypes ADT 54, *Kichadi samba* and CR 1009 were selected for high rice bran oil content and it might be utilized as a donor in rice breeding to explore the high rice bran oil properties.

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ARRW/SIRC/Theme I/43

Combining ability for yield and yield components in rice (*Oryza sativa* L.) using diallel analysis

Deepika. K[1]., Manimaran. R[1]., Suresh. R[2]., Pushpa. R[1]., and Sathiya Bama K[3]

[1]*Department of Genetics and Plant Breeding, TRRI, Aduthurai-612101, Tamil Nadu, India.*

[2]*Department of Genetics and Plant Breeding, CPBG, TNAU, Coimbatore-641003, Tamil Nadu, India.*

[3]*Department of Soil Science & Agricultural Chemistry, TNAU, Coimbatore-641003, Tamil Nadu, India*

Rice (*Oryza sativa* L.) (2n = 24) is the second most common cereal crop in the world. It provides staple food for nearly half of the world's population. In 2022, rice production was recorded 512.4 million tons. Traditional breeding methods still provide the possibility of the development of rice hybrids. Diallel cross technique is one of the different methods of assessing the nature of the gene action of parents. It estimates the combing ability of parents and gene effects (Fasahat *et al*. 2016). Parental lines and their hybrids can be assessed through diallel analysis in all possible combinations. The general combining ability (GCA) and specific combining ability (SCA) analyses facilitate in selecting excellent parents for using in breeding programme and also to know the promising cross-combinations for cultivar improvement.

OBJECTIVE

To estimate the combining ability for Yield components in rice hybrids.

MATERIALS AND METHODS

The Experimental material consist of high yielding varieties, photoinsentive and land races *viz*., ADT 56, CO 54 and TPS 5 and Chinkinikar and Thandipalliyan were crossed together using half diallel cross genetic design. Fifteen entries (5 parents and 10 hybrids) were grown in randomized block design with two replications in Tamil Nadu Rice Research Institute, Aduthurai, Tamil Nadu, India. Selected parents were raised in staggered sowing and crossed to evolve High yielding varieties with high nutritional values like iron, zinc and protein. The observations were recorded on 5 randomly selected plants for yield and yield traits like days to 50% flowering, plant height, productive tillers/ plant, flag leaf length, flag leaf width, panicle weight, panicle length, filled grains /panicle, unfilled grains, number of grains per panicle and 100 grain weight. Combining ability analysis were carried out as per Griffing (1956), method-2 (Model-I) using TNAUSTAT software.

RESULTS

The observations were documented for the fifteen genotypes *i.e*. five parents, ten hybrids in two replications for eleven different characters and used for calculation of the mean performance. The observations were first averaged for five plants taken randomly for each genotype in each replication and further averaged over both replications. In the present research work five parents and hybrids were selected and screened for yield, yield components and for the Combining ability. Mean and Standard deviation of all entries for all the traits revealed a wide range of phenotypic variation. The differences were significant among parents and their crosses regarding GCA and SCA effects. This also suggested the importance of the effects of additive and non-additive genes in the inheritance of the traits under study. The estimates of the components due to GCA and SCA effects and their ratio showed that non additive gene effect was higher than additive effect for all the yield and quality characters like filled grains and number of grains per panicle. The results indicated that both general and specific combining ability were highly

Table 1. Relative effects of general combining ability effect (*gca*) and specific combining ability (*sca*) of parents and Crosses of Rice genotypes.

Patrents	DFF	PH	NOT	FL	FW	PW	PL	FG	UFG	NG	HSW
1.	-0.320	-9.433 **	-1.280	-0.335	-0.260	-0.079 *	-0.864 *	29.180 **	-3.280*	26.433 **	-0.200**
2.	-0.353	-9.500 **	-2.980 *	-3.125 **	0.370	-0.045	-0.224	6.180	7.786 **	14.500 **	-0.014
3.	1.913 **	-11.733**	-0.846	-0.535	0.273	0.041	-1.074 **	-26.120**	-5.646 **	-31.233 **	0.072 **
4.	0.213	14.300 **	4.220 **	2.544 **	-0.230	0.026	1.932**	14.746 **	16.253 **	28.866 **	-0.014
5.	-1.453 **	16.366 **	0.886	1.451	-0.153	0.055	0.229	-23.986 **	-15.113**	-38.566 **	0.156 **
Mean	118.38	123.60	20.88	32.06	1.59	2.36	29.90	146.33	39.38	185.28	2.13
SE	0.39	2.16	1.22	0.91	0.23	0.03	0.34	3.44	1.44	3.70	0.02
SED	0.62	3.41	1.77	1.44	0.37	0.05	0.54	5.45	2.77	5.85	0.04
Crosses	*sca* of crosses										
1×2	-0.213	-4.500	-1.120	0.445	-0.340	0.599 **	-0.466	36.153 **	0.346	35.966 **	-0.359**
1×3	0.353	-13.900**	-2.920	3.338	-0.310	-0.487 **	-0.882	-65.046**	-8.720 **	-74.300 **	-0.296**
1×4	0.053	11.366*	6.180 *	-0.291	0.126	0.010	2.477**	54.753**	-11.120**	45.766 **	-0.142**
1×5	0.553	-20.366**	-3.153	-6.664 **	0.316	-0.555 **	-2.986**	-20.513**	13.080 **	-7.966	0.087
2×3	1.386	-5.033	-2.220	-3.538	1.426 **	0.061	-0.522	29.620 **	10.046 **	39.133 **	-0.032
2×4	0.586	4.433*	1.213	-1.284	-0.353	-0.590 **	2.404 **	-65.246**	20.813 **	-42.300 **	-0.129 *
2×5	-1.413	3.033	0.383	0.792	-0.346	-0.201 **	-0.026	-16.513 *	-5.820	-22.866 **	0.150 **
3×4	-0.846	4.166	13.833**	1.025	-0.106	0.134	-0.979	-34.613**	10.246 **	-22.233 **	0.217**
3×5	2.320 **	9.566 *	-0.253	-2.164	-0.383	0.368 **	1.940 **	34.120 **	0.946	34.533**	0.080
4×5	2.686 **	5.566	2.680	-2.228	0.186	0.491 **	-2.566**	-46.746**	-12.286**	-56.900 **	-0.416**
Mean	118.97	168.08	28.97	39.94	1.82	2.87	31.90	162.02	29.20	205.22	3.29
SE	0.81	4.45	2.31	1.88	0.49	0.07	0.72	7.11	2.96	7.63	0.05
SED	1.58	8.70	4.52	3.69	0.96	0.16	1.67	13.9	5.80	14.9	0.10

*, ** Significant at 5% and 1% level respectively

significant for all the studied characteristics except flag leaf width and panicle weight. The parents ADT 56, TPS5 and Chinkinikar were identified as good, so these parents were suggested for further recombinant breeding programmes. The GCA was estimated for the grain yield components of the five parental genotypes (Table 1) and that showed that the parents ADT56 and Chinkinkar had the highest and positive GCA indicating that these two parents are good combiners for grain yield. The best combiners for the varieties were plant height, filled grains per panicle, unfilled grains and number of grains per panicle was Thandipallian, Chinkinkar and CO54. For estimation of SCA, the 11 characters are presented in Table 1. Indicated that the cross 1 × 4 had the best SCA for filled grains, number of grains per panicle, 2 × 3 cross had highest number of grains per panicle. The cross 1 × 2 and 3 × 5 had best SCA for filled grains and number of grains per panicle. Cross 1×4 had best for plant height, number of tillers per plant, panicle length and number of grains per panicle.

CONCLUSION

The genotypes ADT 56, Chinkinkar and Thandipallian were indentified as best parents for yield, yield components. These parents were suggested for a further recombinant breeding programme to evolve high yielding lines. These varieties are also having high Zn (26.8mg/Kg) and Fe (18.4 mg/Kg) in Chinkinkar and high protein in Thandipallian (16.4%). These can considered as best combiners in breeding programme.

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ARRW/SIRC/Theme I/44

Correlation study among micronutrient content and yield attributing traits in F_2 population of rice (*Oryza sativa* L.)

Rahul Singh[1], Sweta Sinha[2], Mankesh Kumar[1], Anand Kumar[1], Satyendra[1], Shashikant[3] Surabhi Kumari[4] and S. P. Singh[1]*

[1] *Department of Plant Breeding and Genetics, BAU, Sabour, Bihar, India*
[2] *Department of Molecular Biology and Genetic Engineering, BAU, Sabour, Bihar, India*
[3]*Department of Biochemistry and Crop Physiology, BAU, Sabour, Bihar, India*
[4] *Department of Genetics and Plant Breeding, BAU, Kanke, Ranchi, India*
**Correspondence E-mail id: sps2007bau2011@gmail.com*

Rice is the most important staple food consumed by more than half of the world's population. Thus these populations may suffer micronutrient malnutrition because rice is not good enough in many micronutrients like iron (Fe) and zinc (Zn) etc. Fe and Zn play vital role in human body; Fe is an important factor of blood hemoglobin whereas Zn acts as cofactor for several enzymes (Ishimaru *et al.*, 2011). Individuals between 25 and 50 years of age require 10 to 15 mg Fe and 12 to 15 mg of zinc (Welch and Graham, 2004). According to NIH, recommended dose of Zn in Child is 8 mg and Fe is 10 mg. A small quantity of micronutrient improvement in rice grain can tackle the problem of micronutrient malnutrition. Moreover, cheap and easy way of enriching the rice grain with micronutrient is bio-fortification. But in general negative correlation has been found between yield and Fe/Zn content in grains.

Hence, knowledge of correlation between micronutrient content and other yield determinant traits can help in the effective selection of associated traits. In this context, present research work was undertaken to study the correlation of micronutrient (grain Fe and Zn content) with other agronomical traits in F_2 population of rice. This study can accelerate bio-fortification program in positive direction by selecting the traits showed positive association with micronutrients so that biofortified rice varieties can be developed with least or without penalty of grain yield.

METHODOLOGY

The present study was conducted in the three successive years (2018, 2019 and 2020) at the Rice Research Farm of Bihar Agricultural University Sabour, Bhagalpur, Bihar, which is geographically located between 25º15′40″ N latitude to 87º2′42″ E longitude at 46 m above the mean sea level.

The investigation was began with crossing between Samba Mahsuri (Fe content 12 ppm and Zn content 14 ppm) and Sathi (Fe content 19 ppm and Zn content 27 ppm) to generate F_1 progenies in the year Kharif 2018. Seeds of twenty-five F_{1s} along with both parents were sown in Kharif 2019 to derive F_2 population. True hybridity test was performed on all F_1 progenies using SSR marker RM206. True F_1 derived 190 F_2 progenies along with the parents were grown in Kharif 2020.

The data were recorded on ten morphological traits including pre harvest and post-harvest observations *viz.,* days to 50% flowering, plant height (cm), panicle length (cm), number of effective tillers per plant, number of filled grains per panicle, grain yield per plant (g), grain length (mm), grain breadth (mm), grain length/breadth ratio and test weight (1000- grain weight in g) from each individual plant. Similarly, two qualitative data (grain Fe and Zn content) were estimated using wet acid digestion method from each individual plant in the F_2 population. All the recorded data were subjected to correlation analysis using "XLSTAT2018.1 VERSION".

RESULTS

Correlation analysis revealed that grain iron and zinc content were found to be significantly and negatively correlated with plant height, number of effective tillers per plant, number of filled grains per panicle and grain yield per plant. However, grain iron and grain zinc content were found to be significantly and positively correlated with each other. Similarly, both Fe and Zn content showed non-significant positive association with days to 50% flowering, while non-significantly negative with panicle length. Individually grain Zn content exhibited non-significant and positive correlation with grain length/breadth ratio and non-significantly negative with grain length, grain breadth and test weight. In contrast, grain Fe content observed to have non-significant and negative correlation with grain length, grain breadth and test weight, while non-significantly negative with grain length/breadth ratio.

Grain yield per plant showed significant and positive association with plant height, number of effective tillers per plant and number of filled grains per panicle. These finding were also in agreement with the result of Calayugan *et al.*, (2020).

CONCLUSION

On the basis of results as summarized above, it is concluded that grain Fe and Zn content didn't show strong positive association with any of the yield attributing traits under study. Hence for simultaneous enhancement in grain Fe and Zn with least yield penalty needs very careful selection of yield attributing traits during rice bio-fortification programme through breeding.

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"*Kataribhog*": An indigenous aromatic rice landrace from Sub-Himalayan terai region of India with low glycemic index (GI) value.

Kantamraju Prudveesh[1*], Nandita Sahana[1], Somnath Mandal[1]

[1]*Dept. of Biochemistry, Faculty of Agriculture, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal (736165), India*

**Email : prudveesh@gmail.com*

Diet is an important factor in managing good health in the busy and stressful modern life. Lifestyle diseases like diabetes are increasing at an alarming rate in the predominantly rice-eating Indian population. Food grains with high nutritive value but low digestible starch and soluble sugar content are considered as healthy. Rice landraces from the Sub-Himalayan Terai region are having unexplored potential in terms of nutritional attributes.

METHODOLOGY

To search for a healthy alternative to high-price basmati rice, twenty-two heirloom short-grain aromatic rice cultivars from this region were investigated for different nutritional parameters, like total carbohydrate content (TSS), reducing and non-reducing sugar, protein content, Total starch content, amylose, amylopectin content, resistant starch content, glycemic index, total antioxidant capacity, using standard colorimetric methods and aroma by sensory evaluation method and GCMS.

RESULTS

Based on the nutritional attributes, these genotypes represented wide variability. These genotypes exhibited values ranging from 88.89% (ChakhaoSampark) to 37.44% (Tulsibhog) for TSS, whereas the starch content of these genotypes ranged from 85.45% (Sadanunia) to 45.86 % (Konkanijoha), and Kataribhog with 54.57 %. Higher amylose content was found in Tulsibhog (29.10%) whereas the lowest amylose was found in genotypes like Chakhao selections, Konkanijoha, Gobindabhog, etc., and Kataribhog with 20.43 % came under intermediate amylose content. Interestingly these genotypes showed considerable variability in the resistant starch and glycemic index values. Kataribhog showed the highest resistant starch (RS) content (2.25%) among all the genotypes whereas powdered Kataribhog grains have been analysed to have remarkable GI as low as 45.72. all the other landraces showed an average glycemic index value of more than 60 whereas a few cultivars like Dubarikomal (54.77), and A-1-1 (58.67), had comparatively low glycemic index... Kataribhog has been registered at NBPGR as a low GI rice accession ($INGR_{21113}$). The protein content and antioxidant activity of Kataribhog were 6.43% and 1586.68 µg/ml respectively.

Rice aroma is due to the contribution of more than 100 compounds, among which only 2-acetyl-1-pyrroline (2-AP) is well-known, produced due to the non-functionality of the Betaine aldehyde dehydrogenase (BADH) enzyme, which is caused by the mutation in the *badh2* gene. These selected genotypes were analysed for Genetic diversity using the *Badh2* gene primers. Kataribhog was found to be in cluster number II along with highly aromatic cultivars like Sadanunia, and Tulsibhog. For a detailed analysis of aroma compounds of Kataribhog, volatile compounds profiling through GCMS was done, and rice Aroma compounds like 2-Acetyl-1-Pyrroline, Hexanal, Pentanal, Heptanal, Octanal, Nonanal, etc. were detected in Kataribhog.

CONCLUSION

Altogether the data reveals that the elite genotype Kataribhog is a nutritively superior antioxidant-rich aromatic healthy rice genotype with a remarkably low glycemic index and consumption of these genotypes may be beneficial for diabetic patients.

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Thicker leaf gas film and greater tissue tolerance is crucial for tolerance to combined stresses of salinity and submergence in rice

Koushik Chakraborty*, Subhankar Mondal, Swagatika Tripathy, Priyanka Jena, Krishnendu Chattopadhyay

ICAR-National Rice Research Institute, Cuttack – 753006, India

Correspondence: Koushik.Chakraborty@icar.gov.in; koushikiari@gmail.com

Rice is a staple food for more than 3.5 billion people worldwide and this number keeps increasing year after year. To meet the demand and feed this large number of people, stable rice production is extremely necessary. But the difficulty is rice growth and yield can be hampered by exposure to different abiotic stresses like drought, salinity, excess water stress, heat, etc. either individually or in combination (Pathak et al. 2021). Therefore, the current trends of rice research programs are now focussed more on elucidating new insights into multiple stress tolerance rather than looking into particular stress singly. In the coastal ecosystem, rice production faces serious threats from salinity, submergence, and stagnant flooding both individually and in combinations. Previous studies identified *SUB1* (for submergence) and *Saltol* or*SKC1* (for seedling stage salinity stress) as two major QTLs for imparting tolerance to rice plants (Sarkar et al. 2019). But little is known about how rice plants behave under a combination of these two stresses. What are the critical plant traits that influence the tolerance of rice plants under such multiple stress conditions are also yet to be identified.

METHODOLOGY

To answer this research gap, we took four distinct rice genotypes *viz*. FR13A (have *SUB1*, but lacks *SKC1* QTL), FL478 (have *SKC1*, but lacks *SUB1* QTL), AC39416A (have both *SUB1* and *SKC1* QTLs), and IR42 (lacks both *SUB1* and *SKC1* QTLs) and subjected them to salinity stress (SS: NaCl equivalent to 12 dS m^{-1} for seven days), submergence (FWS: two weeks of complete submergence using fresh/non-saline water) and combination of these two stresses (SWS: two weeks of complete submergence with saline water of 12 dS m^{-1}). All the stresses were imposed at the early seedling stage (corresponding to the 3-4 leaf stage). Tissue samples were collected at different time intervals from control and treated plants. Important traits like leaf gas film (LGF) thickness, tissue porosity, tissue ionic distribution, tissue tolerance ability, and gene expression profiles were examined.

RESULTS

After seven days of salinity stress (SS), FL478 maintained the maximum biomass of shoot and root tissues, followed by AC39416A, FR13A, and IR42. Apart from biomass,FL478 showed the least increase inleaf Na^+/K^+ ratio, followed by AC39416A, FR13A, and IR42 which suggests thatFL478 performed best in SS among all genotypes. We observed the highest survival with the least internode elongation in FR13A, followed by AC39416A under both FWS and SWS treatments(Fig. 1). Interestingly, the difference in survival was non-significant for FWS and SWS. Though the internode elongation was restricted more under SWS treatment. Both the initial thickness of LGF and leaf epicuticular wax concentrations were highest in FR13A, followed by AC39416A.But, the depletion of LGF and wax were significantly faster under SWS than FWS. Although no difference in initial tissue porosity (49-56%) was observed in the studied genotypes, but the day-wise reduction in porosity was faster under SWS treatment than FWS. In general, *in planta* ethylene accumulation was found higher under SWS treatment, but the initial concentration and its over the time build-up was significantly lesser in FR13A, followed by AC39416A. The build-up of leaf Na^+concentation was started to show a sharp rise after 9th day of SWS stress, while in IR42 it was 6th day onwards. After two weeks, the leaf Na^+concentration was least in AC39416A (247 mmol g^{-1} DW), followed by FR13A (300 mmol g^{-1} DW) and FL478 (336 mmol g^{-1} DW), while it was highest in IR42 (378 mmol g^{-1} DW).

To understand the genotypic difference in response to saline water submergence, we also evaluated the tissue tolerance potential of these genotypes underboth submerged as well as aerobic environment in response to 12 dS m^{-1} salinity stress. We observed that the tissue tolerance scores (measured as LC_{50} value denoting the amount of Na^+ required to bring down the initial chlorophyll content of the leaf to a half) were significantly lesser for a particular genotype when they were exposed to dual stresses of salinity and submergence. Both FR13A and AC39416A were better genotypes having an LC50 score of >270 and >425 mmol Na^+ g^{-1} DW under anaerobic and aerobic environments, respectively. Besides, we found a much greater expression of *OsSUB1A-1* in FR13A and AC39416A, but a lesser expression of ethylene biosynthesis genes like *OsACS5* and *OsACO3*.

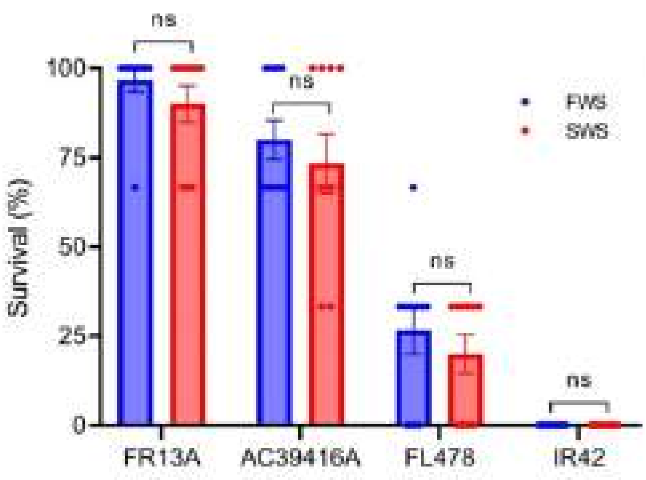

Fig. 1. Difference in survival rate of four rice genotypes under fresh and saline water submergence

These genotypes also showed a significantly lower expression of *OsAMY3D* compared to FL478 and IR42. Thus they could maintain a higher leaf starch concentration at the end of the stress period.

CONCLUSION

From the present study, it is clear that the tolerance mechanism against individual stresses of salinity and combined action of salinity and complete submergence differs significantly. Taken together we conclude that

i. Salinity tolerance (ion exclusion) singly does not have much role in withstanding the combined stresses of saline water submergence.

ii. A better submergence tolerance ability manifested by the thicker LGFand presence of *SUB1* QTL plays a crucialrole in tolerance to both fresh and saline water submergence in rice.

iii. Tissue tolerance (TT) instead of ion exclusion can improve saline water submergence tolerance in *SUB1*-containing rice. But individually TT also does not have much role to play.

iv. For developing multiple stress-tolerant rice for withstanding saline water submergence, a greater emphasis on traits governing submergence and tissue tolerance may be given.

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ARRW/SIRC/Theme I/49

Molecular characterization of rice genotypes derived from half-sib RILs of CMS line Pusa 6A

Prachi Priya[1], Satyendra*[1], Mankesh Kumar[1], Sweta Sinha[2], Anand Kumar[1], S. P. Singh[1] and P. K. Singh[3]

[1]Department of Plant Breeding and Genetics, [2]Department of Molecular Biology and Genetic Engineering, [3]Directorate of Research Bihar Agricultural University, Sabour-813210 (Bhagalpur)

**Corresponding author: drsatyendratomar@gmail.com*

For hybrid rice development, diversification of parental lines is one of the most important task for plant breeders. Since the hybrid rice technology has been proved to be successful, need is to explore more and more diverse crosses for better segregants that could be worthy for plant breeders. Present study is based on such an effort made towards identification of good genotypes from advance segregating generations of crosses having Pusa 6A, a famous CMS line, in common and several other diverse genotypes including green super rice (GSR) lines. Molecular characterization of these lines was done for several important traits including availability of restoration genes.

METHODOLOGY

56 rice genotypes including 51 half-sib Recombinant Inbred Lines (RILs) derived from crosses having Cytoplasmic Male Sterile (CMS) line Pusa 6A as common parent along with five famous check varieties of different maturity duration were evaluated for molecular characterization using micro-satellite and gene specific DNA markers for major fertility restoration genes *Rf3* and *Rf4*, wide compatibility (*WC*) gene and salt tolerance.

RESULTS

Total 38 genotypes were found to be homozygous for *Rf4* gene. Individual plants, homozygous for both *WC* and *Rf4* genes, and for both *Saltol* QTL and *Rf4* were selected. Presence of *Rf4* gene showed positive but non-significant correlation with spikelet fertility percentage. It was observed that good spikelet fertility percentage in the genotypes showing absence of *Rf4* at molecular level could be due to presence of other genes responsible for restoration of fertility for CMS source studied.

CONCLUSION

Selected plants, homozygous for genes and QTLs (*Rf4*, *WC* and *Saltol*) can further be evaluated and used in future breeding programs as promising restorer lines and for the development of new varieties/hybrid.

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ARRW/SIRC/Theme I/50

Response to marker assisted selection for *Pi9*, *GRAIN NUMBER1* and *SPIKELTE NUMBER* genes in early segregating population of rice

M James, Urmila Maibam, Magudeeswari P, Abilash Behera, Wricha Tyagi, Mayankrai*

**School of Crop Improvement, College of Post Graduate Studies in Agricultural Sciences (CPGS-AS), Central Agricultural university (I), Umiam, Meghalaya- 793103, India.*

**Corresponding author: mrai.cau@gmail.com*

Rice grown in hill regions of north east India are most susceptible to the rice blast fungus (*Magnaporthe oryzae*) causing yield loss upto 50%.Till date more than 107 blast resistance genes (Annegowda et al. 2021) and 87 yield related genes (Abbai et al. 2019) were identified in rice. Validating and utilizing these genes in specific combinations will offer broad-spectrum and long-term durable resistance to the rice blast disease coupled with higher yield.

METHODOLOGY

A biparental population (ULRC 88) was developed by crossing BLM (rice blast resistant) with CAUS103 (advanced breeding line) and the successive generations F_1, F_2 and F_3 were grown in experimental farm ofCPGS-AS during *kharif*, 2020, 2021 and 2022 respectively. Phenotyping selection was done in F_2 and F_3 generations and observations were recorded in 20 random and 10 selected plants for traits like yield per plant (YPP-in grams), leaf blast (LB-score 0-5) and panicle blast (PB-infected panicles per plant). Genotyping was done using various blast and yield specific markers in parents; and a haplotype analysis was carried out in 263 plants of F_3 generation considering *pi9, GN1* and *SPIKE* genes.

RESULTS

The trait YPP in the cross ULRC88 followed a normal frequency distribution with an average of 17.2g, 9.3g and 11.9g in F_1, F_2 and F_3 generations respectively. Phenotypic selection in F_2 gave 50% increase in yield (18.5g), and the response to selection in F_3 was 2.58with heritability of 28%. The mean of the progenies selected in F_3 were 25.1g showing a progressive increase in YPP through selection. The genotype BLM had blast resistant genes like *Pi9*(9Pro), *Pi20*and*Pi54*(Pi54); CAUS103 had yield related genes like *GN1*(Gn1a indel3) and *SPIKE* (Spike indel3) genes, whereas both the genotypes had *Pita*, *Pikm*,*GS5* and *TGW6*genes. Marker trait association by t-test showed that LB and PB was associated with the marker 9pro (P =2.42e-05 and 0.013), YPP was associated with the gene *GN1* (P=0.013) and *SPIKE* showed poor association with YPP (P= 0.10). Haplotype analysis forthe three genes (*pi9, GN1* and *SPIKE*) gave eight haplotypes. Haplotype I was positive for all the three desirable genesyielding 11.7±2.9g and LB score of 0.4 and PB of 1.1 per plant; whereas the haplotype VIII was negative for all genes and yielded 8.3±1.6g,LB and PB scores of 1.7 and 1.5 per plant respectively.

CONCLUSION

The markers9pro and GN1a indel3 had significant positive association with the traits LB and YPP respectively. More than 50% of the phenotypically selected plants in F_3 generations had atleast any two desirable genes mentioned above. This study proves the fact that marker assisted phenotypic selection in early segregating generations is fruitful, such that we could select elite plants with blast disease resistance (*Pi9*) and superior yield (*GN1, SPIKE*)combinations.

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ARRW/SIRC/Theme I/51

Peaceful applications of radiation techniques for enhancement in the agronomic traits of traditional rice landraces of Chhattisgarh

[1*]Deepak Sharma, [1*]Parmeshwar K. Sahu, [1]Richa Sao, [1]Raviraj Singh Patel, [1]Samrath Baghel, [1]Ishu Kumar Khute, [1]Satyapal Singh, [2*]B.K. Das

[1]Department of Genetics and Plant Breeding, Indira Gandhi Krishi Vishwavidyalaya, Raipur-492012 (C.G.), India
[2]Nuclear Agriculture and Biotechnology Division, Bhabha Atomic Research Centre, Mumbai-400085 (M.S.), India
**Corresponding Author's E-mail: deepak1962@igkv.ac.in (Deepak Sharma) / bkdas@barc.gov.in (B.K. Das)*

Chhattisgarh is endowed with tremendous rice biodiversity due which this state is popular as '*Rice Bowl of India*'. More than 23250 rice germplasm have been recorded in the state which is conserved at Indira Gandhi Krishi Vishwavidyalaya, Raipur. Interestingly, several traditional rice landraces possess valuable traits like resistance to biotic & abiotic stresses, good yielding ability, premium grain quality, special aroma, therapeutical properties, nutritional values etc. Unfortunately, many of these rice landraces have not been grown in farmers' field due to poor yield potential (2-3 t/ha), late maturity duration (150-175 days) and tall plant height (150-180cm) and therefore they are at edge of getting extinct. However, most of them are very popular among the farmers and they wanted cultivate them, if their yield potential could be increased by maintaining their unique features and original grain quality. To overcome this, mutation breeding could offer a simple and quick approach for improvement of these landraces through radiation induced mutagenesis without altering their original features.

METHODOLOGY

IGKV, Raipur and BARC, Mumbai started a joint program for the improvement and revival of over 100 traditional rice varieties of Chhattisgarh through radiation (gamma rays, electron beam, X-rays, proton beam and thermal neutrons) induced mutation breeding in 2013. The major aim of this collaborative work is to develop dwarf to semi-dwarf (100-120 cm), early to medium maturity duration (105-125 days) and good yield potential (4.5 to 6.5 t/ha) mutant rice varieties by maintaining their original features and quality traits. All the wet lab (field) works are being carried out at IGKV whereas BARC is providing technical and financial support for this work.

RESULTS

Radiation techniques have several peaceful applications in field of Agriculture one of them is development of crop mutants. The large amount of energy associated with the splitting of atoms could be utilized for various peaceful applications. Radiation induced mutation breeding is completely skill based phenomenon where one can select for their desirable trait after creating variability in large population. Under the BARC-IGKV collaboration, five rice mutant varieties *viz.*, TCDM-1, Vikram-TCR, CG Jawaphool Trombay, TCVM and TCSM have been released and notified by Government of India. TCDM-1, CG Jawaphool Trombay and TCVM are aromatic fine grain mutant varieties whereas Vikram-TCR and TCSM have non- aromatic but high yield potential. More than 50 stable rice mutants are under evaluation at station, state and national multi-location trials. In addition, about 550 mutant lines in the background of 35 rice landraces are in various mutagenic stages of confirmation, stabilization and evaluation. Interestingly, the mean percentage reduction in plant height was 7% to 55% and days to maturity was 6% to 40% whereas the mean percentage increase in grain yield per plant was 10% to 65% in various rice mutants with respect to parent, which indicated the potential of radiation induced mutation breeding. In addition to the development of rice mutants, BARC-IGKV have also organises several seed distribution workshop to disseminate the seeds of developed mutant rice varieties among the farmers. Interestingly, these mutant varieties are getting popular among the farmers and they are cultivation=ng these varieties in large areas. Currently, the rice mutation breeding program under BARC-IGKV collaboration is the World's largest active mutation breeding program for the improvement and revival of traditional rice landraces. The success of this collaborative work indicated that radiation induced mutation breeding is one of the most viable tools for improvement and revival of the traditional rice landraces and could be applied in other crops also to improve one or two major drawbacks.

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ARRW/SIRC/Theme I/52

Vikram-TCR: a semi-dwarf, high yielding and blast resistant rice variety developed through radiation induced mutation breeding

Parmeshwar K. Sahu[1], Richa Sao[1], Raviraj Singh Patel[1], Samrath Baghel[1], Ishu K. Khute[1], Satyapal Singh[1], *B.K. Das, Ljupcho Jankuloski[3], *Deepak Sharma[1]

[1]*Department of Genetics and Plant Breeding, Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur-492012 (C.G.), India*
[2]*Nuclear Agriculture and Biotechnology Division, Bhabha Atomic Research Centre (BARC), Mumbai- 400085 (M.S.), India*
[3] *Plant Breeding and Genetics Section, Joint FAO/IAEA Centre, International Atomic Energy Agency, 1400 Vienna, Austria*
**Corresponding Author's E-mail: deepak1962@igkv.ac.in (Deepak Sharma) / bkdas@barc.gov.in (B.K. Das)*

Safri-17, a traditional rice variety from central Chhattisgarh, India is very popular for long slender grains, drought tolerance ability, good grain quality and good puffed rice making quality. Apart from many advantages being possessed by Safri-17, it is not in much cultivation covering wide areas due to poor yield potential, tall plant stature (prone to lodging), and late maturity duration (require more inputs and time duration in field operations). Therefore, present study was planned to improve and revive the Safri-17 through radiation induced mutation breeding. Mutation breeding is a powerful technique to improve one or two major defects in rice landraces by maintaining their original qualities and unique features. Vikram-TCR is the mutant rice variety developed from Safri-17 variety through gamma ray (300 Gy) induced mutation breeding under the joint collaboration of IGKV, Raipur and BARC, Mumbai. Vikram-TCR has all the traits of its parent Safri-17 along with dwarf stature, early maturity habit and high yield potential. This variety has been notified for commercial cultivation on 02nd February, 2021 by Government of India with Notification No: 456.

METHODOLOGY

Pure and healthy seeds of Safri-17 were treated with 300 Gy of Gamma rays at BARC, Mumbai and grown as M1 population at IGKV, Raipur in the year 2013-14. M1 harvested seeds were grown as M2 population during Kharif season 2014 and selections for desirable plants were done. Selected putative mutants were confirmed in M3 generation during Rabi season 2014-15 and total four promising mutants were subsequently evaluated in replicated yield trials in M4, M5 and M6 generations during Kharif 2015, Rabi 2015-16 and Kharif 2016, respectively. The promising line Safri-17-2 (Vikram-TCR) was then promoted to state MLT in Kharif 2017 and evaluated for three consecutive years. Subsequently it was submitted for AICRIP MLT in Kharif 2018 and evaluated for two consecutive years. Further, it was evaluated for blast resistance under artificial (UBN) and natural conditions at three different locations.

RESULTS

Mutation breeding has great potential to develop novel traits in any breeding line for development of new variety. Vikram-TCR is one of the miracles of radiation induced mutation breeding. It has all the unique features of its parent Safri-17 along with improved traits *viz.,* semi-dwarf stature (101-106 cm), mid-early maturity duration (118-123 days) and high yield potential (55-60 q/ha). It has 54.56% higher yield potential, - 43.79% reduced plant height and -23.64% reduced maturity duration over the corresponding parent, Safri-17. The potential yield of this variety is 73 q/ha. Under the station trial, Vikram-TCR has given 6000 kg/ha average yield at Raipur centre over the 3 years (2017, 2018 and 2019) and obtained 20.82% yield advantage over its parent Safri-17. Under state multi-location trials, Vikram-TCR gave 5244.43 kg/ha in SPVT-2 (2017), 5639.16 kg/ha in SUVT-2 (2018), and 5360 kg/ha in

SUVT-2 (2019) with average yield 5414.47 kg/ha over the three years and 18 locations (6 locations each year) and gave yield advantages up to 7.8% over IR64 and 26.3% over MTU1010. Average yield of the proposed entry IET No.27773 was 5258 kg/ha across the 43 locations of five zones during first year of testing under All India Co-ordinated Rice Improvement Program (AICRIP) in IVT- IME. It gave higher yield advantage in zone-VI (17.87%), zone-II (12.61%), zone-V (9.38%) and zone-VII (6.92%) over the zonal checks. It is highly responsive to fertilizers in respect to grain yield but not in terms of plant height. It can survive (non lodging) even after applying 150% RDF. It gave highest yield 6612 kg/ha and 6014 kg/ha in 150% RDF at Raipur and Ambikapur, respectively. Interestingly, this variety showed resistance against the rice blast in state MLT and AICRIP NSN trials which was further confirmed under artificially screening at ICAR-IIRR, Hyderabad an IGKV, Raipur. The proposed variety exhibited field tolerance to drought stress conditions and good recovery after water stresses as similar to Safri – 17. This variety has long slender grain with intermediate alkali spreading value (gelatinization temperature), intermediate amylose content and gel consistency. It has 78.80% hulling percentage, 69.30% milling percentage and 65.10% head rice recovery percentage which indicated its good grain quality features. This variety has been disseminated among the farmers of Chhattisgarh through consecutive mini-kit seed distribution program and front line demonstration program and during last Kharif season-2022, it has been grown in more than 1000 ha area of Chhattisgarh. Farmers are accepting this variety as the replacement of MTU1010 due to similarity in grain type and maturity duration with higher yield potential and many additional advantages. The area of cultivation of Vikram-TCR is likely to be expanded soon in coming years.

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Characterisation of rice landraces of NE hill region of India for yield and seed quality traits

Urmila Maibam, James M, Abhilash Behera, Wricha Tyagi, Mayank Rai*

**School of crop improvement, College of Post Graduate Studies in Agricultural Science, Central Agricultural University (I),Umiam, Meghalaya- 793103, India.*

**Corresponding author:- mrai.cau@gmail.com*

Rice is a principal crop and is the staple food of more than 50% of the world's population.Along with yield enhancement demand for good quality rice gradually increased with the improved living standard of people. Landraces are a source of unique traits harbouring unique genes for grain morphology and quality traits including amylose and protein content. Hence assessment of nutritional quality ofrice landraces will provide a valuable source for future crop improvement programmes.

METHODOLOGY

One twenty rice landraces collected from various states of NE India were purified for a seasonand further evaluation was done in field condition during *Kharif* 2021 in augmented design withfour blocks and five standard checks. Observations were recorded for 14 traits *viz*. Days to 50% flowering(DTF), Plant height (PH), Tiller number(TN), panicle length (PL), Test weight (TW), Plot yield*i.e.*, yield of 24 plants (PY), Decorticated grain length (DGL), Decorticated grain breadth (DGB), Seed length (SL), Seed breadth (SB), Filled seeds (FS), Spikelet fertility (SF), Amylose content (AC) and Protein content (PC).AC and PC was estimated by the method of Juliano (1971) and Lowry (1951) respectively.The observations were subjected to augumented design analysis to get adjusted means which was used in PCA and Wards clustering method.

RESULTS

Analysis of variance indicated that elevenout of the fourteen characters studied were significantly different.Correlation analysis revealed that PY was positively and significantly correlated to DTF (0.80**), PH (0.81**), TN (0.70**), FS (0.81**) and SF (0.73**) while it was significant and negatively correlated with AC (-0.70**) and PC (-0.68**); whereas AC was positively and significantly correlated to PC (0.94**).PCA analysis for 14 traits grouped the estimated variables into two main components which explained 80.6 % of the total variation.The genotypes were distributed into two distinct groups as observed fromPCA biplot. Yield attributing parameters like PY, TN and SF contributed positively to PC1, and the corresponding genotypes *viz*UR 95 (469.5g), Pnah Hiong(326.5g), and Chakhao Amubi(241.7g) lying on the first quadrant have high yield coupled with good TN and SF.Cluster analysis based onwards method also classified the landraces into two clusters in which high yielding genotypes like Pnahhiong and chakhao amubi were grouped in the same cluster.

CONCLUSION

From this study intermediate AC landraces likePhourennakupi (21.30%), Sang sangba (20.53%), Irrate (20.35%)andmedium PC genotypes coupled with high yield like ChakhaoAmubi (11.6%), San kang (9.6%), and PnahHiong (9%) can be used as parents in hybridisation programmes to improve the existing varieties and to develop varieties withdesirable traits.

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Genetic improvement in yield potentials, plant stature and maturity duration of three popular traditional rice landraces through induced mutagenesis

[1]Richa Sao, [1]Parmeshwar K. Sahu, [2]Suvendu Mondal, [2*]B.K. Das, and [1*]Deepak Sharma

[1]Department of Genetics and Plant Breeding, Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur-492012 (C.G.), India
[2]Nuclear Agriculture and Biotechnology Division, Bhabha Atomic Research Centre (BARC), Mumbai- 400085 (M.S.), India
**Corresponding Author's E-mail: deepak1962@igkv.ac.in (Deepak Sharma) / bkdas@barc.gov.in (B.K. Das)*

Swarming human population has set an alarm to amplify the food production and productivity in limited arable land which are being decreasing day by day due to urbanization and industrialization. Since modern varieties have limited variability therefore, utilization of rice landraces in breeding program is must. Rice landraces are the important source of several valuable genes for crop improvement except with few lacunae *viz.,* poor yield potential, tall plant stature, late maturity duration which restrict their commercial cultivation. Radiation induced mutation breeding offers simple, fast and efficient way to rectify these major defects without altering their original identity.

METHODOLOGY

The present study deployed the radiation (gamma rays @ 300Gy) induced mutation breeding for improvement and revival of three traditional rice landraces *viz.,* Samundchini, Vishnubhog and Jhilli. These landraces are admired in specific districts of Chhattisgarh (C.G.), India *i.e.* Bilaspur, Sarguja and Mahasamund for Samundchini, Vishnubhog and Jhilli respectively. Desirable mutants identified were evaluated based on 13 agro-morphological and 16 grain quality traits in M_4, M_5 and M_6 generations along with their parents and three checks *viz.,* Rajeshwari, Dubraj Selection-1 and Vishnubhog selection-1. Further SSR markers based genomic similarity and genetic diversity study was also preformed in all the mutants and corresponding parents.

RESULTS

In the present study, total 81, 98 and 51 putative mutants, respectively were identified in M_2 generation which were then confirmed in M3 generation and only three, ten and five rice mutants of Samundchini, Vishnubhog and Jhilli, respectively were advanced to M_4, M_5 and M_6 generations along with their parents and three checks for evaluation based on 13 agro-morphological and 16 grain quality traits. Interestingly, all the mutants of the three landraces showed reduction in maturity duration and plant height compared with their parents. Reduction in days to 50% flowering ranges from 4.94% (Vishnubhog Mutant V-67) to 21.40% (Jhilli Mutant J-2-13) whereas reduction in plant height varies from 11.28% (Vishnubhog Mutant V-45-2, Vishnubhog Mutant V-67) to 37.65% (Jhilli Mutant J-15-1). Furthermore, two, six and three mutants of Samundchini, Vishnubhog and Jhilli have increased yield potential over their parents, respectively. Interestingly, Samundchini Mutant-18-1 (22.45%), Vishnubhog Mutant-74-6 (36.87%) and Jhilli Mutant-13-5 (25.96%) showed highest yield advantage over their parents. Further, ANOVA based on RCBD revealed ample variations among the genotypes for studied traits, indicating the potentials of radiation in inducing the desirable variability in crop plants. In addition, all the traits consistently showed high to moderate PCV and GCV and slightly difference between them in all the three generations. Moreover, in association analysis, the traits *viz.* fertile spikelets/

panicle, panicle length, total tillers/plant, spikelet fertility percent and 100 seed weight with grain yield/plant whereas the traits, hulling (%) and milling (%) with HRR (%) were consistently showed high direct effects and significant positive correlation. SSR marker based genome similarity in rice mutants and corresponding parents ranged from 95.60% to 71.70% (Vishnubhog); 95.62% to 89.10% (Samundchini) and 95.62% to 80.40% (Jhilli), indicating the trueness of the mutants. Moreover, UPGMA algorithm and Gower distance based dendrogram; neighbour joining tree and PCA scatter diagram assured that mutants were grouped with their respective parents and fell into separate cluster showing high similarity between mutants and parents and dissimilarity among the 24 genotypes. Overall information and materials generated from current study will be very useful and informative for students, researchers and plant breeders. Besides, our results also showed that irradiation could generate a considerable amount of genetic variability, and provide new avenues for crop improvement and diversification.

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ARRW/SIRC/Theme I/55

Genetic analysis and trait association in F_2 inter sub specific population in rice

R Sangeetha, R.Saraswathi, K.Amudha and R.Rasitha

Department of Genetics and Plant Breeding, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore – 641 003

Email: rasitharahamath@gmail.com

Rice is the life and the prince among cereals as this distinctive grain helps to sustain two thirds of the world's population. To meet the indispensable demand of the constantly increasing population, improvement of the yield potential through genetic manipulation will be a key tool in rice breeding programs. Introduction of new favorable genetic material from genetically related groups of Asian rice is considered a promising approach. Rice yield can be further enhanced by exploiting the heterosis among the subspecies of rice which shows significant dissimilarities in stress resistance, quality and yield. Estimates indicate that about 30% higher yield can be obtained from the heterosis of *indica*/*japonica* varieties than those of *japonica* or *indica* cultivars (Guo *et al.*, 2016). The success of any plant breeding programme depends upon the existence of genetic variability present in a given crop species for the character under improvement which a plant breeder relies upon for ensuring efficient selection. Understanding the association of individual trait with the plant yield will be highly informative and useful along with genetic analysis.

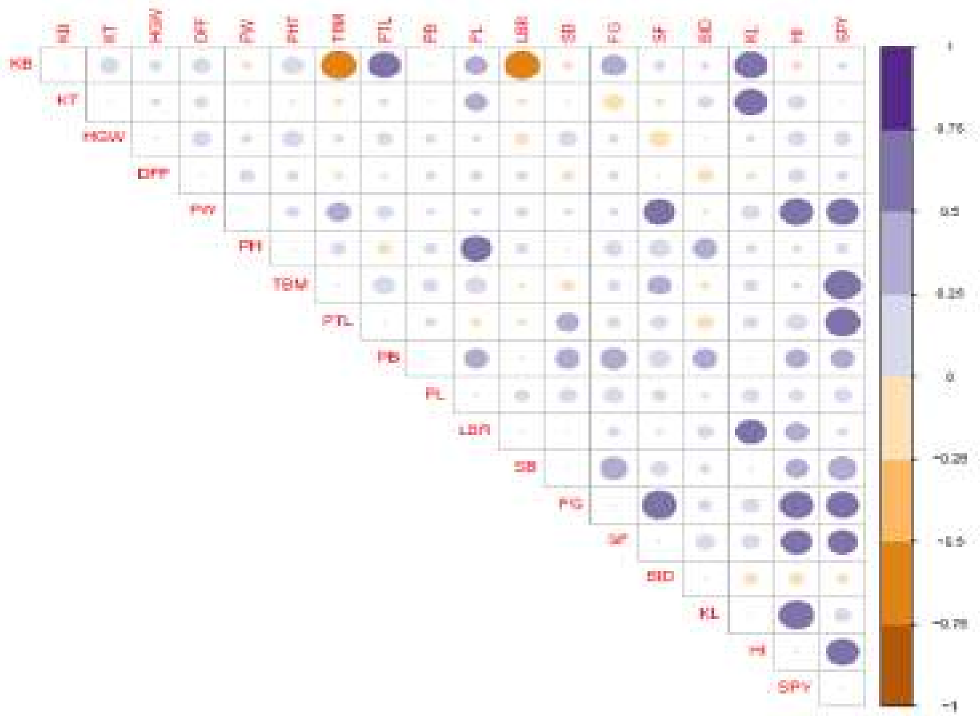
MATERIAL AND METHOD

The F_2 of cross Paiyur 1 x Nira (*indica* x tropical *japonica*) was evaluated during summer season at Paddy Breeding Station, TNAU, Coimbatore for the extent of variability and genetic parameters for 18 characters which includes, yield and yield attributing characters and physical grain quality parameters. The observations were recorded in 400 plants in F_2 population.

RESULTS

The values of phenotypic variance were greater than the genotypic variance for all the characters except for panicle weight, kernel length, and kernel breadth indicating the least/nil influence of environmental effects for these traits. High phenotypic and genotypic co-efficient of variation coupled with high heritability and high genetic advance as per cent of mean were exhibited by spikelet fertility, hundred grain weight, basal internode diameter, number of primary branches, total biomass, panicle weight, number of productive tillers, number of secondary branches, single plant yield, harvest index and number of filled grains panicle^{-1} which indicated that these traits were controlled by additive type of gene action and there is a good chance for improvement through selection.

In association studies, single plant yield was found to be determined by component traits like number of productive tillers, total biomass, harvest index, and panicle traits *viz.,* panicle length, number of primary branches, number of secondary branches, number of filled grains panicle^{-1}, panicle weight and spikelet fertility which is evident from their highly significant positive correlation (Figure 1). In path analysis, high positive direct effect on single plant was exhibited by the traits total biomass and harvest index. Number of productive tillers showed a high positive indirect effect *via* total biomass and moderate positive indirect effect on single plant yield through harvest index. Hence these traits are advocated in selection of superior single plants to further generations.



CONCLUSION

Genetic studies for variability parameters and association studies in F_2 population (Paiyur 1 x Nira) is useful for identification of promising single plants with high mean values for different traits that can be advanced to next generation. The breeding lines to be developed from the harvested F_2 and F_3 of these inter sub specific crosses is expected to realize genetic gains for yield in future that can be exploited in both varietal development programmes and in hybrid breeding programmes

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Pyramiding resistance genes for bacterial leaf blight (*Xanthomonas oryzae* pv. *oryzae*) into Pratikshya, a popular rice variety of Odisha

Madhuri Pradhan and Debendranath Bastia

Department of Agriculture and allied sciences, C.V. Raman Global University, Bhubaneswar, India[1]
Department of Plant Breeding and Genetics, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, India[2]
Email : madhuripradhan44@gmail.com

Rice being the oldest of the cereals in the world accounts for a significant contribution to the total food grain production in India. Among all the rice infecting diseases, bacterial leaf blight (BLB) is an important disease. Bacterial leaf blight disease of rice caused by *Xanthomonas oryzae* pv. *oryzae* reduces rice yield in all rice-growing parts of the world. Depending upon the stage of the crop, cultivar susceptibility, and the environmental conditions, the estimated yield loss due to leaf blight under severe infection varies from 50 to 80% in tropical Asia (Khush; 1989). To control BLB no effective chemical control measures have been found (Devadath *et al*; 1989), so deployment of resistant cultivars is the most economical and effective method to control the disease.

Gene pyramiding with help of MAS has emerged as hope for advancement of broad-spectrum resistance. Pratikshya is a late duration popular rice variety released by Odisha University of Agriculture and Technology (OUAT), Odisha, India. However, it is vulnerable to bacterial leaf blight (BLB) infection which is endemic disease to many rice growing parts of Odisha. So, for obtaining resistance in long run it is essential to opt for pyramiding multiple genes from Swarna MAS into Pratikshya genetic background. The present investigation has been done to validate and identify resistant plants to bacterial leaf blight of rice induced by *Xanthomonas oryzae* pv. *oryzae* (*Xoo*) inoculation and with help of molecular markers.

METHODOLOGY

Two varieties of rice viz., Pratikshya and Swarna MAS are used as parent. Swarna MAS collected from NRRI, Cuttack. Swarna MAS possessing (*xa5*, *xa13* and *Xa21*) was used as donor parent as it has three BLB genes. Pratikshya is used as recipient recurrent parent. The two parents Pratikshya and Swarna MAS were screened against bacterial leaf blight at the field level using the isolates of *Xanthomonas oryzae* pv. For foreground selection, SSR markers RM122, xa13prom, and pTA248 were used to identify *xa5*, *xa13* and *Xa21* genes, respectively. 45 polymorphic SSR markers were used for background selection. PCR was set up using 1 U of Taq DNA polymerase and 10XPCR buffer in 10ìl reaction volume with a thermal profile of 94°C for 5 min (initial denaturation), followed by 35 cycles of denaturation at 94°C for 30s, annealing at 50°C for 1min, extension at 72°C for 1 min and a final extension of 7 min at 72°C. The amplified product was electrophoretically casted in 3% agarose gel containing 0.5 mg/ml of ethidium bromide in 0.5XTBE buffer and visualized under UV in a Gel-Doc system and photographed. Progenies obtained from cross Pratikshya x Swarna MAS were selected for their evaluation of yield and ago-morphological traits along with recurrent parent. The mean values of agronomic traits viz., Days to 50% flowering, plant height (cm), number of tillers per plant, number of productive tillers per plant, panicle length (cm), number of filled grains per panicle, seed yield per plant (g) and 1000 grain weight (g) were recorded and evaluated.

RESULTS

Genomic DNA from the resistant parent (Swarna MAS) and susceptible parent (Pratikshya) were amplified using the three SSR markers viz., RM122, xa13prom, and pTA248 markers and concluded that all of the three bacterial leaf blight resistance genes *xa5*, *xa13*, and *Xa21* conferring resistance were present in Swarna MAS and absent in susceptible parent Pratikshya.

F_1 seeds were obtained from the cross between Pratikshya and Swarna MAS. 21 true F_1 plants were obtained and hybridized with the recurrent parent Pratikshya to produce BC_1F_1 seeds. Foreground selection was performed in 124 BC_1F_1 plants to select plants carrying *xa5*, *xa13*, and *Xa21* genes in the lines, and 68 plants were found to have all three resistant genes. Selected resistant BC_1F_1 plants were backcrossed to Pratikshya to produce BC_2F_1 seeds. Foreground selection was performed in 190 BC_2F_1 plants and 50 plants were found to have all three resistant genes. 55 plants from BC_2F_2 generation selected by phenotypic screening by artificial inoculation of *Xoo* inoculum. Seeds from resistant plants having similar agronomic characteristics to Pratikshya were raised to obtain the BC_2F_3 population. When all the markers were comparatively studied in all the plants, 19 plants possessed all three genes that conferred resistance to bacterial blight in rice.

Based on data generated by foreground selection, background selection was done using 45 SSR markers in the BC_2F_3 population to check the recovery of the recurrent parent genome. Among 19 plants, 8 plants showed the high recurrent parent genome recovery percentage of more than 90 percent.

19 three-gene pyramid lines at BC_2F_4 generation along with the donor and recipient parents were evaluated. Using mean values of agronomic traits, the statistical analysis revealed that many lines did not show any significant variation as compared to Pratikshya for most of the characters. The mean of all characters was at par with Pratikshya in most of the lines and to that of the average of the population. Many lines showed seed yield higher than recurrent parent Pratikshya. In most of the lines mean seed yield/plant was at par with the recipient parent Pratikshya. The eight lines having a parental genome recovery percentage of more than 90% were at par with Pratikshya for all the characters. The yield and agronomic traits of the three gene pyramided line in this study are similar to those of the recurrent parent, Pratikshya, indicating no yield penalty associated with the presence of three bacterial leaf blight resistance genes.

CONCLUSION

In conclusion, this study identified 19 pyramided lines, among which eight pyramided lines, having all the target genes combination, which is accompanied by high genomic recovery of recurrent parent Pratikshya. Also, some of the pyramided line showed high seed yield per plant in comparison to Pratikshya. The study showed that the introgressed lines provide broad spectrum resistance to *Xoo* strains which can be further evaluated for release of a variety and they can also be used as BLB donor for introgressing in other elite genetic background.

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Pasting and colour properties of fortified rice noodles

T B Bagchi*, G Kumar, M Sivashankari[1] and K Chattopadhyay

**Senior Scientist, CPB Division, ICAR-NRRI, Cuttack, Pin-753006, Odisha, India,*
[1]Scientist,CPD Division, ICAR-NRRI, Cuttack, Pin-753006, Odisha, India,
Email: torit.crijaf09@gmail.com

Rice noodles (RN) is popular in many Asian countries due to presence of carbohydrates that provide energy for humans. It is mostly preferable to the consumers for its good springy quality, delicious taste and high nutritional value. Viscosity and colour properties of rice flour are very important factors for making good quality noodles. Physical fortification with carrot, beat root and moringa leaves (drumstick leaf) improves the nutritional qualities of RN. These vegetables are the rich source of bioactive ingredients like vitamin-A, flavonoids, minerals and antioxidants. So fortification of RN with these vegetables made it attractive gluten free alternatives of wheat noodles.

METHODOLOGY

The ingredients for the preparation of RN were (1) Rice powder- 50g (2) Carot powder(C)/Beat root powder(B)/ moringa leaf(M) powder-2.5g (5%) (3) Xanthan gum-0.5g (4) water-40ml. For higher quantity of RN, the ingredients should be increased in this proportion. In this study, three rice varieties viz. Swarna (R1), CR Sugandhadhan(R2) and Lalat(R3) were taken and each rice varieties were fortified with these vegetables separately. C1, C2 and C3 i.e. only rice flour of R1, R2 and R3 respectively were taken as control.The pasting properties (viscosity) were measured using a RVA model Tec Master (M/S Perten Pvt Ltd., Singapore) and TCW3 software taking 3.5 grams of the sample (100 mesh size and 12% moisture basis). The colour of the RN samples was determined by CIE colour scales L*, a*, and b* using Hunter Lab digital colourimeter (Model D25M, Hunter Associates Laboratory, Reston, VA). Where L* indicates the degree of lightness or darkness of the sample extended from 0 (black) to 100 (white), a* indicates the degree of redness (+a) to greenness (-a) and whereas b* indicates the degree of yellowness (+b) to blueness (-b).

RESULT AND DISCUSSION

Pasting properties of various fortified RN were presented in Table1. Pasting viscosities signifies the interaction among various starch molecules during heating and cooling. The long internal B-chains of amylopectin exhibited higher viscosity during starch gelatinization whereas shorter internal B-chains tends to have a lower viscosity (Zhu, 2018). Peak viscosity exhibits the ability of starch to swell during initial gradual increase of temperature before physical breakdown (Delcour et al., 2010). The peak viscosity could indicate the free expansion ability of starch before rupture, which was related to the water holding capacity and stiffness of starch. It is significantly varied among the treatments and R3C, R3B and R3M showed higher peak viscosity than others i.e Lalat fortified with vegetables had higher peak viscosity. Fortified Swarna noodles showed the lowest value. In wheat noodles it was varied between 1477 to 2703 mPa.s (Di An et al.2022).The breakdown viscosity (BD) represents the stability of starch granules to resist heating and shear force, and it is the difference between peak and trough viscosity. In this case also fortified Lalat noodles showed the highest value than the others. The total set back is an indicator of the short-term rearrangement degree of starch molecules during decreasing of temperature and calculated as the difference between final and trough viscosity. Interestingly, lowest (negative) setback was observed in Lalat noodles whereas control (C1)

Table 1 Pasting properties (viscosity) (mPa.s) of rice noodles flour

Treatment Name	BD	Final	Peak	Setback	Trough	PT(ºC)	Peak Time (min)
R1C	656.00^{E}	5307.50^{AB}	4143.00^{F}	1164.50^{B}	3487.00^{A}	83.98^{B}	8.14^{AB}
R2C	1083.50^{D}	4886.50^{BCD}	4533.50^{CDE}	353.00^{CD}	3450.00^{A}	73.88^{C}	8.23^{A}
R3C	2527.00^{AB}	4461.50^{CDE}	4981.00^{A}	-519.50^{F}	2454.00^{G}	83.30^{B}	7.20^{CD}
R1B	771.00^{DE}	5240.00^{AB}	4188.00^{EF}	1050.00^{B}	3417.00^{AB}	83.23^{B}	7.93^{AB}
R2B	1571.00^{C}	5053.00^{ABC}	4805.00^{ABC}	248.00^{CDE}	3234.00^{BC}	73.25^{C}	8.14^{AB}
R3B	2539.00^{AB}	4491.00^{CDE}	5032.50^{A}	-541.50^{FG}	2493.50^{FG}	82.93^{B}	7.27^{CD}
R1M	845.50^{DE}	5015.00^{ABCD}	3996.50^{FG}	1018.50^{B}	3151.00^{C}	82.55^{B}	7.70^{ABC}
R2M	1900.00^{C}	4486.00^{CDE}	4625.50^{BCD}	-139.5^{DEF}	2725.50^{DE}	72.80^{C}	7.87^{AB}
R3M	2815.50^{A}	3842.00^{E}	4917.00^{AB}	-1075.0^{G}	2101.50^{H}	82.50^{B}	6.97^{D}
C1	808.00^{DE}	5719.00^{A}	3685.50^{G}	2033.50^{A}	2877.50^{D}	89.03^{A}	7.20^{CD}
C2	1656.50^{C}	4937.00^{BCD}	4307.00^{DEF}	630.00^{BC}	2650.50^{EF}	89.33^{A}	7.63^{BC}
C3	2336.50^{B}	4341.50^{DE}	4560.50^{CD}	-219.00^{EF}	2224.00^{H}	84.35^{B}	6.87^{D}
p-Value	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Tukey HSD 5%	340.87	709.02	351.92	543.4	193.36	2.5578	0.5598

R1= Swarna, R2= CR Sugandhadhan, R3=Lalat, C= Carrot, B= Beat root, M= Moringa leaf, C1, C2 and C3= Control (Swarna, CR Sugandha Dhan and Lalat respectively without fortification), BD=Breakdown viscosity, Final=Final viscosity, PT= Pasting temp., Peak= Peak viscosity, Setback= Setback viscosity, Trough= Trough viscosity

Swarna showed highest. In the viscosity curve, the increase of trough to final viscosity occurs as the system cools to 50°C. The composition of the paste at the trough also influences the lift-off , during which amylose molecules aggregate into a network, embedding remnants of starch granules, with proteins likely to contribute also. Highest final viscosity was observed in all the Swarna products and R2B. The pasting temperature was highest in controls as compared to fortified noodles. The quantitative colour difference of noodles was showed in Table2 and observed that L* (whiteness) and b* (yellow to blue) value was highest in carrot noodles and lowest in beat root noodles whereas a* (red to green) value was highest in carrot noodles.

Table2. Colour properties of fortified rice noodles

	L*	a*	b*	dE
R1C	45.50±1.4	16.54±0.9	42.53±1.3	66.26±0.5
R2C	43.74±1.2	17.07±0.8	39.85±1.1	65.98±0.8
R3C	45.32±0.9	16.75±0.5	40.33±1.2	65.01±1.0
R1B	27.75±0.3	13.71±0.4	14.65±0.6	68.68±1.3
R2B	26.45±0.6	14.38±0.4	13.47±0.3	69.86±1.1
R3B	27.66±0.5	13.24±0.1	11.74±0.6	68.16±0.9
R1M	35.12±0.2	2.28±0.01	21.74±0.5	62.07±1.2
R2M	30.25±0.8	2.20±0.02	20.61±0.6	66.30±0.5
R3M	30.20±0.9	2.61±0.04	20.37±0.8	66.30±1.2

R1= Swarna, R2= CR Sugandhadhan, R3=Lalat, C= Carrot, B= Beat root, M= Moringa leaf

CONCLUSION

Fortification of rice flour with vegetables powder not only significantly affects the entire sets of viscosity, it also affects the colour of the noodles. As the viscosity of RN was higher than that of wheat noodles, RN became little bit harder in nature.

** This research was performed with the help of EAP-197*

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ARRW/SIRC/Theme I/58

Genomics-assisted characterization of rice-yellow stem borer (YSB) interaction

C G Gokulan[1], Umakanth Bangale[2], Vishalakshi Balija[2], Suneel Ballichatla[2], Padmakumari Ayyagari Phani[2], Hitendra Kumar Patel[1,3,*], Sheshu Madhav Maganti[2,4,*], Ramesh Venkata Sonti[1,5,*]

[1]*CSIR-Centre for Cellular and Molecular Biology, Telangana, India - 500007.*
[2]*ICAR-Indian Institute of Rice Research, Telangana, India - 500030.*
[3]*Academy of Scientific and Industrial Research, Uttar Pradesh, India - 201002.*
[4]*Present address: ICAR-Central Tobacco Research Institute, Andhra Pradesh, India - 533105.*
[5]*Present address: International Centre for Genetic Engineering and Biotechnology, New Delhi, India - 110067.*
** Addresses for correspondence: hkpatel@ccmb.res.in, sheshu24@gmail.com, sonti@ccmb.res.in*

Yellow stem borer (YSB) is a major pest of rice in India, that can lead to 20-60% yield loss. YSB infestation is predominantly managed by the usage of chemical pesticides, which has serious implications on health and ecosystem. Effective and sustainable management of YSB infestation is challenged by the absence of natural sources of resistance. Mutation breeding provides an excellent avenue to expand the extant germplasm. The advent of ever-advancing genomics and transcriptomics approaches has accelerated plant breeding and plant biology to unprecedented levels. The results from our attempt to characterize a rice mutant line that exhibits promising level of YSB tolerance is summarized here.

OBJECTIVES

1. To identify the locus/loci associated with YSB tolerance using bulked segregant analysis in combination with next generation sequencing approaches.
2. To develop markers that co-segregate with YSB tolerance.
3. To identify putative candidate genes involved in YSB tolerance using transcriptome profiling.

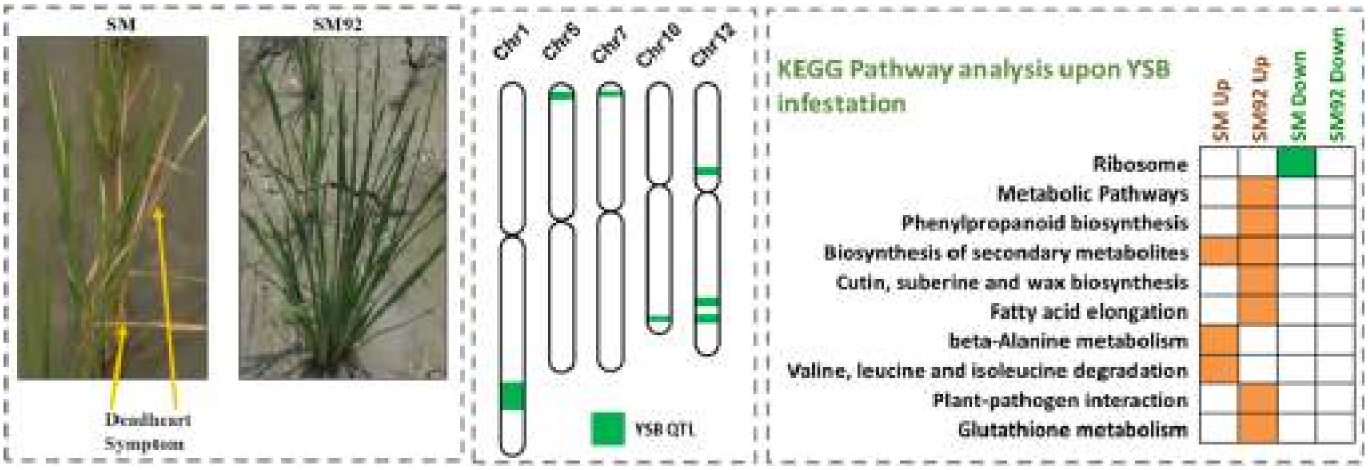
METHODOLOGY

Samba Mahsuri (SM) - an elite rice cultivar that is susceptible to YSB, and SM92 - an induced mutant of SM that is highly tolerant to YSB, were used in this study. A F_2 mapping population developed from the cross of SM x SM92 was screened for YSB tolerance during the vegetative growth stage in field conditions. Gene mapping was performed using the QTL-seq approach. To this end, two DNA bulks comprising of 21 tolerant F_2 progenies and 24 F_2 susceptible progenies were sequenced and analysed using the QTL-seq pipeline. Further, RNA samples from YSB-infested and uninfested culms of SM and SM92 were sequenced and analysed using the *STAR-featureCounts-DEseq2* pipeline for transcriptome profiling experiments. Kompetitive Allele-Specific PCR (KASP)-based SNP markers were developed and were used for genotyping the F_2 population to perform marker-trait association analysis.

RESULTS

Gene mapping and marker development : Using bulk-segregant analysis in combination with next-generation sequencing, Quantitative Trait Loci (QTL) intervals were mapped in five chromosomes of rice that could be associated with YSB tolerance. Further, marker-trait association analysis revealed six SNP markers that showed significant association (P<0.01) with YSB tolerance. These markers are located in chromosomes 1 (n=1), 10 (n=4), and 12 (n=1).

Transcriptomics : RNA-sequencing of SM and SM92 revealed a possible link between phenylpropanoid metabolism and YSB tolerance.



Multiple genes present in the candidate QTL intervals were also found to be differentially regulated upon YSB infestation. The highest upregulated gene in SM92 by YSB was observed to be located in Chr10 QTL. Structure prediction and preliminary biochemical assays indicated that the gene could be an alpha-amylase inhibitor, thus suggesting a possible mechanism of tolerance to YSB in SM92.

CONLCUSION

Taken together, this study provides notable insights on rice-YSB interaction at genomic and transcriptomic level. Importantly, a potential breeding line and markers for YSB tolerance have been developed that can aid in marker-assisted breeding.

ARRW/SIRC/Theme I/59

Phosphorus-starvation tolerance in *aus* rice (*Oryza sativa* L.) diversity panel

Rachna Deo[1], Puranjoy Sar[2], Jitendra Kuamr[2], BC Verma[2], Amrita Banerjee[2], NP Mandal[2], Somnath Roy[2]*

[1]*Department of Biotechnology, Birla Institute of Technology, Mesra, Ranchi, India*
[2]*Central Rainfed Upland Rice Research Station, ICAR-National Rice Research Institute, Hazaribag 825301, Jharkhand, India*
*Email: *sroypbr@gmail.com; Somnath.Roy@icar.gov.in*

Phosphorus is indispensable macronutrient in rice production systems as it plays a pivotal role in plant growth and development. Natural phosphorus (P) reserve is limited. Insufficient plant-available soil P is a major constraint for rice production mostly under conditions which are commonly characterized by highly acidic and P fixing soils. Therefore it is important to develop phosphorus-efficient rice varieties. Within *Oryza sativa* gene pool, the *aus* varietal group is well recognized for tolerance to low soil P conditions. A major quantitative trait locus (QTL) for P-starvation tolerance, *Pup1,* was first identified in *aus* variety Kasalath from Assam, India. Later *Phosphorus starvation tolerance 1* (*PSTOL1*), a protein kinase gene has been characterized within *Pup1* QTL (Gamuya et al., 2012). *PSTOL1* acts as an enhancer of early root growth, thereby enabling plants to uptake P from deeper soils. In addition, A few genes such as *PTF1, PHR1, PHR2, OsPTF1, OsSPX1, OsSPX2, OsSPX3, OsIPS1* and *OsIPS2* have been reported in P deficiency signalling (Wang et al., 2009). The absence of *PSTOL1* and other tolerance genes from modern rice varieties underlines the importance of exploring traditional germplasm. In this study, 181 *aus* rice accessions from the 3000 Rice Genome Panel have been screened for tolerance to low soil P based on grain yield, above ground biomass and other traits. The germplasm has been surveyed for six gene models in *Pup1* QTL as well as for the *PSTOL1* gene.

METHODOLOGY

181 *aus* accessions along with four check varieties (Vandana, Sahbhagi Dhan, IR64 and Sadabahar) were grown under low-P (8-10 ppm) and high-P (20-24 ppm) in a randomized block design. Data recorded on days to 50% flowering, early vegetative vigour, tiller no, plant height, biomass, and grain yield. Observation were recorded from 1m row plot of each of the three replications. Analyses were done for descriptive statistics including frequency distribution and normality of the traits was check using Shapiro Wilk test. The significance of difference between low-P and high-P treatments was determined using paired t test. The *PSTOL1* presence/absence polymorphism was scored using three sets of PCR primers covering different portions of the gene (Vigueira et al. 2016). Accessions that generated a negative PCR result at least twice for all three primer pairs were scored as null for the *PSTOL1*. Moreover, six primer sets, designated at core set, were also used to assess the variation within the *Pup1* QTL. Principal coordinate analysis and dissimilarly-based dendrogram were done using the scoring data.

RESULTS

Significant variation for grain yield and component traits was recorded for both low- and high-P treatments. Under low-P condition, tiller number varied from 8.3 to 124.3 with coefficient of variation (CV) of 32.7% (Fig. 1a). Accessions with higher tiller number were: Sunga wala, Bongeza, Boro275, Porashi, Kalia, Kortik Kaika,

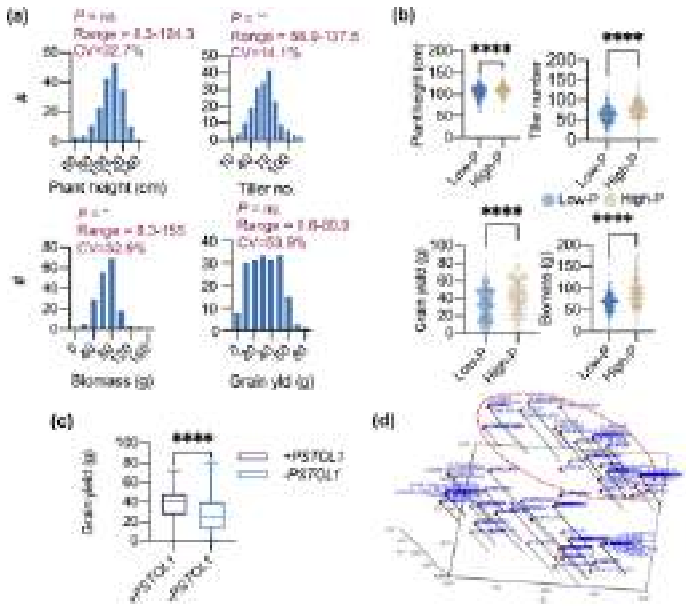


Fig. 1. Screening of *aus* rice germplasm for phosphorus starvation tolerance. (a) Frequency distribution of phenotypic traits under low-P. *P* values <0.05 (ns) indicated normal distribution using Shapiro-Wilk test; (b) Performance of germplasm under low-P and high-P conditions; (c) *PSTOL1*-positive accessions recorded significantly higher grain yield those devoid of the gene; (d) Principal coordinate analysis using *Pup1* core marker sets and *PSTOL1* genotyping data indicated two major clusters within *aus* germplasm.

Jambali and Butnapar. Grain yield showed CV of 53.9% and ranged between 0.6-80.9%. Promising accessions with higher grain yield were Kalabokri, Jasure aus, ARC12021, Devarsi, ARC7336, ARC12101, AUS329, Kada Chopa, Rani bhog, Kalia, Bak Tulsi. Above ground biomass also showed higher variation (CV = 32.9%). Pearson's correlation coefficient analysis indicated that under low-P tiller no., plant hight and biomass were positively correlated with grain yield. Except days to 50% flowering and early vegetative vigour (21 DAS), all other traits showed significant reduction under low-P conditions (Fig. 1b).

Based on genotyping with three sets of *PSTOL1*-specific markers, 85 accessions were found to be positive for the gene. The grain yield of *PSTOL1* positive accessions was significantly higher than that of accessions negative for the gene. For other traits, the presence of *PSTOL1* did not resulted in a significant higher trait values (Fig. 1c). Based on genotyping data on six core markers of *Pup1* QTL, two major groups were detected where genotypes such as Dular, Vandana and Sahbhagi Dhan, having Kasalath-type *Pup1* haplotype clustered together along with a large number of *aus* accessions (Fig. 1d).

CONCLUSION

The study identified many promising accessions for low-P tolerance which can be further characterized and used as donors. The data will be further used GWAS for identification of any new loci, other than *PSTOL1* conditioning tolerance to low-P.

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ARRW/SIRC/Theme I/60

Marker-assisted introgression of Sub1 QTL into an elite rice variety "Sabour Shree"

Sweta Sinha*, Kumar Sarvjeet, Digvijay Singh, Saurav Kumar, Yogendra Kumar, Amarendra Kumar, Suresh Prasad Singh, Satyendra, Mankesh Kumar and Prabhas Kumar Singh

Bihar Agricultural University, Sabour, Bhagalpur, Bihar-813210, India
** Corresponding author e-mail: swetabaumbge@gmail.com*

Bihar is one of the flood-prone states. Out of the 13.6 lakh hectares lowland area of rice in Bihar, around 11 lakh hectares rice growing areas are regularly affected by flood (Ismail *et al.*, 2013). The rice crop unpredictably suffers from frequent flash floods which occur mostly after the second week of August in major part of the Bihar and damages the standing crop under the current climate change scenario. Therefore, there is a great need for submergence tolerance ability in the locally adapted popular variety to sustain rice productivity in the state. To address the problem of submergence due to flash floods, work was started to improve an elite rice variety Sabour Shree for submergence tolerance through marker-assisted backcrossing approach.

METHODOLOGY

To introgress submergence tolerance QTL, the crosses were made between Sabour Shree and Swarna Sub1. For foreground selection, Sub1BC2 markers linked to submergence QTL were used to select plants possessing the Sub1 QTL (Septiningsih *et al.*, 2009). The GBS approach was used for the background selection on the selected lines.

RESULTS

The see the effect of introgression of Sub1 QTL in terms of tolerance against submergence, selected lines were screened for submergence tolerance. The recovery level in plants after de-submergence was similar to the donor parent Swarna Sub1. The maximum recovery of the recurrent parent genome in BC_2F_1 plants was 92.95%. Evaluation of the yield of advanced selected lines is being done through multi-location testing. The improved lines were found superior over the recurrent parent.

CONCLUSION

The use of molecular markers for selection facilitated screening and identification of Sub1 QTL introgressed lines with the highest proportion of the recurrent parent genome. The improved lines with submergence tolerance QTL in the background of Sabour Shree rice variety have the immense potential to help farmers in reducing losses due to submergence.

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ARRW/SIRC/Theme I/61

Development of recombinase polymerase amplification (RPA) based rapid detection protocol for aroma gene in rice

Amrita Banerjee[1], S. Bharti[2], J. Kumar[1], P. Sar[1], Priyamedha[1], N. P. Mandal[1], S. Sarkar[3], Somnath Roy[1*]

[1]*Central Rainfed Upland Rice Research Station, ICAR-National Rice Research Institute, Hazaribag 825301, Jharkhand, India*
[2]*Department of Biotechnology, Vinoba Bhave University, Hazaribag, Jharkhand 825301, India*
[3]*Crop Improvement Division, ICAR-National Rice Research Institute, Cuttack, Odisha 753006, India*
*Email: *sroypbr@gmail.com; somnath.roy@icar.gov.in*

Aromatic rice is a highly valued rice varietal group because of its pleasant and highly desirable aroma, and other grain quality traits. Aroma in rice is controlled by a recessive gene *BADH2*on chromosome 8 (Lorieux et al, 1996; Bradbury et al, 2005). The functional nucleotide polymorphism (FNP), is well characterized by three SNPs and an 8-bp deletion, in the 7th exon of *BADH2* resulting in a premature stop codon and partially truncated *BADH2* protein (Bradbury et al, 2005). In aromatic rice breeding, a number of sensory methods are adopted by the breeders to select desired lines. Molecular markers, especially functional markers linked to aroma have been developed to provide a rapid, simple and relatively inexpensive way of selecting aroma in rice samples based on the most frequent 8bp-FNP in *Badh2*. Although these markers have been widely used by rice breeders around the world, there arestill many laboratories in developing countries lacking thermal cyclers and associated instruments. Therefore, a less expensive but simple and reliable technique is required for selecting aroma. Recombinase polymerase amplification (RPA) is a robust is other malamplification method with high specificity and sensitivity. It has been utilized as an alternative to the polymerase chain reaction (PCR) in diagnostics of animal and plant pathogens. In this study, an RPA protocol has been successfully developed and validated for the detection of aroma genes in rice.

METHODOLOGY

Four pairs of primers were initially designed from the *BADH2* exon 7 spanning the 8 bp functional polymorphism following the TwistAmp assay primer design guidelines (http://www.twistdx.co.uk). The gene sequences of the aromatic cultivar Basmati385 (NCBI Accession No. JN599151) and the non-aromatic cultivar Nipponbare (NCBI Accession No. AP014964) were used to design the primers. Standard PCR was performed to evaluate the specificity and efficiency of the primers using the genomic DNA of the aromatic variety Pusa Basmati 1 and the non-aromatic variety Sahbhagi Dhan. Subsequently, the primer pair Aro-RPAF1/R1 (Fig. 1a) was selected for further experiments based on specificity and ability to generate desired amplicons.RPA was performed with the selected primer pair (Aro-RPAF1/R1) using both the genomic DNA and crude leaf extract as templates.Crude leaf extract was prepared by crushing 100 mg of leaf tissue in 500 µL of 0.5 mol/L NaOH in a microcentrifuge tube using a micro pestle and kept at room temperature for 10 min. The assay was carried out using TwistAmp® Basic Kit (TwistDx, Cambridge, UK) following the manufacturer's protocol with slight modifications.A comparison of the detection sensitivity of RPA and PCR was done using serial dilutions of genomic DNA and crude leaf extract. For further validation of the RPA assay, a panel of 27 diverse rice genotypes (consistingof 17 rice genotypes from the Basmati/Sadri group of 3000 rice genome panel, 8 aromatic varieties and 2 non-aromatic varieties) along with F_1 hybrid plants of Pusa Basmati1 × Sahbhagi Dhan were tested by RPA as well as PCR using both genomic DNA and crude leaf extract as templates.

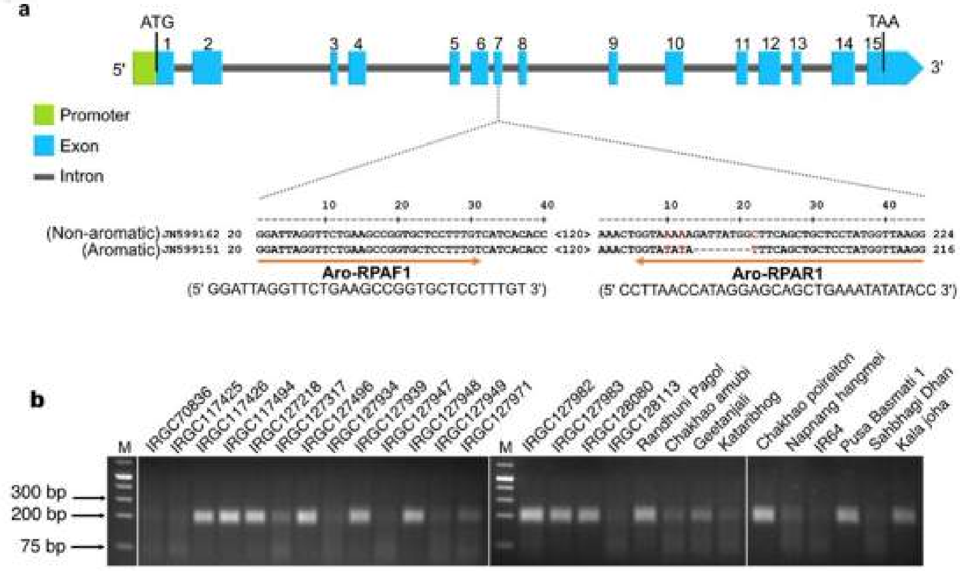

Fig. 1. Aro-RPAF1/R1 marker for detection of 8 bp-FNP in *BADH2* gene. (a) The schematic of Aro-RPAF1/R1 marker location in exon 7 of thegene. (b) Detection of 8 bp-FNPby RPA using Aro-RPAF1/R1 marker from crude leaf extract. Lane M, 100 bp plus DNA ladder (Thermo Scientific, USA)

RESULTS

In the PCR evaluation, the primer pair Aro-RPAF1/R1 successfully differentiated aromatic and non-aromatic genotypes by producing the specific amplification of desired size (197 bp) only in the aromatic genotype. To determine the effectiveness of the selected primer pair (Aro-RPAF1/R1) in RPA, a standard procedure was followed using TwistAmp® Basic Kit (TwistDx, Cambridge, UK) by taking purified DNA and crude leaf extract of aromatic and non-aromatic checks. The reaction mixture was incubated at 37 ºC for 30 min in a dry bath. To visualize RPA amplicons, 10 µL of the products were incubated at 65 ºC for 10 min prior to loading on 2% agarose gel. A desiredamplicon of 197 bp was observed only in Pusa Basmati 1 with both genomic DNA and crude leaf extract. However, a smear-like pattern was observed when the incubation step was not included. Further, the sensitivity of RPA in comparison to PCR was assessed using serial dilutions of genomic DNA (starting with an initial concentration of 100 ng/µL) and crude leaf extract up to 10^{-7}-fold of Pusa Basmati 1. The RPA showed higher sensitivity than the PCR in detecting the 8-bp FNP at different dilution levels.During validation assay, RPA using both genomic DNA and crude leaf extract showed desired amplifications of 197 bp in all the 15 aromatic rice genotypes earlier identified as carrying the8-bp FNP based on ASA marker(Fig. 1b). The RPA assay was also applied in detecting the 8-bpFNP in F_1 hybrid plants of Pusa Basmati 1 and Sahbhagi Dhan, where it resulted in a similar pattern of amplification in both hybrids and homozygous aromatic parent.

CONCLUSION

The RPA assay was more sensitive than PCR-based detection both in case of purified DNA and crude leaf extract. RPA can detect a plant gene up to 10^{-7}dilutionsof both purified DNA and leaf extract. Therefore, the developed assay will be highly useful for a rapid and sensitive selection of aromatic lines under a resource-limited setup.

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ARRW/SIRC/Theme I/62

Nutrient management practices to improve rice grain quality under the influence of short-term flooding

A.K. Srivastava[1*], Vivek Kumar Singh[1], Malay K. Bhowmick[1], P.Panneerselvam[1] and Sudhanshu Singh[1]

[1]*International Rice Research Institute-South Asia Regional Centre, NSRTC Campus, Collectory Farm, Industrial Estate, Varanasi 221006, Uttar Pradesh, India, *E-mail: a.srivastava@irri.org*

About 22 million hectares of arable lands are prone to flood/water logging in South and Southeast Asia. *SUB1*introgressed rice varieties as released in the last decade are currently available in the open domain for cultivation. These varieties have the potential to tolerate 10-14 days of complete submergence with a 1-2 t/ha grain yield advantage over the susceptible/farmers' varieties in the rainfed lowland environment. But the grain quality parameters deteriorate gradually with the intensity of the flooding stress. However, the damage is not as severe as observed in the susceptible ones. Very less information is available on how to improve the grain quality traits in the crop after recovery from the abiotic stresses. The grain quality traits are determined by the complex alleles based on different chromosomes. However, up to a certain extent, doses and time of nutrient application can impact different quality parameters as well as major yield attributes, besides ensuring quick recovery and regeneration of rice plants after submergence. One possible way is to adopt efficient nutrient management practices since the nutrients can both directly and indirectly influence the grain's physical, chemical, and organoleptic traits like grain size, shape, appearance, etc. In this view, an experiment was executed to evaluate the impact of exogenously applied inorganic and organic sources of nutrients on the recovery, yield attributes, and grain quality parameters (physical and chemical) after the imposition of complete submergence.

METHODOLOGY

The rice variety 'Swarna-Sub1' was exposed to nine different nutrient management treatments viz. T_1- Recommended dose of fertilizer (RDF; 80-60-40-5 kg N-P_2O_5-K_20-Zn/ha + 5 t farm yard manure (FYM)/ha), T_2- RDF (full dose of basal P through SSP), T3- RDF –N in four splits (30% basal, 30% at maximum tillering, 20% at panicle initiation, 20% before flowering (BF)), T4- RDF + 1% K foliar application at BF, T5- RDF + 1% $MgSO_4$ foliar application at BF, T6- RDF + 25 kg $CaSO_4$/ha basal application, T7- RDF + 1% $FeSO_4$ foliar application at BF, T8- RDF + 0.5% foliar application of Vermiwash at BF, T9- T6 + Foliar spray at BF (1% K) + 0.5% $MgSO_4$ + 0.5% $FeSO_4$)] following randomized block design in three replicates at International Rice Research Institute (IRRI)-South Asia Regional Centre (ISARC)Research Farm, Varanasi, Uttar Pradesh during the wet season of 2019. 32-day-old seedlings were subjected to complete submergence for 10 days in the outdoor pond under natural conditions. Plant height, biomass, and other phenological parameters were recorded before submergence (Bs) and just-after desubmergence (As).Survival was recorded 21days after de-submergence at recovery (Ar).Grain quality parameters (hulling%, milling%, head rice recovery (HRR) %, alkali spread value, and grain chalkiness) were assessed after harvesting following the methodology of Molina *et al.* (2019).

RESULTS

Post-submergence application of nutrients (Fe, Mg, Ca, K) through foliar spray in the submergence-tolerant rice variety under transplanted condition could produce 4-8% higher grain yield over the sole application of RDF. Among grain quality parameters, the HRR was remarkably found to

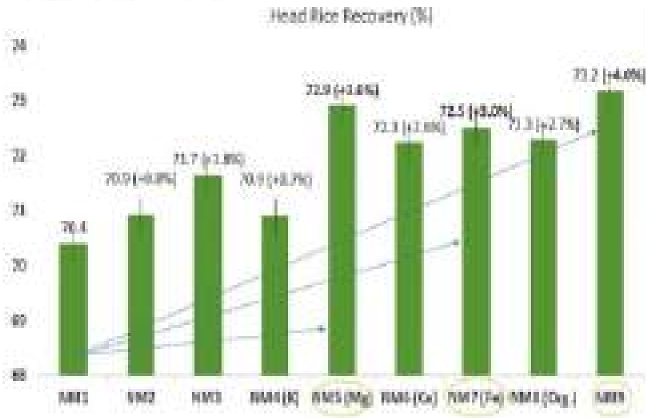

Fig. Head rice recovery (%) of the Swarna-Sub1, as influenced by different nutrients in an on-station experiment conducted at ISARC, Varanasi

increase from 3.0 to 3.6% due to foliar application of 1% $MgSO_4$ and 1% $FeSO_4$, respectively, at the heading stage (Fig.). Besides, exogenous application of nutrients was found effective in improving crop stand as well as post-submergence survival.

CONCLUSION

Nutrients in combination or alone exhibit a direct relation with grain quality traits. Application of nutrients at appropriate doses and at the right stage of crop growth can play an important role in improving grain quality as well as major yield attributes. Being an important grain quality trait, HRR plays an important role in millers' preference by fetching higher market price of the rice produced in the flood-prone environments.

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ARRW/SIRC/Theme I/63

Identification of low glycemic index rice based on types of resistant starch

Awadhesh Kumar*, Upasana Sahoo*, Monalisha Biswal*, Rameswar Prasad Sah†

**Crop Physiology & Biochemistry Division, ICAR- National Rice Research Institute, Cuttack*

†Crop Improvement Division, ICAR- National Rice Research Institute, Cuttack

Email: awadhesh.kumar@icar.gov.in; awadh_iari@yahoo.com

Diabetes mellitus is a long-term, multi-etiological endocrine-metabolic condition associated with elevated blood glucose levels. The intake of high starchy food diet is linked to a larger percentage of diabetes cases, in addition to genetic factors and sedentary lifestyle patterns. According to the IDF 2019, globally, 463 million and nationally 77 million people are affected by diabetes. Although rice is one of the world's leading food crops contributed more than 42% of calories to the human population, it also considered as high glycemic index (GI) crop and regular consumption leads to elevated risk of type II diabetes, obesity and other metabolic diseases. In this context, rice with lower GI (<55) can serve as a disease-preventive agent. Apart from the GI, non-glycemic starch fraction i.e., resistant starch (RS) content affects starch digestibility as it escapes digestion almost entirely and, therefore, its calories are unavailable for cells to use. Normally type-5 resistant starch is found in rice in which amylose and lipids forms a thermostable complex made up of hydrophobic polyglucan chains that cause slow digestion in small intestine decreases postprandial glucose and insulin responses which help to control type II diabetes.

METHODOLOGY

For this experiment, seventy numbers of ICP accessions were collected from IRRI, Phillipines and stored at 4°C. For analysis of GI and Amylose content (AC), grains were first dehusked using a dehusker followed by homogenization using an electric blender to 100 mesh size. Amylose content (AC) of the samples was determined by colorimetric measurement of the amylose-iodine complex as described by Juliano 2003. An improved *in vitro* method established in our laboratory was used for estimating GI (Kumar *et al.*, 2018). Starches were treated with starch digestive enzymes i.e., pepsin, α-amylase and amyloglucosidase (AMG) under restricted condition (dialysis membrane). Released glucose was measured at 510 nm by adding GOPOD (3 ml) to the solution. Maltose was used as standard carbohydrate. Average values were used to plot curves followed by computing area under curve (AUC). Hydrolysis index was evaluated and converted to GI using the formula given by Goni *et al.*, 1997. Resistant content (RS) was estimated using resistant starch kit, Megazyme International, Ireland. According to kit's protocol provided by manufacturer, initially non-resistant grain starch content was hydrolyzed to D-glucose by á-amylase and AMG. Then, the left-over RS pellet was treated with potassium hydroxide followed by neutralization using acetate buffer and the starch is quantitatively hydrolyzed to glucose with AMG. D-glucose was measured using GOPOD reagent.

RESULTS AND DISCUSSION

Rice genotypes recorded a wide variation in the GI values ranging from 55.58-60.95. Genotype ICP 9 showed lowest GI (55.58) while highest value was found in ICP 50 (60.95). Lowest AC was observed in ICP 50 (15.2%) having highest GI while the highest in ICP 9 (22.87%) having lowest GI (55.66) [Fig. 1]. Above result suggested that rice with higher AC generally exhibit lower GI values than low amylose genotype. Therefore, a negative correlation has been found between GI and AC which is supported by the report of Foster Powell *et al.*, 2002. Another genotype ICP 58 also showed

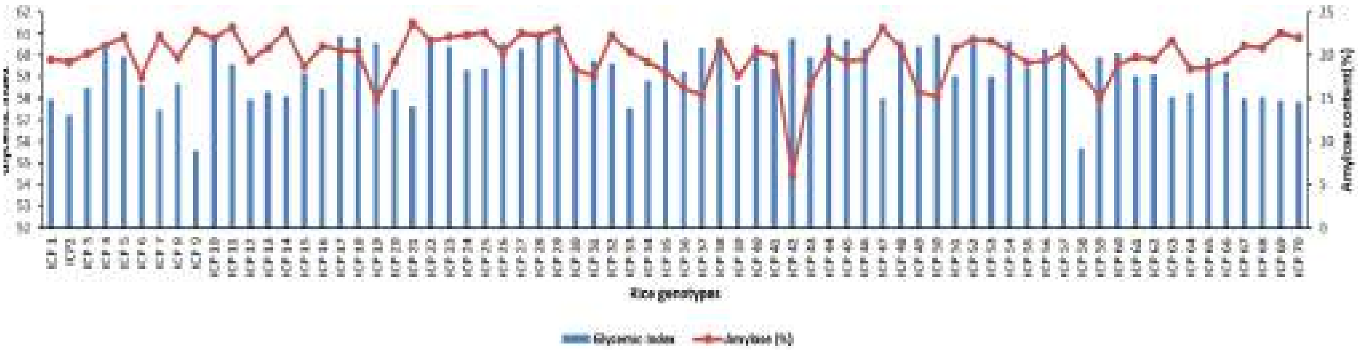

Fig. 1: Glycemic index and amylose content of 70 rice genotypes.

lower GI i.e., 55.66 and having intermediate AC. To evaluate the result, genotypes with contrasting GI and AC (ICP 9 and ICP 50) were selected along with ICP 58 (having lower GI and intermediate AC) for their RS content. Among the selected genotypes, lowest RS (0.75%) was found in ICP 50 (0.75%) while the highest in ICP 9 (1.82%). Surprisingly, ICP 58 also showed higher RS content (1.6%) . The RS present in ICP 58 might be retrograded starch (Type 3 RS) which is formed due to trimming of long amylopectin branches by the involvement of debranching enzymes (*Isoamylase* and *Pullulanase*). The linearized long chain amylopectin could behave like long polyglucan chain of amylose which helps in lowering starch digestibility. Tuano *et al*., 2021 confirmed that linearized amylopectin chain also influences starch digestibility in rice. In case of amylose rich variety ICP 58, starch digestibility reduced due to presence of type 5 RS formed by amylose-lipid complexion. Zhou *et al*. 2016 suggested type 5 RS in rice cause lowering of starch digestibility and reducing GI in genotypes having high AC.

CONCLUSION

To combat increasing diabetes cases in the rice eating countries, best possible approach is to screen and develop rice based on low GI with high RS content. In this context, rice with higher AC and RS could play decisive role in reducing diabetes cases in rice consuming population. Apart from type 5 RS, retrograded RS might also present in rice which could be consider as a prime indicator to screen low GI rice.

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ARRW/SIRC/Theme I/64

"rCCI"- a novel physiological trait for qualitative discrimination of nitrogen stress in rice using multivariate linear discriminant analysis.

A. Harika[1], Dhandapani R[1], Sudhir Kumar[1], Lekshmy S[2], Vinutha T[3], Viswanathan C[1]

[1]*Nanaji Deshmukh Plant Phenomics Center, ICAR-IARI, New Delhi, India-110012*
[2]*Division of Plant Physiology, ICAR-IARI, New Delhi, India -110012*
[3]*Division of Biochemistry, ICAR-IARI, New Delhi, India -110012*

Rice is the most important food crop produced and consumed worldwide. nitrogen is the basic nutrient input required for rice plant growth and development. However, excessive application leads to environmental concerns and production cost escalation. Conventionally, N is applied through broadcasting methods, with or without analysing the soil analysis or assessing the qualitative plant requirements. Several techniques, handheld leaf colour chart (LCC) and SPAD or CCI meters, drone imaging-based variable rate applications etc., are used for assessing plant N stress levels and calculating the dosage of N fertilizer to be supplied. In all these cases, visual colour-based indices are used for the discrimination of N stress-affected plants from non-stress (control) plants. That too mostly, leaf colour status (a proxy for leaf chlorophyll or nitrogen content) of top leaves are measured for qualitative discrimination of plant N stress level. However, it is well known that nitrogen is highly mobile within plants and typical N deficiency symptoms (such as inverted "V" shaped chlorosis from leaf tip towards the base) appears mostly in lower leaves, apart from overall full body chlorosis, stunted plant growth, reduced biomass and grain yield. In addition, the leaf colour may be affected by several factors like genotype and age; environmental conditions like sunlight, and water stress, apart from nitrogen availability. Moreover, N stress-tolerant genotypes utilise diverse adaptive strategies like nitrogen remobilisation to achieve higher N status in top photosynthetic active leaves. With all this prior-art information, very little is known about the physiological traits suitable for qualitative discrimination of plant N stress level (plant require N or not). We hypothesised to identify the novel physiological traits that can be used for qualitative discrimination of plants grown in sufficient and deficit soil N conditions, irrespective of genotype tolerance level.

METHODOLOGY

Hence, a pot culture experiment was conducted with 15 rice genotypes with contrasting N stress tolerance (7 tolerant; 7 susceptible genotypes and 1 National check for higher nitrogen stress tolerance) insufficient and deficit soil N levels during the *Kharif* season 2022. We measured around 140 phenotypic traits that were grouped into three categories morphological architecture traits (comprises of leaf system architecture, root system architecture, phenology and growth, flag leaf architecture, plant architecture traits); physiological traits (comprises of chlorophyll content, colour indices, photosynthesis traits) and yield traits. These traits were measured at a multi-temporal scale for 3-time snaps starting as early as 0, 30 and 60 DAT. Multi-traits linear discriminant analysis was preferred to use instead of principal component analysis for dimensionality reduction using JASP software as suggested by Kenobi et al., (2017).

RESULTS

The statistical analysis of trait features clearly showed that there was a significant genetic, treatment and genetic x environmental interaction effect observed in 30 and 60 DAT. Among the

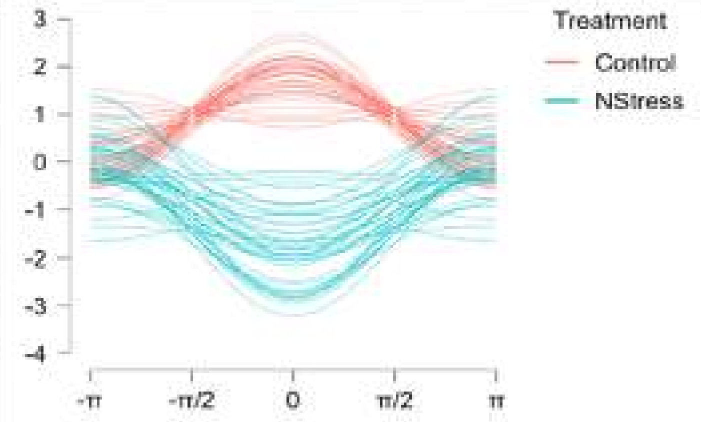

Figure 1. Andrews curve plot for visualisation of superior multi-dimensional data (rCCI and QY_BL_30)

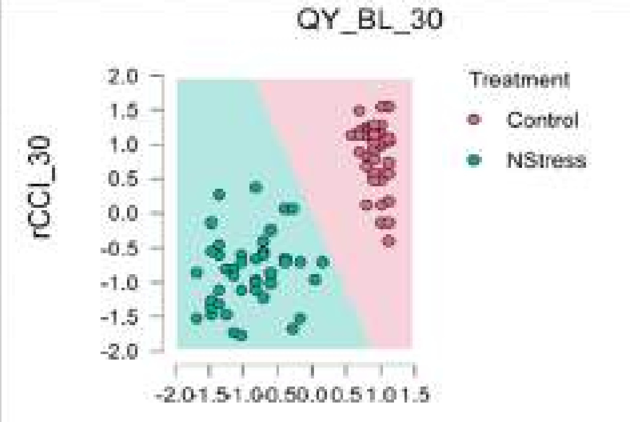

Figure 2. Decision boundary matrix for linear classification N stress level using hyperplane on rCCI and QY_BL_30

140 trait variables used for multivariate linear discriminate analysis (LDA), rCCI (relative ratio between chlorophyll content index measured in the bottom and top leaf) estimated during 30 DAT and rQY (relative ratio between quantum yield measured in the bottom and top leaf) at 60 DAT was identified as novel physiological traits for qualitative discrimination of N stress plants from non-stress rice plants. The LDA model developed was able to discriminate the rice genotype irrespective of genotypes groups as both the independent variable (rCCI & rQY) used for analysis were found to possess very high heritability, contributed highest phenotypic variance to the first linear discriminant component as it encompasses both top and bottom leaf derived constants. The linear discrimination ability of two traits viz., rCCI and QY_BL_30 were found to outperform all other traits for early stage (30 DAT) prediction.

CONCLUSION

Therefore, our result suggested using rCCI at early stage prediction and ChlF-related traits (rQY) can be used for qualitative discrimination of N stress levels at later stages in rice plants. Similarly, rCCI and QY estimated from bottom leaves were identified as the best superior traits for early prediction of N stress levels. These results may be useful for image-based high throughput phenotyping of a large set of the population to breed better rice genotypes with enhanced nitrogen use efficiency, N stress tolerance and development of precision agriculture technologies in future.

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Fine Mapping of the QTL, *qShB-1.1* Conferring resistance to Sheath Blight Disease in Rice (*O. sativa L.*) from the Cultivar CR 1014

Archana Bal, Pankajini Samal, Meera Kumari Kar, Mridul Chakraborti, Arup Kumar Mukherjee, Kutubuddin A. Molla, Lambodar Behera

ICAR-National Rice Research Institute, Cuttack-753006, Odisha, India

As food grain, rice is consumed by nearly half of the people living on different continents of the world. As the crop is grown in highly diverse ecosystems ranging from below mean sea levels to mountains and semi-arid to humid climates, the challenges for growing rice are also diverse. Sheath blight (ShB) of rice caused by the pathogenic fungus *Rhizoctonia solani* Kühn (Teleomorph: *Thanatephorus cucumeris* (Frank) Donk), has evolved as a major disease of rice, especially in the areas following intensive cultivation practices. Semi-dwarf cultivars which generally require high crop densities and higher doses of fertilizers (especially nitrogen) provide a favorable microclimate for disease development and spread. To date, fully resistant lines were not identified for this disease, only some partially resistant lines were found from the landraces and other germplasm (Molla *et al*, 2020). CR 1014, a popular low land variety developed by ICAR-NRRI, Cuttack was identified as a moderately resistant genotype against the virulent strain CRRI-RS-8 (MTCC12232, IMTech, Chandigarh) of *Rhizoctonia solani*. Swarna-Sub1 and Tapaswini are high-yielding semi-dwarf varieties, but both are highly susceptible to the disease. A stable QTL *qShB-1.1* was mapped on the long arm of chromosome 1 in $F_{2:3}$ lines of cross Swarna-Sub 1 / CR 1014 and validated in an alternative population (Tapaswini / CR 1014). The QTL, *qShB-1.1* was flanked by linked markers RM11935 (homologus position: 37.8 Mb of Nipponbare chromosome 1) and RM11968 (homologus position: 38.3 Mb of Nipponbare chromosome 1) covering ~0.51 Mb region (Bal *et al*, 2020). In the present study, the QTL region was saturated, and fine mapping was carried out to identify the putative candidate genes.

METHEDOLOGY

A total of 630 recombinant inbred lines (RILs) of cross Swarna-Sub1 / CR 1014 were further advanced for fine mapping of the QTL *qShB-1.1.* The RILs along with the parents were artificially phenotyped by using the virulent strain of the fungus. Relative Lesion Height (RLH) and disease rating score were recorded as per the Standard Evaluation System (SES) for rice (IRRI, 2002). The QTL *qShB-1.1* region was saturated by using 18 simple sequence repeats (SSR) from the Gramene database and 138 Insertions Deletions (InDels) markers from the Rice SNP-seek database. The polymorphic SSR and InDels markers found between the parent were used for genotyping of 630 RILs. Both the phenotyping and marker data of the RILs were used for QTL analysis using integrated QTL IcMapping (v. 4.0) software (www.isbreeding.net). Using the rice database RAP-DB search tool, a total of 81 genes were predicted within the region of the mapped QTL *qShB-1.1*. Out of 81 genes, 11 genes were found to be disease responsive. To study the time course gene expression analysis both the parents Swarna-Sub1 and CR 1014 were inoculated with virulent strains of *Rhizoctonia solani* under the net house condition. Leaf samples were collected at different time course intervals (0hr, 24hr, 48hr, 72hr and 96hr) of inoculation. Total RNA was isolated by using Qiagen RNAeasy plant mini kit (Qiagen, Germany), and the quantification of the extracted RNA was done by Nanodrop Spectrophotometer. A reverse transcriptase reaction was done to synthesize the cDNA of respective RNA samples using a cDNA synthesis kit. Primers were designed for 11 predicted genes using Primer 3 software.

RESULTS

A total of 156 (18 SSR and 138 InDels) markers were used to saturate the QTL *qShB-1.1* region. Out of them, 13 markers (3 SSR and 10 InDel markers) were found to be polymorphic between the parents Swarna-Sub1 and CR 1014. The polymorphic markers were used for genotyping of 630 RILs. The marker data and phenotyping data were used for QTL analysis. The result showed that the stable QTL, *qShB-1.1* was localized between the SSR marker RM11945 and RM11968 of chromosome 1 with a LOD score of 14.76 and it explained 21.89% of total phenotypic variance. A total of 81 genes were predicted using the rice database (RAP-DB) search tool, within the QTL, *qShB-1.1* region. Out of 81 genes, 11 genes (*LOC_Os01g65100.1*, *LOC_Os01g65440.1*, *LOC_Os01g65450.1*, *LOC_Os01g65450.2*, *LOC_Os01g65460.1*, *LOC_Os01g65460.2*, *LOC_Os01g65650.1*, *LOC_Os01g65800.1*, *LOC_Os01g65900.1*, *LOC_Os01g65920.1*, and *LOC_Os01g65950.1*) were found to be disease responsive. An in-silico expression profile of leaf and shoot tissues for the selected 11 genes were obtained from Rice Expression Database. Two leucine-rich repeat (LRR) motifs containing genes (*LOC_Os01g65650* and *LOC_Os01g65920*) and a Chitin-inducible gibberellin-responsive (CIGR) protein-coding gene (LOC_Os01g65900) showed high expression levels in leaf and shoot tissues. Two genes *LOC_01g65800.1* (Powdery mildew resistant protein 5) and *LOC_Os01g65450.1* (Ubiquitin-like domain-containing CTD phosphatase 1) were validated through quantitative real time PCR (qRT-PCR). The result showed that the expression of both the genes were relatively higher in case of CR 1014 as compared to Swarna-Sub1.

CONCLUSION

This study identified tightly linked molecular markers to the QTL, *qShB-1.1* and plant defense related genes involved in imparting tolerance to ShB disease from the cultivar CR 1014. The fine mapping of the QTL, *qShB-1.1* can help in precise transfer of the trait to other high yielding backgrounds.

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ARRW/SIRC/Theme I/66

Exploring variability in stomatal traits in *aus* rice germplasm under vegetative stage moisture stress

Puranjoy Sar[1], Jitendra Kumar[1], Motilal Behera[2], Koushik Chakraborty[2], Amrita Banerjee[1], BC Verma[1], NP Mandal[1], Somnath Roy[1]*

[1]*Central Rainfed Upland Rice Research Station, ICAR-National Rice Research Institute, Hazaribag 825301, Jharkhand, India*
[2]*Crop Physiology and Biochemistry Division, ICAR-National Rice Research Institute, Cuttack, Odisha, India*
*Email: *sroypbr@gmail.com; Somnath.Roy@icar.gov.in*

Stomata, the microscopic valve surrounded by guard cells, which connect plants with the atmosphere regulates the evapotranspiration and CO_2 exchange (Murchie et al., 2002). Stomatal opening enables evaporative cooling to control plant temperature under well-watered situations. Stomatal closure reduces water loss in water-limited (drought) conditions by imposing a penalty on increased canopy temperature and reduced carbon assimilation. The impact of heat stress is expected to intensify under moisture stress particularly while adopting a more water-use-efficient cultivation practices involving less water. As stomata play a fundamental role in regulating plant water use, they represent a key target for improving WUE and making rice 'climate-ready'. The *indica* rices have a higher photosynthetic rate, also associated with high stomatal density and low gas diffusion resistance, compared with the *japonicas*. Quantitative trait loci (QTL) analysis has been used to identify the genes underlying naturally occurring variation in traits (Sun et al., 2019). But, the role of identified loci in modulating density or size of stomata remains elusive. In this study, we studied the variation in stomatal features and their relationship with other physiological traits such as stomatal conductance, plant temperature, transpiration, and net photosynthesis in *aus* rice genotypes under moisture stress and normal environments. Genome-wide association study (GWAS) has been done for the stomatal features to identify any potential candidate loci.

METHODOLOGY

A total of 170 *aus* rice accessions from 3000 Rice Genome Panel (3K-RGP) were used. The genotypes were grown in *summer* 2022 in alpha-lattice design with three replication under water-stress conditions at NRRI-CRURRS, Hazaribag, Jharkhand. Stomatal imprints were made on fully expanded penultimate leaf using transparent nail polish peel offs onto microscope slides. Typically, three plants per genotype and ten measurements per leaf were examined from the central portion of the leaf, between midrib and margin. Images were taken at x40 magnification using an EVOS microscope (Invitrogen, Singapore). Stomata length (µm), area, perimeter and density (converted to mm^2) were calculated using ImageJ software. Correlation coefficient among stomatal traits and other physiological traits was worked out. The phenotype data along with ~200K SNPs of 170 rice accessions was then used for GWAS analysis in GAPIT platform.

RESULTS

Within *aus* rice germplasm stomatal traits varied considerably (Fig. 1a). Stomata density ranged from 602.8 (Bir Bahadur) to 1328 per mm^2 (DL5) with a coefficient of variation of 14.8% (Fig.1b). Popular drought tolerant cultivars such as Dular (789.5), N22 (857.9), Vandana (957.2) and Sahbhagi Dhan (844.5) showed lower stomatal density. Stomata length varied between 14.1-26.8 µm. Both stomata length and area showed high negative corelation with stomata density (Fig. 1c). Stomatal density under moisture stress was

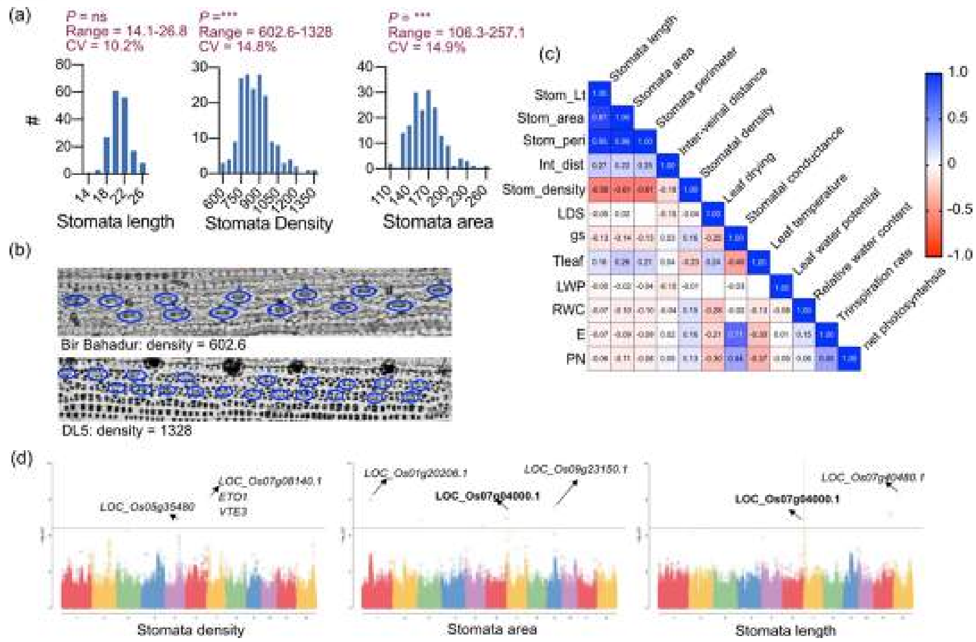

Fig. 1. Screening of aus rice germplasm under vegetative stage moisture stress for stomatal traits. (a) Frequency distribution of the traits under studies. P values <0.05 (ns) indicated normal distribution using Shapiro-Wilk test; (b) variation in stomatal density analysed using ImageJ (c) correlation among the traits under strudy (d) GWAS analysis of stomatal traits by exercising various statistical methods in GAPIT platform.

positively associated with stomatal conductance (gs), net photosynthesis (PN), transpiration rate (E) and leaf relative water content (RWC) (Fig. 1c). Stomatal density, stomata length and area were used for GWAS analyses (Fig. 1e) and we found some significant association for stomatal density i.e. LOC_Os05g35480.1 (phosphor-ribosyl transferase) and LOC_Os07g08140.1 (transcription factor) loci are identified and they are juxtaposed with *ETO1* and *VTE3*. *ETHYLENE-OVERPRODUCER1* is associated with drought tolerance and VTE3 is associated with tocopherol accumulation which acts as an antioxidant and prevents oxidative damage. For stomatal area and stomatal length some important loci (Fig. 1d) such as LOC_Os07g04000.1 (lectin-like receptor kinase), LOC_Os01g20206.1 (methyltransferase), LOC_Os09g23150.1 (hydrolase), and LOC_Os11g40480.1 were identified. These loci are involved in cell signalling, various metabolic process and they response to abiotic stimuli and provide stress tolerance.

CONCLUSION

The *aus* germplasm exhibited significant variation for stomatal traits under study. The correlation among stomatal features and other physiological traits under water stress will provide a basis for selecting stomatal features for improved drought tolerance. The preliminary results of GWAS have identified some promising candidate genes. However, further functional studies need to be carried out.

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ARRW/SIRC/Theme I/67

Evaluation of genetic variability for yield attributing traits in short grain aromatic rice (*Oryza sativa* L.) of Odisha

Binod Kumar Jena[1], Parimal Tarai[2], Swarnasarika Behera[2], Saumya Ranjan Barik[3], Paresh Ch. Kole[1], Sharat Kumar Pradhan[4]

[1]*Dept. Genetics & Plant Breeding, Palli Siksha Bhavana (Institute of Agriculture), Visva-Bharati, Sriniketan, West Bengal*
[2]*Krishi Vigyan Kendra Rayagada, Rayagada-765022, Odisha University of Agriculture & Technology, Bhubaneswar, Odisha*
[3]*ICAR-National Rice Research Institute, Cuttack-753006, Odisha, India*
[4]*Assistant Director General (FFC), Indian Council of Agricultural Research, New Delhi-110012, India*

Rice is the major food grain of more than half of the world population. Different regions of world witness remarkable difference in cultivation, consumption and commerce of rice. India occupies the highest international trade of aromatic Basmati type rice. In different regions of India different types of non-basmati short grain aromatic rice are preferred whose genetic worth has not yet been exploited for its yield advantages, quality traits and commercial value. It is pertinent to evaluate the genetic worth of local short grain aromatic rice in terms of genetic diversity and its genetic potential for yield and quality traits and to withstand different stress situations.

OBJECTIVES

- To assess the genetic variability of short grain aromatic rice genotypes to different yield and its component traits.
- To study the mean performance of genotypes with different yield and yield attributing traits.

METHODOLOGY

In this experiment 294 local short grain aromatic rice genotypes were planted in RBD with three replications with 3 row plots of 2m long with row to row spacing of 0.2m and plant to plant spacing of 0.15m with normal crop management practices at Krishi Vigyan Kendra Rayagada, Odisha in Kharif 2022. Observations were recorded on 11 quantitative traits for analysis.

RESULTS

The ANOVA of the experiment revealed that all the materials possess considerable genetic variations irrespective of any character (Borbora

Table 1. Analysis of variance of various characters (Mean sum of squares), mean, range, co-efficient of variation, genotypic and phenotypic co-efficient of variation, heritability and genetic advance in percent mean for eleven quantitative traits in short grain aromatic rice

Sl.No.	Characters	Source of variation (d.f.)									
		Replication (2)	Genotypes (293)	Error (586)	Mean	Range	CV	GCV	PCV	h^2	GA %
1	Plant Height (cm)	91.54	225.378**	24.10	103.8	72.5-135	0.84	7.89	9.2	73.57	14.47
2	Panicle Number	5.66	5.189**	0.66	8.4	5.0-12.0	1.58	14.63	17.53	69.63	2.11
3	Panicle Length (cm)	8.62	33.2**	0.87	23.05	14.3-35.5	1.46	14.24	14.81	92.54	6.5
4	Flag Leaf Length(cm)	3.78	79.872**	0.34	24.49	12.2-36.9	2.13	21.02	21.16	98.74	10.5
5	Flag Leaf Area(cm^2)	0.21	104.659**	0.03	16.83	4.54-34.52	3.54	35.09	35.1	99.92	12.2
6	DFF (No. of Days)	9.24	145.613**	0.79	112.1	93-131	4.18	6.20	6.249	98.4	14.2
7	Grains/Panicle(No.)	197.86	7506.251**	135.1	127.9	14-348	3.94	38.75	39.8	94.79	99.4
8	F%	12.32	418.723**	0.79	79.55	15.9-99.7	1.5	14.84	14.88	99.43	24.2
9	Grain Test Weight(g)	0.29	86.766**	0.06	17.99	8.5-30.8	3.02	29.89	29.93	99.78	11.1
10	Grain Yield/Plant(gm)	1.02	16.207**	0.07	7.817	2.41-17.48	3	29.67	29.86	98.74	4.75

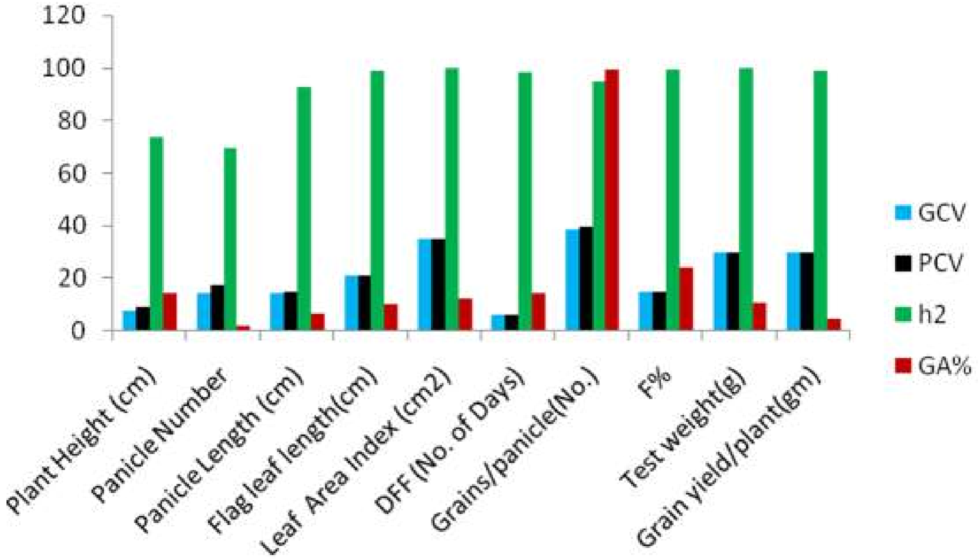

Fig.1. Bar diagram of genotypic and phenotypic co-efficient of variation, heritability, genetic advance in percent of mean for eleven quantitative traits

& Hazarika, 1998; Chaudhary *et al*., 2018). The magnitude of genetic variance was found to be highest for grains per panicle followed by flag leaf area, 1000-grain weight, grain yield per plant, flag leaf length, fertility percentage, panicle number and panicle length. The study on genotypic co-efficient of variation (GCV) in different traits maintained correspondence with phenotypic coefficient of variation (PCV) for most of the traits except for plant height and panicle number. In general PCV was higher than GCV suggesting the influence of environmental factor. PCV was found to be low (less than15%) for days to 50% flowering, plant height, panicle length and fertility percentage ; moderate (15-20%) for panicle number and high (more than 20%) for number of fertile grains per panicle, 1000-grain weight, flag leaf length, flag leaf area and grain yield per plant. It was observed that in majority of traits there were smaller differences between PCV and GCV indicating little influence of the environment and selection of these traits on the basis of phenotypic values is expected to be effective. But low values of GCV for plant height, days to 50% flowering, panicle number, panicle length and fertility percentage indicated the limited scope for the improvement of the concerned traits.

CONCLUSION

The presence of considerable amount of genetic variability in the test material provides enormous scope for selection. Traits like grain yield per plant, 1000-grain weight, number of fertile grains per panicle and flag leaf area have high genetic variations which have direct bearing on grain yield of rice may be sorted out as important selection criteria for realization of higher yield in rice.

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ARRW/SIRC/Theme I/68

Unraveling the Mechanisms of Low Light Tolerance in Rice

Darshan Panda[1], Soumya Mohanty[2], Swagatika Das[2], Sudhanshu Sekhar[2], Baneeta Mishra[1], Awadhesh Kumar[1], Devanna Basavantraya Navadagi[2], Rameswar Prasad Sah[2], Sharat Kumar Pradhan[3], Sanghamitra Samantaray[2], Mirza Jaynul Baig[1], Lambodar Behera[2*]

[1] *Crop Physiology and Biochemistry Division, ICAR-National Rice Research Institute, Cuttack 753006, Odisha, India*

[2] *Crop Improvement Division, ICAR-National Rice Research Institute, Cuttack 753006, Odisha, India*

[3] *ADG (FFC), ICAR, New Delhi*

* *Email- lambodarjamujhadi@gmail.com*

INTRODUCTION AND OBJECTIVES

Light in the plant canopy is critical because it influences the photosynthetic rate and subsequent photomorphogenesis events, modulating growth and development processes. Previous research has found a substantial relationship between rice grain yield and irradiance. Furthermore, earlier research has indicated that cumulative sun radiation of 14,000 g cal/cm2 is required for optimal grain output during the reproductive phase of rice. Low light (LL) stress occurs when sunlight is reduced to less than 1000 MJ/m2/day due to dense planting, anthropogenic air pollution near crop fields, and gloomy sky during the *Kharif* or wet season. LL is also produced as a result of density planting, climatic change, and pollution, in addition to monsoon-induced shadowing. The primary goal of our research is to elucidate the physiological, biochemical, and molecular mechanisms of low light tolerance in rice.

METHODOLOGY

The ICAR-National Rice Research Institute (NRRI) experimental plot in Cuttack, Odisha, India (20.4625N, 85.8830E) conducted field experiments on the clay-type soil of the Mahanadi delta during Rabi (January-June) and Kharif (July-December) seasons of 2021. Purnendu, GR4, Swarnaprabha, and IR8 were employed in this investigation (Panda et al. 2022). All readings occurred during reproduction. 15 days after transplantation, agro-shade nets matted on a timber frame intercepted 25% of photosynthetically active sunlight during *Rabi* and *Kharif* seasons, respectively, whereas no net was utilized for normal light (NL) conditions. Physiological traits such as total chlorophyll contents, photosynthetic rate, stomatal conductance, transpiration rate, the maximum quantum efficiency of PSII (Fv/Fm), photochemical quenching(qP), and non-photochemical quenching (NPQ) were estimated as described by Panda et.al.(2023). Grain starch(GS), sedoheptulose 1,7 bisphosphatase (SBPase) activity, and total soluble sugar (TSS) contents of leaves were estimated as described by Panda et.al.(2023). Photosynthesis-associated gene expression from the flag leaves was estimated as followed by Panda et al. (2023). Yield-associated parameters such as grain yield, total biomass, tiller number, and spikelet fertility were estimated after harvest.

RESULTS

LL-tolerant(LL-T) genotypes, such as Swarnaprabha and Purnendu, exhibited subtle changes in physiological, biochemical, and molecular features that fluctuated in LL-susceptible(LL-S) genotypes, such as GR4 and IR8. Specifically, gas exchange characteristics like stomatal conductance were reduced by about 15% and 35% in LL-T and LL-S, respectively. This was also seen in the decreased photosynthetic rate. In addition, the total chlorophyll (Chl) concentration increased as the Chl a/b ratio decreased under LL. In LL-T, the Chl increase and Chl a/b decrease were greater than in LL-S. This is concurrently accompanied by an increase in the Fv/Fm ratio, which suggests an expansion of the LHCII complex under LL. This trend of adaptation to shade in LL-T rice genotypes is further supported by a greater expression of lhcb genes under shade. With an increase in NPQ, the qP, and ETR fell. This trend was more pronounced in LL-S than LL-T genotypes. Also, the GS, SBPase activity, and TSS were reduced under LL but were maximized in LL-T genotypes compared to LL-S genotypes. The pattern of expression of photosynthetic genes in LL-T rice genotypes was indicative of greater photosynthetic maintainability under LL than in LL-S rice genotypes. This was reflected in the agronomic traits in which the LL-T genotypes had comparatively reduced grain yield than LL-S genotypes.

CONCLUSION

LL tolerance in rice is a dynamic process and is primarily orchestrated by a series of physiological, biochemical, and molecular events. LL tolerance in rice is associated with the maintenance of larger LHCII complexes with optimized stomatal conductance, photosynthetic rate, qP, and ETR. These adaptations ensure a better carbon budget under the shade that assists the plant to accumulate the required biomass under the shade.

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ARRW/SIRC/Theme I/70

Combining biotic stress resistance alongwith herbicide and abiotic tolerance in rice mega variety 'Swarna' through minimal use of molecular markers

Debajyoti Roy[1,3], Mridul Chakraborti[1], Meera Kumari Kar[1], Pritiranjan Sahoo[1], Motilal Behera[1], PankajiniSamal[1], Dipti Ranjan Pani[2] and Tapash Dasgupta[3]

[1] *ICAR-National Rice Research Institute, Cuttack, Odisha, 753006*

[2] *ICAR-National Bureau of Plant Genetic Resources, Base Centre, Cuttack, Odisha, 753006*

[3] *Ramakrishna Mission Vivekananda Educational and Research Institute, Narendrapur, Kolkata, 700103*

Rice is cultivated in the most diverse ecologies, geographical locations, and climatic conditions among all the crop plants. However, due to the challenges that arise from biotic and abiotic stresses while growing the crop, the cultivators at many times, cannot harvest the crop to its best potential. Bacterial blight (BB) disease, caused by the pathogen *Xanthomonas oryzae* pv. *oryzae* (*Xoo*), is a major disease of rice in India. Sudden submergence of rice fields due to flash floodsis one of the major abiotic stress which may lead to complete crop loss. The use of the *Sub1* gene helps to circumvent such losses. Weed management is another critical component for rice cultivation and nearly 18–48% yield loss can happen due to weed infestation alone (Grover et al. 2020).In practice, weeds are managed by keeping constant stagnant water in the field, or through manual or mechanical weeding operations. The currently available herbicides of rice can't control weedy rice (*Oryza sativa* f. *spontanea*) which is an emerging weed under direct seeded upland cultivation. Imazethapyr herbicide not only kills all the weed flora of rice including the weedy rice but also kills the rice crop itself. However, the discovery of imazethapyr tolerant mutant in rice has now made it possible to develop rice varieties that will not be killed by the herbicide (Shobha et al. 2017). The rice mega variety Swarna is susceptible to bacterial blight, flash floods, and imazethapyr herbicide. We explored the possibility of combining these traits in Swarna through indirect selection and phenotyping without using molecular markers. Thereafter, the selected plants were validated through the molecular markers.

METHODOLOGY

A popular indica rice variety 'Swarna', susceptible to submergence, bacterial blight and imazethapyr herbicide was chosen as recurrent parent or base material for the study. Near isogenic lines for flash flood tolerance (Sub), herbicide tolerance (HT) and bacterial blight (BB)resistance have been produced individually earlier at ICAR-NRRI. To create multiple combinations of the four genes (*HT/AHAS*, *Sub1A*, *xa5*, and *Xa21)*, Swarna (*xa5*+*Xa21*) and Swarna Sub1-HT near-isogenic lines (NILs)were crossed to generate ICF_1 plants. The true hybrid plants were identified and ICF_2 seeds were collected. In ICF_2 generation, the seedlings in the seed bed and plants in the main field were sprayed following a "double-killing protocol" (unpublished) standardized at ICAR-NRRI. The surviving ICF_2 plants were inoculated with a virulent *Xoo*strain and resistant plants were identified. Among the resistant plants, progenies were segregated based on their husk colour (straw white and golden brown) and single plant panicles were collected. $ICF_{2:3}$progenies were raised from those selected plants and molecular marker profiling was performed using closely linked markers/ closely linked flanking markers as well as functional markers to compare the results of selection through phenotyping and morphological markers of ICF_2 with $ICF_{2:3.}$ We also further selected NILs with different combinations of the four genes.

RESULTS

Molecular marker profiling confirmed 100% efficiency of the "double-killing protocol" to select only the herbicide-tolerant plant which is even better than closely linked marker RM6844. We recorded one plant out of 94, where the marker profile was like herbicide susceptible type, but the plant survived Imazethapyr spray. The tolerance was confirmed further through progeny testing which showed the genotype is a heterozygote for herbicide tolerance but homozygote for the susceptible allele profile of RM6844. All bacterial blight resistant plants identified in ICF_2 were carrying at least one resistant gene in desirable allelic combination (*Xa21Xa21/Xa21xa21*or*xa5xa5*) besides a few genotypes with both genes in desirable combinations. In the case of the *Sub1* gene the selection for husk colour was 100% effective like the "double-killing protocol" for herbicide tolerance. All progenies with straw-white husk were carrying the favourable functional allele of the *Sub1A* gene (*Sub1A1*) and were either homozygous or heterozygous for the *Sub1* locus. Whereas all progenies with golden brown husk were devoid of the *Sub1A1* allele. Overall, we have been able to develop Swarna genotypes with added traits of HT, HT+BB resistance, HT+BB+Sub which are of immense practical value for rice farmers of India. Additionally, the work helped us to develop an alternative methodology to combine multiple traits with minimum cost and resources in a single background.

CONCLUSION

Using an efficient low-cost strategy, we developed NILs with multiple stress tolerance in the rice mega variety Swarna. The novel strategy used in our study is equally or better effective as compared to marker-assisted selection and may be further tested in multiple varieties of rice.

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Seed Fe content and identification of superior haplotypes for Fe deficiency tolerance in rice under direct-seeded conditions

Annamalai Anandan[1], Siddharth Panda[2], Sutapa Sarkar[3], K. Bhojaraja Naik[1], Anjitha George[1], C.S. Shantharaja[1], K.V. Sripathy[1], G. Vanishree[1], Udaya Bhaskar Kethineni[1], P. Ramya[1], S. Aravindan[1] and Sanjay Kumar[4]

[1.]ICAR-Indian Institute of Seed Science, Regional Station, Bengaluru, [2.]Department of Genetics and Plant Breeding, IAS, SOA(DU), [3.]ICAR-National Rice Research Institute, Cuttack.
ICAR-Indian Institute of Seed Science, Mau, Uttar Pradesh

Iron deficiency threatens dry direct-seeded rice cultivation, especially in the alkaline and calcareous range (Pal et al. 2008). Rice secretes root exudates or phytosiderophores to facilitate the uptake of Fe from the rhizosphere. In rice, many reports have identified genes like iron-regulated transporter (IRT), vacuole iron transporter (VIT), and natural resistance-associated macrophage protein (NRAMP) that play an important role in the Fe homeostasis in the cells. The present report is one of its kind to combine the study of the effect of iron deficiency on the shoot and root system and process them in a GWAS pipeline.

OBJECTIVES

To identify genetic loci associated with nutrient use efficiency under low levels of iron and superior haplotype, suitable donors for tolerance to low levels of Fe.

MATERIALS AND METHODS

BAAP was used in the present study with 183 representatives under a controlled nutrient hydroponic system during the 2021 dry season, along with two rice genotypes RA23 (tolerant check) and Lalat MAS (susceptible check). Additionally, grain Fe content was estimated from the seeds used for sowing.

RESULTS

The percentage contribution of the genotypes for all the shoot traits was high (>80%), whereas a great variation was seen among the root traits. The percent contribution in the case of Seed Fe content was 94.3%. The population mean was 13.11 µg/g, while the RA23 had 34.9 µg/g, and Lalat MAS had 7.86 µg/g iron content. Among the shoot traits, the mean SPAD value (2nd leaf) was 6.98 (Lalat MAS – 3.57 and RA23 – 11.57), with a heritability of 95.67. The mean SPAD value of the 3rd leaf was 16.70 (Lalat Mas-14.89 and RA23-16.67), with a high heritability of 99%. This shows that the population was apt for selection under Fe deficiency. The chlorophyll index of the 3rd leaf had a significant positive correlation with leaf number (0.50) and a significant negative correlation with the Fe score (0.78) (a low Fe score indicates higher tolerance to Fe deficiency). In turn, the Fe scores positively correlated with Seed Fe content (0.72). The Fe score was significantly associated with an SNP located at 26918182bp on chromosome 8. The putative candidate gene selected for the Fe score was an ankyrin repeat domain-containing protein, LOC_Os08g42690. The gene had four nonsynonymous mutations creating four haplotypes, of which haplotype B, which had a sequence similar to Nipponbare, was significantly different and superior (mean Fe Score – 4.35) than other haplotypes. BR16, Sada Boro and DJ123 were common in all the superior haplotypes.

CONCLUSION

The present investigation is the first of its kind to report the existing variability of a diverse panel and identify putative candidate genes underlying Fe deficiency tolerance by studying shoot and root traits. The identified superior donors and haplotypes can be used to further develop lines for direct seeded rice with high Fe content.

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Genetic diversity in rice (*Oryza sativa* L.) landraces from Nagaland

Jitendra Kumar[1], Somnath Roy[1*], Bhaskar Chandra Patra[2], Uma Shankar Jogi[3], Puranjay Sar[1], Nabaneeta Basak[4], Amrita Banerjee[1], Zenwang Konyak[5], Nimai Prasad Mandal[1], K. C. Bansal[6]

[1]*Central Rainfed Upland Rice Research Station, ICAR-National Rice Research Station, Hazaribag 825301, Jharkhand, India,*
[2]*Division of Crop Improvement, ICAR-National Rice Research Station, Cuttack 753006, Odisha, India,*
[3]*Department of Biotechnology, Vinoba Bhave University, Hazaribag 825301, Jharkhand, India,*
[4]*Division of Crop Physiology and Biochemistry, ICAR-National Rice Research Station, Cuttack 753006, Odisha, India,*
[5]*Department of Botany, Kohima Science College, Jotsoma 797002, Nagaland, India*
[6]*National Academy of Agricultural Sciences, New Delhi, India*
** Corresponding authors: S Roy: Somnath.Roy@icar.gov.in*

Crop landraces are genetically diverse populations which are selected cultivated and managed by the traditional farming communities over several generations. Most of these landraces have tolerance to several biotic and abiotic stresses. The diversity in the landraces created through farmer's selection and exchange among the farming communities plays an important role in sustaining local agricultural resilience and adaptive capacity. The northeastern region of India is considered as one of the hot spots of rice genetic resources. The region is also considered as a primary center of origin of rice and estimated to possess > 10,000 indigenous rice cultivars. As a part of Indo Burma region, Nagaland is a Biodiversity hotspot. Characterization of landraces from ecologically and culturally rich regions like Nagaland is necessary to understand the environment-specific adaptation and the direction(s) of farmers' selection. In this study, we aimed to estimate the level of genetic diversity in landraces collected from Nagaland. We also analyzed how rice genetic diversity associated with ethno-linguistic and ecological diversity.

METHODOLOGY

PLANT MATERIALS AND GENOTYPING : A total of 84 rice accessions comprising of 74 rice landraces collected from five districts (Kohima, Tseminyu, Wokha, Zunheboto and Phek) of Nagaland and adjoining Mao areas in Senapati district of Manipur along with 10 genotypes as checks: 3 *indica* (N22, IR64 and Swarna), 3 *aus* (AUS257, Bhutmuri and Black gora), 3 aromatic landraces from Northeastern India (Chakhaopoireiton, IRGC117426 and Kala joha) and one *tropical japonica* (Moroberekan) were used for genotyping work. The accessions were grown in the greenhouse and one plant per accession was taken for DNA extraction. Total genomic DNA was extracted using Modified CTAB method. Thirty SSR markers selected from the 'Gramene' (http://www.gramene.org/ markers/ microsat/) GCP panel of 50 was used for PCR. Moroberekan (*tropical japonica*check) and IR64 (*indica*check) were kept as reference in PCR. The size of the amplified alleles for each SSR marker was determined.The band with the lowest molecular weight was assigned allele number 1 and the progressively heavier bands were scored incrementally.

DATA ANALYSIS : Binary data obtained from SSR were used for cluster analysis, principal coordinate analysis, construction of Neighbour-joining dendrogram, estimation of genetic distance and dissimilarity matrix. Estimation of genetic diversity including the number of alleles per locus, major allele frequency, gene diversity and polymorphism information content (PIC) values were also obtained. Pairwise F_{st}, pairwise R_{st} and analysis of molecular variance (AMOVA) were analyzed.

RESULTS

A total of 108 alleles, with an average of 3.6 alleles per locus, were detected across 84 accessions. The average expected heterozygosity (H_e) and polymorphism information content (PIC) of the markers was 0.53 and 0.48, respectively.

Population structure analysis of 84 accessions based on 30 SSR markers revealed

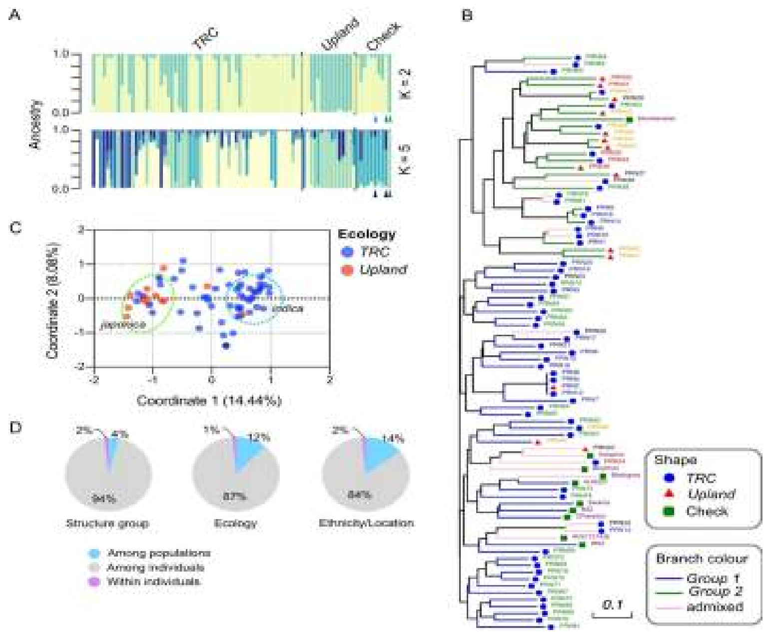

FIG. 4. Genetic structure and diversity of Nagaland landraces based on 30 SSR loci. (A) STRUCTURE analysis plots with *K* value 2 and 5. The *tropical japonica* check is marked with green triangle, while *indica* checks are indicated with blue triangles below graph; (B) Dendrogram showing the genetic similarities between landraces and checks. Classification of accessions based on Structure grouping and ecology is shown. The locations (districts) of landraces indicated by different colours: Kohima (blue), Tseminyu (black), Wokha (red), Zunheboto (orange) and Phek (green). (C) Principal coordinate analysis with two rice field ecotypes colour coded, while *indica* and *japonica* groups outlined; (D) Analysis of molecular variance (AMOVA) of landraces classified according to Structure grouping, ecology and location.

forty-one rice landraces of Nagaland clustered within one subpopulation (*Group 1*) that also included five *indica* and *aus* checks. While, 22 landraces and tropical japonica check variety Moroberekan were grouped into a second subpopulation (*Group 2*) (Fig. 1A). The remaining 10 landraces and three checks (2 *aromatic* and 1 *aus*) were identified as *admixed* sharing <70% ancestry with either group. *Group 1* consisted largely of *TRC* cultivars from Kohima and Phek districts, while *Group 2* consisted mostly of the *Upland* accessions collected from Tseminyu, Wokha and Zunheboto. When analyzed by subgroups, the rice accessions of *Group 1* showed greater diversity than *Group 2* as measured by allelic richness and gene diversity. The rice ecology based analysis revealed that *TRC* accessions harbour higher genetic diversity than those of *Upland* accessions. When classified based on ethnicity, landraces of Rengma community (district: Tseminyu) showed the highest genetic diversity followed by those from Chakesang community (district: Phek). Similar results were obtained in genetic distance-based NJ phylogeny and principal coordinate analysis (Fig. 1B,C).

A significant population differentiation was observed between *TRC* and *Upland* landraces (F_{st}=0.12 at P=0.000, R_{st}=0.11 at P=0.000). There was also significant differences at ethnicity-level except for Lotha (district: Wokha) vs. Sumj (district: Zunheboto).Analysis of molecular variance (AMOVA) indicated that theecological differences of the landraces could explain 12% of the total genetic variance, while ethnicity/ locational variation explained 14% of the total variance.

CONCLUSION

Overall, the present study area offered unique opportunity to understand the effect of ecological, geographical and social factors in shaping the genetic diversity in rice landraces of Nagaland. Further studies have been initiated to screen these landraces for various stress conditions.

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Genetic Relatedness among Multiple Sets of Donors and Recurrent Parent(s) in Marker Assisted Backcross Breeding

Lakshmidevi G#, JaiVidhya LRK#, Laxmi Bhavani P, Laha GS, Prasad MS, Padmakumari AP, Jhansi Lakshmi V, Subba Rao LV, Sundaram RM and Jyothi Badri*

ICAR-Indian Institute of Rice Research, Rajendranagar, Hyderabad
**Corresponding author Jyothi Badri: jyothirishik@gmail.com*

Marker-assisted introgression involving two elite cultivars 'Krishna Hamsa' (Badri et al., 2022) and 'WGL14' was aimed at improvement for resistance to bacterial blight (BB), blast (BL), and BPH. Along with the aforementioned three traits, two additional traits, including gall midge (GM) and drought, were also targeted in the improvement of 'WGL14'. Although the commonality in target trait and gene introgression for at least three traits and five genes for both the recurrent parents (RPs), different set of donor parents were chosen for each RP considering the morphological similarities for desirable agronomic traits between RP and donor. In the identification of polymorphic markers between RP and multiple donors, several interesting observations were made on genetic relatedness among the genotypes chosen as donors with a particular RP based on molecular marker diversity.

METHODOLOGY

Four genotypes *viz*., 'IRBB60'(G3), 'RP Bio Patho-3'(G4), 'Tetep' (G5) and 'IR71033-121-15-B' (G6) were selected as donors for MABB of 'Krishna Hamsa' (G1) while ten genotypes namely 'Improved Samba Mahsuri (ISM)'(G7), 'RP Bio Patho-1' (G8), 'RP Bio Patho-2' (G9), 'RP Patho-3'(G10), 'Rathu Heenati'(G11), 'RP5924-23' (G12), 'RP5925-24' (G13), 'IR96321-1447-561-B-1'(G14), 'IR81896-96-B-B-195' (G15) and 'IR74371-46-1-1-13' (G16) for MABB of WGL14 (G2). About 687 randomly chosen SSRs were screened among 16 genotypes to identify polymorphic markers between RPs and donors. POPGENE 32 Software (Yeh et al., 2000) was used in the calculation of genetic diversity parameters, the cervus software version 3.0.7 (Kalinowski et al., 2007) for polymorphism information content (PIC), GenAlex version 6.5 (Peakall and Smouse, 2006) for Wright's Fixation index (F), The NTSYSpc version 2.0 (Rohlf, 1989) for the genetic relatedness and SAHN module (Sequential, Agglomerative, Hierarchical, and Nested clustering) (Sneath and Sokal 1973) for the phylogenetic relationships.

RESULTS

Parental Polymorphism for background selection: Of the 687 SSR markers, 375 amplified ranging from 19-45 with an average of 31 markers per chromosome. Maximum polymorphism (8-16 markers) was observed on chromosomes 1 and 4 in almost all donors (11) with their respective RPs except in G4, G7 and G9 on chromosome 1 and in G4, G6 and G7 on chromosome 4. Up to 15% (12.53-15.47%) were found polymorphic, with 47, 51, 58 and 54 markers showing polymorphism between G1 and G3, G4, G5 and G6, respectively. Seven SSRs *viz*., RM 3549 on chr-1, RM 16591, RM 8072 and RM16642 on chr-4, RM 25187 on chr-10 and RM 26200 and RM 332 on chr-11 were polymorphic between G1 and all the four donor parents. The % polymorphism between G2 and ten donors (G7 to G16) varied between 4.53 (G7) and -20.53 % (G11) with 17, 58, 54, 62, 77, 75, 65, 71, 71 and 75 markers showing polymorphism between G2 and G7, G8, G9, G10, G11, G12, G13, G14, G15 and G16 respectively. Low polymorphism (4.53%) was observed between G3 and G7, indicating the highest similarity level. Three markers RM 3643, RM 258 and RM 332 on chr-4, 10 and 11, respectively were the common markers polymorphic between G3 and all the ten donor parents. In all, 174 SSRs (46.4%) were polymorphic, with an average PIC of 0.38 and a total of 480 alleles. Only 40 loci (22.98%) were with PIC >0.5, while 134 (77%) were with <0.5 and RM 28357 was with the highest PIC (0.72). Observed Heterozygosity (Ho), Expected Heterozygosity (He), Observed homozygosity, expected homozygosity and F values ranged from 0.0-0.625, 0.12-0.76, 0.375-1.000, 0.22-0.88 and 0.03-1.0 respectively.

The genotypes were grouped into three major clusters, I, II and III at a similarity coefficient value of 0.66 (Fig 1). Cluster I consisted of G1, G3 and G6 with a similarity coefficient (SM) of 0.68 and G1 and G3 within had an SM of 0.73. Cluster II consisted of G5 and G4 with an SM of 0.69, G2, G7 with SM of 0.83, G9 and G11 with SM of 0.71 and G12 and G13 with a SM of 0.84 which is the highest among the population. Cluster III consisted of G14, G15, G16, G10 and G18 with a SM of 0.77 between G14 and G15 and SM of 0.76 between G10 and G8. The SM of G2 and its crossing set ranged from 0.61 to 0.83, whereas G1 and its crossing set from 0.58 to 0.73.

CONCLUSION

In the present study, donors were chosen that have a close morphological resemblance to the RP as the selection of the donor parent is critical to minimize the breeding population for MABB and to reduce the period for NIL development. The pairwise comparisons indicate 'IRBB60' and 'ISM' as ideal choices of donors in the improvement of 'Krishna Hamsa' and 'WGL14', respectively. The same is the case with donors for BL resistance genes. Also, it is interesting to observe the clustering of 'WGL14' and 'ISM' in one cluster and 'Krishna Hamsa' and 'IRBB60' in another cluster in the dendrogram. When multiple trait combinations are targeted into a single background, the most important factor to be considered in the choice of donors is the proximity/relatedness of the donors with the recurrent parent for ease in background recovery and to avoid background noise and linkage drag.

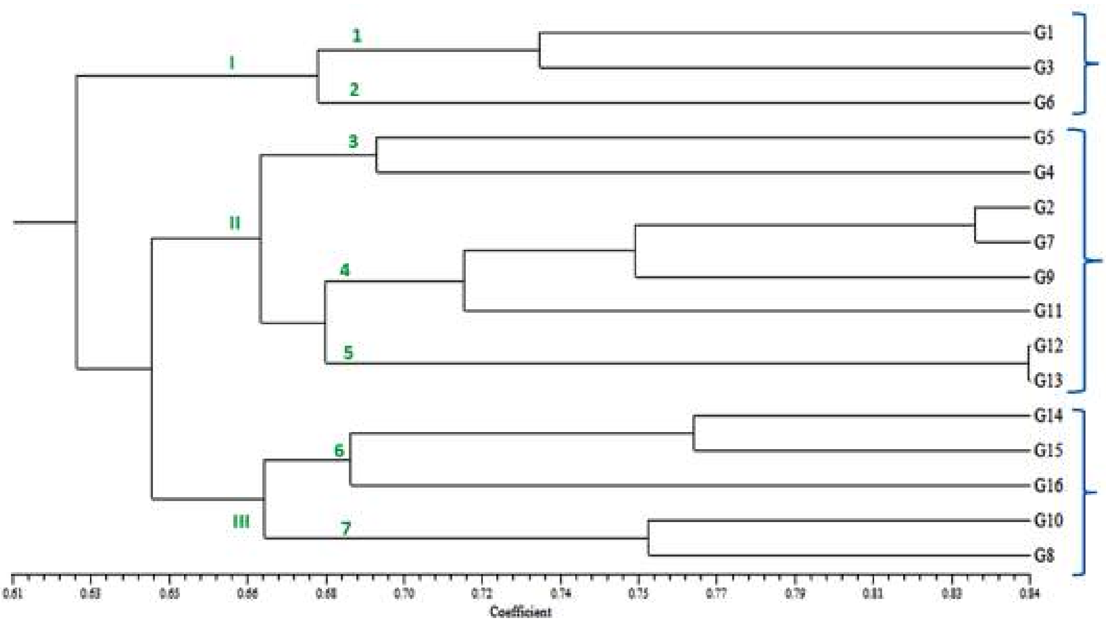

Fig 1. Genetic Relationship among the donors and recurrent parents estimated using

Unbiased Neighbour-Joining dendrogram. G1: Krishna Hamsa; G2: WGL14 (Warangal Samba); G3: IRBB60; G4: RP Bio Patho-4 (IR 64 NIL with *Pi2*); G5: Tetep; G6: IR 71033-121-15-B; G7: Improved Samba Mahsuri (RP Bio 226); G8: RP Bio Patho-1 (B95-1 NIL with *Pi2*); G9: RP Patho-3 (Samba Mahsuri NIL with *Pi54*); G10: RP Bio Patho-2 (B95-1 NIL with *Pi54*); G11: Rathu Heenati; G12: RP 5924-23; G13: RP 5925-24; G14: IR 96321-1447-561-B-1; G15: IR 81896-96-B-B-195; G16: IR74371-46-1-1-13

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Aluminum toxicity in rice: the north-east India

Akib Ali[1] and Bijoya Bhattacharjee[1]

Division of Crop Sciences, ICAR Research Complex for NEH region, Umiam, Shillong, Meghalaya- 793103, India

Aluminum (Al) toxicity is the most significant contributing factor impeding crop production on 67% of the total acid soil area in the world. Although rice (*Oryza sativa*) is Al toxicity tolerant crop, it shows considerable variations among rice genotypes to Al exposure. Therefore, it is pertinent to understand Al toxicity and underlying mechanisms for Al tolerance in rice. The North Eastern (NE) region of India is considered as a Centre of diversity of rice; as rice accounts for 80% of the food grain production in this region. However, excessive rainfall in NE region is key factor in leaching basic cations from soil, thereby reducing pH of the soil. About 21 million ha of total land area is acidic in nature,with maximum area under Arunachal Pradesh (6.8Mha) followed by Assam (4.7Mha), Meghalaya (2.2 Mha), Manipur (2.19Mha) and Mizoram (2.0Mha). Although aluminum toxicity has one of the active interests in research for increased yield in rice, however, a proper diversity study, physiological, molecular and genetic basis to understand Al toxicity in rice is still sparse.

OBJECTIVE

To enumerate key aluminum responsive genes and identify potent Al-toxicity tolerant indigenous rice lines from North-East India.

MATERIALS AND METHODS

Sixty three (63) rice lines (*Oryza sativa* L.) were collected from ICAR Research Complex for NEH Region, Meghalaya, India. Healthy grains from each rice line were surfaced sterilized and germinated. Seedlings were then transferred to half strength Hoagland nutrient solution. Al treatment was done by adding 0(control), 25, 50, 100 and 200μM $AlCl_3$ to fresh pre-treatment solution containing 500 μM $CaCl_2$ (pH 4.2) for 48 hours. The fresh weights, dry weights and root

Fig. 1 : Seed germination analysis of rice germplasm /lines grown in nutrient solution supplemented with 200 ìM Aluminum concentration; rice genotypes: 1. Anjali, 2. Chankimaso, 3. Moiramsbhi, 4. Col- 4, 5. Ching, 6. Vl-31329, 7. Ir1552, 8. Shaku, 9. Michiying, 10. Assam, 11. Dhao Tipnuakulon, 12. Bhalum-3, 14. Lespah 15. Vr-14, 16. Vl - 31331, 17. Zam 18. Sanri Fiirii 19. Pancoas 20. Bhalum-1, 21. Upr 2992-17-3-1, 22. Upr 2919-14-1-1, 23. Likhamo, 24. Asukni Maghowa, 25. Ioro, 26. Longpa, Tsuk, 27. Merangkong, 28. Konpemo, 29. Michiying, 30. Motodhan, 31. Rcpl- 13, 32. Yimyu, 33. Mange, 34. Ioro 35. N-861, 36. Vietnam – 1, 37. Khasha, 38. Hahsho, 39. Tsaknak, 40. Khougjai Phou, 41. Kasalath, 42. Tsamu Fiirii, 43. Posimot, 44. Vietnam – 3, 45. Gobindobhog N-861 47. Bang Nayk, 48. Skau-390 49. Kalojeera 50. Aaha, 51. Silky Rice, 52. Kenasu Kedowa, 53. Koyabo, 54. Akiyiuti Ashe 55, Epyo, 56. Ir 72, 57. Satabdi, 58. Meyisao, 59. Nung Khum, 60. Bpt - 5204, 61. Yimya Mapok 62. Sang Chang, 63. Idaw

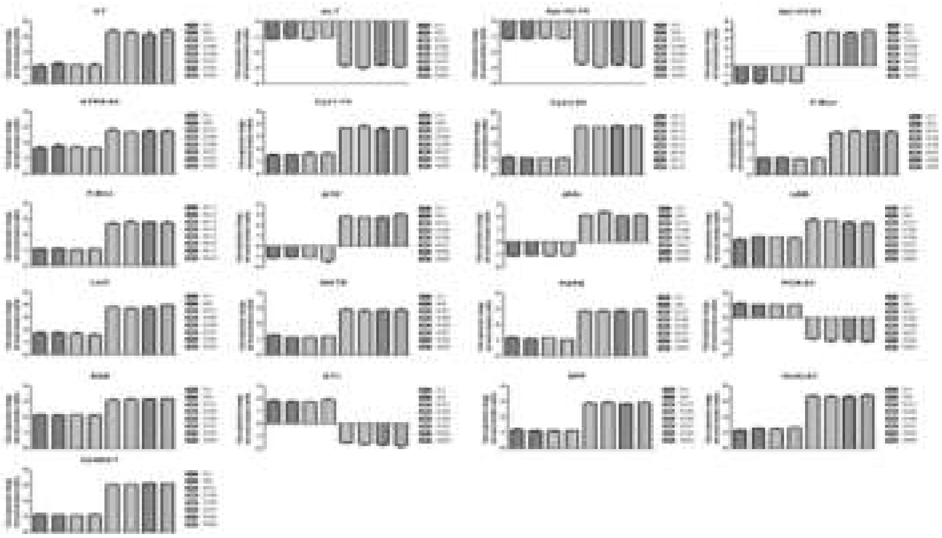

Fig. 2: Al-induced fold expression changes (with mock-treated control) of Al-responsive genes viz., ALT, Alanine aminotransferase; AT, Putative anion transporter; ATPS, ATP sulfurylase; CYS1, an isogene of cysteine synthase; CYS3, an isogene of cysteine synthase; F-box,F-box domain protein; Apr-02, an isogene adenosine 5'- phosphosulphate reductase; Apr-03, an isogene adenosine 5'- phosphosulphate reductase; GTF, Putative glucosyltransferase; IPPI, Isopentenylpyrophosphate isomerase; LRR, Leucine-rich repeat family protein; Lsi2, Silicon efflux transporter; MATE, Multi-drug and toxin extrusion transporter; NRAT1, Nramp aluminum transporter 1; OsALS1, ABC transporter; PAPS, Purple acid phosphatase; PCS, phytochelatin synthase; SQS, Squalene synthase; ST1, Putative sulphate transporter 1; ZFP, Zinc finger protein-like in rice genotypes. Rice genotypes: S1,S6, S31, S38, S47, S56 and S60 were interchangeably written as AL1, AL2, AL3, AL4, AL5, AL6, AL7 and AL8 respectively.

lengths were taken to estimate the relative root length (RRL), relative tolerance index (RTI), Root Relative Water Content (RRWC) and relative root reduction (RRR%). Total RNA was isolated from the fresh root tissues of Al toxicity susceptible and Al toxicity tolerant rice lines using Trizin (GCC Biotech, India) as per manufacturer's protocol. cDNA synthesis was carried out with oligo-(dT) primer using R2D cDNA Synthesis Kit (GCC Biotech, India). Reliability of the potential reference gene ensured by the expression profile of twenty one genes and normalized with the most stable reference gene as determined by geNORM v3.4. The relative expression of data were calculated using the formula $QR=2^{-(ÄÄCT)}$. Each experiment was performed with three technical and three biological replicates

RESULTS

Rice genotypes screened under Al stress showed significant physiological variations. While 'Motodhan' was found most tolerant, 'Lespah' was one most susceptible genotype. Amongst 21 differentially expressed genes studied, qRT-PCR revealed 16 novel candidate genes, while five genes have been previously known as Al regulated. Patterns of gene expression, mechanisms of Al toxicity and tolerance suggest that genes associated with cytoskeletal dynamics, metabolism, ion transporter could play major roles in Al adaptation and/or tolerance in rice.

CONCLUSION

The Al toxicity tolerant/sensitive rice lines and transcripts analysis of potential marker genes further can used to study functional genomics and in breeding program for transfer of the selected trait to the popular varieties which are Al sensitive for upland area of North East India.

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ARRW/SIRC/Theme I/75

Fine mapping of *qDS3.1*, A novel QTL to breed brown planthopper resistant rice varieties

G. Padmavathi[1]*, B. Umakanth[1], V. Jhansilakshmi[1], M. Sheshu madhav[2] and R.M. Sundaram[1]

[1.]ICAR-Indian Institute of Rice Research, Hyderabad, Telangana-500030, India
[2.]ICAR-Central Tobacco Research Institute, Rajahmundry, Andhra Pradesh-533105, India

Brown planthopper (BPH) is the most devastating and rampant pest of rice worldwide, which causes 100% yield loss under severe infestation. Many of the forty-two reported BPH resistance genes are ineffective against India's most virulent biotype 4 of BPH. Hence it is indispensable to identify novel and potential resistant loci for deployment in rice breeding programs. Identification of BPH resistance-linked markers facilitates accelerated varietal development through marker-assisted breeding. Hence we report here the fine mapping of a previously identified major QTL (*qDS3.1*) employing genotyping by sequencing (GBS) method for deployment in future rice breeding programs.

METHODOLOGY

A mapping population consisting of 135 Recombinant Inbred lines (RILs) derived from a cross between Swarna (a susceptible mega variety) and Sinnasivappu (BPH-resistant donor) was developed through single seed descent method. They were screened for their response to BPH under controlled conditions during the seedling stage. Further, they were genotyped using the GBS approach (Elshire et al., 2011) on an Illumina HiSeq system. Both SNP marker data and phenotypic data on damage scores were analysed for QTLs using QTL IciMapping V4.1 software (Wang et al., 2016). The QTL region was further

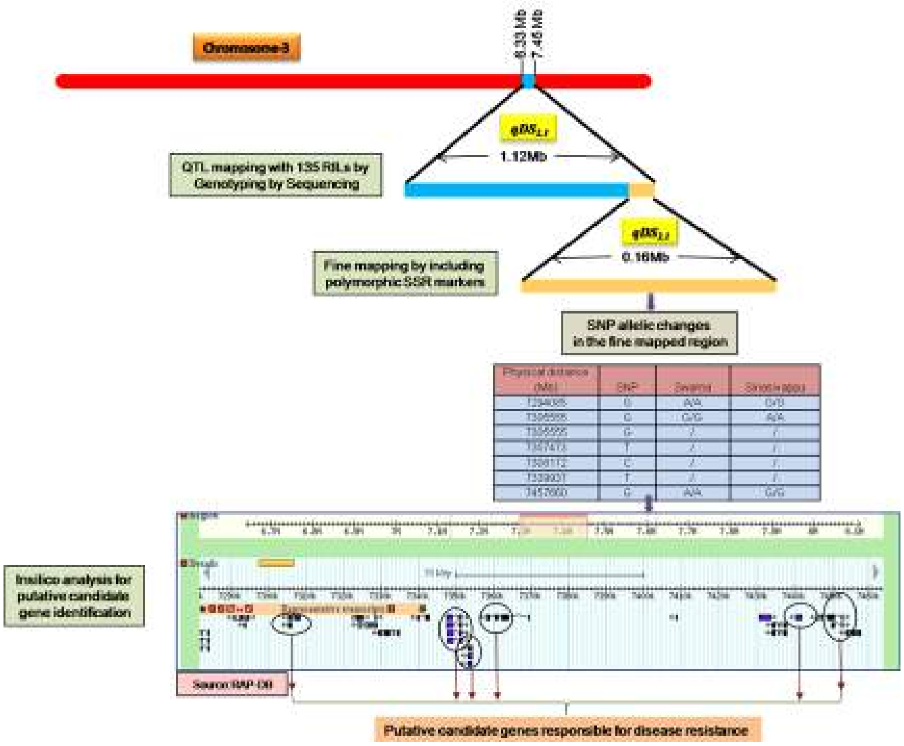

Fig 1: Flow chart representing the mapping of *qDS3.1* for BPH resistance

fine-mapped using polymorphic SNP markers spanning the QTL.

RESULTS

A high-density genetic linkage map of 21,237 cM length with an average marker density of 5.86 cM was constructed. The QTL analysis using SNP data and damage scores identified a major QTL for BPH designated as *qDS3.1* flanked by SNP markers C3_6332631 to C3_7457660 (1.12 Mb) and explained 13% of the phenotypic variation. The *qDS3.1* region is further narrowed down from 1.12 Mb to 0.16 Mb between two SNP markers, C3-7294085 and C3-7457660, exhibiting a phenotypic variance of 12.1% (Fig 1). Fourteen candidate genes for BPH resistance were predicted within the *qDS3.1* locus, of which 6 have a biological function, viz., Inositol polyphosphate-related phosphatase, Zinc finger (C2H2), Zinc finger (PHD type), Zinc finger (RING/FYVE/PHD-type), Basic-leucine zipper (bZIP) transcription factor, and Like-Sm ribonucleo protein (LSM) domain that plays a key role in regulating the plant's defence against biotic stresses.

CONCLUSION

A novel and major QTL *qDS 3.1* for BPH resistance was fine-mapped to a 160 kb region. The identified resistance-linked SNP markers, C3-7294085 and C3-7457660, could be utilized for the introgression of *qDS3.1* into popularly grown BPH-susceptible rice cultivars, thereby developing resistant varieties through marker-assisted breeding.

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ARRW/SIRC/Theme I/76

Development and validation of HS-SPME- GCMS/MS Method for Quantification of 2-Acetyl-1-pyrroline in Rice Cultivars

Totan Adak*, Arabinda Mahanty, Sutapa Sarkar, Nabaneeta Basak, Gaurav Kumar, Priyadarsini Sanghamitra, Torit Baran Bagchi, Mridul Chakraborti

ICAR-National Rice Research Institute, Cuttack, Odisha, India-753006
Email : Totan.Adak@icar.gov.in | totanadak@gmail.com

2-Acetyl-1-pyrroline (2-AP) is the principal compound that contributes to aroma in rice. 2-AP is a chemical that emits a buttered-popcorn-like aroma at specific concentrations. The commercial significance of accurate and simple quantification of 2-Acetyl-1-pyrroline (2-AP) cannot be overstated. Present study was carried out to standardize a method for extraction and accurate quantitation of 2-AP from rice grain using GC-MS/MS equipped with HS-SPME auto sampler. The effect of sample quantity, addition of solvent, grinding process, sample particle size, head space parameters and SPME fiber incubation parameters, were optimized in the developed method.

METHODOLOGY

Identification and quantification of 2-AP was done using GC-MS/MS (Trace 1300-TSQ 9000, Thermo Scientific, USA) equipped with HS-SPME auto sampler (TriPlus RSH, Thermo Scientific, USA) and a capillary column (TR-WAXMS; length: 30 m, i.d.: 0.25 mm, film thickness: 0.25 µm) (Fig 1). Optimization of the method was carried out with respect to sample weight, grinding method (with or without addition of liquid nitrogen while grinding), sieving, temperature of incubation, duration of incubation, adsorption time. Absolute area count was used as a measure of the quantity during optimization. The developed method was

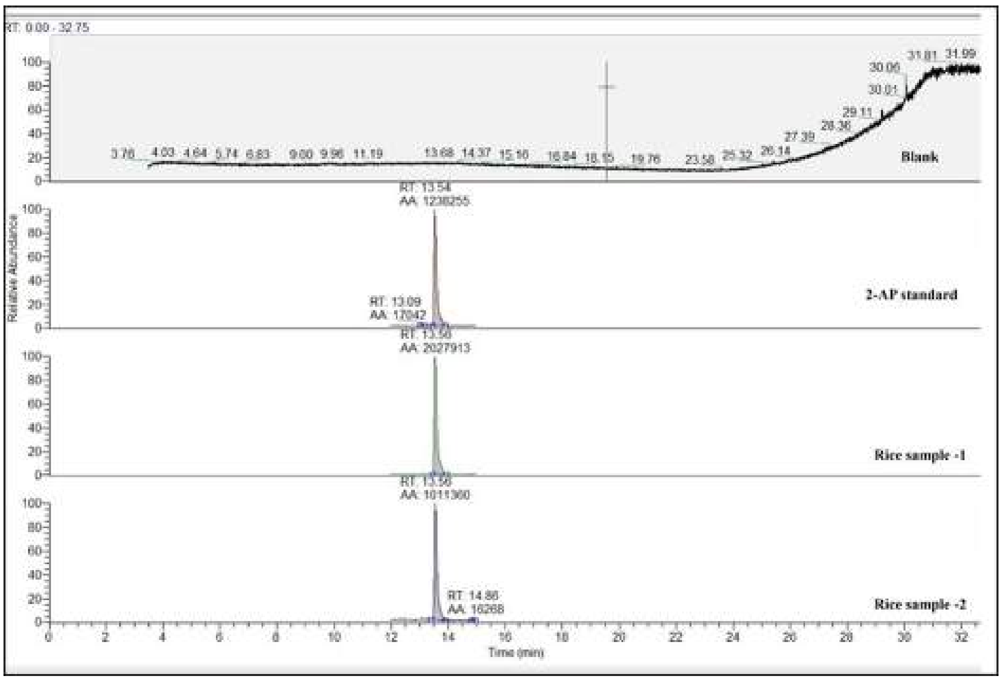


Fig 1. Chromatogram of 2-AP in standard and rice samples

validated by further applying it for quantification of 2-AP in four Basmati varieties and two purified sorts of *Gobindobhog* landraces.

RESULTS

Dehusked rice powder (2 g) prepared under liquid nitrogen, and passed through the 80-mesh sieve, incubated for 40 minutes at 80°C in headspace, followed by fiber (DVB/Carbon WR/PDMS) saturation time of 15 minutes, could produce the maximum response. The recovery of 2-AP from fortified sample ranged between 7.02-9.02% at 50-200 ng g^{-1} fortification irrespective of the grain matrices used. Standard addition method was appropriate to overcome the matrix effect and recovery of 2-AP was more than 90% using this method. The developed method was further utilized for quantification of 2-AP in four Basmati and two non-Basmati aromatic rice samples. The content of 2-AP ranged between 57.17-147.10 ng g^{-1} of rice and varied with geographical location.

CONCLUSIONS

Standard addition method could recover more than 90% of the 2-AP from rice matrices and the method is validated using major aromatic rice varieties to quantify the 2-AP content. As the extraction step is fully automated, the method could improve the work efficiency and reduce error during 2-AP estimation. The method could effectively be used for the screening of aroma (2-AP) content in different rice varieties. The established method further could help in promoting rice varieties in export market.

ARRW/SIRC/Theme I/77

Development of hybrid for BLB and Herbicide Tolerance in Rice

Somyashree Mishra, Ram Lakhan Verma*, Debarchana Jena, Awaneet Kumar, Arpita Mohapatra, Diptibala Rout

National Rice Research Institute, Cuttack, Odisha, India

[1]Dept. of Genetics and Plant Breeding, Institute of Agricultural Sciences, Siksha 'O' Anusandhan Deemed to be University, Bhubaneswar, Odisha, India

somyashree199@gmail.com | ram.pantvarsity@gmail.com

Bacterial leaf blight of rice is known to be one of the most devastating pathogens of rice in nearly all the rice-growing parts of tropical and temperate regions, especially in Asian countries. The pathogenicity of bacterial leaf blight has confirmed that the causal bacterium is named *Xanthomonas oryzae pv. oryzae* (*Xoo*). BLB infection causes leaf blight and seriously affects the growth of rice plants, leading to yield losses of nearly 10% in rice production and even up to 50–60% in its severe form. At present, 45 BLB resistance genes have been identified in diverse rice sources. Among these genes, Xa23 is a major disease-resistance gene identified from wild rice (*Oryza rufipogon*) and was found to act in a dominant manner and confer strong resistance to all naturally occurring biotypes of *Xoo* at all developmental stages. Another major yield reduction reason in rice crops is weeds.

Weeds compete with rice for nutrients, water, sunlight, and space. The presence of weeds also increases the occurrence of diseases and insect pests. These problems lead to varying degrees of reduction in rice yield and grain quality. It was reported that the rice yield could be reduced by more than 40% due to weed damage. As urbanization speeds up, a large number of laborers are flowing to cities and adding to labor shortages in rice-growing areas. Traditional measures to control weeds in rice fields include a combination of tillage, irrigation, and hand-weeding, which require extensive labor and other resources. The rational utilization of herbicides is the most effective way to weed control. However, most of the herbicides that kill weeds in rice fields also cause certain damage to the rice.

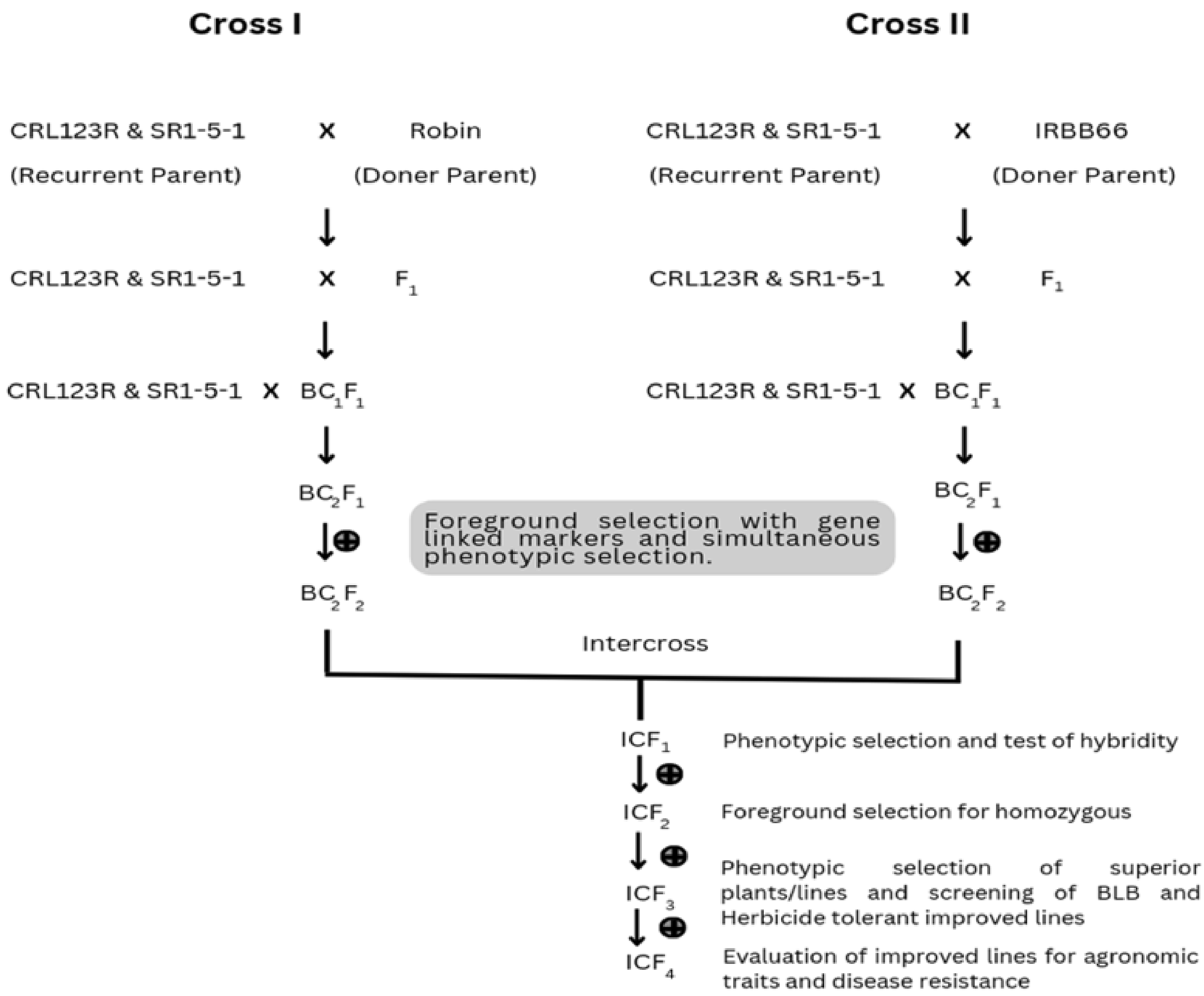
It is widely accepted that the utilization of broad-spectrum and durable resistance for rice improvement is the most cost-effective approach to preventing the loss of rice yield. These problems can be effectively solved by developing NILs (near-isogenic lines) with herbicide tolerant genes in combination with BLB resistance.

METHODOLOGY

In this study, we use Robin (herbicide tolerant rice mutant) as a donor and CRL123R & SR1-5-1 as the recurrent parent (RP) for the transfer of HT trait. Whereas plant material IRBB66 (BLB-resistant, carrying Xa21 + xa13 + Xa7 + xa5 + Xa4) as donor parent, and CRL123R & SR1-5-1 (BLB-susceptible) as a recurrent parent were chosen before initiated the backcrossing breeding program. After the selection of plant materials, two independent crosses between CRL123R & SR1-5-1 (as recurrent parent) X IRBB66 (as donor parent) and CRL123R & SR1-5-1 (as recurrent parent) X Robin (as donor parent) are to be done in order to transfer the targeted BLB resistant and Herbicide-tolerant genes, respectively. PCR was done for foreground and background selection, followed by phenotyping for BLB resistance and herbicide tolerance.

CONCLUSION

The use of molecular markers in breeding programs is a powerful tool for tagging gene regions which is not available in traditional plant



breeding techniques. The markers could have linked to specific plant traits, allowing plant breeders to identify the character of interest and make their selection. This exercise is called marker-assisted selection (MAS). Based on these advantages, we utilized MAS as a support tool in our rice breeding program. We will use this approach to introgress resistant genes into our elite rice variety, CRL123R & SR1-5-1, to improve resistant characteristics against bacterial leaf blight (BLB) disease and herbicide usage. These developed lines will serve as the donor for BLB resistance and herbicide tolerance in rice genotypes for future breeding programs.

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ARRW/SIRC/Theme I/78

Effect of high temperature stress on rheological textural and antioxidative properties of rice grain

Nabaneeta Basak[1*], Gaurav Kumar[1], Priyadarsini Sanghamitra[2], Prashantkumar S Hanjagi[1], Sutapa Sarkar[2]

[1]*Crop Physiology and Biochemistry Division, ICAR-National Rice Research Institute, Cuttack-753006, Odisha, India*

[2]*Crop Improvement Division, ICAR-National Rice Research Institute,Cuttack-753006, Odisha, India*

** Corresponding author. Email:bsk.nabaneeta@gmail.com*

Amongst the multitude of environmental abiotic stresses that affect the plant growth and productivity, the constantly rise in atmospheric temperature is certainly a detrimental one severely affecting plant growth and metabolism. The ability of rice growing systems to maintain or improve production under future warm temperatures is crucial for maintaining global food security since rice is thermosensitive (Fahad et al., 2016). The anthesis and grain filling phases of the rice crop are impacted by heat stress, which reduces rice output by 7–10%. Heat stress also has a detrimental effect on grain quality traits and reduces the sensory characteristics mainly through differential accumulation of and distribution of macro and micro elements. Depending on the severity, length, and timing of the stress, the effects of heat stress during major growth stage like grain filling may differ among various crop species. The expression level of many genes of the starch biosynthetic pathways and storage proteins may be altered on exposure to heat stress. The variation in starch and protein composition affects the rheological, textural and physicochemical properties of rice grains which may affect their quality. The present investigation was aimed at studying the effect of heat stress on antioxidant system, protein profile, starch rheological properties and texture profile of rice grains.

METHODOLOGY

A field experiment was carried out with the rice cultivars Ratna, N-22, Annapurna, Lalat, Satabdi, Naveen and IR-72 in ICAR-NRRI, Cuttack to study the effect of temperature conditions during grain filling on quality parameters. The cultivars were subjected to different temperature regimes with the transplanting carried out on different dates.

Finely ground rice samples were used for RVA. 3.5 grams of the rice powder was weighed (12% moisture basis was adjusted), 25 mL distilled water was mixed. After mixing, the rice-water slurry was transferred to the disposable canister of RVA (RVA-tecmaster, Newport Scientific, Warriewood, NSW, Australia) and the rheological properties were studied. The rice grains were exposed to the texture profile analysis by “Stable Micro Systems” texture analyzer model TA.XT plus (Stable Micro Systems Ltd, Surrey, UK).

Total phenol content was determined by the modified protocol of Zilic et al., (2011). Total flavonoid content was determined according to Eberherdt et al., (2000). Determination of CUPRAC activity of the samples was performed according to the modified method of Apak et al. (2004). ABTS radical scavenging was assayed by modified protocol of Serpen et al. 2008. FRAP was assayed according to Benzie and Strain (1996).

RESULT

The RVA profile indicates starch gelatinization, disintegration, and swelling capacities, and is used as a tool for evaluating rice cooking quality. The characteristics of the visco-analyzer profile were peak viscosity, final viscosity, trough viscosity, breakdown (the difference between peak viscosity and trough viscosity) and setback (the difference

Fig. 1. Standard mean of RVA profile characteristics across varieties under control and heat stress

	Breakdown Viscosity (cp)		Setback Viscosity (cp)		Peak Viscosity (cp)		Trough Viscosity (cp)		Final Viscosity (cp)	
	P1	P4	P1	P4	P1	P4	P1	P4	P1	P4
SM	1445	2379	2176	2475	3994	2725	2464	2194	6425	5438

P1: Control P4: high temperature stress

between final and peak viscosities). The rheological properties, amylose content and the gelatinization temperatures were all found to be affected by heat stress. High-temperature stress was found to increase the grain breakdown, set back and gelatinization temperature. The viscosity analysis showed a decrease in peak, trough and final viscosities (Fig.1). The mechanical attributes of cooked rice grains are reflected by its textural characteristics and is a representation of the consumer's preferences. Certain attributes indicated by the textural profile like, hardness, adhesiveness are typically indicated in grain quality evaluation programs. In the present study, the hardness and adhesiveness was found to decrease under high temperature stress (Fig. 2). Antioxidant content in matured grains was generally found to decrease under high temperature. Phenol content was found to be at par or decreased under high temperature with the exception of IR 72. The flavonoid content was followed a similar trend (Fig. 3).

Fig. 2. Standard mean of textural profile characteristics across varieties under control and heat stress

	HARDNESS		ADHESIVENESS	
	P1	P4	P1	P4
SM	40.489	30.294	21.374	18.834

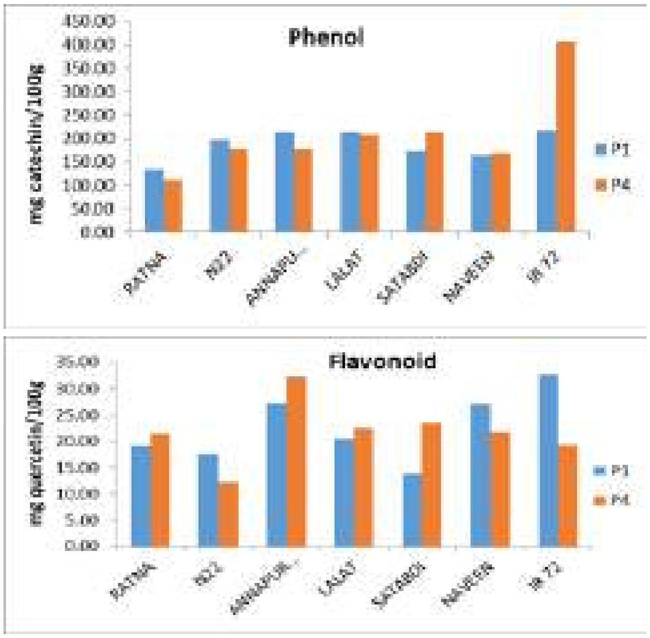

Fig. 3. Phenol and Flavonoid content of the germplasms under control and heat stress

CONCLUSION

The study revealed that high temperature affects the cooking and eating quality by modifying both starch properties as well as its sensory attributes. Among all the seven varieties tested for temperature stress tolerance, N-22 and Annapurna were found to be the best in terms of nutritional quality.

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ARRW/SIRC/Theme I/79

Improvement of Agronomic Traits of Traditional Medicinal Rice Varieties of Chhattisgarh Through Mutation Breeding and Validation of Medicinal Properties using Metabolomics and Mouse Models

Antra Thada[1,3], Shalakha John[1,3], Parmeshwar Sahu[1], Anjali Chauhan[2], Raghavendra Patwardhan[3], B.K. Das[2,4], Deepak Sharma[1], Deepak Sharma[3,4]

[1]*Department of Genetics and Plant Breeding, IGKV, Raipur 492012 Chhattisgarh, India*
[2]*Nuclear Agriculture and Biotechnology Division, BARC, Mumbai India 400085*
[3]*Radiation Biology & Health Sciences Division, BARC, Mumbai India 400085*
[4]*Homi Bhabha National Institute Mumbai India 400094*

Rice is the staple food for the majority of the world's population. Approximately 500 million metric tonnes of rice are consumed every year globally. Agriculture has become one of the most affected fields due to climate change. With the rise in population and decline in arable lands, pressure for developing new cultivars with high yields and high nutritional quality is rising. The need of the hour is to generate varieties that require low inputs and less cost of cultivation and fulfil the goal of sustainable agriculture. Radiation-induced mutation breeding promises a viable foreseeable future. Ancient Ayurveda texts and knowledge collected from tribes have described various therapeutic and medicinal properties of different rice varieties. In the present study, five traditional medicinal landraces of paddy (Layacha, Maharaji, Gudma, Dawar and Lohandi) from the repository of IGKV Chhattisgarh created by Dr. R.H. Richharia, were mutated with gamma rays. The aim was to select high-yielding, dwarf/semi-dwarf, short-duration and evenly maturing mutants. These rice varieties are traditionally used for the treatment of specific ailments. However, there are no systematic scientific studies to support traditional medicinal claims. Therefore, the pharmacological properties of these varieties were tested in various experimental models *in vitro* and *in vivo*.

METHODOLOGY

Irradiation of seeds was carried out at BARC, Mumbai. The plant-to-progeny method was followed to advance the M1 generation to M2 (Ramchander *et al*., 2015). Selection for superior agro-morphological traits was made in the M2 generation and was advanced until the M4 generation. The brown rice from parent varieties was used to prepare methanolic extract (Mex). DPPH and ABTS radical scavenging activity assay was performed *in vitro,* and absorbance was taken at 517nm and 734nm, respectively, using a plate reader. Effect of Mex on phagocytosis of bacteria by Raw 264.7 macrophages was studied using fluorescently labelled pHRhodo bioparticles and live cell imaging. For western blot analysis, Raw 264.7 Macrophages were treated with Layacha rice methanolic extract for preparation of whole cell extracts. 50 µg of protein from cytosolic extracts were resolved by SDS-PAGE (10%), transferred onto nitrocellulose membrane, and probed with primary antibodies specific to phospho-Nrf2 β-actin.

RESULTS

Total 56 promising mutants were selected in the M2 generation (Dawar – 23, Gudma – 26, Lohandi -8), which were advanced to M3 and M4 generations and can be further advanced to develop high-yielding varieties with intact medicinal values. Fourteen out of the 23 mutants of Dawar, four mutants in Gudma had an average height of less than 100 cm, while the average height of the parent was 136 cm and 103 cm, respectively. Some promising mutants with higher number of tillers, reduced height, increased panicle length and increased yield were also selected. Dawar, Gudma, Lohandi, Maharaji and Layacha rice were investigated for their possible medicinal effects. LC-MS/MS analysis showed the presence of phytochemicals with antioxidant and immunomodulatory properties. Mex of these varieties showed potent antioxidant activity against ABTS and DPPH radicals. Layacha rice showed antioxidant action in mouse lymphocytes *in vitro* and also improved innate immunity via activation of Nrf2 *in vivo*.

CONCLUSIONS

Mutation breeding can be an effective tool in improving the existing landraces. The mutants discovered in this study can be further evaluated for release as varieties. Scientific validation of traditional medicinal knowledge will help in boosting the cultivation of these varieties and value-added products can be formulated accordingly.

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ARRW/SIRC/Theme I/80

Gathuwan: A traditional Indian medicinal rice with potent immunomodulatory activity

Anjali Chauhan[1,3], Rahul Checker[2,3*], Deepak Sharma[2,3], Deepak Sharma[4], Bikram K.Das[1,3,*]

[1] *Nuclear Agriculture and Biotechnology Division, BARC, Trombay, Mumbai-400085, India.*
[2] *Radiation Biology & Health Sciences Division, Bio-science Group, BARC, Trombay, Mumbai-400085, India.*
[3] *Homi Bhabha National Institute, Anushaktinagar, Mumbai-400094, India*
[4] *Department of Genetics and Plant Breeding, Indira Gandhi Krishi Vishwavidyalaya, Raipur-492012, India*

Nutritional quality of food is a critical aspect of food security to ensure active and healthy life of people and hence warrants active research in the area of dietary intervention for the prevention of human ailments. Rice, a staple food crop which feeds more than half of the world population, not only provides 20 percent of the caloric requirements but is considerably rich in genetic diversity[1]. Ancient literature in many countries,including India, have mentioned medicinal properties of their local rice varieties. This traditional knowledge retained by some local farmers is the reason for these varieties being maintained. However, the integration of this knowledge with specific application is limited by lack of scientific evidence. Recently, many studies have been taken up wherein different rice varieties werereported to offer a gamut of biological effects such as anti-oxidant, anti-inflammatory, anti-cancer and anti-diabetic. Scientific validation of functional properties in traditional rice will be helpful in restoration of the genetic diversity of rice.Gathuwan, a rice landrace native to Chhattisgarh, has traditionally been used in the treatment of joint ailments such as arthritis. Since, pathogenesis of Rheumatoid arthritis involves chronic activation of T-lymphocyte activation we hypothesized that the biological activity Gathuwan brown rice may be mediated via its ability to modulate T-cell responses. Hence, the present study was initiated with the aimof exploring the immunomodulatory potential of Gathuwan brown rice and identifying the mechanism(s) involved.

METHODOLOGY

T- cell activation and proliferation were studied using antibody staining and CFSE dye dilution followed by flow cytometry. Cytokine secretion was studied using ELISA. Cellular redox status was studied using redox sensitive dyes (DCF-DA, mitosox red and MCB). Expression of signalling proteins and their downstream targets genes/ proteins was studied using Western Blotting and real time-PCR. In-vivo efficacy of Gathuwan BRE was evaluated using mouse model of Graft-versus-host-disease (GVHD).

RESULTS

Gathuwan Brown Rice Extract (BRE) suppressed mitogen induced T cell proliferation in a dose dependent manner without inducing cell death. BRE also prevented mitogen induced upregulation of T-cell activation markets and suppressed secretion of effector cytokines (IL-2, IL-4, IL-6 and IFN-γ). BRE exhibited DPPH and ABTS+ radical scavenging activity in cell free system with IC50 values of 0.43 mg/ml for DPPH radical scavenging and 0.15 mg/ml for ABTS+ radical scavenging.BRE treatment altered the cellular redox balance wherein it reduced intracellular ROS and GSH levels and increased mitochondrial ROS levels. Further, BRE induced nuclear translocation of Nrf2, a redox sensitive and immune-regulatory transcription factor, via increased phosphorylation of MAP Kinases (ERK and p-38 MAP Kinase). BRE alsoincreased the expression of Nrf2-dependent antioxidant genes (SOD, CAT, HO-1, GPx and TrxR) in lymphocytes. Treatment of donor cells with BRE before transplantation to allogenic mice, rescued the recipient mice from GVHD induced mortality and morbidity.

CONCLUSIONS

Our study provides important scientific evidence which aligns well with the available literature about the medicinal properties of the traditional rice variety "Gathuwan" from Chhattisgarh, India. It willsupport the global recognition and acceptance of Indian traditional knowledge about the genetic resources of rice and other food crops.

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ARRW/SIRC/Theme I/81

Enhancing the *in vitro* callus induction potential of selected rice genotypes

Allan V* and N. Meenakshi Ganesan

Department of Genetics and Plant Breeding, CPBG, Tamil Nadu Agricultural University, Coimbatore- Tamil Nadu
E mail: albertoogy@gmail.com

To create variations in plant genotypes different approaches like mutation, hybridization and recombination were followed in plant breeding. Recently *in vitro* culture techniques for genetic transformation are often used to create genetic variants. For each genetic manipulation, the intermediary phase of undifferentiated cells or embryogenic calli is required. The success of getting genetically transformed plants depends on development of embryogenic calli, proliferation rate and its regeneration efficiency. Various explants can be used to induce embryogenic calli and it is limited by genotypes, media supplements and culture conditions. Mature embryos were selected for the study due to its year around availability. Hence, the study focuses on the callus induction frequency of selected rice genotypes with different combination of plant growth regulators (PGR).

METHODOLOGY

Mature seeds of rice genotypes viz., ADT 37, ADT38, ADT42 and CR1009-SUB1 were taken to study the embryogenic callus induction. Dehusked mature seeds were sterilized and taken as the explants. The seeds were inoculated in basal media containing Murashige and Skoog's (MS) salts with Gamborg (B5) vitamins. Further the media was added with 30% sucrose (w/v) and 0.8% (w/v) agar at pH 5.8. The basal media were supplemented with different combinations of PGR of 2,4-dichlorophenoxyacetic acid (2,4-D-2.0,2.5 mg/L) and Kinetin (Kn-0.5,1.0 mg/L). After the mature seed inoculation, the cultures were kept in dark condition for callus induction at 25±1°C. The days to callus induction, callus induction frequency (CIF %), color and texture of callus after 30 days of callus induction were observed in all four genotypes. Means of parameters were compared by Duncan multiple range test using windows R version 3.3.0.

RESULTS

The interaction of different plant growth regulators on four rice genotypes in basal media is shown in Table 1. The calluses protruded from the scutellum region clearly visible after 7-10 days of inoculation. The response of number of days to callus induction is similar in all four rice genotypes, irrespective of different (PGR) concentrations. The frequency of callus induction varied from 11.1 to 33.3 per cent in ADT 37, 33.3 to 55.6 per cent in ADT 38, 0 to 11.1 per cent in ADT 42, and 11.1 to 55.6 per cent in CR 1009 SUB1.

In our study the response of all the four genotypes showed no specific pattern in correlation with the PGR concentrations used. High proliferation and better callus induction were observed in different treatments for different genotypes. The lowest callus induction for ADT 37 was observed in T2 and T6, for ADT 38 the lowest Callus induction of 33.33 was observed in T1, T2, T3 and T6, for ADT 42 the callus induction were found to be very low and in most of the treatments callus induction were not observed (T1, T3, T4, T5, T6) and in CR 1009 SUB 1 the lowest callus induction was observed in T6 where there was no callus induction and in T3 there was a 11.1 per cent of callus induction.

Among the four rice genotypes the highest and better callus induction was observed in ADT

Table.1 Response of plumule of selected rice varieties for callus induction with different PGR

Treatment	Genotype	Media used	Plant growth regulators (mg/l)		CIF (%)	Proliferation rate	Colour of callus	Texture of callus
			2,4-D	Kn				
T1	**ADT 37**	**MS**	2.0	0.0	33.33	Medium	Cy	Fr, W
T2			2.0	0.5	11.11	Low	Cy	Fr, W
T3			2.0	1.0	22.22	Low	Cy	Fr, W
T4			2.5	0.0	22.22	High	Cy	Fr, W
T5			2.5	0.5	33.33	Medium	Cy	Fr, W
T6			2.5	1.0	11.11	Low	Cy	Cp, D
T1	**ADT 38**	**MS**	2.0	0.0	33.33	Medium	Cy	Cp, W
T2			2.0	0.5	33.33	Medium	Cy	Fr, W
T3			2.0	1.0	33.33	Medium	Cy	Fr, W
T4			2.5	0.0	55.56	High	Cy	Fr, W
T5			2.5	0.5	44.44	High	Cy	Fr, W
T6			2.5	1.0	33.33	Medium	Cy	Fr, W
T1	**ADT 42**	**MS**	2.0	0.0	0.00	-	-	-
T2			2.0	0.5	11.11	Low	Cy	Cp, D
T3			2.0	1.0	0.00	-	-	-
T4			2.5	0.0	0.00	-	-	-
T5			2.5	0.5	0.00	-	-	-
T6			2.5	1.0	0.00	-	-	-
T1	**CR 1009 SUB1**		**MS**	2.0	0.0	22.22	Medium	Cy Fr, W
T2			2.0	0.5	55.56	High	Cy	Fr, D
T3			2.0	1.0	11.11	Medium	Cy	Fr, W
T4			2.5	0.0	55.56	High	Cy	Fr, D
T5			2.5	0.5	33.33	Medium	Cy	Fr, W
T6			2.5	1.0	0.00	-	-	-

CY – Creamy Yellow, Fr – Friable, Cp – compact, D – Dry, W – Wet

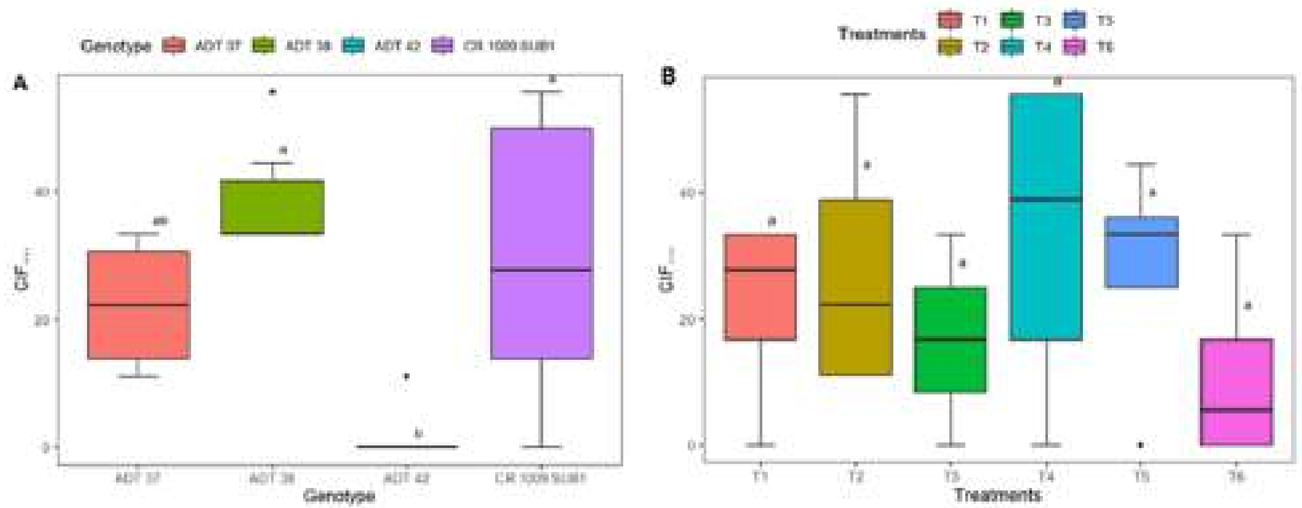

Fig. 1: DMRT boxplot for comparison between different treatments and varieties.

A- DMRT boxplot for comparison between different genotypes**, B -** DMRT boxplot for comparison between different treatments

38 and CR 1009 SUB 1, also in these genotypes the proliferation rate is medium to high. ADT 37 showed medium to low proliferation rate and ADT 42 showed the lowest callus induction and lowest proliferation rate. The differences in callus induction is due to genotypic efficiency of the genotype. All the four rice genotypes showed creamy yellow color callus irrespective of genotypes and different PGR concentration. Among the four rice genotypes, ADT 37, ADT 38 and CR 1009 SUB 1 produced friable calli and ADT 24 produced compact calli.

CONCLUSION

In this study, *in vitro* callus induction was studied in four rice genotypes. The finding of this study shows, to improve the high callus induction frequency the optimum concentration of PGR combination (2,4-D and Kn) should be optimized. Among the four rice genotypes ADT 38 and CR 1009 SUB1 showed the highest callus induction frequencies and can be denoted as the best amenable genotypes for tissue culture of the four genotypes studies. ADT 42 showed lower or no callus induction in all the treatments studied and hence should be studied with different combinations of PGRs or basal media.

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ARRW/SIRC/Theme I/82

Study of Rheological attributes affected by starch content in pigmented and non-pigmented rice

Gaurav Kumar[1*], Nabaneeta Basak[1], Sutapa Sarkar[1]and Priyadarsini Sanghamitra[1]

[1]*ICAR- National Rice research Institute, Cuttack-753006, Odisha, India*

e-mail: gauraviari@yahoo.co.in

The main ingredient of rice, starch, is what gives its physiochemical characteristics, like gel strength and pasting abilities. The majority of producers use rice flour over starch when creating processed products. However, lipids, proteins, and mineral components were also able to affect the swelling and pasting abilities of starch granules in addition to starch. The peak viscosity will be low swelling is less in starch granules during gelatinization. The rapid viscoanalyzer (RVA) functions as a physical indicator for the estimation and as a fore runner of heating and processing qualities in order to comprehend the viscosity characteristics of rice starch. When estimating the cooking quality of rice starch characteristics, setback and breakdown values among the various RVA profiles are significantly more important than peak viscosity and others parameters (Kesarwani et al., 2016). Higher peak viscosity and breakdown as well as a lower setback value improve the grain quality, which is closely related to the RVA characteristic and the flavour quality of rice. The cooked rice will have soft and sticky texture.

METHODOLOGY

Four varieties of rice(two pigmented: Chakhao and Manipuri black and two non-pigmented: Naveen and CRD 310) have been used for this study. Amylose estimation was according to Juliano (1992) by using Iodine solution with slight modification. Finely ground rice sampleswere used for RVA. 3.5 grams of the rice powder was weighed (12% moisture basis was adjusted), 25 mL distilled water was mixed. After mixing, the rice-water slurry was transferred to the disposable canister of RVA (RVA-tecmaster, Newport Scientific, Warriewood, NSW, Australia) and the rheological properties have been identified.

RESULTS

Amylose content: The general cooking, eating, and pasting qualities of a rice variety can be significantly influenced by the amylose content of that variety. The main ingredient in rice is starch, and different rice cultivars have different amylose contents.The amylose content was estimated in all the four varieties and they showed a large variation. The value ranges from 11.75 in chakhao to 21.4 in CRD 310 (Table 1). Amylose content determines the softness for the rice after cooking.

Rheological properties: Rheological properties are indirectly depicts the starch softness and cooking quality of the product. Disruption of the gelatinized starch granule structure is what reflects the breakdown viscosity. Thus, the difference between the viscosities when swollen, gelatinized starch granules existed and the viscosity when the gelatinized starch granules are disrupted, either entirely or partially, determines the extent of breakdown. In sensory evaluation of rice, one of the indirect markers for eating quality is typically the RVA profile. The ease of cooking starch and the stability of the paste are both reflected in the

Table 1. Amylose content in pigmented and non-pigmented rice varieties

Sl No.	Variety	Amylose Content (%)
1	Naveen	20.75
2	CRD 310	21.4
3	Manipuri Black	16.25
4	Chakhao	11.75

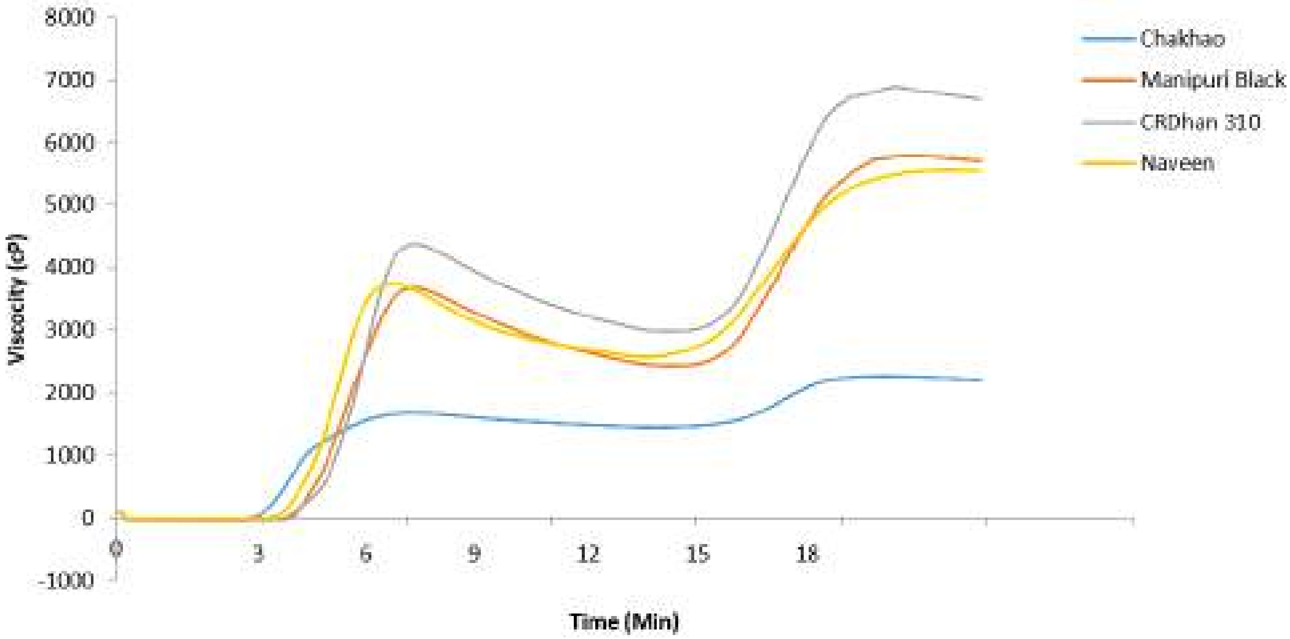

Fig. 1. RVA profiles of pigmented and non-pigmented rice cultivars.

viscosities at the beginning of the holding time and during cooling, respectively. Each viscosity can be used to pinpoint a specific trait of a particular rice variety.Both in pigmented and non pigmented rice, the starch paste of the detected rice varieties displayed a process "up-down-up" except in chakhao where the variation was not much intense (Figure 1). The values of paste viscosity properties were presented in Table 2.In the case of chakhao, which had the lowest starch content, the break down and setback viscosities were lowest. Similarly CRD 310 showed the highest break down and setback viscosities with highest starch content. Thus it can be confired that the important rheological properties, break down and setback viscosities are modulated under change in starch content. However, pigmentation does not show any relationship with RVA properties.

CONCLUSION

Thus the study confers that the important rheological properties, break down and setback viscosities are modulated under change in starch content. However, pigmentation does not show any relationship with RVA properties.Cooking quality of rice starch characteristics, setback and breakdown values among the various RVA profiles are significantly more important than peak viscosity and others parameters.

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ARRW/SIRC/Theme I/83

High-Yielding Rice Samba Mahsuri Mutant Derivatives: Novel Genetic Resources Exhibiting Resistance to Yellow Stem Borer (*Scirpophaga Incertulas*)

B. Suneel[1], E. Prashanth Varma[1], C.G. Gokulan[2], J. Karteek[1], M. Sravan[1], A.P. Padma Kumari[1], G.S. Laha[1], L.V. Subba Rao[1], Kalyani M Barbadikar[1], R.M.Sundaram[1], Hitender Patel[2], R.V. Sonti[2], M.S.Madhav[1]*

[1.] *ICAR-Indian Institute of Rice Research, Rajendranagar, Hyderabad, 500030, India*
[2.] *CSIR-Center for Cellular and Molecular Biology, Tarnaka, Hyderabad, 500007, India*
Corresponding author email: sheshu24@gmail.com

Rice productivity is seriously threatened by biotic stresses, especially insect pests like Yellow stem borer (YSB), which significantly lowers rice yields by 5–10% and even up to 60% under favorable conditions (29^{0}C & RH 90%) (Renuka et al., 2017). It also causes 3–95% more yield losses in India than any other insect pest of rice. Due to the complicated genetics of the trait and the lack of knowledge regarding the genetics of YSB resistance, no sources of resistance to the common yellow stem borer are present in the rice germplasm (Katupalli et al., 2021). Ethyl Methane Sulphonate (EMS) mutants of Samba Mahsuri, a well-known rice mega-variety, were generated under a collaborative project between ICAR-IIRR and CSIR-CCMB (Potupureddi et al., 2021) and served as an important genetic resource for economically critical trait identification.

METHODOLOGY

Phenotyping for Yellow Stem Borer was done at the reproductive stage under controlled YSB artificial releases in the field (augmented design) in the experimental field at ICAR-Indian Institute of Rice Research and ICRISAT farm Patancheru, Hyderabad. Phenotyping for dead hearts and white ears was recorded on the SES-IRRI scale for YSB.

A subset of 100 EMS mutagenized lines (M3) was screened in Rabi and Kharif in 2013 and 2014, and the mutant displaying consistent tolerance to YSB (dead heart and white ear; score = 0) was forwarded to the next generations. The YSB tolerant mutant line named SM-92 was deployed for developing mapping populations (SM-92*BPT-5204), and at each generation, YSB screening was done, and yield and yield-related traits were recorded. The tolerant lines having high yields were forwarded through the single seed descent method. At the F5 stage, 20 lines were screened along with SM-92, other YSB promising mutants for YSB.

RESULTS

The phenotyping screening of four seasons emanated that the mutant SM-92 displayed tolerance to YSB with a consistent score of 0 among all the mutants screened with high yield over BPT-5204. In *Kharif* 2019 YSB screening, among 20, seven individual lines showed a “0” score, and the remaining 13 plants showed a “1” score.

CONCLUSION

The identified stabilized mutant and its derived stabilized lines have the potential to be used in future rice breeding programs for YSB resistance.

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ARRW/SIRC/Theme I/84

Marker assisted validation for the superior isogenic *sub1* line(s) in the background of 'Swarna'

Auromira Sahoo[1], Saumya Ranjan Barik[1], Deepak Kumar Nayak[1], Arpita Moharana[1], Sushant Kumar Dash[1] and Sharat Kumar Pradhan[2]

[1]*ICAR- National Rice Research Institute, Cuttack-753006, Odisha, India*
[2]*Indian Council of Agricultural Research, New Delhi-110001, India*

Submergence is the one of biotic stress that impacts on rice plant growth and development. Heavy rainfall or flash flood sometimes impose stress on plant and affect the productivity of plants or in severe cases leads to complete mortality, if it continues for days together. This kind of situation often occurs due to change of climate. In south and Southeast Asia, submergence act on 15 million hectares rainfed lowland areas usually. SUBMERGENCE 1 (*SUB1*) a quantitative trait locus was identified and mapped for development of submergence tolerant rice variety. *Sub1*, on chromosome 9 has given ample chance to apply marker assisted selection to advance submergence tolerant versions of rice cultivars that are widely grown in the region. Swarna being the one of the mega variety has some special demand for its typical characteristics. In this context, superior isogenic lines of swarna may be useful even to replace Swarna Sub-I.

OBJECTIVES

Development of superior isogenic lines, carrying submergence tolerance genes in the background of the popular low land variety "Swarna".

METHODOLOGY

In this present experiment CR Dhan 801 containing Sub1 QTL was hybridized with CR Dhan 800 (Swarna introgressed with three BB resistance genes, *xa5*, *xa13* and *Xa21*). The F_1seeds were selfed to produce F_2 and the seedlings were transplanted in submergence tank. After exposing submergence stress for 14 days the survived plants are analyzed for submergence tolerance. For genotypic validation and extraction of genomic DNA, leaves were collected from 20 days old plants. After grinding with liquid nitrogen, leaves were isolated, for pure genomic DNA using CTAB extraction method. After extraction, these genomic DNA were checked by using 1% agarose gel followed by DNA amplification, gel documentation and validation.

RESULT

A total of 726 F_2 lines were developed from F_1 seeds. Among that, 182 lines were survived from submergence stress. Parental analysis between susceptible (CRDhan 800) and tolerant (CRDhan 801) parents using four specific markers viz. Sub1-A203, Sub1 –C173,Sub1-BC2 and RM8300 revealed that Sub1Bc2 has given clear polymorphism between susceptible and tolerant genotypes for submergence using the four primers tested. Those 182 lines were analyzed with Sub1 markers. 45 homozygous lines containing sub1 QTL were identified.

CONCLUSION

Out of 726 F_2lines were developed from F_1 seeds, 182 lines were survived with submergence stress. After genotyping, 45 homozygous lines found containing sub1 QTL were identified. To develop superior genotype, these 45 lines will be further evaluated for yield and other phenotypic traits.

ARRW/SIRC/Theme I/85

Mapping and annotation of clustered QTL region on the long arm of chromosome 7 for major panicle traits in rice

G Ariharasutharsan[1], Geetha S[1*], Saraswathi R[1], Raveendran M[2], Amudha K[1] and Suresh R[2]

[1]*Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore, 641003*
[2]*Centre for Plant Molecular Biology, Tamil Nadu Agricultural University, Coimbatore, 641003*
[*]*Email of the corresponding author: sutharsang7@gmail.com*

Rice (*Oryza sativa* L.) is an important food crop that is extensively grown around the world. It contains a rich source of energy, 80% of carbohydrates and starch, 7% of proteins with a high amount of glutamic and aspartic acid, and vitamins E (Tocopherol), B_1 (Thiamine), and B_3 (Niacin) (Carcea, 2021). The number of grains per panicle is an important trait in determining grain yield and a major trait of concern for developing new plant types in rice (Zhong *et al.*, 2021). The SSR-based QTL mapping has been applied in rice for panicle traits by various researchers (Tian *et al.*, 2015). The QTLs with a major effect on grain number per panicle can be utilized in marker-assisted breeding to improve grain yield in rice.

METHODOLOGY

The F_2 mapping population was constructed from the cross combination, IET 28749 (high grain number per panicle) × IET 28834 (low grain number per panicle). The polymorphic SSR markers were screened in a large F_2 mapping population. The banding pattern of SSR markers in the F_2 population was screened and scored as 0, 1 and 2. The phenotypic data of major panicle traits observed in the F_2 population. The phenotypic and genotypic data combinedly analysed using QTL-IciMapping. The annotation of genes present in the QTL region was done using NCBI- rice genome database. The genes related to panicle traits were identified based on the protein function.

RESULTS

The clustered QTL region in the long arm of chromosome 7 contains QTLs for four major traits, *viz.*, number of spikelets per panicle (qNOSPP-7-1), number of filled grains per panicle (qNFGPP-7-1), number of spikelets in secondary branches (qNOSISB-7-1) and spikelets density (qSD-7-1) with the LOD value of more than three (Table 1). The R^2 value recorded maximum in qSD-7-1 (61.65 %) followed by qNOSISB-7-1 (40.39 %), qNOSPP-7-1 (37.66 %) and qNFGPP-7-1 (9.85 %). These clustered QTL regions are flanked by the markers RM248 and RM70, which have a physical distance of 6.5 Mbp. The gene annotation in the clustered QTL region revealed that it contained a total of 725 genes and among this, 168 genes are uncharacterized. Within the remaining 557 genes, 32 genes showed high relatable with panicle traits based on previous studies (Table 2). These 32 genes exhibited the various protein functions from various protein groups *viz.*, zinc finger protein, ethylene-responsive transcription factors, MADS-box transcription factor, F-box protein, and

Table 1. List of QTLs identified in the clustered QTL region of chromosome 7

Sl. No.	Trait Name	QTLs	Chr No.	Position	Left Marker	Right Marker	LOD	R^2	Add	Dom
1	NOSPP	qNOSPP-7-1	7	12	RM248	RM70	3.53	37.66	-91.35	-39.33
2	NFGPP	qNFGPP-7-1	7	13	RM248	RM70	3.17	9.85	-82.96	-28.39
3	NOSISB	qNOSISB-7-1	7	11	RM248	RM70	4.07	40.39	-85.98	-47.51
4	SD	qSD-7-1	7	7	RM248	RM70	8.11	61.65	-0.99	-0.72

Table 2. Annotation of clustered QTL region present in long arm of chromosome 7

Chr	Interval	Number of genes	Grain number related genes	Major genes	Protein function
7	22,776,704 - 29,339,845	725	32	LOC4343851	MADS-box transcription factor 18-like%2C transcript variant X2
				LOC4343912	ethylene-responsive transcription factor 1-like
				LOC4343915	F-box only protein 13
				LOC4344233	ethylene-responsive transcription factor FZP-like
				LOC4344266	ethylene-responsive transcription factor RAP2-3
				LOC4344331	ETHYLENE INSENSITIVE 3-like 1 protein
				LOC107281516	transcription factor bHLH149

transcription factor bHLH149. The physiological attributes of ethylene production in panicle at anthesis time impacted grain filling, grain number and grain density in rice. This ethylene-responsive gene has the role of achieving higher grain filling in compact panicle types of rice.

CONCLUSION

From the above study, the identified clustered QTL region has the significant association with the important panicle traits, including number of spikelets per panicle, the number of grains per panicle, the number secondary branches per panicle, and spikelets density. The flanked markers RM248 and RM70 can be used in marker-assisted selection and backcross breeding to increase the grain yield. The gene annotation in this QTL region revealed the possible candidate gene for important panicle traits. Especially the ethylene-responsive gene is essential for getting higher grain filling in the long compact panicles, which is required for developing new plant type-based rice varieties

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ARRW/SIRC/Theme I/86

Unraveling the role of *OsCCA1* under low light stress using genome editing approach

Debasish Pattnaik*, Manaswini Dash, Debasmita Panda, Subhashis Karmakar, Kutubuddin A. Molla and M. J. Baig

National Rice Research Institute, Cuttack, Odisha, 753006
Email- debasishpattnaikag@gmail.com

Rice is primarily grown as a Kharif crop in India and South Asia. The optimum irradiance required by rice plants to perform normal photosynthesis is 1500 ìmol $m^{-2}s^{-1}$. Hence, low irradiation results in decreased photosynthesis. Plant growth (morphology, anatomy, physiology, and cellular biochemistry) is highly influenced by the fluctuation of light intensity during cloudy days, which ultimately influences the flowering time and plant productivity. *OsCCA1* plays a significant role in photoperiodic flowering by exhibiting critical day length in rice, and its defective mutants exhibited delayed flowering phenotypes under long-day but not short-day conditions.

To unravel the role of gene *OsCCA1* in rice plants under low light stress, we are trying to generate knock-out mutants using CRISPR-Cas9. A polycistronic tRNA-gRNA system was used for CRISPR multiplexing. We have selected two guides, for targeting the gene, driven by the OsU3 promoter. The assembled product was cloned into both expression vectors. Rice protoplast transfection was performed for transient expression and to check the efficacy of sgRNA. After protoplast transfection, gDNA was isolated, and target regions were amplified using specific primers. Successful editing was confirmed through Sanger sequencing of the amplified products.

Low light tolerant and susceptible rice varieties such as Swarnaprabha and IR-8 were identified in earlier studies. We also standardized the regeneration media for performing *Agrobacterium*-mediated transformation. Since low-light tolerant varieties show a 2-fold upregulation of *OsCCA1* under low-light-stressed conditions, we assume it has some role. Therefore, CRISPR-Cas9 generated rice *cca1* knockout mutants will be used for characterization and to decipher the role of the gene in rice under low light stress.

METHODOLOGY

- Amplification of the fragments using Q5 hi-fidelity polymerase from pGTR vector
- Assembling of fragments using Golden gate assembly.
- Cloning of assembled product into pGEMT-easy vector background.
- Clone confirmation using restriction enzyme digestion.
- Sanger sequencing of the positive clones.
- Sub-cloning of assembled product into expression vector background.
- Transient expression analysis into protoplast in Kitaake rice variety.
- Checking of guide efficiency by PCR and Sanger sequencing
- Standardization of various regeneration media of variety Swarnaprabha and IR-8.

RESULTS AND DISCUSSION

CRISPR-Cas9 is an adaptive immune system found in bacteria and archaea, used for successful genome editing for both eukaryotes and prokaryotes (Jiang et al 2017). SpCas9 generates blunt end cuts at the target sites in the genome and makes random and unpredictable mutations using non-homologous end-joining systems (Molla et al 2020). In this present investigation, we are targeting *OsCCA1* using CRISPR-Cas9 mediated multiplex knockout tool in rice. Initially, we validated the successful generation of mutations in rice protoplast analyzed after 72 hours of transfection. Since we used two guides for each gene, it is expected that the intervening region of the two predicted double-strand break (DSB) would be deleted. Target-specific PCR products amplified from transfected protoplast showed expected deletion, as evidenced by smaller bands. When we Sanger sequenced the PCR products, we observed deletion of 59 bp in *OsCCA1*.

We have also standardized regeneration media for IR8 and Swarnaprabha variety for performing *Agrobacterium* mediated transformation and we got 23% and 30% regeneration efficiency in both the varieties, respectively. We will proceed with obtaining the mutants which will reveal the role of *OsCCA1* gene under low light stress.

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Effect of high temperature and humidity on seed germination in rice

Swastideepa Sahoo[1,2], P Sanghamitra[2] and S K Pradhan[3]

[1]*Dept. Of Seed Science and Technology, College of Agriculture, OUAT, Bhubaneswar751003, India*
[2]*Crop Improvement Division, ICAR-National Rice Research Institute, Cuttack-753006, Odisha, India*
[3] *ICAR, New Delhi, India*

Rice being the staple food of our country owes the largest yield. For maximum yield, optimum utilisation of the inputs in the field and plant population is the vital need which can be achieved by optimising the seed quality. Herecomes, the pictures of viable and healthy seed. Seed deterioration is a natural inevitable process. Whereas, the rate of seed deterioration depends on the seed moisture content, temperature and relative humidity of the storage (Ellis *et al*. 1992). Deterioration cannot be stopped but can be slowed down to elevate the time of seed death. Ageing and deterioration are the key factors to study the seed behaviour in storage. In this experiment, five rice genotypes were studied for deterioration of seed germination under elevated temperature and moisture conditions for Five days to determine the change in the germination percentage over the period of stress.

OBJECTIVES

To study performance of rice genotypes under elevated temperature and moisture conditions

METHODOLOGY

In this experiment 5 rice genotypes were subjected for seed deterioration via accelerated ageing at 45°C and 100% relative humidity (RH) for 24, 48, 72, 96, 120 hr in three replications. Treated seeds were put for germination and observations were recorded for seed for each day treatment on the last count day of rice.

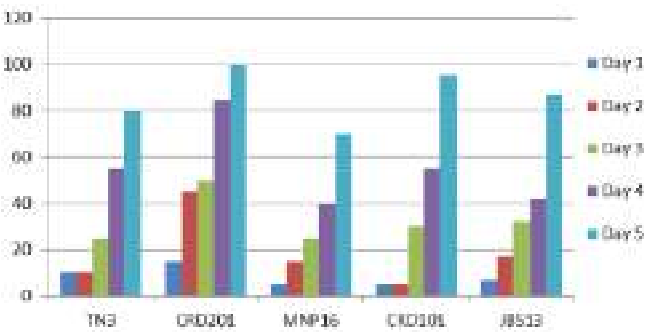
Table. Mean germination percentage of five genotypes (control and 1-5days of treatment

	Germination%					
Genotypes	Treatment					
	Control	Day 1	Day 2	Day 3	Day 4	Day 5
TN3	100	90	90	75	45	20
CRD201	100	85	55	50	15	0
MNP16	95	90	80	70	55	25
CRD101	95	90	90	65	40	0
JBS13	97	90	80	65	55	10

RESULTS

The results showed a rapid decline in the germination percentage of the genotypes with increase in duration of the treatment. A drastic decline has been seen on day 5 of the treatment with respect to the control. The mean percentage decrease in germination in each five genotypes of the three replications can be seen in the table.

The decline of the germination% has been relatively slow in MNP16 than other genotypes. The Bar graph shows the percentage decline in germination of genotypes on each day of treatment.



Bar graph- percentage decline in germination of genotypes on each day of treatment.

CONCLUSION

The percentage of decline in seed germination during ageing is specific for each genotype. The rate of detoriotaion depends on the genotype as well as the duration of the treatment.

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ARRW/SIRC/Theme I/88

Development of upland-smart rice variety by pyramiding QTLs for deeper rooting, phosphorus uptake and yield under drought stress

Sourav Surav Yadav[1], Soumya Abhilipsa Satpathy, Bhabesh Kumar Majhi, Sharat Kumar Pradhan[2] and Elssa Pandit[1*]

[1]*Department of Biosciences and Biotechnology, Fakir Mohan University, Balasore- 756089*

[2]*Crop Improvement Division, ICAR-National Rice Research Institute, Cuttack-753006*

Email: elsambio@gmail.com

Drastic climate change is causing frequent drought stress. Almost 50% of India's 143Mha rice growing area is under rainfed conditions that face erratic rainfall and severe drought. Rice being a shallow rooting plant, becomes vulnerable to stress. Changing the root architecture from shallow to deeper rooting by altering the root angle can help the rice plant to escape drought. One major QTL/gene for deep rooting *Dro1* and a few minor QTLs like *Dro2*, *Dro3*, *Dro4* and *Dro5* have recently been mapped, of which only *Dro1* has been cloned. In addition to drought, low phosphorus availability is a major limitation in upland ecology. Almost 50% of rice soils are P-deficient worldwide. The cost of required phosphatic fertilizers to improve yield is becoming a constraint to Indian farmers. The development of rice genotypes that are efficient in the absorption and utilization of phosphorus under low availability will be a great help. A major QTL *Pup1* on chromosome 12 exhibiting 78.8% phenotypic variance for P-uptake is the only QTL available for marker-assisted breeding programs for efficient P-uptake. Also, the candidate gene, *phosphorus-starvation tolerance 1 (PSTOL1)*, has been cloned and gene-based markers are available. Overexpression of *PSTOL1* in such varieties significantly enhances grain yield in phosphorus-deficient soil. PSTOL1 is an enhancer of early root growth, enabling plants to acquire more phosphorus and other nutrients. Yield under drought stress is a necessary trait required for varietal improvement. The major drought yield QTLs, *qDTY1.1, qDTY2.1, qDTY2.2, qDTY2.3, qDTY3.1, qDTY3.2, qDTY4.1, qDTY1.1, qDTY6.1, qDTY6.2, qDTY9.1, qDTY10.1* and *qDTY12.1*, have been demonstrated to give tolerance to reproductive stage drought stress minimizing the yield loss. Under this scenario, the present study aims to pyramid QTLs for yield under reproductive stage drought stress, deeper rooting and P-uptake in a popular background.

METHODOLOGY

Marker-assisted backcross breeding method was followed for pyramiding the deeper rooting, P-uptake and yield under drought QTLs/genes. Phenotyping for deeper rooting, yield under drought and P-uptake efficiency was done under controlled conditions.

RESULTS

The developed NILs in the background of MTU1010 possessing *Pup1*, *Dro1* and *Dro2* genes/QTLs were used as donors to develop the pyramided lines. During the backcross generations, gene-based markers, as well as closely linked flanking markers, were used to select the plants having *Pup1+Dro1+Dro2+qDTY2.3 +qDTY3.2* gene combination. In addition, polymorphic markers between the recurrent parent and the donor lines were used to select plants with maximum recurrent genome recovery in BC_1F_1 generation. The work is in progress to develop NILs in BC_3F_2 generation.

CONCLUSION

The new version of the popular variety with an in-built capacity to tolerate drought having deeper rooting, better uptake of Phosphorous with better yield potential under reproductive stage drought stress will be more adopted by the farmers as it will be in a popular background. The income of the farmers dependent on rainfed ecology will be increased. The pyramided line(s) that will be developed in the study can also be used as a potential donor in other breeding programs.

CRISPR-Cas-mediated mutants for rice *CA, PEPC, ME, and PPDK* genes for deciphering their function

Manaswini Dash*, Subhashis Karmakar, Debasmita Panda, Kutubuddin A. Molla and M.J.Baig

National Rice Research Institute, Cuttack, Odisha, 753006
Email- manaswini.crri@gmail.com

Rice (*Oryza sativa* L.) is a major staple food and source of energy for half a billion of the world's population. Its small genome and ease of transformation make it an ideal crop for biotechnological application. Photosynthesis is a crucial factor that determines the yield potential of crops. So, improvement in photosynthesis is correlated with the enhancement in productivity. C4 plants are photosynthetically superior to C3 plants and have higher water- and nitrogen-use efficiency. *PEPC*, *PPDK*, *CA,* and *ME* are the four key C4-photosynthesis-related genes. Although rice is a C3 plant, it contains homologs of these four C4 pathway genes. However, the actual roles of these genes in C3 rice remain mostly unclear. To unravel the role of these genes in rice plants, we have generated knockout mutants of all four genes using CRISPR-Cas9. A polycistronic tRNA-gRNA system was used for CRISPR multiplexing. We have selected two guides for each of the four targeted genes. OsU3 promoter was used to drive the expression of guides. The assembled product was cloned into both expression vector as well as binary vector backgrounds. Rice protoplast transfection was performed for transient expression and also to check the efficacy of sgRNA. After protoplast transfection, gDNA was isolated and target regions were amplified using specific primers. Successful editing was confirmed through sanger sequencing of the amplified products. Furthermore, the binary vector was transformed into the Kitaake rice variety. Regenerated plants were transferred into rooting media and subsequently into the soil after four weeks of transformation. Putative plants were analyzed, and positive mutant lines were selected for further analysis. This CRISPR-Cas9 generated rice C4 knockout mutants will be used for characterization to decipher the role of these genes in rice.

METHODOLOGY

- Amplification of the fragments using Q5 hi-fidelity polymerase from pGTR vector
- Assembling of fragments using Golden gate assembly.
- Cloning of assembled product into pGEMT-easy vector background.
- Clone confirmation using restriction enzyme digestion.
- Sanger sequencing of the positive clones.
- Subcloning of assembled product into an expression vector as well as a binary vector background.
- Transient expression analysis into protoplast and *Agrobacterium-mediated* stable transformation into Kitaake rice variety.
- Analysis of mutant plants and deciphering the role of these genes in C3 rice.

RESULTS AND DISCUSSION

CRISPR-Cas9 is an adaptive immune system found in bacteria and archaea, used for successful genome editing for both eukaryotes and prokaryotes (Jiang et al. 2017). SpCas9 generates blunt end cuts at the target sites in the genome and makes random and unpredictable mutations using non-homologous end-joining systems

(Molla et al., 2020). In this present investigation, we have selected four C4 pathway genes, namely *OsPEPC*, *OsPPDK*, *OsCA,* and *OsNADP-ME* for CRISPR-Cas9 mediated multiplex knockout study in rice. Initially, we validated the successful generation of mutations in rice protoplast analyzed after 72 hours of transfection. Since we used two guides for each gene, it is expected that the intervening region of the two predicted double-strand breaks (DSBs) would be deleted. Target-specific PCR products amplified from transfected protoplast showed expected deletion, as evidenced by smaller bands. Upon Sanger sequencing of the PCR products, we observed deletion of 176 bp for the *OsCA*, 706 bp for the *OsPEPC*, 241 bp for the *OsPPDK,* and 520 bp for the *OsNADP-ME* gene. After successful editing in protoplast, we have constructed binary editing vectors for calli-mediated transformation. We transformed the four constructs separately to rice calli and regenerated putative genome-edited plants for each genes. For screening, we isolated genomic DNA from the regenerated plants and used them for PCR amplification using gene-specific primers. Gel electrophoresis and Sanger sequencing were used for screening. The mutants obtained in the study will be characterized for physio-biochemical properties to unravel the key function of these C4 genes in C3 rice.

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Molla KA and Yang Y Predicting CRISPR/Cas9-induced mutations for precise genome editing. *Trends Biotechnology* 38.2 (2020): 136-141.

Validation of molecular markers responsible for deeper rooting (*Dro1*) QTL in rice

Ankita Mishra[1,3], Saumya Ranjan Barik[1], Lambodar Behera[1], Sharat Kumar Pradhan[2] and Tapas Kumar Mishra[3]

[1]*ICAR-National Rice Research Institute, Cuttack-753006, Odisha, India*
[2]*Indian Council of Agricultural Research, New Delhi-110001, India*
[3]*Odisha University of Agriculture & Technology, Bhubaneswar- 751003, Odisha, India*

Rice (*Oryza sativa* L.) is the most versatile food crop and provides staple food for more than half of world's population. More than 90% of rice growing field is present in Asia. Conventional rice cultivation requires a substantial amount up to 5000 litres of irrigation water to produce 1 kg of rice. However, emerging water crisis, water intensive nature of rice and increasing labour charges has led for development of water-labour-energy efficient rice cultivar for global sustainability of food security. Plant root architecture is vital for absorption of water and nutrients in optimum amount. Therefore, inducing deeper rooting through incorporation of root angle gene in very high yielding irrigated rice will combat the moisture stress faced due to climate change. In such a situation, rice genotypes which have deeper root system can be a great help. Marker validation is a useful technique to detect the target gene and can be implemented during the breeding program. Molecular markers can increase the efficiency by allowing selection of genotypes and minimizing linkage drag. This is the first step in breeding programme to identify the recipient and donor parents. Screening of rice varieties using microsatellite markers will led to selection of donor parent which can be used for transfer of our desired *Dro1* QTL into a suitable recipient parent.

OBJECTIVE

a. Marker validation of rice genotypes for *Dro1* QTL.

b. Identification of donor germplasm(s) for deeper rooting trait.

MATERIALS AND METHOD

The seeds of thirty-five rice germplasms were taken comprising backcross generation (BC_1F_1) progeny of Maudamani and CR19-9-45-1. Phenotypic validation was performed in net house under optimal water deficit stress condition. For genotypic validation, leaves were collected from 15-20 days old seedlings for extraction of genomic DNA. After grinding with liquid nitrogen, leaves were isolated for pure genomic DNA using CTAB extraction method. After extraction, these genomic DNA were checked by using 1% agarose gel followed by DNA amplification, gel documentation and validation. Three linked markers namely, RM7424, RM24393 and RM242 were used to screen the rice varieties (Uga *et al.*, 2011; Uga *et al.*, 2013). Data were analysed through statistical software.

RESULT

Out of 35 derived lines, three lines were performing better in stress condition in comparison to rest of the lines. In genotyping, six lines were showing positive band to RM242 and RM 7424 each while seven genotypes were showing positive band to RM 24393 individually. Also, five lines found positive with two combinations (RM242/RM7424 and RM242/RM24393) of marker whereas four derived lines showing positive with RM7424 and RM24393 marker combination. Combining all the markers, three derived lines *viz.*, 14, 15 and 27 were found positive to all the marker combination (RM242+RM7424+RM24393). These lines were

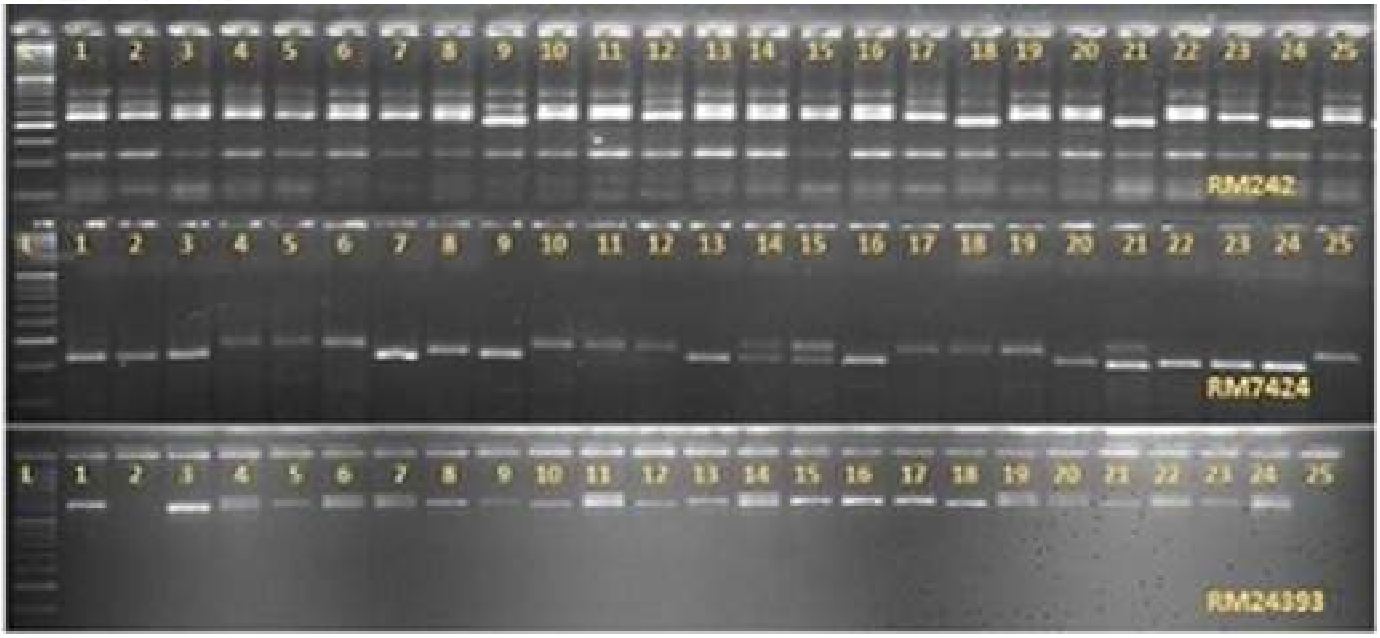

Fig. Screening of *Dro1* QTL using RM242, RM7424 and RM24393 markers in BC_1F_1 derivatives

carried forward for further backcross program and marker-based selection for enhancement of deeper rooting.

CONCLUSION

Based on the results found in the present experiment it can be concluded that the BC_1F_1 derived lines *viz.*, plant no. 14, 15 and 27 of cross between Maudamani/ CR-19-9-45-1 showing gene for deeper rooting. As observed, SSR markers RM242, RM7424 and RM24393 can be used for validation of deeper rooting in rice genotypes. The genotypes having *Dro1* gene shows more root growth angle and deeper roots helping it to absorb which will help the genotypes to survive in water-deficit condition. Hence, the NIL lines of the identified genotypes can be used further as good potential donors for deeper rooting.

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ARRW/SIRC/Theme I/91

Genetic enhancement for drought tolerance to improve the productivity of rainfed drought-prone rice environment

Nimai P Mandal, Somnath Roy, Priyamedha, Amrita Banerjee and S Bhagat

Central Rainfed Upland Rice Research Station, ICAR-National Rice Research Institute, Hazaribag 825301, Jharkhand, India

The rainfed rice systems including both upland and lowland areas occupy nearly 38% of the total rice cropped area, contributes only 21% of the total rice production due to low productivity caused by drought and other abiotic stresses (Khush, 2005). Worldwide, drought affects approximately 23 million ha of rainfed rice. These drought vulnerability scenarios are likely to worsen in the future with predicted climate change scenarios, which will also lead to more complex interactions of drought with other abiotic and biotic stresses (Lesk et al. 2016). It is therefore critical that drought mitigation through improved drought-tolerant rice varieties and complementary management practices represent an important exit pathway from poverty. The foremost challenge, therefore, is to breed high quality varieties that would confer enhanced grain yield along with multiple stress tolerance including drought, low-phosphorus, diseases and insect pests.

METHODOLOGY

Germplasm characterization is the first step of any crop improvement program. At CRURRS, during past decades, several rice accessions comprising of upland adapted and drought tolerant *aus, indica, japonica* and NERICA genotypes have been characterized and a few of them (Brown gora, Kalakeri, Lalnakanda 41, Waikoku, N22, BRRI Sail, C22, and many more) have been utilized for developing drought tolerant varieties. In the recent climate change scenario, both reproductive and vegetative stage drought are becoming more frequent due to uneven monsoon rainfall and to combat these problems reliable screening techniques have been put in, which can be used for characterizing genetic resources. Genotypes with both vegetative and reproductive stage drought tolerance with high yield (CR143-2-2, CRR747-13-3-B, Kalakeri, RR433-2-1 and Dular) have been identified and registered with PGRC portal of ICARwhich can be utilized for stabilizing rice production in rainfed ecologies.

RESULTS

Significant achievements were made in improving productivity of rainfed upland ecology through conventionally bred varieties such as Vandana, Anjali, Virendra, CR Dhan 40,CR Dhan 103 and Purna. Similarly, varieties like Abhishek, Sahbhagi Dhan, IR64 Drt1, CR Dhan 320 found to be highly suitable for rainfed drought-prone shallow lowland.Popularity of these varieties can be judged from the fact that large quantities of breeder seed indent received and produced for these varieties during last ten years and recently, Sahbhagi Dhan, covering more than 2 mha areas during *kharif* season, has been recognized as a landmark variety for ensuring food security in drought-prone rainfed ecologies of eastern and north-eastern India. In the recent years marker assisted breeding (MAB) approach has accelerated the progressin developing of drought tolerant varieties and combining with other abiotic or biotic stresses. IR64 Drt1 is the first drought tolerant variety developed though MAB and subsequently other varieties developed through this approach are CR Dhan 107 (drought+blast resistance) and CR Dhan 804 (drought+submergence tolerance).

CONCLUSION

The drought tolerant varieties developed at NRRI-CRURRS will definitely help in stabilizing the rice production in rainfed drought-prone ecology of the country for a sustainable growth. For climate smart agriculture which aims to sustain production even in adverse climatic conditions it will be required to incorporate many other tolerance traits keeping the market need in mind, though it's a holistic approach which requires balanced integration of genetic manipulation and management practices.

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ARRW/SIRC/Theme I/91

Parental line improvement for submergence tolerance in rice – a marker assisted backcrossing strategy for hybrid development

P Senguttuvel*, Manasa Y, Beulah P, Karthika Guna, Nagaraju P, Veerendra J, Lohit Ram, HariPrasad AS and RM Sundaram

Hybrid rice unit, Crop Improvement Section, Indian Institute of Rice Research, Rajendranagar, Hyderabad, Telangana, India.
Corresponding author: senguttuvel@gmail.com

Rice generally grows in waterlogged conditions but gets adversely affected by complete submergence at early vegetative stage caused by flash floods ultimately reducing the grain yield. Hybrid rice which strikingly out yields rice varieties; an approach for developing a hybrid that can sustain submergence/flash floods and meet the production demands in terms of yield and food requirement will be an advancement in rice breeding. Keeping in view, the present investigation was undertaken with the following specific objectives to introgress major gene(s) Sub-1 for submergence into genetic background of hybrid rice parental line KMR-3R, further to characterize and evaluate marker assisted backcrossing for tolerance to submergence parental line and finally evaluate parents and F_1's for combining ability and extent of heterosis.

METHODOLOGY

In the present study, the parental line KMR-3R and Swarna Sub-1 (flood-tolerant variety containing the SUB1 (Submergence) gene) were considered for the hybridization program as recurrent and donor parents respectively. True hybrids were confirmed by foreground markers and simultaneously two backcrosses were made to produce Backcross Inbred lines (BILS) and at BC_2F_4 generation confirming the presence of SUB1 gene by foreground markers (SUB1BC2, SUB1BC3, Sub1A, SUB1C173, RM 23911, RM23865) and recovery of recurrent parent genome by background markers distributed among all the 12 chromosomes. Phenotypic screening for submergence tolerance at the vegetative stage was done by imposing a stress environment for 14 days in the cement tanks

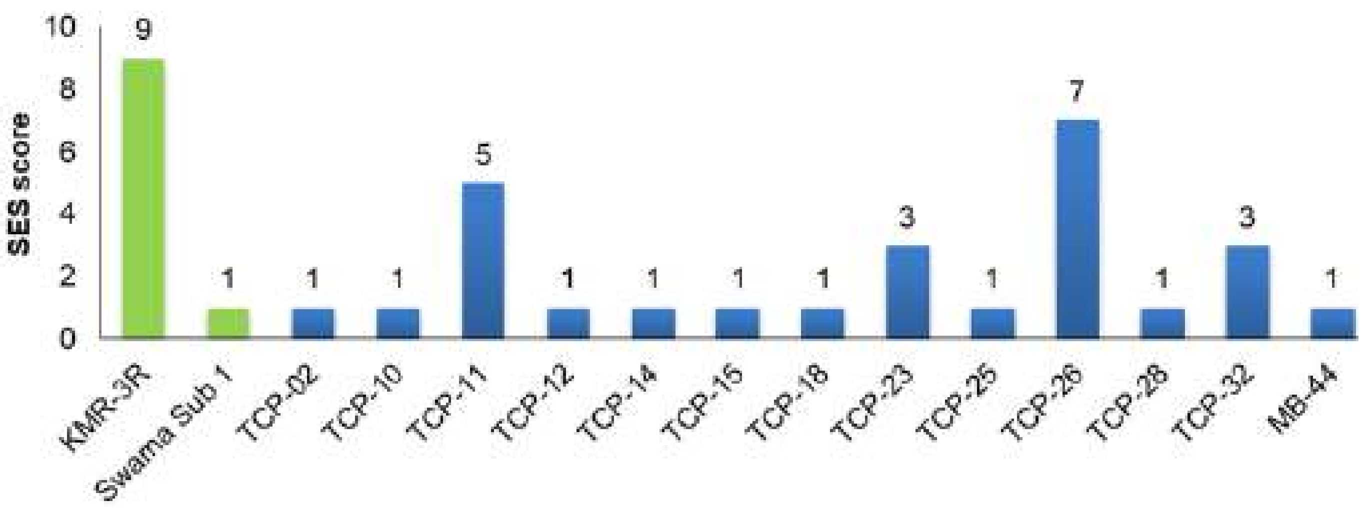

Fig. 1: Submergence screening of BILs at seedling stage in rice

where the seedlings were submerged underwater above 55cms. Based on survival ability, a visual score was given using SES scale (1, 3, 5, 7 & 9) (SES IRRI, 2014) and tested for physiological traits under submergence stress conditions.

RESULTS

Based on the tolerance level showed by BIL's in comparison with donor parent and morphological attributes, the 13 best lines were selected (Fig. 1) and screened further for the presence of fertility restoration (Rf4 and Rf3) with molecular markers (RM 6100 and DRRM-Rf3-10 respectively). Further, these BILs were evaluated for combining ability and heterosis in L x T fashion by crossing diverse cytoplasmic male sterile (CMS) lines, and identified five promising BILs TCP-2, TCP-10, TCP-12, TCP-25 and MB-44for good general combines and hybrids for grain yield. Additionally, these selected BILs also showed tolerance level with reference to physiological traits namely total chlorophyll content and *Fv/Fm* pattern.

CONCULSION

Our study demonstrated that, systematic MABB approach with phenotypic selection for development of submergence tolerance of a popular rice restorer parent KMR-3R background. The identified BILs would serve as valuable genetic stock and enable breeders to derive potential high yielding hybrids for flood prone ecologies in breeding programs.

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ARRW/SIRC/Theme I/93

Assessing the interactive effects of elevated CO_2 and salinity on physiological traits of rice genotypes

Sushma. M. Awaji*, Prashantkumar. S. Hanjagi, Koushik Charaborty and M.J. Baig

ICAR-National Rice Research Institute, Cuttack-753006, Odisha, India

**Corresponding author e-mail: Sushma.awaji@icar.gov.in, sma1624@gmail.com*

Rice (*Oryza sativa L.*) being a staple food crop of the world with a considerable impact on world food security is continuously being threatened by present climate change scenarios (Chauan et al.,2017). The productivity of rice, has been steadily impacted by numerous abiotic factors, particularly drought, salinity, flooding, and extreme temperatures in most rice-growing habitats. Due to the effects of climate change, it is projected that the occurrence, intensity, and duration of these stresses will increase, necessitating robust rice yields to feed the growing global population. Climate predictions show rising CO_2 levels and rising average global temperatures over the 21st century. (IPCC. Synthesis Report.,2014). As a result, significant efforts are being made to evaluate the effects of climate change on rice yield and production and to find measures to reduce such effects (Balbinot et al.,2021). In this regard, a study was carried out to evaluate the interactive effects of elevated CO_2 and salinity in rice genotypes.

METHODOLOGY

Four rice varieties viz., FL-478, Kamini, AC-41585 and IR-29 were taken for the study and experiment was carried out in Open Top Chamber (OTC) facility at ICAR-NRRI. Seeds of four rice genotypes were surface sterilized with 1% sodium hypochlorite solution and then put for germination, one week after germination seedlings were transferred to hydroponic system with Hoagland's solution and the imposed treatments are: T1- ambient CO_2 (380µmol/L) – salinity, T2 - ambient CO_2 (360µmol/L) + salinity (150mMNaCl), T3 - elevated CO_2 (700µmol/L) – salinity and T4 - elevated CO_2 (700µmol/L) + salinity (150mM NaCl). Each treatment had three replicates. An automated CO_2 control system was used to maintain the CO_2 concentration. It measured and adjusted the CO_2 concentration every 30 seconds throughout the experiment. Stress treatment was imposed 21 days after germination and continued for 2 weeks. At the end of the stress period, sampling was done to measure several physiological parameters.

RESULTS

There was significant variation among rice genotypes in response to elevated CO_2 concentration under salt stress was observed and it was found that elevated CO_2 reduced the adverse effects of salt stress on physiology of rice genotypes by enhancing growth parameters. Among the genotypes studied, AC-41585 showed better tolerance to salinity stress combined with elevated CO_2 by maintaining higher plant dry weight, chlorophyll content, cell viability, K content which can be attributed to positive impact of elevated CO_2 on growth and physiological traits (Figure 1).

CONCLUSION

It is evident from the present study that, the deleterious effects of salinity were nullified by the elevated CO_2 in terms of enhanced plant dry biomass and tissue tolerance, however there is a lot of genotypic variations exists which needs to be studied thoroughly in order to understand the detailed mechanisms of salinity tolerance under elevated CO_2 conditions.

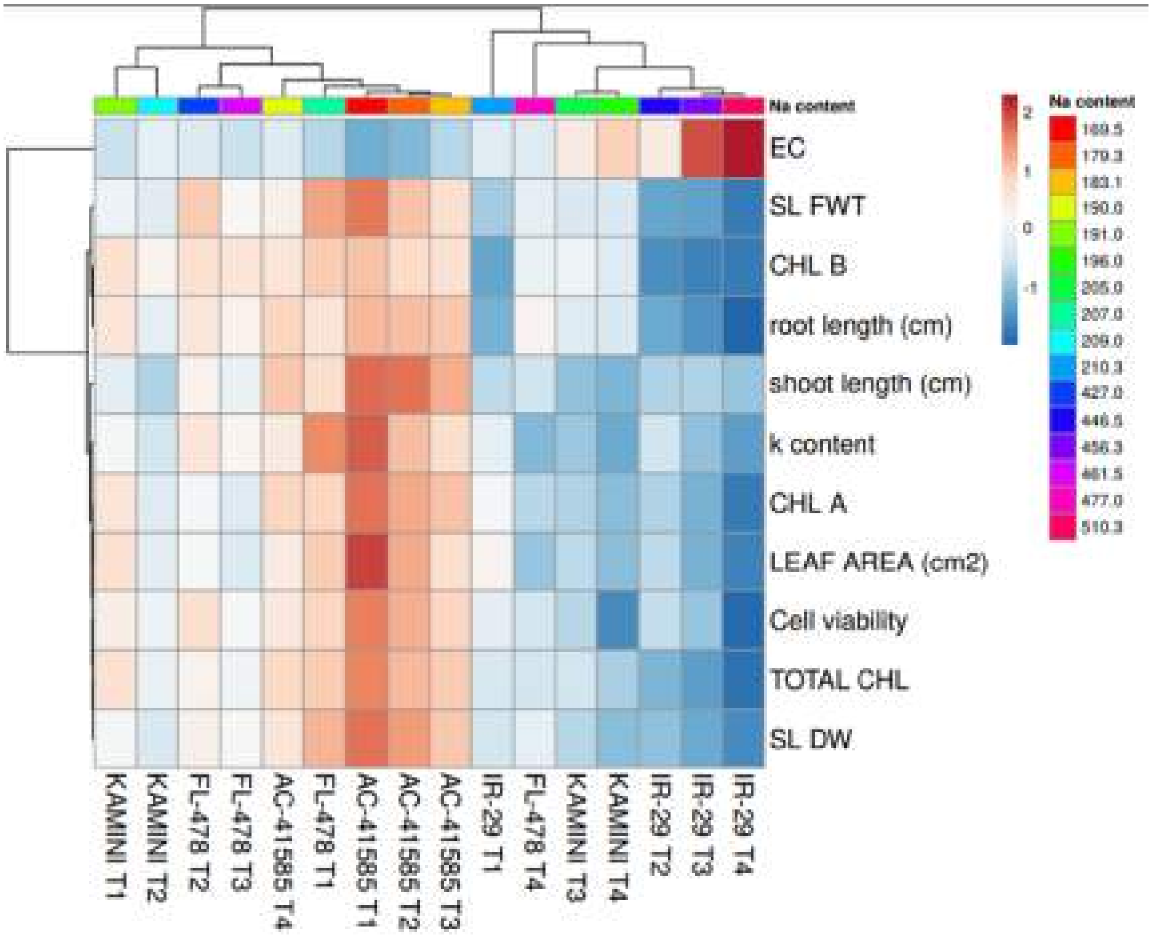

Fig 1: Heat map showing the genotypic variation among the studied traits at different treatments of elevated CO_2 and salinity. In this study, AC-14585 recorded the highest values in all the traits (based on color indication-red) even at T_4 except for membrane leakage (EC) and sodium (Na) content followed by tolerant check FL-478. While the susceptible check IR-29 and Kamini recorded the lowest values among the genotypes studied (blue).

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ARRW/SIRC/Theme I/94

Improvement of popular rice cultivar of indo-gangetic plain zone for biotic stress through genomic assisted shuttle breeding-GASB

Prakash Singh[1,2,3], Ram Lakhan Verma[2], Ravi S. Singh[4], Sunil Kumar[1], K K Prasad[3], Md. Reyaz Ahmed[3], Prabhat Kumar[1], V.K. Singh[1], Arsode Pandurang[2] and S. Samantaray[2]

[1]*Department of Plant Breeding and Genetics, Veer Kunwar Singh College of Agriculture, Dumraon (Buxar), Bihar , India*
[2]*Division of Crop Improvement, ICAR-National Rice Research Institute, Cuttack, Odisha-753 006, India*
[3]*Department of Plant Breeding and Genetics, Bihar Agricultural University, Sabour, Bihar – 813 210, India*
Author for correspondence: Dr. Prakash Singh <*Email: prakash201288@gmail.com*>

Rice (*Oryza sativa* L.) is an important staple food crop of the world and world rice production is mainly concentrated in Asian countries. In the Asian context, it is grown under diverse ecological conditions and gets exposed to different biotic and abiotic stresses, in which, bacterial blight, false smut, sheath blight, blast diseases are major biotic constraints, has fungal, bacterial and/ or viral origin. Among major biotic diseases, bacterial blight (BB) caused by bacteria *Xanthomonas oryzae* pv. *oryzae* (Xoo), not only causes severe yield loss up to 21-59 % but also impair the quality of the rice grain in rice-growing countries of the world (Singh et al. 2020). BB are being systemic seed and soil born; there are no effective ways to protect or combat rather than to develop of resistant cultivars. Genomics-assisted shuttle breeding-GASB has been advocated as a highly efficient breeding method due to its rapid and precise selection of the targeted genes and less time taking process than the other approaches of plant breeding. To address the above problems of BB disease, genomics-assisted shuttle breeding-GASB has been utilized for rapid improvement of the recurrent parents for the targeted disease.

METHODOLOGY

Introgression of major resistant genes was accomplished by using donor parent IRBB66 to improve susceptible cultivar Rajendra Sweta through genomics-assisted shuttle breeding-GASB approach. IRBB66, a short grain, medium maturing NIL of IR24 rice variety, was utilized as the donor for introgression of bacterial blight resistance genes, *i.e.*, *xa5*, Xa7, *xa13* and *Xa21* into Rajendra Sweta. Foreground selection was performed using tightly linked or gene based markers for BB resistant genes and background selection was performed by covering the 12 chromosomes through 360 SSR markers followed by the conventional backcross breeding method between Rajendra Sweta and IRBB66 up to two backcross generations.

RESULTS AND CONCLUSION

Foreground selection was performed using tightly linked or gene based markers for BB resistant genes i.e., *xa5*, Xa7, *xa13* and *Xa21*, however, for background selection, each linkage group covered by 4 5 - 7 polymorphic marker, supplemented with 76 polymorphic SSR markers between Rajendra Sweta andIRBB66 were utilized. The resistance cultivar IRBB66 showed higher level (4.1 %) of disease resistance, while highly susceptible/ negative check TN-1 showed 76.3 % disease severity and susceptible cultivar Rajendra Sweta showed 56.7 % disease severity against the bacterial pathogen *Xoo*. Improved lines of Rajendra Sweta showed yield advantages of up to 9.39 to 4.23%, respectively. The performance of the BB-resistant version of Rajendra Sweta produced by inter-crossing the improved lines of IRBB66 was on at par with or superior to the original R. Sweta. While, the F_2 (segregating) and back-cross (B_1 and B_2) populations were phenotypically classified into three distinct classes as highly resistant or resistant, moderately resistant, and moderately susceptible or susceptible in the ratio 13 : 3, 1 : 1 and 1 : 0 (non-segregating type), respectively which is mainly due to cumulative effects of three resistant genes *Xa21, Xa7* and *xa13/ xa5*. Details of genomics-assisted shuttle breeding-GASB for developing the new version of *Indica* rice cultivar R. Sweta with high degree of resistant against the bacterial blight disease will be discussed during the presentation.

ARRW/SIRC/Theme I/95

Characterization of African rice (*Oryza glaberrima* steud.) genotypes for low soil phosphorus tolerance

K. Niranjana[1&3#], B.V. Varaprasad[3], D. Srinivasa chary[2], B. Muralidhara[1], C.A. Manoj[1], V.G. Ishwarya Lakshmi[1], D. Aleena[1], C. Gireesh[1#], P. Senguttuvel[1], K.B. Kemparaju[1], K. Suneetha[1], Santosha Rathod[1], L.V. Subba Rao [1], R.M. Sundaram[1], M.S. Anantha[1 *#]

[1]*Department of Plant Breeding, ICAR-Indian Institute of Rice Research, Hyderabad, Telangana, 500030*
[2]*Central Instrumentation Cell, PJTSAU, Hyderabad, Telangana, 500030*
[3]*Department of Genetics and Plant Breeding, PJTSAU, Hyderabad, Telangana, 500030*
**Corresponding author: anugenes@gmail.com*

Phosphorus deficiency is a major abiotic factor, limiting rice productivity in many resource poor farming conditions globally. Minimizing phosphorus input could be facilitated by the development of more phosphorus-efficient crop cultivars that will yield more per unit of phosphorus input. African rice, *Oryza glaberrima* Steud., is known for its wider adaptability and resistance to various indigenous biotic and abiotic stresses including low phosphorus availability in acidic soils (Tobita et al., 2003). It is also known that *pup1* is largely conserved in cultivars adapted well under rainfed ecosystem, where *O. glaberrima* is highly prevalent under African rainfed ecosystems. Thus, the present investigation was undertaken to evaluate 31 accessions of *O. glaberrima* along with four checks under low soil phosphorus field conditions coupled with molecular validation of the accessions using *pup1* gene specific molecular markers.

METHODOLOGY

Thirty-one rice accessions of *O. glaberrima* with four checks (Rasi, Swarna, Improved Samba Mahsuri and MTU 1010) were screened for low soil phosphorus tolerance in the low soil P plot (Available P <5 kg ha^{-1}) at ICAR-IIRR, Hyderabad. A total of 15 parameters of yield traits and root-shoot characteristics were recorded along with different stress indices for phenotypic evaluation. The genomic DNA from the young leaves of the accessions was isolated and PCR amplification was carried out using three *Pup1* specific markers *viz.,* K 46-1, K 46-2, and K 52 for validation.

RESULTS

Phenotypic screening under low soil phosphorus conditions led to the identification of few *O. glaberrima* accessions showing better performance for yield and related traits. Molecular validation revealed the presence of *pup1* loci in 62.86%, 97.14% and 88.57% of accessions for K46-1, K46-2 and K52 marker loci respectively. Among the accessions studied, EC 861784, EC 861812 and EC 861813 exhibited higher yield compared to the checks and also got validated with all the three *pup1* gene specific markers. Of these, one *O. glaberrima* accession *viz.,* EC 861784 seemed to be promising with highest yield, stress tolerance

(a) Resistant and (b) susceptible accessions of *O. glaberrima* under low soil P conditions

index and with *pup1* loci pointing its importance as an efficient source in breeding programmes to enhance the genetic base of the *O. sativa* cultivars for phosphorus use efficiency.

CONCLUSION

Our study was handy in the identification of three African rice genotypes *viz.*, EC 861784, EC 861812 and EC 861813 that were tolerant to low soil phosphorus conditions with genomic regions for all the three pup1 markers loci validated. Narrowed down, EC 861784 accession recorded the highest yield, tolerance index coupled with *pup1* loci indicating its utilization as a low soil phosphorus donor in future rice breeding programmes.

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A trehalose-6-phosphate phosphatase (*OsTPP7*) regulates culm length in rice under aerobic and flooded condition

S Sabarinathan[1,2], Priyadarsini S[1], Parameswaran C[1*], Cayalvizhi B[1], Devraj L[2], Biswaranjan B[1], Devanna BN[1], Jawaharlal Katara[1], Ramlakhan Verma[1], and Sanghamitra S[1]

[1]*Crop Improvement Division, ICAR-National Rice Research Institute, Cuttack-753006, Odisha, India*
[2]*Department of Seed Science and Technology, College of Agriculture, OUAT, Bhubaneswar-751003, Odisha, India*
**Corresponding author Email: agriparames07@gmail.com*

Culm length is an important agronomic trait in rice that directly affects yield. The main practical problem with culm length is that this trait is also influenced by other major genes in rice and affects nutrient use efficiency. In rice, a major gene namely *OsTPP7* (LOC_Os09g20390) associated with anaerobic germination (Kretzschmar *et al*., 2015) tolerance facilitates germination and seedling vigor under anaerobic condition through regulating seedling height. Thus, this research aims to identify and validate the degree of association of *OsTPP7* to culm length in rice using random forest classifiers.

METHODOLOGY

A 115 SNPs identified in 1765 rice genotypes of *OsTPP7* (trehalose-6-phosphate phosphatase) associated with culm length were computed from the SNP Seek database. Boruta wrapper algorithm was used for imputation and possible ntree and mtry combinations were analyzed using random forest models to predict phenotypic association, and root mean square deviation for the prediction of important variants.Additionally, validation ofTPP7 gene specific In/Del primers (Chidambaranathan *et al*., 2022) were evaluated in 128 recombinant inbred line crosses between Bhalum2 and N22 under aerobic and flooded condition and analyzed for statistical significance through Z test and LSD mean separation analysis

RESULTS

The Boruta wrapper algorithm predicted 13 out of 77 SNPs associated with the culm length. Further, training and testing dataset analysis predicted multiple R square of 0.0695 and 0.0804, implying around 8% phenotypic variation. Further, root mean square deviation for the significant variants was found to be ~ 26.60 cm of culm length. Similarly, mean decrease in accuracy for the feature importance plot showed that top two SNPs (Chr09:12253887-12253191) are highly important for predicting the culm length in rice. This unique 3' UTR allele is present in only 1.5% of genotypes in the rice 3k panel, indicating recent origin. The allelic effect of TPP7 showed a highly significant (P=0.00**) difference between flooded and aerobic conditions.

CONCLUSION

Thus, the supervised machine learning model identified the contribution of 8% in the culm length phenotypic association of the *OsTPP7* gene. Further, the mean phenotypic difference for culm length in N22 and Bhalum2 allele under aerobic and flooded condition was found to be ~13 and 14 cm, respectively. Therefore, introgression of the novel alleles of *OsTPP7* not only promotes anaerobic germination tolerance but also regulates culm length in aerobic and flooded condition.

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Genome-wide identification, characterization and marker development of simple sequence repeats in rice pathogens

Lipsa Kuanr[1], Nairita Vaidya[1*], Gyanisha Nayak[1], J.L.Katara[1], Parameswaran C[1], Prabhukarthikeyan SR[2], Mathew B[2], Ramlakhan Verma[1] and Sanghamitra Samantaray[1]

[1] *Crop Improvement Division, ICAR-National Rice Research Institute, Cuttack-753006, Odisha, India*

[2] *Crop Protection Division, ICAR-National Rice Research Institute, Cuttack-753006, Odisha, India*

**Corresponding author email: nairitavaidya@gmail.com*

Rice is a cereal of utmost importance as it serves as a staple diet of almost half of the global population. Brown spot, false smut and bacterial leaf blight are some of the important diseases that affect rice and hence reduce the yield of the crop. They are caused by pathogens *Bipolaris oryzae*, *Ustilaginoidea virens* and *Xanthomonas oryza* pv *oryza,* respectively. Development of molecular markers led to discovery of genes responsible for resistance to various diseases (Ashraf *et al.*, 2005). This work focuses on identifying simple sequence repeats in the genome of rice pathogens, *Xanthomonas oryza, Bipolaris oryzae* and *Ustilaginoidea virens* and developing the hyper variable simple sequence repeats markers and validation of the few markers developed in selected pathogen.

METHODOLOGY

The whole genome sequence of the pathogens were downloaded from NCBI in FASTA format and used in the KRAIT software (Du *et al.*, 2018) which identified the simple sequence repeats in the genome. This was followed by utilizing the whole genome sequences and the sequences of SSR obtained from KRAIT as input files in the In-silico PCR tool to obtain amplicons and analyzing the resulting file for the amplicon length and position in the genome. Next, the entire amplicon file was imported in FASTA format and queried in Primer 3 Plus program for designing the primers. The last process involved validation of the primers designed in selected pathogen.

RESULTS

The prevalence of SSR motifs were analyzed in each pathogen and it was discovered that in *Bipolaris oryzae,* there are around 4948 numbers of perfect simple sequence repeats in the genome with a repeat length of 93,712 bp. Trinucleotide repeats were most abundantly found constituting 34.84% of all perfect repeats found. In case of *Ustilaginoidea virens*, 18505 number of perfect simple sequence repeats were found with a repeat length of 3,91,175 bp and mononucleotides were the most abundant repeats constituting 49.01% of the perfect repeats discovered. Similarly, 41 number of perfect simple sequence repeats were found in the genome of *Xanthomonas oryzae* with a repeat length of around 791 bp. Trinucleotide repeats constituting 34.15 % were the most abundant perfect repeats identified. The markers developed in each pathogen produced predicted amplicon size in their respective pathogens and hence were validated.

CONCLUSION

The above investigation included a genome-wide sequence search in three pathogens which are causal organisms of false smut, brown spot and bacterial leaf blight to identify simple sequence repeats in these pathogens from which perfect SSR markers were developed using KRAIT tool. This led to development of primers using Primer 3 Plus which were further validated via PCR analysis and gel electrophoresis. The SSR markers developed for these pathogens could be a useful tool for analyzing genetic diversity, population biology and strain identification of the pathogens.

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ARRW/SIRC/Theme I/98

Differential regulation of pyruvate metabolism pathway under vegetative stage drought stress in rice

Gyanisha Nayak[1,2], Madhuchhanda Parida[1], Nairita Vaidya[1], Parameswaran C[1], Prabharani Chaudhari[2], Sanghamitra Samantaray[1], Padmini Swain[1], Prashantkumar S Hanjagi[1], Jawahar Lal Katara[1*]

[1]*ICAR-National Rice Research Institute, Cuttack-753006, Odisha, India*
[2]*Department of Genetics and Plant Breeding, Indira Gandhi Krishi Vishwavidyalaya, Raipur-492012, Chhattisgarh, India*
**E mail: jawaharbt@gmail.com*

In the rainfed rice agro-ecosystem, drought is the primary factor limiting rice yield (Pandey and Bhandari). At the seedling, vegetative, and reproductive phases, modern rice varieties are extremely sensitive to drought stress, and even minor drought stress can result in a considerable yield drop in rice (Torres and Henry, 2016). A number of QTLs and/genes have been identified for reproductive stage drought stress and have been transferred into popular rice varieties. However, only limited information is available on the identification of genes for the vegetative stage drought stress in rice. Therefore, a total of three rice genotypes; Mahulata and CR-143-2-2 (drought tolerant) and IR 20 (vegetative stage susceptible variety) were taken for the identification of differentially expressed genes (DEGs) using RNA-Seq analysis. Transcriptome analysis using RNA-Seq is advantageous in several aspects over the other existing methods of genome-wide expression analysis, which could provide insights DEGs implying vegetative stage drought stress.

METHODOLOGY

Sowing of all the three genotypes; Mahulata, CR-143-2-2 and IR20 have been carried out at drought experimental field ICAR-NRRI, Cuttack. Drought stress was initiated on the 30 days after sowing and the soil moisture was monitored in alternative days by tensiometer. The drought treatments were continued until leaves of the tolerant parent, Mahulata displayed marked differences in leaf damage. Leaf samples were harvested from all rice lines (stress and control) in three replications, snap-chilled in liquid nitrogen, and immediately stored at “80°C for further use. Total RNA was isolated from all the samples using Trizol Method. The paired-end sequencing libraries were prepared from the isolated total RNA sample and PCR enriched libraries were analyzed on 4200 Tape Station system using high sensitivity D1000 Screen tape as per manufacturer instructions. The 2X150 PE illumina libraries were loaded onto Novaseq 6000 for cluster generation and sequencing. For bioinfo analysis quality of the raw reads were checked using the fastp tool and all the high quality reads were mapped against the reference (EMBL Database) using the Hisat2 genome assembler. All the mapped reads were used for quantification of transcripts using the FeatureCount Package of Rsubread followed by differential gene/transcript expression using the DESeq2 Package of R. DEGs having significant t-test of P value <0.05 were subjected for Gene Ontology (GO) analysis using ShinyGO tool to identify pathways involved under vegetative stage drought tolerance in rice.

RESULTS

ShinyGO analysis revealed that differential regulation of pyruvate metabolism pathway involving up-regulation of several genes enriched in response to vegetative stage drought stress. Cytosolic NADP-ME 3 (*Os01g0743500*) was 7.8 fold highly expressed in IR-20 (Stress) compared to IR-20 (Control). Pyruvate dehydrogenase E1 alpha subunit (*Os06g0246500*) and Adh 1

(*Os11g0210300*) were 4.85 and 2.76 fold highly expressed in IR-20 (Stress) compared to IR-20 (Control) respectively. DJ-1/PfpI domain containing protein C (*Os04g0671700*) and mitochondrial malate dehydrogenase (*Os01g0649100*) were two fold highly expressed in IR-20 (Stress) compared to IR-20 (Control). Similarly, cytosolic NADP-ME 2 (*Os05g0186300*) was found to be 2.35 fold highly expressed in IR-20 (Stress) as compared to CR-143-2-2 (Stress). Further, nodule-enhanced malate dehydrogenase (*Os07g0630800*) was 1.7 fold highly expressed in IR-20 (Stress) compared to CR-143-2-2 (Stress) and 2.1 fold highly expressed in IR-20 (Stress) compared to Mahulata (Stress). Alcohol dehydrogenase superfamily (*Os10g0159800*) was 2.2 fold highly expressed in IR-20 (Stress) compared to CR-143-2-2 (Stress) and 1.4 fold highly expressed in IR-20 (Stress) compared to Mahulata (Stress). Besides, pyruvate kinase 5 (*Os11g0216000*) was 1.5 fold highly expressed in IR-20 (Stress) compared to CR-143-2-2 (Stress) and 2.2 fold highly expressed in IR-20 (Stress) compared to Mahulata (Stress).

CONCLUSION

According to prior findings, a large number of RNA-seq-identified genes that are responsive to drought have functionally been verified to have a role in reducing water stress during drought. This study showed pyruvate pathway was differentially regulated in drought tolerant and susceptible varieties of rice. This up regulation of the pyruvate pathway under drought stress might coordinate the biosynthesis of fatty acids and amino acids pathway through pyruvate flux required for vegetative growth in rice.

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Influence of pericarp color on pre-harvest sprouting in rice genotypes

Repudi Shalem Raju*[1], Chittaranjan Sahoo[1], Prashantkumar S Hanjagi[2], Samal K C[1], Devanna B N[2], Manasi Dash[1], Sushma M Awaji[2] and M J Baig[2]

1. Odisha University of Agriculture and Technology, Bhubaneswar, Odisha-751003
2. ICAR- National Rice Research Institute, Cuttack, Odisha-753006
**Corresponding author: repudishalemraj@gmail.com*

Pre-harvest sprouting (PHS) or vivipary (seed germination on the mother plant), caused by the increased frequency of cyclonic storms with week-long rainfall/heavy rains flooding rice fields during the grain maturity period is substantiallyeffecting rice output.Hence, in order to avoid yield reductions and quality declines, it is crucial to characterize rice genotypes for PHS. It is important to prioritize the development of PHS-resistant rice varieties (Kang, 2018). Carotenoid concentration in the seed coat has been linked to increased seed dormancy and acts as a precursor for -carotenoid synthesis and, indirectly, to the ABA biosynthesis, leading to strong seed dormancy (Rodriguez-Concepcion *et al*., 2001). In view of this scenario, we conducted the current investigation to study the influence of pericarp color on PHS resistance in rice genotypes.

MATERIALS AND METHODS

In the present work, 96 different rice accessions from the ICAR-National Rice Research Institute,

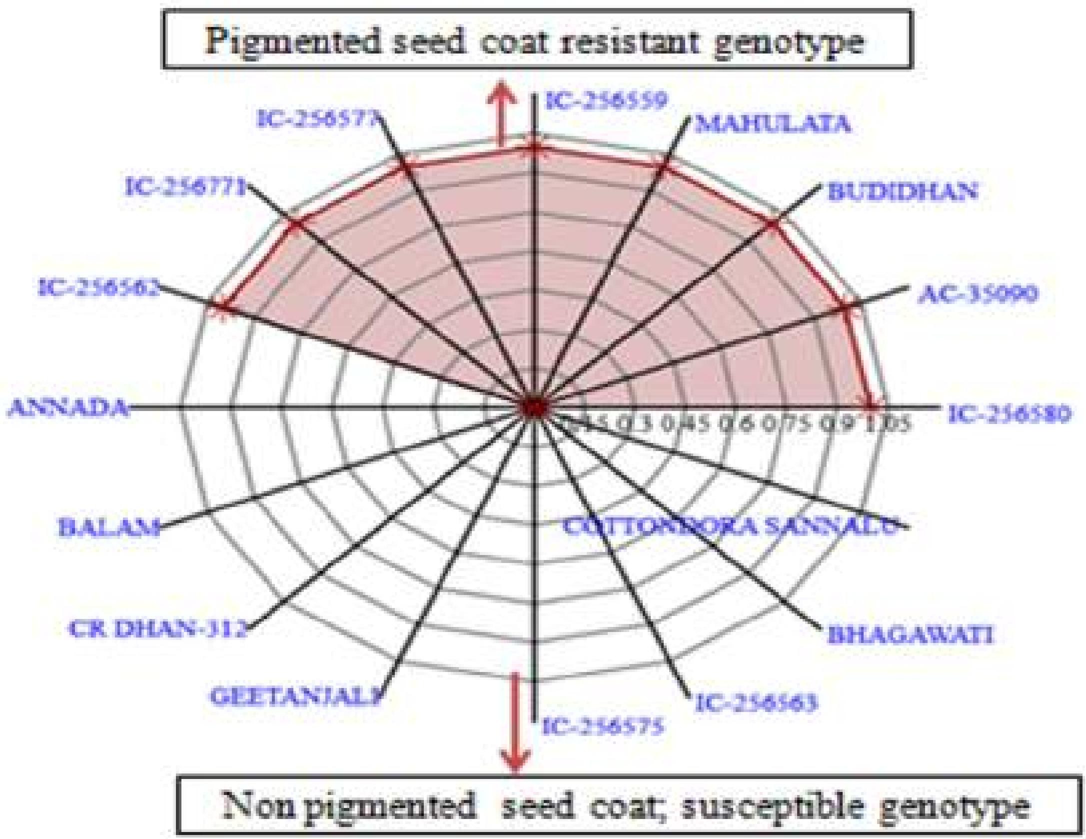

Fig 1. Radar plot differencing the genotypes based on pigmentation white (susceptible) and red (resistant)

Cuttack, Gene Bank were characterized for PHS.A standardized in vitro protocol(Hanjagi *et al*., 2022) was used to evaluate rice genotypes for PHS resistance and recorded the PHS response at five different flowering stages (20 to 40 DAF).From these 96 genotypes, 16 contrasting genotypes for PHS were further studied for influence of pericarp color on PHS resistance.Genotypes with red and white pericarp were assigned the values 1 and 0 to indicate dormancy and susceptibility to PHS, respectively.

RESULTS

Six days after incubation, viviparity was observed in the rice genotypes from 20 to 40 DAF. The viviparous grain ratio in the panicle, which was determined six days after incubation and divided them into five groups based on PHS, served as the basis for the varietal distribution.After studying the 16contrasting genotypes for pericarp color and its association with PHS resistance, we found that out of 8 resistant genotypes 7 genotypes were having red pericarp colorwhile one genotype had non pigmented/white pericarp colour. The susceptible genotypes were found to have non-pigmented/white pericarp color which were highly susceptibile to PHS (Fig 1.).

CONCLUSION

A great genetic diversity for PHS/vivipary was observed among the 96 diverse rice genotypes. Seven out eight resistant genotypes had red pericarpwhich might haveaided in the PHS resistance by promoting ABA biosynthesis. Form this study, we can conclude that pericarp colour influences the PHS response in rice genotypes.

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Development and application of Iso-cytoplasmic restorer: a tool of heterosis enhancement in rice hybrids

Arpita Mohapatra, Ram Lakhan Verma, Banshhidhar Pradhan, Debarchana Jena, Diptibala Rout, Somyashree Mishra

National Rice Research Institute, Cuttack.Odisha
Corresponding e-mail : arpitamohapatra831@gmail.com

Three line system of hybrid development is a most important available way of heterosis exploitation in rice (*Oryza sativa* L.). This system involves three parental lines namely, male sterile parent (CMS), unable to produce fertile pollens and used as female parent in seed production; maintainer parent, an isogenic of CMS line used to maintain male sterility of CMS; and restorer, a genetically diverse parent served as pollen parent and having ability to restore the fertility in hybrids. In this system, cytoplasm of CMS exerts ill effect on hybrid and reduces the complete heterosis expression (reduces up to 5-10%) in F1.

In this view, iso-cytoplasmic restorer, a transgressive segregant of three line hybrid, will have same cytoplasm as of male sterile, may express more heterosis (5-10%) in combination with other iso-cyto CMS. In this regards, a total of 96 fertile iso-cytoplasmic restorers of six line hybrids (AxR hybrids: CRMS31A/Hanseshwari, CRMS32A/Hanseshwari, CRMS31A/Purnendu, CRMS32A/Rayada, 2-31A/CR664 and IR62829A/Gayatri) were developed and utilized in hybrid development at NRRI. Restorer gene (*Rf3 and Rf4*) status of all iso-cytorestorer was assessed through linked molecular markers and 15 (*Rf3 and Rf4* +ve) lines were used in test crosses. Iso-cytorestorer, inspite of being MS carrier having >85% fertility and superior for other agro-morphological traits were used as pollen parents in hybrid development. *Per se* yield, CRHR 3-786-15, a fertile derivative of CRMS31A/ Purnendu F_1 has shown good combining ability with CRMS 31A and CRMS 32A recorded per plant yield of i.e. 53.0g and 49.0g grains/plant, respectively. Therefore, utilization of iso-cytorestorer in hybrid rice development may enhance the heterosis in rice hybrids, marginally and serve substantially towards food security of India.

In three line hybrid rice system, it has been found that defective cytoplasm of CMS exerts ill effect (CMS penalty) and thus reduces the complete heterosis expression (up to 5-10%) in hybrids. In this view, iso-cytoplasmic restorer, having same cytoplasm as of male sterile, may remove the said deleterious cytoplasmic interactions in hybrids and thus assures more heterosis in combination with other iso-cyto CMS. Iso-cyto-restorer is the fertile transgressive segregant of CGMS based hybrid, will have same cytoplasm as of seed parent, CMS and hence remove the fatal cytoplasmic interaction in hybrid while combining with female parent having same cytoplasm. It is developed by 6-7 successive selfing followed by selection in hybrid and to be used as male/pollen parent. In addition, fertile iso-cytorestorers which are at par with parent hybrid in yield, may add an extra heterosis in suitable combination. At NRRI, a total of 96 fertile iso-cytoplasmic restorers of six AxR hybrids are developed and being utilized in crossing programme. In this way NRRI has developed some excellence hybrid combinations, having potential to override the existing heterosis level.

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ARRW/SIRC/Theme I/101

Pyramiding deeper rooting and P-uptake efficiency QTLs in the background of popular irrigated rice variety, Satabdi and Naveen

Elssa Pandit*[1], Swapnil Pawar[2], Sourav Surav Yadav[1], Soumya Abhilipsa Satpathy[1], Deepak Kumar Nayak[2], Saumya Ranjan Barik[2], Shakti Prakash Mohanty[2] and Sharat Kumar Pradhan[2]

1 Department of Biosciences and Biotechnology, Fakir Mohan University, Odisha- 756089, INDIA
2 Crop Improvement Division, ICAR-National Rice Research Institute, Odisha-753006, INDIA
Email: elsambio@gmail.com

Low phosphorus availability is one of the major limitations in upland ecology. Also, with changing climatic scenario, drought stress is the most important threat to both rainfed lowland and upland rice production, affecting the yield stability in Asia. Introducing the efficient P-uptake and deeper rooting characteristics into high yielding rice cultivars of rainfed ecologies may be one of the ways to improve their drought tolerance and augmenting rice yield from rainfed ecologies. Combining these two traits is a novel approach for varietal improvement.

METHODOLOGY

A major QTL *Pup1* for P-uptake and two major QTLs *Dro1* and *Dro2* for deeper rooting were transferred to two popular varieties Satabdi and Naveen through marker assisted backcross breeding strategy.

RESULTS

Landrace rice, Surjamukhi possessing *Pup1, Dro1* and *Dro2* genes/QTLs was used as the donor to develop 0the pyramided lines. During the backcross generations, gene-based markers as well as closely linked flanking markers were used to select the plants having *Pup1+Dro1+Dro2* gene combination. Polymorphic markers between the recurrent parents and the donor line Surjamukhi were used to select plants that had maximum recurrent genome recovery. Selected BC_3F_1 plants were selfed to produce homozygous BC_3F_2 plants having the target genes.

CONCLUSION

These improved lines of Satabdi and Naveen having *Pup1, Dro1* and *Dro2* can be cultivated in rainfed/upland ecologies under drought and low phosphorous availability without compromising yield.

Correlation and path coefficient analysis in rice

Reshmi Raj K.R

ICAR- National Rice Research Institute, Bidyadharpur, Cuttack, Odisha- 753006
**Email : reshmirajkr@gmail.com*

The global rice productivity should be increased at a rate of 2.4% per year to double its production by 2050 for achieving food security. The grain yield is complex in nature, thus selection of genotypes based only on grain yield will not be effective. Therefore, it is very essential to understand the interrelationship of yield with other yield attributing traits and to comprehend the direct and indirect effects of each character towards yield. The present study was done with an objective to understand the character associations in rice genotypes, its direct and indirect effect on yield for further utilization in rice improvement programs.

METHODOLOGY

The forty North East rice accessions, collected from NRRI gene bank was evaluated at research field of ICAR-NRRI, Cuttack during *Kharif* 2022. The 21 days old seedlings of each genotype were transplanted in the field in randomized block design with three replications at spacing of 20 × 15 cm. The observations were recorded on plant height, number of productive tillers per hill, flag leaf length, flag leaf width, panicle length and grain yield per hill in five randomly selected plants per replication. The statistical analysis for correlation and path anlaysis was done using R software.

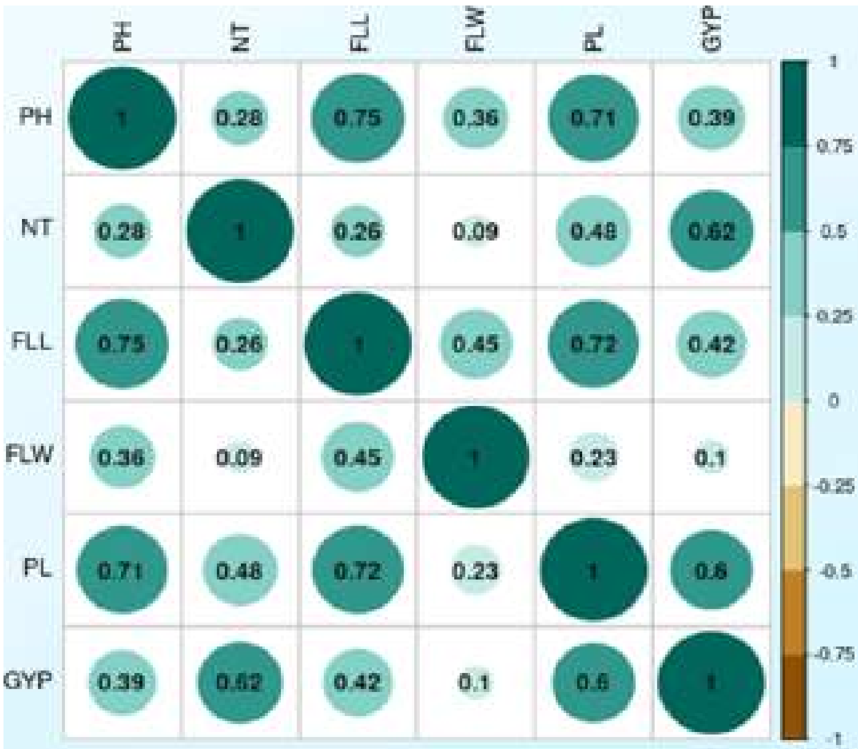

Fig. 1: Correlation analysis in 40 rice germplasm

RESULTS

The results of correlation analysis revealed that the estimates of genotypic coefficients were higher than phenotypic correlation coefficients for all the characters. The positive significant association with grain yield was recorded by number of productive tillers per hill (0.620), panicle length (0.596) and flag leaf length (0.424). These results are in conformity with the earlier reports of Nayak *et al*. (2001), Kole *et al*. (2008) and Chandra *et al*. (2009). The results of path analysis revealed that high positive direct effect on grain yield was recorded by number of productive tillers per hill (0.559) followed by flag leaf length (0.213) and panicle length (0.18). The negative direct effect on grain yield was exhibited by plant height (-0.034) and flag leaf width (-0.096). Similar findings were reported by Bala (2001), Fiyaz *et al*. (2011) and Nikhil *et al*. (2014). Thus the characters *viz.*, number of productive tillers per hill and panicle length recorded both significant positive correlation and high positive direct effect on grain yield per hill. Hence, yield improvement in rice can be done through selection of these traits.

CONCLUSION

Seed yield is a dependent trait and is contributed by many component characters. Thus indirect selection for component characters with significant correlation and high positive effect on yield is done for improving yield in rice. In the present study, number of productive tillers per hill and panicle length recorded both significant positive correlation and high positive direct effect on grain yield per hill which can be used for yield improvement in rice.

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Characterization of rice genotypes for Pre-Harvest Sprouting resistance

Prashantkumar S Hanjagi*[1], S.K. Dash[1], Sushma. M. Awaji[1], Repudi Raju Shalem[2] & M.J. Baig[1]

[1]*ICAR- National Rice Research Institute, Cuttack, Odisha*
[2]*OUAT, Bhubaneshwar, Odisha*
**Corresponding author: psh7160@gmail.com*

Pre-harvest sprouting (PHS) in rice (*Oryza sativa* L.) is one of the key abiotic constraints affecting the development of good quality grain. It is a detrimental characteristic in grain production globally, resulting in significant economic losses each year. Due to the extended rainfall events throughout the harvest season, PHS is common in rice, particularly in Southeast Asia. In view of the high annual economic losses caused by PHS (Black *et al*., 2006), PHS resistance is regarded as one of the most significant breeding objectives for rice and other cereal crops. Identification of PHS resistant genotypes and understanding the genetic basis of seed dormancy and its breakage is critical for improving PHS and responding to unexpected environmental changes. In consideration of this predicament, we carried out this research to characterize rice genotypes for PHS resistance.

MATERIAL AND METHODS

A set of 176 mapping population were used for present investigation including very high yielding Next Generation Rice (NGR), moderately yielding and low yielding cultivars with biotic stress resistance. A standardized in vitro protocol developed by Hanjagi *et al*., 2022 was used to

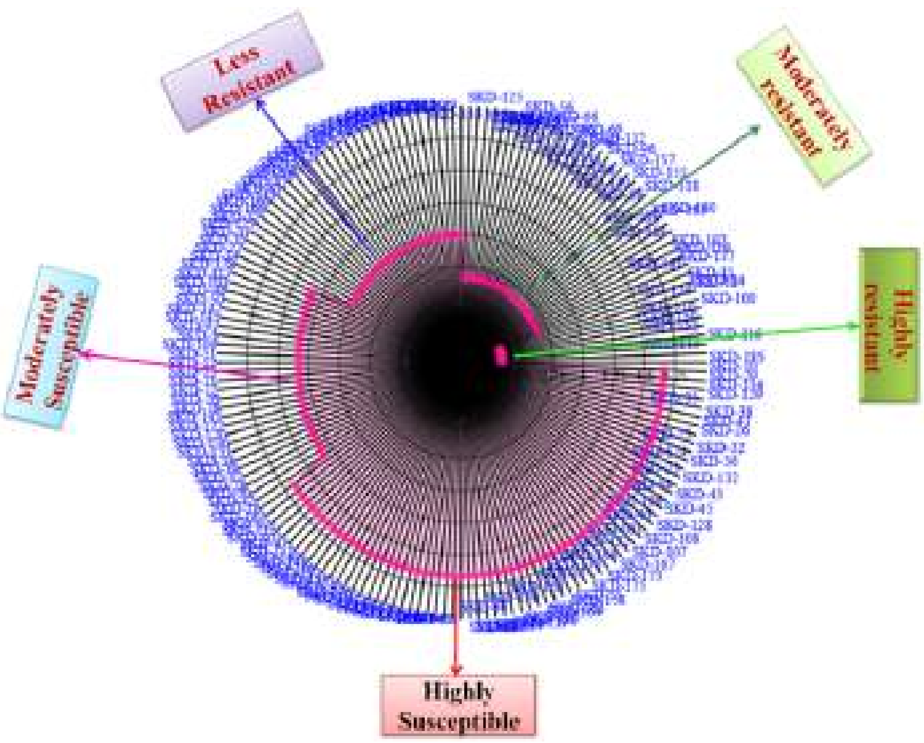

Fig. 1. Radar plot showing that clustering of genotypes based on the germination percentage

evaluate rice genotypes for PHS resistance and recorded the PHS response at five different flowering stages i.e. from 20 to 40 DAF (days after flowering) and classified the genotypes in to five groups based on germination percentage.

RESULTS

Vivipary was evaluated at the 20, 25, 30, 35 and 40 DAF and observed at 20 and 25 DAF was less germination in the susceptible genotypes. From 30 to 40 DAF the germination percentage was increased in susceptible genotypes. The genotypes were classified based on germination percentage in to five groups by using K analysis clustering (fig 1). Results showed that 10, 34 and 32 genotypes were classified in to highly (0%), moderately (0.01-5%) and less resistant (5.01-10%) groups respectively. The 71 and 29 were found to be highly (<15%) and moderately susceptible (10.01-15%) genotypes respectively. The large group was found to be highly susceptible genotypes and 10 genotypes found to be resistant to PHS.

CONCLUSION

The investigation of 176 mapping populations revealed a high genetic diversity for PHS/vivipary, and 10 new rice genotypes with extremely strong PHS resistance were found from the mapping population with 0% germination at all stages of flowering.

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ARRW/SIRC/Theme I/104

Omics Approaches to Unravel the Clues of Differential Grain Protein Content in Rice

K. Chattopadhyay[1], TB Bagchi[1], K. Chakraborty[1], N. Moharana[1], SS Mohapatra[1], N. Basak[1], L. Behera[1], M. Chakraborti[1], A. Mohanty[1], S. Sarkar[1], T. Adak[1], S. Samatary[1], SG Sharma[1], B. P. Mohanty[2] and T. Mohapatra[3]

[1]*ICAR-National Rice Research Institute, Cuttack*
[2]*ADG (Inland Fisheries), Krishi Bhavan, ICAR, New Delhi*
[3] *Former Secretary DARE and DG, ICAR, New delhi*

Protein content in rice grain is generally lower (7%) in quantity but higher in quality as compared to protein in other cereals. Some of the low-yielding landraces such as ARC 10075 from Assam were detected with higher grain protein content (GPC). CR Dhan 310, a backcross derived line from Naveen/ ARC 10075 cross has been released as the high-protein rice variety in India in 2016 with an average of 10.2% grain protein (Chattopadhyay et al. 2019a). This biofortified rice variety having phenotypic similarity with Naveen has been established as its valid replacement for enhancing nutrition in the diet of rice consumers. The investigations make an effort in making inventorization of protein present in rice proteome and try to understand the higher accumulation of storage protein resulting in nutritional superiority of high protein rice variety CR Dhan 310.

METHODOLOGY

Naveen, ARC 10075, backcross derived mapping populationand introgression lines such as CR Dhan 310 derived from Naveen/ARC 10075 cross were taken for enzymatic assays, identification of QTLs and genes and qRT-PCR based gene expression analysis and protein related to N-assimilation and storage during grain filling stages.

Enzymatic assay at different stages of reproductive growth starting from panicle initiation of CR Dhan 310 and Naveen was done for Nitrate reductase (NR), Nitrite reductase (NIR), Glutamine Oxoglutarate Amino Transferase (GOGAT) and Glutamine Synthetase (GS) enzymes spectrophotometrically. High throughput genotyping using 5400 polymorphic SNPs and multi-environmental data of grain protein content using NIR spectroscopy of mapping population from Naveen/ARC 10075 was employed for QTL analysis and detection of probable functional genes inside QTL region.The proteome profile of the grain sample of CR Dhan 310 and Naveen was generated using Waters Synapt G2 Q-TOF instrument for MS and MSMS analysis. Quantitative reverse transcription–PCR (qRT–PCR)-based gene expression analysis was performed for a few selected genes related to N-assimilation that also showed differential expression in proteomic analysis.

RESULTS

NR, NIR, and GS activities were found significantly higher in CR Dhan 310 than in Naveen in all the developing stages of the panicle. GOGAT activity was also significantly higher in CR Dhan 310 in all the stages except the ripening stage. Proteomic analysis (PRIDE database accession no. PXD026531) indicated high abundance of the proteins Glutamate synthase 2 (NADH), Glutamate dehydrogenase 3, Probable serine acetyltransferase 4, Probable serine acetyltransferase 3, Tryptophan aminotransferase, Tryptophan aminotransferase-related protein 1, Cysteine synthase, Asparagine synthetase, Ammonium transporter 3, Asparagine synthetase, High-affinity nitrate transporter 2.1, 2.2 and 2.3, Aspartate aminotransferase, 63 kDa globulin-like protein and 19 kDa globulin in CR Dhan 310. When qRT-PCR-based gene expression analysis was done for these genes, we found that in the dough stage (14days after anthesis) the upregulation of Glutamate dehydrogenase 3 (7.81), Glutamate synthase 2(NADH) (1.5), Aspartate aminotransferase 1 (6.61), Tryptophan aminotransferase 1 (11.49), NRT 2.2 (2.16), FADH-GOGAT (1.5), NRT 2.1 (1.8), AMT 1.3 (1.49) were significantly higher in CR Dhan 310. On contrary, theexpression of NADH-GOGAT (0.16)and NRT 2.4(0.36) werehigher in Naveen. A consisting QTL (*qGPC1.1*) for grain protein content was detected on chromosome 1 (Chattopadhyay et al. 2019b). Inside this QTL region, a probable functional gene (*Os01g0111900*) was found which encoded glutelin family protein, was detected and validated through *in silico* expression profile at RiceXPro database. Donor parent ARC10075 and high protein introgression lines such as CR Dhan 310 contained this QTL with an elevated level of glutelin fraction as well as essential amino acids such as lysine.

CONCLUSIONS

Overall higher N-metabolism-related enzyme activities evidenced by higher expression at transcript level with high abundance of proteins pointed towards the probable explanation of higher storage protein accumulation during N-assimilation in CR Dhan 310 as compared to the recurrent parent Naveen. Further validation through generation of knockouts for identified highly upregulated functional genes in CR Dhan 310 will further strengthen this finding.

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ARRW/SIRC/Theme I/105

Principal Component Analysis for Anti-Oxidant Activity in Advanced Black Rice Breeding Lines

DBKV Mani[1], P Sanghamitra[2], Nabaneeta Basak[2], SS Mishra[3], N Payra[4],S Sarkar[2]

[1]*College of Agriculture, OUAT, Bhubaneswar 751003, India*
[2]*ICAR-National Rice Research Institute, Cuttack 753006, India*
[3]*UtkalUniversity, Vanivihar, Bhubaneswar 751004, India*
[4]*Ramakrishna mission Vivekananda educational and Research Institute, W.B. 700103, India*

Black rice is well known as "Imperical rice" or "forbidden rice" because it was reserved solely for the Chinese royalty from centuries. Consumption of black rice provides lot of health benefits like, it prevents heart attack (CVD), Alzheimer's, urinary tract infections, constipation, anaemia, cancer, obesity, diabetes, improves visual and neurological health. It's anti-aging and anti-inflammatory properties gives a good scope for it in cosmetics industry. It is also traditionally served to pregnant women to reduce complexity during childbirth in Manipur. Among all black pigmented rice, the aromatic black rice of Manipur popularly known as *Chakhao* is a speciality glutinous rice, for which protection under geographical indication in India has been granted recently (Reg. No. 602,:APRIL 30, 2020 22:28 IST).

MATERIAL AND METHODS

In this study *kharif*-2020 harvest from eighty-three advanced semi dwarf, non-lodging black rice breeding lines derived from a cross between *Chakhao* and Ratna were analyzed for the four antioxidant related traits *viz*., anthocyanin (Fuleki and Francis, 1968) gamma oryzanol (Chen and Bergman 2005), phenols (Zilic*et al.*, 2011) and flavonoid (Eberhardt*et al.*, 2000) by following the standard protocols. To analyze the existing diversity in the present breeding population and to quantify the relative contribution of each trait to the total phenotypic diversity, the data was subjected to Principal Component analysis.

Table 1: Total variance explained by different principal components

Principal component	Eigen value	% of variance	Cumulative % of variance
PC1	2.357	58.919	58.919
PC2	1.022	25.54	84.459
PC3	0.382	9.545	94.004
PC4	0.24	5.996	100

RESULTS AND DISCUSSION

The screen plot analysis revealed that PC1 is the major contributor complying 58.92% of the variation present in the population followed by PC2 (25.54%), PC3 (9.55%) and PC4 (6.0%). PC1 and PC 2 with eigen values 2.357 and 1.022 together explained more than eighty percent of the variability and remaining components with eigen values < 1 contributed 15.541 percent variability (Table1 and Fig1). The percent of total variability 58.919 of PC1 had high positive

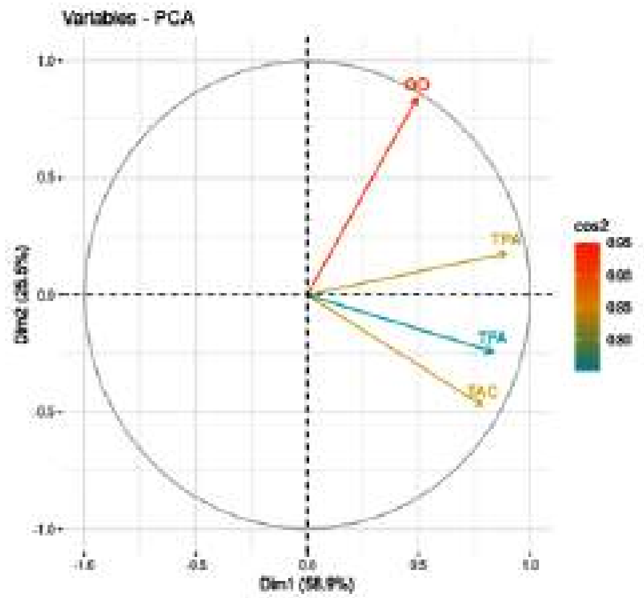

Fig 1. Screen plot analysis

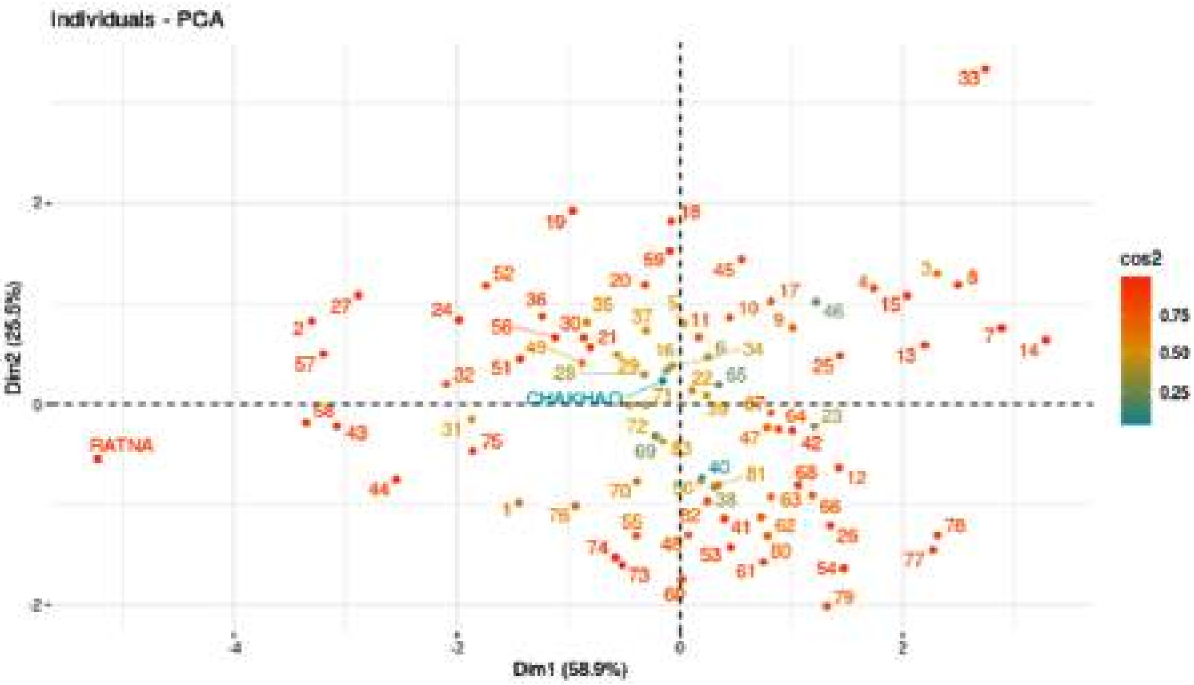

Fig 2.Distribution and grouping of breeding population

component loading from total phenol content (0.895), total flavonoids content (0.833), total anthocyanin content (0.787) followed by gamma oryzanol (0.493). In the PC2, high positive component loading was observed from gamma oryzanol (0.841) while others have either low or negative loading for the component (Table 2). From the four PCs it was clear that the characters with largest absolute value closer to unity within the principal component influence the clustering. Large variances have important dynamics; therefore, principal components with larger associated variances represent data patterns while those with lower variances represent noise. Therefore, lines that fall in a common principal component were observed to be the most important factors (Fig 2). So that a good hybridization breeding program can be initiated by the selection of genotypes from the PC1, as it is contributing maximum towards diversity with maximum eigen value.

Table 2. Principal factor analysis; Correlation between variables and PCs

Variables	PC1	PC2	PC3	PC4
TAC	0.787	-0.473	-0.297	0.263
GO	0.493	0.841	0.022	0.221
TPC	0.895	0.178	-0.214	-0.35
TFC	0.833	-0.242	0.497	-0.003

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Correlation Study on Aromatic Short Grain Rice of Eastern India on the Basis of Grain Quality and Cooking Parameters.

Nillahit Payra[1], SS Mishra[3], DBKV Mani[4], G Kumar[2], S Sarkar[2]

[1] *Ramakrishna Mission Educational and Research Institute, Narendrapur, WB 700103, India*
[2] *ICAR-National Rice Research Institute, Cuttack 753006, India*
[3] *Utkal University, Vani Vihar Bhubaneswar 751004, India*
[4] *College of Agriculture, OUAT, Bhubaneswar 751003, India*

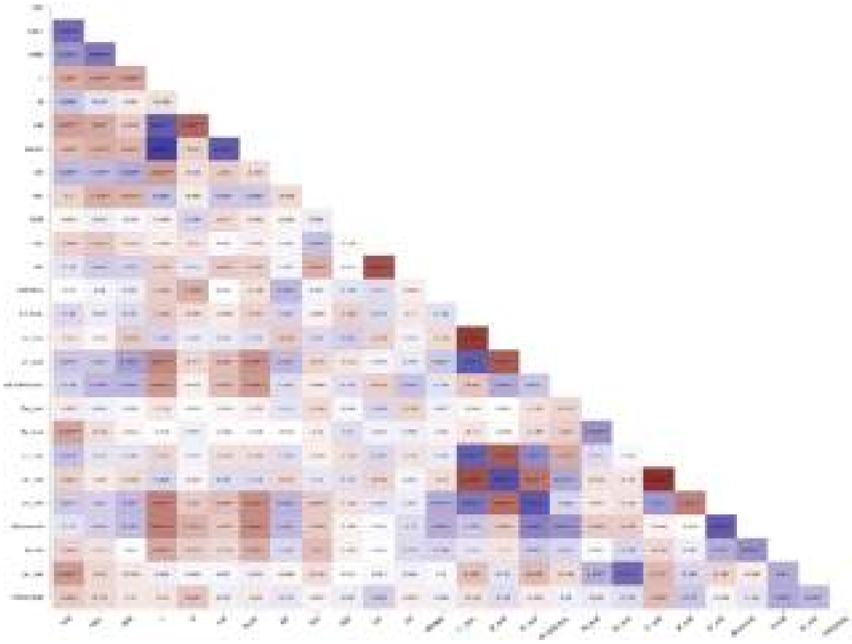
Rice (Oryza sativa L.) is an important staple food grain which is consumed by more than half of the world's population. Besides yield, now- a- days quality improvement of grain has lots of scope especially in aromatic short grained rice (ASG). Proper characterization of ASG group for quality parameters is needed. Sixty-three aromatic landraces of eastern India were characterised for quality and cooking parameters and correlation study was done to understand the relationship among the parameters.

METHODOLOGY

Total twenty-one quality parameters were studied namely Hulling %, Milling %, Head Rice Recovery % (HRR), Kernel Length before cooking (L) and Kernel breadth before cooking (B), L/B ratio, Amylose content (Juliano,1979), Aroma, four colour segments of both hulled and milled rice, Iron, Zinc content in hulled and milled rice and Protein. On the other hand, kernel length after cooking (KLAC), Elongation ratio (ER), Water uptake (WU), Volume Expansion Ratio (VER) and Gel consistency (GC), total of five cooking parameters were included. Two set of replicated data from each parameter were taken and correlation analysis was done with the mean data.

RESULTS AND DISCUSSION

From this correlation study, we observed that Hulling % had significant and positive correlation with Milling %, HRR, Kernel breadth, ER, Yellow colouration of grain (brown and milled rice), light colouration of milled rice and significant negative correlation with kernel length, L/B, KLAC, Zn content (milled rice and brown rice). Milling degree had significant positive correlation with HRR, ER, yellowish hull colour and overall colour variation (dE_cmc) of brown rice and significant negative correlation found between Kernel length, L/B ratio, WU, KLAC and GC. HRR was significantly and positively correlated with ER, yellowish colour component and total colour variations(dE_cmc) of colorimeter of both brown and milled rice and significant negative correlation with kernel length, WU, KLAC, GC, and colour component a*(reddish hull colour). Kernel Length (L) was positively and significantly correlated with L/B ratio, WU, KLAC and significant negative correlation was observed with ER, Fe content of milled rice, yellow colour component and total colour variation of brown and milled rice. Except for L/B ratio, Breadth (B) did not correlate significantly with other parameters. Length and breadth ratio had a significant positive correlation with WU and KLAC and negative significant correlation with amylose content, yellow colour component and dE_cmc colorimeter of both hulled and milled rice. Kernel Length After Cooking (KLAC) had significant positive correlation with L/B ratio, WU and significant negative correlation with hulling%, milling%, HRR%, kernel length, overall colour variation of brown and milled rice, yellow colour component of brown and milled rice and Fe content of milled rice. Elongation Ratio (ER) was positively correlated with hulling%, milling%, HRR%, Aroma and yellow colour segment of colorimeter in case of both brown and milled rice and total colour variation of milled rice. Water Uptake (WU) had a positive significant correlation with KLAC cooking and GC and significant negative correlation with amylose content, Fe and yellow colour segment of milled rice. Correlation between



water uptake and amylose was significantly positive. Volume Expansion ratio (VER) had no significant correlation with any other parameters due to the very narrow range of variation of the trait. Gel consistency (GC) was positively significant with water uptake, L/B and kernel length and significantly negatively correlated with amylose content, milling%, HRR%. Amylose Content (AC) was found to have significant positive relation with total colour variation (dE_cmc) component of milled rice and significant negative correlation with Gel consistency. Aroma was found to be significantly and positively correlated with ER, yellow colour component of brown and milled rice and dE_cmc (overallmilled rice colour variation) and significantly negative correlation with Breadth.

Among the 63 germplasm most of them are land races. The positive correlation with yellow colour may be due to selection biasness of the farmers for slightly coloured grains for offerings to God (*bhog* rice), *khichri* or *payasam* leading to a visual sensory preference after cooking for the purpose. Similarly, small breadth and after cooking good elongation ratio is preferred by farmers especially in the case of aromatic rice. So, we can conclude that this correlation is influenced by the selection preferences by the farmers. No significant correlation is found with other parameters. Fe of milled rice has significantly positive correlation with Zn content of milled and hulled rice, protein content, dE_cmc of milled rice and significant negative correlation was identified with KLAC, WU and Kernel length. This may be due to the fact the voids being occupied by Fe and Zn that possess difficulty in the kernel elongation during cooking. Fe of brown rice positively correlated with Zn content of both brown and milled rice. Such correlation has also been reported by Nagesh *et al.,* 2013. Zn of milled rice have significant correlation with iron content of milled rice, zinc content of hulled rice, protein content, and yellow colour segment of hulled rice and significant negative correlation with Hulling% and l segment of colour of milled rice. Zinc content of hulled rice is significantly and positively correlated with iron content of hulled rice and Zn content of milled rice. And significant negative correlation with hulling%.

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ARRW/SIRC/Theme I/107

Marker-trait Association for yield attributing traits in New Generation Rice using SSR and Indel markers

Ashish Mohanty[1], Awaneet Kumar[2], Anilkumar C[1], R. P. Sah[1], Babyrani Panda[1], H.N.Subudhi[1], L. Behera[1], J. Meher[1] and S.K. Dash[1]

[1]*Crop Improvement Division, ICAR-National Rice Research Institute, Cuttack-753006, Odisha, India*
[2]*Department of Plant Breeding & Genetics, Faculty of Agricultural Sciences, S'O'A, (Deemed To Be University), Bhubaneswar*
**Corresponding author's E-mail: skdash139@gmail.com*

Irrigated rice ecology contributes around 75% of total rice production, but only from about 55% of total rice area i.e., about 22 million hectares area in the country. In this context, it is more important to focus for this ecology for future food security. For breaking the yield plateau innovative approaches need to be initiated. The concept of "New Plant Types" was developed by Khush in late 1990s (Khush, 1995). The main idea of this is to modify the plant ideotype with 30-50% more yield potential than the existing semi dwarf varieties in tropical environment during the dry season. The NPTs were developed by extensive use of *tropoical japonicas*. However, the success was quite limited.

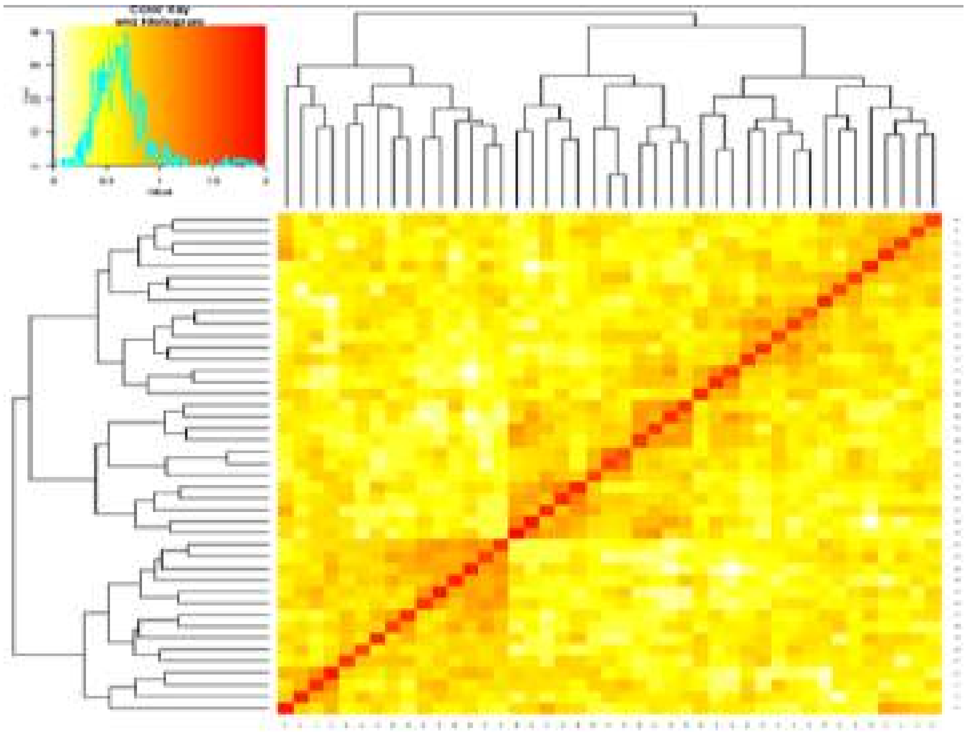
New Generation Rice (NGR) has been conceived for breaking yield plateau in irrigated situation. It is established on ideotype concept, a typical plant type in purelines, with improved quantitative and physiological traits. There is more emphasis on heavier panicle with higher grain number, longer and wider flag leaf with superior leaf density, moderately high tiller number, and higher root volume. The number of tiller and spikelet number need to be in a balanced manner which has considerable impact on photosynthesis, which leads to superiority in yield performance (Dash, et.al, 2021). Moderately high tillering capacity is very much needed to raise the production of biomass and enhance compensation the loss of tillers in the vegetative stage, because of several reasons including insect damage, late planting or any other. It additionally appeared advantageous to decrease the compact arrangement of spikelets. There is a meagre study on QTLs governing high yield in NGRs. In this context, association analysis was undertaken with an objective of identification for marker trait association in NGRs and HYVs.

MATERIALS AND METHODS

This study involved association mapping of diverse rice genotypes related to NGR and Nitrogen efficient lines. The MLM analysis, Q-Q ploting and Manhattan ploting were used for GWAS analysis of 17 yield attributing traits, by including Q+K matrices using R softwere. The p-values at t <0.005 level of significance have been utilised to determine the significant association of SSR markers. In MLM analysis, association analysis was carried out at 1000 permutations for the correction of multiple test.

RESULTS AND DISCUSSION

Many plant traits are quantitatively inherited, making QTL mapping an appropriate choice for these characters. It is cumbersome to detect the genomic regions pivotal for these traits. GWAS analysis is the one of the most effective idea to identify these important traits. The study was conducted using a panel of 43 diverse rice genotypes, phenotyped for 16 agronomic characters and yield traits. Further, genotyping was done by using 56 polymorphic markers. By performing structured association analysis using MLM approach, a total of 10 marker-trait associations were identified for 7 plant characters.



Heat map of kinship matrix.

The MTAs were found to be available in six chromosomes namely, chromosomes number 1, 5, 6, 8, 9 and 12. The indel markers GS-5 indel-1 was found linked with tiller number. Among the genes, SUB1BC2 is directly linked with plant architecture, like panicle length, unfilled grains and yield, SCM2- indel-1 is associated with flag leaf width, RM 25 was associated with root length, marker RM 19 found to be presented in both fertile grain and grain yield and GN1A-17 SNP mainly involved in for grain yield. The multiple involvements of markers could be employed in practical rice breeding strategy to improve a number of yield attributing traits once they are validated. Large number of genes indicated novel associations with characters that had never been reported before. This could be because the majority of gene functions discovered through fine mapping and gene cloning research were limited to only one or a few traits. However, detailed study should be undertaken to reveal whether these genes have an effect even on other traits also.

CONCLUSION

Authentication of above QTL/gene markers, as well as their implication in selection of quantitative parameters across a diverse of populations and backgrounds is very important. These initial reports indicated the importance of cgSSR markers and recognition of marker-trait association for ideotype responsible of NGR. It could also be validated in different groups based on molecular similarity, which is extremely important for subsequent breeding strategy.

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ARRW/SIRC/Theme I/108

Androgenic derived doubled haploids in stacking of multiple genes in rice

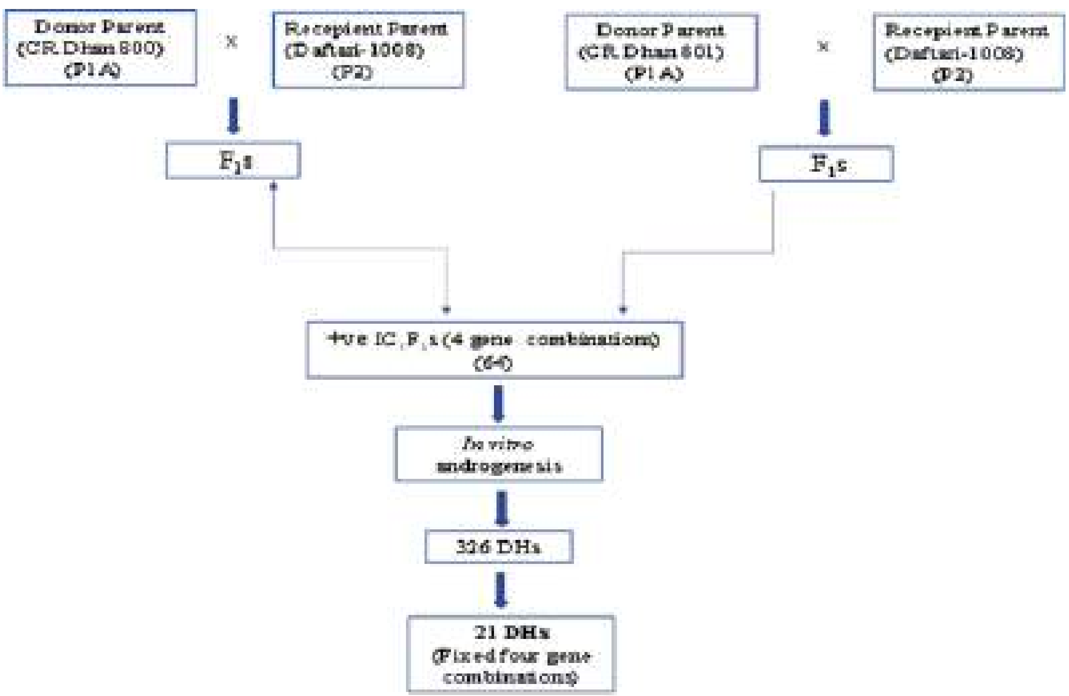
Prachitara Rout[1], Snigdha Samir Pattnaik, Manjusha Chandravani, Ram Lakhan Verma[1], Parmeswaran C[1], Jawaharlal Katara[1] , Devanna BN[1], Sanghamitra Samantaray[1]

[1]ICAR-National Rice Research Institute, Cuttack-753006, Odisha, India,
Email id: prachitararout@gmail.com

Climate change has significantly impacted agriculture and is a huge impediment to the sustainable production of rice (*Oryza sativa* L.). Being the most significant and commonly consumed cereal crop, rice is negatively impacted by biotic and abiotic stresses (Velásquez et al., 2018). The most commercially consequential bacterial disease is rice BB caused by *Xoo* while drought is an important abiotic factor that affects crop growth and limits yield. Doubled-haploid (DH) breeding through anther culture has emerged as an exciting and powerful tool, and a convenient alternative to conventional techniques for crop improvement. (Samantaray et al.,2021). Though MAS has greatly facilitated gene stacking in various crops, the rapid advances in DH development has opened many avenues with the objective of maximizing selection progress using minimum time and resources in two generations. Our primary objective was to develop DHs from the intercross combinations of recipient line (Daftari-1008) with the two donors CR Dhan 800 (BB) and CR Dhan 801 (qdty).

METHODOLOGY

The present study was conducted at the National Rice Research Institute, Cuttack. In this study, CR Dhan 800 (*xa5, xa13, Xa21*) and CR Dhan 801(*qDTY2, qDTY3.1*) were used as donor sources for BB and drought tolerance respectively while



Daftari-1008 was used as recipient parent. Firstly, the IC_1F_1s generated were validated through gene specific/linked markers followed by production of the green plants through anther culture which were assessed for their ploidy status on the basis of morphological characters.

RESULTS

A total of 331 plants were generated through androgenesis showing callus induction (37.45%) and green plant regeneration frequency (78.12%) from the inter-cross combinations. Out of which, 326 plants were confirmed to be doubled haploids through phenotypic and molecular characterization. Finally, 21 DHs were authenticated having fixed 4 gene combinations involving targeted QTLs/ genes (*xa5, xa13, Xa21, qDTY2.1, qDTY3.1*) through linked/ gene-based markers .

CONCLUSION

Over time, we have noticed that the majority of rice-growing regions experience severe abiotic and biotic stresses, which lower yield and produce grain with lower quality. Therefore, DH approach coupled with MAS technology could help detecting the availability of desirable genes and making them fixed in a single generation.

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ARRW/SIRC/Theme I/109

Utilization of Anther culture for Development of Doubled Haploids: Improvement in *indica* Rice Hybrids:

S.S.Pattnaik*[1,2] , P.Rout[1], R.L.Verma[1], J.L.Katara[1], C.Parameswaram[1], B.N.Devanna, N.Ramesh[2], S.S. Samantaray[1]

[1]*ICAR-National Rice Resesarch Institute, Cuttack, Odisha,753006*
[2]*Bharathidasan University,Tiruchirapalli, Tamilnadu, 620024*
**Email- snigdhasameer89@gmail.com*

The demand for rice will rise in the next years as a result of the fast-growing global population. A significant amount of work has made into improving the key agronomic characteristics of rice, from which hybrid rice technology is a practical and easily adaptable strategy demonstrating 15-20% yield gain in comparison to other rice varieties. However, it has a few drawbacks, like high seed costs and labor-intensive seed production, for which emerging technology intervention is needed to address the issues related to the hybrid rice cultivation (Rout. et al). The quick development of homozygous lines that breed true to type in a single generation and improve selection efficiency is thought to be possible with the help of the plant breeding technique known as anther culture. DH technique shows its significance by generating fertile, stable recombinant homozygous lines from the elite rice hybrids in a single generation (Pattnaik.et al). However, the recalcitrance of *indica* cultivars to tissue culture limits the practical application for production of homozygous lines for which an effort was made to produce DHs of a popular quality *indica* rice hybrid, 27P63 by manipulating chemical and physical factors through anther culture.

OBJECTIVES:

- To standardize the chemical and physical factors for optimization of callus induction and green shoot generation of elite rice hybrids.
- To evaluate the ploidy status of the anther derived plants through morphological characters and molecular markers.
- To isolate and evaluate fertile doubled haploids for morpho-agronomic characters, yield and its components under field conditions.

METHODOLOGY

This study was carried out at National Rice Research Institute, Cuttack, Odisha. A medium duration elite rice hybrid, 27P63 developed by DuPont Pioneer, Hyderabad was taken for the study. Panicle boots were collected from the rice variety with different internode length starting from 8cm to 20cm Cold pre-treatment was given at 10°C, 12°C for 2, 4, 6,7,8, 10, 12 days in darkness whereas Control spikes were not subjected to cold treatment. For callus induction, two different basal media i.e. MS (Murashige and Skoog 1962) and N6 (Chu et al. 1975) were prepared with three different combinations and concentrations of BAP (0.5-1.0 mg l^{-1}), Kn (0.1-1 mg l^{-1}) and 2, 4-D (1.5-2.5 mg l^{-1}) along with 3% maltose (Table 1). For callus regeneration, two media were formulated using MS medium along with combinations of growth regulators BAP (1.0-2.0 mg l^{-1}), Kn (0.5-1.0 mg l^{-1}) and NAA (0.5-1.0 mg l^{-1}) along with 3% sucrose. Likewise, MS media supplemented with NAA (2.0 mg l^{-1}), Kn (0.5 mg l^{-1}) and 5% sucrose were used for rooting.

RESULTS

A total of 345 green plants were generated from 27P63 out of which 325 showed normal

Fig 1. Androgenesis of 27P63

morphological appearances with 65-95% grain fertility; other 20 plants were found as haploids and polyploids. Thereafter, SSR markers discriminated 324 DHs from 325 fertile green plants by distinguishing a single heterozygote. After morpho–agronomic traits evaluation, 92 DHs were selected based on the grain yield and quality. This investigation could be exploited to study the genome structure of promising doubled haploids with respect to the parental hybrids to identify the genomic regions contributing to yield heterosis.

CONCLUSION

Among all the speed breeding procedures that have been created, DH technology could be considered as an effective way to develop promising rice lines to feed the growing population. Furthermore, this approach could be used to quickly produce biofortified rice.

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In vitro mutation on reduction of height of Kalajeera, a popular landrace

Manjusha Chandravani, Swagatika Baral, Byomkesh Dash, Sudhansu Sekhar Bhuyan, Sanghamitra Samantaray

ICAR-National Rice Research Institute, Cuttack-753006, Odisha, India,

Email id: manjusha.chandravani@gmail.com

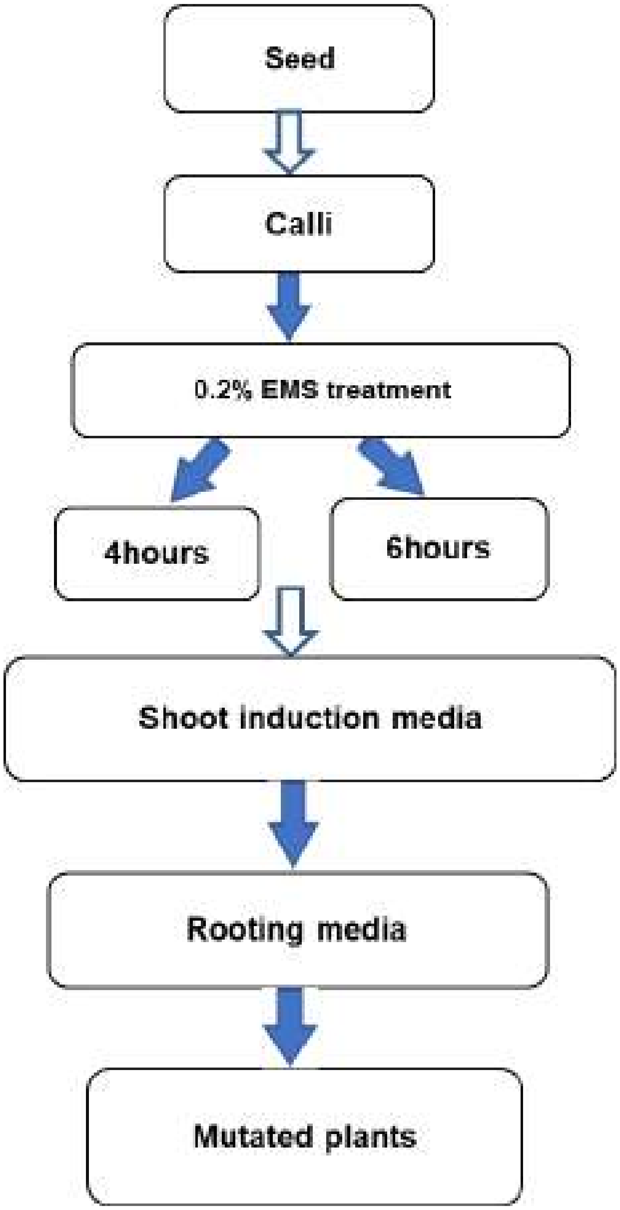
Rice (*Oryza sativa* L.) is the most widely consumed staple food for a large part of the world's human population especially in Asia. Landraces are genetic treasure and well adapted to the local environments. Odisha is known for rich rice genetic diversity and many landraces are still grown in different regions of Odisha by the farmers. These landraces in Odisha are popular due to its aromatic quality and tolerance to multiple biotic and abiotic stresses. However, yield of the landraces are very low due to less number of productive tillers and lodging during grain filling stage of the crop. Mutagenesis has the ability to modify only a very few characters particularly plant height without altering the remaining and often unique genetic background of the promising cultivars. Chemical mutagens have been found to be 2-2.5 times more effective than physical mutagens in rice for creating desirable variations in population. Among chemical mutagens, EMS has been proved to have improved agronomically important traits in crop plants. The degree of mutation depends on the dosage and time of exposure to the mutagen along with plant tissue used for mutagenesis. EMS dose applied to mutagenize rice seeds is in the range of values 0.2-2.0% with durations ranging from 2 to 22 hours.In Odisha, one of the landrace named as Kalajeera is highly popular among the farmers (Roy et al, 2016). Additionally, Kalajeera is also moderate yielder but due to tall character, lodging during grain filling stage reduces the yield (Roy et al, 2016). Our objective was to develop mutant lines of Kalajeera using in vitro mutagenesis approach and evaluated the mutated plants in M_1 generation for agronomic traits i.e height reduction.

METHODOLOGY

Mature grains of Kalajeera collected from NRRI were used for the study. Seeds were inoculated in basal MS medium supplemented with different plant growth regulators for callus induction. Calli were treated with 0.2% EMS for 4 hours and 6 hours respectively. After 10 days, treated calli were transferred to regeneration medium for shoot induction. The mutated green plantlets (1-2 cm) were transferred to rooting media for root initiation. Plantlets with well-formed roots (after 21 days) were separated from culture medium, washed thoroughly and planted into the pots with sterile soil, kept in green house for 7 days then transferred to net house. Height of the mutated plants was measured in M_1 generation.

RESULTS

Significant variations were observed in shoot regeneration efficiency after EMS treatment at different durations. The number of shoots regenerated from the treated calli reduced with increasing treatment duration from 4 to 6 hours. In contrast the increased shoot regeneration efficiency of kalajeera, compared to control can be due to the growth promotion effect of EMS induced auxins and gibberellic acid in the treated calli, responsible for stimulation, acceleration of cell division and cell elongation, causing increase in shoot regeneration and number of shoots regenerated per callus (Jaleel et al.,). A reduction of 30% in plant height was observed in mutants compared to the parent.



CONCLUSION

Kalajeera was found to be responsive to mutagenesis. EMS (0.2%) at 6 hours followed by 4 hours treatment was found to be most effective. A total reduction of 30% in height of mutants without any significant change in the yield shows the applicability of EMS based mutation. Furthermore, the result can be reproduced for the improvement of other rice genotypes. Higher mutation in the genotypes studied can be attributed to the use of in vitro mutagenesis technique in which calli are more exposed to mutagens than whole seeds during treatment process.With the availability of efficient plant regenerating systems from cultured cells the opportunity of combining in vitro culture with chemical mutagenesis i.e in vitro mutagenesis can be an efficient and powerful tool for crop improvement.

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ARRW/SIRC/Theme I/112

Studies on variability and character association in rice

Mihir Ranjan Mohanty[1*], Parshuram Sial[2], Chinmaya Kumar Das[3]

[1] *Regional Research and Technology Transfer Sub Station (OUAT), Jeypore - 764001*
[2] *Regional Research and Technology Transfer Station (OUAT), Semiliguda - 763002*
[3]*Regional Research and Technology Transfer Station (OUAT), Ranital - 756111*
**mihirgenetics@gmail.com*

Germplasm collection provides enormous scope for grain yield improvement in rice by using suitable breeding methods. The diversity of parents is of utmost importance for a successful breeding programme. Grain yield is a complex character, which is influenced by a large number of characters. The correlation and path analysis in combination give a better insight into cause and effect relationship between yield and other component characters. The understanding on association between yield and other traits improves the efficiency of selection. The observed correlation between yield and its component trait is the result of direct and indirect effects of the component character through other yield attributes. The total correlation between grain yield and its component characters may sometimes be misleading since it may be over or under estimate of its association with other characters. Hence, correlation coefficient needs to be split into direct or indirect effects using path coefficient analysis.

METHODOLOGY

The sixty rice (*Oryza sativa* L.) genotypes were evaluated at Regional Research and Technology Transfer Sub Station (OUAT), Jeypore, Odisha during *Kharif* 2022. The experiment was conducted in RBD design with two replications. The genotypes were evaluated for genetic variability, correlation and path coefficient analysis considering ten quantitative traits viz. days to initial flowering, days to 50% flowering, days to maturity, plant height (cm), number of tillers/m^2, panicle length (cm), number of fertile spikelets/panicle, number of sterile spikelets/ panicle, test weight (g) and grain yield (kg/ha). The statistical analysis for variability, correlation and path analysis was done.

RESULTS

The analysis of variance revealed significant differences among the genotypes for all the traits studied. This indicated that the genotypes were genetically diverse and wide spectrum of variability observed among the genotypes provides enough scope for significant yield improvement in these genotypes through selection. The genotypic correlations were found higher than the corresponding phenotypic correlations. This is due to the modified effect of environment on character association at the genetic level. Grain yield exhibited significant positive correlations with days to initial flowering, days to 50% flowering, panicle length, number of fertile spikelets/panicle and test weight at both genotypic and phenotypic levels. Thus selection for these characters can be used for yield improvement in these genotypes. Path coefficient analysis was done to understand the direct and indirect effect of yield attributing characters on grain yield. The results of path analysis revealed that number of fertile spikelets/panicle had highest positive direct effect on grain yield, followed by no of tillers/m^2, days to 50% flowering and test weight. Thus the characters *viz.*, number of fertile spikelets/panicle, test weight, number of tillers/m^2 and days to 50% flowering which had both significant positive correlation and high positive direct effect on grain yield. Therefore improvement of yield in rice can be done through selection of these traits.

CONCLUSION

The variability, correlation, path analysis were done on 60 rice germplasm. The results of analysis of variance revealed that the genotypes were genetically diverse. The correlation and path analysis study revealed that number of fertile spikelets/panicle, test weight, number of tillers/m^2 and days to 50% flowering can be used for yield improvement in rice.

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Utilization of maintainer lines for development of hybrid rice: can doubled haploid approach capable in extracting yield related favorable alleles?

Anindita Mishra[1]., Nihar Ranjan Singh[2]., Ram Lakhan Verma[1]., Sanghamitra Samantaray[1]. [*]

[1] *Agricultural Biotechnology, Crop Improvement Division, ICAR-National Rice Research Institute, Cuttack, Odisha- 753006*

[2] *Associate Professor, Department of Botany, Ravenshaw University, Cuttack, Odisha, India, Pin code- 753003*

Correspondence author email- smitraray@gmail.com

Rice as a cereal crop is the predominant staple food for a large part of the world's human population. It is estimated that by 2050 the need of the global food demand will be double. However, presently the production rate is in declining state. In developing countries like India, the changing climatic scenarios are the major constraints in rice production. Use of recent technologies offers a sustainable way to meet the demand and develop the agricultural system. Keeping in view of the diminishing land, development of High Yielding Varieties (HYVs) is essential in order to meet the farmers need for which development of sustainable HYVs is the need of the hour. However, production and productivity HYVs have almost come to a plateau. Alternatively, adoption of hybrid rice technology is being popular in achieving higher yield as it enhances farm productivity by 20-30% more than the HYVs (Birchler *et al.*, 2003, Schnable *et al.*, 2013). Most commonly, three-line system of hybrid rice (consisting of Cytoplasmic Male Sterile(A), Maintainer(B), Restorer(R) lines) development is followed in India. However, the prime limitations of hybrid rice are unstable male sterility, inherited CMS load, poor grain quality, hybrid sterility; moreover, farmers need to buy the seeds year after year due to segregation in each generation. Therefore, development of inbred lines from hybrid rice is a viable option for which Doubled Haploid technology is the most significant approach to extract the yield related favorable alleles in a short period of time. The major objective is to generate a large number of androgenic DHs from crosses of distantly related well combining maintainer and restorer lines. The brief methodology includes the development of F1s from B x R lines for anther culture and collection of spikelets. Followed by the callus induction and green shoot regeneration using MS media & N6 media. The developed green regenerants are transferred for rooting, development of plantlet and acclimatization in Net House. Further, the assessment of ploidy level in regenerants and authentication of doubled haploids are to be done, these DHs are genotyped using molecular markers and phenotyped for yield and yield related traits. The callusing and regeneration efficiency of the BXR plants are much higher than that of the AXR plants. The DHs developed from BXR lines shows higher frequency

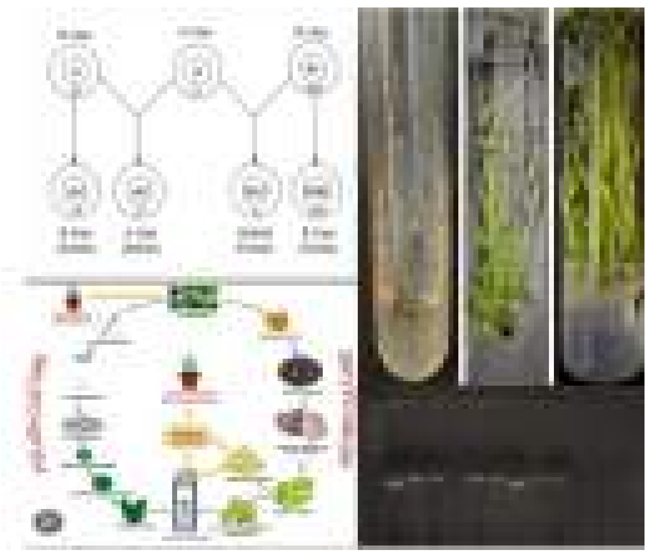

fig: Showing callusing, regeneration and rooting of plantlets developed from F_1s from BXR lines. Agarose gel electrophoresis representing DHs.

than that of DHs from AXR lines. However, it is presumed that the developed inbred lines from AXR lines might show sterility in future as it carries the cytoplasm of A line which has defective mitochondria. Since B line is near isogenic to A, maintainer (B) line can be used in overcoming the sterility issue for generation of inbred lines through DH approach. Androgenesis of hybrid rice derived from BxR lines will encourage the development of 100% fertile DHs as compared to Cytoplasmic Genetic Male Sterility (CGMS).

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Expression of structural genes involved in anthocyanin biosynthesis pathway during grain filling stage in Chakhao Poireiton, a scented purple rice variety of Manipur

Asem Mipeshwaree Devi* & Sudripta Das

Plant Bioresources Division, Institute of Bioresources and Sustainable Development (DBT-IBSD), Takyelpat, Imphal, Manipur
**email: mipeasem@yahoo.com*

Chakhao (literally translated as tasty rice) in Manipur is known for its deep purple colour, glutinous, unique flavour and special aroma. The rice cultivar has bagged the Geographical Indication (GI) tag (GI Reg. No. 602) in the year 2020. Previous studies on the rice variety had uncovered the diversity of Chakhao in view of the grain colour, anthocyanin and polyphenolic content along with their antioxidant properties. Earlier studies have shown the presence of a various secondary metabolites particularly flavanoids with potentially health benefits. Among them, anthocyanins are an important class of flavonoids that represent a large group of plant secondary metabolites.

Of over 600 anthocyanins identified in natures, the derivatives of six widespread anthocyanidins, namely pelargornidin, cyanidin, delphinidin, peonidin, petunidin, and malvidin are common. Anthocyanin is biosynthesized and accumulated during the developmental process especially during the grain filling stage. Many structural genes are responsible for the accumulation of the grain colour.In many plant species, biosynthesis pathway which starts with the chalcone synthase followed a series of reactions till the formation of a coloured anthocyanidins by anthocyanidin synthase. The final step in the formation of anthocyanin is catalyzed by various members of the glycosyltransferase enzyme family.

Transcriptomic profiling of the black rice, Chakhao Poireiton was performed to understand the differential expression of the key enzymes involved in the anthocyanin biosynthesis pathway. Our study indicated that expression of key structural genes were regulated at different growth stages and tissues. As an instance, genes encoding for enzyme UDP-glucose flavonoid 3-O-glucosyltransferase were not expressed in leaves at heading and anthesis periods but was found to be expressed in grain. The expression level gradually increased with maturity of the plant in leaves but it is more or less constant in grain. Our study will provide valuable insights of the expression of structural genes related to anthocyanin biosynthesis in the Chakhao rice cultivar.

ARRW/SIRC/Theme I/46

Morpho-molecular characterization of three line Rice Hybrids

A Ravi Kumar[1], Ravi Kant[1*], D N Kamat[1], Rajesh Kumar[1], R K Choudhary[3], K L Bhutia[4], Nilanjaya[1], V K Choudhary[1], and C S Choudhary[2]

[1]Department of Genetics and Plant Breeding, [2]Department of Plant Pathology, [3]Department of Agricultural Statistics, [4]Department of Agricultural Biotechnology & Molecular Biology, Dr. RPCAU, Pusa, Bihar- 848125, India

The present investigation was undertaken with a view to generate Morpho-molecular characterization of three line Rice Hybrids for 18 traits by Analysis of variance, correlation, path coefficient analysis, heterosis and molecular markers. The experimental material comprised of 31 three-line rice hybrids and 3 commercial checksevaluated in RBD design. ANOVA exhibited significant Mean Sum of Square values due to genotype for all traits that reflect presence of ample amount of variability in studied rice genotypes. All studied traits except days to 50% flowering, leaf width (cm), culm diameter (mm), panicle length (cm), root volume (lit) and days to maturity were showing positive and significant correlation with yield per plant. No. of tillers per plant, plant height, root fresh weight, leaf length, no. of panicles per plant, leaf width, kernel length, root volume revealed a significant direct impact on grain yield per plant. Among the checks the variety the Rajendra Sweta performed best for the grain yield per plant. Two rice hybrid genotypes namely IR68897A × KMR-3R and Rajendra-3A × RRR–4 was exhibited superior standard heterosis over all three checks for trait grain yield per plant. By utilising 12 primer pairs, a total of 33 shared alleles and 13 unique alleles were produced as amplified products. Among 12 primers seven primers found to be comparatively informative for all nineteen hybrids and eleven parents. Only five primers namely MRG2894, RM515, RM 520, RM 538 and RM 555 were able to confirm the F1 with respective parental lines.

Key words: *Correlation, Molecular marker, Path Rice (oryza sativa) and Standard heterosis*

ARRW/SIRC/Theme I/48

Selection of rice (*Oryza sative* L.) accessions for tolerant to drought at the seedling stage under rainout shelter

Deepak Gauraha and Atul Pachauri

Department of Genetics and Plant Breding, Indira Gandhi Krishi Vishwavidyalaya Raipur,Chhattisgarh,492012 India
Email: dgauraha@yahoo.co.in

Drought stress is a major constraint to the production and yield stability of crops. Rice (*Oryza sativa* L.) is considered as a drought-sensitive crop species. Within these species, there are considerable amount of varietal differences for drought sensitivity is appeared. Therefore, an experiment was conducted at the Department of Genetics and Plant Breeding, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh during February to April 2022, to evaluate 500 rice genotypes along with susceptible and resistant checks for drought tolerance at early seedling growth stage. The genotypes were tested after 35 days after sowing for drought tolerance. The experiment was laid out in augmented design. The result showed that seedling height, SPAD Chlorophyll value, leaf rolling and leaf drying decreased in all rice genotypes with the increase of water stress level in the experiment. Based on Standard Evaluation System (SES), 13 genotypes were found promising. Among the 13 genotypes, IC378170, IC377122, IC206954, IC459006X, IC 388900, IC380497, IC390457, IC206864, IC387012, IC514535, IC300592, IC458213X and IC554873 were showed higher seedling vigor, SPAD chlorophyll value along with 0 scale for leaf rolling and drying as compared to the check entries as per SES Score 2013. These identified tolerance genotypes will be further screen and incorporate in crop improvement programme.

***Keywords**: Drought stress, seedling vigor, rice genotypes and tolerance.*

ARRW/SIRC/Theme I/69

Induction of herbicide Imazethapyr resistance in rice (*Oryza sativa* L.)

Ekhlaque Ahmad[1], Shahina Parween[1], Fatima[1], Krishna Prasad[1], Ashok Kumar Singh[2], M K. Barnwal[3], Binay Kumar[4], Varsha Rani[5], and O. N. Singh[6]

[1]Department of Genetics & plant Breeding, [2]Department of Agronomy,[3]Department of Plant Pathology, [4]Department of Entomology, [5]Department of Crop Physiology, [6]Vice-Chancellor

Birsa Agricultural University, Ranchi, Jharkhand, India-834006

Corresponding author: ekhlaque.bau@gmail.com

Rice is an important staple food crop of Jharkhand as well for India. It ranks first in terms of area (17.63 ha) and production (53.65 lakh tones) during the year 2021-22 in the state. This crop grown in all three ecology of rice cultivation. Weeds are menace for its wider cultivation which seriously affects rice yield and grain quality. Scarce of manpower and higher wages of labourers affects today's agricultural operations and increase cost of cultivation, so why farmers are bound to practice direct seeding. Herbicide resistance in crop plants, herbicide resistant rice variety in particular is valuable for weed management in rice field. Imazethapyr is a wide spectrum effective herbicide generally used in pulse crops. Rice crop is sensitive to Imazethapyr. In view of aforesaid problem, an effort was initiated at Birsa Agricultural University during *Kharif* 2021 to develop Imazethapyr herbicide resistant genotypes in rice. The present experiment was conducted at Birsa Agricultural University, Ranchi during *Kharif* 2021, summer 2022 and *Kharif* 2022. Two kg seed of commercial hybrid rice (27P28) is treated with 1.5% Sodium Azide solution for 8 hours. After draining the solution the treated seeds were spread overnight on paper. Next day sowing was done in the nursery. After 21 days, transplanting was done in close spacing of 10 cm x 10 cm. Single seed (M_2F_2) were harvested from individual plant (single seed descent method). On 5th January, 2022 collected seeds were sown for raising the nursery. Imazethapyr herbicide (2.5 ml/l water) was applied in standing plants on 19th February, 2022. Only five plants were survived out of about estimated 25,000 plants and produces seeds. Survived five plants were raised for further seed production. Individual plant seeds were harvested and sown again as plant-progeny rows by direct seeding on 6th July, 2022. On 25th July again Imazethapyr herbicide was applied in standing crops. None of the plants were affected by this herbicide and field was completely free from weeds. Different types of rice segregants with herbicide resistance plants were observed. In M_3F_3 generation, different types of rice segregants with herbicide resistance fixed plants were obtained. This mutation had no negative effect on the plant physiology and morphology as well as on yield. Earlier workers were also find similar types of findings.

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ARRW/SIRC/Theme I/110

Optimization of rice regeneration protocol

Laxmipreeya B [1, 2], Kailash CS[1], Sanghamitra S[2], Pawan KA[1], Parmeswaran C[2]

[1] *Odisha University of Agriculture and Technology- 751003, Odisha, India*

[2] *Crop Improvement Divisions, ICAR-National Rice Research Institute-753006, Odisha, India*

Corresponding email: klaxmipreeya1@gmail.com

Without effective and repeatable regeneration and stable genetic transformation, understanding the management of linked molecular systems is difficult. Genotypes, tissue source of explants, mix and concentration of growth regulators, and culture conditions are all important aspects in effective transformation for genome editing. Despite the fact that rice has a well-established transformation system compared to other crop plants, most indica rice types are still challenging to regeneration and genetic change. As a result, a pre-requisite event for the development of genome edited plants should be the refining of tissue culture protocols for the formation of embryogenic calli and the regeneration of fertile plants from a single cell. In this report, we present high-frequency robust Transformation techniques for Lalat and MTU-1010, three popular elite Indica cultivars. Explants generated from mature seeds were employed as the starting material. In MS medium containing 3.0 mg/l 2,4, D + 0.25 mg/l BAP as phytohormonal combinations, the highest callus induction percent was observed followed by phytohormonal combinations of 2.5 mg/l 2.4 D + 0.5 mg/l kinetin. In addition, maximum regeneration was observed in MS salts +30 g/l maltose, 2 mg/l kinetin, 0.2 mg/l NAA, pH 5.8, 10 g/l agarose; 250 mg/l cefotaxime and 30 mg/l hygromycin in regeneration media-1 and MS salts +30 g/l maltose, 2 mg/l BAP, 0.5 mg/l kinetin, 0.25 mg/l NAA, pH 5.8, 4 or 8 or 10 g/l agarose; 250 mg/l cefotaxime and 10 mg/l hygromycin.. Improved callus health lead to successful transformation and proliferation of calli on selection media, but a low frequency of plantlet regeneration occurred when calli were transferred to regeneration media. The efficiency of plantlet regeneration was greatly improved by reducing the antibiotics (Hygromycin) from 30mg/l in regeneration media-1 follwed by 15mg/l in regeneration media-2, with the minute quantity of hygromycin 10mg/lit in rooting media. Regeneration percentage of transformed calli is 75.18% in MTU-1010 and 89.92 in case of Lalat variety. Whereas transformation percentage is high in case of MTU-1010 (74.40%) compared to Lalat (71.20%).

Theme - II

Ecological and sustainable management of rice-based production systems

INVITED LECTURE

Enhancing resilience of rice-based cropping systems to climate change

Sudhanshu Singh*, Malay K. Bhowmick, Ashish K. Srivastava, Panneerselvam Peramaiyan and Amit Srivastava

IRRI-South Asia Regional Centre, Varanasi, Uttar Pradesh 221106, India

Email: sud.singh@irri.org

Rice is the major staple food for nearly 4.0 billion people worldwide and about 0.8 billion people in India. Nearly two-thirds of the worldwide rice area belongs to Asia, where rice is primarily grown in four different ecosystems: flood-prone, upland, rainfed lowland, and irrigated. In India, ~16.33 m ha of rainfed arable areas are prone to abiotic stresses, including drought (7.18 m ha), flood (5.36 m ha), and salinity (3.79 m ha). The resource-poor small and marginal farmers in these areas mostly depend on the rice-based cropping systems (RBCS), which are becoming more vulnerable to climate change as the systems require a large volume of water. The rice production under the irrigated and rainfed systems in Asia is heavily impacted by climate change. There are numerous challenges to address and overcome to continue producing enough rice to feed the growing population. Some of the main challenges include depleting natural resources, extreme climatic variability, inadequate farmers' awareness, labor migration from rural to urban areas, rising labor wages, the inclusion of women and young people, fragmented and small landholdings, and declining profit margins. The International Rice Research Institute (IRRI) has been working with R&D institutes, farmers, extension agents, policymakers, and other stakeholders to provide consolidated research support and education services towards improving productivity, profitability, and resilience of RBCS while achieving the Sustainable Development Goals.

MANAGEMENT OF ABIOTIC STRESSES

Drought :

Drought affects ~23 m ha of rainfed rice in South and Southeast Asia. In drought-affected areas, the majority of farmers' preferred varieties typically succumb and provide insignificant or nominal yields. However, drought-tolerant rice varieties such as Sahbhagi Dhan, DRR Dhan 42 (IR64-Drt1), DRR Dhan 44, DRR Dhan 46, DRR Dhan 47, Shusk Samrat, etc. can withstand dry spells for up to two weeks during the active tillering stage and even produce more or less double the yields of popular varieties. In rainfed upland areas, the combination of improved (drought-tolerant) varieties and best management practices (BMPs) can provide ~20% yield gains over the farmers' varieties and their own management, whereas the improved varieties and BMPs can provide ~14 and 12% yield advantages over the farmers' preferred varieties and farmers' management practices (FMPs), respectively.

Submergence:

Submergence affects ~15-20 m ha of rice fields in South and Southeast Asia. Through the introgression of *Sub1A-1* gene, several mega rice varieties have been transformed into submergence-tolerant rice varieties such as Swarna-Sub1, Samba-Sub1, BINA Dhan 11, CR 1009-Sub1, IR 64-Sub1, etc., which exhibit a yield advantage of 1-3 t/ha over their recurrent parents, even after 10-15 days of flooding. In flood-prone rainfed lowland environments, proper nursery management, use of healthier and more robust seedlings, and post-submergence nutrient management help improve better survival of the stress-tolerant rice varieties (STRVs) with an additional yield gain of 0.5-1.0 t/ha. In a recent study at IRRI South Asia Regional Centre, Varanasi, exogenously applied nutrients (Fe, Mg, K) along with the recommended dose of fertilizers (RDF) produced 5.8-28% higher grain yield with improved physical grain quality in Swarna-Sub1 over the RDF applied alone under severe short-term flooding situation.

Salinity:

Rice productivity often becomes very low (<1.5 t/ha) in salt-affected areas of Asia due to the presence of excess salt and other soil-related problems (Singh, 2021). Many rice varieties such as CSR 36, CSR 43, CSR 46, CSR 60, Jarava, Luna Sampad, Luna Suvarna, DRR Dhan 58, Narendra Usar Dhan 2008, Gosaba 5, Gosaba 6, etc. have been developed for growing on degraded soils. The major recommendations for growing salt-tolerant rice varieties in coastal areas include using adequate organic manure (farmyard manure, green manuring with *Sesbania* or *Azolla* as a biofertilizer), higher nitrogen doses (100 kg N/ha) in the nursery, transplanting three to four seedlings/hill at a spacing of 20 cm x 15 cm, and applying 150-60-40-5 kg N-P_2O_5-K_2O-Zn/ha in the main field.

Multiple stresses:

Successive occurrences of abiotic stresses such as heat, drought, submergence, and/or salinity within the same cropping season lead to incremental rice yield losses at farmers' fields. With the use of IRRI breeding materials, climate-smart rice varieties such as CR Dhan 801, CR Dhan 802, and DRR Dhan 50 have been developed to combat multiple stresses (flood and drought) in Swarna and Samba Mahsuri background, respectively. The Nepal Agricultural Research Council has also released Bahuguni Dhan 1 and Bahuguni Dhan 2 for flood- and drought-prone areas. BRRI Dhan 78, released by the Bangladesh Rice Research Institute, can tolerate vegetative stage flooding and reproductive stage salinity. The multiple STRVs provide 4-5 t/ha yield under normal conditions and 2.9-4.0 t/ha under varying levels of abiotic stresses. Since Green Super Rice (GSR) varieties genotypes are highly input-efficient and can withstand multiple abiotic stresses, advancing their agronomy would significantly boost rice production and productivity in stress-prone vulnerable areas (Singh, 2021).

INNOVATION AND MECHANIZATION

Direct-seeded rice (DSR) has been emerging as a cost-effective and climate-resilient alternative to puddled transplanted rice (PTR) in South and Southeast Asia. Despite its multiple benefits, DSR-based systems' medium-to-long-term sustainability is under scanner due to yield decline, low germination under anaerobic conditions, irregular stand establishment, intense and diverse weed problems, nematode infestation, etc. IRRI has established a global DSR Consortium targeting to identify the improved cultivars that are more adapted to DSR conditions with appropriate management practices (https://dsrc.irri.org). Dry-DSR (drill-DSR and precision broadcast-DSR), combined with integrated weed management, may offer a pathway for simultaneously reducing costs and markedly increasing productivity. Screening or developing anaerobic germination (AG)-tolerant and herbicide-tolerant (HT) rice genotypes with an improved management package is an innovative strategy that provides a ray of hope for facilitating wider adoption of DSR in stress-prone environments. There is also a need to assess the extent of water saving, system productivity and resource budgeting of rice-based production systems under different micro-irrigation systems (surface and sub-surface drip). There exist huge possibilities and opportunities to make DSR robust, mechanized and precise to improve farm income, food security, and environmental sustainability. Adaptation of zero/minimum tillage reduces the N_2O as well CO_2 emissions as compared to conventional tillage in the rice-wheat system. Custom hiring based machinery banks are required to be established for field-level adoption of large machines by medium and marginal farmers. Rural entrepreneurs can be encouraged and trained to operate and maintain different machines and tools for seed-to-seed mechanization.

PRECISION AGRONOMY FOR RESILIENCE AND SUSTAINABILITY

Precision rice farming is currently based on digital tools/apps and geospatial tools/technologies, including global positioning system, decision support system, variable rate technology, etc. One of the most recent advancements in precision agriculture is a data-driven agronomic intelligence system, which uses machine learning techniques to deliver soil and crop management recommendations for each location (even at the 250 m pixel level). This location intelligence helps the fertilizer manufacturers to produce custom blended fertilizers to address the specific regional soil fertility problems and positioning the fertilizers where a high response is expected. Similar intelligence can be provided to seed, pesticides and market industry to save cost while improving resource use efficiency. IRRI has developed Rice Crop Manager (RCM) as a web-based decision-making tool that provides location-specific fertilizer recommendations in irrigated and stress-prone rice-based systems. Farmer-friendly tools like Green Seeker and leaf color chart (LCC) are useful for site-specific nitrogen management (SSNM) to improve yield benefits and lower down greenhouse gas (GHG) emissions in rice production. Likewise, a number of digital apps/ databases/tools (Easy Harvest, GHG Emission Calculator, Rice Doctor, RKB, SeedCast, WeRise, *etc.*) have been developed by IRRI to support the research and farm management needs in rice sector. Nano-fertilizers are expected to improve crop performance in terms of ultra-high absorption, nutrient use efficiency, *etc.*, and also prevent eutrophication and water resource pollution. Under rainfed situation, scaling of alternate wetting and drying (AWD), sprinkler and drip irrigation systems is an issue. Hence, AutoMon^{PH} is an Internet of Things (IoT) solution, which enables efficient water management through irrigation scheduling, real-time monitoring and reporting, and easier computation of methane emission. Laser guided land leveling helps save irrigation water, improve crop establishment with uniform maturity, enhance input use efficiency, increase productivity, reduce weed infestations, *etc*. IRRI and collaborating partners are also developing an android-based beta version of WeedApp for accurate weed management. Geographic Information System (GIS) and related Earth-observing technologies like Remote Sensing (RS), Global Navigation Satellite System (GNSS), and Unmanned Aerial Vehicles (or drones) offer a variety of applications, including crop growth monitoring, modeling and forecasting, damage assessment, pesticide applications, rice-fallow mapping, data-driven dynamic agro-advisories *etc.*, which would help in increasing productivity and sustainability of RBCS.

SYSTEM DIVERSIFICATION, INTENSIFICATION AND OPTIMIZATION

Building the resilience of RBCS under climate change is sensible and possible through crop diversification and intensification either in space (replacing one crop with another) or in time (replacing the crops in rotation or cropping systems). The effects of harsh weather conditions, such as the unpredictable and variable monsoon in rice and the terminal heat stress in wheat, can be alleviated with proper crop management and timely crop establishment. Transformative gains in wheat yields are achievable only when rice and wheat are managed as a coupled system in eastern India. Food security, profitability, and climate resilience will benefit from the efforts to “keep time” through improved management of the annual cropping calendar both now and as a base for adaptation to progressive climate change (McDonald *et al.*, 2022). Short- to medium-duration STRVs can create new potentials for transforming rice-based systems through diversification, intensification, and optimization when combined with alternate crop establishment methods and scale-appropriate mechanization.

CONCLUSION

Rice production is highly vulnerable and unreliable to climate change. Risks and concerns are further intensifying due to knowledge gaps with the farmers who usually grow rice varieties with conventional practices, including suboptimal crop management. Compared with irrigated rice, rainfed rice typically confronts greater risks and hazards. Hence, there is an overall need for a holistic approach from the crop planning to the post-harvest processing phase of production, deploying improved genotypes, cutting-edge technologies, best-bet management practices and scale-appropriate mechanization to enhance the system resilience, productivity, and profitability of the RBCS under stress-prone fragile environments.

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INVITED LECTURE

Direct-Seeded Rice for Economic and Environmental Sustainability of Rice in Asia: Overview

Virender Kumar[1], Ashok Kumar[2], RK Malik[3], Panneerselvam Peramaiyan[2], Malay Bhowmick[2], Sanjay Saha[4], and Sudhanshu Singh[2]

[1]*International Rice Research Institute (IRRI), Los Banos, Philippines*
[2]*IRRI South Asia Regional Center (ISARC), Varanasi, India*
[3]*International Maize and Wheat Improvement Center (CIMMYT)-India office*
[4]*ICAR-National Rice Research Institute, Cuttack, India*

In Asia, there is increased interest to shift from puddled transplanted rice (PTR) to direct-seeded rice (DSR) to improve the economic and environmental sustainability of rice farmers as DSR saves labor and water, cultivation cost, and reduces greenhouse gas emissions. DSR is widely practiced in many Asian countries such as Malaysia, Sri Lanka, Vietnam, Thailand, Myanmar, and Cambodia. Many countries including South Asia are going through the transition from PTR to DSR. Despite multiple benefits, there are few risks associated with DSR which limit its wide-scale adoption and attainment of optimal grain yields in DSR. These risks include poor crop establishment, higher weed infestation leading to the risk of higher yield losses, limited knowledge on precision water and nutrient management, and lack of suitable cultivars bred for DSR conditions. Many current agronomic practices are very inefficient and large scope exists to improve efficiency and sustainability of DSR through precision crop and resource management practices. To address these DSR issues and to develop and catalyze the wide-scale adoption of mechanized and precise sustainable DSR systems in Asia, IRRI established a new public-private multi-stakeholders R4D platform known as 'DSR Consortium (DSRC)'. Progress made through DSRC to make DSR risk-free and economically and environmentally sustainable will be discussed. In addition, new emerging opportunities which will catalyze wide scale adoption of DSR will be discussed.

INVITED LECTURE

Aerobic rice cultivation for sustainable rice production in India

B.N. Singh[1*]

[1]*Center for Research and Development (CRD) Gorakhpur, 273008 Uttar Pradesh, India*
**Email: baijsingh65@gmail.com*

Rice production was close to 128 million tons in 2021-22. Indian exports has also been increasing since 2012, and it was 19 million tons in 2022 to maximum of 166 countries globally. With a growing population of 17 million, India needs to produce additional 5 million tons rice annually to feed them. Climate change affects the national rice production, and we have to develop strategies to achieve the targeted goal. In 2021, late rains in October- end led to lodging in many paddy cultivars, and in 2022 June– July, delayed rains affected the rice areas in States of Jharkhand, Madhya Pradesh, West Bengal, Chhattisgarh, Uttar Pradesh and Bihar. Paddy area declined by 2.29 million ha as compared to previous year. Aerobic rice cultivation through direct seeding and supplementary irrigations will bring more area under rice, save water and labour, and increase rice production [1]. Aerobic rice is a production system of growing input responsive, non-lodging, high yielding rice varieties in direct seeded unpuddled moist field condition with irrigation. It is growing rice like wheat. Irrigation is must, as direct seeding is done with pre-sowing irrigation, or after pre- monsoon rains. In absence of rains later during crop season, irrigation must be provided at 10-12 days interval, depending on soil moisture holding capacity. Number of irrigations will depend on rainfall pattern. Irrigation can be through surface, sprinkler or drip method. CRD since 2014 is doing on-station and on-farm research on varietal selection, and integrated crop management (ICM) with good agricultural practices (GAP). In a NABARD funded project, aerobic rice cultivation was demonstrated in 24 ha in farmers' field during 2019-20. Incentive of Rs.10, 000 ha^{-1} was provided in form of seed, line seeding by tractor driven seed cum fertilizer drill, pre and post emergence weedicides, micronutrients, and need based pesticides use. Maximum Paddy yield of 6.5 tons ha^{-1} was obtained, similar to irrigated rice. Samba-Sub1, Swarna, BINA Dhan 11, and Bio 690 hybrid had higher yield than others. Submergence tolerant varieties were also suitable for flood prone, water logged and irrigated areas. In hybrids, false smut incidence was high. Saving of an average Rs. 10,000 ha^{-1} was obtained from aerobic cultivation as compared to transplanted rice. Nursery raising, irrigation water for puddling, and transplantation cost were major savings. Aerobic rice saves around 55% water, mainly from seedling raising, and puddling. It also reduces hired labour use by 40%. Direct seeding reduces methane production from paddy fields. Breeding for aerobic rice in India, is 20 years old and around 19 varieties have been released through All India Co-ordinated Rice Improvement Project [2]. Research and varietal improvements have been done in Brazil, Bolivia, China, Indonesia, Philippines, Bangladesh, Pakistan, India & Nepal. For selecting aerobic rice cultivars, semi-dwarf non lodging cultivars should have preferably drought tolerance, diseases and insects resistance, submergence & waterlogging, and other location specific abiotic stresses tolerance. False smut is now a major problem, and tolerant types should be selected. Grain type, cooking & eating quality, and higher grain yield, beyond 6 tons ha^{-1} are preferred traits. The duration of cultivar vary depending on rainfall distribution and availability of irrigation. Higher seedling vigour is preferred trait, but not essential. For ICM, seed rate of 25 kg ha^{-1} for varieties, and 20 kg ha^{-1} for hybrids, Basmati grain types, and short grain types cultivar is sufficient. Higher seed rate leads to lodging of crop. At sowing P_2O_5 and K_2O should be applied, and later after two weeks onward, nitrogen should be applied as Urea for topdressing in three splits after weedicides use. Soils with iron and zinc deficiency should be applied with 25 Kg ha^{-1} ferrous sulphate and zinc sulphate as basal or as foliar spray. NPK dose should be 120 Kg N, 60 Kg P_2O_5 and 40 Kg K_2O ha^{-1}. Mostly medium and late duration varieties are preferred. Deep summer ploughing by MB Plough will break the hard plough layer and more rain water will recharge ground water. This will make the water available to roots during rainless period. Use of pre- emergence weedicide (Pendimethalin) should be done preferably on same day of seeding, and post emergence weedicide (Bispyribac Sodium) should be applied at least 15 to 25 days after germination with surfactant, depending upon weed flora for effective weed management. In 2021, Punjab and Haryana States have grown around one million ha under direct seeded aerobic rice cultivation. The number of irrigation reduced from 25 to 10 and water use by 30%. There is need to develop and select rice varieties suitable for both direct seeded and transplanted conditions with multiple resistance to major disease, insects and abiotic stresses. Most of the varieties released for aerobic rices are intermediate height and lodging types. A 12 points strategy has been developed for aerobic rice cultivation [2]. Time of seeding depends on rainfall pattern of an agro climatic region. Deep summer ploughing by MB plough increases water holding capacity of field. Variety of appropriate duration will ensure maximum yield. Mechanical seeding by seed cum fertilizer drill will ensure enough plant population. Pre and post emergence weedicides use at appropriate time will reduce the weeds damage in field. There is need to do research on Integrated Nutrients Management (INM) for direct seeded aerobic rice.

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ARRW/SIRC/Theme II/01

Enhancing resource use efficiency of rice based integrated farming systems for sustainable production and profitability in Konkan region

NV Mhaskar, SB Bhagat, PS Bodake and SG Bhave

AICRP on IFS, Regional Agricultural Research Station,
Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Karjat – 410201, Raigad Maharashtra, India
Email: namdev_mhaskar@rediffmail.com

In an era, characterized by high population growth and increasing pressure on agricultural systems, efficiency in the use of natural resources has become central to sustainable agricultural practices. Food security, employment, income generation, resource conservation and environmental protection have been emerged as major concerns all over the world. Integrated farming system (IFS) is one of the approach towards transforming the idea of sustainable development from concept to reality (Rao, 2017). IFS are vulnerable to address climate change and must be adopted to maintain and improve productivity and its stability. The concept of eco-efficiency involves both the ecological and economic aspects of sustainable agriculture. Therefore an investigation was made with the following objectives.

i. To develop an ideal and profitable model of IFS.
ii. To demonstrate efficient use of available farm resources.
iii. To assess the impact of Integrated Farming System model in respect of employment generation, recycling of farm produce and increasing profit per unit area per unit time.

METHODOLOGY

Konkan region of Maharashtra comes under high rainfall zone receiving on an average 3000 to 3500 mm rainfall in 95 to 110 rainy days during *kharif* season. The IFS model comprised of different enterprises *viz.*, crops and cropping systems covering an area of 0.50 ha, horticulture component (fruit crops + nursery) 0.40 ha, livestock components namely, dairy, goatary and poultry on area of 35.75 m^2 each (107.25 m^2), vermicompost unit on 18.00 m^2 and rest of the land (874.75 m^2) is used for operational and other purposes.

RESULTS

Considering the Agro-climatic conditions, natural resources, land holding of farmers and farmer's needs of Konkan region, an ideal integrated farming system model for small and marginal farmers has been developed on an area of 1.00 ha for family having 3 males and 3 females (6 persons) at Regional Agricultural Research Station, Karjat, Raigad under All India Co-ordinated Research Project on Integrated Farming Systems. This region is dominated by rice based cropping systems due to high rainfall. Therefore, the total production of the model is converted in terms of Rice Equivalent Yield (REY). The average of six years data showed that (Table 1) the total production of 47.09 t REY was obtained from 1.00 ha area. In terms of economic returns, the gross and net returns were Rs. 7,15,957/- and Rs. 2,10,553/-, respectively. IFS have created more number of working days in the system due to involvement of more enterprises than cropping systems alone. Six years average employment generation through present IFS model was found to be 1085 man days and its value was Rs. 2,04,819/- which contributed 40.53 % in the total cost of production. This has provided employment opportunity almost throughout the year. In the present IFS model, the average

Table 1: Rice equivalent yield, economic parameters and employment generation of IFS Model

Particular	Mean of 6 yrs
REY (t)	47.09
Gross Returns (Rs.)	715957
Cost of Cultivation (Rs.)	505404
Purchased cost (Rs.)	193250
Recycled cost (Rs.)	107336
Labour cost (Rs.)	204819
Employment generation	1085
Net Returns (Rs.)	210553
B:C ratio	1.42
Net GHG emission	-8842.50 CO_2eKg

employment generation was found to be 1085 man days and its value was Rs. 2,04,819/-. The average total cost of production of the IFS model was Rs. 5,05,404/- ha^{-1}, which included outside purchase for Rs. 1,93,250/- ha^{-1} (38.24 %), value of recycled material within the system of Rs. 1,07,336/- ha^{-1} (21.24%) and for farm labours costing Rs. 2,04,819/- ha^{-1} (40.53 %). On an average of six year study, the benefit : cost ratio was 1.42 by inclusion of different modules in the model. These results are in conformity with the Patel et al., (2018), who found integration of different enterprises as beneficial in their research at different states.

CONCLUSION

Farmers can sustain and economically viable by adopting different modules in IFS. Farmers can increase their net returns by saving the expenditure on farm labours through employment of family labours. The six years compiled data of IFS model showed that as far as the demand of essential foods for a family of 6 members per annum is considered, the annual production in this model was surplus for cereals, oilseeds, milk, fruits and vegetables commodities.

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ARRW/SIRC/Theme II/02

Climate mitigation through resource management technology in rice based cropping systems

NV Mhaskar., SB Bhagat, AS Dalvi . and LS Chavan

AICRP on IFS, Regional Agricultural Research Station, Karjat – 410 201, Dist. Raigad (M.S.)
Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India
Email : namdev_mhaskar@rediffmail.com

The agriculture sector is believed to contribute to the green house effect and the ensuring climate change is likely to have adverse impact on this sector (Pathak H., 2017). The effects of climate change on Agriculture are becoming more obvious and pose serious threats and challenges to food security and sustainability in Agriculture. A cropping/ farming system approach with optimum utilization of natural resources with less reliance on agrochemicals and promoting higher level of below ground and above ground biodiversity and carbon sequestration will prove beneficial to achieve resilience in soil health, which can help to address the challenges in the future scenarios of climate change. The objectives of the study are

1. To design and identify efficient and economically viable farming practices for resource conservation.
2. To study the effect of resource conservation technologies on yield, economics and soil health.

METHODOLOGY

To explore ways of mitigating the negative effects of climate change on Agriculture through resource conservation and management of cropping systems, a field experiment was conducted consecutively for six years from 2010-11 to 2015-16 in a split plot design with three replications at Regional Agricultural Research Station, Karjat, Dist. Raigad (M.S.). The main plot treatments were two tillage systems (minimum tillage and conventional tillage) and four cropping systems (*Kharif* rice followed by *Rabi* cowpea, brinjal, sweet corn and grain *Amaranthus*). Sub plot treatments comprised two mulching treatments (no mulching and mulching @ 3 t ha^{-1} rice straw to *Rabi* crops) and two fertilizer levels (RDF : Recommended dose of fertilizers and 125 % RDF).

RESULTS

The pooled results of 6 years revealed that conventional tillage resulted in significant increase in grain yield of *Kharif* rice by 1.29 q ha^{-1} (2.84 %) as against minimum tillage which produced grain yield of 45.42 q ha^{-1}. The B: C ratio of the system was identical under minimum tillage (2.16) and conventional tillage (2.16) indicating that *Kharif* rice and *Rabi* crops can be grown under minimum tillage. The 'Rice-cowpea' cropping system produced significantly the highest grain (48.45 q ha^{-1}) and straw (58.19 q ha^{-1}) yields of *Kharif* rice over rest of the systems studied. 'Rice-Brinjal' cropping system produced significantly the highest REY (373.66 q ha^{-1}) over rest of the systems. The 'Rice-Brinjal' cropping system realized maximum and significantly higher net returns (Rs. 3,23,139/- ha^{-1}). However, B:C ratio (2.94) was significantly the highest in 'Rice – Sweet corn' cropping system over rest of the cropping systems except 'Rice – Brinjal' cropping system (2.69). Mulching of rice straw @ 3 t ha^{-1} to *Rabi* crops significantly increased grain and straw yields of *Kharif* rice as well as main produce yield of *Rabi* crops as compared to no mulching. Mulching of rice straw to *Rabi* crops @ 3 t ha^{-1} significantly increased total REY (232.95 q ha^{-1}), net returns (1,85,424/- ha^{-1}) and B:C ratio (2.17) of the system as compared to no mulching. Application of 25 per cent higher RDF produced significantly higher system REY of 233.69 q ha^{-1} as compared to application of RDF (219.51 q ha^{-1}). Application of 25 per cent higher RDF to both *Kharif* and *Rabi* crops caused significant increase in net returns (1,88,048/- ha^{-1}) and B:C ratio (2.21) of the system as compared to RDF. 'Rice-Cowpea' cropping system recorded numerically higher values of organic carbon (1.10 %) and available N (228.06 kg ha^{-1}) as compared to other cropping systems. There was no any significant effect of different cropping systems on available P_2O_5 and K_2O content of soil determined after harvest of *Rabi* crops. Mulching of rice straw @ 3 t ha^{-1} to *Rabi* crops significantly increased organic carbon (1.10 %), available N (228.20 kg ha^{-1}), available P_2O_5 (24.48 kg ha^{-1}) and available K_2O (274.38 kg ha^{-1}) content of soil as compared to no mulching. Application of 25 per cent higher recommended dose of fertilizers significantly increased the organic carbon content (1.10 %), available P_2O_5 (24.51 kg ha^{-1}) and available K_2O (273.07 kg ha^{-1}) contents of soil as compared to RDF. Similar opinion with regards to tillage operations on economics were reported by Jha *et. al*., 2011.

CONCLUSION

On the basis of 6 years data it can be concluded that to get higher yields and economic returns, 'Rice-Brinjal' and 'Rice-Sweetcorn' systems may be grown with minimum tillage by applying 125 % RDF to both the systems and 3 t ha^{-1} rice straw mulch to *Rabi* crops to mitigate climate change effects through resource conservation and management of cropping systems.

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ARRW/SIRC/Theme II/03

Study of natural farming practices on productivity, economics and soil health in rice - groundnut cropping systems under Konkan region

NV Mhaskar, SB Bhagat. and DG Jondhale

AICRP on IFS, Regional Agricultural Research Station, Karjat – 410 201, Dist. Raigad (M.S.)
Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India
Email : namdev_mhaskar@rediffmail.com

Natural Farming is considered as agro-ecological based diversified farming system which integrates crops, trees and livestock with functional biodiversity. It is a chemical-free alias traditional farming method. Natural farming is an environmentally sustainable way of growing food. Natural farming is also referred to as "the Fukuoka Method", "the natural way of farming" or "do-nothing farming", is an ecological farming approach established by Masanobu Fukuoka. Although natural farming is sometimes considered a subset of organic farming, it differs greatly from conventional organic farming (Elpel T. J., 2002). An investigation was made on natural farming with the following objectives.

1. To study the influence of natural farming practices on crop productivity, soil health and economics in different agro-ecologies
2. To evaluate and integrate the natural farming inputs in to organic farming packages

METHODOLOGY

To study the effect of natural farming in rice – groundnut cropping systems a field experiment was conducted during *Kharif*-2020 and *Rabi*-2020-2021 in randomized block design with three replications at Regional Agricultural Research Station, Karjat, Dist. Raigad (M.S.). The rice variety *Karjat 9* and groundnut variety *SB – XI* was used with spacing of 20 cm x 15 cm and 30 cm x15 cm in respective crops. Total nine treatments were allotted randomly in both the crops without disturbance. The treatments having complete natural farming practices (Beejamrit + Ghanjeevamrit + Jeevamrit, Crop residue mulching, Intercropping and maintaining whapasa conditions) with deleting one practices in each treatment was included. The other treatments are recommended organic farming package and integrated crop management (50 % nutrient application through organic manures and 50% nutrient application through inorganic sources) + Prophylactic/preventive method of application by organic and need based pesticides for pest management were also tested.

RESULTS

The data pertaining to yield and REY of *Kharif* rice and *Rabi* groundnut showed that treatment having recommended organic farming package recorded significantly highest *Kharif* REY and *Rabi* REY and remained at par with treatments having integrated approach of crop management (50 % nutrient application through organic manures and 50% nutrient application through inorganic sources) + Prophylactic/preventive method of application by organic and need based pesticides for pest management over rest of the treatments under study. Long-term trends of crop yield from the All India – Network Programme on Organic Farming (AI-NPOF) experiment showed that the organic approach is better than inorganic and is at par with integrated (a mix of organic and inorganic) methods (Khurana *et al.,* 2022). The economics of different treatments were worked out and it showed that the highest net returns 9Rs. 44,765/-ha^{-1} and B:C ratio (1.25) was recorded by treatment where integration of organic and inorganic sources were used with organically prevention methods used for control of disease and pests followed by complete package of organic farming. AI-NPOF project shows that the cost of cultivation is higher with the organic approach than integrated. The soil chemical properties were analyzed after complete of sequence and results showed that all soil parameters were statistically non significant response.

CONCLUSION

The system yield of rice – groundnut cropping systems was significantly higher in treatment having AI-NPOF package over remaining treatments except treatments of integrated crop management (50% organic + 50% inorganic with spraying of organic based plant protection measures or need based pesticide

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ARRW/SIRC/Theme II/04

Weed management in transplanted *Kharif* rice (*Oryza sativa* L.) and its residual effect on *Utera* Lathyrus (*Lathyrus sativus* L.)

K. Jana[1], S. Biswas[2], R. Mondal[3], K. Mondal[4]and A. Sarkar[1]

Department of Agronomy, Bidhan Chandra KrishiViswavidyalaya, Mohanpur, Nadia, West Bengal-741252, INDIA
**Corresponding author's Email: kjanarrs@gmail.com*

Rice (*Oryza sativa* L.) plays a vital role in food and livelihood security for almost every household and it is a principal source of food for more than half of the world's population. Weeds are most severe and widespread biological constraints to crop production in India and weeds alone cause 33% of losses out of total losses due to pests (Verma *et al.* 2015).Weeds are considered as major contributors of rice yield loss generally ranged between 18-20% in transplanted rice, 30-35% in direct sown puddled rice and more than 50% in direct seeded upland rice.Considering all these facts, the present experiment was planned to evaluate the weed management through application of chemical herbicide in transplanted *kharif* rice and its residual effect on performance of utera (follow up) crop lathyrus in lower gangetic plain of West Bengal.

METHODOLOGY

The field experiment was carried out at Central Research Farm (CRF), BCKV, Gayeshpur, Nadia, West Bengal, India during 2019-20 and 2020-21 under randomized complete block design (RCBD) comprising 10 treatments (T_1-Pretilachlor 50% EC @ 375 g a.i./ha, T_2-Pretilachlor 50% EC @ 500 g a.i./ha, T_3-Pretilachlor 50% EC @ 625 g a.i./ha, T_4-Pretilachlor 50% EC @ 750 g a.i./ha, T_5-Pretilachlor 50% EC @ 875 g a.i./ha, T_6- Pendimethalin 30% EC @ 1000 g a.i./ha, T_7- Butachlor 50% EC @ 1250 g a.i./ha,T_8- Hand weeding at 15 and 30 days after transplanting (DAT), T_9- Unweeded control, T_{10}-Pendimethalin 30% EC @ 1500 g a.i./ha), replicated thrice. Rice variety Satabdi (IET-4786) was sown in nursery and then transplanted on the main field at a spacing of 20 cm × 15 cm with 2 seedlings / hill. 10 days before harvesting of *kharif* rice, seeds of utera (follow up) crop lathyrus (cv. Nirmal) was sown on the experimental field to evaluate residual toxic effect of applied herbicide on succeeding crop lathyrus.

RESULTS

Pretilachlor 50% EC @ 625 g/ha recorded lowest population in all three categories of weed biomass

Table: Effect of different weed control measures on yield attributes and yield of transplanted *kharif* rice (Pooled of two years)

Treatments	No. of productive tillers/m^2	No. of filled grains/ panicle	Grain yield (t/ha)	Straw yield (t/ha)	Harvest Index (%)
Pretilachlor 50% EC @375 g/ha	316.3	80.11	3.89	4.71	45.06
Pretilachlor 50% EC@ 500 g/ha	328.4	82.64	4.02	4.78	45.71
Pretilachlor 50% EC@ 625 g/ha	336.2	83.12	4.39	4.98	46.52
Pretilachlor 50% EC@ 750 g/ha	320.5	81.58	3.97	4.52	47.00
Pretilachlor 50% EC @875 g/ha	312.7	76.82	3.82	4.72	44.57
Pendimethalin30% EC@1000 g/ha	284.4	72.76	3.54	4.46	44.14
Butachlor 50% EC@1250 g/ha	299.1	74.10	3.68	4.30	46.09
Hand weeding at 15 and 30 DAT	345.4	84.18	4.46	5.08	46.60
Unweeded Control	237.1	65.21	2.12	4.84	30.35
Pendimethalin 30% EC @1500 g/ha	290.2	73.46	3.59	4.77	42.48
S. Em (+)	3.8	2.3	0.11	0.08	0.31
LSD (P=0.05)	10.5	6.7	0.32	0.23	0.91

during 30, 45and 60 Days after application. It was also noted that Pretilachlor 50% EC at various doses were superior to Butachlor 50% EC and Pendimethalin 30% EC in suppression of dominant weed floras of rice field.Application of selective herbicide, Pretilachlor effectively reduced weed density from rice field, which might be due to its inhibitory effect on cell division of weeds (Challam and Thabah, 2018). Pretilachlor 50% EC @ 625 g/ha was almost equally effective as hand weeding during both the period of observations. Pretilachlor 50% EC @ 625 g/ha ensured best results weed control efficiency (WCE) at 30, 45 and 60 days after application.Among chemical measures, maximum grain and straw yields were attained under application of Pretilachlor 50% EC @ 625 g/ha which remained almost equally effective as hand weeding at 15 and 30 DAT. There was no residual effect of herbicidal application in transplanted *kharif* rice on *utera* (follow up) crop lathyrus. Germination % at 10 DAS, plant height, pods/plant, seeds/pod and seed yield of lathyrus did not significantly vary under herbicidal application in previous crop rice.

CONCLUSION

Post emergence application of Pretilachlor 50% EC @ 625 g /ha can be recommended to rice growers of gangetic plain of West Bengal, India for achieving high suppression of dominant weed flora and ensuring high productivity of rice as well as its follow up (*utera*) crop lathyrus.

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ARRW/SIRC/Theme II/05

Influence of nutrient management through organic and in-organic on the growth, yield and quality of aromatic rice cultivar, Lalbadshabhog

Naorem Meena Devi*, Champak Kumar Kundu[1], Mirtyunjay Ghosh[1], Kollol Battachraya[2], Anurup Majumder [2], Soumyajyoti Das[1] and Lalatendu Nayak[1]

[1]*Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia-741252, WB.*
[2]*Deptt. of Agricultural Chemistry & Soil Science, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia-741252, WB.*
Department of Agricultural Statistics, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia-741252, WB.
**Corresponding author's name: Naorem Meena Devi, Ph.D. scholar, Department of Agronomy, BCKV. WB*

ABSTRACT

A field trial was conducted at the farmer's field of Ghentugachhi under Chakdah Block in Nadia district West Bengal during the kharif season, 2021 to evaluate the effect of organic and inorganic nutrients on the growth, yield and quality of aromatic rice cultivar, Lalbadshabhog. From the result postulated, application of organic and inorganic nutrients with RDF (40:20:20 NPK kg/ha) got better results on all the growth and yield parameters. Among the organic treatments, application of Vermicompost @3 t/ha showed maximum plant height, number of tillers/m^2, dry matter production/m^2, etc. which remains at par with the application of FYM @ 10t/ha and the same treatment also recorded maximum number of panicles/m^2 and number of filled grains/ panicle. However, other parameters like panicle length and test weight (1000grain weight), there was no significant difference among the treatments. In case of inorganic nutrient management, application of RDF with zinc sulphate @ 20 kg/ha has recorded highest growth and yield parameters. Maximum grain and straw yield were also recorded with the application of Vermicompost @3t/ha and RDF with zinc sulphate @20kg/ha. Application of organic and inorganic nutrient didn't show any significant effect on the quality parameters like protein and aroma of the cultivars, however maximum was recorded with Vermicompost and RDF+ zinc sulphate @20kg/ha.

Rice is the staple food for most of the Asian countries. And there are various rice varieties, genotypes and land races which has unique characteristics features like texture, size, aroma, glutinous nature etc. India is the one of the most leading country in exporting aromatic rice in different parts of the world. Globally, Basmati rice is the only popular group of aromatic rice exported in the international market from the country. However, with the increasing demands from consumer side and the government's assistance and schemes regarding aromatic rice, now rice growers in India are giving more emphasis on the non-basmati aromatic rice group. The production of aromatic rice needs unique favorable abiotic conditions and the quality and aroma of aromatic rice differ with changing environment. Generally, Indian soils are deficient in nitrogen and phosphorus. And the soil health has also been degraded due to imbalance use of fertilizers. Nutrient like phosphorus, its availability in the soil of Indo-Gangetic plains, Central and North East India are reported as low. According to Singh, 2006 the deficiency of zinc in Indian soils is likely to be increased from 49-63% by the year 2025. And around 55% of the soil in West Bengal is found to be deficient in zinc. Plant required both organic and inorganic nutrients in balanced quantity for proper growth and development. So the present experimental trail is conducted to evaluate the effect of organic and inorganic nutrient on growth, yield and quality of Lalbadshabhog.

MATERIALS AND METHODS

The field trial was laid out at farmer's field of Ghentugachhi under Chakdah Block in Nadia

Table 1. Effect of organic and inorganic on the quality of aromatic rice cultivar, Lalbadshabhog

Particulars	O_1	O_2	O_3	S.Ed(±)	CD	I_1	I_2	I_3	S.Ed(±)	CD
Protein %	7.49	7.64	8.18	0.43	NS	7.44	7.67	8.20	0.43	NS
Aroma	1.43	1.38	1.40	0.04	NS	1.33	1.49	1.39	0.04	NS

district during the kharif season, 2021 to assess the effect of organic and inorganic nutrients on the growth, yield and quality of aromatic rice cultivar, Lalbadshabhog. The trail was carried out in Factorial Randomized Block Design (FRBD) with two factors namely organic (O_1- no organic; O_2-FYM @ 10t/ha; O_3-vermicompost @3t/ha) and inorganic (I_1- RDF i.e. 40:20:20 NPK kg/ha; I_2-RD N &K with 50 kg/ha; I_3- RDF with $ZnSO_4$ @ 20kg/ha) and replicated thrice. The soil of the field had 6.8 pH having medium levels of nitrogen, phosphorus and potassium.

RESULTS

Application of organic and inorganic nutrient had shown significant effect on the growth and yield of crop. From the data recorded from the field trial, it can be postulated that among the organic treatments, application of Vermicompost @3 t/ha showed maximum plant height, number of tillers/m^2, dry matter production/m^2, etc. which remains at par with the application of FYM @ 10t/ha. And the same treatment also recorded maximum number of panicles/m^2 and number of filled grains/ panicle. However, the same treatment had no significant effect on the other parameters like panicle length and test weight (1000grain weight), there was no significant difference among the treatments. The same result was recorded by Apon *et al*., 2018.

Application of zinc and phosphorus in addition to the recommended dose increased the growth and yield of the plant. In case of inorganic nutrient management, application of RDF with zinc sulphate @ 20 kg/ha has recorded highest growth and yield parameters. The same trend was recorded with Mustafa *et al*., 2011. Maximum grain and straw yield were also recorded with the application of Vermicompost @3t/ha and RDF with zinc sulphate @20kg/ha. Application of organic and inorganic nutrient didn't show any significant effect on the quality parameters like protein and aroma of the cultivars, however maximum was recorded with Vermicompost and RDF+ zinc sulphate @20kg/ha as shown in Table 1.

CONCLUSION

From the data postulated, it is clearly indicated that application of organic and inorganic nutrients has significant effect on all the growth, yield and quality of aromatic rice. Application of Vermicompost @ 3t/ha showed maximum growth and yield and same trend was also recorded with the application of RDF with $ZnSO_4$ @ 20kg/ha. Among all the treatment combination, application of Vermicompost with RDF + $ZnSO_4$ @ 20 kg/ha showed highest in all the parameters of growth and yield. Apon *et al*., 2018 also postulated that integrated nutrient management can significantly increase grain yield.

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ARRW/SIRC/Theme II/06

Soil Organic Carbon and Mineral Nitrogen Under Rice Based Cropping System

B.C.Verma*, S.Saha, S.M.Prasad, S.Roy, N.P.Mandal, A.Banerjee, D. Bhaduri, Priyamedha and S.Bhagat

Central Rainfed Upland Rice Research Station (ICAR-NRRI), Hazaribag, Jharkhand, India
ICAR-National Rice Research Institute, Cuttack, Odisha, India
**Corresponding author E- mail: bibhash.ssac@gmail.com*

Prevalent rice mono-cropping or rice-fallow system in rainfed upland areas lead to deterioration of soil fertility and quality mainly due to improper nutrient management (Maiti et. al., 2018). Thus upland soils are becoming low in fertility and consequently the productivity is also low. Therefore, evaluation of soil fertility is very much required in this fragile ecosystem. As nitrogen (N) is the key building element for the plants and on the other side soil organic carbon (SOC) is the crucial component which provides nutrients to crops through decomposition and influences most of the soil properties. Hence estimation of mineral N and SOC can provide a picture of soil fertility.

METHODOLOGY

An experiment was initiated under sole rice and rice-pigeonpea intercropping system with the combination of nutrient management options containing inorganic, organic and integrated source of nutrients. Variety Sahbhagi Dhan and Birsa Arhar-1 were selected for rice and pigeonpea, respectively. The crop was grown with the different nutrient management under rainfed condition. The experiment was conducted in randomized block design with eight treatments (nutrient management) with three replications under two systems (sole rice and rice- pigeonpea intercropping). Soil Samples were collected from

Table 1. Effect of nutrient management and depth on organic carbon and mineral nitrogen content in soil

Treatment (T)	Sole Rice						Rice- Pigeon pea					
	SOC (%)			Mineral N (ppm)			SOC (%)			Mineral N (ppm)		
	Depth (D) (cm)		Mean	Depth(D) (cm)		Mean	Depth(D) (cm)		Mean	Depth(D) (cm)		Mean
	0-15	15-30		0-15	15-30		0-15	15-30		0-15	15-30	
T_1	0.38	0.36	0.37	23.1	23.1	23.1	0.45	0.35	0.40	31.5	35.7	33.6
T_2	0.53	0.48	0.50	52.5	39.9	46.2	0.55	0.49	0.52	58.8	48.3	53.6
T_3	0.63	0.50	0.57	50.4	39.9	45.2	0.62	0.52	0.57	46.2	37.8	42.0
T_4	0.68	0.60	0.64	52.5	39.9	46.2	0.70	0.62	0.66	56.7	54.6	55.7
T_5	0.66	0.59	0.62	44.1	39.9	42.0	0.69	0.63	0.66	48.3	44.1	46.2
T_6	0.67	0.58	0.63	42.0	35.7	38.9	0.71	0.58	0.64	44.1	42.0	43.1
T_7	0.71	0.66	0.68	42.0	37.8	39.9	0.73	0.67	0.70	44.1	44.1	44.1
T_8	0.71	0.59	0.65	46.2	33.6	39.9	0.71	0.56	0.64	39.9	42.0	41.0
Mean	0.62	0.55		44.1	36.2		0.65	0.55		46.2	43.6	
CD (p=0.05)	T = 0.03; D = 0.02; T X D = 0.05			T = 5.5; D = 2.8; T X D = 7.9			T = 0.03; D = 0.02; T X D = 0.05			T = 6.6; D = NS; T X D = 9.3		

T_1: Control; T_2: 100% Recommended dose of fertilizers (RDF)*, T_3: 50% RDF + Farm Yard Manure (FYM) @ 5 t ha^{-1}; T_4: 50% RDF +FYM @5 t ha^{-1} + Arbuscular mycorrhiza (AM) 1.5 q ha^{-1} + Phosphorus Solubilizing Bacteria (PSB) 4 kg ha^{-1}; T_5: 50% RDF + Reside Incorporation (RI); T_6: 100% FYM @10 t ha^{-1}; T_7: 100% FYM @10 t ha^{-1} + VAM 1.5 q ha^{-1} + PSB 4 kg ha^{-1}; T_8: 100% FYM @10 t ha^{-1} +RI

*RDF (60:30:30 N:P_2O_5: K_2O kg ha^{-1}) in rice and (40:30:30 N:P_2O_5: K_2O kg ha^{-1}) in rice –pigeon-pea intercropping two depths (0-15 and 15-30 cm) to analyze the important fertility parameters *viz* soil organic carbon (SOC) (Walkley and Black, 1934) and mineral nitrogen (N) (Rowell, 1994). The observed data were analyzed using SPSS-16.0 to find the effect of nutrient management practices on soil fertility status of both the systems.

RESULTS

Effect of nutrient management and depths were significant on SOC in both the cropping systems. Highest SOC was found in T_7 followed by T_4 whereas; T_4, T_5, T_6 and T_8 were at par in sole rice. Similar trend was observed in rice-pigeon pea intercropping system. Upper depth contains significantly higher SOC in both the systems. In sole rice highest mineral N was found in T_2 and it was at par with $T_{4,}$ however, other nutrient management options have the low mineral N content. More or less, similar trend was found in rice- pigeon pea intercropping system. Mineral N content is higher at upper surface in sole rice; however in rice- pigeon pea intercropping both the layer were at par. The study showed that T_4 (integrated nutrient management option) is able to maintain the high OC as well mineral N content in soil.

CONCLUSIONS

From this study it can be concluded that integrated nutrient management (50% RDF along with FYM and phosphorus solubilizing bacteria) help in improving the soil fertility by increasing SOC and mineral nitrogen content, which can be a better options to maintain the soil fertility.

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Improvement of productivity and resource use efficiency in rice–groundnut cropping system

TK Samant[1*], LM Garnayak, RK Paikaray, PJ Mishra and D Mishra[1]

Department of Agronomy, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha751003, India

[1]Krishi Vigyan Kendra (Orissa University of Agriculture and Technology), Angul, Odisha 759 132

[*]E-mail : tksamant_2003@yahoo.co.in

Rice (*Oryza sativa* L.) and rice-based cropping systems are integral part of agriculture. India occupies the world's largest area (44.5 Mha) under rice. But its low productivity (2.75 t ha^{-1}) worries more than 60% of Indian population (Kundu et al., 2020). The present investigation was carried out to study the effect of different nutrient management and rice establishment methods on productivity and resource use efficiency in rice – groundnut cropping system.

METHODOLOGY

A field experiment was conducted during the rainy (*kharif*) and winter (*rabi*) seasons of 2019-20 and 2020-21 at Odisha University of Agriculture and Technology, Bhubaneswar, Odisha and laid out in a split-plot design with three replications. Six treatment combinations comprising of two rice establishment methods {direct seeded rice (DSR) and transplanted rice (TPR)} and three levels of nutrient management {inorganic-100% STBF, organic-*dhaincha* green manuring + 1/3rd STBN (vermicompost) @ 2 t ha^{-1} + 1/3rd STBN (neem oil cake) @ 0.87 t ha^{-1} and INM-green manuring + 50 % STBN (inorganic @ 50.0 kg N ha^{-1}) + 100% P_2O_5 + 100% K_2O} in rice during *kharif* were allotted to the main-plots. Three nutrient management practices to groundnut during *rabi* viz., 75% STBF,

Table 1. Effect of nutrient management and rice establishment methods on productivity and resource use efficiency of rice–groundnut cropping system (pooled data of 2 years)

Treatment	System yield (t REY ha^{-1})	Land-use efficiency (LUE) (%)	Employment generation Efficiency (EMGE)(%)	Partial factor productivity (PFP) (kg REY kg^{-1} N+ P_2O_5+K_2O added)	Energy efficiency ratio for main product(EER)	Heat use efficiency(HUE) (kg m^{-2} ^{0}day^{-1})
Rice establishment method						
Direct seeded rice	12.51	67.9	73.4	43.97	5.78	1.01
Transplanted rice	11.71	71.1	80.3	40.72	5.69	0.92
SEm (±)	0.068	0.02	0.11	0.240	0.027	0.012
CD (0.05)	0.20	0.05	0.3	0.71	0.08	0.04
Nutrient management in rice						
Inorganic	11.33	68.9	76.4	40.62	4.75	0.92
Organic	12.25	70.1	74.0	46.28	6.64	0.92
INM	12.76	69.3	80.2	40.14	5.81	1.06
SEm (±)	0.084	0.02	0.13	0.294	0.033	0.014
CD (0.05)	0.25	0.06	0.4	0.87	0.10	0.04
Nutrient management in groundnut						
75% STBF	11.55	69.9	73.7	43.46	5.98	0.90
100% STBF	11.95	69.2	77.4	40.86	5.89	0.97
INM	12.84	69.3	79.4	42.72	5.33	1.03
SEm (±)	0.089	0.01	0.21	0.315	0.031	0.017
CD (0.05)	0.25	0.02	0.6	0.90	0.09	0.05

100% STBF and INM-75% STBN + 25% STBN (FYM) @ 1.63 t ha^{-1} + 0.2 LR @ 0.38 t Lime ha^{-1}+ biofertilisers (*Rhizobium* + PSB) + 100% P_2O_5 + 100% K_2O were allotted to the sub-plots.

RESULTS

DSR, INM in rice and INM in groundnut registered maximum system yield of 12.51, 12.76 and 12.84 t REY ha^{-1}, respectively (Table 1). TPR registered higher LUE (71.1%) and EMGE (80.3%) than DSR, On the other hand, PFP, EER and HUE were higher in DSR than TPR. INM in rice increased EMGE and HUE to 80.2% and 1.06 (kg m^{-2} $^{0}day^{-1}$). But organic nutrition in rice improved LUE, PFP and EER. INM in groundnut resulted in higher EMGE and HUE. However, LUE, PFP and EER were higher in 75% STBF because of sub optimal dose of fertilizers and lesser energy input. Inclusion of oilseeds, pulses and vegetables improved the resource-use efficiency of rice-based cropping systems (Patra et al., 2018).

CONCLUSION

Integrated use of *dhaincha* green manuring + 50% soil test based nitrogen (50 kg ha^{-1}) + 100% P_2O_5 + 100% K_2O under direct seeded rice followed by 75% soil test based nitrogen (18.75 kg N ha^{-1}) through inorganic source + 25% STBN through 1.63 t FYM ha^{-1} + 0.2 LR @ 0.38 t Lime ha^{-1} + biofertilisers (*Rhizobium* and PSB) to succeeding groundnut crop can be recommended for higher productivity and resource use efficiency of rice–groundnut cropping system.

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ARRW/SIRC/Theme II/08

Performance of aromatic rice varieties under different nutrient management practices in rice-chickpea *paira* cropping system

Anshuman Nayak[1]* and Chandramani Khanda[2]

Regional Research and Technology Transfer Station, OUAT, Bhawanipatna, Kalahandi, Odisha-766001, India
[2]AICRP on Rapeseed and Mustard, Regional Research and Technology Transfer Station, Ranital, Odisha -756111, India
**E-mail: anshumanouat@gmail.com*

Aromatic rice is considered auspicious in India due to its superfine grains, pleasant aroma with taste, export potential and rich heritage in Indian culture. A large number of indigenous aromatic rice varieties having export potential are cultivated in India. Non use of improved aromatic rice varieties and improper nutrient management practices are the key issues of low productivity of aromatic rice. Moreover, inclusion of a legume in the cropping system adds to the farmer's income and at the same time restores the soil fertility by symbiotic nitrogen fixation (Khanda *et al.*, 2020). Keeping this in mind the experiment was conducted with the objective to evaluate the performance of aromatic rice varieties under different nutrient management practices in rice-chickpea *paira* cropping system.

METHODOLOGY

The experiment was conducted at Regional Research and Technology Transfer Station, Bhawanipatna of OUAT during 2017-18 and 2018-19 to evaluate the different integrated nutrient management practices on *kharif* aromatic rice varieties and it's residual effect on chickpea sown as *paira* crop. The experiment was conducted in *split-plot* design with fifteen treatment combinations, consisting of three aromatic rice varieties *viz*. Geetanjali, Gangabali and

Table 1: Effect of different nutrient management practices on yield attributes, yield and economics of aromatic rice varieties under rice - chickpea *paira* cropping system (Pooled over two years)

Treatment	Effective tillers m $^{-2}$ (No.)	Grains Panicle^{-1} (No.)	Grain Yield of Paddy (kg ha^{-1})	Seed Yield of chickpea (kg ha^{-1})	REY (kg ha^{-1})	System Gross return (Rs.ha^{-1})	System Net return (Rs.ha^{-1})	Return Rupee^{-1} invested (Rs. Re^{-1})
Varieties (Main Plot)								
Geetanjali	228	156	3172	274	4079	83240	36585	1.82
Gangabali	241	170	3344	200	3962	81773	36316	1.83
Badshabhog	223	122	2963	176	3526	72789	28070	1.65
SEm±	12	3.3	113	11	127	2455	2455	0.05
CD at 5%	NS	10	369	37	413	8007	8007	0.17
Nutrient management (Sub Plot)								
40:20:20	212	139	2817	174	3342	69058	27399	1.66
60:30:30	215	141	2917	185	3475	71834	29465	1.70
80:40:40	263	171	3546	249	4297	88257	44389	2.02
40:20:20+FYM	234	146	3201	259	3982	81632	33375	1.70
40:20:20+FYM+BF	239	150	3318	286	4182	85556	36635	1.75
SEm±	6.7	5.0	117	13	134	2636	2636	0.06
CD(0.05)	19	14	334	38	381	7495	7495	0.17

*Cost of paddy Rs.20.00/kg and straw Rs.1.00/kg 2017-18 and 2018-19 and chickpea Rs.50.00 and Rs.55.00/kg during 2017-18 and 2018-19, respectively.

Badshabhog in main plot and five nutrient management practices *viz.*40:20:20, 60:30:30 , 80:40:40 kg N: P_2O_5: K_2O ha^{-1}, 40:20:20 kg N: P_2O_5: K_2O ha^{-1} + FYM 5 t ha^{-1} and 40:20:20 kg N: P_2O_5: K_2O ha^{-1}+ FYM 5 t ha^{-1} + Biofertilizers (Azospirillum and PSB 5 kg ha^{-1} each) in *sub- plot* replicated thrice. *Local* chickpea variety was sown as *paira* crop 15 days before the harvest of rice.

RESULTS

The results from the two years experiment revealed that among the varieties Gangabali recorded maximum number of effective tillers m^{-2} (241), grains $panicle^{-1}$ (170), grain yield (3344 kg ha^{-1}), whereas, seed yield of chickpea (274 kg ha^{-1}), rice equivalent yield (REY) of 4079 kg ha^{-1}, system gross return (Rs.83240 ha^{-1}) and net return (Rs.36585 ha^{-1}) were higher in treatment grown with var. Geetanjali. Higher number of tillers m^{-2} (263), grains $panicle^{-1}$ (171), grain yield (3546 kg ha^{-1}), REY (4297 kg ha^{-1}), system gross return (Rs. 88257 ha^{-1}) and net return (Rs. 44389 ha^{-1}) were observed in the treatment applied with 80:40:40 kg N: P_2O_5: K_2O ha^{-1} followed by 40:20:20 kg N: P_2O_5: K_2O + FYM 5t ha^{-1} + BF and 40:20:20 kg N: P_2O_5: K_2O + FYM 5t ha^{-1}. However, chickpea seed yield was found to be higher in 40:20:20 kg N: P_2O_5: K_2O + FYM 5 t ha^{-1} + BF (286kg ha^{-1}). The higher REY and system gross return were realized due to better availability of applied nutrients to aromatic rice and it's residual effect on chickpea sown as *paira* crop. These results were in close conformity with the findings of Kumar *et al.* (2014) in rice-pea cropping system.

CONCLUSION

Transplanting scented rice var. Geetanjali with application of 80:40:40 kg N: P_2O_5: K_2O ha^{-1} followed by chickpea as *paira* crop produced maximum REY which was at par with application of 40:20:20 kg N: P_2O_5: K_2O ha^{-1} + FYM5 t ha^{-1} + Azospirillum and PSB 5 kg ha^{-1} each.

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ARRW/SIRC/Theme II/09

Risk reducing practices to evade salinity and submergence stress in lowland rice in coastal salt affected soils

Sukanta K. Sarangi[1], H.S. Jat[2], P.C. Sharma[2], S.L. Krishnamurthy[2], Virender Kumar[3], Sudhanshu Singh[4], Ashish Kumar Srivastava[4] and Pardeep-Sagwal[4]

[1]ICAR-Central Soil Salinity Research Institute, RRS, Canning Town, West Bengal 743 329, India
[2]ICAR-Central Soil Salinity Research Institute, Karnal 132 001, Haryana, India
[3]International Rice Research Institute, Manila, Philippines
[4]International Rice Research Institute, South Asia Regional Centre, Varanasi 221 106, Uttar Pradesh, India
Email: sksarangicanning@gmail.com

Direct seeded rice (DSR) avoids nursery raising, seedling uprooting, puddling,and transplanting, and thus reduces the labour requirement. Conventional puddled transplanted rice (PTR) requires much labour in the critical operation of transplanting, which often results in a labor shortage during the peak period of transplanting operations. DSR squarely addresses the issues of labor, energy, cost constraints and reduces the cost of cultivation, and minimizes the risk of seedling mortality caused by flooding in transplanted rice due to submergence stress because of taller plants in DSR than transplanted rice at the time of flooding/submergence (Sarangi *et al*., 2020a). However, the risk of salinity stress at the seedling stage increases with DSR, which is associated with its early establishment when salinity is high. Therefore, to harness the full potential of this technology, there is a need to develop risk-reducing practices to avoid salinity stress through agronomy and crop-modelling approaches. A study was undertaken to evaluate rice varieties under DSR and PTR and to study the yield loss in rice due to salinity and submergence stress during the *Kharif* season in coastal rainfed lowlands.

MATERIALS AND METHODS

Field experiments were conducted during the *Kharif* seasons of 2019 and 2020 at ICAR-CSSRI–Regional Research Station (RRS), Canning Town, West Bengal (Latitude 22^{0}152 N, Longitude 88^{0}402 E, Altitude 3.0 m). The experiment was in a split-plot design with three replications. The main plot treatments were DSR without gap filling (DSR-G), DSR with gap filling (DSR+G), PTR without gap-filling (PTR-G) and PTR with gap-filling (PTR+G). The sub-plot treatments (rice varieties) wereAmal-Mana (V1), Sabita (V2), Partikshya (V3) and Swarna Sub 1 (V4).

RESULTS

There was a deficit rainfall during July (213.6 mm in 2019 and 257.3 mm in 2020) as compared to long-term average of 2001-18 (417.7 mm), whereas during August, the rainfall was excess (458 mm in 2019 and 515.1 mm in 2020) as compared to long-term average (377.8 mm). Therefore, the rice crop faced salinity during July and submergence in August. The mean grain yield for Amal-Mana, Pratikshya, Sabita and Swarna-Sub 1 was 4.71, 4.63, 4.42, 4.26 t ha$^{-1,}$ respectively. The highest mean grain yield of 4.82 t ha^{-1} was observed when gap filling was done following salinity or submergence stress compared to 4.09-4.30 t ha^{-1} without gap filling. There was the mortality of seedlings due to salinity in DSR plots (ECe7.31 - 7.73 dSm^{-1}) in the month of July and due to submergence (waterlogging 37 – 49 cm) in puddled transplanted plots in the month of August. Plant heights of both Amal-Mana and Sabita were significantly higher than Pratikshya and Swarna-Sub1. However, between Pratishya and Swarna-Sub1, plant height was higher in Pratikshya (132 cm) compared to Swarna-Sub1 (123 cm).During the *Kharif* 2019, due to salinity stress, there was 17.7 – 22.1% yield reduction in rice, whereas due to submergence,

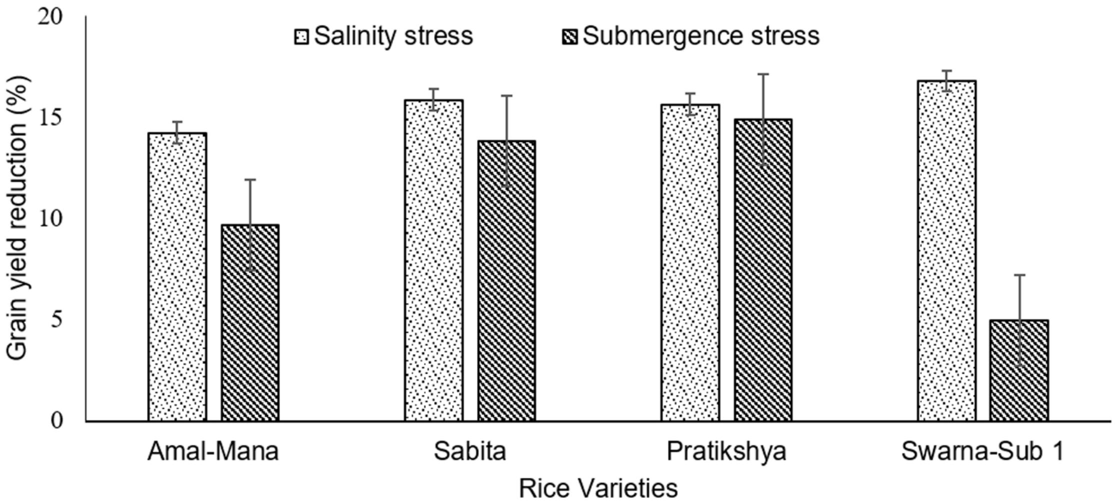

Fig. 1. Yield penalty due to salinity and submergence stress on lowland rice at Canning Town, West Bengal (mean data of*Kharif* 2019 and 2020)

there was 3.1 – 20.0% yield penalty. Due to submergence lowest (11%) yield penalty was observed in Amal-Mana, whereas highest yield loss was in Pratikshya (20%). During the *Kharif* 2020, the average grain yield reduction due to salinity was 10.7 – 14.0%, whereas the same was 6.9 – 11.3% due to submergence. Overall, salinity stress resulted in a grain yield penalty of 14.2-16.8%, while due to submergence, the yield loss varied between 5.0 – 14.9% depending upon the variety. Salinity stress impacted Swarna-Sub1 significantly; however,due to submergence, the lowest (5.0%) yield loss was observed in Swarna-Sub1 and the highest (14.9%) was observed in Pratikshya (Fig. 1). It was observed that gap filling significantly increased the grain yield of both DSR and PTR affected either by salinity or submergence, hence a risk averting practice in these risk-prone ecosystems. Submergence stress in coastal lowland rice could also be significantly reduced by deploying Sub 1 introgressed rice varieties (Sarangi *et al*., 2020b)

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ARRW/SIRC/Theme II/12

Escalating growth and quality grain production of local scented rice var. Radhunipagal through using bio-growth enhancer

Megha Mondal, Suman Bakli, Mahadev Pramanick and Koushik Brahmachari

Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India, 741252

Rice (*Oryza sativa L.*) is the staple food for more than 60% of world population, especially in Asia and Africa. India ranks 1st in terms of area (45 million ha *i.e.* 29% of global rice area) and its production reaches around 121.46 million tonnes (MOA & FW, 2021). Being there in small but important sub-group, aromatic rice became famous for its pleasant aroma due to the presence of 2-acetyl-1-pyrroline (Routray *et al.,* 2017). The majestic taste, fragrance and texture of aromatic rice vary from variety to variety and specific to its native cultivated area. Radhunipagal is an indigenous non-basmati type aromatic rice mainly cultivated in Rahr and Gangetic-alluvial region of South Bengal. The word 'Radhunipagal' literally means 'cook maddening aroma'. Being a local, long statured, photosensitive, elite variety of rice it may be a good choice in lieu of HYV. But, due to poor fertilizer responsiveness of local land races, use of bio-growth enhancer along with different organic sources of nutrients may be the alternative nutrient management system for getting profitable economic return. Bio-growth enhancer plays significant role in metabolic pathways, triggers disease response pathways and increases stress tolerance. Adopting these options, over dependence on four pillars of Green Revolution *viz*. HYV seeds, chemical fertilizers, ground water lifting as well as plant protection chemicals would be reduced. The degradation of soil fertility, environmental pollution, pest resistivity, loss of biodiversity and above all decline in crop productivity will also be checked.

Keeping these issues in view the investigation was carried out with objectives *viz.* (a) To study the effect of bio-growth enhancers on growth, yield and quality of local scented rice variety cv. Radhunipagal and (b) To assess the economic benefit of using the bio-growth enhancer based organic nutrient management.

METHODOLOGY

The field experiment was conducted under medium land situation in *kharif* season (July-December) of 2021 in New Alluvial soils at 'C' Block Farm of Bidhan Chandra Krishi Viswavidyalaya (22°57' N latitude and 88°20' E longitude with an altitude of 9.75 m above mean sea level), Kalyani, Nadia, West Bengal, India. The textural class being sandy clay loam and the order of the soil is Entisol. The experiment was laid out in randomized block design (RBD) with 9 treatments replicated thrice. The treatment details were T_1: Agrimoss (AM) @ 2ml/L at 21 DAT + RDN, T_2: AM @ 2ml/L at 21 & 42 DAT + RDN, T_3: AM @ 3ml/L at 21 DAT + RDN, T_4: AM @ 3ml/L at 21 & 42 DAT + RDN, T_5: Agri-nanotek (AN) @ 1.5g/L at 21 DAT + RDN, T_6: AN @ 1.5g/L at 21 & 42 DAT + RDN, T_7: AN @ 2.5g/L at 21 DAT + RDN, T_8: AN @ 2.5g/L at 21 & 42 DAT + RDN, T_9: 100% RDN. Recommended dose of Nitrogen (RDN) @ 50 kg/ha was provided through Mustard oil cake and FYM each @1/3rd of RDN as basal and Vermicompost @ 1/3rd of RDN as top dressing at 21 DAT. [/L stands for per litre of water].

RESULTS

The growth attributes like plant height, LAI, dry matter accumulation (DMA), crop growth rate (CGR) were recorded highest in T_4 treatment followed by T_8 treatment which was statistically at par with all growth attributes except LAI and lowest results recorded in T_9 treatment. The maximum increase in the yield attributes like panicle length, no. of panicles/m², no. of filled grains/panicle were obtained from T_4 treatment followed by T_8 treatment and minimum results were recorded in T_9 treatment. The maximum grain yield (2.32 t/ha) was obtained from T_4 treatment being at par with T_8 treatment (2.25 t/ha) and the minimum grain yield was recorded in T_9 treatment (1.50 t/ha). Maximum brown rice (76.27%) and milled rice (62.57%) were recorded in T_4 treatment than all other treatments. Highest gross return was recorded in T_4 treatment (Rs.70390/ha) followed by T_8 treatment (Rs.68130/ha). Lowest gross return was recorded in T_9 treatment (Rs. 49870/ha). The highest B:C was obtained at T_4 treatment (1.49) followed by treatment T_8 (1.44) and T_5 (1.39).

CONCLUSIONS

Based on growth, grain yield, quality attributes and B:C application of recommended dose of nitrogen (RDN) through FYM, Mustard cake and Vermicompost along with bio-growth enhancer Agrimoss @ 3 ml/L of water at 21, 42 DAT (T_4) can be considered as an effective nutrient management for obtaining good yield and high return in *kharif* rice (Radhunipagal).

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Growth, yield and NUE of rice (*Oryza sativa* L.) influenced by varieties and fertilizer levels under direct seeded condition

S. M. Shende[1*], R. R. Hasure[2], N. V. Kashid[3], and A. V. Satpute[1]

Agronomy Section, RCSM College of Agriculture, Kolhapur- 416004, MPKV, Rahuri-413722 (India)
1. PG Student, Agronomy Section, RCSM College of Agriculture, Kolhapur (M.S.) – 416004 (India)
2. Agronomist, Regional Sugarcane and Jaggery Research Station, Kolhapur (M.S.) – 416005 (India)
3. Associate Professor of Agronomy and Officer In-charge, ARS, Vadgaon-Maval, Pune (M.S.) - 412106 (India)
****Corresponding Author:** PhD Scholar, Department of Agronomy, PGI, MPKV, Rahuri (M.S.) - 413722 (India),*
Email: sudarshanshende77@gmail.com

One-tenth of the world's arable land is used to cultivate rice, which is a staple meal for more than 60% of the world's population and a source of energy for around 40% of the world's population (Virdia and Mehta, 2009). Transplanting is the most common method of rice growing in India. However, transplanting is becoming increasingly difficult because of labour shortages and expensive costs, paucity of water, and decreased profit. As a result, direct sowing is gaining favour among farmers in India and other Asian countries. Direct seeding includes both wet and dry seeding and eliminates the need for seedlings, nursery preparation, seedling uprooting, and transplanting. The ability of crops to absorb and use nutrients to maximize yields is proven by their nutrient utilization efficiency (NUE), it is influenced by several factors, such as agro-climate, soil conditions, parental rock type, crop factors, crop variety, fertilizers, particle size, organic matter, humus and water content, pH, aeration, temperature, root surface area, microbes, etc. Fertilizer management and rice cultivars grown under direct seeding conditions are among the factors considered in the current study to improve nutrient consumption efficiency in rice. The research study will be useful in selecting appropriate cultivars and fertilizer doses to get a better optimum yield under dry planting conditions. With these considerations in mind, a field experiment was conducted at the Post Graduate Research Farm, Agronomy Section of Rajarshee Chhatrapati Shahu Maharaj College of Agriculture, Kolhapur (M.S.), India, during the 2019 Kharif season with the following objectives: 1) To identify suitable direct seeded rice varieties for the Sub Montane Zone of Maharashtra under rainfed conditions and 2) To determine the fertilizer requirement for different rice.

METHODOLOGY

The experiment was designed in a split-plot design with 4 replications & 9 treatment combinations of 3 rice varieties Indrayani, Phule Radha, and Bhogawati as main plot treatments and 3 fertilizer levels 75% RDF, 100% RDF, and 125% RDF as subplot treatments. On June 3, 2019, the rice was direct seeded with various varieties and fertilizer levels. Growth parameters were measured at 15-day intervals throughout the life of the rice crop till harvest. The chemical assessment of total nitrogen, phosphate, and potassium was performed using samples from various plant sections of observing plants & NUE were calculated using yield, nutrient analysis (Dobermann, 2007).

RESULTS

In terms of growth, grain (53.35 q/ha) and straw yield (67.50 q/ha), the variety Indrayani greatly outperformed the Bhogawati variety. Similar results were obtained with the application of 125% RDF which was at par with 100% RDF as compared to 75% RDF in terms of growth, grain (54.55 q/ha) and straw yield (69.88 q/ha). The variety Indrayani had a higher rate of nutrient usage efficiency and

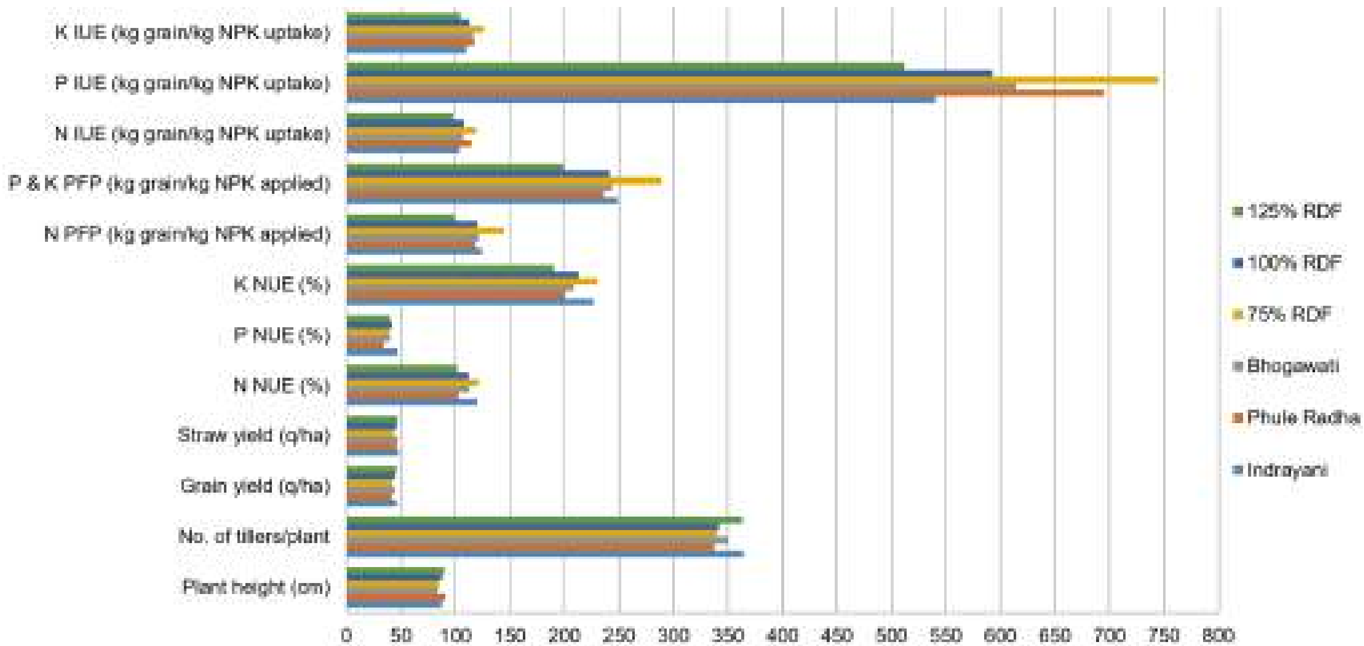

Fig 1. Growth, Yield & Nutrient Use Efficiencies of rice influenced by varieties & fertilizer levels

partial factor productivity for NPK nutrients, and 75% RDF also increased these rates. However, the internal consumption efficiency of the Phule Radha variety and 75% RDF were higher.

CONCLUSION

Based on the agronomic investigation, it can be concluded that among the rice varieties, Indrayani, as well as Bhogawati, is suitable for gaining more growth and yield in the Sub Montane Zone of Maharashtra and Kolhapur district under direct dry-seeded conditions. Among the fertilizer levels tried, the application of 100% RDF ha^{-1} and 125% RDF ha^{-1} is suitable for more growth and yield of rice under dry-seeded conditions. The ability of crops to absorb and use nutrients to maximize yields is proven by their nutrient utilization efficiency (NUE). The variety Indrayani & 75% RDF has more nutrient use efficiency and partial factor productivity. However, the variety of Phule Radha and 75% RDF has more internal utilization efficiency.

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Productivity and physiology of aerobic rice (*Oryza sativa* L.) as influenced by pink pigmented facultative Methylotrophs (PPFM)

J. C. Aswathy [1*], P Shalini Pillai[2], Jacob John[3]

[1,2]*Department of Agronomy, Kerala Agricultural University, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala*
[3] *Kerala Agricultural University, Integrated Farming System Research Station, Karamana, Thiruvananthapuram, Kerala*
*Email :*jcaswathy@gmail.com*

Rice is the premier crop of the world which feeds more people than any other agricultural crop. As with the case of other commodities, the demand for rice is also increasing with increase in population. However, with shrinking resources like land and water, this is a daunting challenge. Traditionally, more than 50 per cent of irrigation water used in Asia is consumed by rice. The conventional wetland rice systems consume substantial quantities of water and are inherently labour intensive. In the current scenario of looming water crisis it has become imperative to frame strategies to adopt water saving rice production systems with higher water productivity. The technology of aerobic rice has been designed to make rice cultivation feasible with limited water. In aerobic system of cultivation, rice is raised in non-puddled, non-flooded and unsaturated soil conditions. However, when rice is raised aerobically during the summer season, moisture stress and high atmospheric temperature have found to affect the yield of the crop. Exogenous application of plant growth regulators and plant growth promoting rhizobacteria has yielded promising results (Ashraf and Foolad, 2007). Pink pigmented facultative methylotrophs (PPFMs) are *Methylobaterium* species, whose exogenous application has been reported to help the crops by its action on moisture stress alleviation and improvement in germination, growth and yield (Hayat *et al*., 2010). During dry spell the osmoprotectant matrix produced by PPFM guard the plants from desiccation and high temperature.

Considering the above observations the present study has been undertaken to study the effect of pink pigmented facultative methylotrophs (PPFM) on the yield and physiology of aerobic rice.

MATERIALS AND METHODS

A field study was conducted at Integrated Farming System Research Station, Karamana, Thiruvananthapuram, Kerala, during summer, 2019 -2020. The variety selected for the study was the medium duration variety MO16 (Uma) which was considered as the most preferred rice variety among the farmers of Kerala. The experiment was laid out infactorial randomised block design with[(5 x 2) + 2] treatment replicated three times. The treatments included five promising isolates of PPFM (P) from the rice phyllosphere, made available from the Department of Agricultural Microbiology, College of Agriculture, Vellayani and two methods of application (M) compared against two controls (C). The isolates were PPFM16, PPFM 26, PPFM 35,PPFM 37 and PPFM 38, the two methods of application were seed treatment (1%) and seed treatment (1%) + foliar application (2%) at 30 and 50 days after sowing (DAS) and the two controls were Kerala Agricultural University Package of Practices (KAU POP) Recommendation and KAU POP + water spray at 30 and 50 DAS. In the case of KAU POP irrigation was given once in three days upto panicle initiation stage and thereafter irrigation was given daily. Wherever foliar application and water spray were provided, irrigation was stopped one week before and after the treatment so as to assess the stress alleviating effect of PPFM isolates, if any.

RESULTS AND DISCUSSION

Yield and Yield attributes :

Among the PPFM isolates tested, the treatment with PPFM 38 exhibited significantly higher number of productive tillers per square metre, grain weight per panicle, number of filled grains per panicle, thousand grain weight and lower sterility percentage as well as significantly superior grain yield, straw yield and harvest index. Seed treatment followed by foliar application of PPFM isolates (m_2) recorded significantly higher number of productive tillers per square metre, grain weight per panicle, grain yield and straw yield whereas p_5m_1 recorded the highest harvest index, on par with p_5m_2(PPFM 38 as seed treatment + foliar application).

The thousand grain weight was significantly higher for p_5m_1 which was also at par with p_5m_2. Between the two controls, c_1 (KAU POP) exhibited significantly higher number of productive tillers per metre square, higher grain weight per panicle, number of filled grains per panicle, thousand grain weight and lower sterility percentage. The higher leaf area index and dry matter production supported by PPFM treatment might have resulted in superiority in the various yield attributes. Lidstrom and Chistoserdova (2002) had observed increase in yield attributes of maize with exogenous application of *Methylobacterium* species and attributed this to the effect of cytokinins and auxins. Grain yield is a function of yield attributes like number of productive tillers, filled grains per panicle and grain weight. The effect of PPFM was observed to be significant for majority of the yield attributes. This might have been reflected in the increased grain yield.

Physiological parameters :

Chlorophyll content and proline accumulation recorded at panicle initiation and flowering stages were significantly higher with PPFM 38. Between the two methods of application of PPFM, seed treatment (1%) with PPFM (m_1) recorded superiority in proline content. Among the treatment combinations, PPFM 38 as seed treatment (1%) + foliar application (2%) at 30 and 50 DAS (p_5m_2) was observed to engender significantly higher contents of chlorophyll and proline, both at panicle initiation and flowering stages. Between the controls, KAU POP recorded higher chlorophyll content whereas proline accumulation was greater with KAU POP + water spray

CONCLUSION

The present study undertaken with MO 16 (Uma) revealed that microorganism PPFM had stress alleviating effect on rice and this was reflected on the yield attributes and yield. Among the five isolates tested, PPFM 38 proved to be superior. The results showed that the seed treatment (1%) followed by foliar application (2%) of PPFM 38, twice, at 30 and 50 days after sowing (p_5m_2) enhanced the yield and physiology of aerobic rice.

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Response of rice varieties to different fertilizer levels in direct dry seeded cultivation for yield, quality and economics of rice (*Oryza sativa* L.)

S. M. Shende[1], R. R. Hasure[2], A. V. Satpute[1*] and N. V. Kashid[3]

Agronomy Section, RCSM College of Agriculture, Kolhapur- 416004, MPKV, Rahuri-413722 (India)
1. PG Student, Agronomy Section, RCSM College of Agriculture, Kolhapur (M.S.) – 416004 (India)
2. Agronomist, Regional Sugarcane and Jaggery Research Station, Kolhapur (M.S.) – 416005 (India)
3. Associate Professor of Agronomy and Officer In-charge, ARS, Vadgaon-Maval, Pune (M.S.) - 412106 (India)
***Corresponding Author:** A.V. Satpute, PhD Scholar, Department of Agronomy, PGI, MPKV, Rahuri (M.S.)-413722 (India)*
Email: ashavsatpute@gmail.com

Due to its widespread use as a staple food by more than half of the world's population, rice (*Oryza sativa* L.) is known as the "Global grain." A staple food for more than 60% of the planet's population and an energy source for almost 40% of the population, rice is cultivated on one-tenth of the globe's agricultural land. In India, the most frequent method of rice cultivation is transplanting. However, transplanting is becoming increasingly difficult because of labour shortages and high expenses, a lack of water, and a drop in profit. As a result, farmers in India and other Asian countries are increasingly turning to direct sowing. Direct seeding avoids the requirement for seedlings, nursery preparation, seedling uprooting, and transplanting by using both wet and dry seeding. The most essential element determining crop output is nutrient supply. The performance of a genotype is entirely dependent on fertilizer supply, sowing and seeding conditions, planting time, and soil moisture. A study of crop nutrient requirements for different cultivars concerning a healthy soil environment is essential for increasing rice production. Farmers' adoption of a variety differs as the variety's performance under poor nutrient conditions is less essential than their performance under optimal nutrient sources. In the context of these factors, a field experiment was carried out in Kolhapur (M.S.), India, during the 2019 Kharif season with the following objectives: 1) To find suitable direct-seeded rice varieties & fertilizer levels for the Sub-Montane Zone of Maharashtra under rainfed conditions & 2) To assess quality and economics of rice varieties for fertilizer management under direct seeded condition.

METHODOLOGY

The experiment was designed in a split-plot design with 4 replications & 9 treatment combinations of 3 rice varieties Indrayani, Phule Radha, and Bhogawati as main plot treatments and 3 fertilizer levels 75% RDF, 100% RDF, and 125% RDF as subplot treatments. On June 3, 2019, the rice was direct seeded with various varieties and fertilizer levels. Samples from various plant portions of the observed plants were used to undertake the chemical assessment ((Jackson, 1973). The economics of various treatments were calculated based on the findings of the field trial with current market prices of produce. Standard approaches proposed by Panse and Sukhatme (1967) were used to conduct the statistical analysis.

RESULTS

Among the fertilizer amounts tested, 100% RDF ha^{-1} and 125% RDF ha^{-1} are suitable for increasing rice yield under dry-seeded circumstances. Indrayani has a higher protein content than Phule Radha and is comparable to Bhogawati. Application of 125% RDF ha^{-1} also has a higher protein content than any other fertilizer levels but is at par with 100% RDF ha^{-1}. Variety Indrayani outperformed Phule Radha in terms of gross, net

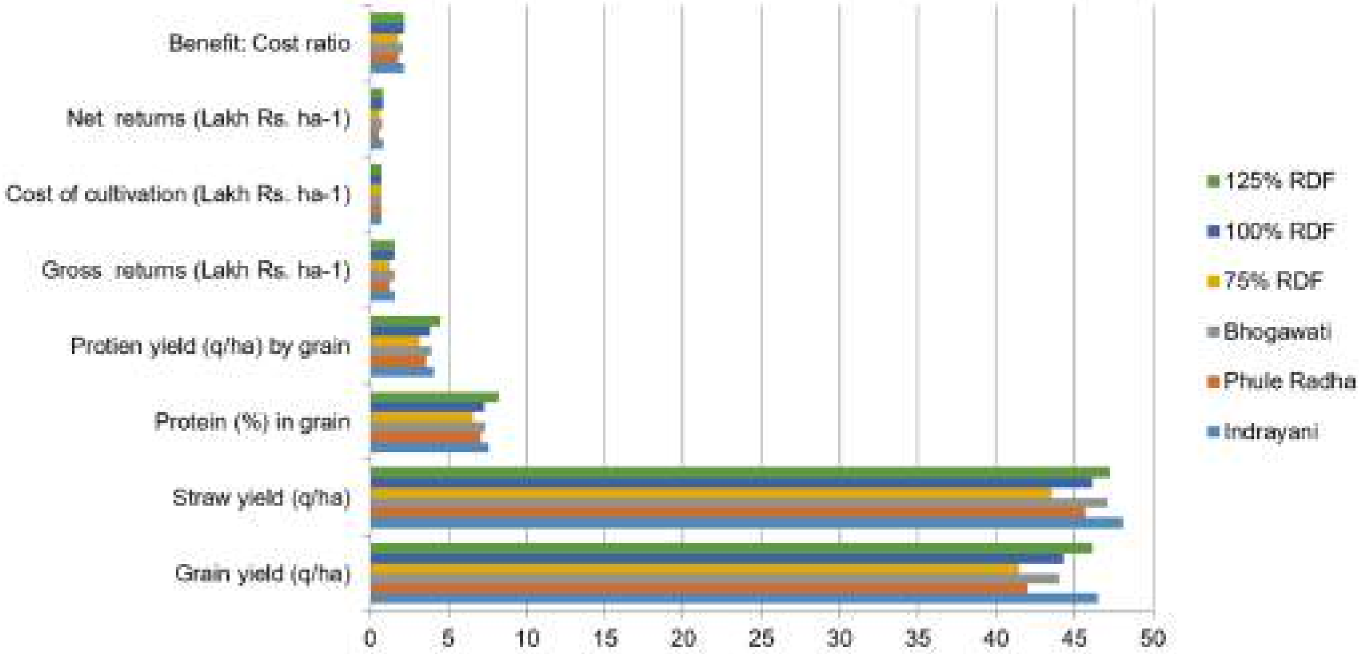

Fig.1. Yield, Quality & Economics of rice affected by varieties and fertilizer levels

monetary returns, and B: C ratio, and was on par with Bhogawati. Similar results were obtained when 125% RDF ha^{-1} fertilizer was applied over 75% RDF ha^{-1}, and it was comparable to 100% RDF.

CONCLUSION

The variety Indrayani surpassed the Phule Radha variety and was on par with Bhogawati in terms of grain and straw output, biological yield and harvest index, protein quality, and economic returns. In terms of grain and straw production, biological yield and harvest index, protein quality, and economic returns, 125% RDF produced comparable outcomes to 100% RDF and was higher than 75% RDF. In terms of gross monetary returns, net monetary returns, and B: C ratio, the variation Indrayani with application 125% RDF has a greater rate of economic returns than any other interaction combination. Thus, it is necessary to change the cultivation system from transplanting to direct seeded rice. DSR reduces production costs due to labour savings and has several advantages over transplanting. DSR crops are faster, easier, maintain soil good health and are less labour-intensive to grow.

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Design and development of ciae economy seeder: an inovative 3-in-1 stubble management solution for combine harvested paddy field and alike

AK Roul[1*], Abhishek Patel[2], KP Singh[1], KN Agarwal[1], Manoj Kumar[1], V V Bimalbhai[3]

[1]Scientist, [2]PhD Scholar, [3]SRF, ICAR - Central Institute of Agricultural Engineering, Bhopal

**Author Email: Ajay.Roul@icar.gov.in*

Ex situ and in situ management methods are performed for straw management. The developed equipment is an in-situ technology in which the three operations—chopping of the residue, tilling the soil and mixing the chopped residue, and seeding—can be done simultaneously. The chopping and seeding units are attached to the rotary tiller unit. The equipment is fabricated in such a way that either all three operations can be done in a single pass, or in a quick detachment and attachment process, the residue chopping, rotary tilling, and seeding can be done independently as separate operations with independent equipment. The chopping mechanism consists of a set of vertical shafts, each with two pairs of serrated blade flanges, one above the other. The standing and loose paddy straw are cut with the chopping unit, then the pieces of straw are mixed into the soil with the rotary tiller, and seeding is done in the loosened soil. The machine was evaluated in verisol in a combine-harvested paddy field, a field with standing maize plant residue, and also in a standing okra field. Sowing of Bengal gram has been done in the standing maize residue, and sowing of wheat has been done in the standing okra and rice residue. The machine performed satisfactorily in all three conditions. From the primary observation, it was found that there was absolutely no effect on the germination of the seeds. The performance of the CIAE economy seeder was also compared to that of existing straw incorporation machines such as the super seeder, mulcher integrated with a rotavator, and rotavator solely in a freshly combine harvested rice field. All of the machines were evaluated on the basis of mixing index (MI), pulverization index (PI), or mean weight diameter (MWD) and bulk density at 3 km/hr forward speed, 40% soil moisture, and 17% straw moisture. The PI of the superseeder, mulcher integrated with rotavator, rotavator alone, and CIAE economy seeder were found to be 9.03, 8.60, 10.20, and 8.42 mm, respectively, whereas the MI were found to be 85.18, 91.18, 28.38, and 96.59%, respectively. The bulk densities of the loosened soil were found to be 1.365, 1.360, 1.390, and 1.32 g/cm3 for the superseeder, mulcher integrated with a rotavator, rotavator alone, and CIAE economy seeder, respectively. A paired t test was performed to test the significance difference among the results, and it was revealed that the CIAE economy seeder outperformed all the equipment.

ARRW/SIRC/Theme II/18

Assessment of rates and players of dissimilatory Nitrate reduction to Ammonium (DNRA) in paddy soil

Megha Kaviraj[a,b,*], Upendra Kumar [a,*], Soumendranath Chatterjee [b], AK Nayak[a]

[a]ICAR-National Rice Research Institute, Cuttack-753006, Odisha, India

[b] The University of Burdwan, Burdwan-713104, West Bengal, India

*Email : meghakaviraj31@gmail.com; ukumarmb@gmail.com

The forgotten pathway of microbially driven dissimilatory nitrate reduction to ammonium (DNRA) in the terrestrial nitrogen (N) cycle can conserve nitrogen (N) by transforming mobile nitrate (NO_3^-) into non-mobile ammonium (NH_4^+) and preventing NO_3^- losses through denitrification, leaching, and runoff (Wang et al., 2022). Interestingly, DNRA and denitrification bacteria, compete for reducing NO_3^- and oxidising carbon sources in a cooperative manner. Moreover, the importance of denitrification in paddy soil has been well established and thoroughly investigated, however, the research on DNRA has usually restricted to other ecosystems like ocean, estuaries, marine sediments, wetlands and floodplains of terrestrial habitats (Pandey et al., 2020). When it comes to paddy soil ecosystems, little information has been uncovered on the DNRA. There is currently a meagre knowledge regarding the global patterns and regulating factors of paddy soil DNRA (Friedl et al., 2018; Pandey et al., 2018). Therefore, the present study provided information on the DNRA rates, *nrfA* gene targeted microbial players and influencing environmental factors cum stimulators for DNRA underdifferent rice ecologies.

METHODOLOGY

The present investigation was carried out at the ICAR-National Rice Research Institute (20º 44' N, 85º 94' E), Cuttack, Odisha, India. The observed rice ecology for this study was irrigated (IR), three lowland ecologies based on water depth *i.e.,* shallow (SL): 0-30 cm; intermediate (IL): 30-50 cm; semi deep (SD): 50-100 cm and two upland (dry: DR and Aerobic: AR) ecologies. The recommended dose of fertilizer (RDF) for N, P_2O_5 and K_2O were 80, 40 and 40 kg ha^{-1}, respectively. The soil samples were collected during dry and wet season of 2019-2020 after 30 days of transplanting at six places randomly from each treatment at 0-15 cm depth by using sample probe. A portion of fresh soil was immediately used for microbial dynamics, microbial community level metabolic profiling and soil enzymatic assays, whereas remaining samples were kept at 4 °C in the refrigerator for further analysis of gene quantification, transcript number quantification and *nrfA* gene targeted metagenomic sequencing to identify the DNRA community. Another portion of the air-dried soil sample was processed (sieved through a 2 mm sieve) for the analysis of physic-chemical properties.

RESULTS

The *nrfA*- targeted illumina sequence revealed that Proteobacteria (41.59-87.18%), irrespective of rice ecologies, showed the most abundant phylum. The OTUs (*nrfA*) of Proteobacteria were recorded higher in AR followed by DR, IR, SD, IL and SL (Fig. 1). OTUs of Actinobacteria (2.38-24.05%), Acidobacteria (0.17-21.11%), Verucomicrobia (1.09-7.87%), Chloroflexi (0.02-5.07%) and Planctomycetes (1.66-9.17%) were also found to be abundant irrespective of rice ecologies. Whereas, OTUs of Deinococci (class) was found highest in SD (4.61%) followed by SL, IR, IL, AR and DR. Interestingly, OTUs of Anaerolineane (class) was found negligible in DR and AR rice ecologies (Fig.

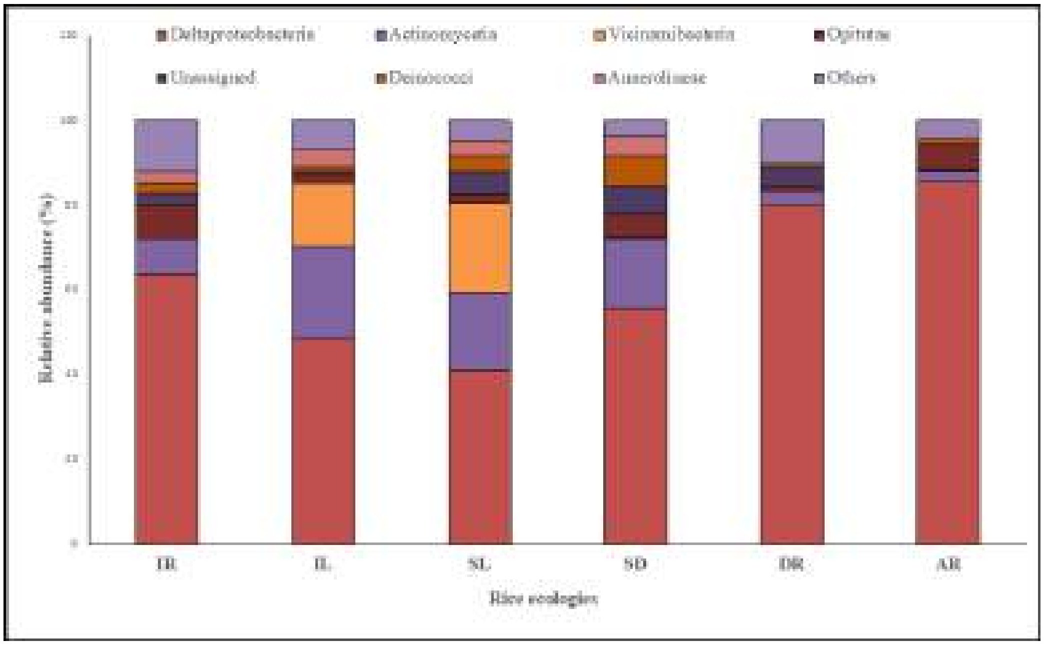

Fig. 1. The relative abundance (%) of*nrfA* gene showed at class level under different rice ecologies.

1). Results also showed that the *nrfA*-containing DNRA bacterial genera were *Anaeromyxobacter*, *Actinomycetes*, *Sorangium*, *Geobacter*, *Meiothermus*, and *Corallococcus* in paddy soil, irrespective of different ecologies.

Moreover, *nrfA* and *nirK* genes were also quantified in paddy soil of different rice ecologies. The log copy number g^{-1} soil of *nrfA* and *nirK* ranged from 6.22-6.71 and 6.07-6.42 in paddy soil samples, respectively, irrespective of rice ecologies. The abundance of *nrfA* gene was found higher in SD followed by AR, IR, DR and SL, whereas *nirK* was found abundant in IR followed by SL, IL, DR, AR, SD, respectively. Similarly, culturable microbial population (log CFU g^{-1} soil) of DNRA and denitrification were observed higher value in SD (4.74) and IR (4.6) rice ecologies, respectively. Biolog-eco plate- based microbial community analysis indicated higher Mc-intosh index and Simpson index in SD (0.96, 0.85, respectively), whereas higher Shannon-Wiener index, Gini coefficient, Margalef's index and Pielou's Evenness index were recorded in DR (0.99), IR (0.08), IL (2.82) and AR (1.17), respectively.

CONCLUSION

Overall, our results conclude that DNRA was higher compared to denitrification in paddy soil irrespective of rice ecologies. Semi deep rice ecology showed higher DNRA activity due to relatively higher abundance of OTUs of Deinococci compared to other ecologies.

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ARRW/SIRC/Theme II/19

Validation of marker linked to herbicide tolerance trait in rice under direct seeded conditions

S. R Mythili*, Manonmani S, Raveendran M, Pushpam R

Tamil Nadu Agricultural University, Coimbatore -641003, Tamil Nadu, India
**Email: mythu71096@gmail.com*

To combat the labour and water intensive conventional rice production technique, recently Direct Seeded Rice (DSR) has been followed by most of the rice growers. The only limitation of the DSR being the uncontrolled growth of weeds causing 20-85% yield loss, chemical management of the weeds with herbicide tolerant crop varieties is the most efficient way for weed management (Rao *et al.,* 2017).AnHerbicide tolerant Mutant HTM-Robin (tolerant against the herbicide Imazethapyr) was developed at TNAUthrough non-transgenic EMS mutagenesis of Nagina22. The SSR marker RM6844 linked to the herbicide tolerant trait wasidentified (Shoba *et al.,* 2017). Thus, in this study, validation of the identified marker is done in Recombinant Inbred Lines of the cross CO51 x HTM. Phenotypic screening of the genotypes CO51, Nagina22, HTM-Robin was done under direct seeded conditions. This marker can be further used in studies for marker assisted breeding of herbicide tolerant rice varieties.

METHODOLOGY

Initially the genotypes CO51 and HTM were crossed to introgress the herbicide tolerance trait.True F_1s were derived and the population was progressed through single seed descendent method to develop the F_8 RIL population at Dept of Biotechnology, TNAU. Out of the 50 F_8 progenies which were genotyped using the reported SSR marker RM6844 for the herbicide tolerant trait, 10 positive lines harbouring HTM-Robin allele and 2 negative lines harbouring the CO51 allele were selected for validation of the marker.Imazethapyr (Commercial name: Pursuit) which is a broad-spectrum imidazoline group of herbicides was used at the rate of 2.5ml/lit along with the adjuvant for phenotyping.

Fig 1. Phenotypic evaluation in RILs of CO 51 X Robin Mutant(left) and CO51, Nagina22, HTM (right)

RESULTS

For validation of marker-trait association, ten positive lines harbouring HTM-Robin allele of RM6844 were selected along with 2 negative lines harbouring CO51 allele of RM6844. All the progenies were raised under direct seeded rice cultivation and herbicide (Imazethapyr @ 2.5 ml/lit) spray was given at 21 days after sowing. Resistance/susceptibility of progenies was assessed based on the survival of plants. Observations at 15 days after spray (Imazethapyr) revealed that all the positive lines harbouring the HTM-Robin allele of RM6844 exhibited 100% survival whereas progenies harbouring CO 51 allele of RM6844 showed 100 percent mortality. (Fig 1 left) Thus it proves the marker-trait association. This marker can be used for foreground selection in CO51 background for marker assisted backcross studies.For the phenotypic screening of the genotypes CO51, Nagina22 and HTM-Robin, the herbicide Imazethapyr was sprayed at 21 DAS at the rate of 3ml/lit along with the adjuvant. The genotypes CO 51 and Nagina22 showed susceptibility against the herbicide spray and exhibited 100 percent mortality. Robin Mutant (HTM) exhibited 100% tolerance against the herbicide spray.Herbicide tolerant mutant exhibited its suitability for chemical weed management under direct seeded rice cultivation (Fig 1 right). Imazethapyr showed upto 85-90% weed control efficiency.

CONCLUSION

This study shows association of the marker RM6844 to the herbicide tolerant trait and can be further used for foreground selection in marker assisted studies. The selected RILs were progressed for yield evaluation trials.

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ARRW/SIRC/Theme II/20

Productivity of rice-rice cropping system influenced by puddling practices and planting techniques

Manukonda Srinivas, L. Rajashekara Reddy, K.M. Dakshina Murthy B. Anusha, M. Ramabhadra Raju and G. Jogi Naidu

Acharya NGRanga Agricultural University, Regional Agricultural Research Station, MARUTERU – 534 122, West Godavari District, Andhra Pradesh, India
E-mail: manukonda.s@angrau.ac.in

Rice is primary food crop for the half of the world's population. In India, rice is cultivated over 45.07 m. ha. area with a production of122.27 m.t. of rice and an average productivity of 2713 kg/ha (DES, 2021). In the state of Andhra Pradesh, rice is grown in an area of 2.3 m. ha with an annual production of 13.0 m.t. and a productivity of 5800kg/ha. Alluvial soils of Godavari delta region are known as the rice bowl of Andhra Pradesh, is one of the major contributors of rice production in India. In this region rice-rice is the predominant cropping system.Rice is planted either by manual or machine transplanting of young rice seedlings in the puddled field. Puddling is the one of the practicesin the paddy cultivation which is used to assist in transplanting of rice seedlings. Puddling is used to create ahard impermeable layer that will reduce water percolation and inhibit weed growth. Puddling followed by levelling of land is necessary for good establishment of crop and it helps to maintain optimum water level during the crop period and helps in removing drainage water easily. The factors that have the most influence on the evaluation of the puddling quality are the puddling techniques and number of passes (Pradhan *et. al.* 2015). Generally,tractor's cage wheels, power tillers and rotavators will be used for puddling operation. In the Godavari zone of Andhra Pradesh most of the farmers are using puddling with power tiller. After puddling

Table 1. Yield attributes and yield of rice as influenced by different puddling and planting methods during *Kharif*, 2021 and *Rabi*, 2021-22

Treatment details	*Kharif*, 2021				*Rabi*, 2021-22				System
	No. of tillers/ m^2	No of panicles/ m^2	Grain yield (kg/ha)	Straw yield (kg/ha)	No. of tillers/ m^2	No of panicles/ m^2	Grain yield (kg/ha)	Straw yield (kg/ha)	Grain yield (kg/ha)
Main Plots									
Puddling with Power tiller	264	209	4688	6963	338	303	3333	4474	8021
Puddling with Rotavator	256	235	4942	7330	353	311	3497	5096	8439
Puddling with Roto puddler	258	245	5138	8880	363	319	3696	5763	8834
CD±	33.2	44.8	269	1289	38.23	31.3	348	744	428
CV	11.31	17.21	10.8	14.7	9.61	8.88	18.8	12.9	12.3
Sub Plots									
Direct sowing (Drum seeder)	237	205	4538	7011	328	291	3298	5748	7836
Line planting	268	235	5038	8020	336	302	3356	5172	8394
Machine Planting	247	223	4773	7378	358	314	3462	4512	8235
Diagonal Planting	284	255	5342	8491	383	338	3919	5012	9261
CD±	28.2	27.4	489	1394	25.9	21.4	513	780	495
CV	10.98	12.02	14.1	18.2	7.45	6.95	14.7	15.4	14.2
M×E	NS	NS	NS	NS	44.87	37.08	424	NS	NS

Table 2. Interaction effect of grain yield (kg/ha) of rice as influenced by different puddling and planting methods during *Rabi*, 2021-22

Puddling/Planting Techniques	Drum Seeding	Line Planting	Machine Planting	Diagonal Planting	Mean
Power Tiller	3350	3073	3383	3527	3333
Rotovator	3110	3510	3793	3573	3497
Roto Puddler	3433	3483	3210	4657	3696
Mean	3298	3356	3462	3919	

operation there is a separate leveler attached to the power tiller and levelling will be done which results in increase the cost of cultivation.Roto puddler is another new option during which the puddlingand levelling will be done simultaneously. This roto puddler helps in green manure incorporation in wet land areas with puddling index of 78% in clay loamy soil and 83% in sandy loam soil.The planting methods followed in this Godavari zone were line planting, machine planting, direct sowing, and Bengal method of planting. These traditional planting methods proved useful but needs to shift towards new methods of planting for saving of labour and cost of cultivation besides improvement in yields. One of the new methods of planting is diagonal planting in this method the number of plants aredoubled compared to normal line planting(Dhawan, 2018).To reduce the duration of land preparation, cost of production,suitable method for planting and selecting appropriate machinery for puddling and levelling is important. Hence the present study evaluates the intercation between puddling practices and crop establishment methods in rice-rice cropping system under alluvial soils with a view to identify the best planting method under varied puddling conditions.

METHODOLOGY

The present experiment was conducted during *kharif*, 2021 and *rabi*,2021-22 seasons under coastal irrigated ecosystem in deltaic alluvial soils at Regional Agricultural Research Station, Maruteru, West Godavari District, Andhra Pradesh. The experiment was laidout in split plot design with 3 main plots and 4 subplotsand replicated thrice. The main plots comprises of M_1:Puddling with Powertiller, M_2: Puddling with Rotavator and M_3: Puddling with rotopuddler and the sub plots with E_1: Direct sowing by using drumseeder, E_2: Line planting, E_3: Machine planting and E_4: Diagonal planting. During *kharif* season, spacing of 20 cm x 10 cm for Drumseeder, 20 cm x 15 cm for line planting, 30 cm x 12 cm for machine planting and 30 cm x 15 cm x 15cm spacing for diagonal planting wasadopted and whrere as for *rabi* season, the spacing were 20 cm x 10 cm, 15 cm x 15 cm, 30 cm x 12 cm and 15 cm x 15 cm x 15 cm spacing respectively with test rice variety MTU 1224 (140 days duration) for *kharif* and MTU 1121(125 days duration)for *rabi* season.

RESULTS

Crop establishment methods significantly influenced the yield attributes and yields of rice in both the seasons. Puddling with rotopudller along with different crop establishment methods proved significant with tiller number, panicle number and yield during both *Kharif* and *Rabi* seasons. Among various puddling practices, puddling with rotopudller recorded significantly higher grain and straw yields of 5138 kg/ha and 8880 kg/ha during *kharif* and 3696 kg/ha grain yield and 5763 kg/ha during *rabi* season. System grain yield (8834 kg/ ha) also found higher with same treatment. In case of crop establishment methods, higher grain yield of 5342 kg/ha during *kharif* and 3919 kg/ha during *rabi*were recorded with diagonal planting method. System grain yield (9261 kg/ha) also found higher with same treatment.The interaction effect during *kharif* season for yield parameters and yield are non-significant but it was significant during *rabi*, 2021-22 as grain yield was maximum (4657 kg/ha) with puddling by using rotopudller along with diagonal planting method of rice cultivation.

CONCLUSION

Rice-rice cropping system was greatly influenced by puddling practices and crop establishment methods. The results of the present investigation clearly shows that puddling by using Rotopudller with diagonal planting method of rice cultivation was found better in terms of growth, yield attributes and yield of rice-rice cropping system.

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ARRW/SIRC/Theme II/21

Estimate of nitrogen content in rice using multiple linear regression models

Rahul Tripathi[1]*, S Mohanty[1], Chinmaya Kumar Swain[1#], Supratim Das[1], Pujyasmita Nayak[1], K C Moharana[1], SD Mohapatra[1], B. Raghavendra Goud[1], S. Raghu[1], RN Sahoo[2], Rajeev Ranjan[2], A K Nayak[1]

[1]*ICAR-National Rice Research Institute, Cuttack, Odisha*

[2]*ICAR-Indian Agricultural Research Institute, New Delhi*

*# Presenting author: chinu.swain@gmail.com, *Corresponding author email: rahulcrri@gmail.com*

Rice, India's principal food crop, is cultivated on around 44 million hectares (m ha). Rice, which has around 130 calories per 100 grammes, accounts for more than 20 percent of the calories consumed worldwide. India consumes around 17 million tonnes of nitrogenous, 6 million tonnes of phosphorous, and 2.50 million tonnes of potassic fertilizers (Govt. of India, 2021). Most Indian soils are deficient in nitrogen (N), which accounts for a substantial portion of India's rice production's fertilizer expenditures. Inefficient scheduling and high N application rates result in inefficient N utilization and environmental deterioration due to rice field methane and nitrous oxide emissions, soil denitrification, ammonia volatilization, and nitrate leaching. The time of N application is defined by predetermined crop growth stages, such as transplanting, maximum tillering, and panicle initiation, regardless of soil, agroclimate, and management differences. A dependable approach for real-time N management should be devised to address these challenges by routine crop monitoring. This method is periodically evaluated, despite its efficacy, because technological advances have made it possible to quickly and non-destructively monitor the leaf N state of crops based on their spectral features and optimize N management. Greenseeker, leaf colour charts, and the Soil Plant Analysis Development metre are examples of non-destructive methods for measuring crop N that are currently available (SPAD). The Greenseeker optical sensor uses the normalized difference vegetation index (NDVI), which is based on the reflection of light in the red and near infrared bands. Despite the fact that the researchers have completed tests for the pretty precise computation of N utilizing a number of optical sensors, the accuracy of the calculation remains questionable. Such research is also uncommon for rice in the tropical region of Eastern India. The present study will demonstrate that the NDVI, CLCC, and SPAD values are credible indicators that can aid in the calculation of N through multiple regression modelling.

OBJECTIVE

The purpose of the study was to develop multiple regression-based models employing NDVI, SPAD, and CLCC values to estimate the nitrogen content of rice. The models were then evaluated for their accuracy in predicting the N content of rice.

METHODOLOGY

The experiment was conducted at research farm of ICAR-National Rice Research Institute, Cuttack, Odisha, India (20^{0}25′ N, 85^{0}55′ E; elevation 24 m above mean sea level). The climate of the study area is sub-humid tropical with a mean annual precipitation of 1400 mm and mean annual temperature of 30.10 °C. The experiment was conducted in *rabi* season (January to April), 2022 with rice varieties as (*Var.* i.e., CR Dhan 312 (135-140 days), CR Dhan 310 (120-125 days), Lalat (130 days), Shatabdi (110 days), Swarna Shreya (115 days), CR Dhan 206 (120 days)) in a split-plot design with three replications. Four N management practices were assigned to main plots and varieties were taken in subplots. The N management practices included, T1: 0 kg N ha^{-1} (control), T2: 80 kg N ha^{-1}, T3: 100 kg N ha^{-1}, T4: 120 kg N ha^{-1}.

Handheld Greenseeker active optical sensor (Trimble, Sunnyvale, CA, USA) was used in this research. This sensor can detect reflection of multispectral, two-band, optical reflectance that measures Vegetation Index (VI) and near infrared (NIR) at around 656 nm and 774 nm wavelengths of spectral regions. The NDVI was calculated using the following formula:

$$NDVI = \frac{F_{NIR} - F_{Red}}{F_{NIR} + F_{Red}} \text{ .... (Equation 1)}$$

Where, F_{NIR} and F_{Red} represent the proportion of near-infrared and red radiations, respectively, that are reflected back to the optical sensor from the crop canopy. Sensor data was recorded over all the rice varieties in each of the experimental plots at 45 days after transplanting (DAT), 49 DAT and 54 DAT avoiding the border rows by holding the Greenseeker approximately 80 cm above the crop canopy and walking at a constant speed of 0.5 ms^{-1}. The SPAD meter was used for taking measurements.

Using Greenseeker, SPAD metre, and CLCC measurements, rice plant samples for determining the total N content of rice leaves were gathered simultaneously. 45 DAT, 49 DAT, and 54 DAT leaf samples were oven-dried at 70°C for 48 hours to a constant weight and digested with a mixture containing 10 mL of concentrated H2SO4 to a temperature of approximately 300^{o}C. The micro-Kjeldahl distillation method was applied to digested samples in order to estimate their total N concentration (Kjeldahl, 1883).

RESULTS

Increased N application rates (0, 80, 100, and 120 kg N ha^{-1}) resulted in higher NDVI values on average. The lowest NDVI values were obtained in control plots, ranging from 0.27 to 0.35, whereas the greatest NDVI values were found in plots receiving 120 kg N ha-1, ranging from 0.57 to 0.72. The NDVI values on a certain day of sensing rose with increasing rate of N application in plots for all of the examined kinds. Rice has lower chlorophyll concentrations in its leaves than other N doses, therefore it reflects light more strongly in the red spectral region and less strongly in the NIR region when N is limiting crop development. Clearly, nitrogen supply effects mesophyll cell shape, and increased nitrogen supply results in increased reflectivity. In the MLR models using

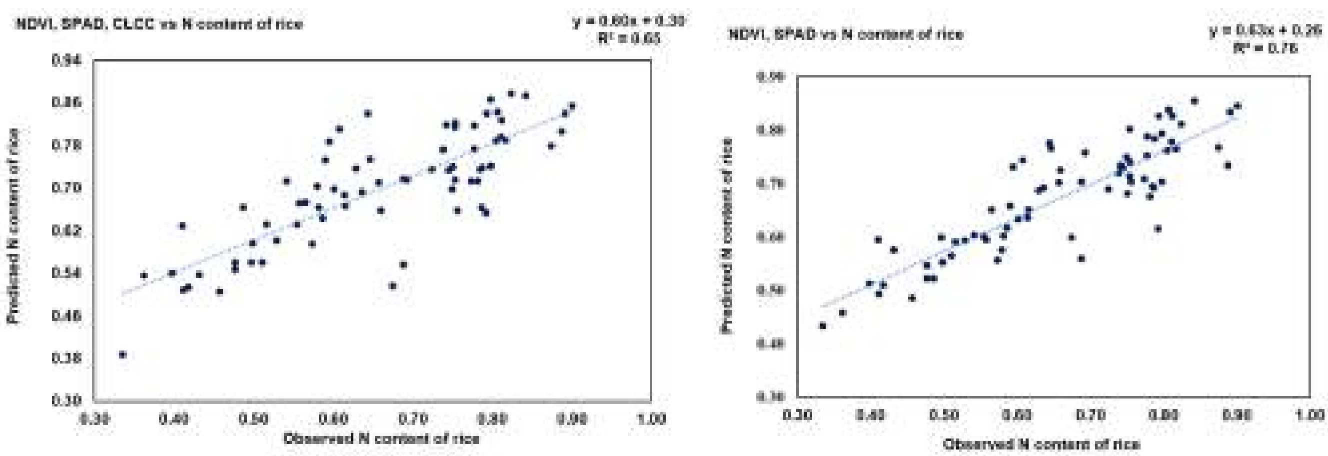

Fig. 1: Scatter plots of predicted N content of rice versus measured NDVI, SPAD, CLCC and NDVI & SPAD respectively for multivariate linear regression (MLR) model of all combined varieties. The line in each graph represents the line y=x.

NDVI, SPAD, and CLCC vs N content of rice, the model with pooled data from six varieties had a lower R2 (0.65) value than models with data from individual varieties. In comparison to the other three variables (NDVI, SPAD, and CLCC), the N content of rice leaves had a greater R2 relationship with NDVI and SPAD (Figure 1). Because NDVI values have a high link with chlorophyll content and N concentration (Atzberger et al., 2010).

CONCLUSION

The Green Seeker Optical Sensor measures plant health with a metric called Normalized Difference Vegetation Index (NDVI), which is calculated from data collected by measuring how much red and near infrared light is reflected (GS). Researchers have tested a variety of optical sensors that can fairly accurately determine N. The tropical region of Eastern India is not a typical location for rice research. Using multiple regression modelling, it is suggested here that the NDVI and SPAD values are reliable indicators that can aid in the determination of N.

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ARRW/SIRC/Theme II/22

Estimating chlorophyll content in rice using multiple linear regression models by employing Optical Sensors

Rahul Tripathi[1*], S Mohanty[1], Chinmaya Kumar Swain[1], Supratim Das[1#], Pujyasmita Nayak[1], K C Moharana[1], SD Mohapatra[1], B. Raghavendra Goud[1], S. Raghu[1], RN Sahoo[2], Rajeev Ranjan[2], A K Nayak[1]

[1]*ICAR-National Rice Research Institute, Cuttack, Odisha*
[2]*ICAR-Indian Agricultural Research Institute, New Delhi*
*# Presenting author: myselfsupratim@gmail.com, *Corresponding author email: rahulcrri@gmail.com*

Rice is main staple food and the most important crop in India in terms of both area and fertilizer use. Occupying an area of 44.7 million ha, it accounted for 17 million tonnes (MT) of nitrogenous fertilizer, 6 MT of phosphorous fertilizer, and 2.50 MT of potassic fertilizer (Govt. of India, 2021). The majority of Indian soils are poor in nitrogen (N), a measure of the chlorophyll (Chl) content that accounts for a large amount of the fertilizer costs associated with rice cultivation in India. Nitrate leaching, soil denitrification, ammonia volatilization, methane, and nitrous oxide emissions from rice fields are some of the environmental pollutants brought on by improper timing and high rates of nitrogen application, results in low chlorophyll content and nitrogen use efficiency of rice. N is a crucial component of chlorophyll molecules and is necessary for photosynthesis. The timing of applying N is dependent on predetermined crop growth stages i.e., transplanting, maximum tillering and panicle initiation notwithstanding variations in soil, agro climate, and management. Since technical advancements have made it feasible to promptly and non-destructively assess the chlorophyll content status of crops based on leaf spectral features, this method, although accurate, is dependent on periodic evaluation. Currently, a number of tools have been emerged for the non-destructive evaluation of rice chlorophyll concentration including Greenseeker (GS), leaf colour charts (LCC), and Soil Plant Analysis Development metre (SPAD). The normalised difference vegetation index (NDVI) is computed by the GS optical sensor. Although studies have been conducted to a small extent for rice in the tropical region of Eastern India to estimate chlorophyll using a variety of optical sensors with reasonable accuracy. Thus, it has been postulated in this work that the NDVI, CLCC, and SPAD values are reliable indicators and can aid us in figuring out the amount of chlorophyll in rice using multiple regression modelling.

OBJECTIVE

NDVI, SPAD, and CLCC measurements were used in the study to create multiple regression-based models for predicting chlorophyll content, and the developed models were validated for their efficacy in predicting chlorophyll content in rice.

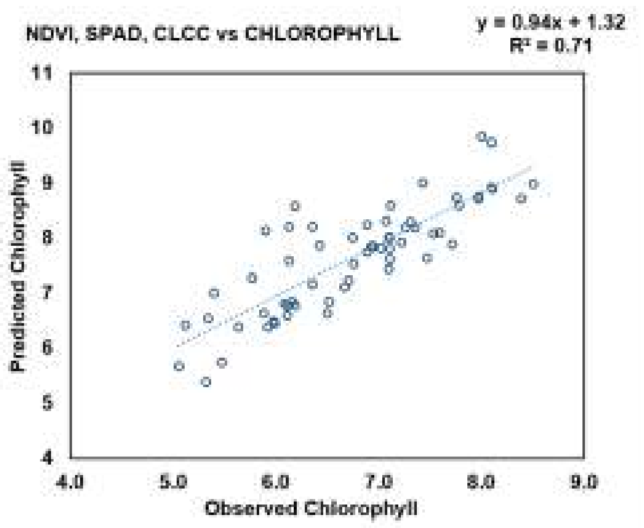
METHODOLOGY

At ICAR-National Rice Research Institute's experimental farm in Cuttack, Odisha, India ($20^0$25' N, $85^0$55' E; elevation 24 m above mean sea level), the experiment was carried out. The research area is characterized by a sub-humid tropical environment with 1400 mm of precipitation and a mean annual temperature of 30.10 °C. Six different rice varieties (CR Dhan 312, CR Dhan 310, Lalat, Shatabdi, Swarna Shreya, and CR Dhan 206) were used in this experiment in a split plot design with three replications during the rabi season (January to April), 2022. Four N management practices— T1: 0 kg N ha^{-1} (control), T2: 80 kg N ha^{-1}, T3: 100 kg N ha^{-1}, and T4: 120 kg N ha^{-1} were assigned to the main plots, and different varieties were chosen for the subplots. Handheld Greenseeker active optical sensor (Trimble, Sunnyvale, CA, USA) was used in this research to calculate the NDVI. Plant sampling and NDVI data collection using GS, SPAD values using SPAD meter and CLCC reading using 5 panel CLCC were performed at 45, 49 and 54 days after transplanting which coincides with the panicle initiation for the varieties used in this study.

The leaf samples were homogenized and ground in 80% acetone. The extract solutions were filtered after sedimentation and then 25 mL of more acetone was added, and reading was taken with the absorbance at 645 and 663 nm for Chl a, Chl b respectively and total Chl concentrations of the solutions were calculated (Porra et al., 1989).

RESULTS

The experiment including six different varieties and four N application doses resulted in a wide range of variation of chlorophyll content within the investigated varieties of rice. Increasing the rates of N applied (0, 80, 100 and 120 kg N ha^{-1}) on an average resulted in higher values of NDVI. Across all rice varieties, the minimum NDVI values were recorded in control plots ranging from 0.27 to 0.35 whereas, maximum NDVI values (varied from 0.57 to 0.72) were recorded in plots receiving 120 kg N ha^{-1}. The NDVI values on a particular date of sensing increased with increasing rate of N application in plots for all studied varieties. When N is limiting to crop growth, rice reflects more strongly in the red spectral region, and less strongly in the NIR region, owing to the lower chlorophyll concentrations in leaves of control treatments compared to other applied N doses. Nitrogen supply apparently affects mesophyll cell structure, which results in higher reflectance with an increased N supply. In the MLR models with NDVI, SPAD, CLCC against chlorophyll content of rice, the model with combined data from six varieties had comparable R^2 value (0.71) to models with data from individual varieties (Fig 1a). Similarly, for models with two independent variables (NDVI and SPAD) also the R^2 value (0.77) for all varieties combined was comparable with models with data of individual varieties (Fig 1b). Similar results were observed for MLR models of two independent variables (NDVI & SPAD) with Chlorophyll and linear regression model of NDVI and chlorophyll content. Since, NDVI data are highly correlated with the chlorophyll content, which acts as an indicator of N concentration (Atzberger et al., 2010).



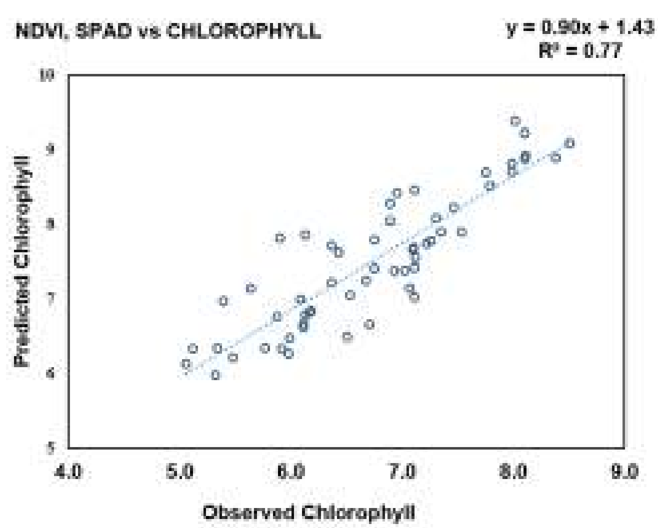


Fig. 1: Scatter plots of observed vs predicted chlorophyll content. Chlorophyll predicted using multiple linear regression (MLR) model between NDVI, SPAD, CLCC and chlorophyll (a) and NDVI, SPAD and chlorophyll (b) data from all six varieties combined.

CONCLUSION

In the present study MLR models between independent variables (NDVI, SPAD and CLCC) and chlorophyll content of rice for different rice varieties were developed. Based on high R^2 values and less prediction errors, the MLR models with two variables, NDVI and SPAD, emerged as the most accurate for predicting chlorophyll content of different rice varieties. While, combined data from six different varieties were used to create MLR models, the predicted values for chlorophyll were comparable to those obtained using models from individual varieties. Hence, we conclude that NDVI and SPAD measurements during panicle initiation stage of rice can satisfactorily be used to predict the chlorophyll content in rice.

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Assessing different crop establishment methods for enhancing rice productivity in eastern India

Rahul Tripathi*, Simran Mohapatra[$], S. Mohanty, Md. Shahid, S.D. Mohapatra, B.B. Panda, S. Saha, S. Priyadarshani, D.R.Sarangi, N.N.Jambhulkar, A.K. Nayak

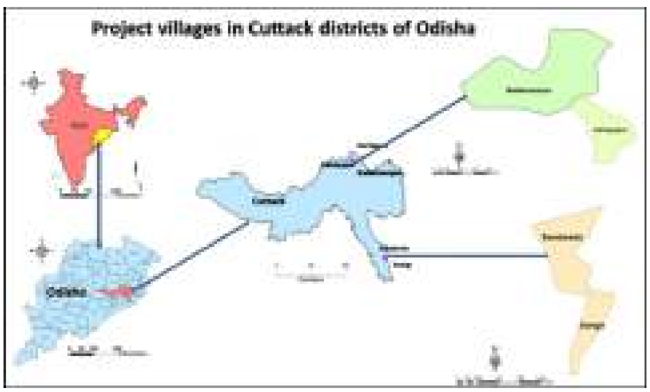
ICAR-National Rice Research Institute, Cuttack-753006, Odisha, India

[*]Corresponding author email: rahulcrri@gmail.com, [$]Presenting author : simranmohapatra24@gmail.com

Climate change has become one of the greatest ecologicaland economic challenges for the world and especially for the developing countries like India which is more sensitive to climate change.To cope up with the current and unpredictable future climate change, agricultural systems must be resilient, and smallholders should be able to adapt to change. CSA technologies such as dry direct seeded rice, wet direct seeded rice, mechanical transplanting and system of rice intensification are viable options to shift production oriented to profit oriented sustainable farming.Keeping the above facts in mind, the objectivefor this study was set to test different rice crop establishment methods and evaluate their performance on yield, yield attributes and profit maximization.

METHODOLOGY

Abhayapur and Badakusunpur of Tangi-Choudwar block; Sundarda and Juanga of Niali block were selected as study sites based on frequency of occurrence of the abiotic stresses. Tangi block was having upland and medium land situations whereas Niali comprised of lowland ecologies.Four climate smart crop establishment methods i.e., Wet Direct Seeded Rice, WDSR (37 farmers), Dry Direct Seeded Rice, DDSR (39 farmers), Mechanical transplanting, MTR (31 farmers), and System of rice intensification, SRI (18 farmers) were tested and validated in project areas through farmer-led 'on-farm demonstrations'. The demos were carried out for three years (2019/20 to 2021/22) during kharif and rabi seasons under RESILIENCE project. Using SAS 9.2, the data from various parameters were statistically analyzed using one-way analysis of variance (ANOVA). Duncan's Multiple Range Test was used to separate analysis of variance and means at the 0.05 level of probability (Gomez and Gomez, 1984).



RESULT

Yield and yield components varied significantly during the experimental years over the treatments (WDSR, MTR, DDSR, SRI, FP). The average yield and yield attributes are presented for three years (2019-2022) for *kharif*and*rabi* seasons in Table 1. In our study 26% & 37% higher yield in *kharif&rabi* season respectively was reported in SRI compared to farmers' practice. During *kharif*season harvest index was found to be higher in WDSR and SRI (0.46) compared to MTR (0.45), DDSR (0.44) and FP (0.40). It varied from 0.43 – 0.47 during the three consecutive years 2019- 2021, Whereas during *rabi* season it was found to be 15%, 10% and 7% higher in SRI, WDSR and MTR and DDSR, respectively than FP. It varied from 0.42-0.44 and it was significantly higher during *rabi* 2022 compared to 2020 and 2021.The higher yield in SRI method may be due to younger seedlings, higher tillering ability,

Table 1: Effect of different crop establishment methods on yield & yield attributes during *kharif* & *rabi* season.

Treatment/year	*Kharif* season					*Rabi* season				
	NP/m²	NGP	GY(t/ha)	SY(t/ha)	HI	NP/m²	NGP	GY(t/ha)	SY(t/ha)	HI
WDSR	342ᴬ	242ᴬ	5.25ᴬ	6.29ᴬ	0.46ᴬ	321ᴬ	221 ᴮ	4.88ᴬ	6.39ᴮ	0.43ᴮ
DDSR	310ᴮ	218ᴮ	4.91ᴬ	6.02ᶜ	0.44ᶜ	298ᴮ	206ᶜ	4.42ᴮ	6.07ᴰ	0.42ᶜ
MTR	335ᴬ	242ᴬ	4.99ᴬ	6.08ᶜ	0.45ᴮ	306ᴬ	252 ᴬ	5.02ᴬ	6.49ᴮ	0.43ᴮ
SRI	350ᴬ	263ᴬ	5.54ᴬ	6.20ᴮ	0.46ᴬ	331ᴬ	265ᴬ	5.59ᴬ	6.67ᴬ	0.45ᴬ
FP	219ᶜ	159ᶜ	4.38ᴮ	5.77ᴰ	0.40ᴰ	218ᶜ	180ᴰ	4.08ᴮ	6.32ᶜ	0.39ᴰ
2019	288ᴬ	219ᴬ	4.81ᴬ	6.12ᴬ	0.43ᴬ	302ᴮ	221ᴮ	4.62ᴮ	6.33ᶜ	0.42ᴮ
2020	321ᴮ	248ᴮ	5.06ᴮ	5.99ᴮ	0.44ᴮ	262ᶜ	221ᴮ	4.73ᴮ	6.47ᴮ	0.42ᴮ
2021	330ᶜ	250ᴮ	5.16ᴮ	6.38ᶜ	0.47ᶜ	319ᴬ	247ᴬ	5.31ᴬ	6.60ᴬ	0.44ᴬ
CD (treatment) at 5%	18.65	23.12	0.77	0.06	0.003	26.47	15.85	0.78	0.10	0.002
CD (year) at 5%	17.31	19.68	1.18	0.05	0.004	24.37	19.99	0.88	0.08	0.002
CD (year x treatment)	32.58	40.39	0.12	0.10	0.006	45.85	27.46	0.13	0.17	0.004

CD: Critical Difference, WDSR: Wet Direct seeded rice; DDSR: Dry Direct seeded rice; MTR: Mechanical transplanting; SRI: System of Rice Intensification; FP: Farmer practice; NP: No of panicle/m²; NGP: No. of grain/panicle; GY: Grain yield(t/ha); SY: Straw yield(t/ha); HI: Harvest index. Mean values with different letters in the same column are significantly different at P <0.05, ns: not significant at P >0.05.

optimum plant population, proper weed management by conoweeder, efficient nutrient and moisture utilization to produce higher grain yield over other crop establishment methods.Kumar et al. (2016) have also reported about 7–30% higher grain yield in SRI over conventional method. During *kharif* season, grain yield (GY) was 20% and 14% higher in W-DSR and DDSR respectively as compared to FP. Higher grain yield in DSR may be due to early seeding vigor, avoidance of transplanting shock, increased panicle number. The rice yield in MTR was found to be 11% lower than SRI whereas 18% higher than Dry DSR and found to be at par with WDSR during Rabi season. The higher grain yield in mechanical transplanting might be due to early tillering, development of more panicles on earlier tillers, longer panicles, extended active leaf life and decreased rate of leaf area reduction. Yield decline in farmer practices may be due to poor soil structure caused by regular puddling, high disease, pest and weed infestation, use of traditional varieties and knowledge gap in efficient nutrient and water management.

Cost of cultivation has been calculated for different crop establishment practices.The income of farmers in project villages (Tangi and Niali in Odisha) increased by 18 to 34% which was mainly due to reduction in cost of cultivation by 10 to 12% and increased productivity by 18.6 to 34.2%.There was benefit in all improved crop establishment practices including FP. However, there was 129%, 111%, 76% and 70% higher benefit in SRI, WDSR, MTR, DDSR as compared to FP.

CONCLUSION

The rice yield enhancedfrom 11 to 37 % by adapting various climate smart agricultural practices while the farmers are getting 70 to 129% higher benefit during cultivation. From this study it has been concluded that SRI is more efficient in terms of productivity during the three consecutive years.

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ARRW/SIRC/Theme II/24

Irrigation and nutrient management strategies to enhance the productivity of rice (*Oryza sativa* L.)

Vasuki Annadurai[1], M. Joseph[2] and M. Hemalatha[2]

Department of Agronomy, AC&RI, TNAU, Killikulam– 628252
Email: vasukiannadurai2211@gmail.com

Rice is the most important food grain grown widely in tropical and subtropical regions of the world and is grown in nearly 114 countries which contributes to 11% of the world's cultivated area(Kumar *et al*., 2014). Major constraints in rice production are deterioration of soil health along with declining water in both quantitative and qualitative terms. Practicing safe alternate wetting and drying method could save water by 30% than conventional method (Bouman 2007). Combined use of organic and inorganic fertilizer improves the soil health besides enhancing the yield.

METHODOLOGY

Field experiment was carried in AC&RI, Killikulam to identify the suitable irrigation regime and nutrient management strategy and its effect on growth, yield and water saving percentage of rice. Experiment was adopted in strip plot design with irrigation regimes on vertical strip *viz.,* Irrigation at 10 cm depletion of field water tube, irrigation at 15 cm depletion of field water tube and continuous flooding. Nutrient management practices such as 100% RDF, 100% RDF+ recommended dose of GLM, 125% RDF (100% N through inorganic fertilizer + 25% N through GLM), 150% RDF (100% N through inorganic fertilizer + 50% N through GLM) and absolute control in horizontal strip.

RESULTS

From the experiment it was observed that, grain and straw yield was maximum in continuous flooding (6758 kg ha^{-1} and 7531kg ha^{-1}) and was statistically identical with irrigation at 10 cm depletion of field water tube (6195 kg ha^{-1}and 6933 kg ha^{-1}). Among nutrient management practices, application of 150% RDF recorded maximum grain yield (7979 kg ha^{-1}) and straw yield (8834 kg ha^{-1}). In case of water use efficiency, irrigation at 15 cm depletion recorded maximum water use efficiency which recorded 5.6 kg ha mm^{-1} and among nutrient management 150% RDF recorded maximum water use efficiency (8.0 kg ha mm^{-1}). Nitrogen use efficiency was calculated and maximum use efficiency was noted in continuous flooding (52.1) and was minimum in irrigation at 15 cm depletion (44.0). With varied nutrient levels, maximum nitrogen use efficiency was noted in 125% RDF (53.7) and 150% RDF (51.1).

CONCLUSION

Combination of continuous flooding with 150% RDF recorded maximum grain and straw yield and was identical with irrigation at 10 cm depletion of field water tube with application of 150% RDF. While water use efficiency was maximum in irrigation at 15 cm depletion and 150% RDF. Nitrogen use efficiency was higher in continuous flooding with 150% RDF. From the above statement it is concluded that, intermittent irrigation and combined use of organic and inorganic is more effective in enhancing the production level of rice besides reducing the resources such as water and nutrient.

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Zinc application phasing impact on Zn pools in rice-wheat cropping system under red and lateritic soil

D.K. Shahi, Arvind Kumar and P.B. Saha

Department of Soil Science, Birsa Agricultural University, Ranchi-834006, Jharkhand, India

Rice is a major crop and grown on about 25 lakh hectares cultivated land in Jharkhand state. Zinc (Zn) deficiency is a major risk factor to crop production and also for human health. Under delineation programme of AICRP-MSPE it was observed that 20-30 percent soils Jharkhand suffer from Zn deficiency. Study undertaken in farmers fields with Zn application in different districts reflected encouraging result on yield and Zn enrichment in rice grain (Kumar *et al*. 2018) . Considering the need of Zn in plant and human being, particularly in red and lateritic soils, a research plan was designed on Zinc application phasing impact on Zn pools in rice - wheat cropping system under red and lateritic soil with the major objectives.

OBJECTIVES

To study the Zn phasing application on crop yield and Soil health monitoring under Zn phasing application in red and lateritic soil.

METHODOLOGY

Experiment was conducted in experimental plots of Soil Science taking Birsa Vikash Dhan (BVD)-203 as test crop. The crop was transplanted on 31st July, 2018. Soil of experimental field was acidic in nature (pH 5.25) with initial Zn level 0.81 mg kg^{-1}. Experiment was formulated with four Zn application levels (2.5, 5.0, 7.5 and 10kgha^{-1}) and three Zn application phasing (P_1:Zn application only in 1st year, P_2:Zn application after one year gap and P3:Zn application in each year). The treatments were replicated three times in RBD design. Zinc was applied in rice only and the succeeding wheat crop was grown on residual zinc.

RESULTS

Experimental result reflected that grain yield of rice significantly increased by 8.4% to 17.4% over control with application of 2.5 to 10.0 kg Zn ha^{-1}. Yield of rice was found at par with the application of Zn @ 7.5 and 10.0 kg ha^{-1}. Similar trend was found in rice straw yield. Zinc content in rice was found higher (30.79 mg kg^{-1}) with 10.0 kg Zn ha^{-1} followed by 29.69 mg kg^{-1} at 7.5 kg Zn ha^{-1} .

Lowest Zn content 25.50 mg kg^{-1} was recorded in control plot. Content of Zn in straw at different Zn application levels varied from 43.17 mg kg^{-1} (0.00 kg ha^{-1} Zn) to 58.17 mg kg^{-1}, (10.00 kg Zn ha^{-1}). Content of Zn in rice straw was 1.5 to 2 times higher than Zn content in grain. Zn content in rice husk varied from 25.17 mg kg^{-1} (0.0 kg Zn ha^{-1}) to 34.72 mgkg^{-1}, (10.00 kg Zn ha^{-1}). Zn accumulation in soil was significantly affected by treatment variations.The accumulation of Zn in post harvest soil was found higher more than (>300 %) at 10.0 kg Zn ha^{-1} and lower 59.18% at 2.5 kg ha^{-1} Zn.

CONCLUSION

Grain yield of rice significantly increased by 8.4% to 17.4% over control with the application of Zn @ 2.5 to 10.0 kg ha^{-1}, Zinc content in rice was found higher (30.79 mg kg^{-1}) with 10.0 kg Zn ha^{-1} followed by 29.69 mg kg^{-1} at 7.5 kg Zn ha^{-1} in soil, Content of Zn in rice straw was 1.5 to 2.0 times higher than Zn content in grain. Zn content in rice husk varied from 25.17 to 34.72 mg kg^{-1} , respectively in control and at 10.0 kg Zn ha^{-1}, Zn accumulation in soil significantly affected due to treatment variation. Increasing accumulation of Zn in post harvest soil was found higher more than (365%) at 10.0 kg Zn ha^{-1} and lower (59 %) at 2.5 kg Zn ha^{-1}, Percent utilization of Zn (8.44%) was found higher at 2.5 kg Zn ha^{-1} followed by 4.76 % at 5.0 kg Zn ha^{-1}.

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ARRW/SIRC/Theme II/27

Effect of organic and inorganic sources of nutrient on yield and yield attributes of rice (*Oryza sativa* L.) in inceptisols of Varanasi

Arvind and P. K. Sharma

Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221005

Rice (Oryza sativa L.) is the most important cereal crop in the developing world and it is consumed as a staple food for over half of the world's population including India. India has the largest area (44.86 m ha) among rice-growing countries and stands second in production (115.60 m t) with a productivity of 2700 kg/ha. Aroma is one of the most important rice sensory quality characteristics. The chemical compound that is known to contribute mostly to the aroma profile of aromatic rice (e.g. basmati rice) is 2-acetyl-1-pyrroline (2-AP) it is present in a very low concentration and has been reported to be the major active aroma compound contributing to the flavour of aromatic rice varieties. Presently, organic agriculture has come out to be the viable alternative for quality food production, eco-sustainability, soil and human health issues along with other social and cultural issues. It is now established globally that organic farming can improve the quality of scented rice. Quality in rice encompasses storage, milling, market quality, cooking and eating quality, and nutritive quality of the grain. Therefore an experiment was conducted to study the effect of organic and inorganic sources of nutrient on growth, yield attributing characters and yield and grain quality parameters of rice.

METHODOLOGY

A pot experiment was carried out during the *kharif* season of 2019-20 at the Department of Soil Science and Agricultural Chemistry, Institute of Agriculture Sciences, Banaras Hindu University, Varanasi on fine texture loam soil. The experiment was laid out in completely randomised design with three replications consisting of ten treatment combinations. i.e. T_{1}-Control, T_2-RDF (100%) (120:60:60 Kg ha^{-1}), T_3-50% RDN + 50% N through FYM (14 t ha^{-1}), T_4-50% RDN + 50% N through Vermicompost (5 t ha^{-1}), T_5-50% RDN + 50% N through Poultry Manure (5.26 t ha^{-1}), T_6-50% RDN + 50% N through Sewage & Sludge (7.5 t ha^{-1}), T_7-100% N through FYM (28 t ha^{-1}), T_8-100% N through Vermicompost (10 t ha^{-1}) T_9-100% N through Poultry Manure (10.53 t ha^{-1}) and T_{10}-100% N through Sewage & Sludge (15 t ha^{-1}).

Table 1. Effect of organic and inorganic sources of nutrients on yield and yield attributes of rice.

Treatments	Panicle length (cm)	No. of filled grain panicle^{-1}	No. of tillers plant^{-1}	Test weight. (g)	Straw yield (g pot^{-1})	Grain yield (g pot^{-1})
T_1	19.44	103	6.67	19.54	38.23	25.45
T_2	23.67	132	9.73	23.64	46.67	35.32
T_3	21.05	122	7.04	21.99	43.56	31.29
T_4	22.73	124	8.43	22.65	45.83	32.99
T_5	20.57	120	8.10	21.49	45.17	31.55
T_6	21.54	118	6.51	22.43	44.21	30.75
T_7	20.95	115	7.68	20.44	40.23	29.68
T_8	22.06	120	8.33	22.14	42.32	31.14
T_9	21.82	119	7.21	22.17	41.03	30.27
T_{10}	22.39	116	8.17	20.92	40.96	28.41

RESULTS

The application of recommended dose of fertiliser (T_2) brought about maximum improvement in the different growth attribute and yield of rice. Combination of organic sources of nitrogen have exerted variable influence on growth and yield of rice. An application of 100% RDF (120:60:60 NPK kg ha^{-1}) was increased the plant height (14.37%), chlorophyll content (22.66%), panicle length (21.75%), number of filled grain $panicle^{-1}$ (28.15%), number of tillers $plant^{-1}$ (45.87%), test weight (20.98%), straw yield (20.07%) and grain yield (38.78%) in over control as followed by treatment T_4-50% RDN + 50% N through vermicompost (5 t ha^{-1}) obtained remarkably increased the plant height (10.47%), chlorophyll content (11.05%), panicle length (11.01%), number of filled grain $panicle^{-1}$ (20.38%), number of tillers $plant^{-1}$ (26.38%), test weight (15.99%), Straw yield (19.87%) and grain yield (29.62%) in over the control. The lower yield attributes and yield of rice were recorded in the control treatments.

CONCLUSIONS

It could be concluded that the application of 100 % organics reduced grain yield as compared to RDF application but increased 20 to 30 percent yield as compared to control. Application of 50% RDN + 50% N through Vermicompost (05 t ha^{-1}) in aromatic fine rice cv. Kala namak performed better in terms of yield and yield components. Application of 100% N through vermicompost , FYM ,poultry manure and sewage sludge as well as 50% RDN + 50% N through organics influenced rice grain quality parameters.

Electric vertical conveyer reaper for paddy crop

Arjya Utkalini Sahoo[1*] and Hifjur Raheman[2]

[1*] *Assistant Professor, C.V. Raman Global University, Bhubaneswar, India 752054*

[2]*Professsor, Agricultural and Food Engineering Department, IIT Kharagpur, West Bengal, India*

**Email : pyarisahoo@gmail.com*

INTRODUCTION

Timely harvesting is an essential factor for achieving better quality and higher yield of paddy crop. Mechanical harvesting methods are required to be adopted for timeliness in harvesting paddy crop as traditional manual method of harvesting is time and labour consuming as well as costly. The machines available for harvesting cereal crops are self-propelled combine harvester, tractor mounted combine harvester, tractor mounted vertical conveyer reaper, power tiller mounted vertical conveyer reaper and self-propelled vertical conveyer reaper. The use of large machinery like combine harvesters and tractor operated vertical conveyer reapers has been limited to large farm holdings. These large machinery are unsuitable for small land and marginal land holdings. Further, the conventional VCR is not women friendly as it is heavy and has high forward speed. Also it produces more vibration and noise during operation. So, the women labourers, which constitute about 37% of the total agricultural labour force in India (Ghosh and Ghosh, 2014 and Mehta *et al.,* 2018) use traditional manual harvesting methods. Moreover, these conventional VCRs are powered by fossil fuels. Fossil fuel, when burns, releases carbon dioxide, which adds to the greenhouse effect and increases global warming (Rai, 2009 and Ellaban *et al.,* 2014). Faster depletion of fossil fuel, rise in the price of fossil fuel, and its unavailability in rural areas have necessitated to move towards the use of renewable sources of energy like solar, wind, hydropower and tidal energy. The agriculture sector is one of the major areas where utilization of energy from battery has enormous potential. Presently batteries are used as power storage units in solar energy harnessing systems. It is being used in pumping water for irrigation purposes. Harvesting of paddy is one of the operations where the use of battery energy has got potential. A limited research work has been done related to the battery-operated harvesting machines and application of those innovations in actual field conditions has rarely been reported. Considering the environmental issues, limitation for using large harvesting machine by marginal farmers and women laborers, an attempt has been made to develop and evaluate an electric vertical conveyer reaper (E-VCR) for paddy crop.

METHODOLOGY

The first step in designing an E-VCR is to decide a suitable cutting width, as it influences field capacity and power requirement of the machine. Power requirement will influence the size of battery and this in turn will influence the weight of the harvesting machine. It is also necessary to know the influence of crop and machine parameters on power required for cutting paddy crops. Thus, prior to the design of the E-VCR, a laboratory setup simulating the cutting unit of the VCR to harvest paddy crop is a prerequisite. Hence, a laboratory set up was designed to represent the cutting process (shear cutting) of paddy crop in actual field conditions. Keeping in view the design of the cutting unit of an E-VCR, the cutting unit of the laboratory setup was designed. The decision of cutting width was considered as a multi-objective optimization problem. The genetic algorithm-based multi-objective optimization problem was formulated to determine the optimum cutting width of E-VCR as well as the laboratory setup. A laboratory setup was developed with a cutting unit of 600 mm. The torque and power required for cutting the paddy crop was measured using the laboratory setup. Based on the findings obtained from the multi-objective genetic algorithm and laboratory set up, a prototype walk-behind type electric vertical conveyer reaper (E-VCR) was designed and developed. The performance of the developed E-VCR was evaluated in paddy fields. Further its performance was compared with that of a conventional IC engine operated vertical conveyer reaper (VST Shakti-5PR).

RESULTS

The developed prototype E-VCR had overall dimensions of 1970 × 988 × 1050 mm with a total weight of 135 kg. It comprised a cutting unit, conveying unit, propelling unit and power supply unit. The cutting unit consisted of a standard cutterbar with ledger guards and knife clips. The conveying unit consisted of crop dividers, star wheels and upper and lower conveyer chains. The propelling unit consisted of a pair of pneumatic wheels (4.00-8). Two DC motors 800 W 48 V and 350 W 24 V were used to power the header unit and propelling unit, respectively. Performance of the prototype was evaluated in test fields having matured paddy crop with an average moisture content of grain and straw as 20-32% and 68-75%, respectively and it was compared with similar internal combustion engine operated conventional vertical conveyer reaper having 1200 mm cutting width. The average field capacity, cutting efficiency and field efficiency of the developed E-VCR when operated at an average forward speed of 1 km/h and a knife speed of 2.20 m/s were found to be 0.05 ha/h, 95% and 83.3%, respectively as compared to 0.18 ha/h, 98% and 75% with the conventional reaper. The maximum power required for cutting and conveying by the header unit and for propelling the electric vertical conveyer reaper in the paddy fields was observed to be 550 W and 322 W, respectively. With the batteries fully charged, the E-VCR worked effectively for 2 h without any power breakdown. Noise and vibration produced by the developed reaper during harvesting of paddy crops were measured to be 9.9 m/s^2 and 88 dB(A), respectively. The hand vibration produced by the E-VCR reaper was 2 times lesser than that produced with conventional VCR. The cost of harvesting paddy crop with the developed E-VCR was found to be 1.7 times higher than that with the conventional IC engine operated VCR and 2.3 times lesser than harvesting manually. The developed reaper should be used to harvest at least 3.26 ha of area per year to make the harvesting of paddy crop economical as compared to manual harvesting method.

CONCLUSION

The developed E-VCR is at par with the IC engine operated VCR in terms of cutting and conveying efficiency. Further, it outperformed the conventional VCR in terms of environment pollution, ergonomic and economic aspects.

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Integrated weed management in aerobic rice

R. Babu* and L.Anusuyadevi

Coconut Research Station, Tamil Nadu Agricultural University, Veppankulam-614906
Email: rbabu67@gmail.com

Aerobic rice cultivation is an alternative to puddling and transplanting of rice as it requires less water, labour and capital input. It matures earlier (7-10 days) and favourable upland areas with access to supplementary irrigation (Belder *et al*., 2005). Weeds are the major problem in aerobic rice which in turn reduces the productivity and production. Hence, different methods such as cultural, manual and chemical need to be adopted in an integrated manner for effective weed management. Therefore, the present study was undertaken to evaluate the effect of herbicide combinations for control of complex weed flora in direct seeded aerobic rice with following objectives

- To find out the effective pre and post emergence herbicide for aerobic rice.
- To find out the effect of rotary weeder on weed control in aerobic rice.
- To work out the economics of weed control in aerobic rice.

MATERIALS AND METHODS

Field experiment was conducted at Agricultural College and ResearchInstitute, Tamil Nadu Agricultural University, Madurai during Rabi 2016 (January-May) to study the weed management in aerobic rice. The treatment consists of PEpendimethalin at 1.0kg/ha on 3DAS *fb* HWon 30DAS(T_1), PEpendimethalin at 1.0kg/ha on 3DAS *fb* rotary weeder on 30DAS(T_2), PEpendimethalin@1.0kg/ha on 3 DAS *fb* POE bensulfuron methyl at 0.06 kg/ha on 30 DAS(T_3), T_3 *fb* rotary weeder on 50 DAS (T_4), T_3 *fb* HW on 50 DAS (T_5), PE pendimethalin at 1.0 kg/ ha on 3 DAS *fb* two HW on 30 and 50 DAS (T_6), PEpendimethalin at 1.0 kg/ha on 3DAS *fb* POE bispyribac sodium at 25 g on 30 DAS (T_7), T_7 *fb* rotary weeder on 50DAS (T_8),T_7 *fb* HW on 50 DAS (T_9)and unweeded control (T_{10}). The trialswas laid out in randomised block design with three replications with rice var Anna 4.

RESULTS

Distinct reduction of total weed density and dry weight of weeds at 60 DAS were observed with PE application of pendimethalin at 1.0 kg/ha *fb* two hand weeding at 30 and 50 DAS andwas comparable with PE application of pendimethalin at 1.0 kg/ha *fb* POE applicationof bispyribac sodium at 25 g/ha on 30 DAS and hand weeding at 50 DAS. In both the cases application of the PE herbicide takes care of control of the weeds at the early stage itself. The weeds that germinate subsequently were controlled by the PoE herbicide bispyribac sodium which was applied on 30 DAS. Thus spraying of both pre emergence and post emergence herbicide followed by hand weeding

Table 1. Effect of weed management practices on total weed density of weeds (Nos./m^2)and dry weight of weeds (g/m^2) inaerobic rice at 60 DAS.

Treatments	Total density of weeds (Nos./m^2)	Total dry weight of weeds (g/m^2)
T_1	6.20 (37.9)	9.30 (85.9)
T_2	6.72 (44.67)	10.80 (116.04)
T_3	7.20 (51.33)	16.82 (282.54)
T_4	3.54 (12.00)	2.65 (6.54)
T_5	4.98 (24.34)	3.49 (11.70)
T_6	3.14 (9.0)	2.15 (4.13)
T_7	6.57 (42.67)	9.70 (93.64)
T8	3.58 (12.30)	2.68 (6.68)
T_9	3.19 (9.67)	2.26 (4.60)
T_{10}	10.73 (114.67)	24.29 (589.46)
SE d	0.41	0.52
CD (P= 0.05)	0.86	0.86

*Data subjected to square root transformation; values in parenthesis are mean of original

Table 2. Effect of weed management practices on growth, yield attributes, yield and B:C ratio inaerobic rice

Treatments	LAI	Tillers/ m^2	Panicle/ m^2	Grain yield	B: C ratio
T_1	4.70	348	322	4147	2.42
T_2	4.66	310	299	3884	2.72
T_3	3.94	293	229	2917	2.11
T_4	5.43	373	338	4582	2.90
T_5	4.95	372	331	4457	2.69
T_6	6.29	463	364	5236	2.89
T_7	4.84	324	305	3974	2.50
T_8	5.51	445	350	5075	2.98
T_9	5.56	448	356	5150	2.90
T_{10}	3.10	103	176	1826	1.55
SE d	0.20	20.48	15	170	
CD (P= 0.05)	0.42	43.04	32	357	

exhibited good weed control of weeds resulting in lowest dry weight at all the stages of measurement. These results are in conformity with the findings of Rahman *et al.* (2012).

Higher plant growth parameters like leaf area index, number of tillers/hill and yield parameters *viz*., number of panicles / m^2 and grain yield were recorded in PE pendimethalin at 1.0 kg/ ha *fb* two handweedings at 30 and 50DAS due to effective control of weeds envisaged by lower total weed biomass, which enhanced the availability of nutrients to the crop and leading to the positive result on parameters recorded.₹Highest BCratio (2.98) was recorded with PEapplication of pendimethalin at 1.0 kg/ha *fb* POE application of bispyribac sodium at 25 g/ha on 30DAS and rotary weeding at 50 DAS and was comparable with and PE application of pendimethalin 1.0 kg/ha *fb* POE application of bispyribac sodium 25 g/ha at 30 DAS and hand weeding at 50DAS.

CONCLUSION

The results of the field experiment, it can be concluded that preemergence application of pendimethalin at 1.0 kg/ha followed by POE application of bispyribac sodium at 25 g/ha at30 DAS and rotary weeding at 50 DAS can be recommended for increased yield and also for effective weed management in aerobic rice cultivation.

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Effect of foliar application of nano urea on *Kharif* rice

[1]Shubhamay Dey, [2]Pushpendu Sardar, [3]Sonali Biswas, Srabani Debnath[4]
Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India, 741252
Email: shubhamaydey@gmail.com

India is one of the largest producer and consumer of rice in the world. Over the last 15 years (2005-2020), rice production in India increased from around 80.0 million tonnes in 2005 to around 121 million tonnes in 2020 (Economic survey 2005-2020). It was made possible mostly by increased inputs use besides exploitation of genetic resources. However, in recent years the input response or factor productivity is reported to be declining in major rice growing states. In India, besides climatic factors, deterioration of soil fertility has been widely reported to be the major cause for stagnating rice productivity. For this reason efforts to pursue atmanirbhar on national food production, especially rice, have become the main concern of most of the Asian countries. In this context, the development of nano urea (liquid) by IFFCO for agricultural use has a pretty good prospect to be able to answer the challenge of precisely providing nutrients for plants through a more efficient nutrient delivery system. This nano urea (liquid), which is included in the FCO, contains nano nitrogen with particle size varies from 20-50 nm and 4.0% total nitrogen (w/v) evenly dispersed in water (IFFCO). Because of high surface area to volume ratio, the effectiveness of nano-fertilizers may surpass the most innovative polymer-coated conventional fertilizers, which have seen little improvement in the past ten years (Naderi*et al.,* 2013).Keeping these in view, the investigation was carried out with objectives: i) To study the effect of nano urea (liquid) compare to prill urea on growth and yield of *Kharif* rice and ii) To assess the economic benefit by comparing the benefit cost ratio.

METHODOLOGY

In order to evaluate the effect of nano urea (liquid), a field experiment was conducted in*kharif* season (July-October) of 2022 in Randomized BlockDesign at District Seed Farm, AB Block, B.C.K.V., Kalyani, Nadia,West Bengal. There are 12 treatements *viz.*T_1: N_0PK (Control); T_2: RDN [Recommended Dose of Nitrogen @ 80 kg ha^{-1} (3 splits)]; T_3: 75% RDN (3 splits); T_4: 50% RDN (3 splits); T_5: T_3 + one nano urea spray; T_6: T_3 + two nano urea spray; T_7: T_4 + one nano urea spray; T_8: T_4 + two nano urea spray; T_9: 1/3rd RDN as basal & two nano urea spray; T_{10}: 2/3rd RDN (2 split) + one nano urea spray; T_{11}: 1/3rd RDN as basal+ 2% urea two foliar spray; T_{12}: 2/3rd RDN (2 split)+ one urea foliar spray. Here, Urea, SSP and MOP as a source of nitrogen, phosphorus and potassium respectively. P and K were applied as basal and N was applied treatment wise in all the treatments. Nano urea was applied @ 1250 ml ha^{-1} on crop leaves at 25-30 DAT and 40-45 DAT.

RESULTS

Among the growth attributes, highest plant height (cm) was recorded in T_6 treatment (108.22 cm) followed by T_{10} (100.09 cm) treatment and lowest plant height was recorded in T_1 treatment (90.95 cm). No. of tillers/m^2 was highest in T_6 treatment (229.66) followed by T_{10} (228.53) and lowest value was obtained from treatment T_3 (185.06). The maximum grain yield (3.06 t ha^{-1}) was obtained from T_6 treatment followed by T_{10} (2.57 t ha^{-1}) treatment and the minimum value was recorded in T_1 treatment (1.68 t ha^{-1}). Highest straw yield was recorded from T_6 treatment (6.75 t ha^{-1}) followed by T_{10} (5.80 t ha^{-1}) treatment and the lowest value was obtained from the treatment T_1 (4.18 t ha^{-1}). Highest B:C was obtained from T_6

treatment (2.68) and lowest value was from the treatment T_1 (1.57).

CONCLUSION

Based on the above results, it could be concluded that application of 75% RDN with two nano urea spray @ 1250 ml ha^{-1} at 25-30 DAT and 40-45 DAT (T_6) considered as an effective nutrient management for obtaining good yield and high return in *kharif* rice.

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Field evaluation study of SRI six row direct paddy seeder with SRI manual transplanting

P. S. Preman*[1], K. Kathirvel, and G. K. Rajesh[2]

Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore – 641003, Tamil Nadu, India.

Email: premanps@gmail.com

On the face of global water scarcity and escalating labour costs, when the future of rice production is under threat, direct seeded rice (DSR) with an appropriately designed drum seeder offers an attractive alternative.The System of Rice Intensification, widely known as SRI, is a method of rice cultivation developed in an unconventional way.The existing system of SRI cultivation includes mainly raising of paddy seedlings in nursery and transplanting it on main field (Krishnan, 2008). One of the major hurdles in the adoption of SRI lies in the transplanting process, since the existing practice of transplanting single seedling is highly labour intensive.Keeping the above facts in view, field evaluation study of SRI six row direct paddy seeder with SRI manual transplantingwas carried out with objectives: (a) work out the cost economics and(b) compare growth, yield attributes and crop yield under both methods.

METHODOLOGY

The study between the treatments ofsix row SRI direct paddy seeder (T_2) and SRI manual transplanting (T_3) was carried out at Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. The field evaluation was laid out in a randomized block design with seven replications using paddy variety CO (R) 50 at field No. D-4 of Southern Block of Agricultural Research Station, TNAU, Bhavanisagar. The SRI six row direct paddy seeder consists of three numbers of seed hoppers, a pair of ground wheels, main shaft and a harness. The seed hopper was of hyperboloid shape drum. The length and diameter of each drum was 300 and 200 mm respectively. On either side of each drum, 7seed holes of 7mm diameter were drilled at equal intervals at a row spacing of 250mm.The seedbed was prepared thoroughly and excess water from the field was drained.In (T_2), seeder was operated with a recommended forward speed of 0.9 km h^{-1} and sown the pre germinated paddy seeds. Single seedling per hill was transplanted manually in (T_3). The row and hill spacing adopted for (T_2) and (T_3) was 250 x 250mm. Germination of seed for (T_2),crop establishment, uniformity of plant spacing, seed rate, cost economics, growth and yield attributes, grain and straw yield and harvest index were recorded by following standard procedures and values were found out accordingly for (T_2) and (T_3).

RESULTS

The germination of seed in direct sown treatment $T_2$was found out as 87.8 %.Crop establishment for T_2 and T_3 was 96.0 and 97.1 %, respectively. The average spacing between hills obtained for T_2 and T_3 was 245 and 250 mm, respectively.The seed rates for $T_2$and T_3 were 5.6 and 5.0 kg ha^{-1} , respectively.The cost of operation for T_2 and T_3 was Rs 465 and 11220 per hectare, respectively.The plant population m^{-2} counted on 20 days after sowing and transplanting for T_2 and T_3 was 41 and 14 numbers, respectively.The mean values of plant height for T_2 and T_3 at harvest stage were 1132 and 1220 mm respectively. The mean values of total number of tillers m^{-2} for T_2 and T_3 at harvest stage were 261 and 280 respectively.The plant dry matter production for $T_2$and T_3 at harvest stage was 9934 and 10004 kg ha^{-1} respectively.Rice in T_2 attained maturity and harvesting was done on 123 days after sowing whereas the harvesting of T_3 was done on 135 days after transplanting.The mean values of total number of productive tillers m^{-2} for T_2 and T_3 at harvest stage were 244 and 250 respectively. Grain and straw yield for $T_2$and T_3 were 5651 and 5777 kg $ha^{-1}$and 8166 and 8251 kg ha^{-1} respectively.Harvest index for T_2 and T_3 was 0.409 and 0.412 respectively.

CONCLUSION

A95.9 per cent saving in cost was obtained for T_2 than T_3 shows that the economic benefit was very much higher with direct sowing.Duration of crop was shortened by 12 days in T_2 compared to T_3.

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ARRW/SIRC/Theme II/33

Effect of different sources of nitrogen on yield, nutrient uptake and nutrient availability of summer rice (*Oryza sativa* L.) under *Terai* agro-climatic zone of West Bengal

Senjit Singh Ashem[1*] and Ashis Kumar Singha Roy[2]

[1]Ph.D. Research Scholar*
[2] Professor, Department of Agronomy
Uttar Banga Krishi Viswavidyalaya, Cooch Behar, 736165, West Bengal, India.
(Corresponding author email: senjitsingh2011@gmail.com)

Rice cultivation depends to a large extent on improvement in soil properties, where mineral nutrition is by and large one of the most important factors. Among inorganic fertilizers, nitrogen (N) fertilizer is considered to be major input affecting the yield of rice. After nitrogen, phosphorus and potassium, widespread of zinc deficiency has been found responsible for yield reduction in rice (Fageria *et al*., 2002). The combined use of organic manure with inorganic fertilizers performed better than sole inorganic fertilizer to sustain the soil fertility and rice productivity as well as meet a part of inorganic fertilizer requirement of crop. The objective of this study was to evaluate the effect of different sources of nitrogen on yield, nutrient uptake and nutrient availability of summer rice under *Terai* Agro-climatic zone of West Bengal.

METHODOLOGY

A field experiment was conducted at Uttar Banga Krishi Viswavidyalaya, Cooch Behar, West Bengal during summer season of 2018 and 2019. The Gotra Bidhan-1 variety is used for experiment. The soil of the experimental site was sandy loam having pH 5.60, high in organic carbon content (15.59 g kg^{-1}), medium in available N (160.56 kg ha^{-1}), medium in available P (38.15 kg ha^{-1}), medium in available K (117.64 kg ha^{-1}) and low in available zinc (1.82 kg ha^{-1}). The experiment was laid out in randomized block design with 3 replications. Ten treatments were allotted in each replication randomly. Different doses of recommended nitrogen viz. 100%, 75% and 50% of recommended dose of nitrogen (80 kg N ha^{-1}) and organic manures viz. vermicompost and farm yard manure contributing 0, 25%, 50% recommended dose of nitrogen were applied with or without (25 kg Zn SO_4 ha^{-1}). The size of plot was 4m x 3 m. A uniform dose of 80 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1} were applied to all the plots.

RESULTS

Among the ten treatments significantly highest grain (5.10 t ha^{-1}) and straw yield (6.93 t ha^{-1}) was recorded under treatment 75% RDN through inorganic fertilizer + 25% RDN through vermicompost + 25 kg $ZnSO_4$ ha^{-1}. Significantly, maximum nitrogen accumulation (2.019% and 1.163% in grain and straw) and total uptake (183.60 kg ha^{-1}) was obtained under the same treatment. Similarly, total uptake of P, K and Zn follows the similar trend depicting the maximum values with the same treatment. Incorporation of 25 kg $ZnSO_4$ ha^{-1} as soil application showed significant superiority to other treatments in increasing zinc content in grain and straw (Anzer and Monoj, 2015) besides increased in N, P, K and Zn uptake by rice plant. Substitution of 50% RDN through organic manure (Vermi/FYM) + 50% RDN through inorganic fertilizer along with 25 kg $ZnSO_4$ ha^{-1} gave higher available N, P, K and Zn. The treatment supremacy was observed under treatments which received a part of N through organic sources (Vermi/FYM) + $ZnSO_4$ with respect to N balance.

CONCLUSION

It was concluded that under *Terai* Agro-climatic zone of West Bengal, application of 75% RDN through inorganic fertilizer + 25% RDN through vermicompost + 25 kg $ZnSO_4$ ha^{-1} recorded higher grain yield, nutrient uptake as well as improved the fertility status of the soil. Hence, optimum inorganic nutrients in conjunction with organic manures and soil application of Zn can play a vital role in exploiting higher potential yield of summer rice through its favourable effects on nutrient supply and soil fertility.

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ARRW/SIRC/Theme II/34

Impact of land use land cover change on land surface temperature distribution in Mahanadi Delta

Rahul Tripathi*[a], KC Moharana[a], D Chatterjee[a], M Debnath[a], S Mohanty[a], Anjani Kumar[a], B R Goud[a] and AK Nayak[a]

[a]*ICAR - National Rice Research Institute, Cuttack, Odisha, India*

It is well known that changes in land use and land cover (LULC) have a significant impact on land surface temperature and various weather variables. However, there is limited study on LST in deltaic environments, particularly the Mahanadi delta. As a result, this study's objectives were set to estimate changes in land use land cover and its impact on land surface temperature (LST) in the Mahanadi delta region from 1990 to 2018 using Landsat imagery, as well as analysing the effects of temporal and spatial variations in LULC on LST.

MATERIAL AND METHODS

The study area is 6802 km^{2}catchment basin of the Mahanadi River in the delta region. The NDVI was calculated using the red and NIR bands of satellite images. Infrared bands 6 and 10 from Landsat TM 4 and 5, as well as band 10 from Landsat 8, were used to determine the top of atmospheric (TOA) radiances.Imagery from Landsat 5 TM was used for land use land cover classification in year 1990, 1995, 2000, 2005, and 2011, while Landsat 8 OLI imagery was used in 2018 for land use land cover classification utilising a decision tree classification technique.

RESULTS

Over a 28-year period, it was calculated that built-up land expanded by 62.32% while agricultural land shrank by 8.7%. Between 1990 and 2000, forest area reduced by 12%, but between 2000 and 2018, it recovered by 28.54%. From 1990 to 2018, there was a consistent decline in the area used for agriculture, with the biggest dip (3.42%) coming between 2011 and 2018. 459 sq.km of agricultural land were converted into built-up land (306 km^2), wasteland (82.5 km^2), woodland (68.1 km^2), and water body between 1990 and 2018. (3 km^2).

Higher NDVI values were recorded during*kharif* season compared to*rabi* season. In comparison to other land use types, forest areas were found to have higher NDVI levels. The NDVI readings over water bodies had the lowest range among all the LULC. Over built-up areas, the maximum LST varied between 308 to 315 ^{o}K over the course of the study, whereas the lowest LST was found over forested areas (289 to 301 ^{o}K). The LST over the research area ranged from 311 to 323 ^{o}K in 2000, making it the warmest rabi season on record compared to previous years.Over the course of the study's years, the LST over developed land was reported to be the highest, and the LST over water bodies was the lowest. The lower NDVI reported during the rabi season may be due to monoculture, or the cultivation of rice during the *kharif* season and fallow land during the *rabi* period. The deep mangrove forest and tropical deciduous forest in Kendrapada district may be to account for some of the relatively high NDVI readings during *rabi*. Vegetation cover is very less during end of the monsoon, leading to increase in LST. Due to variations in the slope orientations of the earth's surface, the amount of solar radiation absorbed at different locations changes, resulting in variable LST at different sites within the same land use type (Zhao *et al.* 2016).

Rising LST values between 1990 and 2018 were associated with quick expansion across both urban and rural built-up areas. Gogoi *et al.* (2019)

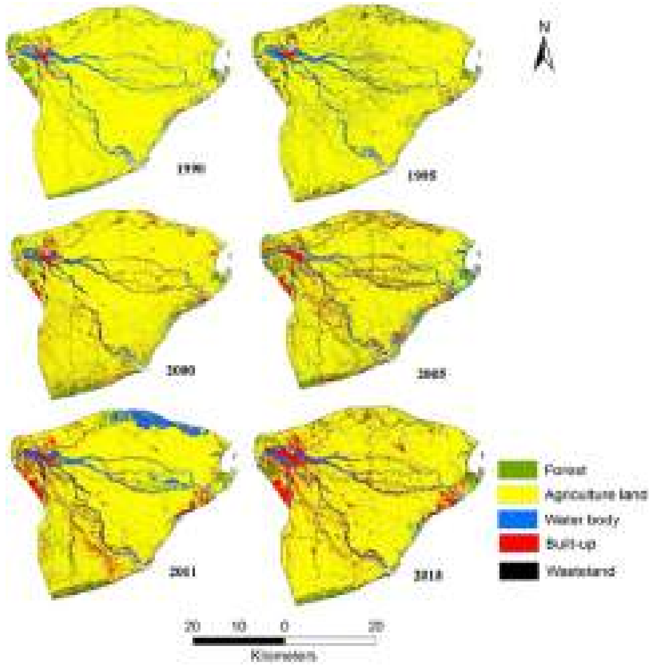

Fig. : Variation in Land use land cover in Mahanadi delta during 1990 to 2018

also observed 40% to 50% increase intemperature in urban areas in the Mahanadi delta indicating that increase in built up areas may result in changes in the temperature and warming of the land surface. LST and NDVI are negatively correlated, with lower NDVI in areas with higher LST. Built-up land has a higher R2 value when establishing a relationship between NDVI and LST.

CONCLUSION

Agricultural land areas declined over a 28-year period while built-up land rose. Forest area dropped between 1990 and 2000, but grew from 2000 to 2018. The *kharif* season was found to have higher NDVI levels than the *rabi* season. Over developed lands, LST was highest, and over bodies of water, LST was lowest. Researchers studying climate change, the environment, and agriculture as well as decision-makers in the Mahanadi Delta region for ecological and agricultural planning may find the conclusions of this study to be of interest.

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ARRW/SIRC/Theme II/35

Effect of conservation agriculture on the yield patterns of short duration rice genotypes in West Bengal

[1]Debarpita Datta Ray, [2]Aniket Baishya, [1]Sutanu Sarkar, [1]Raghunath Sadhukhan

[1]Department of Genetics and Plant Breeding, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal 741252, India
[2]Department of Soil and water conservation, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal 741252, India

Conservation agriculture represents a climate-smart agriculture standing on three key principles (Chatterjee et al., 2021) as direct planting of crops with minimum soil disturbance, permanent soil cover by crop residues or cover crops, and crop rotation or diversification. The existence of genotype x resource-conserving-crop-management-practice interactions, traits influencing these interactions and breeding strategies that can be used to improve yield under sustainable practices are prerequisite in that context. Certainly, the advancement in conservation agriculture is possible through genetic improvement in crops and varieties, which are suitable for better adaptation to different farming system environments. In the case of rice, water is the one of the most important factor, which governs the productivity of rice in Asia. Many studies have already reported the effects of different conservation agricultural practices on the soil and other microclimatic factors of the rice crop. There is, however, not many research works in India that have identified good performers or contrasting parental lines from a population under screening in a well-established field conditions with different degrees of tillage. In this study, therefore, these gaps have been addressed with the objective to select suitable rice genotypes based on their performance and fitness towards CA practices.

METHODOLOGY

A population of twenty early maturing genotypes involving a range of characteristic responses to stresses were grown under three separate cultivation systems. The population is divided into three groups based on their flowering and maturity i.e early (90- 120 days), medium (120-140 days), late (140-180 days). The genotypes to be evaluated in the kharif seasons under three major tillage condition i.e Conservation Tillage (CT), Zero Tillage (ZT) and Reduced Tillage (RT). The three tillage platforms are supported by rice residue retention from previous years. The CT conditions are grown as a normal puddled Rice (2 Primary and 2 Secondary Tillag). The ZT system presents no tilled-direct seeded Rice without submergence (micro irrigations) to be delivered in later stages as per requirement). The RT system is partially tilled (1 Primary and 1 Secondary tillage) with submergence. The experiment will be done in augmented design. Yield per plant were recorded for the twenty genotypes over three years under the three tillage platforms.

RESULTS

The three-way ANOVA revealed that there were significant variations present among the three years ($P<0.01$), tillage effects as well as the genotypes also ($P<0.01$). The interaction effects between the year×tillage, year×genotype and tillage×genotype systems were significantly varying. The Pearson correlation coefficients revealed significant and positive correlations among all the tillage systems (CT:RT: r=0.861, $p<0.01$), (CT:ZT: r= 0.826, $p<0.01$), (RT:ZT: r=0.770, $p<0.01$). The stability analysis of the genotypes over three systems for three years stated that L-35, Dular and Ajit had an overall ideal performances across the systems. Sahabaghi Dhan was the best performer under zero tillage

(39.7 g/plant), while Asanlya under conventional (34.53 g/plant) and reduced tillage (32.53 g/plant)

CONCLUSION

The correlations among the tillage conditions suggest the higher yielders under conventionally cultivated condition has been uniformly performing better under the reduced and zero tillage systems as compared to the other genotypes. Dular and Sahabaghi Dhan can be recommended as conservation agriculture-responsive short duration rice varieties under West Bengal.

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ARRW/SIRC/Theme II/36

Optical sensor based N recommendation for top dressing in low land rice of eastern India

Sangita Mohanty[1]*, Rahul Tripathi[1], Chinmaya Kumar Swain[1], Supratim Das[1], B. Raghavendra Goud[1], Pujyasmita Nayak[1], A.K. Nayak[1]

[1]ICAR-National Rice Research Institute, Cuttack-753006 (Odisha), India
**e-mail of corresponding author: sangitamoha@gmail.com*

Synchronization of nitrogen (N) supply with that of crop demand is crucial for environmentally sustainable rice production. Crop demands change season-to-season and are variety specific, therefore, a practical decision support tool is required to decide amount of N need to be applied based on in -season crop needs and corresponding environmental conditions. GreenSeeker optical sensor is a recent advance in precision nutrient management research which senses wavelengths of reflected light from the crop canopy and produce a normalized difference vegetation index (NDVI). The NDVI correlates well with the leaf chlorophyll content, and based on the relation topdressing nitrogen rates synchronizing site-specific crop needs can be prescribed (Bijay Singh et al., 2015). However, there is a need for region specific calibration of Greenseeker for generating recommendation for a group of cultivars. Therefore, the study was conducted with the objectives of calibration and validation of Greenseeker for generating N recommendation for top dressing in low land rice of eastern India

METHODOLOGY

Calibration experiment to develop relationships for predicting yield of rice from in-season optical sensor measurements was conducted with 6N levels (0, 40, 60, 80, 100, 120 N ha^{-1}) and 2varieties (Lalat and Naveen) during kharif season of 2021-22. The NDVI measurements were recorded at 22 and 46 DAT. The in-season-estimation-yield (INSEY) was calculated by dividing NDVI of sensed date with the number of days with GDD>0. The yield potential with no additional fertilization (YP0) was calculated using an empirically-derived function YP0= a * $(INSEY)^b$. The relation between INSEY and yield showed best fit to power function equation at 46 DAT for both the varieties, hence used to calculate the greenseeker based fertilizer recommendation for PI stage using following equation- Fertilizer N

Evaluation of Greenseeker based recommendation with respect to yield and N use efficiency.

Experimental Sites	Variety	Treatment	N applied (kg ha^{-1})			Total N applied	Yield	PPFN
			Basal	MT	PI	(kgha^{-1})	(t ha^{-1})	(kg kg^{-1})
Byree, Jajpur	Naveen	RDF	40	20	20	80.00	4.1	51.3
		GS	40	20	18.3	78.31	4.2	53.6
Isani Berhempur Jagatsinghpur	Naveen	RDF	40	20	20	80.00	4.2	52.5
		GS	40	20	23.05	83.05	4.4	53.0
Praharajpur Jagatsinghpur	Lalat	RDF	40	20	20	80.00	4.3	53.8
		GS	40	20	24.8	84.81	4.6	54.2
Salepur Cuttack	Lalat	RDF	40	20	20	80.00	4.3	53.8
		GS	40	20	20.8	80.8	4.2	52.0

GS: Greenseeker based

dose (kg ha^{-1}) = (YPN-YP0)*1.2 /(0.5*100) , as described by Bijay-Singh et al. (2015). Field trials were conducted in the kharif season of 2022-23 at four different locations of Jajpur, Jagatsinghpur and Cuttack district to validate the GS based recommendation.

RESULTS

The optical sensor based NDVI measurement generated recommendation for PI stage ranged from 18.3-to 24.8 kg ha^{-1} in four different locations. In most of the locations GS based recommendation produced similar yield as that of RDF, and in Praharajpur village GS based recommendation produced higher yield as compared to RDF.

CONCLUSION

The Greenseeker based N optimization algorithm developed following NDVI measurement can be used to generate second top dressing N application recommendation for medium duration (120 -125 Days) varieties.

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ARRW/SIRC/Theme II/37

Weed dynamics and system productivity under rice-maize cropping system

Mangal Deep Tuti *[1], R. Mahender Kumar[1], B. Sreedevi[1], Nirmala Bandumula[1], K. Surekha[1], Bandeppa[1], Soumya Saha[2], V. Manasa[1], S. Nagalakshmi[3], K. Prabhavathi[4] and Raman Meenakshi Sundaram[1]

[1]*ICAR-Indian Institute of Rice Research, Hyderabad-500030, India*
[2]*ICAR-National Rice Research Institute, Cuttack-753006, Odisha*
[3]*College of Horticulture, Parvathipuram, Dr. YSR Horticultural University, Andhra Pradesh*
[4]*Horticultural Polytechnic, Ramagirikhilla, SKLTSHU, Telangana*
**Email: mangal.iari@gmail.com*

Conservation agriculture (CA) is seen as a feasible approach for crop intensification that is both sustainable and profitable. To maximize the benefits of CA, location-specific appropriate crop rotations and system-based CA strategies must be devised (Tuti *et al*., 2022). A five-year fixed plot trial was conducted at Rajendranagar Farm of ICAR-IIRR, Hyderabad to study the effect of different CA and establishment methods in rice on system productivity, profitability, and soil carbon status in a rice-maize system.

METHODOLOGY

In the rainy season, the trial consisted of two main treatments: (i) normal manual transplanting and (ii) direct-wet seeding, and three sub-main treatments at different sowing dates with fifteen day intervals. In addition, in the winter season, two tillage treatments (conventional and minimum tillage) were imposed over the rainy season treatments. Both rice and maize were grown under irrigated conditions.

RESULTS

System productivity of CA-based minimum tilled rice–maize was inferior during the first three years but was superior to the conventionally tilled method in the fourth and fifth year. Pooled analysis revealed that the conventionally tilled rice-maize system resulted in a similar system productivity as that of the CA during the study period. *Echinochloa crusgalli* (L.) Beauv., *Echinochloa colona* (L.) Link., *Cyperus esculentus* L., *Cyperus rotundus* L. and *Parthenium hysterophorus* were among the weed flora that appeared in the rice-maize system over time. Three weeds, *E. colona*, *C. rotundus*, and *C. esculentus*, were found to be absent throughout the five-year research under the traditionally tilled transplanting system. *D. Aegyptium*, *E. colona* and *C. rotundus*, on the other hand, were present in every year under the wet direct seeded minimum tilled system. In the transplanted rice, *Echinochloa crusgalli* was present for all five years, but was absent for the first three years and only appeared in the fourth year onward in the wet direct seeded rice. Similarly, *Melilotus indica* (L.), *Anagallis arvensis* L., *Coronopus didymus* (L.) Smith, *Chenopodium album* L. and *Rumex dentatus* L. infested the conventionally tilled and minimally tilled maize. Regardless of treatment, the total weed population rose as the years continued. In all five years of the winter maize cropping, the wet direct seeded rice-based plots had a larger overall weed population than the transplanted rice-based plots. The total weed populations were lower in the conventional tilled maize plots than the minimum tilled plots in all five years. The highest total weed population was 146 no/m^2 in the minimum tilled plots in the year 2020–2021.

CONCLUSION

Thus, CA can be recommended for southern India and similar agro-ecological tropic and sub-tropic conditions. This system can be followed with appropriate location-specific modification in South-Asian countries, where crop yields and soil health are declining as a result of continuous cereal–cereal crop rotation.

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ARRW/SIRC/Theme II/38

Improvement in growth and yield of hybrid rice (*oryza sativa* l.) with right combination of organic management practice and P-fertilizer rate

Aditi Pahari[1] and Hirak Banerjee[2]

Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia

[1.]Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia-741 252, West Bengal, India

[2.]Regional Research Station (CSZ), Bidhan Chandra Krishi Viswavidyalaya, Akshaynagar, Kakdwip-743 347, South 24 Parganas, West Bengal, India

With growing prosperity and urbanization, the total area under rice cultivation in India is decreasing rapidly; however, the demand for rice is bound to increase in near future as population rises (Banerjee and Pal, 2011). It is challenging task to meet this demand using current high yielding cultivars (HYVs) of rice using best management methods as the yield of these cultivars has already plateaued. The only option left with us is to increase rice productivity by hybrid rice technology (Banerjee and Pal, 2009). Till date, hybrid rice cultivation is done by excessive use of chemical inputs especially fertilizers. This has not only exerted numerous negative impacts on both water and soil environment. Such problem can only be solved through the adoption of sustainable agricultural practices that includes partial substitution of chemical fertilizer (especially N) with locally available organic manures. Moreover, phosphorus (P) being an essential plant nutrient is required by hybrid rice crop to a great extent in alluvial region of West Bengal. Hence, refinement of chemical P-fertilizer rate is also urgently needed in order to fulfil the demand of hybrid rice crop.

METHODOLOGY

The field experiment was conducted at Regional Research Sub-Station, BCKV, Chakdaha, Nadia under new alluvial zone (NAZ), West Bengal (23°532 N latitude; 83°532 E longitude; 9.75 m above MSL) during wet season (*kharif*) of 2022. The experimental soil was sandy clay loam in texture (46.50% sand, 25% silt and 28.5% clay) and neutral in reaction (pH 7.05) with medium organic carbon (0.68%), available nitrogen (319.30 kg ha^{-1}), phosphorus (16.00 kg ha^{-1}) and potassium (129.00 kg ha^{-1}) content. During the growing period, the crop received 1002.3 mm rainfall (48 rainy days) while the minimum and maximum temperature fluctuated between 15 °C to 25.9 °C and 26.8 °C to 36.1 °C. Seeds of hybrid rice cultivar 'PAN 2423' were used for the present study. The crop was transplanted on 25 July, 2022 with 1 seedling $hill^{-1}$ at a spacing of 20 cm x 20 cm. The experiment was laid out in strip plot design with 3 replications having 28 treatment combinations. The vertical strips were consisted of four different P-fertilizer rates (20, 40, 60 and 80 kg P_2O_5 ha^{-1}) and the horizontal strips were consisted of six organic management practices (farm yard manure @ 4 t ha^{-1}, vermicompost @ 0.67 t ha^{-1}, poultry manure @ 0.66 t ha^{-1}, animal bone dust @ 0.57 t ha^{-1}, municipal waste @ 1.43 t ha^{-1} and goat manure @ 0.67 t ha^{-1}) and one absolute control (No application of organic manures and fertilizers). Total number of plots was 84 with 12 m^2 individual plot size. All the plots received a uniform dose of N and K-fertilizer (80 and 40 kg ha^{-1}, respectively). All the amount organic sources were calculated to fulfil 25% N requirement of the crop (20 N kg ha^{-1}). All other agronomic management practices were followed to grow the test crop as per the recommendation for the study site and the crop was harvested on 28 October, 2022.

RESULTS

Data in Table 1 reveals that different P-fertilizer rates used for the present study brought about

Table 1. Effect of organic manure application in conjunction with inorganic P-fertilizer on growth, yield attributes and yield of hybrid rice (cv. PAN 2423) during wet (*kharif*) season of 2022

Organic management practices (O)	Plant height (cm)					Dry matter accumulation (g m^{-2})					No. of panicle m^{-2}				
	P-fertilizer rate (kg ha^{-1})					P-fertilizer rate (kg ha^{-1})					P-fertilizer rate (kg ha^{-1})				
	20	40	60	80	Mean	20	40	60	80	Mean	20	40	60	80	Mean
FYM @ 4 t ha^{-1}	96	97	97	107	99	560	655	742	818	694	292	329	275	283	295
VC @ 0.67 t ha^{-1}	106	108	108	114	109	790	877	921	1105	923	267	275	283	258	271
PM @ 0.66 t ha^{-1}	118	119	121	122	120	1090	1122	1295	1324	1208	275	317	325	317	309
ABD @ 0.57 t ha^{-1}	123	125	126	129	126	1423	1465	1532	1720	1535	254	325	329	321	307
MW @ 1.43 t ha^{-1}	100	104	105	106	104	651	728	884	962	806	275	350	333	283	310
GM @ 0.67 t ha^{-1}	110	113	114	116	113	905	987	988	1235	1029	217	350	250	317	284
Absolute control	99	100	102	105	101	600	616	628	629	618	235	240	246	254	244
Mean	107	109	110	114		860	921	999	1113		259	312	292	290	
	SEm±		CD (P=0.05)			SEm±		CD (P=0.05)			SEm±		CD (P=0.05)		
P	1.45		5.00			21.20		73.37			4.73		NS		
O	1.19		NS			27.35		84.28			14.12		43.51		
P × O	3.91		NS			44.67		NS			22.65		64.97		

Organic management practices	No. of filled grains $panicle^{-1}$					Test weight (g)					Grain yield (t ha^{-1})				
	P-fertilizer rate (kg ha^{-1})					P-fertilizer rate (kg ha^{-1})					P-fertilizer rate (kg ha^{-1})				
	20	40	60	80	Mean	20	40	60	80	Mean	20	40	60	80	Mean
FYM @ 4 t ha^{-1}	79	104	111	124	105	2.53	2.58	2.61	2.75	2.62	4.73	5.45	5.58	6.73	5.62
VC @ 0.67 t ha^{-1}	114	104	136	117	118	2.72	2.73	2.77	2.77	2.75	5.94	6.34	6.89	7.49	6.66
PM @ 0.66 t ha^{-1}	141	125	155	132	138	2.88	2.92	2.91	2.92	2.91	6.67	7.32	7.92	8.35	7.57
ABD @ 0.57 t ha^{-1}	159	142	175	156	158	2.86	2.66	2.98	2.75	2.81	7.57	8.53	8.83	9.08	8.50
MW @ 1.43 t ha^{-1}	106	126	120	107	115	2.98	2.93	3.01	2.96	2.97	5.67	5.65	6.02	7.33	6.17
GM @ 0.67 t ha^{-1}	127	142	145	129	136	2.89	2.94	2.81	2.93	2.89	6.24	6.64	7.49	7.84	7.05
Absolute control	82	83	88	95	87	3.1	2.6	2.8	2.8	2.82	3.4	3.6	3.7	3.9	3.65
Mean	115	118	133	123		2.85	2.76	2.84	2.84		5.74	6.21	6.63	7.24	
	SEm±		CD (P=0.05)			SEm±		CD (P=0.05)			SEm±		CD (P=0.05)		
P	3.24		11.22			0.04		NS			0.05		0.16		
O	3.73		11.50			0.09		NS			0.08		0.24		
P × O	6.39		18.32			0.19		NS			0.20		0.57		

FYM, Farm yard manure; VC, Vermicompost; PM, Poultry manure; ABD, Animal bone dust; MW, Municipal waste; GM, Goat manure ; NS, Non-significant

significant variation in growth attributes of tested hybrid rice (cv. PAN 2423), mainly in plant height and dry matter accumulation (DMA). Application of 80 kg P_2O_5 ha^{-1} produced significantly taller plants (114cm) with higher DMA (1113g m^{-2}) and yield (7.24 t ha^{-1}), registering 6.5%, 20.8% and 26.1% more than the values obtained with lowest dose of phosphorus application (20 kg P_2O_5 ha^{-1}). However, the application @ 60 kg P_2O_5 ha^{-1} were found effective in increasing the number of filled grains $panicle^{-1}$ (133), accounting 15.7% more than that obtained with 20 kg P_2O_5 ha^{-1} (115). Various organic management practices followed in hybrid rice cultivation also caused significant variation in DMA, no. of filled grains $panicle^{-1}$ and grain yield (Table 1). Application of animal bone dust @ 0.57 t ha^{-1} produced plants with significantly higher DMA (1535 g m^{-2}), no. of filled grains $panicle^{-1}$ (158) and grain yield (8.50 t ha^{-1}), accounting 148.4%, 81.6% and 132.9% more than the values obtained with absolute control condition. However, the no. of panicles m^{-2} was found to be higher (310) with the application of solid municipal waste @ 1.43 t ha^{-1}, registering 27.0% more than control situation. Interaction of both the factors (P-fertilizer rate and organic management practice) exerted significant effect on no. of panicles m^{-2}, no. of filled grains $panicle^{-1}$ and grain yield of tested hybrid rice (Table 1). The application of 40 kg P_2O_5 ha^{-1} in combination with either municipal waste @ 1.43 t ha^{-1} or goat manure @ 0.67 t ha^{-1} gave higher number of panicles m^{-2} (350). However, no. of filled grains $panicle^{-1}$ (175) was found to be higher with combined use of 60 kg P_2O_5 ha^{-1} and animal bone dust @ 0.57 t ha^{-1}. Finally, 80 kg P_2O_5 ha^{-1} when applied in conjunction with animal bone dust @ 0.57 t ha^{-1} produced significantly higher grain yield (9.08 t ha^{-1}) of tested hybrid rice; being statistically at par with the treatments receiving 40 kg P_2O_5 ha^{-1} + animal bone dust @ 0.57 t ha^{-1} (8.83 t ha^{-1}) and 60 kg P_2O_5 ha^{-1} + animal bone dust @ 0.57 t ha^{-1} (8.53 t ha^{-1}).

CONCLUSION

The growth and yield of hybrid rice (cv. PAN 2423) can be improved through the application of animal bone dust @ 0.57 t ha^{-1} in conjunction with 40-80 kg P_2O_5 ha^{-1}, besides conventional use of 80 kg N and 40 kg K_2O ha^{-1} during wet (*kharif*) season in new alluvial zone of West Bengal.

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ARRW/SIRC/Theme II/39

Performance of wet direct seeded rice (*Oryza sativa* L.) under graded levels and sources of slow-release urea fertilizers

K. Aruna[1]*, Mangal Deep Tuti[2], K. Bhanu Rekha[1], M. Yakadri[1] and K. Surekha[2]

[1]*College of Agriculture, PJTSAU, Rajendranagar-500030*

[2]*ICAR-Indian Institute of Rice Research, Hyderabad-500 030, Telangana, India*

**Email: arunasree613@gmail.com*

Among the primary nutrients nitrogen (N) is crucial for achieving optimal rice yields (Amanullah *et al.,* 2020). Many experimental studies have shown that slow-release urea fertilizers (SRUF) are effective in enhancing the yield and NUE of rice (Guo *et al.*, 2020; Fu *et al.,* 2021). Recently, developed silicon coated urea (SCU) and cedar wood oil coated (CWO) slow release urea fertilizers at ICAR-IIRR laboratory and evaluation of the efficiency of these fertilizers under field conditions is very much essential.

OBJECTIVES

To find out the effect of slow release urea fertilizers on the growth and yield of Wet DSR and to optimize the dose of silicon and cedar wood oil coated urea fertilizers.

METHODOLOGY

This experiment was carried out in *kharif* 2022 at ICAR-Indian Institute of Rice Research, Rajendranagar, Hyderabad which falls under the Southern Telangana zone of semi-arid tropics. The soil texture was clay loamy and was medium in available N. Ten treatments were laid in Randomized Block Design and replicated thrice. Treatments consist of T_1: Neem coated urea at 100% of RDN (120 kg ha^{-1});T_2: Silicon Coated Urea (SCU) at 50% of RDN (60 kg ha^{-1});T_3: SCU at 75% of RDN (90 kg ha^{-1});T_4: SCU at 100% of RDN (120 kg ha^{-1});T_5: SCU at 125% of RDN (150 kg ha^{-1});T_6: Cedar Wood Oil coated urea (CWO) at 50% of RDN (60 kg ha^{-1});T_7: CWO at 75% of RDN (90 kg ha^{-1});T_8: CWO at 100% of RDN (120 kg ha^{-1});T_9: CWO at 125% of RDN (150 kg ha^{-1});T_{10}: Control with no application of urea fertilizer. Uniform dose of FYM, P_2O_5 and K_2O was applied @ 10 t ha^{-1} @ 60 and 40 kg ha^{-1}, respectively to all treatments except T_{10} 25% of RDN was applied as basal, 25% of RDN each at active tillering and 25% of RDN at panicle

Table 1. Effect of different sources and dose of slow release urea fertilizers on growth, yield parameters and yield of rice crop

Treatment	Dry matter at active tillering (kg ha^{-1})	Productive tillers m^{-2}	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1-Neem coated urea at 100% of RDN	4741	252	4382	6006
T_2-SCU at 50% of RDN	4449	210	4063	5414
T_3-SCU at 75% of RDN	4593	234	4625	5896
T_4-SCU at 100% of RDN	5820	269	6249	7113
T_5-SCU at 125% of RDN	5693	255	5581	6534
T_6-CWO at 50% of RDN	4572	224	4328	5552
T_7-CWO at 75% of RDN	4728	245	4875	5970
T_8-CWO at 100% of RDN	5925	284	6025	7257
T_9-CWO at 125% of RDN	5703	271	5502	6591
T_{10}-Control	3148	196	3753	3842
SE(m)±	171	9	234	254
CD (p=0.05)	508	28	696	755
CV (%)	6	6	8	7

emergence and 25% of RDN at flowering stages in 3 equal splits.

RESULTS

Maximum dry matter accumulation at the active tillering stage was recorded in plots that received SCU at 100% of RDN (5820 kg ha^{-1}) followed by plots CWO at 100% of RDN (5925 kg ha^{-1}). Minimum dry matter accumulation was observed under control plots (3148 kg ha^{-1}) with no nitrogen application. Similarly, significantly higher number of productive tillers were recorded in SCU at 100% of RDN (269) followed by CWO at 100% of RDN (284) which might be due to the higher number of tillers in these treatments. Likewise higher grain and straw yield was recorded in plots applied with SCU at 100% of RDN (6249 and 7113 kg ha^{-1}) followed by plots CWO at 100% of RDN (6025 and 7257 kg ha^{-1}) and the lowest grain and straw yield was obtained with control plots (3753 and 3842 kg ha^{-1}) respectively.

CONCLUSION

It can be concluded that among the sources and doses of slow release urea fertilizers tested silicon coated urea and cedar wood oil coated urea at 100% of RDN (120 kg ha^{-1}) resulted in higher grain and straw yield and helped to save 25% of nitrogen application over 125% of RDN. Further, the application of both SRUF doses at 125% RDN (150 kg ha^{-1}) produced better yields compared to neem coated urea at 100% RDN (120 kg ha^{-1}).

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ARRW/SIRC/Theme II/40

Impact of crop establishment method and nutrient management on hybrid rice during wet season

Megha Sana[1], Sukanta Pal[1] and Hirak Banerjee[2]

[1.] *Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia-741 252, West Bengal, India*
[2.] *Regional Research Station (CSZ), Bidhan Chandra Krishi Viswavidyalaya, Akshaynagar, Kakdwip-743 347, South 24 Parganas, West Bengal, India*

During last few decades, rice yield growth has slowed down due to saturation in adaptation of high yielding varieties, lack of expansion in acreage and depleting soil fertility. But rice hybrids, recently introduced in cultivation, on an average, give 20-30% higher yield over the common high yielding varieties (Maiti *et al.,* 2006). Transplanting in puddled soils is the most dominant and traditional method of rice establishment in irrigated lowland ecosystem. However, this crop establishment method demands higher water and labour. To overcome this problem, farmers are gradually switching over to dry direct seeding which reduces labour requirement substantially and lowers the crop duration by 8-10 days. Hybrid rice with high yield potential per unit area and time requires higher amount of primary nutrients than HYVs. The balanced use of fertilizers has a substantial impact on growth, development and productivity of hybrid rice (Banerjee and Pal, 2012). In India, intensive agriculture incorporating hybrid rice cultivars has resulted in a massive withdrawal of nutrients from the soil over the last three decades. Furthermore, farmers' disproportionate use of chemical fertilizers has caused greater harm to soil health and reduced soil organic carbon content, posing a threat to sustainability. The new methods for using organic amendments in agriculture have already proved to be effective in improving soil structure, boosting soil fertility, and raising crop yields. Organic amendment has greater agricultural use, and if correctly handled, it can be a vital and cost-effective source of plant nutrients to replace imported and expensive inorganic fertilizers. With this backdrop, the present study was planned to mark the response of hybrid rice to nutrient management options under different establishment methods.

Table 1. Effect of crop establishment methods and nutrient management strategies on yield attributes, yield and soil residual nutrients of hybrid rice during wet (*kharif*) season

Treatments	Panicles m^{-2} (Nos.)	Filled grain $panicle^{-1}$ (Nos.)	Grain yield (t ha^{-1})	Soil organic carbon (%)	Soil available N(kg ha^{-1})	Soil available P(kg ha^{-1})	Soil available K(kg ha^{-1})
Crop establishment methods							
M_1	253	109	6.36	0.54	286.4	35.3	172.4
M_2	240	99	5.35	0.55	298.5	37.0	175.7
SEm±	3.93	2.54	0.07	0.01	1.80	0.34	1.07
CD (P=0.05)	15.93	8.46	0.46	NS	10.94	2.07	NS
Nutrient management strategies							
F_1	215	86	4.30	0.44	272.3	25.5	149.7
F_2	254	105	6.08	0.47	282.4	32.3	157.9
F_3	263	123	7.15	0.58	295.5	37.6	177.8
F_4	253	104	5.94	0.62	303.3	41.5	185.7
F_5	237	90	4.93	0.67	314.1	46.7	199.2
F_6	259	116	6.75	0.54	296.2	36.4	162.8
SEm±	6.81	4.40	0.13	0.01	3.02	1.19	1.85
CD (P=0.05)	21.49	13.87	0.42	0.03	9.50	3.76	5.81

METHODOLOGY

The field experiment was conducted at Regional Research Sub-Station, Bidhan Chandra Krishi Viswavidyalaya, Chakdaha under new alluvial zone of West Bengal during wet season (*kharif*) of 2021. The experimental soil was sandy clay loam in texture (46.50% sand, 25.76% silt and 28.90% clay) and neutral in reaction (pH 7.2) with medium organic carbon (0.680%), available nitrogen (282.6 kg ha^{-1}), phosphorus (26.83 kg ha^{-1}) and potassium (165.8 kg ha^{-1}) content. During the growing period, the crop received 1014.2 mm rainfall while the minimum and maximum temperature fluctuated between 16 °C & 26.5°C and 27.4 °C & 35.2 °C, respectively. The hybrid rice cultivar 'Arize 6444 gold' was used as test crop. The experiment was laid out in a strip plot design with three replications. Two crop establishment methods *viz.* M_1: transplanted rice (TPR) and M_2: direct seeded rice using drum seeder (DSR) were assigned to vertical plots and six nutrient management strategies *viz.* F_1: Farmers fertilizer practice (FFP) i.e. 60-30-30 kg N, P_2O_5 and K_2O ha^{-1}, F_2: 100% RDF i.e. 80-40-40 kg N, P_2O_5 and K_2O ha^{-1}, F_3: 150% RDF, F_4: 75% RDN + 25% N through Municipal compost + *Azospirillum* (2 kg ha^{-1} soil application), F_5: 50% RDN + 50% N through Municipal compost + *Azospirillum* (2 kg ha^{-1} soil application) and F_6: SSNM based on Nutrient Expert ® *i.e.*. 90-42-45 kg N, P_2O_5 and K_2O ha^{-1} were placed in horizontal plots with an individual plot size of 4m x 3m.

RESULTS

Results revealed that all the measured parameters on hybrid rice varied significantly with crop establishment methods, except soil organic carbon and soil available potassium (Table 1). Supremacy of hybrid rice (cv. Arize 6444 gold) was recorded when grown under irrigated transplanted condition over dry direct seeded condition in terms of superior yield parameters. But in case of residual nutrient in soil, hybrid rice cultivation under direct seeded condition showed better result than irrigated transplanted condition. Transplanted hybrid rice produced significantly higher number of panicles m^{-2} (253), number of filled grains $panicle^{-1}$ (109) and grain yield (6.36 t ha^{-1}), accounting 5.41%, 10.10% and 18.87% more than that of direct seeded hybrid rice respectively. On the other hand, direct seeded hybrid rice cultivation left significantly higher soil available nitrogen (298.54 kg ha^{-1}) and phosphorus (37.01 kg ha^{-1}), accounting, 4.25% and 4.72% more than that of transplanted hybrid rice cultivation, respectively. Nutrient management strategies also brought about significant variation in measured yield parameters and residual soil nutrient in hybrid rice cultivation. Application of NPK fertilizer beyond RDF (150% RDF in particular) was instrumental in augmenting hybrid rice performance to a greatest extent, irrespective of crop establishment methods. On receiving 150% RDF, a significant improvement in yield of tested hybrid rice cultivar was marked with respect to higher number of panicle m^{-2} (263), number of filled grains $panicle^{-1}$ (123) and grain yield (7.15 t ha^{-1}), registering 22.32%, 43.02% and 66.27% more than the crops receiving FFP, respectively. But in case of soil residual nutrient, the treatment where 50% nitrogen was used through municipal compost along with 50% RDF and *Azospirillum* left highest soil organic carbon, available nitrogen, available phosphorus and available potassium, registering 52.27%, 15.37%, 83.37% and 33.06% more than the crop cultivation under FFP, respectively.

CONCLUSION

Results of the present study suggest that hybrid rice cultivation under irrigated transplanted condition can provide higher yield advantage over dry direct seeded condition with 150% RDF (120 kg N, 60 kg P_2O--$_5$ and 60 kg K_2O ha^{-1}) during wet (*kharif*) season in new alluvial zone of West Bengal.

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ARRW/SIRC/Theme II/41

Accounting of methane fluxes and related soil microbial diversity of degraded mangroves-rice ecologies in Sundarban, India

Soumya Ranjan Padhy*, S P Parida, S K Nayak, A Das, S Swain, M Rath, P Bhattacharyya

ICAR-National Rice Research Institute (NRRI), Cuttack, Odisha-753006, India.

**Presenting Author; Mail Id: padhysoumya14@gmail.com*

Mangrove-rice systems are present adjacent to each other having unique soil, plant and microbial characteristic in wetlands of Sundarban, India. It is a common system found in Sundarban (in habitat and buffer zone) except core and restricted areas. Despite of huge ecosystem services provided by mangroves around 10.3% of Sundarban mangroves become degraded in last 80 years (based of remote sensing data 1930 and 2013 (Padhy et al., 2021). Majority of mangroves converted either to rice or aquaculture. There was temporal shift of mangroves to agriculture over last century. Therefore, assessment of typical mangrove-rice system in terms of climate change mitigation, GHGs emissions, microbial and soil diversity and productivity are important.

Microbial mediated metabolic processes, like methanotrophy (methane oxidation), methanogenesis (methane production) and sulphur reduction are the key regulator of methane (CH_4) emissions in mangroves and rice system in coastal wet land. Methane produced by methanogens in soil gets oxidized by the methane oxidizing bacteria (methanotrophs) present in the upper soil before being emitted to the atmosphere. Methanotrophs are aerobic bacteria and they are utilizing methane as a carbon and energy source. Whereas the methanogens are anaerobic and primarily compete with sulfate-reducing bacteria (SRB) in the wetland ecologies, like Sundarban. So, higher methanogens community in the soil may not necessarily causes higher CH_4 emission, if oxidation of a major fraction of CH_4 takes place by methanotroph in that particular ecosystem. Thus, the relative abundance of methanotrophs, methanogens, and SRB and their ratios (methanotrophs:methanogens and SRB: methanogens) play a significant role in the net CH_4 flux from the soil to the atmosphere (Bhattacharyya et al., 2019; Padhy et al., 2021). Considering the above mentioned regulatory mechanism, we formulated the objectives of the study was to quantify the CH_4 fluxes in mangrove-rice ecologies and correlate those with soil microbial diversities.

METHODOLOGY

The gas and soil samples were collected from six different locations (Sadhupur, Dayapur, Pakhiralaya, Mathurakhand, Satarkona and Bijoyanagar) during four seasons (summer, winter, pre-monsoon and monsoon) of from degraded-mangrove and adjacent rice ecologies in Sundarban, India. The manual close chamber method was used to collect gas samples which were further analysed in gas chromatography for the estimation of methane concentration (Bhattacharyya et al., 2019). The fresh soil samples were used to quantify the abundance of related soil microbial diversity through whole-genome metagenomics approach.

RESULTS

The methane fluxes were ranged from 53 to 83, 113 to 144, 161 to 210 and 204 to 300 µg m^{-2} h^{-1} during winter, summer, pre-monsoon, and monsoon season, respectively at six different locations of mangroves in Sundarban. In mangroves, the average CH_4 flux was highest during monsoon (253 µg m^{-2} h^{-1}) and lowest during winter (69 µg m^{-2} h^{-1}). However, higher CH_4 fluxes were observed during summer (4943 μg m^{-2} h^{-1}) followed by monsoon (3624 μg m^{-2} h^{-1}), pre-monsoon (1820 μg m^{-2} h^{-1}) and winter (273 μg m^{-2} h^{-1}) in rice. Among the systems, considering all the seasons and locations the mean CH_4 flux was higher in rice (2665 μg m^{-2} h^{-1}) compared to mangroves (159 μg m^{-2} h^{-1}).

The abundance reads of methanotrophs, methanogens and SRB were higher in rice compared to rice in different locations. The average ratios of methanotrophs:methanogens were 42.6% higher in mangroves than rice. Similarly, the average ratios of SRB:methanogens at different locations were higher in mangroves (8.14), than rice (2.29).

CONCLUSION

The shifting of mangrove to rice resulting more CH_4 fluxes. Significantly lower CH_4 fluxes in the mangrove was due to higher salinity, periodic changes in the anaerobic condition and higher sulphate concentrations, lower methanogens abundance and higher ratios of methanotrophs:methanogens and SRB:methanogens.

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Evaluating the greenhouse gas emissions from consumption of common Indian diets for mitigating climate change

Supriya Priyadarsani, Rahul Tripathi, Amaresh Kumar Nayak

ICAR-National Rice Research Institute, Cuttack-753 006

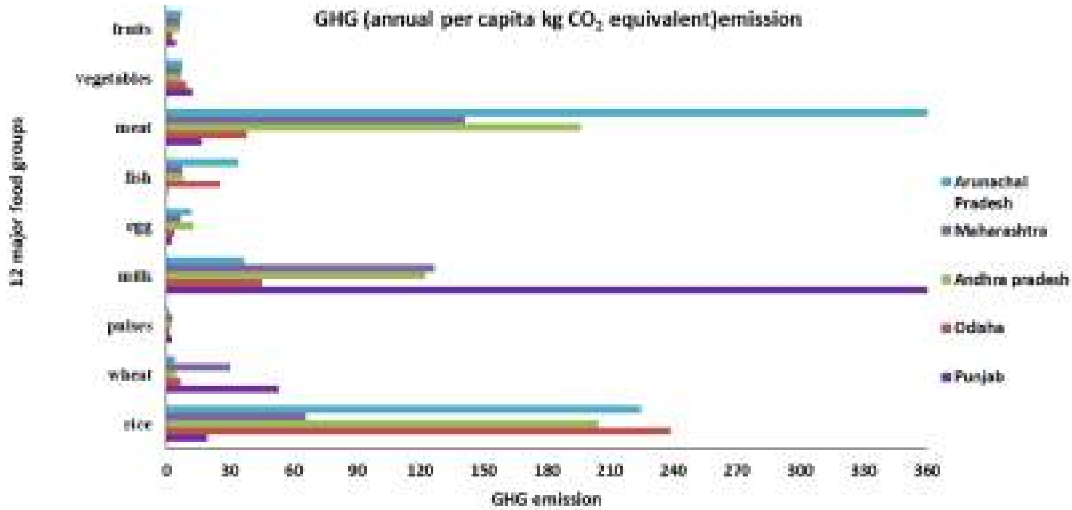
With the rise in modernisation, the environment is under more pressure as with an increase in population as well as food consumption. Rarely has the evaluation of greenhouse gas (GHG) emission been done in research on the environmental implications of food consumption; instead, the focus has typically been on energy use and waste generation. Carbon dioxide (CO_2) is the most significant GHG resulting from food consumption, followed by methane (CH_4) as well as nitrous oxide (N_2O). The primary causes of CO_2 emissions are fuel combustion processes, whereas the primary causes of CH_4 emissions are animal husbandry and rice farming, and the primary causes of N_2O emissions are soil nitrogen cycling, the use of N fertiliser, and industry. The cumulative amount of GHG emissions that a product emits is known as its carbon footprint. It is usually described as the carbon dioxide equivalent of all released GHGs. The computation of the GHG emissions determines the carbon footprint of a product. Once it is known, a roadmap can be developed to reduce it through technological advancements, improved process as well as product management, and alternative consumption habits. Various life cycle steps, such as the production, transportation, processing, and preparation of food products, result in the emission of GHG. In the Fourth Assessment Report (AR4) of Inter-Governmental Panel on Climate Change (IPCC) indicated that lifestyle along with behavioural changes can substantially contribute to mitigate climate change across all sectors. Besides, it is also argued that reducing the consumption of animal protein can alleviate the GHG emissions. The objectives of this article was to analyse the GHG emission from different parts of India based on food consumption pattern. This will in turn help individuals to calculate the GHG emission of the food they consume and shall create awareness to develop safety measures.

METHODOLOGY

For this research activity, GHG emission at various stages of the life cycle of 64 food items have been included (data taken from 68th round of NSSO). The listed food items are classified under 12 broad groups (rice, wheat, other cereals, pulses, fruits, vegetables, spices, milk, fish, egg, meat & oilseeds). Most States and Union Territories participated in the survey: a “State sample” was surveyed by State Government officials in addition to the “Central sample” surveyed by NSSO. The states were divided into 5 zones as North, East, West, South and North-east zone based on the similarity of the food habit. Out of these 5 zones, five states were chosen randomly for study studying the GHG emission. The consumption data includes the FAO conversion factors for calculation at each step from production, storage, transport, processing, cooking and waste respectively.

RESULTS

From the graph, it is clearly seen that per capita annual GHG emission for the five different states is different from the 12 major food groups. As milk is highly consumed in Punjab (per-capita milk availability of 937 grams per day), 360.53 kg CO_2 per capita is emitted annually because of emission of methane by ruminants along with maximum processing of milk making it fit for consumption. The north eastern states like Arunachal Pradesh consumes meat proportionately higher than rice which emits maximum annual GHG emission



nearly 380.16 kg CO_2 per capita. The western state like Maharashtra also contribute to GHG emission, with consumption of milk and meat because of changing food habit. The food products from animal such as mutton, poultry meat, dairy products and fish dominated the CH_4 emission. Higher consumption of rice in Odisha as well as Andhra Pradesh contributed to higher annual GHG emission of 238.20 and 204.34 kg CO_2 per capita respectively.

From the graph, it is clearly seen that consumption of wheat, pulses, eggs, fruits and vegetables emit very less GHG emission as compared to rice, dairy and meat products. Substituting the intake of meat products with pulses to meet the daily protein requirement may be a step forward to mitigate the growing GHG emission.

CONCLUSION

This study indicated that a change in dietary habits provides opportunities for reducing GHG emissions. Adopting food products that have less of an impact on the environment may be one way to reduce GHG emissions. There are a few ways to reduce the GHG emissions caused by food consumption, including eating more locally produced food, eating less mutton, and replacing meat and milk with other sources of protein from plants. However, when switching food products, nutritional qualities (vitamins, proteins, and minerals) as well as calorific value of the shifted diet along with health implication must be considered while mitigating the GHG emission to bring sustainability to the environment.

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Rice straw derived biochar and rice husk derived biochar differently affect the crop yield and soil aggregate stability

Sushmita Munda, Pratap Bhattacharrya, Sanjoy Saha and AK Nayak

ICAR-National Rice Research Institute, Cuttack-753006, India

**Corresponding author e- mail: sustot@gmail.com*

Pyrogenic organic matter is a heterogeneous organic substance high in aromatic carbon and minerals and plays a similar role in soil as soil organic matter. It can be produced by pyrolysis of plant biomass viz., rice straw and rice husk under controlled conditions and the resultant product is simply called biochar. It is established that biochar contributes towards conditioning of soil which includes increasing the carbon content, availability of various soil nutrients, and porosity of soil (Munda et al., 2018). However, the extent of stability imparted through aggregate formation upon application of rice husk and rice straw derived biochar in lowland rice soil is not well known. Therefore, we conducted field trials to assess the effect of rice husk and rice straw derived biochars on yield of rice crop and soil aggregate formation in lowland rice soil.

METHODOLOGY

A mini plot experiment was conducted to assess the effect of rice husk and rice straw derived biochars on yield of rice crop and soil aggregate formation in lowland rice soil. Treatments consisted of the recommended dose of fertilizers, RDF (control) and application of 2, 4, 8 and 10 tha^{-1} each of straw derived biochar (SDB) and rice husk derived biochar (RHB) in three replications. Aggregate separation was done by using wet sieving apparatus (Yoder, 1936). Aggregates were then fractioned into macroaggregates (MacA, >2000 µm), mesoaggregates (MesoA, 250–2000 µm) and microaggregates (CMicA, 100–250 µm). The sum of aggregates>250 µm was clubbed as macroaggregates (MacA) while aggregates <250 µm termed as microaggregates (MicA) and presented in Table 1.

Table 1: Distribution of soil water-stable aggregate size fractions (percentage) under different doses of rice husk biochar (RHB) and rice straw derived biochar (SDB)

Treatment	Aggregate size (percentage), 0-15 cm				Aggregate size (percentage), 15-30 cm				Yield
	Macro (>2000 µm)	Meso (2000-250 µm)	Micro (<250 µm)	WSA (%)	Macro (>2000 µm)	Meso (2000-250 µm)	Micro (<250 µm)	WSA (%)	(t/ha)
Control (RDF)	34.40^{C}	40.45	25.15^{A}	72.60^{D}	31.92^{A}	39.95	28.13^{A}	58.15^{D}	5.38^{B}
RDF + 2.0 t ha^{-1} RHB	35.01^{C}	42.29	22.70^{AB}	79.72^{CD}	35.52^{A}	39.84	24.63^{AB}	67.10^{C}	5.65^{AB}
RDF + 4.0 t ha^{-1} RHB	40.78^{BC}	36.93	22.28^{AB}	86.54A^{BC}	39.55^{A}	37.81	22.64^{AB}	71.20^{BC}	6.21^{AB}
RDF + 8.0 t ha^{-1} RHB	43.13^{ABC}	34.36	22.51^{AB}	90.55A^{BC}	39.77^{A}	36.39	23.84^{AB}	73.19^{ABC}	6.27^{AB}
RDF + 10.0 t ha^{-1} RHB	43.93^{AB}	36.79	19.28^{AB}	92.58^{ABC}	40.55^{A}	37.41	22.04^{AB}	74.58^{AB}	6.79^{A}
RDF + 2.0 t ha^{-1} SDB	42.61^{ABC}	35.94	21.45^{AB}	80.97^{BCD}	37.84^{A}	36.16	25.99^{AB}	66.52^{C}	5.90^{AB}
RDF + 4.0 t ha^{-1} SDB	43.12^{ABC}	34.85	22.03^{AB}	91.99^{ABC}	34.95^{A}	38.24	26.81^{AB}	72.22^{ABC}	6.37^{AB}
RDF + 8.0 t ha^{-1} SDB	48.71^{AB}	33.82	17.48^{B}	93.00^{AB}	43.19^{A}	33.77	23.04^{AB}	74.33^{AB}	7.03^{A}
RDF + 10.0 t ha^{-1} SDB	50.63^{A}	33.05	16.32^{B}	94.49^{A}	43.49^{A}	36.18	20.33^{B}	78.96^{A}	6.95^{A}
SE(d)	4.165	2.970	2.115	3.637	3.376	2.568	1.984	2.032	0.56
Tukey HSD at 5%	14.817	NS	7.525	12.937	12.009	NS	7.0581	7.2278	1.23

RESULTS

The results reveal that yield increase was significant till application rate of 4 t ha^{-1} both in SDB and RHB. Grain yield declined at application rate of 10 t ha^{-1} of SDB, whereas, non-significant increase in grain yield was recorded with RHB (10 t ha^{-1}). RHB recorded 15.6% yield increase over RDF (control) whereas, SDB recorded a yield increase of 27.7% indicating a positive impact of SDB on soil physical, chemical and biological properties of soil. Similarly, an overall higher water stable aggregate (WSA) % was recorded with SDB with highest in treatment with application of 10 t ha^{-1} SBD (94.49% in 0-15 cm soil and 78.96% in 15-30 cm soil).

CONCLUSIONS

It can be concluded that SDB application has more noteworthy effect on crop yield and soil aggregation compared to RHB. Since rice straw utilization is a burning issue, its utilization as biochar may be considered as an option to address the issue.

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ARRW/SIRC/Theme II/44

Layering of micro-irrigation in conservation agriculture-based rice under rice-wheat and rice-maize systems for improving water productivity in Eastern IGP of India.

K. Srikanth Reddy[*1,2], Panneerselvam Peramaiyan[2], C. M. Parihar[1], H.S. Nayak[3], Virender Kumar[4]

[1.]*ICAR-Indian Agricultural Research Institute, New Delhi, 110012, India.*
[2.]*International Rice Research Institute (IRRI), South Asia Regional Center, Varanasi, 221106, Uttar Pradesh, India.*
[3.]*School of Integrative Plant Science Soil and Crop Sciences, Cornell University, Ithaca, New York, USA.*
[4.]*International Rice Research Institute (IRRI), Los Banos, Philippines.*
Corresponding author Email id: srikanthreddykalwala@gmail.com

The future of rice production in South Asia is at risk due to the decreasing aquifers and rising demand for subterranean water under forecasted climate change scenarios. Conventional management practices such as flood irrigation, intensive tillage, and excessive use of fertilizer are endangering the sustainability of the rice crop. In light of the impending water shortages, it is crucial that we focus on developing alternative and efficient techniques for water usage in high water requiring rice production systems. Micro irrigation systems are a promising solution for rationalizing irrigation water. Direct seeded rice (DSR) has been identified as a technique that can be effectively paired with drip irrigation in rice production. Surface and subsurface drip fertigation (SDF and SSDF) are increasingly used in horticultural crop production, and offer a unique opportunity to enhance the advantages of irrigation water saving and nitrogen use efficiency. However, adoption of these water-saving options for field crops, and rice in particular, has been slow due to issues with field application (surface drip) in conventional tillage-based management systems. Because, in these systems, drip laterals must be removed and replaced multiple times due to multiple operations during the growing season. The SSDF method can be used without interrupting the field operations. The finding of previous studies has also shown that fertilizer application paired with drip irrigation promotes nutrient usage efficiency while minimizing nitrogen losses due to leaching and volatilization. Research based evidences on the adoption of SSDF method for rice crops is scarce in South Asia and other parts of the globe. Therefore, the present study was conducted to assess the effectiveness of SDF and SSDF in high water demanding rice crop with respect to crop performance and water productivity.

MATERIALS AND METHODS

A field experiment was conducted during the *kharif* season of 2022 at the International Rice Research Institute-South Asia Regional Centre (IRRI-SARC) experimental farm at Varanasi, Uttar Pradesh, India. The location of the farm is at a latitude of 25.310 N, longitude of 82.970 E and an altitude of 80.71 meters above mean sea level (MSL). The soil at the experimental site was sandy loam in texture with a pH of 7.8. The experiment was set up in a split-plot design with 8-combinations of crop establishment techniques and irrigation methods as main plot factors [DSR followed by Zero-tilled Maize (ZTM) with flood irrigation (DSR-ZTM_FI); DSR followed by Zero-tilled Wheat (ZTW) with flood irrigation (DSR-ZTW_FI); DSR followed by ZTM with Surface drip fertigation (DSR-ZTM_SDF); DSR followed by ZTW with Surface drip fertigation (DSR-ZTW_SDF); DSR followed by ZTM with Subsurface drip fertigation (DSR-ZTM_SSDF); DSR followed by ZTW with Subsurface drip fertigation (DSR-ZTW_SSDF); Puddled

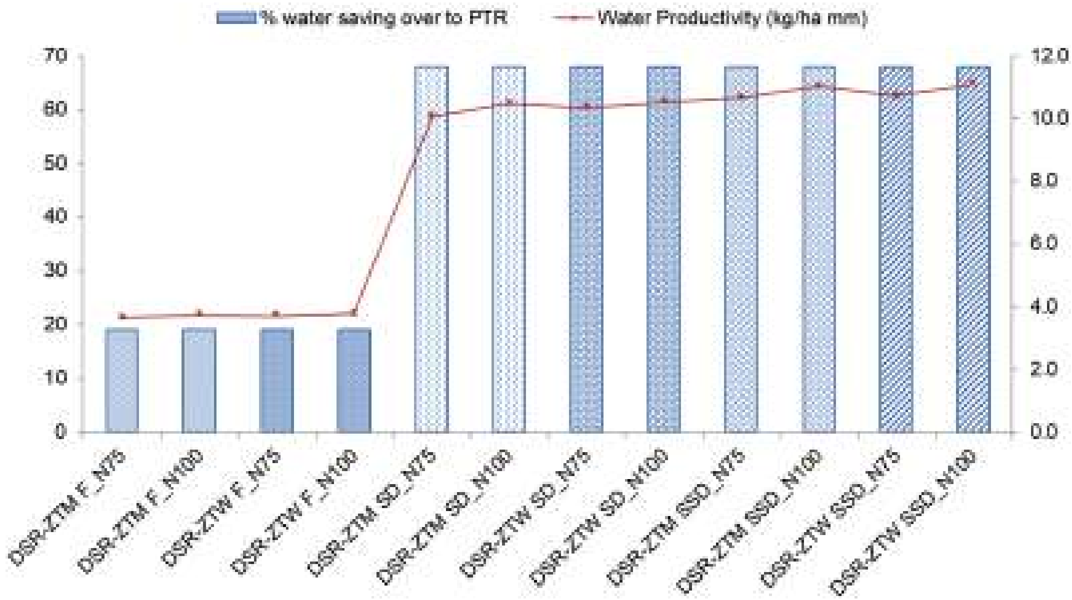

Fig. 1: Effect of crop establishment techniques and irrigation methods on water saving and water productivity of conservation agriculture based direct seeded rice in Eastern IGP of India.

transplanted Rice (PTR) followed by ZTM with flood irrigation (PTR-ZTM_FI); and PTR followed by ZTW with flood irrigation (PTR-ZTW_FI)] and 2-sub-plot factors includes 100% recommended dose of nitrogen (RDN) and 75% of RDN, and were replicated three times.

RESULTS AND DISCUSSION

The finding of the present experiment revealed the adoption of micro irrigation methods i.e., surface (SD) and subsurface drip fertigation (SSDF) in combination with conservation agriculture based direct seeded rice production resulted a substantial increment in irrigation water saving ~67% and ultimately in the irrigation water productivity by ~19% compared to flood irrigation methods, irrespective of nitrogen management options. This might be due to reduced losses of irrigation water (Sidhu *et al*., 2019). Additionally, SSDF plots may have lost lower water through evaporation and supplied the water and nutrient in close proximity of crop roots as per the demand. The finding of present study showed that increasing the nitrogen fertiliser level did not have significantly impact on crop performance and water use. The findings of present study are aligned with previous studies on adoption of SSDF for rice production (Sharda *et al*., 2017). The adoption of conventional tillage-based puddled transplanted rice (PTR) management systems with flood irrigation in farmer practises results in use of more irrigation water. Hence the SSDF implementation with conservation agriculture based direct seeded rice cultivation attains significant water saving (Fig 1). Therefore, further efforts can be directed to increasing farmers awareness about the benefits of such technology for the cultivation of high water-demanding field crops.

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ARRW/SIRC/Theme II/45

Reactive nitrogen loss under diverse nitrogen management in sub-tropical lowland rice

Dibyendu Chatterjee*[1], Saikat Ranjan Das[1], Sangita Mohanty[1], Baishnab Charan Muduli[1], Arti Bhatia[2], Bitish Kumar Nayak[1], Robert M Rees[3], Julia Drewer[4], Amaresh Kumar Nayak[1], Mark A. Sutton[4]

[1]*ICAR-National Rice Research Institute, Cuttack, Odisha, 753006, India*
[2]*ICAR-Indian Agricultural Research Institute, New Delhi-110012, India*
[3]*SRUC, West Mains Rd., Edinburgh, EH9 3JG Scotland, UK*
[4]*UK Centre for Ecology & Hydrology, Bush Estate, Penicuik, EH26 0QB, Edinburgh, Scotland, UK*

The fate of applied nitrogen (N) under diverse N management practices for rice soils is not well documented for subtropical lowland rice. Practices include the use of chemical fertilisers, nitrification inhibitors, jeevamruta (an organic nutrient source used in natural farming), organic nutrient management and integrated nutrient management. Improving N use efficiency in lowland rice agroecosystems is difficult due to the multiple pathways of N loss such as ammonia (NH_3) volatilization, nitrate leaching, and nitrous oxide (N_2O) emissions from denitrification. Nitrogen fertilizer application has improved crop yields, but with significant negative environmental impacts. Of the applied N, 0-30% is lost by volatilization, 0-20% by leaching, and 5-35% by denitrification (Nayak et al. 2017). Therefore, the N recovery efficiency of rice is very low at 30-40% or even lower. It is estimated that the annual net emission of N_2O-N from rice fields in India is 0.18-9.11 kg ha^{-1}, which accounts for up to 77% of the country's N_2O emissions (Pathak, 2015). Ammonia emissions vary from 1 to 25.8 kg N ha^{-1} depending on soil, crop, and fertilizer (Pathak, 2015). In lowland rice soils, total leached nitrate-N at 45 cm soil depth varied from 3.4-16.1 kg ha^{-1}, corresponding to 3.2-10.6% of total N applied. Different N applications not only directly affect yield and N use efficiency, but also affect reactive N loss to the environment. Changing the amount, source, timing, and placement of N fertilizer offer effective ways to reduce N_2O and NH_3 emissions. In this study we apply an experimental approach to compare performance of different practices in the subtropical region of eastern India (Orissa) as part of the Global Challenges Research Fund (GCRF) South Asian Nitrogen Hub (SANH).

METHODOLOGY

A field experiment was conducted in two consecutive seasons (wet season 2021 and dry season 2022) to evaluate the effects of contrasting approaches to N management on yield, NUE, and various N losses of the rice cropping system. In this experiment, seven N treatments were tested in four replicates using a randomized block design: T1: 0 N; T2: soil test-based N application by neem-coated urea (NCU); T3: 3-sprays of Jeevamrutha; T4: one half of the N dose from farmyard manure (FYM) and the other half from Azolla; T5: 100% N from NCU with dicyandiamide applied at 10% N basis with NCU); T6: 100% N from NCU + FYM @5 t ha^{-1} and T7: 75% N from NCU + FYM @5 t ha^{-1}. Naveen, a rice variety with a growth period of 120-125 days, was grown in the dry season and Maudamani, a rice variety with a growth period of 135-140 days, was grown in the wet season. A fertilizer dose of 80 kg of N (with NCU), 40 kg of P (with single superphosphate), and 40 kg of K (with muriate of potash) was applied. The total P, K, and half N doses were applied as a basal fertilizer. The remaining N was divided into two parts and applied at the time of active tillering and panicle initiation of rice. Grain and straw yields were recorded after crop harvest. Total N uptake, partial factor productivity, agronomic use efficiency, and recovery efficiency of N were analysed according to the standard procedure. Estimation of nitrate leaching from rice using irrometer soil solution access tubes (SSAT) randomly installed at a depth of 60 cm to collect leachate. Ammonia volatilization was measured by the static cuvette method using a small static chamber on the soil surface and N_2O losses from the rice field were measured using the manual closed chamber method.

RESULTS

At the end of two consecutive seasons with different N management treatments, the highest grain yield was recorded with soil test-based N application during the wet season, as grain yield was increased by 34% compared to the control; whereas 100% N from NCU together with FYM showed the highest grain yield during the dry season, which was improved by 38% compared to the control. Total N losses by nitrate leaching and NH_3 volatilization were 1.31-8.55 and 0.12-4.46 kg ha^{-1} across the both seasons, respectively. The highest N_2O emission was observed when N was applied based on soil tests (214.1 ìg m^{-2} h^{-1} in the wet season and 252.97 ìg m^{-2} h^{-1} in the dry season), followed by 100% N from NCU combined with FYM (198.13 ìg m^{-2} h^{-1} in the wet season and 239.19 ìg m^{-2} h^{-1} in the dry season) in both seasons. Total N uptake by rice was highest at 100% N from NCU along with FYM (101-111% higher than the control in both seasons), while N recovery efficiency was highest at 100% N from NCU with dicyandiamide in both seasons, possibly due to the application of the nitrification inhibitor. Leaching and volatilization losses (**Figure 1**) were highest when urea was applied at the basal stage, while the lowest was recorded at panicle initiation stage. Highest N_2O emissions were observed at panicle initiation stage. Greater

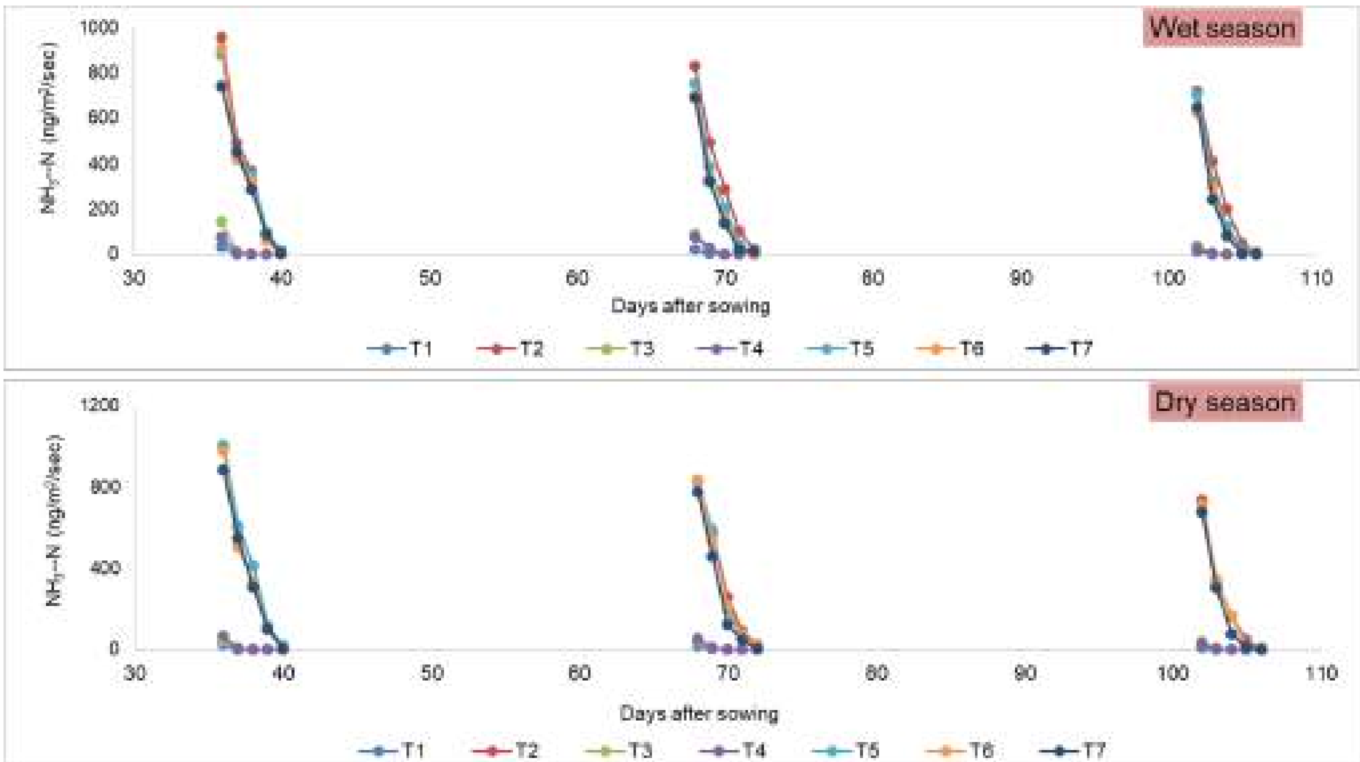

Fig. 1: Ammonia volatilisation loss in lowland rice during dry and wet seasons

[T1-T7 represent treatments 1 to 7 as described in the main text] losses due to NH_3 volatilization and N_2O emissions were observed in the dry season than in the wet season, while nitrate leaching was highest in the wet season, which could be explained by the high rainfall.

CONCLUSION

The present study provided a systematic quantification of N fluxes, including the different mechanisms of N loss and N use efficiency in lowland rice. In comparing the different N management approaches, the application of NCU resulted in better yields but also higher N losses in all treatments. The integrated application of NCU and FYM (with corresponding reduction in NCU dose) resulted in lower cumulative nitrate leaching and NH_3 volatilization, but N_2O emissions increased. We conclude that among the various N losses observed in rice fields, nitrate leaching seems to be the most dominant loss mechanism, followed by NH_3 volatilization, and the least is N_2O emission in subtropical lowland rice. The trade-offs between yield and different N loss pathways resulting from the contrasting management approaches highlight the complexity of developing a sustainable approach to N management. Further studies are needed to better quantify the N_2 emissions.

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Functional and structural diversity of nitrifying bacteria under long-term organically managed rice soil

Aseema Mishra, Dibyendu Chatterjee, Upendra Kumar, Bitish Kumar Nayak*, Saikat Ranjan Das, Megha Kaviraj, A.K. Nayak

ICAR-National Rice Research Institute, Cuttack, Odisha, 753006

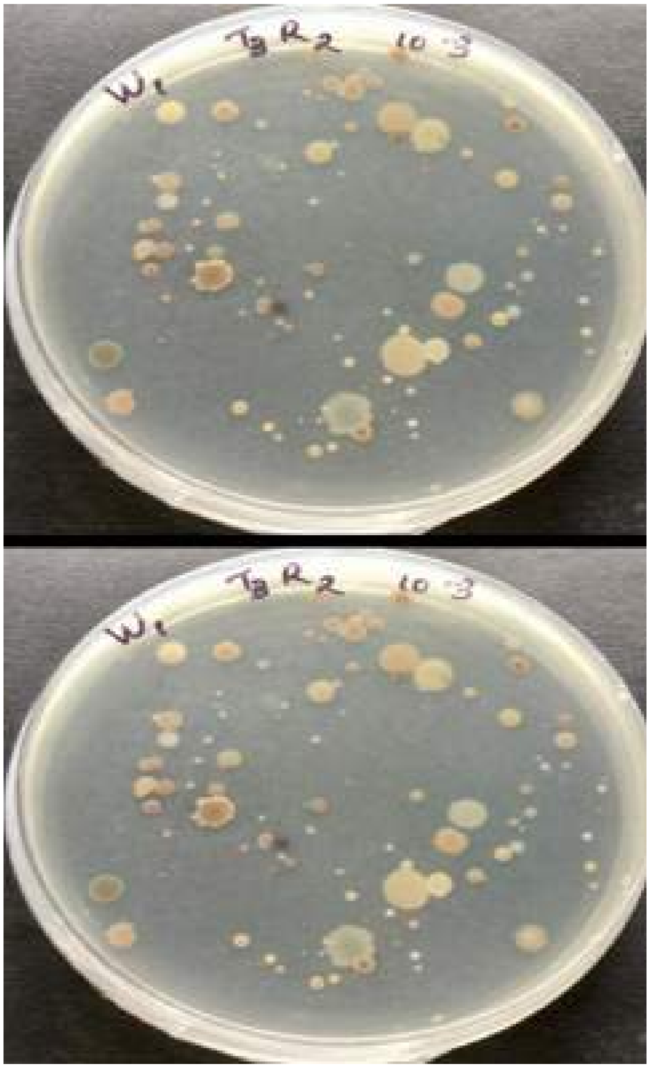
Organic agriculture is helpful to the environment, much better to pollinating insects and provide equivalent or more nutritious food with less agrochemical residue. Organic farming systems have lower yields compared to conventional farming as organic farming rely heavily on ecosystem services to achieve better yield of crops, while the conventional agriculture rely on inputs from external sources. The biological component of soil is crucial for soil health, particularly on organic farms where synthetic additives did not take the role of biological soil functions. Nitrification is one of the most significant processes in the biogeochemical nitrogen cycle among the different soil processes. Two sequential reactions make up nitrification process: the oxidation of ammonia by ammonia-oxidizing bacteria (AOB) or archaea, which turns ammonium into nitrite, and the oxidation of nitrite by nitrite-oxidizing bacteria (NOB), which turns nitrite into nitrate. In this study, the nitrifying bacteria were isolated and characterized from an alluvial rice soil amended with organic amendments over two decades with the objective to evaluate the influence of long-term organic nutrient management on nitrifying bacterial diversity and to relate the functional diversity with soil chemical and biological properties.

METHODOLOGY

The research was conducted at the research farm of the ICAR National Rice Research Institute, Cuttack in randomized block design with eight treatments and three replications in kharif 2021 with Govindabhog, an aromatic rice variety under long-term organically managed rice soil. The treatments were absolute control, farmyard manure application (FYM) alone, green manure application (GM), half the N dose from FYM, and the other half from GM (FYGM), half the N dose from FYM and the other half from Azolla (FYAZ), application of GM together with rice straw (5 t ha^{-1}) (GMRSF), half the dose from GM and the other half from Azolla (GMAZ), and application of GM together with rice straw (2.5 t ha^{-1}) (GMRSH). 0–15 cm of rhizosphere-level soil samples were taken for biochemical and microbiological analysis like; culturable microbial population (bacteria), population of nitrifying bacteria (media preparation, serial dilution, spread plate method), soil enzymatic activity (dehydrogenase, urease, L-asparaginase, L-glumtaminase, nitrate reductase), nitrogen fractions in soil (microbial biomass nitrogen (MBN), nitrate nitrogen, ammonium nitrogen, available nitrogen) (Nayak et al. 2016; Chatterjee et al. 2021).

RESULTS

The outcome of utilising the aforementioned techniques reveals that the total ammonium oxidizing bacteria (*Nitrosomonas*) and total nitrite oxidizing bacteria (*Nitrobacter*) population was higher observed in Dhaincha (T3) treatment. In case of total bacterial population, the highest total culturable bacterial population was recorded in FYM and Dhaincha (T4) treatment. Among eight different treatments, Dehydrogenase activity (42.30 µg TPF g^{-1} d^{-1}), urease activity (272.45 µg urea g^{-1}h^{-1}), L-asparaginase activity (187.5 nanomol g^{-1}min-1), L-glutamase activity (409.27 nanomol g^{-1}min-1) were observed the highest



Nitrifying bacterial population

under FYM and *Azolla* (T5) treatment. In case of nitrate reductase activity highest was observed under FYM and Dhaincha (T4) (18.67 µg NO_2-N g^{-1} dry soil h^{-1}). As per soil chemical studies, available nitrogen (397.23 kg ha^{-1}), ammonium nitrogen (105.36 kg ha^{-1}) and microbial biomass nitrogen (29.72µg g^{-1}) were observed highest under FYM and *Azolla* (T5). But in the ammonium nitrogen (42.58 kg ha^{-1}) highest was observed under Dhaincha (T3).

CONCLUSION

From the above findings, we conclude that the long-term organic management of soil positively impact the microbial population and biomass nitrogen in the soil. The nitrifying bacterial population, various enzymatic activities, and total microbial population (bacteria) are also increased under organic management.

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ARRW/SIRC/Theme II/47

Effect of long-term organic nutrient management on weed flora in rice-fallow

Dibyendu Chatterjee, Saikat Ranjan Das*, Sushmita Munda, Abhijit Pradhan, Sanjay Saha, Amaresh Kumar Nayak

ICAR-National Rice Research Institute, Cuttack, Odisha, 753006

Weeds compete with crops for most abiotic components in cereal fields, including light, water, and nutrients, and their presence often results in significant reductions in crop quality and yield. Weeds have always resulted in yield losses because they consist of a variety of weed species with very different competitive strengths and in many cases are more economically important than fungi, insects, or other pest species. Many agronomic components affect the composition, abundance, and richness of a weed population such as land management, fertilisation, allelopathic interactions, and herbicide use. Fertilisation alters soil fertility and affects not only crop development but also the growth and diversity of related weeds. The type of weed control measures needed depends on the diversity of weed species, and differences in diversity may indicate potential weed control problems. Currently, most weed research focuses on weed communities, crop-weed competition, responses to fertilisation alone (Lal et al. 2014). The aim of the present study was to investigate the effects of different organic nutrient management on weed community diversity and their nutrient uptake in a 21-year long-term rice-fallow system.

METHODOLOGY

The long-term organic experiment was started at the Indian Council of Agricultural Research-National Rice Research Institute research farm in the Kharif season of 2001 and was conducted for 21 years to evaluate the long-term effects of organic fertilization. In this experiment, eight organic nutrient management, including absolute control, farmyard manure application (FYM) alone, green manure application (GM), half the N dose from FYM, and the other half from GM (FYGM), half the N dose from FYM and the other half from Azolla (FYAZ), application of GM together with rice straw (5 t ha^{-1}) (GMRSF), half the dose from GM and the other half from Azolla (GMAZ), and application of GM together with rice straw (2.5 t ha^{-1}) (GMRSH) were tested in three replicates in a completely randomized design. The weed survey started in July 2021-2022 and was conducted during the stage of maximum tillering and panicle initiation stage of rice in both dry and wet seasons. Plants present in the quadrats were recorded, sampled, sorted by species, and counted. Mature weeds were also sampled in a 100 cm × 100 cm quadrat selected to avoid resampling previously sampled plots at harvest time. Mature weeds were collected, dried, and weighed, and total N, P, and K content in weed tissue was analysed using standard procedures. Nutrient accumulations in weed biomass were calculated by multiplying the nutrient concentrations and the dry weight of the plants.

RESULTS

As part of long-term organic nutrient management, a total of 11 weed species from 9 families were recorded during 2021-2022. *Poaceae* was the predominant family, followed by *Sphenocleaceae* and *Marsileaceae* at the maximum tillering stage, while *Poaceae* and *Onagraceae* were the two predominant families at the panicle initiation stage in the wet season. The highest relative weed density and dry matter was observed in GM, FYGM, and GMRSF, while the lowest was

Table 1. Density, dry matter and nutrient accumulation of weed species

Treatments	During crop cycle (wet season)					During fallow (dry season)				
	Weed density	Weed dry matter (g m^{-2})	Nutrient accumulation (g m^{-2})			Weed density	Weed dry matter (g m^{-2})	Nutrient accumulation (g m^{-2})		
			N	P	K			N	P	K
Control	41 ± 1^{BC}	27.33 ± 0.58^{AB}	0.30^{B}	0.03	0.27^{B}	168 ± 1^{C}	154.94 ± 0.82^{AB}	2.07^{B}	0.19^{C}	1.83^{D}
FYM	31 ± 1^{D}	23.80 ± 0.84^{B}	0.37^{AB}	0.03	0.28^{AB}	183 ± 2^{AB}	162.91 ± 1.11^{AB}	2.56^{A}	0.22^{AB}	2.16^{AB}
GM	40 ± 1^{C}	28.71 ± 0.61^{A}	0.45^{A}	0.04	0.33^{AB}	172 ± 3^{BC}	147.64 ± 1.79^{B}	2.44^{AB}	0.20^{C}	1.99^{CD}
FYGM	52 ± 2^{A}	28.13 ± 0.59^{AB}	0.40^{AB}	0.04	0.35^{A}	177 ± 2^{ABC}	147.91 ± 1.58^{B}	2.38^{AB}	0.20^{C}	1.99^{BC}
FYAZ	42 ± 1^{BC}	25.08 ± 0.72^{AB}	0.34^{AB}	0.03	0.29^{AB}	191 ± 1^{A}	165.17 ± 0.96^{A}	2.64^{A}	0.22^{A}	2.26^{A}
GMRSF	53 ± 2^{A}	28.88 ± 0.84^{A}	0.42^{A}	0.04	0.33^{AB}	178 ± 2^{ABC}	152.75 ± 1.2^{AB}	2.49^{A}	0.20^{BC}	2.14^{ABC}
GMAZ	39 ± 1^{CD}	25.45 ± 1.2^{AB}	0.40^{AB}	0.03	0.31^{AB}	179 ± 4^{ABC}	153.06 ± 1.81^{AB}	2.59^{A}	0.21^{ABC}	2.15^{ABC}
GMRSH	49 ± 2^{AB}	27.58 ± 0.47^{AB}	0.41^{AB}	0.03	0.34^{AB}	171 ± 3^{BC}	148.87 ± 1.26^{AB}	2.29^{AB}	0.20^{ABC}	2.10^{BC}
Average	44	26.87	0.39	0.03	0.31	177	154.16	2.43	0.20	2.08
p-Value	<.0001	0.0081	0.0160	0.0622	0.0186	0.0016	0.0164	0.0027	0.0006	<.0001
CV (%)	6.44	5.67	11.02	8.67	8.80	2.83	3.85	5.57	2.99	2.71

recorded in FYM, GMAZ, and GMRSH during the wet season growing period, but it was highest in FYM and FYAZ during the fallow period of dry season (**Table 1**). The highest relative dry matter was observed in the *Poaceae* family, followed by *Sphenocleaceae* and *Onagraceae*. At the end of two consecutive seasons with different organic management, the highest nutrient accumulations were recorded in GM, GMSH and GMRSH during the wet season, while treatments FYM, FYAZ and GMAZ had the highest N, P and K accumulations in weed species during fallow, which was at par with FYGM, GM and FYM, with the difference being significant only in the control.

CONCLUSION

The different organic nutrient management of the long-term experiment had a major effect on the density, dry matter, and nutrient uptake in the weed communities. From this experiment, we conclude that in all treatments, grasses dominated at each growth stage, followed by broadleaves. Weed density and weed dry matter were comparatively lower during crop growing cycle but higher during the fallow period in the dry season. The N, P and K uptake is higher during the fallow because there is no competition with the plants. Evaluating the response of the agronomic weed community to organic fertilisation is critical for developing improved weed control methods in tropical rice-fallow systems and for varying weed diversification.

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Hydronano M spray improves productivity and micronutrient content in lowland rice

Dibyendu Chatterjee[1], Abhijit Pradhan*[1], Mohammad Sahid[1], A.K. Nayak[1], Mukesh Agarwal[2], Bitish Kumar Nayak[1],

[1]*ICAR-National Rice Research Institute, Cuttack, Odisha, 753006*
[2]*Invati creations private Limited, Kolkata.*

Awareness of global food security and environmental consciousness has increased recently. This has increased consumption of organic foods for their high quality and lower levels of chemical residues (Puech et al., 2014). However low productivity of organic system is a major concern. Additionally, micronutrient deficiencies have been reported in 50% of the world's soils and in many crops result in a significant reduction in the amount and quality of food, which negatively affects human health and the economic status of farmers. With this background, the present study was conducted to investigate the effect of HydroNano M™ on productivity and micronutrient content of rice. HydroNano M™ is a product of Invati Creations Private Limited which is a nano particle-based plant nutrient which is a good source of water-soluble forms of all essential minerals for plant growth. It is a safe, nontoxic, and eco-friendly bio stimulant and featuring nutrient coated Ca, Mg, B, Fe, and Zn nanoparticles ensure rapid mobility/cellular uptake of nutrient and essential minerals without any unwanted interactions and losses with significantly improves growth and productivity of plants and crops (Anonymous 2023).

METHODOLOGY

A field experiment was conducted in *kharif* and *rabi* seasons in the year 2021-22 at the experimental farm of the National Rice Research Institute, Cuttack, India (20°25′N, 85°55′E; and 20°26′N, 85°55′E and the experiment is laid out in split plot design with 8 levels of nutrient management in organically managed rice and 4 levels of varieties. Treatments were replicated thrice in the experiment, viz, T_1=Control; T_2= Farmyard Manure (FYM) @ 5t ha^{-1}; T_3=Hydronano M spray (3ml), T_4=Hydronano M spray (6ml); T_5=Hydronano M spray (8ml); $T_{6=}$Hydronano M spray (3ml) +FYM; T_7=Hydronano M spray (6ml) +FYM and T_8=Hydronano M spray (8ml) +FYM. The four varieties in *kharif* season were CR Sugandh Dhan 909, Geetanjali, Gobindabhog and Nuakalajeera, while in *rabi* season varieties were Naveen, CR Dhan 310, Abhisek and Shatabdi. Hydronano M was sprayed @ 3, 6 and 8 ml per litre of water as per the treatment at 30 days after transplanting of rice, followed by a second spray of Hydronano M at 60 days after transplanting. Well rotten FYM was bought from NRRI farm and applied during land preparation in respective treatment. The yield and yield attributing characters were recorded following the standard procedure. Total Fe, Mn, Zn and Cu in soil were determined by diacid digestion method and analysed using Atomic Absorption Spectrophotometer. Boron was determined by azomethine-H method, while Ca was measured using versenate (EDTA) titration method.

RESULTS

Hydronano M spray (8 ml) combined with FYM treatment obtained the highest grain yield of rice with 3.91 t ha^{-1} (Nuakalajeera) in *kharif* season and the same treatment obtained the highest grain yield of 2.48 t ha^{-1} (Shatabdi) in *rabi* season. As per the results obtained in *kharif*, spray of Hydronano M @ 3ml, 6ml and 8ml increased grain yield by 8.8, 13.9 and 15.2% over control, while

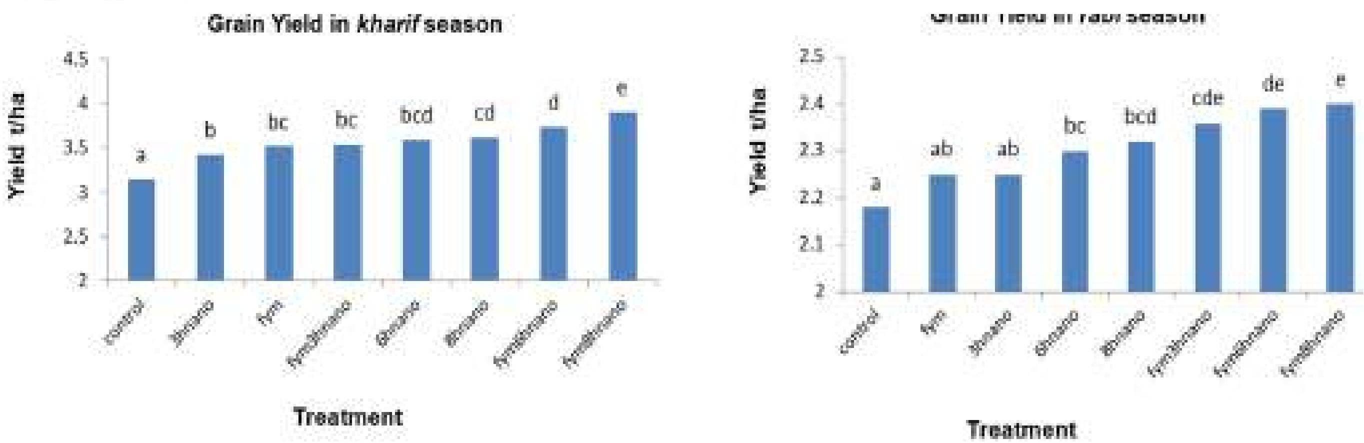

Fig 1: Yield of rice as impacted by Hydronano M application

its combined application with FYM increased grain yield by 12.5, 18.5 and 24.3% over control, respectively (Fig 1). It seems the application of Hydranano M bio-stimulant has helped to mobilize available soil nutrients which promoted plant growth, and the nanofabricated micronutrients in Hydronano M has enhanced the grain yield of rice in both seasons and also increased Ca, B, Fe and Zn contents of the crop over no application Hydronano M. However, as per experiment in rabi season spraying with Hydronano M @ 3 ml, 6 ml and 8 ml increased grain yield by 3.2, 5.5 and 6.4% over the control, while combined application of Hydronano M along with FYM increased grain yield by 8.2, 9.6 and 10.1% over the control, respectively (Fig 1).

In both seasons, micronutrient levels were significantly higher in the Hydronano M spray (8 ml l^{-1}) treatment along with FYM than in the control. In *kharif* and *rabi* season Hydronano M spray (8 ml litre^{-1}) along with FYM was found to have the greatest concentrations ranges from Zn (20.3-29.9 mg kg^{-1}), Fe (91.7 - 96.3 mg kg^{-1}), B (4.42 – 5.21 mg kg^{-1}), and Ca (0.324 – 0.371%) in grain. Among all varieties, Gobindbhog and Geetanjali had the highest zinc contents in grain. However, the highest iron and boron content in grain was recorded in *kharif* season in Nuakalajeera. Similarly, in *rabi* season the highest zinc and iron content in grain was found in Abhisek and CR Dhan-310. The highest boron content in grain was found in Shatabdi in *kharif* season.

CONCLUSION

Application of hydronano M has increased yield performances significantly in both aromatic rice varieties and high yielding rice varieties under irrigated condition, with increase in Ca, B, Fe and Zn content in grains. Spraying of Hydranano M @ 8ml along with FYM may be recommended for aromatic rice varieties as an additional nutrient supplement.

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ARRW/SIRC/Theme II/49

Soil microbiome changes in aerobic and wetland rice-pulse crop rotation

Periyasamy Panneerselvam[1*], Ansuman Senapati[1], Parameswaran Chidambaranathan[2], Prabhukarthikeyan S.R.[2], Debasis Mitra[1], Amaresh Kumar Nayak[1] and Annamalai Anandan[4]

[1]*Crop Production Division, ICAR – National Rice Research Institute, Cuttack, Odisha, 753006, India*
[2]*Crop Protection Division, ICAR – National Rice Research Institute, Cuttack, Odisha, 753006, India*
[3]*Crop Improvement Division, ICAR – National Rice Research Institute, Cuttack, Odisha, 753006, India*
[4]*ICAR- Indian Institute of Seed Science, Regional Station, Bengaluru, Karnataka, 560065, India*

For improving crop yield and soil quality in rice based cropping systems, pulse crop rotation has become a generally recognised agronomic practice. There are no long-term studies available on changes of soil microbiome in aerobic rice cultivation, which is an alternative cultivation method to wetland rice cultivation for sustaining rice yield with limited use of water. As soil microorganisms play an integral role in sustaining cropping ecosystem, it is important to examine the impact of rice monoculture and pulse crop rotation on microbial diversity.

METHODOLOGY

Collected soil samples from rice-rice and rice-pulse based cropping system from long term aerobic (10 years) and wetland (50 years) paddy fields situated at ICAR-NRRI research farm. Soil DNA extracted from these samples were analysed using high-throughput amplicon sequencing approaches in Illumina Miseq platform. Classified the population of soil fungi into several ecological guilds and investigated how crop rotation strategies in aerobic and wetland rice farming affected changes in fungal diversity [1]. The prokaryotic function and metabolomic interaction of bacterial population was also studied. Further co-occurrences networks were constructed to understand the species interaction across different taxonomic levels in respective ecosystem [2].

RESULTS

Our results support comprehensive understanding of how pulse crop rotation in aerobic and wetland rice farming has changed the diversity of the soil's microbial population. Comparing the fungal and bacterial diversity in wetland soil to aerobic soil, the pulse rotation had a significant impact on soil microbiome based on the alpha and beta microbial-diversity measures. In aerobic rice-pulse cultivation, a greater percentage of fungal pathotrophs were noticed.

CONCLUSION

The results of the network analysis suggested in both aerobic and wetland rice cultivation, the intervention of pulse crop rotation increased microbial species richness however, higher diversity was found in aerobic rice-pulse cropping system.

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ARRW/SIRC/Theme II/50

Exploring co-occurrences of AMF in aerobic and wetland rice ecosystem – an omics approach

Ansuman Senapati[1,3*], Periyasamy Panneerselvam[1], Parameswaran Chidambaranathan[2], Amaresh Kumar Nayak, Debasis Mitra[1], Chinmay Pradhan[3] and Annamalai Anandan, [4]

[1]*Crop Production Division, ICAR – National Rice Research Institute, Cuttack, Odisha, 753006, India*
[2]*Crop Improvement Division, ICAR – National Rice Research Institute, Cuttack, Odisha, 753006, India*
[3]*Department of Botany, Utkal University, Bhubaneswar, Odisha 751004 India*
[4]*ICAR- Indian Institute of Seed Science, Regional Station, Bengaluru, Karnataka, 560065, India*

Arbuscular mycorrhiza fungi (AMF) are soil-dwelling, symbiotic microorganisms that help their host plants by improving nutrient uptake, and protect the plant against a wide range of biotic and abiotic stress. Due to their obligatory aerobic nature of metabolism, there is a prevailing opinion that AMF will perform less effectively in waterlogged environments. Therefore, we analysed their co-occurrences in both wetland and aerobic rice habitat in order to understand the impact of water regime on the diversity of AMF.

METHODOLOGY

Rhizosphere soil samples were collected from rice plants cultivated in aerobic and wetland rice ecosystems situated at ICAR-NRRI research farm. These samples were subsequently subjected to high-throughput sequencing (Illumina MiSeq) as described by Panneerselvam *et al*., 2020. By comparing the diversity of AM fungi in two different rice environments, namely aerobic and wetland, co-occurance network analysis was performed to discover keystone species of arbuscular mycorrhizal (AM) fungi in rice ecosystem. Further to investigate their worldwide reported appearances in various niches as well as their growth characteristics, the FUNGuild database was searched using the taxonomic data from the OTUs found from aerobic and wetland rice environments.

RESULTS

The sequencing analysis showed that 88.8% of operational taxonomic units (OTUs) were shared by rice ecosystems in both aerobic and wetland conditions, while 6.1% and 5.1%, respectively, had distinct OTUs. In aerobic ecosystem, it was revealed that species from the families Glomeraceae, Paraglomeraceae,Acaulosporaceae, Geosiphonaceae, and Gigasporaceae were more abundant than those from the families Claroideoglomeraceae and Diversisporaceae, which were abundant in wetland ecosystem. *Glomus* sp. were more prevalent in aerobic soil, but *Claroideoglomus* sp. were more prevalent in wetland soil. Co-occurance network analysis using random forest models revealed the keystone genus *Paraglomus*, which was found in both aerobic and wetland ecosystems exhibited stronger relationships with *Glomus*, *Archaeospora*, *Scutellospora*, and *Diversispora* species.

CONCLUSION

Based on the findings that *Paraglomus* is one of the keystone genera in both ecosystems, it has been proposed that *Paraglomus* is an important genus that, when used in combination with species from the Glomerales, particularly *Glomus* spp. for aerobic environments and *Claroideoglomus* spp. for wetlands, may increase the diversity of AM fungi in rice ecosystems.

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ARRW/SIRC/Theme II/51

Preparation of double layered engineered rice husk biochar for decontamination of pesticides from water

Bibhab Mahapatra[1,2#], Abhijit Kar[1], Sushmita Munda[1], Basana Gowda Gadratagi[1], Naveenkumar Patil[1], Govindharaj Guru-Pirasanna-Pandi[1] & Totan Adak[1*]

[1]*ICAR-National Rice Research Institute, Cuttack, Odisha, India-753006*

[2]*Fakir Mohan University, Vyasa Vihar, Balasore, Odisha, India- 756019*

 # Presenting author: Bibhab651@gmail.com

** Corresponding author: Totan.Adak@icar.gov.in & totanadak@gmail.com*

Biochar composites with strong adsorptive surfaces could be used to decontaminate pesticide from water. There is no doubt, the pristine biochars are efficient enough to trap wide range of pollutants, but the sorption capacity of biochar can be further improved by modifying its surface area. Co-pyrolyzing of paddy husk with $ZnCl_2$ and bentonite clay, which is rich in Al_2O_3 and other minerals helps to activate the biochar chemically. Chemical activation with both Zn and Al will form double layered biochar which will be efficient enough to remove pollutants(Palapa et al., 2021), especially pesticides. The synthesized composites were evaluated for its adsorption efficiency against three commonly used pesticides namely, bispyribac sodium, carbendazim and imidacloprid.

METHODOLOGY

Engineered rice husk biochar (ERHB) was prepared by co-pyrolyzing rice husk, bentonite clay and $ZnCl_2$. The pyrolysis conditions such as ratio of compositions, pyrolyzing temperature and pyrolyzing duration was optimized with the help of central composite design (CCD) of Response Surface Methodology (RSM). Similarly, the sorption conditions, initial concentration, contact time, pH and dose of adsorbent was also optimized with the help of CCD of RSM (Design Expert, Stat-ease). Pesticide removal study of all the above mentioned three pesticides was done using LC-MS/MS. Adsorption isotherm and kinetics studies were done. Zero-point charge was estimated with the help of pH drift method. The physio-chemical characterizations of the composites were done using such as Scanning Electron Microscopy, Energy dispersive X-ray and Fourier Transform Infrared Spectroscopy (Fig 1).

RESULTS

Composition of rice husk, bentonite and $ZnCl_2$ at the ratio of 2:1:1 was pyrolyzed at 500°C for 2

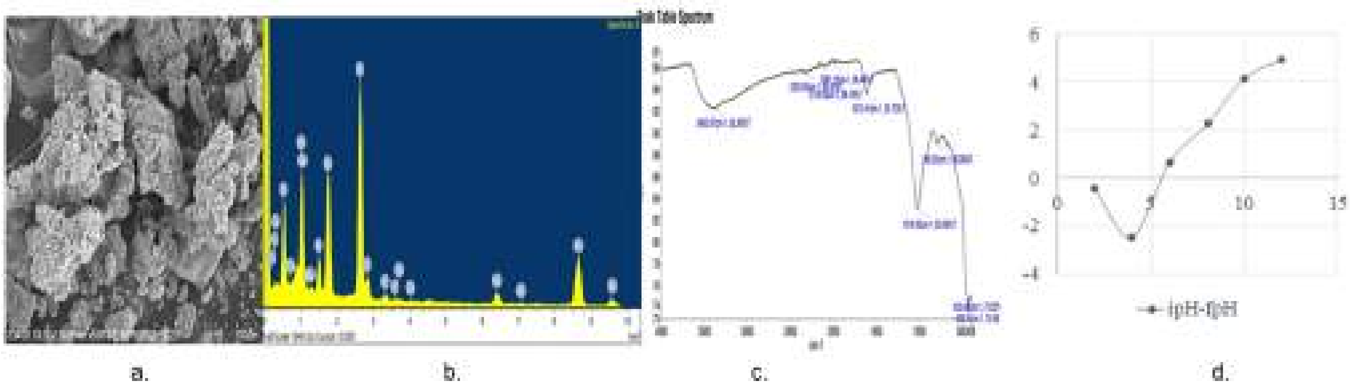

Fig 1. Physico-chemical characterization of synthesized biochar composite (a. SEM image, b. EDX image, c. FTIR Image, d. Zero-point charge calculation)

hours to have ERHB as the most efficient to remove pesticides. The composite could adsorb 61.80 mg of imidacloprid, 52.36 mg of carbendazim and 96.07 mg bispyribac sodium per gram of adsorbent. Optimization of sorption study showed that maximum adsorption occurs at neutral pH, when concentration of the solution was maintained 24.97 mg/L and contact time was kept for 2 hours. Dose was optimized at 0.1 g for 30 mL of pesticide solution. The adsorption isotherm of carbendazim and bispyribac sodium was fitted into non-linear form of Langmuir and Freundlich model. Whereas, imidacloprid showed monolayer adsorption which can be only fitted with Langmuir model. Sorption kinetics data of three pesticides fitted very well to Pseudo first order (PFO), Pseudo second order (PSO), and Elovich models (r^2=0.999). The zero-point charge was 5.61. According to the SEM images, the ERBH biochar composites have distinct, rough pores spread across their surfaces, which enhances the amount of surface area available for pesticide adsorption. Using Fourier-transform infrared spectroscopy, functional groups such free phenol (-OH), cyanide group (CN), alkene (C=C), and esters (C-O) were found in the ERHB.

CONCLUSIONS

Rice husk, bentonite and $ZnCl_2$ were mixed at the ratio of 2:1:1 and pyrolyzed at 500°C for 2 hours to develop an efficient ERBH to adsorb a wide range of pollutants. Estimated maximum adsorption capacity was 75.471 µg/mg. This biochar composite can be used to remove a wide range of pollutants from water.

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ARRW/SIRC/Theme II/52

On farm assessment of integrated nutrient management practices in local scented rice (*oryza sativa* l.) cv. Sitabhoga for enhancing productivity and profitability under changing climatic situation.

Lalita Kumar Mohanty, Siba Prasad Mishra and Subrat Kumar Panigrahi

Krishi Vigyan Kendra, Jajpur, Odisha University of Agriculture and Technology, Bhubaneswar ,
Email : lalita.mohanty@rediffmail.com

Rice (*Oryza sativa* L.) is called as "Global grain" due to its primary role as a staple food all over the world. Rice is one of the most important cereal foods of the globe and it feeds fifty percent of the world population. Next to China, India contributes 21.5 % of global rice production and plays an important role in the economic development of our country. It is cultivated in diverse ecologies spreading over 42.7 million hectares in India. Rice is cultivated in an area of 4.18 million hectares in Odisha. The productivity of rice in Odisha is 1820 kg./ha. Only, which is much less than many states of India.(Odisha Agricultural Statistics-2013-14). India has rich genetic diversity of aromatic rice landraces, majority of them having small to medium grains which are classified into a separate group. Other than Basmati, the indigenous short grain aromatic rice landraces are grown in localized pockets in almost all parts of the country. Increasing productivity and profitability of short grain aromatic rice through integrated nutrient management practices have an edge over traditional basmati rice for their varied and intense aroma with long retention capacity in relatively warmer region. Rice based cropping system has got under the scanner for questionable sustainability. With heavy addition of fertilizers and agro-chemicals, the rice soils are getting deprived of their inherent fertility which is a potential concern for soil health in the long run. A judicious and rational fertilizer usage can advertently increase the yield and improve the quality of rice (Khan et al., 2009).

METHODOLOGY

The participatory on-farm trial was conducted in Dagarapada village of Badachana block and Choramuha village of Dharmsala block of Jajpur district (20^0 $33^/$ to 21^0 $10^/$ North Latitude and 85^0 $40^/$ to 86^0 $44^/$ East Longitude) during wet season of 2022. The experiment was carried out in Randomized Block Design (RBD) with three treatments viz. T_1 - Farmers practice (Low dose of fertiliser 40-30-20 NPK kg/ha)+ FYM 1 t/ha), T_2 – Recommended dose of fertiliser (60-30-30 kg NPK/ha + FYM 2 t/ha)+ Zinc 5 kg//ha + Sulphur 20 kg/ha) and T_3 – Recommended dose of fertiliser (60-30-30 kg NPK/ha) + FYM 5 t/ha + Zinc 5 kg//ha + Sulphur 20 kg/ha + Azospirrilum 5 kg/ha + PSM 5 kg/ha). The treatments were replicated 7 times in farmer's field under medium land situation. The experiment was carried out under assured irrigation and good drainage condition. The scented rice seeds (variety Sita bhoga) were sown in the nursery and 21 days old seedlings were transplanted in the main field giving the spacing of 20 cmx15 cm. during the month of July and harvested during December 2022. The soil was loamy to clay loam in texture with low available Nitrogen (243.9 kg/ha), medium in available phosphorus (18.9-35.4 kg/ha.) and high exchangeable potassium (289.6-345.5 kg./ha.) The soil was acidic in nature having pH of 5.8. The organic carbon content was low (<0.46 %) and EC was 0.31 -0.52 ds^{-1}m.Full dose of Phosphorus 25 % Nitrogen and &75 % of Potassium were applied as basal.50 % nitrogen was applied after 30 DAT (Day after transplanting) and 25 % at panicle initiation stage.

Table 1. Effect of Integrated Nutrient Management in scented rice on productivity yield attributes and economics

Treatments	EBT/m^2	Panicle length(cm)	No. of grains/Panicle	Grain Yield (t/ha.)	Net Return(Rs.)	B:C Ratio
T_1	197	20.8	142	3.11	90000	2.39
T_2	226	22.1	163	3.58	109000	2.55
T_3	292	24.5	187	4.14	135000	2.87
CD (5 %)	16.4	1.6	10.8	0.41	12500	0.13

Selling Price of scented rice Rs. 50,000/ ton

The FYM , Zinc and Sulphur were incorporated in the soil during puddling. The prophylactic plant protection measures were taken as per requirement. The price of produce was estimated as per the prevailing market price.

RESULTS

The yield attributes *viz.* EBT/m^2, Panicle length and number of grains per Panicle were studied. It was observed that From the experiment it was observed that (T_3) produced the highest grain yield of 4.14 t/ha which was 33.11 % increase over (T_1) with net return of Rs. 135000 /ha.(Table –1). The higher yield of rice in T_3 due to highest nutrient use efficiency. This might be due to better growth of plants on account of reduced competition for nuttrients resulting in proper availability of nutrient and beneficial effects biofertilisers. The benefit cost ratio (B:C ratios) of three treatments were 2.39, 2.55 and 2.87 respectively.

CONCLUSION

Therefore it is concluded that application of recommended dose of fertiliser (60-30-30 kg NPK/ ha) + FYM 5 t/ha + Zinc 5 kg//ha + Sulphur 20 kg/ha + Azospirrilum 5 kg/ha + PSM 5 kg/ha) is most suitable for medium land situation in transplanted scented rice cv.Sita bhoga of Jajpur district of Odisha and recommended for higher income and profitability.

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ARRW/SIRC/Theme II/53

Effect of green manuring *in-situ*, nitrogen top dressing and zinc in small grain aromatic rice of West Bengal

Ayan Bag*, Mrityunjay Ghosh, S. Bera, T. Biswas and S. Banerjee

Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal 741252, India

Presenting Author's Email: ayanbag1998@gmail.com

'Gobindabhog', a golden-yellow color short-grain aromatic rice, is traditionally cultivated mainly in Bardhaman, Hooghly, Nadia, Birbhum, North 24 Parganas, Bankura, Murshidabad, Howrah region of West Bengal. With the modernization of farming activities and intensive farming, integrated nutrient management with green manuring *viz. dhaincha*, cowpea and use of bio-fertilizer *viz. Azospirillum* is a economically viable and environmentally sustainable strategies towards greater allocation of natural resources while leaf colour chart (LCC) based top-dressing, use of neem-coated urea and nano urea are new options for economic and effective N management.

METHODOLOGY

A field experiment was conducted during *kharif* season of 2022 at 'C' Block Farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal, India. Treatments replicated thrice were allocated in strip-split plot design comprising 4 basal nutrient management [N_1: Neem Coated Urea @ 20 Kg N ha^{-1} as basal, N_2: *Dhaincha* as green manuring *in-situ*, N_3: Cowpea as green manuring *in-situ*, N_4: Seedling root dipping with *Azospirillum* @ 7.5 kg ha^{-1}] as vertical strip plots, while 3 top dressing based nutrient management [T_1= Top Dressing with Neem Coated Urea @ 15 kg N ha^{-1} at 21 DAT and 42 DAT,T_2= LCC based top dressing with Neem Coated Urea @ 15 kg N ha^{-1}, T_3= Nano Urea @ 1.25 l ha^{-1}, 4 ml l^{-1} of water, 312.5 litre for 1 ha at 21 DAT and 42 DAT] as horizontal strip plots and 2 levels of Zinc application [M_1 : Control (No Zn), M_2: $ZnSo_4$ @ 20 kg ha^{-1} as basal] as sub plots. 27 days old seedlings of aromatic Gobidabhog paddy were transplanted

Table 1. Effect of nutrient management on plant characters of aromatic 'Gobindabhog'rice during *kharif* season of 2022

Treatment	Plant height (cm)	Tillers m^{-2} at maximum tillering stage	Total chlorophyll content at flowering	SPAD value at flowering stage stage (mg g^{-1})	Lodging (score)
4 Basal nutrient management					
Neem Coated Urea	140.1	368.9	2.0	33.0	2.5
GM with *Dhaincha*	150.4	400.0	1.9	34.3	3.8
GM with Cowpea	142.5	329.8	2.1	32.8	2.6
Seedling root dipping with *Azospirillum*	145.6	382.2	2.1	34.2	3.0
CD (P=0.05%)	NS	NS	0.2	NS	0.74
3 Top dressed based N management					
Top Dressing with Neem Coated Urea	149.0	382.5	2.1	34.2	3.1
LCC-based top dressing with Neem Coated Urea	145.3	362.9	2.1	33.5	2.9
Nano Urea	139.7	365.2	1.9	33.1	2.6
CD (P=0.05%)	7.7	NS	0.02	NS	NS
Micro nutrient					
Control (No Zn)	143.3	371.8	2.0	33.5	2.8
$ZnSo_4$	146.0	368.6	2.1	33.7	3.0
CD (P=0.05%)	NS	NS	0.08	NS	NS

Table 2. Effect of nutrient management on yield characters of aromatic 'Gobindabhog' rice during *kharif* season of 2022

Treatment	Panicle length (cm)	Panicles m^{-2} at harvest	Filled grains $panicle^{-1}$	1000 Grain Weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
4 Basal nutrient management						
Neem Coated Urea	26.6	265.0	166.9	10.9	2.7	7.6
GM with *Dhaincha*	27.9	293.9	201.2	11.3	3.1	8.1
GM with Cowpea	26.0	255.9	167.4	11.2	2.5	6.7
Seedling root dipping with *Azospirillum*	27.2	277.4	188.2	11.4	3.0	7.3
CD (P=0.05%)	NS	NS	23.54	NS	0.5	NS
3 Top dressed based N management						
Top Dressing with Neem Coated Urea	27.1	302.9	185.4	11.0	2.8	7.9
LCC-based top dressing with Neem Coated Urea	27.2	258.0	179.2	11.5	2.7	7.3
Nano Urea	26.4	258.3	178.2	11.3	2.6	6.6
CD (P=0.05%)	NS	NS	NS	NS	NS	NS
Micro nutrient						
Control (No Zn)	26.6	278.2	179.3	11.1	2.7	7.3
$ZnSo_4$	27.2	268.0	182.6	11.4	2.7	7.2
CD (P=0.05%)	NS	NS	NS	NS	NS	NS

@ 2-3 $hill^{-1}$ at a spacing of 20 cm × 15 cm in puddled field during 3rd week of July.

RESULTS

Among basally applied nutrient management practices, green manuring *in-situ* with *dhaincha* recorded highest plant height (150.0 cm) at harvest and tiller production (400) in1 m^2 at maximum tillering stage, but the differences with other treatments were not significant (Table 1). Top dressing with neem coated urea at 3 and 6 WAT led to the production of taller plants (149.0 cm), maximum tillers m^{-2} (382.5), higher chlorophyll content (2.1 g mg^{-1}), SPAD value (34.2) at flowering stage, but showed greater lodging susceptibility (score 3.1).

Panicle length and test weight, being genetical characters, were not significantly influenced by the plant nutrition techniques adopted in the investigation (Table 2). Green manuring *in-situ* with *dhaincha* resulted in highest grain yield (3.1 t ha^{-1}) due to more number of panicle m^{-2} (293.9) and filled grains $panicle^{-1}$ (201.2). Pooniya and Shivey (2011) also found better effect of *Sesbania aculeate* on grain yield of Basmati rice (Pusa 1121) compared to cowpea, mungbean or summer fallow at New Delhi. N top dressing treatments did not vary among themselves for yield associated characters and grain yield.The application of $ZnSo_4$ @ 20 kg ha^{-1} as basal usually could not influence the growth attributes and yield of Gobindabhog crop over control in the study, except chlorophyll content in leaf at flowering stage.

CONCLUSION

Green manuring with *dhaincha* recorded taller plants (150.0 cm), highest tiller production (400 m^{-2}) and SPAD value (34.3), and highest grain yield (3.1 t ha^{-1}) of Gobindabhog rice in New Alluvial Zone of West Bengal. The application of $ZnSo_4$ could improve the total chlorophyll content in leaf at flowering stages lightly over control.

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ARRW/SIRC/Theme II/54

Elucidating the effect of elevated atmospheric ozone concentrations on physiological and morphological responses of rice and greenhouse gas emissions from rice soil

Ziom Adam Michael[ab], Ashish Kumar Dash[a], Periyasamy Panneerselvam[b], Narayan Panda[a], Amaresh Kumar Nayak[b] and Anjani Kumar[b]*

[a]*College of Agriculture, OUAT, Bhubaneswar, Odisha 751 003, India.*
[b]*ICAR - National Rice Research Institute, Cuttack 753 006, Odisha, India.*
Presenting author email: adam4908@icloud.com
Corresponding author email : anjaniias@gmail.com

Ozone is one of the most destructive tropospheric air pollutants affecting plant growth and productivity. Due to its strong oxidative property, O_3 damages crop by reducing photosynthesis and other vital physiological functions, resulting in weaker plants, inferior crop quality, and diminished yields (Singh *et al.,* 2013). Rice, one of the crucially imperative crops in the global food supply, has been found to be particularly sensitive to O_3. However, the effects of O_3 may extend to the below-ground processes via the changes in carbon allocation to roots, root exudates, and substrate availability for soil microbes (Jones *et al.,* 2009). Such changes would alter the structural and functional components of soil microbial community with potential impacts on emissions of methane (CH_4) and nitrous oxide (N_2O), both of which are potent long-lived greenhouse gases. Therefore, this study was commenced to illuminate the physiological and morphological changes in rice plant exposed to different levels of elevated O_3 concentrations. The experiment was conducted in Open Top Chambers equipped with the facility of maintaining elevated O_3 concentrations.

MATERIALS AND METHODS

Field experiments were conducted during the *Kharif* season of 2022 at ICAR – National Rice Research Institute, Cuttack. The experiment was conducted under Open Top Chambers (OTC's) having the facility of upholding different elevated O_3 concentration levels. Rice varieties like Naveen and CR Dhan 311 were grown under (i) Open field condition with ambient O_3 concentration (T1), (ii) OTC's with ambient O_3 concentration (T2), (iii) OTC's upheld at elevated O_3 concentration (40 ppb; T3), (iv) OTC's upheld at elevated O_3 concentration (60 ppb; T4). Plants were exposed to elevated O_3 from transplanting to harvest @11 hours day^{-1}. Greenhouse gas sampling was done using the closed chamber method at periodic intervals. Standard protocols were followed for laboratory analysis of the collected samples.

RESULTS

A significant effect of elevated atmospheric O_3 was observed on both the rice varieties (Naveen and CR Dhan 311) as compared to the ambient O_3 concentration. The mean plant height decreased significantly under elevated O_3 by 9-10% as compared to ambient O_3 concentration. Plant height may have decreased due to low stomatal conductance to water vapors and reduced net photosynthetic rate due to accumulative ozone damages in leaves. Decreased stomatal conductance led to low photosynthetic activity, resulting in lower biomass production. O_3 due to its oxidative nature, significantly influenced the height of different rice genotypes. The mean tiller number hill^{-1} of rice crops decreased significantly under elevated O_3 by 15-16% as compared to ambient O_3 concentration. This reduction is due

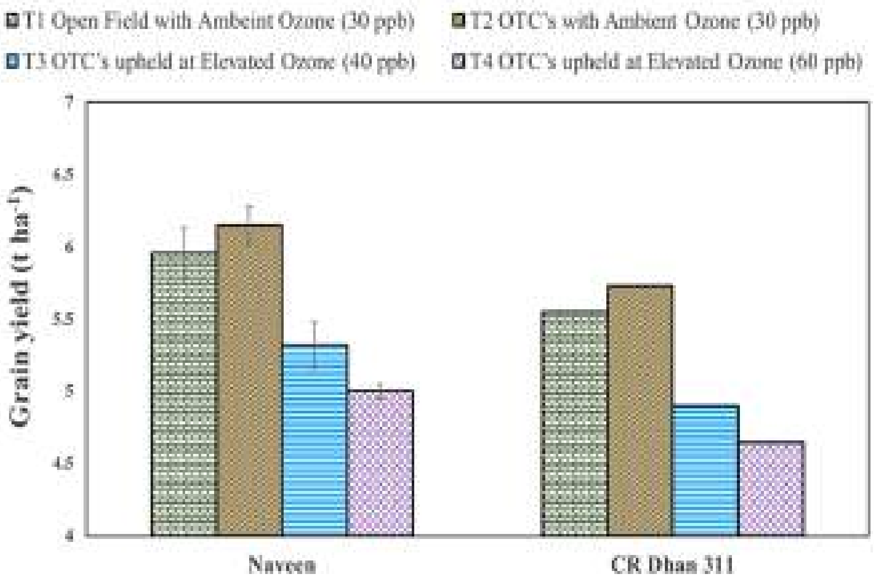

Fig. 1: Effect of elevated O_3 on Grain yield (t ha^{-1}) of rice cultivars at ICAR – NRRI, Cuttack.

to the loss of photosynthetic capacity which directly affects the foliar carbon assimilation rate, which inhibits the production of tillers. The mean grain yield of rice crops decreased significantly under elevated O_3 by 18-19% as compared to ambient O_3 concentration. The yield reduction owing to elevated O_3 was primarily due to reduction in the photosynthetic activity, reduction in whole-plant growth during the early vegetative period, reduction in biomass allocation to panicle during the reproductive period, reduction in grain weight panicle^{-1}, reduction in number of panicles plant^{-1} and the number of grains panicle^{-1}.

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ARRW/SIRC/Theme II/55

Influence of source segregated municipal solid waste compost on yield and heavy metals concentration in rice-based cropping system

Suman Samui* and Sukanta Pal

Department of Agronomy, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal
** Corresponding author: sumansamui369@gmail.com*

Land filing disposal of municipal solid wastes (MSW) contributes offensive odours, air pollution, flooding, breeding of insects and rodent vectors, the spread of diseases and polluting ground water quality. Composting is the simplest yet best option for biodegradable MSW management, as its availability is increasing day by day because of rapid urbanization. However, the use of MSW compost is limited since it is generally poor in essential plant nutrients and the crops do not respond to its exclusive addition compared to chemical fertilizers (Sultana, 2020). The co-application of chemical fertilizers and organic composts is the suitable opportunity to improve soil nutrients and crops productivity. Gradual decomposition of organic matter increased the efficiency of nutrients and lasting effect of these compounds on plants' yield and soil properties for several years (Eghball et al. 2004). There are many reports revealed that continuous application of untreated MSW increases the heavy metal concentration in soil. Thus, present investigation was carried out with the objectives to study the effect of source segregated municipal solid waste compost (SSMSWC) integrated with chemical fertilizer on yield and accumulation of heavy metals in soil and plant in rice-based cropping system (potato-okra-rice) in Inceptisols.

METHODOLOGY

A series of field experiments were conducted in the sub-humid subtropical climatic condition of West Bengal at the Regional Research Sub-Station (RRSS), Chakdaha, Nadia under Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India for two consecutive years (*Rabi*, pre-*kharif* and *kharif* seasons of 2017-18 and 2018-19, respectively). The farm is located at $23^0$5.3'N latitudes and $83^0$5.3'E longitude and at an elevation of 9.75 meters above the mean sea level in the New Alluvial Zone (NAZ) of West Bengal. The crops viz., potato (var. Kufri Jyoti) followed by okra (var. Mahy-64) followed by rice (var. Shatabdi) was grown in the same plots in succession. Before starting the present investigation, rice was grown continuously for the last five years during both *kharif* and *rabi* seasons on this field. Two types of compost were used in these experiments i.e., compost prepared from source segregated municipal solid waste which was collected from Kalyani Municipality of Nadia, West Bengal, India and another compost was commercial compost (CC) which is supplied by M/S Krishi Rasayan enterprise. In field experiments, three levels of chemical fertilizers viz., 0, 50% and 100% of the RDF of the respective crop were integrated with SSMSWC and CC at the rate of 3.75 t ha^{-1}. RDF (State Govt. recommendation) applied for potato, okra and rice was 200:150:150, 140:70:70 and 60:30:30 kg ha^{-1} N, P_2O_5 and K_2O, respectively. Chemical fertilizers were applied for NPK nutrients through urea, single super phosphate (SSP) and muriet of potash (MOP). A biodegradable mulch film was also included with both the composts. Field trial was designed in a simple randomized complete block design (RCBD) with three (3) replications and seven (7) treatments [$\mathbf{T_1}$: Absolute Control (Untreated), $\mathbf{T_2}$: RDF, $\mathbf{T_3}$: 100% RDF+ CC @ 3.75 t ha^{-1}, $\mathbf{T_4}$: 100% RDF + SSMSWC @ 3.75 t ha^{-1}, $\mathbf{T_5}$: 50% RDF + SSMSWC @ 3.75 t ha^{-1}, $\mathbf{T_6}$: 100% RDF+ CC @ 3.75 t ha^{-1} + biodegradable mulch, $\mathbf{T_7}$: 100% RDF+ SSMSWC @ 3.75 t ha^{-1} + biodegradable mulch].

RESULTS

Nutrient management integrating SSMSWC with chemical fertilizers with biodegradable mulch exerted significant influence effectuating decrease in the soil Cd value after harvesting of the potato, okra and also rice. Highest soil Cd build up was observed under T_3 (0.35 mg kg^{-1}) after okra which was 250% higher than initial (0.10 mg kg^{-1}) and also the lowest soil Cd value was recorded under the T_7 (0.23 mg kg^{-1}) after the same crop, which was 130% higher than initial and 20.69% lower than the control treatment. After harvesting of potato and rice crop, T_7 treatment also exerted lower Cd content than control. Irrespective of all the treatments, soil DTPA-Pb content substantially increased over its initial value (3.63 mg kg^{-1}) of experimental soil under all the treatments. Highest soil Pb content was recorded under the T_2 (16.30 mg kg^{-1}) after potato which was almost 349% and 53.63% higher over initial and control plot (T_1) respectively. After harvesting of rice, while the lowest soil Pb was observed under the unfertilized control plot (4.35 mg kg^{-1}), highest value was recorded under T_6 (9.34 mg kg^{-1}) followed by T_2 (9.18 mg kg^{-1}). Compared to other treatments, SSMSWC with or without mulch resulted in slight build-up of extractable Ni in the experimental soil after potato. However, after okra and rice crop its content in the soil was Below Detection Level (BDL). While the lowest soil Cu (5.31 mg kg^{-1}) was recorded under T_1, the highest value (7.96 mg kg^{-1}) was observed under T_7 followed by T_4 (7.57 mg kg^{-1}) after rice harvest. Integrated use of SSMSWC with 100% RDF and biodegradable mulch (T_7) resulted in 35.8%, 26.77% and 77.67% higher available Zn after harvesting of potato, okra and rice respectively than control (T_1).

Pooled data generated from the experiment clearly indicated that integrating MSW compost with chemical fertilizers and mulch effectuated significant negative changes in heavy metal e.g., Cd, Pb and Ni concentration in potato tubers, okra pod and rice grain as well as straw, whereas positive effect exerted in case of Zn and Cu concentration. Potato tuber recorded lower Cd concentration as compared to okra pod and rice grain and straw, where highest Cd concentration was observed under control plot (0.016 mg kg^{-1}) and lowest under T_7 (0.013 mg kg^{-1}) which was at par with T_6, T_5 and T_4. Irrespective of the treatments highest pooled mean value of Pb concentration (2.649 mg kg^{-1}) was recorded in rice straw followed by rice grain as compared to other component crops, where greatest Pb concentration was observed under T_3 (2.688 mg kg^{-1}) followed by control (2.669 mg kg^{-1}) and lowest was recorded under T_7 (2.615 mg kg^{-1}). highest Ni concentration was recorded in potato tuber under the control plot (1.815 mg kg^{-1}), which was significantly higher than the other treated plots. Whereas, least Ni concentration was found in rice grain under the treatment integrating SSMSBWC with chemical fertilizers and biodegradable mulch (0.140 mg kg^{-1}). However higher Zn concentration was observed within rice grain with the pooled mean value of 25.02 mg kg^{-1} where T_7 recorded highest with 56.05% higher Zn concentration compared to control plots. T_7 treatment recorded 28.54%, 67.58%, 23.19% and 48.04% more Cu concentration in potato tuber, okra pod, rice grain and rice straw respectively, as compared to its control plots.

In all the three crops, the yields were significantly higher in the treated plots (T_2 to T_7) compared to control plots (T_1). While the highest potato tuber yield of first year was recorded under the T_2 (21.30 t ha^{-1}), in second year it was recorded under the T_7 (24.80 t ha^{-1}). Application of SSMSWC along with chemical fertilizers and biodegradable mulch (T_7) also recorded highest okra pod yield (16.15 t ha^{-1} and 26.33 t ha^{-1} in first and second year respectively) in both the year among all the treated plots. Similarly, higher grain and straw yield of rice was also observed in T_7 treatment.

CONCLUSION

Although conjunctive use of municipal composts and chemical fertilizers with biodegradable mulch sheet significantly increases the harmful heavy metal build up in soil, its concentrations in plant parts of the component crops were comparatively lower. Compost prepared from source segregated municipal solid waste which was applied along with chemical fertilizers and biodegradable mulch not only increases the yield of potato-okra-rice cropping system but also this practice is so much vulnerable for our environment and a best approach towards sustainable municipal solid waste management.

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ARRW/SIRC/Theme II/56

Integrated nutrient management effectuate dynamic changes in different nitrogen fractions of rice rhizosphere and rice yield in a *typic haplustalf* soil

Prasanta Kumar Patra*; Ghosh, Mousumi; Chakrabarty, Dipsikha; Pal, Subhajit; Md Wahiduzzaman; Pal, Sukanta

Bidhan Chandra Krishi Viswavidyalaya, P.O.- Krishi Viswavidyalaya; Mohanpur-741252, Nadia, West Bengal
**drpatrapk@gmail.com*

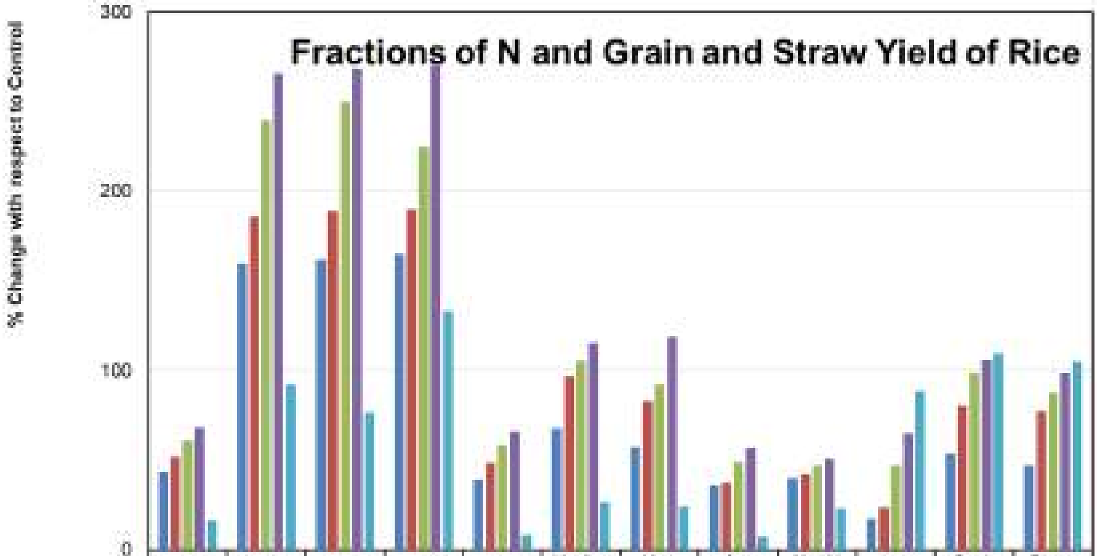
While the capability of integrated nutrient management (INM) in short-term carbon sequestration has been demonstrated (Ghosh *et al*., 2021) little is known about the related changes in soil nitrogen fractions. The present study examined the dynamic changes in different N fractions and yields after application of different organic manures combined with chemical fertilizers in a rice–rice (Oryza sativa L.) (cv.IR-36) cropping system in the Red and Laterite agro-climatic zones of West Bengal, India.

METHODOLOGY

The treatments in the field experiment conducted during three consecutive seasons in a farmer's field in a *Typic Haplustalf* soil of the Red and Laterite Zone of West Bengal included non-fertilized control; rice straw (RS) + nitrogen, phosphorus and potassium fertilizer (NPK); Gliricidia (GL) + NPK; farmyard manure (FYM) + NPK; vermicompost (VC) + NPK; and NPK only. The amount of N, P_2O_5 and K_2O added through organic amendments were adjusted and the balance amount of N, P_2O_5 and K_2O for an intended rate of N: P_2O_5: K_2O:: 80:40:40 Kg ha^{-1} were applied through urea, single super phosphate and muriate of potash, respectively. Rhizosphere soil samples collected from rice field during the three critical growth stages *viz*., tillering, flowering and harvesting, were analyzed for different inorganic and organic nitrogen fractions. Grain yield and straw yield were also recorded. The generated data were statistically analyzed following standard methods.

RESULTS

Organic amendments as well as inorganic fertilizers exerted significant influence on the dynamics of N, growth and yield of rice. Compared to control treatment, significant increase in the levels of total N (Tot N), available nitrogen (Av N) and the organic fractions of N was observed in chemical fertiliser treated as well as in the plots under integrated application of chemical fertilizer along with organic amendments (INM). With respect to the control plot, while in INM plots the quantum of increase in Tot N in soil ranged between 43.9 and 68.1%; the increase in the Av N ranged between 159.7 and 265.8%; that in ammonium N (Am N) between 161.8 and 268.5%; in nitrate N (Nit N) between 165.2 and 270.4%; in total hydrolysable N (Thy N) between 39.1 and 66.1%; in hydrolysable ammonium N (Hy Am N) between 67.9 and 115.5%; in hexose amine N (Hex Amine) between 57.7 and 119.0%; in amino acid N (Am Acid) between 36.1 and 57.1%; in Non-hydrolysable N (Non HyN) between 39.9 and 50.6%; in microbial biomass N (MBN) between 17.1 and 65.4%, the corresponding values (%) under chemical fertiliser alone were 16.8, 92.4, 77.2, 133.4, 8.4, 27.0 and 24.1, respectively. A significantly higher build-up of organic fractions of N could be observed under INM treatment compared to chemical fertiliser treatment. The grain and straw yields were however, the highest under chemical fertiliser treated plots than under control as well as under INM. The quantum of increase in grain and straw yield of rice with



	Tot N	AV N	Am N	Nit N	Thy N	Hy Am N	Hex Amine	Am Acid	NonHyN	MBN	Grain Yield	Straw Yield
Rice Straw+NPK	43.9	159.7	161.8	165.2	39.1	67.9	57.7	36.1	39.9	17.4	54.1	47.2
Glyricidia Leaves+NPK	51.7	186.0	189.0	190.0	48.8	96.7	83.1	37.8	42.3	23.5	80.3	77.4
FYM+NPK	61.3	239.6	249.5	224.9	58.4	105.7	92.3	49.5	47.3	47.1	98.3	87.7
Vermi Compost+NPK	68.1	265.8	268.5	270.4	66.1	115.5	119.0	57.1	50.6	65.4	106.1	98.5
Chemical Fertilisers	16.8	92.4	77.2	133.4	8.4	27.0	24.1	7.1	23.4	88.7	109.6	105.2

Fig.1.Effect of amendments on the % change in different fractions of nitrogen (%) of the rice rhizosphere soil and grain and straw yield compared to their values under control treatment (Pooled over the three crop growth stages and three consecutive seasons)

respect to the control treatment under INM ranged between 54.1 and 106.1% and 47.2 and 98.5%, respectively while these values under chemical fertilisers were 109.6 and 105.2%.

CONCLUSION

This experiment clearly brought out the beneficial role of organic amendment towards immobilization of N by microorganisms and thereby build-up of different organic fractions of N decreasing its loss from the rhizosphere soil. The results of this study suggest that the dynamic changes in different soil nitrogen fractions primarily depend on the type of organic manure used. Vermicompost, FYM and GL provide more available N, which can improve rice yield over the long term. It is suggested to explore the dynamics and buildup of N in different pools and rice yields over longer periods of time and under diverse soil and climatic conditions.

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ARRW/SIRC/Theme II/57

Influence of organic nutrient sources on yield and quality of scented rice landraces of North Bengal

Sanjivani Karki*, Mrityunjay Ghosh, Binoy K. Chettri, T.S. Ghimiray, S. Banerjee and T. Biswas

Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal 741252
Presenting Author's Email: sanjivanikarki1@gmail.com

While the capability of integrated nutrient management (INM) in short-term carbon sequestration has been demonstrated (Ghosh *et al*., 2021) little is known about the related changes in soil nitrogen fractions. The present study examined the dynamic changes in different N fractions and yields after application of different organic manures combined with chemical fertilizers in a rice–rice (Oryza sativa L.) (cv.IR-36) cropping system in the Red and Laterite agro-climatic zones of West Bengal, India.

METHODOLOGY

The treatments in the field experiment conducted during three consecutive seasons in a farmer's field in a *Typic Haplustalf* soil of the Red and Laterite Zone of West Bengal included non-fertilized control; rice straw (RS) + nitrogen, phosphorus and potassium fertilizer (NPK); Gliricidia (GL) + NPK; farmyard manure (FYM) + NPK; vermicompost (VC) + NPK; and NPK only. The amount of N, P_2O_5 and K_2O added through organic amendments were adjusted and the balance amount of N, P_2O_5 and K_2O for an intended rate of N: P_2O_5: K_2O:: 80:40:40 Kg ha^{-1} were applied through urea, single super phosphate and muriate of potash, respectively. Rhizosphere soil samples collected from rice field during the three critical growth stages *viz*., tillering, flowering and harvesting, were analyzed for different inorganic and organic nitrogen fractions. Grain yield and straw yield were also recorded. The generated data were statistically analyzed following standard methods.

The Sikkim-Darjeeling Himalayas is a unique reservoir of rice genetic resources, where diverse types of rice landraces are still grown by the farmers in hill terraces during monsoon season. Among them, Kalture and Kalonunia are traditionally cultivated in hill and terai region of North Bengal for making traditional dishes like *payesh* (sweet rice), *bhog* (pulse intermixed rice), *polao*, *pitha* (homemade cake), *selroti* (ring-shaped sweet bread), etc. The rice farming in Himalayan hills includes the use of cattle manure since ancient times, while vermicompost is gaining importance for sustained crop production and soil health. Besides, mustard cake has been using by limited farmers in short-grained aromatic rice cultivation in South Bengal. Although leaf mould, the locally-available decomposed material of forest leaves, is used as a nutrient input in garden and orchid cultivation in hilly areas, but it has not been tested in scented rice cultivation till date.

Table 1. Plant characters and yield of aromatic rice cultivars under organic nutrient management in hills of West Bengal

Treatment	Plant height (cm)	Lodging (score)	Panicle length (cm)	Panicles^2 m$^-$	Field grains panicle^{-1}	1000 grain weight(g)	Grain yield (t ha^{-1})
Cultivar							
Kalture	137.1	4.0	21.0	325	77.4	16.09	2.86
Kalonunia	126.9	1.0	24.2	356	90.1	12.87	3.23
CD (P<0.05)	5.04	0.43	1.59	14.4	4.70	0.29	0.06
Organic nutrient management							
Cow dung manure @ 5 t ha^{-1}	126.5	3.0	21.8	335	79.5	14.57	2.88
Vermicompost @ 1.5 t ha^{-1}	134.1	3.0	23.0	366	85.6	14.68	3.22
Mustard cake @ 0.5 t ha^{-1}	131.6	2.4	22.8	339	84.9	14.69	3.11
Leaf mould @ 1 t ha^{-1}	135.8	1.7	22.7	323	85.0	13.98	2.97
CD (P<0.05)	5.26	0.69	NS	23.5	3.60	NS	0.21

Table 2. Grain quality of aromatic rice cultivars under organic nutrient management & residual nutrient status in hills of West Bengal

Treatment	Head rice(%)	Kernel length (mm)	Protein content(%)	Alkali spreading (score)	Aroma (score)	Residual nutrient status(kgha^{-1}) N	P	K
Cultivar								
Kalture	62.1	5.04	6.7	5.7	1.6	196.8	20.0	117.8
Kalonunia	62.2	4.83	7.3	6.0	1.8	220.7	21.2	114.7
CD (P<0.05)	NS	NS	0.23	NS	NS	6.76	NS	NS
Organic nutrient management								
Cow dung manure @ 5 t ha^{-1}	63.8	5.06	6.7	5.8	1.6	215.0	20.9	116.6
Vermicompost @ 1.5 t ha^{-1}	62.1	4.91	7.1	6.0	1.6	193.7	20.0	124.6
Mustard cake @ 0.5 t ha^{-1}	62.3	4.73	7.1	6.3	1.7	235.1	23.4	112.7
Leaf mould @ 1 t ha^{-1}	60.5	5.04	7.1	5.3	1.9	191.2	18.1	111.1
CD (P<0.05)	NS	NS	0.11	0.63	NS	6.77	3.1	3.89

METHODOLOGY

A field experiment was conducted at the Regional Research Station Farm of Uttar Banga Krishi Viswavidyalaya, Kalimpong, West Bengal, India during *kharif* (wet) season of 2021. Treatments replicated thrice in a split-plot design consisted of 2 aromatic rice landraces (Kalture and Kalonunia) in main plots and 4 organic nutrient management (cow dung manure @ 5 t ha^{-1}, Vermicompost @ 1.5 t ha^{-1}, Mustard cake @ 0.5 t ha^{-1}, and Leaf mould @ 1.0 t ha^{-1}) in sub-plots. 25 days old seedlings were transplanted manually @ 2-3/hill at a spacing of 20 cm × 15 cm in puddled field. The grain quality parameters were determined following standard methods at Aromatic Rice Laboratory, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal.

RESULTS

Kalture had taller plants (137.1 cm) at harvest and lodging susceptibility (score 4.0) at hard dough stage, while Kalonunia remained unlodged (Table 1). The plants nourished with cowdung manure @ 5 t ha^{-1} or vermicompost @ 1.5 t ha^{-1} became susceptible to lodging and most of the plants (>50 %) lodged slightly (score 3.0) at hard dough stage, but less lodging was noted in the plots receiving mustard cake @ 0.5 t ha^{-1} (score 2.4) or leaf mould @ 1.0 t ha^{-1} (score 1.7). With regard to yield components, Kalture produced <10 panicles hill^{-1}, <80 filled spikelets panicle^{-1}, straw-coloured grain with purple spot at tip and >16 g test weight; while Kalonunia had <11 panicles hill^{-1}, >90 filled grains panicle^{-1}, black-coloured grain with medium-long black awn and <13 g 1000 seed weight. Kalonunia produced greater grain yield (3.32 t ha^{-1}) due to significant improvement in number of panicles m^{-2} (356.18) and filled grains panicle^{-1} (90.09) compared to Kalture (2.86 t ha^{-1}). However, Sarkar et al. (2020) reported lower grain yield of Kalonunia rice (2.98 t ha^{-1}) when grown in New Alluvial Zone of West Bengal. The application of vermicompost @ 1.5 t ha^{-1} could result in higher grain yield (3.22 t ha^{-1}) being at par with mustard cake @ 0.5 t ha^{-1} (3.11 t ha^{-1}), while the lowest yield (2.88 t ha^{-1}) was obtained with cowdung manure @ 5 t ha^{-1}.

The milling recovery and aroma were not significantly influenced by cultivars and organic nutrient sources tested in the investigation (Table 2). Although both aromatic rice cultivars had medium-slender (MS) white kernels, but Kalonunia had higher protein content (7.3%), alkali spreading value (score 6.0) and aroma (score 1.8) than Kalture (6.7%, score 5.7 and score 1.6). The use of mustard cake resulted in maximum protein content (7.14%), moderate aroma (score 1.72), with greater residual N (235.1 kg ha^{-1}), P (23.4 kg ha^{-1}) and K status (112.7 kg ha^{-1}) in soil.

CONCLUSION

Kalonunia performed well in terms of grain yield (3.32tha^{-1}), non-lodging habit, protein content (7.3%) and aroma (score 1.8) compared to Kalture in the study. Although the application of vermicompost@1.5tha^{-1} could result in higher grain yield (3.22tha^{-1}), but mustard cake@0.5tha^{-1} could be better option due to moderate yield (3.11 tha^{-1}), higher protein content(7.1%) and moderate aroma (score 1.7) in Hill zone of West Bengal.

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ARRW/SIRC/Theme II/58

Study on bio-efficacy of cyhalofop-butyl 10% EC against weeds in direct-sown rice (*Oryza sativa* L.)

J. K. Singh*, Amit Kumar Yadav and G. P. Reddy

Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi 221 005 Uttar Pradesh, India
**Corresponding author Email: jksinghbhu3@gmail.com*

Direct seeded rice requires only 34% of the total farm workers required and saves 29% of the total cost of the transplanted crop (Ho and Romli, 2000). It also allows for the early establishment of successful wheat crops, lowers methane emissions, and ensures higher profits in areas with guaranteed water supply (Balasubramanian and Hill, 2000). Weeds are a major biotic stress to rice production in direct seeded systems because they increase production costs and cause yield loss. In India, a number of herbicides have been developed for weed control in rice, but none of them can be used alone to control a wide range of weeds in rice effectively and economically. Furthermore, the herbicides currently available for rice have a limited selectivity range, and the weed species that compete with rice may shift as a result of long-term use of a specific herbicide. As a result, continuous development and evaluation of new herbicide chemistry is critical to mitigating emerging problems of weed shift and herbicide resistance in weeds. Furthermore, sequential/ mixed herbicide application appears to be more promising than individual herbicide application. cyhalofop-butyl is a post-emergence herbicide used to control a broad range of weeds, particularly broad leaf infesting rice. However, literature on its use in direct seeded rice, either alone or in combination with other rice herbicides, is limited and scarce. Therefore, present study was taken up to assess the efficacy of herbicides on weed flora, grain yield and economics in direct-sown rice.

METHODOLOGY

A field experiment was carried out during rainy (*kharif*) season of 2020 at the Agricultural Research Farm, Banaras Hindu University, Varanasi (25^{o} 18′ N, 83^{o} 03′ E and 75.7 m above the mean sea-level), Uttar Pradesh, India. The site was well drained sandy clay loam soil, *p*H 7.32 (1: 2.5 soil: water) and contained 0.33% organic car bon, low in available N (176 kg/ha), medium in available P_2O_5 (23.43 kg/ha) and medium in available K_2O (207 kg/ha) during 2020. The weekly mean maximum temperature, during the period of crop growth 31.3 to 33.6^{o}C. The weekly mean minimum temperature varied 25.5^{o}C–22.0^{o}C While total rainfall received was 118.6 mm. The experiment was laid out in a randomized block design, replicated thrice, comprising 8 treatments, *viz.*, cyhalofop-butyl (Best Crop Sc LLP Sample) 75.0 g/ha, cyhalofop-butyl EC (Best Crop Sc LLP Sample) 80.0 g/ha, cyhalofop-butyl EC (Best Crop Sc LLP Sample) 85.0 g/ha, cyhalofop-butyl (Market sample) 75.0 g/ha, Fenoxaprop-p-ethyl (Market sample) 54.5 g/ha, oxyfluorfen (Market sample) 152.8 g/ha, hand weeding at 20 and 40 DAS and untreated control (weedy check).The field was ploughed and leveled before start of monsoon, thereafter, rice seeds were sown on 25th June 2020. Application of alone post-emergence herbicides was done as per the treatments using knap-sack sprayer fitted with flat-fan nozzle. Species-wise weed density and their dry weight were measured at 60 DAS by placing a quadrate of 0.50 m × 0.50 m randomly at 2 places in each plot. Weed biomass data were subjected to square root transformation (x+0.5) before statistical analysis. Weed control efficiency (WCE) was calculated using the following formula:

Weed control efficiency (WCE) =

$$\frac{\text{WDMc} - \text{WDMt}}{\text{WDMc}} \times 100$$

Where WDMc, weed biomass (g/m^2) in control plot; WDMt, weed biomass (g/m2) in treated plot.

RESULTS

The major weed flora with their relative composition observed in experimental field included *Echinocloa colona* (L.) and *Echinochloa crusgalli* (L.) (14.04 %), *Phyllanthus niruri* L. (4.84%) and *Paspalum conjugatum* (5.63%) at 60 DAS. Moreover, at 60 DAS cyhalofop-butyl 75.0 g /ha recorded lower total weed dry weight than cyhalofop butyl 80 g /ha, cyhalofop butyl 85 g / ha, cyhalofop butyl (market sample) 75.0 g /ha fenoxaprop-p-ethyl 54.5 g /ha, and oxyfluorfen 152.8 g /ha (Table 1). Amongst the herbicidal treatment cyhalofop butyl 75.0 g /ha resulted in higher weed control efficiency followed by cyhalofop butyl 80.0 g /ha, cyhalofop butyl 85 g /ha, cyhalofop butyl (market sample) 75.0 g /ha fenoxaprop-p-ethyl 54.5 g /ha, and oxyfluorfen 152.8 g /ha. Among the herbicidal treatments cyhalofop-butyl 75.0 g /ha resulted higher effective panicles, grains per panicle, panicle length (cm), panicle weight, test weight(g), grain yield, straw yield and net return followed by cyhalofop butyl 80 g /ha and cyhalofop butyl 80 g /ha.

CONCLUSION

Based on one year study it may be concluded that application of cyhalofop-butyl 75.0 g /ha could be the feasible option for minimum weed growth, higher yield and more remunerative in direct-sown rice.

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ARRW/SIRC/Theme II/59

Nutrient and water management influence the dynamics of some cationic micronutrients in soil and rice yield

Md. Wahiduzzaman*, Kaila Tara Meghna, Himadri Saha, Dipshikha Chakrabarty, Subhajit Pal, Prasanta Kumar Patra

Bidhan Chandra Krishi Viswavidalaya, Mohanpur, Nadia, 741252, West Bengal, India
**mdwahiduzzaman97@gmail.com*

Chemical fertilizer based imbalanced use of nutrients and faulty water management practices over the years have resulted in deficiency of micronutrients leading to decline in soil fertility and yield of rice crop (Singh *et al.*, 2001) necessitating adoption of strategies of integrated nutrient management (INM) along with optimum use of irrigation water. The present work reports the results on the impact of INM and water management on the availability of cationic micronutrients viz., Fe, Mn, Zn and Cu in rhizosphere soil in relation to growth and yield of rice (cv. Shatabdi) in an Alluvial soil of West Bengal.

METHODOLOGY

A pot culture experiment was carried out at BCKV, Kalyani, Nadia, West Bengal, India to study the effect of three water management practices viz., (I_1) Farmer's common practice *i.e.,* 3-5cm of standing water throughout the crop growth periods; (I_2) Irrigation at soil hair crack stage during vegetative phase + 3 cm of standing water through panicle initiation and flowering stage, and (I_3) Moist condition throughout the cropping season and six nutrient management treatments comprising (i) N_1:100 % RDF (100: 50: 50:: N: P_2O_5:K_2O kg ha^{-1}) + Neem Cake @2 t ha^{-1}; (ii) N_2: 25% N from Vermicompost + 75% N from Urea + P_2O_5 + K_2O + Neem Cake @ 2 t ha^{-1}; (iii) N_3: 50% N from Vermicompost + 50% N from Urea + P_2O_5 + K_2O + Neem Cake @ 2 t ha^{-1}; (iv) N_4: 75% N from Vermicompost + 25% N from Urea + P_2O_5 + K_2O + Neem Cake @ 2 t ha^{-1}; (v) N_5: 100% N from Vermicompost + P_2O_5 + K_2O + Neem Cake @ 2 t ha^{-1} and (vi) N_6: 100 % RDF (100: 50: 50:: N:P_2O_5: K_2O), replicated thrice in a Factorial CRD. The amount of fertilizer N, P_2O_5

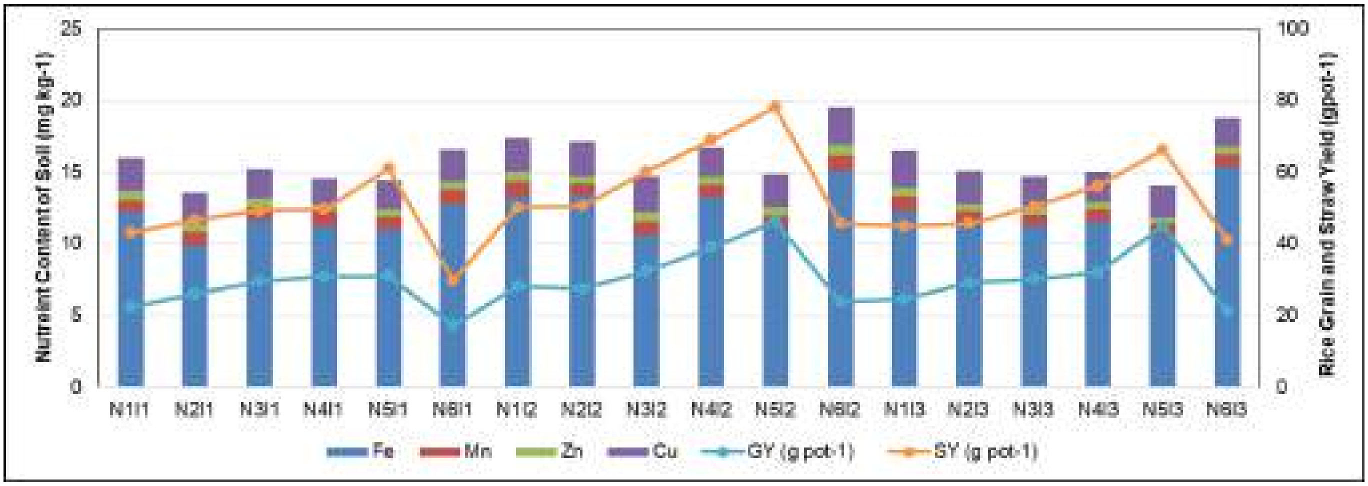

Fig-1. Influence of water and nutrient management on the mean DTPA extractable cationic micro-nutrient content in rhizosphere soil (averaged over the three growth stages) and grain and straw yield of rice.

and K_2O to be applied were ascertained after calculating their contents in the applied organic manures and deducting the values from the RDF. Rhizosphere soil samples collected from the rice rhizosphere during the three critical growth stages *viz*., tillering, flowering and harvesting, were analyzed for different micronutrient contents. Grain yield (GY) and straw yield (SY) were also recorded. The generated data were statistically analyzed following standard methods.

RESULTS

The interactive effect of water and nutrient management significantly influenced the DTPA extractable Fe, Mn, Zn and Cu content (mgkg^{-1}) of rhizosphere soil (Fig -1) and rice grain and straw yield. The lowest grain yield of 17.25 g pot^{-1} was recorded in N_6I_1 while the highest grain yield (46.25) was observed under N_5I_2 where irrigation was applied at soil hair crack stage.

CONCLUSION

The combined effect of water and nutrient management effectuated significant influence on micronutrient availability in the rice rhizosphere soil and grain yield of rice compared to their individual effects. Treatment combination N_5I_2, N_5I_3, N_4I_2, N_4I_3 proved their superiority producing higher grain and straw yield in the experimental soil. The present pot culture experiment though generated valuable information on the dynamics of cationic micronutrients in rice rhizosphere soil, the results need to be validated in the field across different soil and agro-climatic conditions before scaling up.

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ARRW/SIRC/Theme II/60

Optimising the yield of rice through P management in relation to Rhizosphere pH

Soubhik Pal*, Sk Md Asif, Arup Sen and Abhijit Debnath

Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal 741252, India

Presenting Author's Email: soubhikpal999@gmail.com

Rice is a staple food for the maximum global population; however, poor management of resources is a serious concern in rice cultivated areas of south-east Asia. Enormous P has been applied to the World's rice cultivated soil yet we know little about its effect on performance. Excessive amount of phosphorus in soil is reported to cause toxicity to many crops as well as high phosphorus application modifies soil pH. These are not desired considering resource management and yield. This necessitates identifying an appropriate combination of phosphorus level and soil pH. In the present study an attempt has been made to determine the role of soil pH and levels of P on the rhizosphere pH ,nutrient uptake and yield of Rice (*Oryza sativa).*

METHODOLOGY

Surface soil sample 0-20cm was collected from Regional Research Station, B.C.K.V., Jhargram, West Bengal. The collected soil was modified to obtain five different pHs ranging from 3.7 to 7.1. Rice (MTU-7029) was grown in the modified soils with 10 levels of phosphorus for about 21 days with moisture levels maintained at 70% of WHC. Roots, with mono layer (~2 mm) soil adhered, were collected to measure the rhizosphere pH. Uptake of P and Fe, Cu, Mn, Zn were measured and yield response was obtained using a modified Mitscherlich equation.

RESULTS

The findings revealed that the levels of P had differing ability to modify the rhizosphere pH that favours nutrient uptake. At low pH, P application increased the rhizosphere pH to a lesser extent; in neutral to alkaline soil it decreased it to a greater extent. P application increased the P uptake progressively while the dry matter yield of crops decreased after a certain level. The dry matter yield was highest when external soil pH was near 6.6 and when the rhizosphere pH was 5.5. Uptake of P in rice was in general high in soil pH range 5.5 to 6.5 when desorption of P from soil was lowest. Uptake of Zn, Cu, Fe in rice plant tissues gradually decreased with increasing pH and levels of P. High level of P lowered the Mn uptake and a pH range of 5.5 to 6.5 may be considered suitable.

CONCLUSION

The present study suggests that priority should be given to consider the rhizosphere pH of rice and P level for yield maximisation and resource management.

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ARRW/SIRC/Theme II/61

Comparative analysis of rice straw management options in summer rice

Madhusmita Bal*, Bhagyashree Behera, Sanat Kumar Dwibedi, Prabhasmita Shatpathy, Kailash Chandra Samal

Odisha University of Agriculture and Technology, Bhubaneswar-751003
**Author for correspondence e-mail: bal.madhusmita9@gmail.com*

Rice not only is the most important crop throughout Asia, but also produces maximum residue. It would be a boon if the utilization of the residue can increase the yield in a rice-rice cropping system by impacting different morphological, physiological, and yield-attributing parameters. Managing the residue properly can also solve the environmental issues that arises due to the traditional farmer's practice of open burning the straw *in-situ*. Biochar derived from pyrolytic combustion of rice straw has the power of addressing all the future issues of rice production and making it a sustainable one (Kamara *et al*., 2015). Similarly, other residue management options like straw incorporation and subsequent application of waste decomposer have its own advantages of solving the dual problem, management of residue and increase in yield. In our experiment we have tried to analyse the yield advantages of different residue management options by assessing the crop's growth physiology; with and without use of soil test based chemical fertilizer application.

METHODOLOGY

Rice variety Lalat (IET-9947) was cultivated in the field in a Factorial Randomised Block Design (FRBD) with two factors, first factor having two levels viz. soil test-based fertilizer recommended (STBFR) application (F_2) and no fertilizer (F_1) (control); and the other factor was rice residue management options with five levels viz. residue removal (T_1), open burning of rice residues (T_2), soil incorporation of straw (T_3), straw incorporation with waste decomposer application (T_4), and straw biochar incorporation (T_5). The treatments were replicated thrice. The straw of previous season rice crop cv. Swarna (MTU-7029) was used in the experiment. Biochar was prepared in a metallic drum-klin at 350 ^oC by burning straw anaerobically for 1 hour and 30 minutes based on thermogravimetric analysis. Soil test-based fertilizer dose of 100:30:40 kg ha^{-1} of $N:P_2O_5:K_2O$ (N- low, P- high, and K- medium) was applied. Morphological, physiological, and biochemical parameters were recorded first after 15 days after planting (DAP) and then twice at 30 days intervals. The internal structure of rice straw, open burnt straw, and rice straw biochar were visualized under the scanning electron microscope (SEM) to observe comparative thermal (burnt straw) and thermochemical (biochar) induced structural modification in rice straw.

RESULTS

The SEM analysis of rice straw, straw biochar and open burned straw revealed that the pores of the rice straw changed with thermodynamic effects of open burning and pyrolysis from irregular fibrous pores in dry straw to regular roundish carbonized pores in biochar. However, the surface morphology of open burnt rice straw was intermediate to the above two biomasses. The pore size in biochar varied from 50 to 100 µm (Lu and Zung, 2018)

Application of STBFR-based chemical fertilizer resulted increase in all most all morphological, physiological and biochemical parameters over the control i.e. without chemical fertilizer. Among the residue management practices incorporation of straw along with the application of waste decomposer was more effective in increasing plant height, tiller number, leaf area, plant dry weight and other morphological parameters as well. It also resulted in maximum chlorophyll a, b and carotenoid content, maximum leaf and grain protein content, highest carbohydrate content and grain and straw N, P and K content during the initial growth stages. Whereas biochar has also shown its efficacy in the latter part of the crop growth stages and its effect on the morphology and physiology of the crop was found to be at par with the incorporation of straw and waste decomposer application. The residue removal and open burning trailed behind other residue management practices in recording most of the morpho-physiological parameters.

Among the treatments with different residue management practices, T_4 had the advantage of recording the highest mean grain (7.43 g hill^{-1}) and straw yield (10.17 g hill^{-1}). Whereas, T_1 had the least grain and straw yields. The mean grain yield was in order of T_4H~T_5>T_3>T_2>T_1 with 1.07%, 5.12%, 6.46%, and 11.17% reduction in T_5, T_3, T_2 and T_1 from T_5, respectively.

CONCLUSION

Instead of burning the straw in the field itself, it can be managed in different ways in order to improve soil health and ultimately increase yield without impacting our environment. Complete removal the straw as well as open burning of the straw results in nutrient loss. Biochar prepared out of crop residue has a long-term impact and the results are visible towards the latter part of the crop growth or maybe in the next crop season. The incorporation of straw along with the application of waste decomposer has a tremendous impact on the growth physiology of the crop as it helps in faster availability of nutrients. So the farmers should opt for managing the crop residue instead of wasting them in order to get higher yield and healthy soil and environment.

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Residue incorporation affects morpho-physiology, growth, yield and composition of lowland rice

Jevelin Swain*, Rajendra Kumar Panda, Rabindra Kumar Paikray and Rabindra Kumar Nayak

College of Agriculture, Odisha University of Agriculture & Technology, Bhubaneswar, Odisha-751003
**Corresponding author: jevelinswain1997@gmail.com*

Research on improved rice residue management can help reduce the environment footprint and enhance revenue from rice production. Recycling of crop residue is an essential component in achieving sustainability and improvement in soil condition leads to better crop growth and yield. Paddy straw incorporation affects physiological and chemical properties of soil, accelerates the decomposition of organic matter and adds a lot of energy to microorganisms, the number and activities of various microorganisms increase accordingly. So, the present study aimed its effect on crop growth, yield and composition of rice.

METHODOLOGY

A field experiment was carried out during *rabi*' 2020-2021 at Central farm, College of Agriculture, Bhubaneswar, Odisha. The cultivar, Lalat, was transplanted in a Randomized Block Design with six treatments viz., paddy straw (residue) removal (T1), residue burning (T2), paddy straw incorporation (T3), paddy straw incorporation +20 kg N/ha (T4), paddy straw incorporation + 20 kg N/ha+20 kg P2O5/ha(T5) and paddy straw incorporation + waste decomposer of (T6) and was replicated four times. The chemical analysis of protein, total soluble carbohydrates and total free amino acid were analysed spectrophotometrically as per standard protocol available. Estimation of C, H, N, S percentage was analysed by CHNS(O) analyser (Elementar, model- UNICUBE,070721) through "flash combustion". Different growth attributes on physiological parameters like LAI, CGR, LAD (Vijayaprabhakar *et al.,* 2020) and yields parameters were evaluated at different growth stages. Microbial populations like bacteria, actinomycetes and fungi were also counted as per Gaind et al.2007. The microbial population was exposed as number of colonies forming units per gram of the soil. The data generated were statistically analysed following Cropstat7. 0..

RESULTS

Results revealed that the plant height, tiller number, total number of leaves per hill, SLA, CGR, SPAD value, protein, carbohydrate and free amino acid contents were highest in T5 and lowest in T2, The highest grain, straw yield, HI (48%), 1000-seed weight (24.27 g), number of filled grain per panicle (143.5) was also recorded in T5. Rice grain quality related to the amount of C, H, N and S showed highest grain N%, C%, H% in T5 followed by T4 and T6 indicating proper translocation of nitrogen to grain. The population of bacteria, actinomycetes and fungi was found highest in T5 (52.5×10^6, 39.5×10^4 ,41.25×10^3 cfu/g).

CONCLUSION

It may be concluded from the present study that rice straw incorporation could be a sustainable supplement along with RDF.

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ARRW/SIRC/Theme II/63

Effect of nutrition methods on growth, yield and economics of aromatic rice (*cv. Harinakhuri*)

Preetam Biswas*, Mrityunjay Ghosh, Sukanta Pal and Gagan Mudi

Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal 741252, India
Presenting Author's Email: preetam.biswas.1@gmail.com

Harinakhuri, a non-Basmati aromatic rice landrace, is grown in sporadic pockets in lower *gangetic* plains of West Bengal for a long time. It has recently been registered as a Farmers' Variety (No. 148 of 2020) under Protection of Plant Varieties and Farmers' Rights Authority, Government of India. Farmers traditionally use cattle manure for nutrition of Harinakhuri rice, but more recently in combination with chemical fertilizers. The use of vermicompost is a new option in present-day agriculture production system, and leaf colour chart (LCC)-based top dressing of nitrogen is advised for real time N management as well as to avoid overuse of N fertilizer in rice farming. Keeping these in view, the present study was undertaken to find out suitable nutrient management schedule(s) for Harinakhuri rice in *gangetic* delta region.

METHODOLOGY

A field trial was carried out at the Instructional Farm of the Bidhan Chandra Krishi Viswavidyalaya (BCKV), Jaguli, Nadia, West Bengal during wet (*kharif*) season in 2019. The experiment consisted of nine nutrient management practices *viz*. Control, Recommended dose of fertilizer (RDF) @ $N_{40}P_{20}K_{20}$ kg ha^{-1}, Farm yard manure (FYM) @ 8 t ha^{-1}, Vermicompost (VC) @ 4 t ha^{-1}, FYM @ 4 t ha^{-1} + $N_{20}P_{10}K_{10}$ kg ha^{-1}, VC @ 2 t + $N_{20}P_{10}K_{10}$ kg ha^{-1}, FYM @ 4 t + Mustard cake (MC) @ 0.4 t ha^{-1}, VC @ 2 t + MC @ 0.4 t ha^{-1}, and Leaf colour chart (LCC)-based N @ 15 kg ha^{-1}, in a randomised block design (RBD) with 3 replications. Transplanting of 32-day old seedlings of Harinakhuri rice was done using 2-3 hill^{-1} in well-puddled field. The crop management practices were adopted as per standard recommendations (Ghosh, 2019). Plant height, lodging, yield components and grain yield were recorded at maturity. The total cost of cultivation, net return, and B:C ratio were computed taking into account the current market prices of the inputs, outputs and labour wages.

RESULTS

Plants received RDF ($N_{40}P_{20}K_{20}$ kg ha^{-1}) were taller at harvest (125.0 cm), being at par with the integrated nutrient management (FYM @ 4 t + $N_{20}P_{10}K_{10}$ kg ha^{-1}), while unfertilized control plot recorded the shortest plants (114.0 cm) in the study (Table 1). However, Raikar *et al*. (2009) reported that integrated nutrient management (FYM + inorganic fertilizer) resulted in significantly greater plant height over organic nutrient management module and farmers' practice in Karnataka, India. The plants of Harinakhuri rice showed variations in lodging susceptibility at the hard dough stage under different nutrition methods; where plants nourished with $N_{40}P_{20}K_{20}$ kg ha^{-1} lodged completely (scoring 5.0), and those fertilized with LCC-based N-nutrition showed slight lodging tendency (score 2.3).

The maximum number of panicles (258.5) in 1 m^2 was noted with the nutrient schedule of FYM @ 4 t + $N_{20}P_{10}K_{10}$ kg ha^{-1}, and that was closely followed by $N_{40}P_{20}K_{20}$ kg ha^{-1} (257.4 m^{-2}), VC @ 2 t + $N_{20}P_{10}K_{10}$ kg ha^{-1} (244.2 m^{-2}) and FYM @ 8 t ha^{-1} (238.7 m^{-2}), being significantly greater over rest of the nutritional treatments. The number of filled grains panicle^{-1} varied between 80.6 (control) and 94.5 (FYM @ 8 t ha^{-1}). The 1000 seed weight of scented Harinakhuri rice remained

Table 1. Plant characters, yield and economics of aromatic rice (*cv*. Harinakhuri) under various nutrient management in lower *gangetic* plains of West Bengal

Treatment	Plant height (cm) at harvest	Panicles m^{-2}	Filled grains $panicle^{-1}$	1000 grain weight (g)	Grain yield (tha^{-1})	Lodging (score)	Net income ($Rs.ha^{-1}$)	B:C ratio
Control	114.0	204.5	80.6	17.28	2.00	2.3	26,497	1.68
$N_{40}P_{20}K_{20}$ kg ha^{-1}	125.0	257.4	90.1	18.05	2.57	5.0	42,126	2.02
FYM @ 8 t ha^{-1}	117.3	238.7	94.5	17.81	2.12	3.7	22,280	1.47
VC @ 4 t ha^{-1}	118.3	226.5	88.8	18.21	2.30	3.7	19,980	1.36
FYM@4 t+$N_{20}P_{10}K_{10}$ kg ha^{-1}	121.6	258.5	90.4	18.14	2.53	4.3	38,070	1.86
VC @ 2 t+$N_{20}P_{10}K_{10}$ kg ha^{-1}	117.7	244.2	93.8	17.55	2.35	3.7	28,403	1.59
FYM@ 4 t +MC @ 0.4 t ha^{-1}	118.8	223.8	90.4	17.98	2.35	3.0	24,730	1.48
VC @ 2 t + MC @ 0.4 t ha^{-1}	120.7	237.7	91.9	18.00	2.50	2.7	25,130	1.45
LCC based N @ 15 kg ha^{-1}	120.8	221.1	88.7	18.15	2.18	2.3	30,611	1.75
SEm	1.37	6.77	2.32	0.89	0.08	0.45		
CD (P<0.05)	4.10	20.30	6.94	NS	0.26	1.35		

Scoring of lodging in 9-point scale (1: no lodging, 3: most plants slightly lodged, 5: most plants completely lodged, 7: most plants nearly flat, and 9: all plants flat); Cost of inputs: Seed= Rs. 50 kg^{-1}, FYM= Rs. 1 kg^{-1}, VC= Rs. 4 kg^{-1}, and MC= Rs. 23 kg^{-1}; Price of grain: Rs. 30 kg^{-1}; Price of straw: Rs. 1 kg^{-1}

unaffected under different nutrition methods adopted in the experiment, and mean test weight of the cultivar was 17.90 g. The highest grain yield (2.57 t ha^{-1}) was obtained from the plots receiving 100% inorganic fertilizers only, which was comparable to integrated nutrient management with FYM @ 4 t + $N_{20}P_{10}K_{10}$ kg ha^{-1} (2.53 t ha^{-1}) and VC @ 2 t + MC @ 0.4 t ha^{-1} (2.50 t ha^{-1}). Similarly, scented rice (Birsamati) grown with recommended inorganic fertilizer produced higher grain yield than the best combination of organic sources (Green manuring @ 5 t ha^{-1} + FYM @ 10 t ha^{-1}) at Ranchi, Jharkhand (Kumari *et al*., 2010).

The total cost of cultivation of Harinakhuri rice varied between Rs. 38,820 ha^{-1} and Rs. 56,020 ha^{-1} at Jaguli, Nadia due to variations in cost of fertilizers, manures and oil cake used in the study (data not shown). Chemical fertilizer-based nutrition ($N_{40}P_{20}K_{20}$ kg ha^{-1}) led to the highest net income (Rs. 42,126 ha^{-1}) and B:C ratio (2.02) due to lower cost of fertilizers compared to manures and oil cakes, while application of VC @ 4 t ha^{-1} resulted in marginal profit and B:C ratio (Rs. 19,980 ha^{-1} and 1.36).

CONCLUSION

The maximum grain yield (2.57 t ha^{-1}), net income (Rs. 42,126 ha^{-1}), and B:C ratio (2.02) of Harinakhuri rice were obtained from the plots receiving chemical fertilizer-based nutrition ($N_{40}P_{20}K_{20}$ kg/ha); however, integrated nutrition (FYM @ 4 t + $N_{20}P_{10}K_{10}$ kg ha^{-1}) might be an alternative option for sustainable cultivation (2.53 t ha^{-1} and Rs. 39,070 ha^{-1}) in the lower *gangetic* plains of West Bengal.

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Phenology, growth and yield of aromatic rice cultivars in red and laterite zone of West Bengal

Sabuj Pati*, Sibajee Banerjee, Mrityunjay Ghosh, Chaitan Soren and Tapas Biswas

Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal 741252, India

Presenting Author's Email: sabujpati1995@gmail.com

The cultivation of traditional rice varieties in farmers' fields has been continuously decreasing after the introduction of high-yielding varieties (HYVs) in the country. But these HYVs need higher inputs compared to rice landraces, and they cause degradation of soil health in the long-run. The lateritic region of the state is characterized by high summer temperature, less monsoon rainfall and poor soil quality. Farmers in such dry farming area experience with non-remunerative rice farming, so they look for alternative suitable rice varieties for better income in resource-poor agriculture system. In the context, aromatic or high-value or good quality table rice varieties having comparable yield potentiality and adaptability dry land areas may good options (Sinha et al., 2017). Keeping these in view, the present study was undertaken to study the phenological development, growth habit and yield performance of sporadically available scented rice cultivars of the state for selection of suitable one(s) in Red and Laterite Zone of West Bengal.

METHODOLOGY

A field experiment was conducted during wet (*kharif*) season of 2021 at Bidhan Chandra Krishi Viswavidyalaya (BCKV), Regional Research Sub-Station, Red and Laterite Zone, Raghunathpur, Purulia, West Bengal, India. 12 indigenous non-Basmati type aromatic rice cultivars [*viz*. Gobindabhog, Gopalbhog, Harinakhuri, Kalojira, Kataribhog, Lal Badshabhog, NC 324, NC 365, Radhatilak, Radhunipagal, Tulaipanji, Tulshibhog] were tested in Randomized Block Design (RBD) with 3 replications. Seeds of these cultivars collected from RKVY Project on 'Bengal Aromatic Rice', BCKV and transplanting was done with 25 day-old seedlings at a spacing of 20 cm × 15 cm in puddled field. A uniform fertilizer dose of 40:20:20 kg ha^{-1} was applied to all the experimental units and other crop management practices were adopted as per standard recommendations. The phenological development of the crop was noted by field visits at 3-4 days interval from sowing to maturity. The growth attributes, lodging and grain yield were recorded following standard methods.

RESULTS

Among 12 aromatic rice landraces, the number of days to maturity varied between 120.0 days (Lal Badshabhog) and 151.0 days (Gobindabhog and Gopalbhog) (Table 1). Perusal of data revealed that all aromatic rice cultivars were long-duration types (>140 days), while Lal Badshabhog (120.0

Table 1. Phenological development of aromatic rice cultivars in West Bengal during wet (*kharif*) season

Cultivar	Phenophase duration (days)					
	S–E	E–AT	AT–F	F–D	D–M	S–M
Gobindabhog	6.0	45.3	67.0	20.3	12.3	151.0
Gopalbhog	7.0	45.7	67.3	20.7	10.3	151.0
Harinakhuri	5.0	43.7	61.3	19.0	14.3	143.3
Kalojira	5.0	44.0	61.7	20.0	10.7	141.3
Kataribhog	6.0	44.7	60.7	21.7	16.0	149.0
Lal Badshabhog	5.0	40.3	46.0	19.0	9.7	120.0
NC 324	5.0	44.3	62.7	20.0	11.0	143.0
NC 365	6.0	45.3	61.0	21.7	10.7	144.7
Radhatilak	5.0	45.0	59.3	19.7	17.0	146.0
Radhunipagal	5.0	44.7	61.0	21.3	17.0	149.0
Tulaipanji	6.0	46.0	51.7	16.3	16.7	136.7
Tulshibhog	6.0	45.0	59.3	21.0	11.0	142.3

S= Sowing, E= Emergence, AT= Active tillering, F= Flowering, D= Dough stage, M= Maturity

Table 2. Growth and yield of aromatic rice cultivars in West Bengal during wet (*kharif*) season

Cultivar	Plant height (cm) at flowering	Lodging (score)	Tillers m^{-2} at panicle initiation stage	LAIat 56 DAT	DM accumulation (g m^{-2}) at flowering	Panicle length (cm)	Grain yield (t ha^{-1})
Gobindabhog	163.4	5.7	398.6	5.39	1392.3	23.6	2.92
Gopalbhog	172.3	5.7	335.1	5.93	1408.5	28.2	3.13
Harinakhuri	163.4	1.0	364.6	6.40	1350.1	27.8	3.56
Kalojira	175.7	5.0	395.1	5.85	1366.0	29.0	3.26
Kataribhog	178.6	6.3	461.7	5.77	1358.5	24.7	2.46
Lal Badshabhog	177.3	7.0	396.8	5.31	1326.4	27.3	2.07
NC 324	165.8	6.3	457.3	5.69	1005.4	25.9	3.38
NC 365	175.4	6.3	383.2	5.35	1109.3	30.8	3.41
Radhatilak	167.3	6.3	378.3	4.91	1067.8	28.2	3.06
Radhunipagal	175.4	7.0	369.0	5.06	1281.8	27.3	3.19
Tulaipanji	156.7	7.7	482.2	4.95	1236.5	28.8	2.36
Tulshibhog	171.8	6.3	383.2	4.22	1325.7	25.6	2.82
SEm±	4.40	0.86	27.01	0.39	63.69	0.51	0.14
CD (P=0.05%)	12.99	2.55	79.73	NS	188.01	1.51	0.43

days) and Tulaipanji (136.7 days) belonged to medium and medium-late category, respectively. The shortest duration of Lal Badshabhog was mainly due to less days required during active tillering to flowering stage (46.0) compared to rest of the cultivars. Mean cultivar days from sowing to emergence, active tillering, flowering, dough and maturity stages were 5.6, 50.1, 110, 130.1 and 143.1 days, respectively.

Plant height was found to vary between 156.7 (Tulaipanji) and 178.6 cm (Kataribhog) at flowering; number of tillers m^{-2} between 335.1 (Gopalbhog) and 482.2 (Tulaipanji) at panicle initiation stage, LAI between 4.22 (Tulshibhog) and 6.40 (Harinakhuri) at 56 DAT and DM accumulation between 1005.4 (NC 324) and 1408.5 g m^{-2} (Gopalbhog) at flowering (Table 2). Although Harinakhuri remained unlodged (score 1.0), but other varieties showed complete lodging (score 5.0-7.7) at dough stage. NC 365 produced the longest panicle (30.8 cm), while Gobindabhog had shortest panicle length (23.6 cm). The highest grain yield was recorded with Harinakhuri (3.56 t ha^{-1}) being closely followed by NC 365 (3.41 t ha^{-1}), NC 324 (3.38 t ha^{-1}), Kalojira (3.26 t ha^{-1}), Radhunipagal (3.19 t ha^{-1}) and Gopalbhog (3.13 t ha^{-1}); while Lal Badshabhog produced the lowest grain yield (2.07 t ha^{-1}).

CONCLUSION

All aromatic rice cultivars were long-duration types (>140 days), while Lal Badshabhog (120.0 days) and Tulaipanji (136.7 days) belonged to medium and medium-late category, respectively. Harinakhuri appeared best due to maximum grain yield (3.56 t ha^{-1}) and non-lodging character, while other six cultivars (NC 365, NC 324, Kalojira, Radhunipagal, Gopalbhog and Radhatilak) could also be selected as promising ones (grain yield >3.0 t ha^{-1}) for cultivation in Red and Laterite Zone of West Bengal, India.

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ARRW/SIRC/Theme II/65

Effect of nitrogen top-dressing methods on traditional rice cultivars in lower *gangetic* plains

Sibajee Banerjee*, Sabuj Pati, M. Ghosh, Sumantan Basu, P. Bhowal, S. Bhattacharya and S. Bhowmick

Bidhan Chandra Krishi Viswavidyalaya, Mohanpur 741252, Nadia, West Bengal, India
**Presenting Author's E-mail: sibajee.bckv@gmail.com*

Efficient and judicious nitrogen management in rice farming is important for desired growth and productivity. Split dose of nitrogen fertilizer in the ratio of 2:1:1 or 1:2:1 at basal, tillering and panicle initiation stages, respectively is most common practice by Indian farmers, without looking on whether the plant really requires N at that time or not. This leads to either loss or a gap between N supply and actual crop N demand. Therefore, precise application of N-fertilizer based on plant need will greatly help in improving the fertilizer use efficiency in rice. The use of neem coated urea is presently advised due to its slow N release capacity, and nano urea is a recent introduction in Indian agriculture for its higher use efficiency and low cost involvement.

METHODOLOGY

A field experiment was conducted during wet (*kharif*) season of 2022 at Instructional Farm of Bidhan Chandra Krishi Viswavidyalaya, Jaguli, Nadia, West Bengal, India. Twelve treatments combinations, replicated thrice, were allocated in Split-plot design comprising 3 cultivars (Harinakhuri, Dudheswar, Kanakchur) in main plots, while 4 N-top dressing methods (Control, Top dressing with Urea @ 15 kg N ha^{-1} at 3 and 6 WAT, LCC-based top dressing with Neem coated urea @ 15 kg N ha^{-1} at each time, and Top dressing with Nano urea @ 0.4% each time) in sub-plots. A uniform basal dose of N:P_2O_5:K_2O @ 20:25:15 kg ha^{-1} and one top dressing of K_2O @ 10 kg ha^{-1} at 6 WAT was applied through chemical fertilizers in all the experimental plots. The seeds of tested cultivars collected from RKVY Project on 'Bengal Aromatic Rice' were sown in wet nurseries and 32 days old seedlings were transplanted using 2-3 seedlings hill^{-1} at a spacing of 20 cm × 15 cm in 3 m × 3 m plots. The growth attributes, lodging susceptibility, yield components, grain and straw

Table 1. Effect of N-top dressing methods on growth attributes and lodging of traditional rice cultivars during wet (*kharif*) season

Treatment	Plant height (cm) at harvest	Tillers m^{-2} at 60 DAT	LAI at 60 DAT	DM production (g m^{-2})		CGR (g m^{-2} day^{-1}) 60-100 DAT	Lodging (score)
				60 DAT	100 DAT		
Cultivar							
Harinakhuri	133.6	261.4	4.15	374.0	692.7	7.97	2.0
Dudheswar	158.5	238.9	3.76	411.6	672.3	6.52	3.7
Kanakchur	154.9	248.3	3.95	347.6	599.6	6.30	6.5
SEm±	3.47	11.04	0.36	24.08	24.58	0.19	0.51
CD (P=0.05%)	13.98	NS	NS	NS	NS	0.76	2.05
N-Top dressing							
Control	145.0	224.1	3.41	344.6	640.6	7.40	3.7
Urea @ 15 kg ha^{-1} at 3 and 6 WAT	151.2	271.8	4.32	386.7	664.3	6.94	4.6
LCC-based NCU @ 15 kg ha^{-1} each time	151.2	262.9	4.26	427.6	650.3	5.57	4.3
Nano urea @ 0.4% at 3 and 6 WAT	148.6	239.2	3.82	351.9	664.1	7.80	3.7
SEm±	1.01	9.18	0.22	14.96	12.77	0.45	0.36
CD (P=0.05%)	3.03	27.47	0.66	44.80	NS	1.35	NS

NCU= Neem coated urea

Table 2. Effect of N-top dressing methods on yield attributes & grain yield of traditional rice cultivars during wet (*kharif*) season

Treatment	Panicle length (cm)	Panicles m^{-2}	Filled grains $panicle^{-1}$	1000 grains weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index
Cultivar							
Harinakhuri	25.5	217.3	122.3	16.57	2.39	6.05	0.28
Dudheswar	24.6	183.6	146.6	16.52	2.04	6.17	0.25
Kanakchur	27.6	196.5	79.8	18.20	1.47	4.75	0.24
SEm±	0.32	4.61	1.34	0.27	0.06	0.99	0.04
CD (P=0.05%)	1.29	13.61	5.38	1.07	0.25	NS	NS
N-Top dressing							
Control	25.5	189.8	107.1	16.68	1.71	5.06	0.25
Urea @ 15 kg ha^{-1} at 3 and 6 WAT	26.2	201.3	130.4	17.24	1.96	5.75	0.25
LCC-based NCU @ 15 kg ha^{-1} each time	26.2	213.9	114.1	17.67	2.06	6.31	0.25
Nano urea @ 0.4% at 3 and 6 WAT	25.5	191.6	113.3	16.79	1.94	5.50	0.26
SEm±	0.13	5.32	1.60	0.21	0.04	0.25	0.01
CD (P=0.05%)	0.39	15.72	4.79	0.62	0.11	0.76	NS

NCU= Neem coated urea

yield, and harvest index were recorded following standard methods.

RESULTS

The higher values of growth attributes like plant height at harvest, tiller production in 1 m^2 and LAI at 60 DAT, and dry matter yield at 60 and 100 DAT, and CGR at 60-100 DAT were recorded in all three N-top dressing plots over control plots receiving no N-top dressing (Table 1). The application of nano urea had little effect on growth habit of tested rice cultivars over control, which indicated its less efficiency compared to urea and neem coated urea. Although Dudheswar recorded maximum plant height at harvest (158.5 cm), but Kanakchur showed greater lodging susceptibility (score 6.5) at maturity compared to other two cultivars.

The yield components *viz*. number of panicles m^{-2}, number of filled grains $panicle^{-1}$ and 1000 grain weight of three special-type rice cultivars of South Bengal varied significantly among four nutritional treatments in the study (Table 2). Harinakhuri recorded maximum grain yield (2.39 t ha^{-1}) mainly due to greater number of panicles m^{-2} (217.3) compared to other 2 cultivars, and Kankchur appeared as a poor yielder (1.47 t ha^{-1}). LCC-based top dressing with Neem coated urea @ 15 kg N ha^{-1} at each time produced longer panicles (26.2 cm), maximum number of panicles m^{-2} (213.9), and higher test weight (17.67 g), which resulted in maximum grain yield (2.06 t ha^{-1}) compared to other N-top dressing treatments. Similar finding for greater production of Sona Mahsuri (BPT 5204) through LCC-based N application was reported by Reddy and Pattar (2006) in Karnataka.

CONCLUSION

The application of N:P_2O_5:K_2O @ 20:25:15 kg ha^{-1} as basal followed by LCC-based top dressing with Neem coated urea @ 15 kg N ha^{-1} at each time and K_2O @ 10 kg ha^{-1} at 6 WAT led to optimum crop growth, and ultimately higher grain yield (2.06 t ha^{-1}) compared to other N top dressing treatments in the study. Harinakhuri might be selected for its higher yield potentiality (2.39 t ha^{-1}) and less lodging tendency (score 2.0) compared to Dudheswar and Kanakchur in lower *gangetic* plains of West Bengal.

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ARRW/SIRC/Theme II/66

Yield and concentration of micronutrients by rice as influenced by duration of variety and nitrogen fertilization

Souptik Sarkar*, Kallol Bhattacharyya, Samrin Parveen, Sudip Sengupta and Parijat Bhattacharya

Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal 741252

Presenting Author's Email: sarkarsouptik64@gmail.com

Rice is the primary food source for more than one third of world's population and provides 21 % of energy and 15 % of protein requirements of human populations globally (Mandal *et al.*, 2021; Sengupta *et al.*, 2021). India holds 2nd position in rice production globally (http://www.fao.org/india/fao-in-india/india-at-a-glance/en/).Rice,being very sensitive to zinc deficiency, is often used as an indicator crop (Khampuang et al., 2020). Zinc deficiency was first reported by Nene (1966) in India and is now reported to be widespread in Southeast. Nearly, 30% of the cultivated soils of West Bengal are deficient in plant available zinc. Deficiency of Fe in rice in India was first reported by Takkar and Nayyar (1979). High pH calcareous soils are frequently associated with Fe, Cu and Mn deficiencies (Singh et al., 2003; Chandel et al., 2010). The work was carried out to assess whether graded doses of nitrogen fertilizer along with majo r rice cultivars having different maturity durations can influence the pattern of micronutrient uptake and yield of the crop.

METHODOLOGY

The field experiment was carried out with boro rice during rabi season of 2022 at Soil Test Crop Response (STCR) field, Bidhan Chandra Krishi Viswavidyalaya, Gayeshpur in Nadia district encompassing the New Alluvial Zone of West Bengal. The experiment was arranged in a split plot design with three replications. Nitrogen fertilizer level (0, low, medium, high) in main plot and varieties (Satabdi, Pratikshya, Swarna masuri) in sub-plots were adopted. The 3 varieties are of different duration. Satabdi (IET 4786) is a mid-early duration (115 days) variety, Pratikshya (IET-15191) is a medium duration variety (125 days), Swarna masuri (MTU 7029) is a long duration variety (140-145 days). The field area of 33 m × 19 m was partitioned into four equal strips with 4 different Nitrogen fertilizer doses. Each strip was further divided into 9 plots where 3 varieties replicated 3 times each and they were allotted at random.

RESULTS

After harvest, it was observed that, with increase in nitrogen fertilization levels, both straw and grain yield of *boro* rice increased sharply, and the difference was statistically significant. The concentration of cationic micronutrients viz. Zn, Cu, Fe and Mn in both straw and grain were increased with increment in N application levels. However, both N application @100 kg ha^{-1} and @150 kg ha^{-1} registered statistically at par higher concentrations of Zn and Cu. For Fe and Mn concentrations in straw and grain, N application @ 150 kg ha^{-1} was found to have statistically significant effect as compared to N application @100 kg ha^{-1}.

Varietal influence on grain and straw yield as well as micronutrient uptake in harvest may be attributed to the life cycle pattern of short, medium and long duration varieties. Medium duration Pratikshya variety, being the medium duration one, significantly outperformed short duration Satabdi variety in terms of yield and micronutrient uptake. As relatively long duration rice varieties have a longer vegetative stage as compared to short duration varieties, it tends to assimilate more amount of macro and

Table 2: Effect of graded dosage of nitrogen fertilization and varieties on grain yield, Zn, Fe, Mn and Cu Conc. On grain of *boro* rice at harvest

Nitrogen	Grain Yield (t/ha)	Zn Conc. (mg/kg)	Fe Conc. (mg/kg)	Mn Conc. (mg/kg)	Cu Conc. (mg/kg)
N_1	3.00[a]	26.56[a]	149.48[a]	89.23[a]	6.95[a]
N_2	4.18[ab]	30.06[ab]	153.77[b]	93.92[b]	9.83[b]
N_3	5.26[b]	35.67[b]	159.07[c]	99.59[c]	15.16[c]
N_4	6.03[c]	36.23[b]	159.65[d]	100.14[d]	15.68[c]
VARIETY					
V_1	3.92[a]	31.34[b]	154.75[b]	93.68[b]	11.46[b]
V_2	5.36[c]	35.42[c]	163.55[c]	103.36[c]	13.88[c]
V_3	4.57[b]	29.63[a]	148.18[a]	89.97[a]	10.37[a]
N X V					
N_1V_1	2.22[a]	26.2[b]	148.55[b]	87.22[b]	6.28[b]
N_1V_2	3.81[b]	28.79[bc]	157.23[cd]	96.65[d]	8.79[bc]
N_1V_3	2.98[ab]	24.68[a]	142.65[a]	83.21[a]	5.77[a]
N_2V_1	3.61[b]	29.14[bc]	152.78[c]	91.33[bc]	9.77[c]
N_2V_2	4.83[d]	33.1[cd]	161.75[de]	101.47[e]	11.15[cd]
N_2V_3	4.11[c]	27.94[b]	146.79[ab]	88.96[b]	8.56[bc]
N_3V_1	4.58[cd]	34.78[d]	158.54[d]	97.89[d]	14.59[de]
N_3V_2	5.97[f]	39.67[e]	167.29[e]	107.34[f]	17.59[f]
N_3V_3	5.23[e]	32.55[c]	151.39[bc]	93.54[c]	13.29[d]
N_4V_1	5.28[e]	35.22[de]	159.12[d]	98.27[de]	15.21[e]
N_4V_2	6.83[g]	40.12[e]	167.94[e]	107.97[f]	17.97[f]
N_4V_3	5.97[f]	33.34[cd]	151.88[bc]	94.18[cd]	13.87[d]

Values with different alphabets are significantly different from each other according to the DMRT test ($P < 0.05$). Each value is a mean of three replicates. Where, N indicates nitrogen fertilization of 0(N_1), 50(N_2), 100(N_3) and 150(N_4) kg ha^{-1} soil; V indicates variety of rice Satabdi (V_1), Pratikshya (V_2) and Swarna masuri (V_3)

micronutrients both from native soil pools and external fertilizer application and those nutrients are ultimately translocated to grain and straw part at harvest

CONCLUSION

The Present study has been conducted to determine the effect of graded doses of nitrogen fertilization and duration of variety on the uptake of cationic micronutrients and yield of boro rice.

Gross reservation of farmer to apply micronutrients to rice based on soil test results often leads to micronutrient deficiency. Dovetailing management practices like application of 100-150 kg N ha^{-1} and cultivation of medium duration variety may be an efficient non-traditional approach for better micronutrient nutrition along with curtailment in cost of production and water use.

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ARRW/SIRC/Theme II/67

Assessment of soil properties in aromatic rice fields under organic *vs.* conventional management

Suprakash Ghosh*, Susanta K. Pal, Mrityunjay Ghosh, J.S. Basak, S. Roy and R. Mondal

Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal 741252, India
Presenting Author's Email: ghoshsuprakash3@gmail.com

Aromatic rice is traditionally cultivated using cattle manure for hundreds of years, but presently it is grown with chemical fertilizers or in combination with different nutrient sources for higher productivity. Grain quality is an important key issue in case of high-value rice along with long-term sustainability of production system. There is also an increasing demand for organic aromatic rice in domestic marketing and export system due to desired quality (Murali and Shetty, 2001). In such situation, the assessment of soil properties and nutrient status under both organic and conventional production system is needed for nutritional management of scented rice in different locations in native region.

METHODOLOGY

Three aromatic rice genotypes, namely Gobindabhog, Radhunipagal, and Kalojira are cultivated organically and conventionally at 3 locations [C-Block Farm (Kalyani, Nadia), Ushagram Trust (Birnagar, Nadia) and Siksha Niketan (Kalanabagram, Purba Bardhaman)] in 2 districts of West Bengal for more than 10 years. Conventionally-grown rice have been receiving NPK @ 50:25:25 kg ha^{-1}, while organically-produced rice genotypes generally receive FYM @ 5 t ha^{-1} along with Vermicompost @ 0.5 t ha^{-1} and Neemastra @ 3% twice at tillering and panicle initiation stage. The soil samples collected from the fields after harvesting of 3 aromatic rice cultivars (Gobindabhog, Radhunipagal and Kalojira) grown during wet (*kharif*) season, 2021 under both organic and conventional management were analyzed at Department of Soil Science, Bidhan Chandra Krishi Viswavidyalaya (BCKV), Mohanpur, Nadia, West Bengal, India. The physico-chemical properties (oxidizable organic carbon, pH and electrical conductivity), and nutrient status of soil (mineralizable N, available P_2O_5 and available K_2O) were determined following the standard methods. The statistical analysis of the data was done following split-plot design for 3 separate farms using OPI-STAT software.

Table 1. Physico-chemical properties of soil in aromatic rice fields at different locations in two districts of West Bengal

Treatment	Location								
	C-Block	Ushagram Trust	Sikhsa Niketan	C-Block	Ushagram Trust	Siksha Niketan	C-Block	Ushagram Trust	Siksha Niketan
	Organic carbon (%)			pH_w (1:2.5)			EC (dSm^{-1})		
Nutrient management									
Organic	0.69	0.77	0.69	6.63	7.57	7.15	0.25	0.25	0.25
Conventional	0.41	0.41	0.61	7.31	7.17	7.26	0.17	0.17	0.17
CD (P=0.05)	0.04	0.04	0.06	0.24	0.36	NS	0.03	0.05	0.02
Cultivar									
Gobindabhog	0.55	0.59	0.63	6.89	7.41	7.31	0.24	0.22	0.21
Radhunipagal	0.54	0.60	0.66	6.76	7.49	7.04	0.20	0.23	0.23
Kalojira	0.57	0.59	0.66	7.25	7.22	7.26	0.19	0.18	0.19
CD (P=0.05)	NS	NS	NS	0.30	NS	NS	0.04	NS	0.02

Table 2. Primary nutrient status in soil in aromatic rice fields at different locations in two districts of West Bengal

Treatment	Location								
	C-Block	Ushagram Trust	Sikhsa Niketan	C-Block	Ushagram Trust	Siksha Niketan	C-Block	Ushagram Trust	Siksha Niketan
		Av. N (kg ha^{-1})			Av. P_2O_5 (kg ha^{-1})			Av. K_2O (kg ha^{-1})	
Nutrient management									
Organic	156.7	145.3	140.8	24.8	25.2	23.5	181.8	211.8	193.1
Conventional	200.3	197.4	234.6	30.1	31.6	31.4	133.3	137.7	243.0
CD (P=0.05)	10.59	12.9	6.72	2.67	3.54	2.91	7.81	4.97	5.50
Cultivar									
Gobindabhog	198.3	158.7	187.0	24.6	27.4	27.2	171.5	177.9	224.7
Radhunipagal	163.8	167.5	183.4	31.4	28.5	27.6	163.1	170.0	220.1
Kalojira	173.5	187.8	192.6	26.2	29.3	27.6	138.1	176.4	209.4
CD (P=0.05)	12.97	15.77	8.23	3.27	4.34	3.56	9.57	6.09	6.74

RESULTS

Perusal of data in Table 1 revealed that the greater values of soil organic carbon (%) and pHw (1:2.5) and EC (dSm^{-1}) were usually noted with Ushagram Trust Farm among 3 locations in the study (Table 1). The organic carbon and pH in soil was much higher (0.69-0.77% and 0.25 dSm^{-1}) in all 3 farms irrespective of varieties than conventionally-managed fields (0.41-0.61% and 0.17 dSm^{-1}). The variations in pH (6.63-7.57) among all the farms indicated that the soil was neutral in reaction irrespective of the locations. The maximum organic carbon was mostly recorded in Kalojira rice fields (0.57 and 0.66%) compared to other two cultivars (Gobindabhog and Radhunipagal) in C-Block and Siksha Niketan farms. But EC in Kalojira rice fields was lowest (0.18-0.19 dSm^{-1}) compared to other 2 cultivars at all 3 locations in the study.

The available N, P_2O_5 and K_2O were significantly influenced among the treatments at 3 locations in the experiment (Table 2). The conventionally-managed aromatic rice fields across locations usually had greater N status (197.4-234.6 kg ha^{-1}) over organic fields (140.8-156.7 kg ha^{-1}). The available K_2O in soil was much higher (193.9-243.0 kg ha^{-1}) in Siksha Niketan Farm compared to C-Block Farm (138.1-181.8 kg ha^{-1}) and Ushagram Trust farm (137.7-211.8 kg ha^{-1}). Moreover, the maximum available K_2O (171.5-224.7 kg ha^{-1}) was recorded in Gobindabhog rice fields in all 3 farms compared to other two scented rice cultivars.

CONCLUSION

It can be concluded that combined use of FYM and Vermicompost for about 10 years resulted in higher organic carbon content and EC in soil, but these organically-managed farms had low nutrient status (N, P_2O_5 and K_2O) compared to conventional cultivation system. Conventionally-managed aromatic rice fields across locations usually had greater N status (197.4-234.6 kg ha^{-1}) over organic fields (140.8-156.7 kg ha^{-1}). The variations in pH (6.63-7.57) among all the farms indicated that the soil was neutral in reaction irrespective of the locations. The maximum available K_2O (171.5-224.7 kg ha^{-1}) was recorded in Gobindabhog rice fields in all 3 farms compared to other two scented rice cultivars.

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Physiological and morphological responses of rice varieties introgressed with drought QTLs under different levels of water deficit stress

Anjani Kumar, A K Nayak, Rahul Tripathi, Manish Debnath, Prashantkumar S Hanjagi, Rubina Khanam, Sangita Mohanty, E Venkatramaiah, Sanjoy Saha, B Raghvendra Goud

ICAR- National Rice Research Institute, Cuttack - 753006

Presenting author email : anjaniias@gmail.com

Water deficit stress (WDS) is one of the main factor limiting rice production globally, as rice is more susceptible to WDS than other cereals (Kumar et al., 2019). Stress response by rice crop is a complex phenomenon including biochemical and osmotic adjustments. WDS resistant plants adopt several mechanisms like decrease in water loss by increasing stomatal resistance, increase in water uptake by developing a large and deep root system, and acclimation to changing environment by altering plant water relations and increasing osmolyte accumulation (Kumar et al., 2017). A comprehensive knowledge on agronomical, physiological and biochemical aspects of rice varieties particularly in water deficit stress environment is crucial for identifying water deficit stress resistant varieties.

METHODOLOGY

A field experiment was conducted with an objective to identify the threshold soil water potential for enhancing water productivity of rice varieties introgressed with drought QTLs. The experiment was conducted during Rabi 2021 in Split Plot Design with five irrigation treatments as main plot and six rice varieties as sub plot treatment. The different irrigation treatments were (a) Fully irrigated condition as the control (b) Re- irrigation at -20 kPa soil water potential (SWP)(c) Re- irrigation at -30 kPa SWP (d) Re-irrigation at -40 kPa SWP (e) Re- irrigation at -60 kPa SWP and different varieties under examination were V1 = DRR Dhan 44, V2 = Swarna Shreya, V3 = IR 64, V4 = CR Dhan 801, V5 = CR Dhan 802, V6 = Swarna.

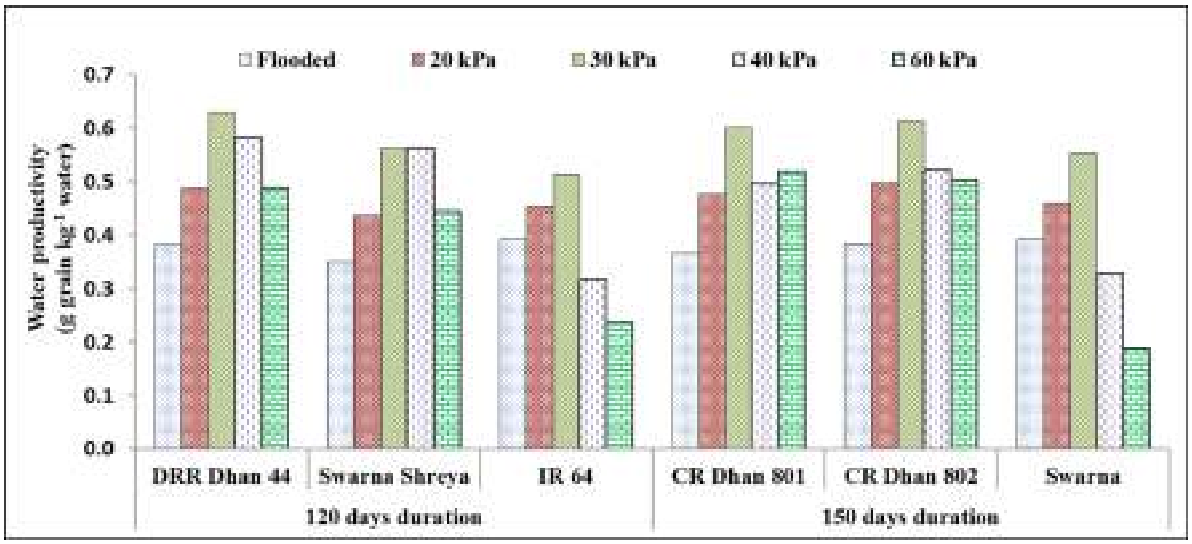

Fig. 1. Water productivity of different varieties under different soil water potential.

RESULTS

From the experimental data it was concluded that varieties introgressed with drought QTLs showed significantly higher grain yield as compared to susceptible varieties under different levels of water deficit stress. Under moderate water deficit stress (-40 kPa) the decline in grain yield varied from 21-35% in tolerant varieties but for susceptible varieties the yield decline was upto 60%.In all the varieties tiller number and fertile grain per panicle decreased as the level of stress increased, however the quantum of decrease was more in susceptible varieties as compared to tolerant. Water productivity of varieties introgressed with drought QTLs was higher at different levels of stress as compared to susceptible varieties. From the analysis of physiological and biochemical parameters, it was evident that enzyme activities such as catalase (CAT), superoxide dismutase (SOD) and peroxidase (POX) significantly increased with increasing level of water deficit stress.

CONCLUSION

Varieties introgressed with drought QTLs had higher activity of antioxidant metabolites that scavenge reactive oxygen species (ROS) as compared to the susceptible varieties under water deficit stress. The quantum of increase in ROS scavenging enzyme activity was more in tolerant varieties as compared to susceptible varieties. Higher levels of relative water content, chlorophyll content, membrane stability index, and low lipid peroxidation resulted in higher grain yield in the tolerant varieties under stress than the susceptible varieties.

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ARRW/SIRC/Theme II/69

Zinc management options for site-specific nutrient management in Odisha

Ajay Kumar Mishra*, Muskula Praveena, Piyush Kumar Maurya and Sheetal Sharma

IRRI South Asia Regional Centre (ISARC), Varanasi-221106, Uttar Pradesh, India
**Corresponding author e-mail: a.k.mishra@irri.org*

Malnutrition in India has been called 'The Silent Emergency.' Despite increased food grain production in recent years, the problem of chronic malnutrition continues to exist extensively, especially among women and children. Zinc (Zn) is now considered the fourth most crucial yield-limiting nutrient after nitrogen, phosphorus, and potassium. Analysis of 256,000 soils and 25,000 plant samples from all over India showed that 48.5% of the soils and 44% of the plant samples were potentially zinc-deficient and that this was the most common micronutrient problem affecting crop yields in India. Periodic assessment of soil test data also suggests that zinc deficiency in the soils of India is likely to increase from 49 to 63% by the year 2025 as most of the marginal soils brought under cultivation are showing zinc deficiency (Singh, 2006). Rice growing areas worldwide are significantly affected due to zinc deficiency or toxicity on grain's physiological growth and nutrient quality (Anwar et al., 2022). Because of its deficiency, paddy production is reduced by 25-50%; therefore, applying Zn in significant quantities and at the appropriate time is critical to achieving optimum rice yield (Zafar et al., 2022). It is a major health risk factor in Asian countries where rice is the main meal, and Zn nutrition for human and animal health has recently received significant emphasis (Shariatifar et al., 2020). Compared to other states of India, Rice production in eastern India is frequently hampered by drought, floods, salinity, low soil fertility, and inadequate or insufficient fertilizer application (Singh and Singh., 2000).

Its deficiency causes a significant drop in yield and quality, especially in rice crops worldwide. Preventing yield limitations from Zn deficiency requires knowledge of commercial Zn fertilizers' application rates and times. To our knowledge, a limited study was conducted regarding the role of timing and dose of application of Zn, which is a prerequisite for getting better crop yield and improving its use efficiency. This study evaluated the effect of timing and dose of Zn application with rice crop manager (RCM) NPK recommendations.

MATERIALS AND METHODS

This study was conducted in 5 districts of Odisha having five treatments with 95 farmers (RCM adopters) selected having the following treatments 1) Half dose Zn in the nursery, 2) Full dose Zn in the nursery, 3) Half dose Zn in the transplanted field, 4) Full dose Zn in the transplanted field. These treatments were further compared against the RCM recommendation generated based on the practice of applying compost in the nursery. Before crop establishment, each farmer underwent an RCM interview to study and understand more about their field location, size, rice variety, anticipated age of seedlings at transplanting, irrigation method (irrigated or rainfed), rice yield in prior years with the same or a similar variety,

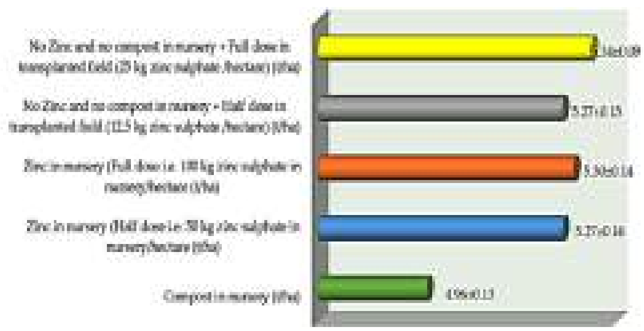

Fig. 1. Treatment-wise average yield (t/ha) obtained with RCM NPK recommendations

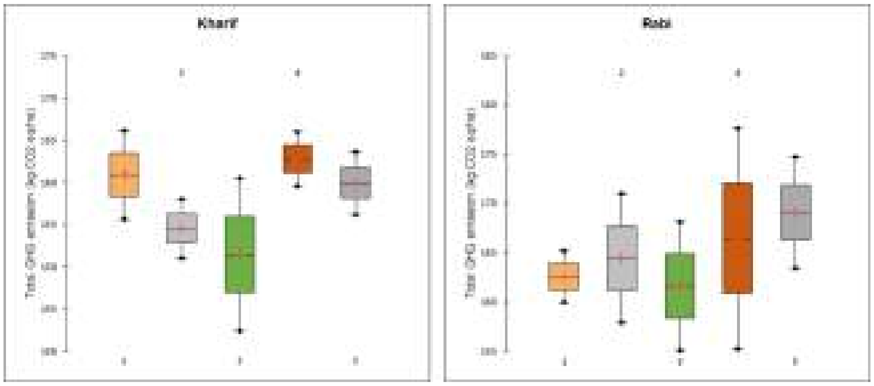

Fig. 2. Total CO_2 emissions (eq/ha) in Kharif and Rabi seasons.

percentage above the ground residues from the previous crop remaining on the field, and choice of fertilizer sources. RCM uses the information given by each farmer to calculate a field-specific fertilizer recommendation to meet a target yield goal. The rates and timing for applying fertilizer sources by the farmer are the keys to RCM recommendation. Typically, RCM sets the target yield higher than the historical yield that the farmer indicated during the RCM interview. However, RCM also modifies the target yield downwards when transplanting is delayed, and RCM limits upward adjustments in yield for low-yielding rice genotypes (Sharma et al., 2019).

RESULTS

The average yield across the sites is depicted in Figure 1. The highest yield was recorded in full dose Zn application in the transplanted field, 0.38 t/ha higher than only compost application in the nursery. The application rates and timing did not show any significant difference in grain yield. However, all the treatments showed higher grain yield than compost application in the nursery. Overall, an added return of 6670 INR/ha was observed in the full dose of Zn application in the transplanted field with RCM recommendations. The full dose of Zn application in the transplanted field consistently contributed to an increase in rice grain yield irrespective of cultivars, environmental conditions, and management practices in all five districts of Odisha.

In particular seasons, the CO_2 flux in GHG emissions in two years varies from 150- 163 kg CO_2 eq/ha in Kharif and 162-170 kg CO_2 eq/ha in Rabi seasons. The CO_2 flux has been analyzed by conversation of one ha farmer's field by guidelines given by (IPCC., 2006). The full dose Zn application in the nursery in the Kharif season is observed to be low in CO_2 emission in 2 years, as shown in (Figure 2), but in Rabi, all the treatments showed high emissions of CO_2.

CONCLUSION

The effect of rates and timing of zinc application did not show any significant difference in rice grain yield in both seasons in all the study sites. However, all the treatments showed higher grain yield than replacing zinc with compost in the nursery. Irrespective of the location, CO_2 emissions were higher in all the treatments during the rabi season than in Kharif. Other low-cost inputs need to be researched for resource-poor farmers, such as chelated Zn, that can potentially substitute Zn sulfate.

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ARRW/SIRC/Theme II/70

Soil C-N mineralization and associated microbial parameters under long-term rice cultivation: Influence of organic nutrient management

Debarati Bhaduri*, Suryakanta Sahoo, Sangita Mohanty

Crop Production Division, ICAR-National Rice Research Institute, Cuttack

**Corresponding author: Debarati.Bhaduri@icar.gov.in/ debarati.ssiari@gmail.com*

Organic agriculture creates a unique production management system, in exclusion of all synthetic off-farm inputs, which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles and soil biological activity. By use of organic farming in field it has minimum negative effect on environment like human and animal health, and it recovers the soil structure, soil functionality, soil organic carbon, water use efficiency and system service. As a low-cost and easily accessible nutrient source for improving the soil's physical-chemical-biological parameters, organic manures facilitates better access to soil nutrients for long-run (Kassam et al. 2011).

METHODOLOGY

The field experiment was completed in *Kharif* season of 2021 at Institute Research Farm designed in a split plot method. The eight solely ONM treatments are T1-Control, T2-FYM, T3-Azolla, T4- Green manure, T5- Vermicompost, T6-FYM + Azolla, T7- FYM + green manure, T8- FYM + Vermicompost to replace the dose of 80 kg N ha^{-1} either 100% or 50% combinations. Three N-responsive rice varieties (Naveen, CR Dhan 311, CR Dhan 308) and one rice genotype was transplanted during that season.

To study the carbon and nitrogen mineralization (C_{min} and N_{min}), soil samples were freshly collected from two depth of soil [D_1: 0-15 cm; D_2:15-30 cm] after harvesting of crop. Two different incubation experiments were setup in laboratory for 90 days and periodic observation was taken for 1, 10, 20, 40, 60 and 90 days. For C_{min} study, CO_2- evolution was measured by unspent alkali titration for different intervals. Similarly, for N_{min} the analysis (NH_4^+ -N and NO_3^- -N) was done using standard protocols. Soil enzymatic activity (dehydrogenase, acid and alkaline phosphatase, urease and fluorescein diacetate) was carried out following standard protocol for soil biochemical analysis using stored soil samples kept at refrigerator (4°C).

RESULTS

It was observed that the contribution of both NH_4^+-N and NO_3^--N to mineralized-N varied between 47-53%, whereas the proportion of mineralized-N to available-N varied between 70-80%. Among the treatments, it was noticed that the inorganic-N varied in both 0-15 and 15-30 cm soil following the trend: T2>T6>T8 ranging between the values 131.6-139.4 mg kg^{-1} of soil (0-15 cm soil) and 122.4-130.9 mg kg^{-1} of soil (15-30 cm soil). For majority of the treatments surface soil D_1 contained higher N_{min} values as compared to D_2 i.e. sub-surface soil. Regarding C-mineralization. The max value of C_{min} reaches up to 13.2 mg CO_2-C g^{-1} soil (0-15 cm) and 9.1 mg CO_2-C g^{-1} soil (15-30 cm). Among the treatments, T7 and T8 showed less C_{min} values as compared to T2, T3, T4 and control. As observed from the analysis in C_{min} the major differences was seen from 40-D to 60-D. For majority of the treatments surface soil D_1 contained higher C_{min} values as compared to D2 i.e. sub-surface soil. Soil dehydrogenase and acid phosphatase activities (T8), alkaline phosphatase and FDA showed (T4) urease (T6) enzyme responded well under influence of ONM. Enzyme activities were correlated with each other with a significant coefficient (r) values.

CONCLUSION

This particular study gives the information about the potentiality of organic nutrient management. FYM in combination with azolla, green manure and vermicompost improves the C and N mineralization contents of soil, mainly on surface soil (0-15 cm) vis-à-vis impacts on the C and N dynamics in soil and ensured soil microbial activity.

ARRW/SIRC/Theme II/71

Impacts of steel slag-based environment-friendly amendments on rice growth, yield and Pb uptake in soil with lead contamination

Banabasini Mohanty, Mohammad Shahid*, Kashyapi Kamalini, Rubina Khanam and AK Nayak

ICAR- National Rice Research Institute, Cuttack- 753006, Odisha, India
**Corresponding Author: m.shahid@icar.gov.in*

Rampant urbanization and industrialization with improper environmental planning often leads to discharge of heavy metals and persistent inorganic pollutants which are of concern due to their potential harmful effects on humans and the environment. Pollution of heavy metals in a rice production system and the risks of their potential entry into the food chain need to be carefully considered. Among heavy metals, Cd and Pb are more troublesome due to their high persistence and toxic nature (Kelepertzis, 2014). Soils, being the major sink of heavy metals, release these metals into the environment in most of the cases without following bio-chemical degradation processes. Several remediation strategies including soil washing, physical treatments, bio/ phytoremediation and electro-kinetics techniques can result in increased metal mobility and changing physico-chemical properties of soil. Therefore, there is a need to investigate alternate approaches like in-situ immobilization/ stabilization by the organic or inorganic amendments which may be proved as a win-win situation when applied in combination with the ever-increasing industrial by-product steel slag. It is rich in Si, Ca, Fe, Mn, and P (Piatak et al., 2015) and also reduces heavy metal mobility by soil pH alteration. Besides the reclamatory properties and fertilizing actions, some steel slags also contain higher amounts of toxic metals. Hence, a study was conducted to explore the potentiality of steel slag for mitigation of lead toxicity in rice.

METHODOLOGY

The soil typic ustochrepts was contaminated with 500 mg Pb/kg, characterized by pH 5.27, cation exchange capacity 0.11 dS m-1 was taken in the pot experiment during rabi season of 2021-2022. Nine treatments were tested including four products i.e. steel slag (SS) at 0.5 & 1.0 t/ha, Biochar+FYM+SS (2:2:1), Coirpith+FYM+SS (2:2:1), Biochar+Coirpith+FYM+SS (1:1:2:1) each applied at 2.5 & 5.0 t/ha and one control. The products were thoroughly mixed with the experimental soil during puddling and rice cv. Shatabdi was planted. Fertilizer was applied at the recommended rate of 80:40:40 kg N: P2O5:K2O ha-1. Whole of the phosphorus, potash and 1/3rd of nitrogen was applied at sowing. Remaining nitrogen was applied in two doses at tillering and panicle initiation stages. Three replications were taken, and completely randomized design (CRD) was used for data analysis.

RESULTS

The result showed that plant growth attributes increased throughout crop growth period with increase in amendment dose. Growth attributes, yield attributes, yield and plant lead uptakes showed positively significant results. Coirpith+ FYM+SS (2:2:1) recorded 18.4% and 42.8% increase in plant height and number of tillers respectively. As compared to the control, all the product combinations had significantly higher grain yield where Biochar+ Coirpith+ FYM+SS (1:1:2:1) @ 5.0 t/ha showed maximum increase by 67.1% followed by Coirpith+FYM+SS (2:2:1) @ 5 t/ha showing 55.8% increase. Grain Pb uptake was significantly lower in Biochar+Coirpith+ FYM+SS (1:1:2:1) @ 5.0 t/ha by over 35.6% than in control, while Biochar+Coirpith+FYM+SS (1:1:2:1) @ 2.5 t/ha recorded maximum straw Pb uptake by 22.9% over control. The findings suggest that steel slag mixed with other organic products could improve the overall growth and economic returns without posing any risk to produce quality.

CONCLUSION

The steel slag produced as an industrial by-product and the agricultural wastes may be combinedly used as soil amendments with the potential to ameliorate lead contaminated soil. This particular study emphasizes on improving rice-soil quality by addition of organic matter and heavy metal availability reduction. Products also indirectly helped in grain quality upliftment by bringing down plant heavy metal uptake. Findings suggest that utilization of steel slag integrated with organic and inorganic matter in subtropical lead polluted paddy soils could contribute to greater soil and plant health as well as aided in minimizing undesired dumping of steel slag.

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Co-application of Zinc oxide suspension concentrate with urea increases rice growth, yield and zinc use efficiency

Anisha Mohapatra, Mohammad Shahid*, Banabasini Mohanty, and Amaresh Kumar Nayak

ICAR- National Rice Research Institute, Cuttack- 753006; Odisha; India
**Corresponding author: m.shahid@icar.gov.in*

Zinc (Zn) deficiency, one of the most serious global health issues, affects roughly one-third of the world's population and is a significant barrier to developing countries meeting yield targets (Shivay et al.,2008). It is present in soil in a variety of forms including, exchangeable and adsorbed forms, soluble organic complexes, insoluble organic and inorganic precipitates and primary and secondary minerals. It plays a significant role in plant growth and metabolism. Since rice is the most significant staple food in Asia and has a naturally low zinc content compared to other diets, the Asian population has a high rate of zinc insufficiency.

Increasing the zinc content of rice grains is currently a significant task that should be handled utilizing agricultural technologies like fertilization and breeding (Phattarakul et al. 2012). Application of zinc salts e.g., zinc sulphate is a common method of correcting zinc deficiency in rice soils after the last puddling. Generally, recommendations for soil application of zinc for crops are 5-17 kg Zn ha^{-1} in the form of $ZnSO_4$. However, the efficiency of zinc sulphate in supplying zinc to plants is thought to be very low. This low efficiency is attributed to reactions of zinc in the soil that limit its availability to plants, or zinc diffusion in certain soils due to the high solubility of zinc sulphate. Hence, changing the zinc source improves zinc absorption and zinc utilization efficiency. Therefore, the present study was conducted to investigate the effect of zinc oxide suspension concentrate (39.5%) by soil application along with urea on rice yield, zinc uptake and recovery efficiency.

METHODOLOGY

Two field trials, each during kharif season of 2021 and rabi season of 2022 respectively were conducted at Research Farm, ICAR- NRRI, Cuttack. Eleven treatments including Control (RDF), zinc oxide suspension at the rate of 813.8 ml ha-1, 1627.5 ml ha^{-1}, 3255 ml ha^{-1}, 6510 ml ha^{-1}, 13020 ml ha^{-1} and zinc sulphate at the rate of 354 g ha^{-1}, 708 g ha^{-1}, 1415 g ha^{-1}, 2830 g ha^{-1}, 5661 g ha^{-1} were taken in a randomized block design (RBD).

RESULTS

Remarkable effects were noted on grain yield, grain zinc uptake and total zinc uptake and recovery efficiency. Highest grain yield (4.96 t ha^{-1} and 5.04 t ha^{-1}) were obtained with zinc oxide suspension (13020 ml ha^{-1}) as compared to controls (4.06 t ha^{-1} and 4.11 t ha^{-1}) during both kharif season of 2021 and rabi season of 2022 respectively. Similarly, the zinc oxide suspension (13020 ml ha^{-1}) was associated with significantly higher grain zinc uptake (261.8 g ha^{-1} and 229.5 g ha^{-1}) and total zinc uptake (681.0 g ha^{-1} and 658.0 g ha^{-1}) during both kharif season of 2021 and rabi season of 2022 respectively. Maximum recovery efficiencies (3.03% and 2.65%) were recorded in treatment zinc oxide suspension (813.8 ml ha^{-1}) during both kharif season of 2021 and rabi season of 2022 respectively. However, recovery efficiency data showed that zinc oxide suspension (13020 ml ha^{-1}) had significantly higher recovery efficiency compared to zinc sulphate (5661 g ha^{-1}).

CONCLUSION

It can be concluded that zinc oxide suspension has a positive impact on rice productivity, Zn concentration and uptake by rice grains, and high recovery of applied Zn.

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IOT based irrigation water management in rice for enhancing water use efficiency and sustainability

R. Mahender Kumar [1], S. Vijay Kumar[1], Vidhan Singh[1], Mukesh Kumar[2], M.B.B. Prasad Babu[1], Jasti Prasad[2], Soumya Saha[1], B. Sreedevi, Mangal Deep tuti, Santhosh Rathod[1], D. Srinivas[1], M.N.Arun [1], B. Nirmala, Mallesh[3] and R.M.Sunderam[1]

ICAR-Indian Institute of Rice Research, Rajendranagar, Hyderabad, Telangana, 500 030

[2] Scientist, IDED, ICAR-CIAE, Bhopal

[3] CultYvate, Bangalore

Rice is water guzzling crop (consumes more than 60 % total irrigation water in India) cultivated mostly through inefficient irrigation methods (5000 lt of water for 1 kg grain) which leads to poor water use efficiency and many environmental problems. It has been reported that AWD can maintain or even increase grain yield (Lampayan et al., 2015) comparison with the continuously submerged conditions. Increasing water use efficiency of rice cultivation will not only solve water deficit and also solve several environmental problems besides enhancing the sustainability of rice-based production system and ensuring food security to the nation.

METHODOLOGY

Different rice crop establishment methods and also irrigation methods which can reduce the water and also supply the water in precise way to enhance the war productivity were evaluated at IIRR Farm. The experiments conducted at IIRR for the during 2020-2021 with Mechnised SRI over flooded rice. These methods are irrigated with 3 methods of irrigation viz. Flooded, 5 cm depletion

Table 1. Effect of the methods of cultivation and irrigation schedule on GY, WP and HI

Main Plot- Methods	Sub Plots- Irrigation regimes	Grain Yield (t/ha)	Straw Yield (t/ha)	Harvest Index (%)	Total Irrigation	Water Productivity (kg/mm)
Mechanised SRI with Hydroponic Nursery	Flooded	5.41	6.57	45.11	1432	3.77
	AWD 10cms	5.99	6.94	46.32	1075	5.09
	AWD 5cms	5.47	6.13	47.16	1193	4.90
Mechanised SRI with Mat Nursery	Flooded	5.59	6.71	45.45	1398	3.97
	AWD 10cms	5.93	6.78	46.63	1120	5.42
	AWD 5cms	5.86	6.86	46.12	1135	5.33
Normal Transplanting	Flooded	5.78	6.84	45.83	1325	4.72
	AWD 10cms	6.16	7.14	46.35	1053	5.77
	AWD 5cms	5.85	6.86	46	1200	5.21
Interaction						
M and T	NS	NS	NS		NS	
T and M	NS	NS	NS		NS	
Mean of Factor-2						
Flooded	5.59	6.71	45.46	1385	4.15	
AWD 10cms Depletion	6.03	6.95	46.43	1083	5.43	
AWD 5cms Depletion	5.73	6.62	46.43	1176	5.15	
CD(0.05)	0.25	NS	NS		0.43	
CV(%)	5.1	4.98	2.25		8.44	
Experimental Mean	5.78	6.76	46.11		4.91	

of Water and 10 cm depletion of water monitored by IOT .

RESULTS

Mechanised transplanting gave on par yields of Normal transplanting (5.62- 5.95 t/ha) with significant saving of labour and cost of cultivation. The water productivity significantly higher with 5 and 10 % depletion of the water (5.15 to 5.45 kg /ha) over flooded rice (4.15). Hence, these methods irrigation schedule provide a viable and found alternative to flooded rice production. AWD method of irrigation resulted higher yields due to better aeration and root growth (Kumar *et al.,* 2013)

Further, the innovative as well as novel technologies like smart irrigation using mechanical water level indicators (CIAE developed AWD pipe), sensors and IoT, water stress identification (*cultYvate*) are gaining momentum and need for upscaling of these technologies. Application of water through alternate wetting and drying (AWD) saved around 11-14 per cent of total water requirement during crop growth period. Irrigation by AWD (implemented through water level indicator developed by ICAR-CIAE) recorded significantly superior irrigation water productivity and WUE.

These technologies also bring back rural youth in to Agriculture and make it more cost effective and also remunerative when adopted in large scale. With the rapid advancement of information and communication technology (AI, Big data Analysis, Drone etc.) it is anticipated that smart and innovative irrigation technologies will be cost effective in the near future and attracts youth into agriculture.

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ARRW/SIRC/Theme II/74

Integrated weed management in aerobic rice

Ashok Kumar Singh[1], Ekhlaque Ahmad[2], Krishna Prasad[2], M. K. Barnwal[3], [4]Binay Kumar, Sambita Bhattacharyya[1] and Ragini Kerketta[1]

[1]Dept. of Agronomy, [2]Dept. of Genetics & Plant Breeding, [3]Dept. of Plant Pathology, [4]Dept. of Entomology
Birsa Agricultural University, Ranchi, Jharkhand-834006 (India)
E-mail: aksinghbau65@gmail.com

Rice (*Oryza sativa* L.) is grown mostly through transplanting in India, in spite of the fact that transplanting is cumbersome practice and requires more labour. In such circumstances, dry direct seeding may be an alternative to transplanting in boosting the rice production. Weeds are the major constraints to aerobic rice production and therefore success of this technology mostly depends on effective weed management to achieve effective, long term and sustainable management in aerobic rice. There is a need to integrate different weed management strategies and judiciously using herbicides as last resort rather than as only resort. Keeping these points in view an experiment on "Integrated Weed Management in Aerobic Rice " was conducted in the same plot during two consecutive years of *Kharif* 2020 and 2021 at Rice Research Farm of Birsa Agricultural University, Ranchi, Jharkhand.

OBJECTIVE

To study the effect of integrated weed management on yield, weed dynamics, nutrient uptake by crops and economics of aerobic rice.

METHODOLOGY

The experiment was laid out in randomised block design replicated thrice with variety IR64 drt1. The treatments comprised of nine different weed management practices *viz.*, Mulching with crop residue@ 5.0 ton/ha at the time of sowing in between rice rows (T_1) ; Mulching with crop residue@ 5.0 ton/ha.at the time of sowing in between rice rows +post emergence application of Bispyribac Sodium@25g a.i./ha.(T_2); Mechanical weeding at 30 and 60 DAS(T_3); Pre emergence application of Pretilachlor@0.75 Kg a.i./ha + post emergence application of Bispyribac Sodium@25g a.i./ha.(T_4); Mechanical weeding at 15 DAS + application of Bispyribac Sodium@25g a.i./ha at 25 DAS.(T_5); Pre emergence application of Pretilachlor@0.75 Kg a.i./ha + mechanical weeding at 30DAS (T_6); Rice+ *Sesbania aculeata* (Sesbania was broadcasted in the field at the time of rice sowing and it was uprooted at 25 DAS and placed in between rice rows,T_7); Weedy check(W_8); Weed free check (W_9).The soil was clay loam in texture and slightly acidic (6.1) in reaction, medium in organic carbon (4.3 g/kg soil) and available nitrogen (225.0 kg/ha), phosphorous (36.6 kg/ha) and potassium (161.80 kg/ha). The recommended fertiliser dose was 80:40:30 kg NPK/ha.

RESULTS

At 60 DAS, the minimum weeds per unit area was recorded with weed free check (26.20/m^2) and was comparable with Rice + Sesbania. The dry matter of weeds at 60 DAS were also minimum with the treatment Rice + Sesbania (36.59 g/m2) and Weed free check (36.36 g/m2). The maximum weed control efficiency at 60 DAS was recorded with weed free check (83.43) followed by Rice + Sesbania (83.32). The nutrient uptake of Nitrogen, Phosphorus and Potassium was recorded maximum with Weed free check (106.81, 18.51 and 110.19 respectively) and Rice + Sesbania (105.73, 16.18 and 110.13 respectively).

Among the different integrated weed management practices, rice + Sesbania fetched maximum net profit (Rs.73398/ha) and B:C ratio

Table: Effect of integrated weed management on weed dynamics, yield, nutrient uptake by rice and economics of rice.(Pooled data of 2 years)

Treatments	Weeds at 60 DAS			Yield	Nutrient Uptake Kg/ha.)			Economics	
	Population (no./m^2)	DM (g/m^2)	WCE %	(t/ha)	N	P	K	Net profit (Rs./ha)	B:C ratio
T_1: Mulching with crop residue@ 5.0 t/ha. at the time of sowing in between rice rows	8.16	9.73 (66.20)	57.05 (94.24)	4.17	86.4	15.66	93.3	56550	1.90
T_2 : Mulching with crop residue@5.0t/ha.+ Bispyribac Sodium@25g ai./ha.	6.77	8.23 (45.60)	69.24 (67.49)	4.52	93.4	17.49	101.6	61179	1.80
T3 : Mechanical weeding at 30 and 60 DAS	7.40	9.32 (4.30)	60.56 (90.44)	4.36	89.4	16.58	98.3	57947	1.70
T4 : Pretilachlor@0.75 Kg ai/ha +Bispyribac Sodium@25g ai./ha.	6.45	7.83 (41.20)	72.21 (60.97)	4.87	101.47	15.22	108.6	71968	2.50
T5 : Mechanical weeding at 15 DAS + Bispyribac Sodium@25g ai./ha at 25 DAS.	7.73	9.53 (59.80)	58.78 (90.44)	4.32	90.0	13.47	101.9	58979	1.80
T6:Pre emergence application Pretilachlor@ 0.75Kg ai/ha+mechanical weeding at 30DAS	8.00	9.70 (63.70	57.29 (93.72)	4.27	86.1	13.29	96.2	58878	1.90
T7 : Rice+ Sesbania	4.89	6.06 (23.60)	83.32 (36.59)	5.01	105.7	16.18	110.1	74414	2.50
T8 : Weedy check	11.72	14.48 (137.80)	- (209.4)	2.02	40.74	6.50	46.5	17249	0.60
T9 : Weed free check	5.16	6.05 (26.20)	83.43 (36.35)	4.97	106.8	18.51	110.2	58944	1.30
C.D(P= 0.05)	0.65	0.86	-	5.50	7.27	1.38	10.54	8821	0.27

(2.46) followed by Pre emergence application of Pretilachlor@0.75 Kg a.i./ha + post emergence application of Bispyribac Sodium@25g a.i./ha with net profit and B:C ratio of Rs.70698 and 2.36 respectively

CONCLUSION

Rice + *Sesbania aculeata* produced maximum yield, weed control efficiency , net profit and B:C ratio and was comparable with weed free check in aerobic rice. Therefore, Rice+ Sesbania is an alternative, feasible and efficient source of weed management in aerobic rice.

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ARRW/SIRC/Theme II/75

Carbon assimilation in soil and plant governed by rice straw biochar under elevated and ambient CO_2 conditions

Debarati Bhaduri*, Sophia Swain, Suryakanta Sahoo, K. Chakraborty, S. Munda

ICAR-National Rice Research Institute, Cuttack-753006, Odisha

**Corresponding author; email: Debarati.Bhaduri@icar.gov.in/ debarati.ssiari@gmail.com*

Climate change results in shifts in temperature and weather patterns affecting rice production and soil health tremendously (Balasubramanian *et al*., 2017). Biochar is a potential soil amendment reported for improving soil physical-chemical-biological properties having a greater role in enhancing soil C-dynamics and to increase yield and improve vegetative growth of plant (Liu *et al.,* 2016). However, there is a research gap that how a biochar can regulate the carbon flow simultaneously in soil and plants under elevated CO_2 conditions.

METHODOLOGY

The pot experiment was conducted during summer, 2022 in Open Top Chamber facility at Institute farm, comprising two rice varieties – V1 (Abhishek) and V2 (Satabdi), with two biochar treatments – BC_0 (Control) and BC_1 (1% BC: w/w ratio) at two chamber conditions – Ambient (400 ppm) and Elevated (550±25 ppm) CO_2 conditions. Biochar was prepared using rice straw under anaerobic chamber of muffle furnace (300°C). Each pot carried 10 kg dry soil. Recommended dose of Urea, SSP and MOP was applied in all pots. Abhishek (duration 115-120 days) is a HYV released from NRRI, Cuttack. Satabdi (duration of 110-115 days) is a fine long slender variety, suitable for upland and medium upland and resistant to various diseases.

To assess the impact of soil C dynamics several C fractions (WSC, RMC, SOC, TC) was measured. Carbon Fractionation (very labile, labile, less labile, non-labile) by modified Walkley-Black method was analysed using standard protocols. Plant biochemical analyses of starch and sugar contents of both leaf and grains were carried out. Agronomic parameters (plant height, no. of tillers, SPAD reading, 10 panicles weight, filled and chaffy grains per panicle, straw yield and grain yield) were also recorded during crop growth phase and harvesting time.

RESULTS

At eCO_2 condition the effect of biochar was prominent for majority of the carbon fractions (WSC, RMC and SOC). Among the labile C-fractions very labile, labile and less labile C fractions was found to be enriched with influence of biochar, this emphasizes the better C-dynamics under changing climate at the root zone of both the varieties. However, the effect was not so distinct at ambient chambers with biochar addition. Interestingly, total starch and sugar analysed at leaf and grain tissues from harvested samples of both Abhishek and Satabdi varieties, and showed a good response of biochar addition under eCO_2 condition. Plant height, panicle weight, fresh straw yield and grain yield were revealed as the biochar-responsive agronomic traits under eCO_2 condition. Microbial activities also varied under biochar treatment and soil enzymes like alkaline phosphatase, dehydrogenase, FDA were found to be better responsive.

CONCLUSION

This study gives a futuristic indication of better C-assimilation in soil and plant tissues at elevated CO_2 condition and the positive role of biochar to play under such scenario. Synergistic effect of elevated CO_2 and biochar might be an important management practice in terms of better C-sequestration and carbon assimilating parameters in different plant tissues.

ARRW/SIRC/Theme II/76

Rice and Water Stress - *A Retrospective analyses on soil-crop-water interface for climate resiliency & sustainable system productivity*

A.Ghosh[1] and O.N.Singh[2]

[1]*ICAR- Indian Agricultural Research Institute, New Delhi and 2- Birsa Agricultural University, Jharkhand, India*

Adversity of climate change foot-print emerges as the paramount challenge in the usual rice-growing micro-environment to achieve the target of 120-125 MT production target of rice by 2030 taking account the current demographic growth rate (1.5 %). One of the major detrimental consequences of climatic aberration is the water stress that could appear with its two different dimensions, *viz.*, deficit water stress and excess water stress situations. Ostensibly, rice, unlike other field crops, has remarkable merits of wide range adaptability at variable hydrological conditions. Although, both the stress situations occurs on account of erratic rainfall, location specific special trait rice variety supplemented with improved crop, nutrient and irrigation management could help the crop migrate the detrimental effects of stress situations substantially. Therefore, understanding the causes and concerns of water stresses, advance technological interventions have been developed so as to address the mitigation mechanism alleviating the intensity of stresses for enhancing sustainable rice production.

METHODOLOGY

Since last more than twenty five years, several field studies addressing both the stress situations were conducted at the on station situations, ICAR-NRRI, Cuttack and ICAR-IARI, New Delhi which were simultaneously fine-tuned following validation at On-farm situations in district Odisha and NCR-Delhi. Addressing the excess water situation at rainfed lowland rice ecology, several studies were conducted on stand establishment, stand management, nutrient management and cropping system; while mostly water, nutrient and cropping system research were conducted addressing the deficit water at aerobic rice ecology.

RESULTS

As a result, advance rice production technology was developed constituted with improved crop management, nutrient management and water management in a system mode perspective.

a) **Improved agro-technology under excess water stress situations :** Results showed that dry seeding rice (DSR)with 400-600 seeds/m^2 at an inter row spacing of 20 cm in 4-5 cm deep furrow and fertilized with 30 kg N /ha was found advantageous under rainfed semi-deep water (0-100 cm) situation (Ghosh, 2007). In rainfed lowland rice, dry direct seeding high density seeds provided 64% more grain yield; while, transplanting fertilized seedling ensured 57% more grain yield than that with unfertilized seedlings. Manipulating seeding geometry with skipping gone row after every four rows at 15 x 20 cm spacing arrangement was reported a 20% saving of the major resources mainly seeds, labor and fertilizer without affecting the yield under semi-deep lowland (0–100 cm) situations. Clonal propagation with 50% tillers removed from a 50-day old DSR crop was found ensuring comparable grain yield with DSR stands and superior to that using conventional nursery seedlings. At post-flood situation, planting robust seedling of medium-duration rice variety treated with 1 kg/m^2 of rice hull ash (8% Si) and FYM increased 25% seed use efficiency and resulted in 10-25% more yield benefit. In rainfed lowland rice, hand weeding twice at 20 and 40 DAS along with beushening at 40 DAS followed by gap filling was reported to enhance grain yield by 12-15% over other methods. Efficacy of weed suppression was more with two summer / off season ploughings at 2 months and 1 month before sowing. In dry season irrigated rice, applying pre-emergence herbicide, butachlor at 1.5 kg a.i./ha 3 days after sowing resulted in grain yield comparable with two hand weedings. Intercropping long-duration (> 160 days) and short duration (~ 80-100 days) rice varieties was found to ensure 15-17% more yield in rainfed medium deep water situation.

Similarly, studies on nutrient management showed that combined application of FYM (10 t/ ha) with urea (20 kg N/ha) gave grain yield comparable with 40 kg urea-N/ha under flood-prone situations. Green manuring rice with intercropped *Sesbania* (GM) (1:1 or 2:1 stand ratio) supplemented with 20 kg N/ha achieved grain yield comparable with that of 40 kg N/ha under flood-prone situations. In flood-prone lowland rice, integrated N management with *Sesbania* and FYM, and urea N at 20 kg N/ha (10:10:20ratio) along with 20 kg P_2O_5/ha gave grain yield comparable with that of 40 kg urea – N/ha with higher N uptake (55.5 kg/ha), NUE (29.5 kg grain/kg N), PUE (12 kg grain/kg P) and apparent N recovery(38.32%). Applying 20 kg urea-N/ha in greengram (GM) intercropped rice produced grain yield comparable with that of 40 kg urea-N/ha with higher NUE (40 kg grain/kg N) under rainfed medium deep lowland. In a jute-rice cropping system, applying 75% N from urea and FYM at 3:1 ratio following soil test-crop response- based target yield equation achieved higher N, P and K productivity of 32.1, 16.3 and 26.8 kg grain/kg nutrient applied. Therefore, on-farm assessment -cum-validation of studies established that optimum productivity could be achieved only when both modern HYV of rice and improved crop management goes hand to hand.

b) Improved agro-technology under deficit water stress situations : Studies conducted under water deficient situations showed that In aerobic rice cultivation, scheduling irrigation at 40 kPa soil moisture content increased water saving (40-44%), water productivity (0.45-0.50 g grain/lit water) without affecting grain yield compared with 0 kPa (Ghosh and Singh, 2010). In transplanted rice, alternate wetting and drying cycle of irrigation maintaining 0.1 bar soil moisture content resulted in higher WUE (3.0-3.5 kg grain/ lit water) and grain yield comparable grain yield with usual irrigation. Maintaining semi-aerobic (20 kPa SMC) soil condition alleviated 20 -24% yield penalty caused on account of 25% increase in concentration of H_2O_2 and proline, and 20% decrease in total soluble protein concentration in successively grown aerobic rice. Zero-till sown forage sorghum after *kharif* rice registered 50% saving in irrigation water without affecting green forage yield.

Regarding weed management, results showed that maintaining lesser crop-weed competition during initial 75, 60 and 45 days of crop growth promoted higher N uptakes of 106.0-106.6 kg / ha, 105.5-105.8 kg/ ha and 100.0-101.2 kg/ ha that achieved significantly higher grain yield of 5.25-5.56 t/ ha, 5.00-5.40 t/ ha and 4.70-5.15 t/ ha, and also higher residual soil N (250.0 kg/ ha). Again, studies on different schedules of weed management, results showed significantly higher grain yield of 3.70 - 3.89 t/ha with integrated weed management followed by 3.61 – 3.62 t/ha with twice manual weeding at 2nd and 4th week stage of crop. However, combined practice of applying Butachlor @ 2.5 lit /ha, a pre-emergence weedicide at 3 days stage followed by manual weeding at 4th week stage, although produced comparatively lesser grain yield resulted in higher net return of INR 15250.0 and B:C ratio of 1.48 for the lowest cost of weed management (INR 6075.0).

CONCLUSIONS

Therefore, the above information could advocate improved varieties as well as agro-management for thriving over the stressful rice growing environment. More specifically, the studies suggested hat negotiating with the water-logged situation in rainfed lowland ecology, ICM and INM of flood water tolerant varieties could be suggested as paramount important factors. While, at water scarcity situation, optimizing irrigation and weed management of deficit moisture stress resistant varieties could be of prime concern sustaining rice production successfully.

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ARRW/SIRC/Theme II/77

Integrated nutrient management in rice under the conservation agriculture system

Bidusi Tripathy[1], B.B. Panda[2], N. C. Sarkar[1]

Visva-Bharati, Santiniketan, West Bengal, 731235

[2]ICAR-NRRI, Cuttack, Odisha, 753006

Rice (*Oryza sativa* L.) is the most important staple food crop in India that holds key to food security. However, intensive tillage, as well as improper residue and nutrient management, lead to soil degradation causing the loss of soil carbon and nitrogen pools, thus lowering rice productivity and threatening food security (Yadav *et al.* 2019). Integrated nutrient management has been found to significantly improve the growth and yield of rice as compared to sole organic and inorganic nutrient management practices (Gholkar *et. al.* 2022). Crop residue retention on cropland also improves soil organic matter and crop production (Gezahegn A.M. 2021). Planting rice under reduced tillage and integrated nutrient management with effective residue recycling is proven to enhance the system productivity, and carbon and nitrogen sequestration in paddy soils of India (Yadav *et. al.* 2019). Considering the importance of integrated nutrient management and conservation agriculture in rice an experiment was conducted with the objective to study the growth and productivity of rice under integrated nutrient management and conservation agriculture system.

METHODOLOGY

A field experiment was carried out in 2022-23 at the Institute Research Farm, ICAR - National Rice Research Institute, Cuttack (Odisha) using a Split plot design having 6 treatments; two main plot treatments and three sub-plot treatments replicated six times with a plot size of 5.5m x 4.2 m in Rice with variety CR Dhan 314. Two different production systems conventional (Conv.) and conservation tillage (CA) were allotted in the main plot with three nutrient management systems in the sub-plot plot; the Recommended dose of fertilizer, RDF; 25% substitution of RDF with FYM (Farm yard manure), INM_{25}; 50% substitution of RDF with FYM, INM_{50}. The sowing was done on 10th June 2022 under both the systems of direct seeding and zero till planting and the crop was harvested on 18th October 2022. The morphological observations, yield attributes, and yield were recorded for studying the performance of the rice plants.

RESULTS

The plant height was recorded highest under the conventional system with 119.39 cm which varies significantly from CA and under INM_{50} with 116.75 cm which non-significantly differs from other treatments. The panicles/m^2 recorded highest under the conventional system which does not show a significant difference from CA and among nutrient management it is highest in INM_{25} and differs significantly from other treatments. The total grains/panicle, test weight, and grain yield has sown no significant difference among main plot treatments as well as among subplot treatments. A significant difference in the straw yield and biological yield was observed with the conventional system having 9.19 t/ha and 14.28 t/ha respectively in comparison to CA whereas, no significant difference was observed in the harvest index among all the treatments.

CONCLUSION

From the above results, it can be concluded that the conservation agriculture system has performed at par with the conventional system in terms of productivity despite omitting several operations of crop cultivation. Among the sub-plot

Table 1: Influence of INM and conservation agriculture system on Growth and yield of Rice

Treatments	Plant height at Harvest (cm)	Panicles /m^2	Grains/ Panicle	Test wt.(g)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index
Main plot: Production system								
Conv (DSR)	119.39	248.19	171.81	24.57	5.08	9.19	14.28	0.36
CA	112.50	216.44	179.61	23.32	4.7	7.92	12.62	0.37
SEm(±)	1.76	9.37	5.67	0.43	0.19	0.31	0.36	0.01
CD(P=0.05)	6.54	NS	NS	NS	NS	1.15	1.35	NS
Sub-plot:Nutrient management								
RDF	115.42	243.43	169.21	24.33	5.13	8.55	13.68	0.38
INM_{25}	115.67	249.10	170.98	23.80	4.66	8.70	13.36	0.35
INM_{50}	116.75	204.42	186.93	23.72	4.89	8.43	13.32	0.36
SEm(±)	0.97	11.46	7.00	0.34	0.24	0.33	0.41	0.02
CD(P=0.05)	NS	34.048	NS	NS	NS	NS	NS	NS

treatments no significant effect of integrated nutrient management is observed with respect to growth and productivity, but hope it will impact in the long run.

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ARRW/SIRC/Theme II/78

Production and quality evaluation of ready to eat fortified rice extrudates from selected NRRI rice varieties

Sivashankari M[1]*, Torit B Bagchi[1], Awadhesh Kumar[2], Subudhi HN[2] and Sutapa Sarkar[2]

ICAR-National Rice Research Institute, Cuttack-753006

**Scientist, Crop Production Division, ICAR-NRRI, Cuttack, Pin-753006, Odisha, India,*

[1]Scientist, CPD Division, ICAR-NRRI, Cuttack, Pin-753006, Odisha, India,

[2]Senior Scientist, ICAR-NRRI, Cuttack, Pin-753006, Odisha, India

Email: sivashankari.m@gmail.com

Increased nutrition levels in rice consumers can be achieved through the effective extrusion of nutrients into rice. The performance of extrusion-based fortification is influenced by nutrient retention, better bioavailability, low post-processing losses, prolonged storage stability, and minimal sensory alterations. The objective of this study was to develop extruded snacks made of rice that were more nutrient-dense. The extruder processing parameters, such as screw speed and barrel temperature, were optimised for the development of extrudates based on rice. Additionally, the study focused on how fortifying agents and variations in the rice variety affected the physico-chemical, nutritional, and sensory properties of the developed extrudates.

METHODOLOGY

The ingredients for the preparation of rice extrudates were rice flour, maize flour, and dal flour. Maize and dal fortified rice extrudates were prepared using 7 different NRRI rice varieties (CR-Dhan 205, CR-Dhan 202, CR-Dhan 312, CR-Dhan 315, CR-Dhan 602, CR-Dhan 313, and Swarna Sub-1) with varying nutritional, functional, and physicochemical properties using a twin screw extruder and optimised extrusion process parameters. The physico-chemical and functional properties, such as thickness (cm), breadth (cm), water absorption index (WAI%), water solubility index (WSI%), and bulk density, were measured. Sensory properties such as its colour values (L*, a*, and b*) and hardness were measured. The nutritional profile, mainly protein, was measured and compared among all the combinations.

RESULTS AND DISCUSSION

The physico-chemical, functional, nutritional, and sensory properties of developed rice-based extruded products fortified with dal and maize flour was presented in Table 1. From the results,

Table 1. Physico-chemical, nutritional and sensory properties of rice based extrudates fortified with Maize (M) and Dal flour (D)

Varieties	Thickness (cm)		WAI (%)		WSI (%)		Bulk density		Expansion ratio		L*		Protein(%)		Hardness (g)	
	M	D	M	D	M	D	M	D	M	D	M	D	M	D	M	D
CR-Dhan 205	0.8	0.93	6.21	5.80	23.92	25.32	0.133	0.179	3.966	4.06	62.37	62.51	5.93	10.50	2966.56	2669.26
CR-Dhan 202	0.85	0.9	4.07	6.05	31.10	28.13	0.1347	0.140	3.933	4.26	61.93	61.48	9.28	8.05	2941.2	2780.96
CR-Dhan 602	0.8	0.9	6.47	7.03	20.19	20.47	0.1543	0.139	4.1	3.73	63.33	59.96	5.60	11.02	3649.33	2660.6
Swarna Sub-1	0.9	0.86	6.068	6.15	29.37	29.89	0.1343	0.141	4.033	3.9	59.89	65.94	5.78	7.52	3136.8	3296.1
CR-Dhan 312	0.95	0.9	5.94	6.10	29.02	29.59	0.1477	0.130	3.83	4.53	58.93	63.83	5.42	11.02	3530.06	1556.4
CR-Dhan 313	0.9	0.95	6.87	6.50	21.23	21.51	0.1026	0.114	3.76	3.86	59.77	63.10	5.42	8.92	2703.1	3349.7
CR-Dhan 315	0.82	0.9	5.82	6.05	28.05	30.27	0.1570	0.185	3.93	3.76	61.92	64.77	5.42	10.15	3252.53	1830.7
p-Value	0.7832	0.7832	0.7985	0.7985	0.6425	0.6425	0.8889	0.8889	0.7588	0.7588	0.7998	0.7998	0.8994	<.0001	<0.05	<.05
Turkey HSD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.8997	1.3281	NS

it was observed that the colour values and protein content had significant differences, whereas there was no significant difference among the functional and physico-chemical properties of the extrudates fortified with maize and dal flour. The quantitative colour difference of rice-based fortified extrudates is shown in Table 1. It was observed that the L* (whiteness) and b* (yellow to blue) values were highest in rice extrudates fortified with maize flour than in their dal flour-fortified counterparts.

CONCLUSION

Fortification of rice flour with maize and dal flour to develop fortified rice based extruded snack item not only significantly affects the nutritional profile especially protein content but also affects the colour and thereby the acceptability of the extrudates.

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ARRW/SIRC/Theme II/79

Simulating the effect of increased area under DSR and climate change on ground water table using integrated modelling approach in five central Punjab districts, India

[1]Manish Debnath, Arjamadutta Sarangi[3*], Dipaka Ranjan Sena[2]

[1]Scientist, ICAR-National Rice Research Institute, Cuttack; [2]Director, ICAR-Indian Institute of Water Management, Bhubaneswar & [3]Principal Scientist, Agricultural Engineering Division, ICAR- Indian Agricultural Research Institute, New Delhi

Corresponding Author: debnathmanish55@gmail.com

Rice-wheat is the major cropping system in Punjab, India. Central Punjab covers around 40% geographical area of the Punjab state, India. Due to excessive ground water pumping, the central Punjab districts have witnessed significant decline in ground water table in past years. Moga, Barnala, Sangrur, Patiala and Ludhiana districts of Central Punjab, India cover 34.4% of the total rice cultivated area of the Punjab state and the ground water table depletion in these five districts at present are the highest. Flooded rice consumes majority of the extracted ground water for meeting its percolation losses during field preparation besides meeting the evapo-transpiration needs, a major shift from conventional flooded rice cultivation to other improved method and technologies for rice cultivation must be emphasized in the study districts. Direct seeded rice (DSR) is presently encouraged in State of Punjab, India. Past studies across the globe reported saving in irrigation water by 10-33 % and increase in ground water recharge potential by 10-15 %, reduction in labour requirement by 40-50 % and energy requirement by 40–45% under DSR as compared to the conventional puddled cultivation method [Yaduraju *et al.*,2021]. Total rice cultivated area in the state of Punjab, India is around 30 lakhs ha, out of which area under DSR in the state was reported 5.4 lakh ha in 2020 and 6.0 lakh ha (20% of total rice cultivation area) in the year 2021 which was further targeted to increase by about 12 lakh hectares of rice area (40% of total rice cultivation area) under DSR in the state. Present study was therefore undertaken to assess the effect of increase in DSR area on ground water table improvement in the study districts under climate change during 2022-2030.

MATERIALS AND METHODS

Study area comprising five central Punjab districts *viz.,* Barnala, Moga, Sangrur, Patiala and Ludhiana, India is located between 29.9°N-31.07°N latitude to 74.9°E-76.8°E longitude covering an area of 1.05 Mha. A robust methodology involving integrated modelling approach using bias corrected climate data and the validated SWAT-GMS model was used in the present study under two formulated management strategies for ground water table simulation under climate change scenario. The methodology involved use of bias corrected IITM-RegCM4 based six model ensemble based monthly climate data under RCP 4.5 scenario to simulate the percolation fluxes and stream flow using validated SWAT model in the study districts (Fig.1). The variability of groundwater table was then simulated using Validated GMS model for the study districts. The two definitive strategies formulated to reduce further decline of water table and ensure ground water sustainability in the region were: ***Strategy-I***: Considering adoption of DSR method of rice cultivation in 25% rice cultivation area in central Punjab districts. The DSR method of rice cultivation was also considered to save 20% irrigation water compared to the conventional puddled rice cultivation also, there is 10% more groundwater recharge potential under DSR compared to conventional puddled transplanted rice cultivation. ***Strategy-II***: Considering adoption of DSR method in 50% rice cultivation area in central Punjab districts along with the similar consideration of irrigation water saving as that of Strategy-I. The Mann-Kendall test and Sen's slope estimator were used to determine the trend of simulated ground water table and the yearly rate of rise or decline in ground water table under different management strategies.

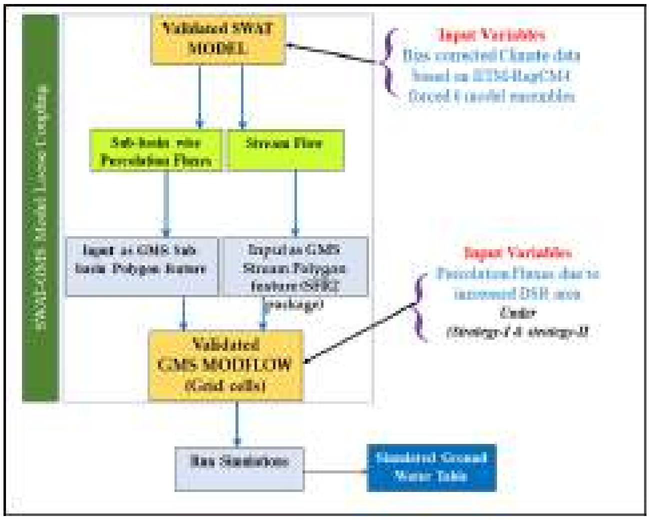

Fig.1 Flowchart describing Methodology for ground water table simulation using integrated model approach under two ground water management strategies

RESULTS

Mann-Kendall test conducted over the simulated ground water table from 2022-2030 showed a rise in ground water table under management *Strategy-I* and *Strategy-II* for all the study districts. It was observed that by adopting 25% of total rice cultivated area under DSR cultivation method (*Strategy-I*) further decline in ground water table can be stopped and the ground water table can be increased by 3.1, 1.8, 4.0 and 3.8 cm/year during 2022-2030 for Barnala, Sangrur, Patiala and Ludhiana districts, respectively, whereas, increasing the DSR cultivation area by 50% the ground water table can be increased by 0.1, 4, 2.5, 4.6 and 4.1 cm/year in Moga, Barnala, Sangrur, Patiala and Ludhiana districts, respectively during the same period (Table 1) .

Table 1: Mann-Kendall test statistics (MK-Z) and Sen's slope estimator (SS) for simulated ground water table from 2022-2030 under management Strategy-I for the study districts

Strategy-I					
Statistics	Moga	Barnala	Sangrur	Patiala	Ludhiana
MK-Z value	-1.1	2.6*	0.8	1.00	1.36
Sen's slope	-0.017	0.031	0.018	0.040	0.038
Strategy-II					
MK-Z value	0.4	2.7*	1.5	1.00	0.87
Sen's slope	0.001	0.040	0.025	0.046	0.041

*Trend at $p<0.05$

CONCLUSIONS

Groundwater depletion in Central Punjab districts, India is a major threat for sustainable crop production where rice-wheat is the major cropping system. A robust methodology on integrated modelling approach using bias corrected climate data and the validated SWAT-GMS model was used in the present study under six formulated management strategies for ground water table simulation under climate change scenario. It was observed that increasing area under Direct Seeded Rice (DSR) cultivation method along with enhancing canal water supply would help improving ground water table in the region.

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ARRW/SIRC/Theme II/80

Effect of water management on arsenic uptake by regulating arsenic availability and transporter expression in rice

Rubina Khanam, Lipsa Tripathy, Mohammad Shahid, Amaresh Kumar Nayak

ICAR-Crop Production Division, National Rice Research Institute, Cuttack-753006, Odisha, India

Arsenic (As) contamination in irrigation water and loading in edible parts is one of the most worrying problems that poses a health risk to more than 150 million people worldwide who live in South and South-East Asian countries—Bangladesh, Cambodia, China, India, Laos, Myanmar, Nepal, Pakistan, Taiwan, and Vietnam (Khanam et al., 2022). Recent research indicates that consuming rice that has been grown and irrigated with groundwater contaminated with As is a significant additional source of As exposure (Khanam et al., 2022). Because of its link to carcinogenicity and other health effects, this is the main reason why people are becoming more and more concerned about the amount of As in food. Therefore, it is necessary to adopt different approaches to reduce As accumulation in rice in flooded paddy field. In continuous flooding (CF), anaerobic condition facilitates reduction of arsenate (V) to arsenite (III) and released into the soil solution resulting in more As bioavailability to the plant. Fe plaque deposit on root is also affected by water management practices. Precipitated Fe can sequester As on rice roots and prevent transfer of As to shoots (Pan et al., 2020). Further, water management practices may regulate the availability of the transporters to carry As from soil to grain. In this study effect of water management practices on the availability of soil As and their accumulation in different plant parts was systematically investigated through a pot experiment.

METHODOLOGY

Two varieties of rice (Shatabdi and IR 64) were selected for the pot experiment at rainout shelter, ICAR-NRRI, Cuttack during Kharif 2021. The experimental soil was collected from Nadia district of West Bengal. There were two water treatment: 1) Continuous flooding (CF) treatment where water level was always maintained around 5cm above the soil. 2) Alternate wetting and drying (AWD) where water was provided only after the drying of the ponded water. The treatments are as follows: continuous flooding+ Shatabdi (T_1:CFV1); alternate wetting and drying + Shatabdi (T_2:AWDV1); continuous flooding+ IR 64 (T_3:CFV2); alternate wetting and drying + IR 64 (T_4:AWDV2).

RESULT

Soil available Si, P and As was enhanced by 1.09, 1.55, 1.04-fold respectively under CF treatment over AWD. Irrespective of growth stages, AWD treatment showed a greater increase in iron plaque deposit as compared to CF treatments. Maximum amount of DCB extractable Fe (3969.1mg kg^{-1}) was recorded in Shatabdi with AWD (T2). Further, the higher root biomass in Shatabdi confirms higher ROL in rhizosphere (Khanam et al., 2021) accelerating deposition of Fe-plaques onto root surfaces. These are validated by the existence of a positive relation between root biomass and Fe-plaque formation ($R = 0.823$, $p< 0.01$). Jointing stage was selected to study the change in gene expressions of transporters involved in As uptake and accumulation in soil-plant system. Expressions of OsLsi 1, OsLsi 2, OsNIP3,3; OsPIP2,6 were found higher in CF over AWD. All of these conditions result higher As accumulation in rice grain under CF (T1 and T3) over AWD (T2 and T4) (Fig 1).

CONCLUSION

Human exposure to As via rice continues unabated despite the management strategies

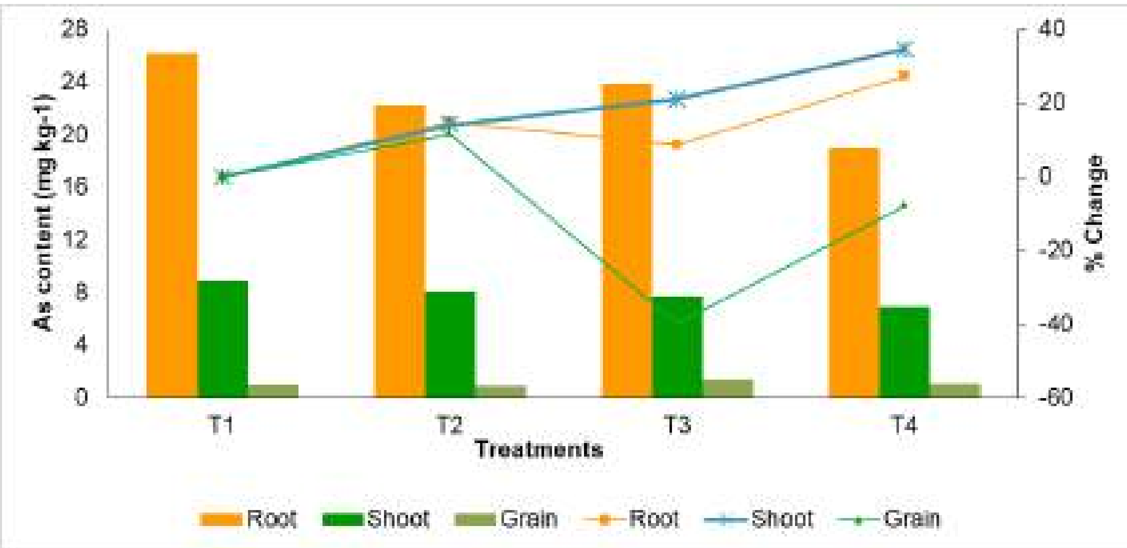

Fig. 1. Arsenic concentration (mg kg^{-1}) and percent change in root shoot and grain under different treatments.

proposed by various researchers at regular intervals. Our result results highlight that water management practices like AWD in combination with lower accumulating variety like Shatabdi can reduce As accumulation in rice grain.

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ARRW/SIRC/Theme II/81

Remediation of Cadmium contaminated soil using steel slag-based fertilizers

Kashyapi Kamalini, Mohammad Shahid*, Banabasini Mohanty, Rubina Khanam, AK Nayak

ICAR-National Rice Research Institute, Cuttack-753006; Odisha; India

**Corresponding Author: m.shahid@icar.gov.in*

The hazardous non-essential metal cadmium (Cd) is primarily found as a divalent cation that forms complexes with other anions. Because of its high solubility and poisonous character, it is listed at number 7 among 20 very hazardous substances (Yang et al., 2004; Hamid et al., 2019). Around 0.1 mg kg^{-1} of cadmium is found in the earth's crust, while up to 15 mg kg^{-1} can be found in sedimentary rocks and marine phosphates. Among all the harmful heavy metals, Cadmium is one of the most mobile elements. Rapid industrialization has put food security and human health in danger by contaminating farmed land, ground water, and crops with heavy metals like cadmium (Cd), lead (Pb), and mercury (Hg). This is due to the rising use of chemical fertilisers, insecticides, and mining. Rapid industrialization has jeopardised food security and human health in vast swaths of China, India, Thailand, Japan, and other countries by exposing farmed land, ground water, and crops to contamination by heavy metals like cadmium (Cd), lead (Pb), and mercury (Hg). It is an extremely poisonous metal that has negative effects on both human and animal health. According to toxicological research, Cd is a very toxic element with three deadly effects, including mutagenesis, carcinogenesis, and teratogenesis, as well as substantial bioaccumulation and chronic toxicity. The most concerning heavy metal in food chains is cadmium (Cd), which plants can take from the soil far more easily than other heavy metals like copper. It can spread directly through vegetables and fruits or indirectly through subsequent animal supply chains. Because of its high-water solubility, it is taken by plant tissues, forms compounds there, and then travels to aerial organs. The discharge of Cd into the soil from many anthropogenic and natural sources ultimately affects the food chain. It poses a serious risk to grain quality, productivity, and ultimately human health. The most essential food for about half the world's population is rice. The uptake and build-up of cadmium in rice has a detrimental impact on plant growth. Hence an experiment was carried out to observe the potentiality of steel slag for amelioration of cadmium toxicity in rice.

METHODOLOGY

Pot experiment was carried out using Shatabdi variety at NRRI, Cuttack during the Rabi season. Products based on steel slag was made using various organic amendments like coirpith, biochar, FYM (farm yield manure) and PMS (paper mill sludge). The soil was contaminated with Cadmium (6 mg kg^{-1}) and products were applied in various doses, i.e., @2.5 t ha^{-1} and @5.0 t ha^{-1}. The treatments included control (RDF 100%), Steel slag (SS) @ 0.5 t/ha, Steel slag @ 1.0 t/ha, Biochar+FYM+SS (2:2:1) @ 2.5 t/ha, Biochar+FYM+SS (2:2:1) @ 5.0 t/ha, Coirpith+FYM+SS (2:2:1) @ 2.5 t/ha, Coirpith+FYM+SS (2:2:1) @ 5.0 t/ha, Biochar+Coirpith+FYM+SS (1:1:2:1) @ 2.5 t/ha and Biochar+Coirpith+FYM+SS (1:1:2:1) @ 5.0 t/ha. Three replications were taken and completely randomized design was used for statistical analysis of data. Recommended dose of fertiliser @ 80: 40: 40 kg ha^{-1} N : P_2O_5: K_2O was applied.

RESULTS

Significant effects were observed in grain yield; Cadmium content in grain, straw and root; and Cadmium uptake in grain and straw. Maximum grain yield (12.6 g plant^{-1} and 14.4 g plant^{-1}) was recorded under treatment Biochar+Coirpith+FYM+SS (1:1:2:1) @ 2.5 t/ha and Biochar+Coirpith+FYM+SS (1:1:2:1) @ 5.0 t/ha respectively as compared to control (9.4 g plant^{-1}). Minimum Cd content in grain (0.21 mg kg^{-1} and 0.16 mg kg^{-1}); straw (3.85 mg kg^{-1} and 3.65 mg kg^{-1}); and root (4.28 mg kg^{-1} and 3.99 mg kg^{-1}) was observed under treatment Biochar+Coirpith+FYM+SS (1:1:2:1) @ 2.5 t/ha and Biochar+Coirpith+FYM+SS (1:1:2:1) @ 5.0 t/ha respectively. Minimum Cadmium uptake by grain (3.48 mg plant^{-1} and 2.55 mg plant^{-1}); and straw (1.98 mg plant^{-1} and 1.35 mg plant^{-1}) was observed under treatment Biochar+Coirpith+FYM+SS (1:1:2:1) @ 2.5 t/ha and Biochar+Coirpith+FYM+SS (1:1:2:1) @ 5.0 t/ha respectively. It has been observed that effect of Biochar+Coirpith+FYM+SS (1:1:2:1) @ 2.5 t/ha and @ 5.0 t/ha has shown remarkable effect on cadmium remediation.

CONCLUSION

Steel slag, which was employed in this experiment, is a by-product of the waste steel industries and has demonstrated significant ability to minimise Cd build-up in rice grains. This experiment showed an increase in grain yield and quality by reducing grain Cadmium uptake with the use of steel slag based amendment.

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ARRW/SIRC/Theme II/82

Aluminum and coal-fired thermal power plants Industrial pollutants and their Impact on Agroecosystem in Jharsuguda

Rajalaxmi Sahoo, Mohammad Shahid*, Chinmaya Kumar Swain, Arpita Tripathy, U Kumar, Rubina Khanam, A K Nayak

ICAR-National Rice Research Institute, Cuttack, Odisha
**Corresponding author email: m.shahid@icar.gov.in*

In the rapid economic development as well as the dramatic growth of energy consumption and more usable products to the human need, emissions may have significantly increased in recent years, leading to complex and regional air pollution as well as to the agriculture crops and to the fields. India's 1.2 billion people depend primarily on food produced within the country, and other Asian and African nations rely heavily on imports of Indian rice (Burneya and Ramanathan, 2014; Mohapatra, and Goswami, 2012). However, Crop yields may be significantly impacted negatively by rising temperatures brought on by growing emissions of long-lived greenhouse gases, and this effect may get worse. Morever, additional climatic modifications brought by short-lived climate pollutants are equally important for agricultural output. Assessment of environmental impacts in a cluster is a complex multi-dimensional problem which is often difficult to measure and manage. In the wake of above findings, present study is formulated to assess primary and secondary pollutants and their impact in the vicinity of Vedanta Limited Factory (VLF), Jharsuguda. Knowing the geographical features would help in assessment of the crop production, factors affecting and impacting the soil, water quality, yield of the area, which will aid us in our scientific approach towards a better environment creating sustainable environmental strategy and enhancing the crop production.

In order to evaluate the susceptibility level of crops to air pollutants, few parameters had been determined and computed together in a formulation signifying the air pollution tolerance index (APTI) of plants. The sensitive and tolerance species need to be identified which can be used as bio-indicators and as sink for air pollutants, respectively. Standards, procedures and methodologies as approved by CPCB/MoEF/CSIR/ICAR/USEPA and international body, etc. has been used for soil, air and plant analysis. The objectives are to assessment of pollutants such as SOx, NOx and Ozone along with initial soil properties and plant enzyme such as chlorophyll has been studied in the vicinity of Vedanta Limited Factory (VLF), Jharsuguda.

METHODOLOGY

Sixteen villages were identified for the research project within the radius of 0-2 km, 2-5 km, 5-10 km and >10 km radius from all the four direction (i.e. North, South, East and West), from the point of Vedanta Limited factory premises. In the all 16 villages three group (Gr), first group of farmers who have been given both seeds and fertilizers along with CLCC and best management practices (Group I); second group of farmers were provided with the seeds only (Group II); and third group of farmers are those where no interventions were done (Farmers practice; Group III). Weather parameters were collected for each of the study location. The scope of work includes the following: Sampling and analysis of air quality for primary and secondary pollutants. Dust sampling was done in 16 villages from the jar at 15 days' interval and further analysis was done in the laboratory. Soil samples were collected as per the identified sampling points. Air sampling was done for SOx, NOx, and Ozone by air sampler in the second week of every month and

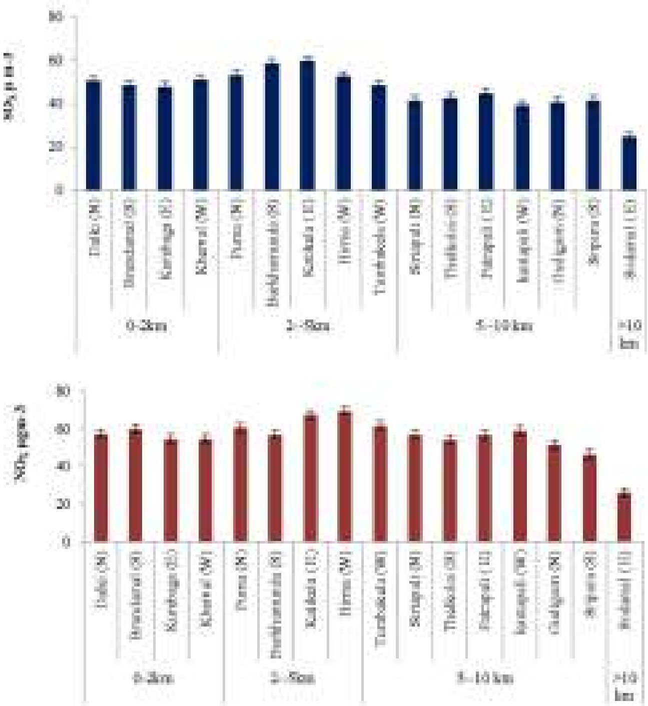

Fig. 1. Variations of concentration of atmospheric air i.e. SOx and NOx concentrations of different villages of Jharsuguda

analysis was done spectrophotometrically in laboratory.

RESULTS

The mean monthly maximum temperature was varied from 30.57 °C to 31.51 °C whereas, minimum temperature ranged from 19.63 °C to 20.62 °C during the kharif season. The soil pH of the sampling sites varied in the range of 5.76 to 6.43, 5.77 to 6.38 and 5.87 to 6.87 for Group I, Group II and Group III, respectively. The SOC content of the soils around Vedanta Ltd., Jharsuguda ranged between i.e., from 0.58-0.78%, 0.55–0.77% and 0.40-0.79% for Group I, Group II and Group III, respectively. The soil organic carbon is in low to medium range for different sites and different groups. Sulphur Dioxide (SO_2) at different villages in. Jharsuguda is found to be minimum of 14.60 µgm^{-3} at Sodamal (>10 km), and maxmium of 34.74 µgm^{-3} at Katikela (2-5 km). The average NO_2 of the study sites from 16 different villages of Jharsuguda was 55.59 µg/m^3 during the study period. NO_2

Emission was maximum (44.31µg/m^3) in Hirma village (2-5 km) whereas minimum (15.79 µg/m^3) in Sodamal village (>10 km) (Figure 1). The values of O_3 of the study sites from 16 different villages of Jharsuguda ranged from 14 to 27.94 µg/m^3 and the maximum values were reported from Tumbakela village (2-5 km) whereas minimum in Sodamal village (>10 km). The chlorophyll content is lower in the rice leaves in 2-5 km distance as compared to the other distances, while higher values are recorded in the Sodamal village (>10 km). Under three groups higher yields were recorded for Grp-I where best management practices were followed along with high yielding varieties and recommended doses of fertilizer application. Under Grp-III (Farmers practice), in general lower yields were recorded.

CONCLUSION

It was observed that from all the analyzed parameters for soil and air are within the permissible limits. Elements are provided in this study to better comprehend the impact of heavily released air pollutants (SO_2, NOx) on the atmosphere. The primary focus was to shed light on the most important precursors and show that there is no such effect these precursors on the agriculture and there can be planned to develop better air quality plans. Additionally, it was noted that in the research area, yields improved with the use of best management methods, such as high yielding seeds, the best suggested amount of fertilizer, and real-time nitrogen management, as opposed to the farmer's practices.

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ARRW/SIRC/Theme II/83

Effect of enriched compost and crop establishment methods on productivity and nitrogen uptake in rice

Himansu Sekhar Gouda[1], Y.V. Singh[2*], Y.S. Shivay[3] and Manu S M[4]

[1]*Assistant professor, Department of Agriculture and allied sciences, C.V. Raman Global University, Bhubaneswar, India*
[2] *Principal scientist (Agronomy), CCUBGA, Indian agricultural research institute, New Delhi*
[3]*Principal scientist, Division of Agronomy, Indian agricultural research institute, New Delhi*
[4]*PhD scholar, Division of Agronomy, Indian agricultural research institute, New Delhi*
himansusekhar153@gmail.com

Rice (*Oryza sativa* L.) is the most important staple food crop which plays a key role in maintaining the food security of the country. But in the current scenario, due to the rising water crisis, depletion of ground water table, rising labour costs with limited resource availability, there is urgency in switching to alternative establishment methods. The sustainability in crop production cannot be achieved without a proper balanced nutrient sheet in a long run. This issue has generated special attention of researchers worldwide due to its ever increasing imbalance. Enriched compost may be one of the game changer which will address the above issue. This will decrease the need for huge quantity of organics needed per unit area and also reduce the competition of these organics from another enterprise. So a field experiment was carried out to find out the impact of enriched organic nutrient sources and establishment methods on productivity and nutrient uptake of rice.

MATERIALS AND METHODS

The field experiment was conducted during *Kharif* seasons of 2018 and 2019 at research farm of ICAR-Indian Agricultural Research Institute, New Delhi. Delhi. The experiment was laid out in split plot design with three replications. The treatments comprised of two main plot treatments viz. aerobic rice (AR) and conventional transplanted (CT) rice and five sub plot treatments viz., Control (No fertilizer), 100% RDF (100% mineral fertilization), 50% P through P enriched compost + 50% P through DAP, 50% N through N enriched compost + 50% N through urea and DAP and 100% organic (through N enriched compost and P enriched compost). The recommended dose of NPK was 120 kg N, 60 kg P and 50 kg kg/ha. Enriched compost was prepared by blending the traditional composting technique with inorganic N (urea), rock phosphate and biologically active substance for improving its nutritional and quality status. Total N, P and K content found in N-enriched compost was 3.44, 1.20 and 0.86% and P-enriched compost had 2.16, 4.01 and 1.1%, respectively.

RESULTS AND DISCCUSION

Crop establishment method significantly affected nitrogen (N) uptake in grain and straw in both the year. N uptake in grain and straw of transplanted rice (56.9 and 60.3 kg/ha in grain and 35.6 and 37.3 kg/ha in straw) were significantly higher than aerobic rice (45.3 and 48.5 kg/ha in grain and 30.0 and 31.3 kg/ha in straw) in both the years. Nutrient management practices significantly affected the N uptake in grain and straw. 50% N through N enriched compost + 50% N through urea and DAP recorded significantly higher N uptake in grain (65.7 and 70.8 kg/ha) and straw (38.2 and 41.6 kg/ha) than other treatments except 50% P through P enriched compost + 50% P through DAP. Significantly higher grain (4.30 and 4.49 t/ha) and straw yield (6.65 and 6.77 t/ha) were recorded in CT rice than AR. Among the nutrient management practices, 50% N through N enriched compost + 50% N through urea and

DAP gave significantly higher grain yield (4.85 and 5.13 t/ ha) and straw yield than other treatments and statistically at par with 50% P through P enriched compost + 50% P through DAP.

Higher concentration of nitrogen in transplanted rice might be due to higher availability of nutrient near the crop root zone which happens due to lesser intra and inter-plant competition in CT rice as compared to aerobic rice. Due to presence of standing water, prevalence of ammonium form of N as compared to nitrate form of N in the anaerobic condition resulting lesser loss in the form of leaching or denitrification losses resulted in more availability and thereby its higher uptake in the transplanted rice as compared to aerobic rice. Similar results were also reported by Davari and Sharma (2010). The higher Nitrogen uptake with integrated application of enriched compost and inorganic fertilizer might be due to better availability of nutrients in synchrony with crop demand resulted in higher nutrient uptake and concentration. Biswas et al. (2019) also found similar kind of results. Combined use of enriched composts and inorganic sources of nutrient could be attributed to better synchrony of nutrient availability to crop, which was reflected in higher grain yield and uptake. Improved soil physical properties in the enriched compost treated plots might have also contributed to the improvement in crop yields.

CONCLUSION

It can be concluded that conventional transplanting of rice along with integrated application of enriched compost and inorganic fertilizer can be recommended to farmers for getting higher nutrient uptake and productivity in rice.

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ARRW/SIRC/Theme II/84

Energetics of Rice Production under different Crop Establishment Methods

Prakash Chandra Jena[1]*, Prabhat Kumar Guru[2], Amaresh Kumar Nayak[1]

[1]*ICAR-National Rice Research Institute, Cuttack-753 006*

[2]*ICAR-Central Institute of Agricultural Engineering, Bhopal-462038*

**Email: prakiitkgp@gmail.com*

Sufficient availability of the energy and its efficient utilisation are prerequisites for sustainable agricultural production. It was realized that crop yields and food supplies are directly linked to energy (Stout, 1990). In the developed countries, increase in the crop yields was mainly due to increase in the commercial energy inputs in addition to improved crop varieties (Faidley, 1992).Particularly the primary objectives of mechanizing crop production are to reduce human drudgery and to raise the output of farm by either increasing the crop yield or increasing the area under cultivation (Jekayinfa, 2006). During the year 1971-72 average farm power availability was 0.42 kW/ha in India which has raised to 2.76 kW/ha in 2020-21 (Singh and Singh 2021). These changes have occurred due to shift from animate power to mechanical power sources. However, data available on energy scenario for cropping systems are more than three decades old and need to be studied as the scenario is continues to change more frequently than ever. The estimates of operational energy use in cultivation of various crops are important to locate high energy consuming farm operations and find ways to reduce them. In this context, energy consumption pattern in rice crop under different crop establishment method was studied.In Odisha, rice is grown under diverse ecosystems and a wide range of climatic conditions. Rice covers about 69% of the cultivated area, covering about 63% area under food grains. Farm mechanisation has made considerable stride and the farm power availability moved to 1.86 kW/ha in 2019-20 from 0.54 kW/ha in 1994-95. Similarly, the consumption of electricity in farm sectors increased by nearly 3folds. Now the farm power availability can be realized as 1.95 kW/ha in 2020-21 (estimated by authors). Rice is a labour-intensive crop which requires an 850-900 man-hours for cultivation for one-hectare area. The cultivation is done by supplementing the traditional energy input i.e. human labour and animal labour with substantial investments in farm machinery, irrigation equipment, fertilizers, soil and water conservation practices, weed management practices, etc. These inputs and methods represent various energies that need to be evaluated so as to ascertain their effectiveness and to know how to conserve them. Energy analysis, therefore, is necessary for efficient management of scarce resources for improved farming system. It would identify farming practices that are economical and effective. Due to higher involvement of labour in different farm operations for rice cultivation, the cost of production of most of the crops in our country is quite high as compared to developed countries. This necessitates to quantify the appropriate farm operation methods to reduce the energy cost besides increasing energy output for sustainable rice production ecology.

METHODOLOGY

Experiments for rice cultivation using manual and mechanical methods were conducted at ICAR-National Rice Research Institute, Cuttack. Energy input and output analysis of different rice establishment methods such as wet direct seeded, dry direct seeded and transplanting were analysed. Field was ploughed twice with cultivator followed by puddling twice after

Table 1 Energy inflow and outflow in different rice establishment methods

Parameters	Wet- DSR (Puddle seeder)	Wet- DSR (drum seeding)	ZT-DSR	D-DSR	Manual-TPR	Mechanical-TPR	ZT-TPR
Energy requirement (MJ ha^{-1})	14435.40	14476.60	12446.08	14827.25	15960.76	16160.89	13122.08
Energy output (MJ ha^{-1})	147833.40	146896.27	141979.30	154047.33	152460.40	139643.93	153775.13
Specific energy (MJ kg^{-1})	2.89	2.90	2.46	2.99	3.02	3.14	2.65
Energy ratio	10.24	10.15	11.41	10.39	9.55	8.64	11.72
Energy productivity (kg MJ^{-1})	0.35	0.34	0.41	0.33	0.33	0.32	0.38
Net energy gain (MJ ha^{-1})	133398.00	132419.67	129533.22	139220.09	136499.64	123483.04	140653.05

receiving adequate rain with rotavator and cage wheels. Sowing of seed was done by using manual drawn three row puddle seeder, manually with drum seeder, power tiller operated zero till seed drill, manual three-row seed drill, manual transplanting and manual four row transplanter. All the sowing machinery used (seed drill, seeder, drum seeder, and zero till seed drill) were calibrated as per standard (IS 6316:1993). The seed rate for rice was kept 20 kg ha^{-1}, respectively, for all the treatments. Pre germinated rice seeds were used for puddle seeder and drum seeder. On the contrary, 25-days old seedlings were used for manual and mechanical transplanting of rice. Recommended fertilizer dose of 80:40:40 kg $N:P_2O_5:K_2O$ was used for rice crop. The energy use ratio, specific energy, energy productivity and net energy gain were calculated to compare the different methods.

RESULTS

Energetics of the system i.e. input and output energy, energy ratio, energy productivity was significantly influenced by tillage, establishment method and implements used. Among all the treatments, tillage operations consumed considerable amount of energy for land preparation and the amount of energy used for tillage was always higher than that of sowing. Land preparation consumed 25.2–27.8% of total energy in all the treatments, except the ZT-DSR (zero till DSR) and ZT-TPR (zero till transplanting) and it was a major advantage over the conventional tillage. The energy productivity was more with ZT-DSR followed by ZT-TPR, Wet-DSR (Puddle seeder), C-DSR (conventional DSR) however no significant change is observed with Wet-DSR (Puddle seeder), Wet-DSR (Drum seeder), D-DSR, Manual-TPR (Mechanical transplanting) and Mechanical-TPR. The highest and lowest B:C ratio was calculated as 1.64 and 1.21 with ZT-TPR and Manual-TPR, respectively (Table 1).

CONCLUSION

Zero tillage transplanting (un-puddled transplanting) of rice curtailed the input energy requirement in rice cultivation and also results in more energy output as compare to traditional rice transplanting methods. It has advantages over DSR that suffers severe weed infestation and requires herbicides application. The zero tillage system, with low energy input and high energy productivity, can be a viable option for East Indian rice growers.

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ARRW/SIRC/Theme II/85

Weed management options for herbicide-tolerant rice under direct-seeded condition

Shubhadip Kar[*1], Rambilash Mallick[1], Indrani Dana[2], Malay K. Bhowmick[3] and Virender Kumar[4]

[1]*Department of Agronomy, Institute of Agricultural Science, University of Calcutta, Kolkata, West Bengal 700019, India*
[2]*Rice Research Station (Govt. of W.B.), Chinsurah, Hooghly, West Bengal 712102, India*
[3]*IRRI-South Asia Regional Centre, Varanasi, Uttar Pradesh 221106, India*
[4]*International Rice Research Institute (IRRI), Los Baños, Laguna 4031, Philippines*
[*]*Email: shubhadipkar1996@gmail.com*

Rice (*Oryza sativa* L.) is the staple food for a majority of people in Asia. Both the issues of productivity and profitability in rice farming are getting challenged by several factors including growing water shortage and labour crisis, escalating input costs and labour wages, climatic changes *etc*. Alternative crop establishment (CE) options in place of conventional transplanting of rice (CTR) are very much imperative (Kumar and Ladha, 2011; Kumar *et al*., 2017). Direct seeding of rice (DSR) using drum seeder in puddled wet soil has been emerging as a potential method although it has a major constraint due to weed problems. Herbicide-tolerant (HT) technology can overcome the weed-related issues associated with DSR, and may therefore facilitate adoption of DSR. Hence, there is a need to make an appropriate recommendation on weed management for HT rice under wet-DSR condition.

METHODOLOGY

A field study was carried out during wet (*kharif*) season of 2022 at Rice Research Station, Chinsurah, Hooghly, West Bengal ($22^{0}52^{2}$ N latitude and $88^{0}24^{2}$ E longitude with an altitude of 8.62 m above mean sea level). Nine weed management treatments *viz.* bispyribac-sodium 10% SC + pyrazosulfuron-ethyl 10% WP (tank mix) 20+20 g/ha as post-emergence (PoE) at 15-20 days after sowing (DAS) followed by (*fb.*) one spot hand weeding (HW) at 35-40 DAS, florpyrauxifen-benzyl + cyhalofop-butyl (ready mix, 12% EC) at 150 g/ha as PoE (15-20 DAS) *fb.* one spot HW (35-40 DAS), imazethapyr 10%SL 100 g/ha as PoE (15-20 DAS), imazethapyr 10%SL 100 g/ha as PoE (35-40 DAS), imazethapyr 10%SL 100 g/ha as PoE (15-20 DAS) *fb*. imazethapyr 10% SL 100 g/ha as PoE (35-40 DAS), imazethapyr 10%SL 100 g/ha as PoE (15-20 DAS) *fb.* one spot HW (35-40 DAS), triafamone 20% + ethoxysulfuron 10%WG (ready Mix, 30% WG) at 45.0 + 22.5 g/ha (pre-mix, 67.5 g/ha) as PoE (12-15 DAS) *fb.* one spot HW (35-40 DAS), weed-free, and control (weedy check) in the HT rice hybrid '*Sava 134 FP*' were compared with the weed-free treatment in non-HT rice hybrid '*Arize 6129 Gold*', which were assigned in a randomized complete block design with three replications. Data were recorded on crop growth and yield attributes along with grain yield at harvest using standard procedures.

RESULTS

The results revealed that both the hybrids (HT and non-HT) yielded higher under weed-free conditions, whereas weedy check plots exhibited enormous yield losses due to weeds. Among the weed management treatments, the integrated weed management (IWM) options involving imazethapyr 100 g/ha or florpyrauxifen-benzyl + cyhalofop-butyl 150 g/ha at 15-20 DAS + one spot HW at 35-40 DAS were found as good as weed-free plots in terms of higher grain yield and significantly reducing the weed growth in the HT rice raised under wet-DSR condition. Higher grain yield in these treatments were attributed to higher values of growth and yield attributes.

CONCLUSION

An IWM approach could effectively manage the complex weed flora in HT rice under direct-seeded conditions. Since the study is of a new kind in India in general and eastern region in particular, it needs valuable confirmation from another year of experimentation. It is also important to assess the potential risks and hazards for developing a sustainable weed management program with HT rice.

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ARRW/SIRC/Theme II/86

Leveraging potentials of suitable rice cultivars under direct-seeded conditions

Malay K. Bhowmick*[1], Panneerselvam Peramaiyan[1], Virender Kumar[2] and Sudhanshu Singh[1]

[1]*IRRI-South Asia Regional Centre, Varanasi 221006, Uttar Pradesh, India*
[2]International Rice Research Institute (IRRI), *Los Baños, Laguna 4031, Philippines*
**Email: m.bhowmick@irri.org*

Direct seeding of rice has been emerging as a climate-resilient, cost-effective, and resource-efficient alternative to puddled transplanting. Despite the fact that the direct-seeded rice (DSR) offers multiple benefits, concerns about the medium- to long-term sustainability of DSR-based systems have been linked to a number of factors, such as early season flooding, poor germination under anaerobic conditions, irregular stand establishment, severe weed problems, soil sickness (micronutrient deficiencies), yield decline, etc. The effectiveness of direct seeding techniques that require less water and labor, and favor mechanization depends on the identification, development, and/or deployment of suitable rice cultivars with robust crop establishment (Bhowmick *et al.*, 2022). In this view, concerted efforts have been taken up by the International Rice Research Institute (IRRI) in collaboration with the national agricultural research and extension systems (NARES), and other stakeholders under the Direct-Seeded Rice Consortium (DSRC) across different landscapes in India (Kumar, 2022).

METHODOLOGY

A number of rice cultivars were evaluated at seven sites: IRRI South Asia Regional Centre (ISARC), Varanasi, Uttar Pradesh (U.P.); Punjab Agricultural University, Ludhiana, Punjab; ICAR-Central Soil Salinity Research Institute, Karnal, Haryana; ICAR-National Rice Research Institute, Cuttack, Odisha; Central Agricultural University, Kyrdemkulai, Meghalaya; Visva-Bharati University, Sriniketan, West Bengal (W.B.), and ICAR-National Institute of Abiotic Stress Management, Baramati, Maharashtra under dry-DSR condition, and at three sites: ICAR-Indian Institute of Rice Research, Hyderabad, Telangana; Rice Research Station (RRS) Chinsurah, W.B.; and Zonal Drought Resistant Paddy Research Station (ZDRPRS) Hathwara, W.B. under wet-DSR condition to identify region-specific suitable cultivars during *kharif* 2021 and at specified locations during *boro* 2021-22.

RESULTS

The results from the study under wet-DSR systems at RRS, Chinsurah revealed that the hybrids could display 28-49 and 17-62% higher yields than the inbreds under weed-free and partially weedy conditions during wet (*kharif*) and dry (*boro*) season, respectively. However, improved rice cultivars of short- to medium-duration groups performed better than the long-duration cultivars under direct sowing at many locations. Hybrids were found to be more weed competitive than the inbreds with 15-20% yield advantages under DSR in Punjab, eastern U.P., Haryana, Maharashtra, Meghalaya, Odisha, Telangana and W.B. due to a smothering effect and the advantage of heterosis that the crop had over the weeds. At ICAR-NIASM, plant height proved to be the key trait contributing towards early vigour, which was crucial for weed competitiveness. At RRS, Chinsurah, the anaerobic germination (AG)-tolerant lines *viz.* IR 14-D-177 and IR 15-D-1072 were identified to perform well in combination with an improved management package under rainfed lowland environments.

CONCLUSION

Rice cultivars suitable for direct seeding should have an appropriate combination of traits, depending on the growing conditions, cropping seasons, and crop establishment methods. Some of the important traits include early seedling vigor and establishment, weed competitiveness, AG tolerance, stress tolerance, early maturity, and higher yield potentials. These potential cultivars offer one of the safe and low-cost technologies for weed management under direct-seeded conditions.

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ARRW/SIRC/Theme II/88

Effect of integrated nutrient management in aromatic rice of Odisha.

S.K. Biswasi[1], D. Debata[2], M. R. Mohanty[3], A.C. Dash[4], A.K.Sethy[5]

[1]Regional Research & Technology Transfer Sub Station, Kirei, [2&5]RRTTS, G. Udayagiri, [3]RRTTSS, Jeypore, [4]SRF, Gambharipalli, OUAT, Odisha

With growing demand for aromatic rice in international market high emphasis is to be given on production and improvement of basmati types. Efficient nutrient management is one of the major factor of production of aromatic paddy. Much work has not been done specially in the domain of integrated nutrient management in aromatic paddy. So this study has been carried out to explore more knowledge on the aspect of nutrient management. Policy makers have identified basmati rice as one of the lucrative options, which can offer better returns to-the farmers. The fine grain, pleasant aroma, soft texture and extra elongation on cooking, endow basmati rice a special place in the domestic and international market (Siddiq, 1990). Integrated nutrient management is defined as a system approach wherein, all the possible components such as on-site resource generation, mobilization of off-site nutrient resources, resource integration and management are given equal importance (Agrawal, 2006).

MATERIALS AND METHODS

The experiment was carried out at Regional Research & Technological Transfer Sub Station, Kirei, Sundargarh during Kharif 2022 is situated at 84° 32′ North latitude and 86° 22′ East longitude with an altitude of 234 meters above the mean sea level with warm and humid climate throughout the year. The mean annual precipitation is 1422.45 mm. More than 85% of this annual rainfall is generally received during the month from June to September at the location. The soil is clay loam and the available nitrogen is 250 kg/ha, available phosphorus is 9 kg/ha and potash is 210 kg /ha. The pH of soil is slightly acidic in nature 5.9. The organic carbon is 0.56%. The experiment consists of seven treatments and cv Kalajeera was used and cultivated in a Randomized Block Design (RBD) with three replications. The aromatic paddy cv. Kalajeera was sown in nursery on 3rd July’22 and transplanted in main field on dated 31st July’22. The crop was harvested on 27th Nov’22. The recommended cultural practices were followed. The observations on morphological characters viz. plant height, leaves/plant and yield characters viz. panicle length and grain yield were recorded and subjected to statistical analysis as per Panse and Sukhatme (1985).

RESULTS AND DISCUSSION:

Yield

The perusal of data on grain yield of aromatic rice cv. Kalakeri is presented in table 2. The data shows that significantly the highest grain yield was recorded with (75% RDFN + 5 t FYM + 25 kg Zinc sulphate/ha i.e 28.7 q ha^{-1} and minimum with

Table 1. Effect of integrated nutrient management on growth attributes of aromatic paddy cv. Kalajeera

Treatments	Plant height in cm	No. of leaves plant
Farmer’s practice (30 kg Urea and FYM 4q/ha)	125.0	10.0
100% STD	130.3	12.0
75% STD + 2t VC/ha	132.0	12.7
75% STD + FYM 5t/ha + Zinc sulphate @ 25 kg/ha	139.7	17.7
50% STD + FYM 5t/ha + VC 2t/ha	137.7	11.7
75% STD + FYM 5t/ha + VC 1.5 t/ha	131.0	13.7
50% STD + FYM 5t/ha + VC 1.5t/ha	133.3	13.3
SEm	3.63	1.09
CD (P= 0.05)	10.8	3.11

Table 2. Effect of integrated nutrient management on yield and yield attribute of aromatic paddy cv. Kalajeera

Treatments	Panicle Length in cm	Grain Yield in q/ha
Farmer's practice (30 kg Urea and FYM 4q/ha)	15.3	18.6
100% STD	19.0	20.0
75% STD + 2t VC/ha	22.3	19.5
75% STD + FYM 5t/ha + Zinc sulphate @ 25 kg/ha	24.0	28.7
50% STD + FYM 5t/ha + VC 2t/ha	19.0	22.7
75% STD + FYM 5t/ha + VC 1.5 t/ha	22.3	22.7
50% STD + FYM 5t/ha + VC 1.5t/ha	20.0	21.7
SEm	1.08	1.15
CD (P= 0.05)	3.3	3.48

farmer's practice where 30 kg Urea and 4 q FYM/ha is applied (18.6 q ha^{-1}). The highest grain yield was 35.2 % higher than the farmer's practice where 30 kg Urea and 4 q FYM/ha was applied. Roul and Mahapatra (2006) observed that application of N as granulated compost gave the highest grain yield of rice, and produced maximum number of panicle m'2, filled spikelets panicle' 1 and test weight. They also inferred that basal application of 40 kg N as FYM-conditioned urea in upland rice produced 62.2 percent higher yield compared to basal application of 40 kg N ha' 1 as urea.

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ARRW/SIRC/Theme II/13

PGP Potential of Endophytic and Rhizospheric Bacteria on White and Black (*Chakhao*) Rice cultivars in Manipur

Debananda S. Ningthoujam

Microbial Biotechnology Research Laboratory (MBRL), Department of Biochemistry, Manipur University, Canchipur-795003 (Manipur), India

**E-mail: debananda.ningthoujam@gmail.com*

Endophytic bacteria and rhizobacteria have been recognized as potential sources of drugs and agrochemical compounds. There is great promise for exploration of bioactive endophytic and rhizobacterial strains in Manipur for potential applications in medicine, agriculture and industry. Six (6) bioactive endophytic bacterial strains, *Streptomyces* sp. AcRz21, *Alkalihalobacillus* sp. PtL11, *Bacillus* sp. TgIb5, *Priestia* sp. TgIb12, *Streptomyces* sp. MBRL 755 and *Streptomyces* sp. MBRL 750 obtained from different ethnomedicinally important plants of Manipur were able to significantly enhance root and shoot biomass of white rice plants. Another promising rhizospheric bacterial strain, *Bacillus* sp. CR12, isolated from *Chakhao Angangbi* (endemic black rice variety grown in Manipur) rhizospheric soil, exhibited significant enhancement in shoot and root lengths and number of leaves of *Chakhao Amubi* rice plants. Some other endophytic strains from folk medicinal plants in Manipur have also shown PGP potential on rice cultivars. These endophytic and rhizobacterial strains could be exploited for applications as biocontrol and biofertilizing agents. This assumes special significance in the climate change scenario and the global trend towards finding better alternatives to synthetic agrochemicals. Detailed findings on these promising PGP strains will be presented in this paper.

ARRW/SIRC/Theme II/32

Impacts of Climate Change on Rice Production and Adaptive Strategies in India: A review

Sangram Paramaguru

Krishi Vigyan Kendra, (OUAT), Gajapati-761016
Email: sparamaguruouat@gmail.com

The rice production system is one of the most climate change sensitive agro-ecosystems. Climate change has evolved from a subject of future speculation to an inconvenient reality of the present. Given the inseparable link of agriculture with climatic variables, impact of climate change on agriculture and food security has been at the forefront of the research and policy agenda in recent times. Climatic alteration in India is becoming fairly perceptible, and the changes are far more evident than in other parts of the country. As a result of climate change, extreme abiotic factors like high and low temperatures, droughts, salinity, osmotic stress, heavy rains, floods and frost damages are posing serious threats to rice production and also are detrimental for the farmers earning livelihood from rice cultivation. There is a dire need to frame strategies against these stresses, so that in order to cope with such impacts crop improvement will help in finding the sustainable and effective solution against the negative impact of climate change. Advancement in Molecular breeding will help in utilizing the inherent potential of wild species by generating abiotic tolerant lines through introgression. Large screening of tolerance in wild genotypes should be done with the help of molecular markers to identify the underlying QTLs/genes. With the development in the field of bioinformatics, DNA microarrays, mass spectrometry, RNA-Sequencing or other modern high-throughput genomic techniques, it is now feasible to decipher the underlying metabolic pathways through top down approach. The present paper provides an overview of the recent evidences, potential impacts of climate change on rice and also offers its mitigation strategy through crop improvement with special reference to northeast India. The results of the impact assessment under different climate scenarios indicated that the rice growth period would shorten and yield would decrease in the future. Further research requires a deeper understanding of abiotic stress physiology and its integration into ecophysiological models to reduce the uncertainty of impact assessment and expand the systematicness of impact assessment.

Theme - III

Biotic stress management in rice : recent scientific advances

ARRW/SIRC/Theme III/01

Promotion of IPM modules for management of insect, pest and diseases of rice in farmer's fields under shallow low land ecosystem

PC Rath, S Lenka, GP Pandi G, Basana Gowda G, NKB Patil, Prasanthi G, Totan Adak, R Jena, Prabhukarthikeyan SR, Raghu S, MS Baite, MK Bag

Email: pcrath67@gmail.com

Promotion of IPM module in the farmer's fields was undertaken in the village Haripur, Derabis, Kendrapara during *kharif*, 2021 involving 27 farmers with Pooja and Swarna in total 21 acres. Before sowing in the nursery bedin IPM practiceseed treatment was done with *Trichoderma* formulation @10g/kg seed. Pesticides were applied in the affected areas only by the farmers in need based. The fungicide Carbendazim 50 WP @1.0 g/litre against sheath blight, brown spot, sheath rot diseases; cartap hydrochloride @ 1kg ai ha^{-1} against LF, YSB, BPH and foliar application of chlorpyriphos 20% EC @ 0.5 kg ai ha^{-1} were appliedagainst gundhi bug. 8 nos. of sex pheromone traps per hectare with lure and bio-control agent (*Trichodermaviride* and *Pseudomonas fluorescens*) formulations provided to the farmers. In farmer's practice, no pest management treatments were applied.

In need based IPM practice in both the varieties Swarna and Pooja, less infestation of targeted diseases and insect, pests were observed in comparison with farmer's practice of pest management. With regards to yield parameters, in both the varieties IPM treatment NB (Need based) outperformed the farmer's practice (FP) of pest management with yield advantage of about 1.92 tha^{-1}. Lesser incidences of rice diseases (sheath rot, brown spot, false smut,sheath blight,) and insect, pest (stem borer causing dead hearts & white ears, gundhi bug) were found in Swarna IPM NB, Pooja IPM (NB) over Swarna FP, Pooja (FP). In case of insect, pest, least incidences of 2.3% DH, 2.8% WEH and 3.5% gundhi bug were found in Swarna IPM (NB) followed by 3.3% DH, 3.5% WEH, 4.2% gundhi bug were found in Pooja IPM (NB) over Swarna (F.P) and Pooja (FP). Whereas, in case of diseases, least incidences of 5.2% brown spot, 7.4% sheath blight in Pooja IPM (NB) and 5.4% sheath rot, 5.2% false smut in Swarna IPM were found.With regards to yield parameters, maximum grain yield of 6.2tha^{-1} in Swarna IPM (NB) and straw yield of 5.6 tha^{-1} in Swarna IPM (NB) were found followed by grain yield of 5.5t/ha and same quantity of straw yield 5.6tha^{-1} in Pooja IPM (NB) over both Swarna (F.P), Pooja (F.P). Benefit – Cost ratio of Swarna IPM was 2.36, Farmer's practice was 1.82 and Pooja IPM 2.12 & Pooja Farmer's practice was 1.50.

ARRW/SIRC/Theme III/02

Evaluation of rice land races for resistance to root-knot nematode (*Meloidogyne graminicola*)

Zakaullah Khan*[1], Rakesh Singh[2], Anushka Sharma[2], A.K. Singh[3], Bharat H. Gawade[1] and V. Celia Chalam[1]

[1]*Division of Plant Quarantine, ICAR-NBPGR, New Delhi-110012, India*
[2]*Division of Genomics Resources, ICAR-NBPGR, New Delhi-110012, India*
[3]*ICAR-IARI, New Delhi-110012, India*
Email: zkhan64@gmail.com*

The rice root-knot nematode, *Meloidogyne graminicola* is an emerging menace to rice (*Oryza sativa*) cultivation. It is a sedentary endoparasite, which is a major pest of rice and has been reported from all the rice growing ecosystems, ranging from rainfed to deep water system (Yao et al., 2020). This nematode causes up to 80% of crop loss when they reach sufficiently high population (Plowright and Bridge, 1990). The characteristic horse-shoe-shaped root gall is the indicative of *M. graminicola* infestation, where the above-ground parts of the infected plants show stunting, wilting, chlorosis, reduced tillering, and empty spikelet which ultimately leads to poor yield. The use of resistant cultivars offers an ecofriendly and sustainable solution to manage this nematode (De Waele et al., 2013; Yao et al., 2020). The search for resistance source is going on globally. In present study, rice land races/ germplasm available in national genebank at ICAR-NBPGR, New Delhi, India was evaluated to find resistance sources to *M. graminicola.* Present screening experiments were conducted at ICAR-NBPGR, New Delhi during summer seasons of 2020-22.

METHODOLOGY

Rice root-knot nematode, *M. graminicola* infected rice plants were procured from Division of Nematology, ICAR-IARI, New Delhi and its identity was confirmed using morpho-metric data as well as female perennial pattern. Pure culture of *M. graminicola* was raised from single egg-mass and was further multiplied on susceptible rice seedlings (Pusa Basmati 1121) for experiment purpose. Screening experiment initiated in 10-cm plastic pots filled with 500-cc soil. Five seeds were sown per pot and thinning was done after germination to maintain only one healthy plant per pot. Fifteen days after sowing, each pot with single plant was inoculated with approximately 500 second stage infective juveniles. Three replicates were maintained for each land race and gall formation was estimated at 25th day after nematode inoculation. Host status of tested rice land races were designated on the basis of number of root galls induced by nematode. Those showing less than 10 galls per root system were considered as resistant. Pusa Basmati-1121 used as susceptible check. The rice land races, which showed promising results were carried forward and rescreened twice to confirm the consistency of their response against *M. graminicola*.

RESULTS

In the preliminary screening, 1650 land races of rice have been screened against *M. graminicola* during summer season of 2020-2022. Based on the preliminary results, among the tested land races, 08 germplasms/ land races recorded as resistant to *M. graminicola.* All these selected land races rescreened twice with high inoculum density 1000 second stage juvenile per pot to ensure their resistance consistency. All the 08 resistant land races exhibited consistent responses throughout the screening period. While the other land races/ germplasms expressed susceptibility to *M. graminicola.*

CONCLUSION

Out of 1650 land raced screened for resistance to *M. graminicola*, a total of 8 landraces identified as new source of resistant to *M. graminicola*. Since screening were carried out during summer season in Delhi condition, therefore, these identified resistant/promising rice land races need to be further screened at different agro-climatic zones of the country to verify their reaction consistency in different rice growing seasons in different parts of the country.

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ARRW/SIRC/Theme III/03

Identification and Characterization of Indian Rice Landraces Diversity for Sustained Resistance Source Development against Bakanae Disease

M. S. Dar[1], Saba Mir[1], Najeebul Rehman Sofi[1]*, Asif B Shikari[2], F. A. Mohiddin[1], Ashaq Hussain[1] and Mehandia Iqbal[2]

[1]*MRCFC, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Khudwani, 192 102*
[2]*Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Wadura Campus, Sopore*
email: najeeb_sofi@rediffmail.com

Rice from the family Gramineae and subfamily Oryzoidea is grown in a variety of eco-geographical regions and is susceptible to both biotic and abiotic stresses. Bakanae disease caused by *Fusarium fujikuroi* in rice has been documented practically everywhere across India. Due to the high genetic diversity in rice causes pathogen to shift its virulence and adapt to monoculture. Therefore, the pathogen is able to overcome the resistant sources. The local rice landraces offers good examples of tolerance and adaptation to various biotic and abiotic stresses and their low susceptibility against the bakanae disease enabled their integration as a source of durable resistance in breeding programmes.

METHODOLOGY

'For this reason, 1000 rice landraces were evaluated individually for bakanae disease at Khudwani Centre of SKUAST-Kashmir under artificially controlled condition. Shalimar rice 1, Shalimar rice 2, Shalimar rice 3 and Shalimar rice 4 were used as resistant and Shalimar rice 5, and K-332 as susceptible checks. The disease symptoms on samples of each plant were periodically checked during the growth season and classified on the basis of their incidence and intensity. The bakanae disease with disease severity ranged from scale of 1-5 and incidence from 1-100%. Based on the disease severity index (DSI) calculated for 1000 germplasm lines grouped them into two categories: varieties having DSI less than 1.6 were classified as resistant and those having DSI above 1.6- 7.86 as susceptible.

RESULTS

It was found that only 257 (25.7%) lines were resistant whileas 743 lines (74.3 %) showed susceptibility.

CONCLUSION

The identified resistant sources may serve as new donors and can be further investigated for the underlying genes/ QTLs. This knowledge would be useful for comprehending the host-pathogen dialogue, identifying the field source of resistance to the bakanae disease and selecting germplasm for providing a source of resistance to plant breeders for development of resilient varieties.

ARRW/SIRC/Theme III/04

Phenotypic Characterization of Blast Resistance in Indian Landraces of Rice (*Oryza sativa* L.)

Saba Mir[1], M. S. Dar[1], Najeebul Rehman Sofi[1], Asif B. Shikari[2], F. A. Mohiddin[1], Gazala H. Khan[1] and Shabir H. Wani[1]

[1]*MRCFC, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Khudwani, 192 102*
[2]*Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura Campus, Sopore,*
Email: najeeb_sofi@rediffmail.com

Blast disease caused by *Magnaporthe oryzae* is a major production constraint in temperate rice-growing ecologies. Identification of effective donors for blast resistance is required for the mapping of novel alleles which can be utilized in marker-assisted selection to develop blast-resistant varieties in rice. Although more than 100 genes for blast resistance have been mapped, the location effectiveness of the genes may vary so that not all the genes can be utilized freely. The phenotyping process is also important for understanding the racial profile or general virulence behaviour of the local isolates.

METHODOLOGY

A set of 2300 diverse Indian rice landraces were screened against blast disease under natural a hot spot environment in the presence of six checks at MRCFC, Khudwani, SKUAST-K during *Kharif* 2022. The seed was sown in a raised bed nursery in 100cm long rows with an inter-row spacing of 10cm. To ensure the uniform spread of disease, *Mushk Budji, a* highly susceptible rice landrace of Kashmir was used as infector row. It was planted after every ten test entries and also sown around the border. Field screening was carried out following the 0–9 Standard Evaluation Scale of IRRI (2012).

RESULTS

Out of 2300 accessions, 374 were found resistant (0-3) and 479 showed moderate resistance reaction (4-5). The remaining 1447 lines were found susceptible.

CONCLUSION

The identified resistant sources may serve as new donors and can be further investigated for the underlying genes/ QTLs.

ARRW/SIRC/Theme III/06

Predictive assessment on the efficacy of pheromone trapping to alter sex ratio of yellow stem borer, *Scirpophaga incertulas* (wlk.) population in rice field at Hooghly, West Bengal, India

[1]Eureka Mondal[*], [2]Chitta Ranjan Satpathi and [1]Kaushik Chakraborty

[1]*Department of Zoology, Raiganj University, Raiganj, UttarDinajpur, West Bengal, India, 733134*
[2]*Department of Agricultural Entomology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India, 741252*

Yellow stem borer (YSB), *Scirpophaga incertulas* Walker, accounts about 10-60 % rice yield loss in India (Pasalu *et al*., 2005). Pheromone traps are highly specific, non-hazardous, economic and time saving in their action. The application of pheromone for managing stemborers provided farmers with protection for their crops that was season long, users as well as environment friendly (Satpathi *et al*., 2017). A steady departure of male: female YSB sex ratio was noted during pre and post pheromone light trapping which ultimately alter field population dynamics.

In view of the economic significance of YSB, the present study was carried out to evaluate the alteration of YSB sex ratio and also subsequent change of population structure by YSB egg mass assessment.

METHODOLOGY

Place of observation: The experiment was carried out at Tarakeswar, Hooghly (22.9041° N, 88.0110° E) West Bengal , India during *kharif* season of 2019-20 and 2020-2021 with rice cultivar IET-9947 (*Lalat*). Each plot was 15m x 15m in length and breadth and separated from the nearby plot with a distance of 20m×20m.

Establishment of pheromone trap: Pheromone traps with Scirpolure were installed at the rate of 15/acre at 10 days after transplanting of crop. The Scirpolure was impregnated with a mixture of (Z)-11 hexadecenal + (Z)-9 hexadecenal in 3:1 ratio@ 5 mg/lure. Traps were checked and male YSB were recorded after 7 days interval after installation in rice field.

Establishment of light trap: Each light trap with a white coloured 18-watt LED bulb was used in the trap and a few drops of Bifenthrin 10 EC insecticide were used for killing the YSB moths. The traps were operated from 7p.m. to 5 a.m. and adult YSB caught in the trap were counted daily.

Assessment of YSB egg mass: YSB egg clutches were recorded at 15, 30, 45,60 and 75 DAT and calculated using the following formula.

$$E_{YSB}(\%) = \frac{Ne}{(Nf + Nh + Ms)} \times 100$$

[E_{YSB}= Average index of YSB egg masses, Ne= Total number of egg masses in all sampled field, Nf= Number of field selected (3), Nh=Number of hills examined (5), Ms= Average number of tiller/hills].

RESULTS

Observation on dynamics: Activity of YSB Moth of *kharif* generation started during 30 Standard Meteorological Week (SMW), reaches to its peak during the 36 SMW and gradually decline from 38 SMW to 42 SMW.

Observation on YSB sex ratio:

Moth collected from light trap before installation of pheromone trap: The sex ratio of the adult YSB (male: female) at 15 DAT and 30 DAT was 1.00:2.20 and 1.00:2.02 respectively and it showed 1.00:2.09 at 45 DAT and 1.00:2.21 at 60 DAT whereas at 75 DAT the ultimate sex ratio was 1.00:1.86.

Table: Abundance of adult YSB and the consequences of egg masses following trapping

Moment of trapping (DAT)	Collected YSB number: Collection of YSB from light trap before installation of pheromone trap — Individuals/light trap: Male	Female	Ratio Male: Female	Egg masses/ 5 hills(5 days after each treatment)	Collection of YSB from light trap after installation of pheromone trap — Individuals/ pheromone trap (only male YSB population)	Individuals/light trap: Male	Female	Ratio Male: Female	Egg masses/ 5hills(5 days after each treatment)
15	1.00[a]	2.20	0.50	1.02	0.00	0.00	1.00	0.00	0.00
	(1.22)[b]	(1.64)	(1.00)	(1.23)	(0.71)	(0.71	(1.22)	(0.71)	(0.71)
30	6.01	12.2	0.50	6.72	22.10	1.20	9.20	0.11	4.88
	(2.55)	(3.56)	(1.00)	(2.69)	(4.75)	(1.30)	(3.11)	(0.78)	(2.32)
45	15.01	31.4	0.48	5.91	39.2	4.00	33.4	0.12	4.29
	(3.94)	(5.65)	(0.99)	(2.53)	(6.30)	(2.12)	(5.82)	(0.79)	(2.19)
60	11.01	24.4	0.45	7.10	31.2	3.00	23.4	0.13	5.24
	(3.39)	(4.99)	(0.97)	(2.76)	(5.63)	(1.87)	(4.89)	(0.79)	(2.40)
75	14.02	26.10	0.53	5.37	34.30	3.00	24.20	0.12	3.78
	(3.81)	(5.16)	(1.01)	(2.42)	(5.90)	(1.87)	(4.97)	(0.79)	(2.07)
CD(P=0.05)	0.034	0.056	0.076	0.013	0.045	0.039	0.0‘19	0.067	0.029

[a]: Average of three observations; [b](...): Figure in the parenthesis are the square root transformed value

Moth collected from light trap after installation of pheromone trap: No male moth was captured at 15DAT but the sex ratio (male: female) altered to 1.00:7.66 at 30 DAT and it showed 1.00:8.35 at 45 DAT and 1.00:7.80 at 60 DAT whereas at 75 DAT the ultimate sex ratio was 1.00:8.06.

Observation on YSB egg mass:

Collection of egg mass only after light trapping: YSB eggs are laid in groups and each group is called egg mass. It was counted after 5 days interval where minimum (1.02) egg masses were reported at 15 DAT whereas it was 6.72, 5.91, 7.10 and 5.37 at 30, 45, 60 and 75 DAT respectively.

Collection of egg mass after post-pheromone light trapping: After installation of pheromone trap no egg mass was reported at 15 DAT but 4.88, 4.29 and 3.78 egg masses were recorded at 30, 45 and 75 DAT respectively. Whereas maximum (5.24) egg masses were reported at 60 DAT.

CONCLUSION

The first appearance of YSB moth was noted during 2nd week of August but it was peaked during 1st week of October. The primary sex ratio (male:female) of YSB was around 1:2 as recorded from light trap collection in rice field. Drastic reduction of male YSB population was recorded in light trap after installation of pheromone trap where the male:female ratio was altered to 1:2 to 1:8. These results explicitly suggest that the alteration of sex ratio in YSB may increase the virgin female in the subsequent generation. It is a novel method of management where chemicals have no direct contact with crop and even it reduce the risk of residue.

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Analysis of nucleotide diversity among alleles of the major bacterial blight resistance gene *Xa27* in cultivars of rice (*Oryza sativa*) and its wild relatives

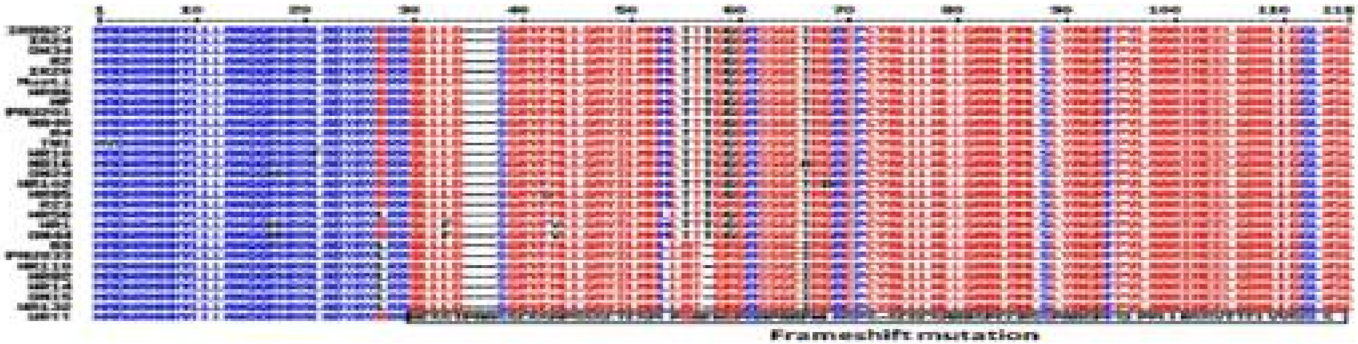
Waikhom Bimolata[a], Komal Bhati[a], Anirudh Kumar[a], Raman Meenakshi Sundaram[b], Gouri Shankar Laha[c], Insaf Ahmed Qureshi[d], Gajjala Ashok Reddy[b], Irfan Ahmad Ghazi[a*]

[a]*Department of Plant Sciences, School of Life Sciences, University of Hyderabad, Hyderabad, 500046, India*
[b]*Crop Improvement Section, Indian Institute of Rice Research, Rajendranagar, Hyderabad, 500030, India*
[c]*Crop Protection Section, Indian Institute of Rice Research, Rajendranagar, Hyderabad, 500030, India*
[d]*Department of Biotechnology, School of Life Sciences, University of Hyderabad, Hyderabad, 500046, India*
Email: komalbhatisingh@gmail.com

Plants are constantly subjected to attacks from various biotic stresses such as different diseases. Both the plants and the pathogens have been co-evolving in response to each other's modulation. *Xa27*, a major BB *R*-gene identified from *Oryza minuta* (BBCC), is one of the six BB resistance genes, which have been cloned (Gu et al., 2005). With the availability of *Xa27* sequence in the public domain, allelic diversity analysis of wild relatives and landraces may help in unlocking new and wide spectrum resistant alleles. Analysis of DNA polymorphism for *Xa27* in Indian accessions of two major wild species of rice, *O. nivara* and *O. sativa* may offer a prospect to divulge the process of fixation of alleles and haplotypes responsible for adaptive variation during evolution. In the present study, we analysed inter and intraspecific polymorphism in *Xa27* locus of Asian cultivated rice *O. sativa* and its ancestor *O. nivara* from 27 different wild rice accessions, introgression lines and landraces. The major objectives of this study were: (1) to determine if the *Xa27* alleles of *O. sativa* and its wild relative share identity; (2) to analyse the level of polymorphism of *Xa27* at the sequence level and explain its molecular evolution; and (3) to analyse the possibility of selection at *Xa27* locus.

MATERIALS AND METHODS

A total of 27 accessions of different *Oryza* species were analysed for sequence diversity of *Xa27* locus. Rice seeds were germinated and were transferred to earthen pots. After 45 days of transplantation, each accession was challenged with five Indian virulent isolates of *Xoo.* The isolates used for screening were DX011 (Pantnagar), DX127 (Cuttack), DX020 (Hyderabad), DX015 (Aduthurai) and DX133 (Raipur). Using this bacterial suspension, 5–6 uppermost leaves of plants were inoculated following the leaf clipping method. Genomic DNA was isolated from young leaves and the entire *Xa27* gene including the promoter and 32 UTRs was amplified from 27 genotypes using overlapping gene-specific primers designed from GenBank accession AY986492. Based on the sequences obtained from the genotypes under study, the coding regions and the UTR regions of the new alleles were predicted through the software utility, FGENESH. Sequences were assembled and subjected to multiple alignments using ClustalX. Nucleotide diversity was analysed by estimating p (average number of nucleotide diversity per site); and q_w, (number of segregating sites). Different test selection analysis such as Tajima's *D* test and Fu and Li's *D* test were conducted separately for *O. nivara* and *O. sativa* accessions using DnaSP program to determine departures from neutrality. Dendrogram predicting the evolutionary relationship among 26 alleles was generated by developing bootstrapped unrooted linear neighbour joining (NJ) tree in MEGA 4.



RESULTS

1. Phenotypic evaluation- Out of the 27 accessions selected for allelic diversity analysis, 10 *O. nivara* accessions were resistant to all five strains and three of them were susceptible to either one of the strains; both *O. alta* and *O. officinalis* were resistant to all the five strains, whereas among the *O. sativa* accessions TN1, IR24 and IR20 were susceptible to all the five *Xoo* strains and remaining accessions were resistant or susceptible to one or the other strain

2. Gene amplification and sequencing-The sequence encompassing the entire *Xa27* gene was amplified from 27 rice accessions using overlapping gene-specific primers. All the sequences were deposited in the NCBI GenBank database and the following accession numbers JF304301–JF304303, HQ888852–HQ888857, JN016505–JN016521 and JN601064 were obtained.

3. Polymorphism of *Xa27* Alleles Comparative analysis in DnaSP, excluding sites with gaps, showed 103 polymorphic sites (in total 1,999 available sites), 74 singleton variable sites, 40 parsimony informative site and 32 InDel events ranging from 1 to 50 bp in length.

The average number of nucleotide differences, 'K' of the entire gene was estimated to be 15.892. The genetic diversity, π of the tested gene was 0.00795 and θ equal to 0.01312. The highest sequence variability was observed in the 52 flanking region of the alleles with π value 0.00916 and the least variability in 32 UTR.The test of neutrality failed to give significant Tajima's and Fu and Li's *D* ($P > 0.01$) in *O. nivara* and *O. sativa* species, even though θ_w value was greater than π resulting in negative Tajima's *D*.

CONCLUSION

DNA sequences of *Xa27* alleles from 27 rice accessions revealed higher nucleotide diversity among the reported *R*-genes of rice. Sequence polymorphism analysis revealed synonymous and non-synonymous mutations in addition to a number of InDels in non-coding regions of the gene. High sequence variation was observed in the promoter region including the 52 UTR with π value 0.00916 and $\theta_w = 0.01785$. Comparative analysis of the identified *Xa27* alleles with that of IRBB27 and IR24 indicated the operation of both positive selection (Ka/Ks > 1) and neutral selection (Ka/Ks H~0). The genetic distances of alleles of the gene from *Oryza nivara* were nearer to IRBB27 as compared to IR24. We also found the presence of conserved and null UPT (upregulated by transcriptional activator) box in the isolated alleles. Considerable amino acid polymorphism was localized in the trans-membrane domain for which the functional significance is yet to be elucidated. However, the absence of functional UPT box in all the alleles except IRBB27 suggests the maintenance of single resistant allele throughout the natural population.

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Population dynamics of *Nilaparvata lugens* (Stål) under the interactive effect of elevated temperature, CO_2 and ozone

YogeshYele[1*], Subhash Chander[2], Sachin S. Suroshe[3]

[1]*ICAR-National institute of Biotic Stress Management, Raipur-493 225, India.*
[2]*ICAR-National Centre for Integrated Pest Management, New Delhi- 110 012, India*
[3]*ICAR-Indian Agricultural Research Institute, New Delhi- 110 012, India.*

The current global climate change scenario threatens to increase crop losses by changing the development pattern and host plant response to insect pests. Distinct climate change parameters and their variability are likely to aggravate insect pest problems in agriculture. Rising surface air temperature and increasing concentrations of greenhouse gases will affect the survival and distribution of pest populations and will establish a new equilibrium between crops and pests. The present study aimed to gauge the effect of these climate change parameters on insect pests and host plants. We studied the impact of elevated CO_2, elevated Ozone and interaction of elevated temperature+CO_2 on *Nilaparvata lugens vis-à-vis* rice variety PB-1121.

METHODOLOGY

The population dynamics of *N. lugens* were assessed at the Free Air Temperature Enrichment (FATE) facility at the Centre for Environment Science and Climate Resilient Agriculture (CESCRA), ICAR-IARI, New Delhi. Four FATE rings equipped with elevated temperature and carbon dioxide (ET+ECO_2), elevated carbon dioxide (ECO_2), elevated ozone (EO_3) and ambient environmental conditions (AM) were used to conduct the experiments. Ten pots with 25-day-old plants covered with mylar cages having two windows were transferred to respective treatments in FATE rings. After 10 days of crop exposure to each condition, 5 pairs of gravid brachypterous females and males were released into 10 replications in each treatment (Pandi *et al.*, 2016). The experiment was conducted in two consecutive rainy seasons i.e., 2019 and 2020. Weekly observations per hill on the number of nymphs, males and females were recorded.

RESULTS

The present study revealed that, during both seasons, *N. lugens* population was significantly higher in ECO_2 and ET+ECO_2 than in other treatments and control. During 2019, two peaks were observed in ECO_2, first in 5th WAR (114.6±6.2 *N. lugens*/hill) and second in 8th WAR (100.7±5.6 *N. lugens*/hill) and mean population density was recorded highest (61.6±13.5 *N. lugens*/hill) amongst all other treatments (Fig. 1). Under ET+ECO_2, *N. lugens* peak population reached in the 8th WAR and the average population density (44.5±9.4 *N. lugens*/hill) was significantly higher than ambient control but was recorded significantly lower than ECO_2. On the other hand, the lowest mean *N. lugens* population density was recorded on EO_3 (17.7±3.1 *N. lugens*/hill) with the peak population reaching in the 6th WAR (28.2±2.3 *N. lugens*/hill). A similar trend was observed during 2020, where mean *N. lugens* population density was highest in ECO_2 (50.6±12.3 *N. lugens*/Hill) than in other treatments. The Highest *N. lugens* peak population was recorded for ECO_2, 84.3±5.0 *N. lugens*/Hill in the 4th WAR and the lowest peak population was observed for EO_3, 46.0±3.5 *N. lugens*/Hill in the 3rd WAR. Under ET+ECO_2, *N. lugens* population density varied between 4.5±0.6 *N. lugens*/Hill at 1st WAR to 75.9±3.8 *N. lugens*/Hill at 4th WAR contributing to a mean population density of 47.5±12.1 *N. lugens*/Hill which was found to be at par with ECO_2 but significantly

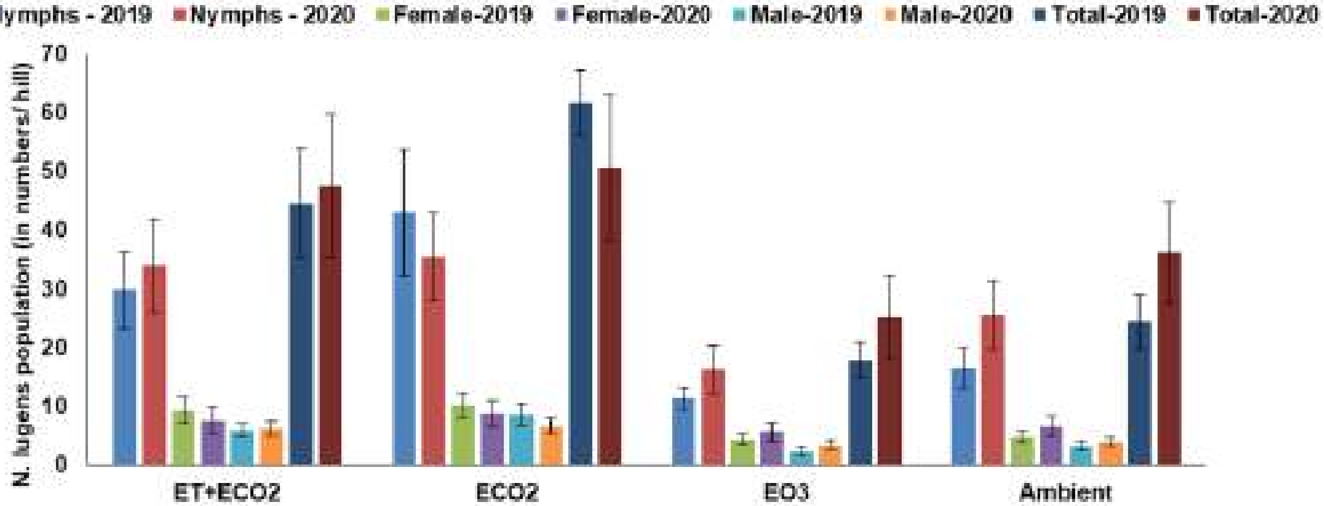

Fig. 1. Mean population of different stages of *N. lugens* recorded during the 2019 and 2020

higher than EO_3 and ambient control. For both seasons, it appeared that *N. lugens* population density and peak population were higher in ECO_2 and ET+ ECO_2 as compared to EO_3 and ambient control.

The nymphal population differed significantly across the treatments in both seasons. The highest nymphal population was recorded in elevated CO_2 and the lowest was found in elevated ozone conditions during both seasons. Interaction of elevated temperature and CO_2 harboured a significantly higher nymphal population than ambient control. Also, the peak nymphal population reached earlier than other treatments in ECO_2 and also harboured a higher nymphal population per hill in all the weeks and contributed to the highest mean nymphal population. Similarly, female and male *N. lugens* population density was higher under ECO_2 and ET+ECO_2 as compared to ozone-treated plants and ambient control in both seasons. The negative effect of elevated ozone was evident, as it recorded the lowest *N. lugens* population density across the weeks with delayed appearance of peak population in both seasons. It is evident from both season data that, *N. lugens* population density is in order of ECO_2>ET+ECO_2>AM>EO_3.

CONCLUSION

The increase in *N. lugens* population under elevated CO_2 alone and elevated temperature and CO_2 may be attributed to congenial micro-climate through denser plant growth which caused higher brachypterous female and nymph population. There is a direct negative effect of elevated ozone on *N. lugens* population development. However, under *N. lugens* infestation it causes more yield losses than ambient conditions. Thus, with changing climate scenario, a higher BPH population will aggravate crop losses in future climate change conditions.

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ARRW/SIRC/Theme III/09

Effect of false smut pathogen on seed germination and defense enzymes activity in different rice cultivars

Ramya selvi N* and R. Saraswathi

Department of Genetics and Plant Breeding, CPBG, Tamil Nadu Agricultural University, Coimbatore- Tamil Nadu, India
**E mail: kpnramya@gmail.com*

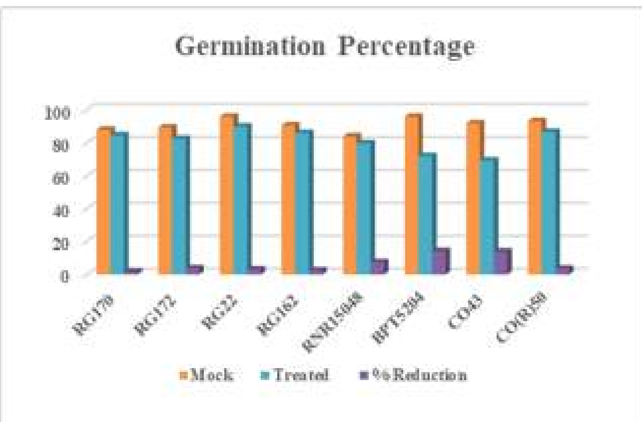
Rice False Smut (RFS) disease caused by *Ustilaginoidea virens* (Cooke) Takahashi, a minor sporadic disease in past has now become one of the most devastating fungal diseases in the world due to changing climatic conditions followed by emerging different fungal races. RFS disease occurrence and production of mycotoxins *viz.*, ustiloxin and ustilaginoidin could affect the yield as well as quality in rice seeds. Different studies have indicated a yield loss estimate from 1-49% across the world. Hence, the study focusses on germination parameters and role of defense enzymes on false smut spore infected and uninfected rice genotypes varying in levels of resistance.

METHODOLOGY

Ustilaginoidea virens was isolated from the available grains with smut balls. Final spore suspension was adjusted to the concentration of 2 ×10^5 conidia/ml. The seedling vigor test was carried out in eight different rice genotypes with different levels of resistance using spore suspension culture (Saleh and Zidan, 2020). The defense enzymes phenylalanine ammonia lyase (PAL) and poly phenol oxidase (PPO) were estimated in mock and infected shoots and roots of rice seedlings (Duan *et al.*2014). Means of parameters were compared by Duncan multiple range test using windows R version 3.3.0.

RESULTS

Seed germination parameters *viz.*, germination percentage (%), shoot length (cm) and root length (cm) were recorded for control and treated (soaking in spore suspension) seeds and results presented in Table 1. Germination percentage ranged from 69.33% (CO 43) to 90.0% (RG22) in treated while in control, it ranged from 84.0% (RNR 15048) to 96.0% (RG22 and BPT 5204). Nevertheless, non-significant differences were observed among genotypes for germination percentage. Germination percentage reduction was low in resistant line RG 170 (1.93) while comparing other genotypes. Among four susceptible lines, BPT 5204 and CO 43 exhibited highest reduction of 14.29% and 14.05% respectively.



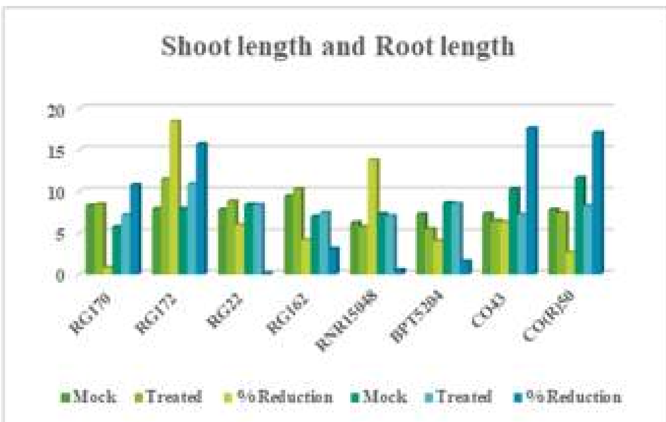


Table1. Effect of False smut spore suspension culture on seed germination in eight genotypes of rice

Table 2. Defense enzymes activity of eight rice genotypes

Genotypes	PAL in shoots (U/mg FW)		% Increment	PAL in roots (U/mg FW)		% Increment	PPO in shoots (U/mg FW)		% Increment	PPO in roots (U/mg FW)		% Increment
	Mock seeds	Treated seeds		Mock seeds	Treated seeds		Mock seeds	Treated seeds		Mock seeds	Treated seeds	
RG170 (R)	7.88 ^{a}	9.21 ^{a}	7.78	1.93 ^{c}	2.68 ^{c}	16.24	34.49 ^{b}	56.00 ^{a}	23.76	26.56 ^{a}	28.80 ^{a}	4.05
RG172(R)	6.18 ^{b}	7.65 ^{b}	10.63	4.73 ^{a}	6.29 ^{a}	14.11	41.97 ^{a}	57.28 ^{a}	15.42	20.94 ^{b}	21.45 ^{c}	1.22
RG22 (MR)	2.19 ^{c}	4.38 ^{c}	33.42	1.26 ^{e}	1.54 ^{e}	10.11	31.89 ^{c}	32.99 ^{c}	1.69	16.71 ^{c}	18.67 ^{e}	5.53
RG162 (MR)	1.12 ^{f}	3.68 ^{d}	53.38	2.99 ^{b}	3.30 ^{b}	4.91	28.39 ^{d}	30.18 ^{b}	3.05	19.02 ^{d}	24.71 ^{b}	13.00
RNR15048 (S)	1.25 ^{e}	1.97 ^{f}	20.04	1.24 ^{e}	1.99 ^{d}	1.52	15.60 ^{f}	19.82 ^{e}	11.92	17.48 ^{d}	19.91 ^{d}	1.65
BPT5204 (S)	1.45 ^{d}	2.17 ^{ef}	22.39	1.20 ^{e}	1.24 ^{f}	1.64	15.23 ^{f}	19.96 ^{e}	13.42	7.06 ^{e}	7.29 ^{g}	6.50
CO43 (S)	1.47 ^{d}	2.46 ^{e}	25.03	1.14 ^{e}	1.25 ^{f}	4.35	15.96 ^{f}	19.45 ^{e}	9.84	7.21 ^{e}	9.71 ^{f}	14.79
CO(R)50 (S)	1.24 ^{e}	1.98 ^{f}	23.14	1.49 ^{d}	1.58 ^{e}	2.91	19.92 ^{e}	21.71 ^{d}	4.29	6.17 ^{f}	9.04 ^{f}	18.89

R-Resistant, MR-Moderately resistant, S-Susceptible

Resistant genotype RG172 exhibited significant differences in shoot (11.48cm) and root length (10.88cm) even after pathogen spore suspension treatment when compared to other genotypes. The increment in shoot and root length was 18.42% and 15.73% respectively after spore treatment. The other resistant line RG170 expressed 10.78% increment in root length. Both the moderately resistant lines RG22 and RG162 exhibited increased shoot length compared to mock but the increment was less. Among the four susceptible genotypes, RNR 15048 exhibited 13.73% reduction in shoot length, while CO 43 and CO (R) 50 showed on par reduction in root length. In treated seeds, the root length differences were non-significant among genotypes except RG172.

In most of the genotypes except RNR15048, production of PAL was higher in shoots rather than roots in treated seeds (Table 2). The amount of enzyme production is higher in treated seeds when compared to untreated irrespective of the genotypes, however genotypic differences exist in quantum of production. In mock seeds, both the resistant genotypes had inherently higher enzyme activity in shoots compared to all other genotypes and hence the increment was lower after treatment, whereas moderately resistant genotypes showed a marked increase in enzyme activity in shoots after treatment. In roots, the resistant genotypes after treatment had an advantage compared to others.

So also, the production of PPO was higher in shoots when compared to roots except RNR 14028 irrespective of mock or treated seeds. Both the resistant genotypes exhibited higher PPO activity in shoots after treatment which was also reflected in higher increment over control compared to all other genotypes. In roots, highest PPO activity was observed in RG170 (R) followed by RG162 (MR) and RG172 (R) after spore treatment.

CONCLUSION

An increase in length of shoots and roots was observed after false smut spore treatment of seeds in resistant and moderately resistant genotypes, while it decreased in all susceptible genotypes. There was a gradual reduction in enzyme activity of PAL and PPO in shoots in both mock and treated seeds between resistant, moderately resistant and susceptible genotypes. Both the resistant genotypes had higher activities of both the enzymes in shoots compared to roots after treatment. The overall activity of enzyme PPO was higher compared to PAL in both shoots and roots of untreated and treated seeds.

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ARRW/SIRC/Theme III/10

Genome-wide association studies for panicle blast resistance in Rice (*Oryza Sativa* L)

Asif Bashir Shikari[1], Raheel Shafeeq Khan[1], Nuzhat Naseem[1], Noor-Ul-Ain[1], Gazala H. Khan[2], Saba Mir[2] and Najeebul Rehman Sofi[2]

[1]*Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Wadura Campus, Sopore,*
[2]*MRCFC, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Khudwani, 192 102*
email:asifshikari@skuastkashmir.ac.in

Panicle blast is a major production constraint which directly affects the yield and quality of rice. More than 100 genes have been reported for leaf blast resistance; however, very few genes have been identified and utilized against neck blast.

METHODOLOGY

Genome-wide association studies were conducted on 233 rice germplasm lines. Evaluation of lines for neck blast was carried out for two years under natural hot spot environment in the presence of five susceptible checks. The scoring was performed as per SES-IRRI (2012).

RESULTS

The data showed Gaussian distribution across the germplasm set. The genotyping of the lines was carried out using genome wide KASP markers. KASP markers are uniplex SNP markers with moderate throughput. The Mixed Linear Model was used for identification of marker-trait associations using R-software. The significant associations for neck blast resistance were recorded on chromosomes 1, 3 and 4.

CONCLUSION

The QTLs identified can be validated, fine-mapped and utilized in resistance breeding programmes against neck blast.

ARRW/SIRC/Theme III/11

Identification of multiple fungal pathogens causing brown spot disease of rice in India

Pramesh, D[a*]., Padma Priya, D[a]., Kiran Kumar, M[a]., Chidanandappa E[a]., Prasanna Kumar M.K[b]., Sharanabasav Huded[a], N. Sumangala[a] and Usha[a]

a: Rice Pathology Laboratory, All India Coordinated Rice Improvement Programme, Agricultural Research Station. Gangavathi, University of Agricultural Sciences, Raichur, India

[b]: Department of Plant Pathology, University of Agricultural Sciences, Bangalore, India

**Author for correspondence: parmi.iari@gmail.com, pramesh84@uasraichur.edu.in*

Rice crop is affected by several fungal diseases; rice brown spot disease is one of the most prevalent diseases causing significant damage to rice yield and quality. Brown spots of rice caused by *Bipolaris oryzae* have been known to occur in Japan since 1900. Since its first report at the beginning of the 20[th] century, brown spot disease of rice was reported to be caused by *B. oryzae* alone, but in recent years the disease has been reported to be caused by other pathogens such as *Curvularia lunata* and *Setosphaeria rostrata* in some of the rice growing countries, including in India (Kamaluddeen *et al*., 2013; Kusai *et al*., 2015). In the present investigation, a detailed study was undertaken to identify different pathogens associated with the brown spot disease of rice.

METHODOLOGY

Collection of disease samples and pathogen isolation: A roving survey was conducted during *Kharif* 2017 in different rice-growing districts of Karnataka. The infected leaves showing typical brown spot disease symptoms were collected from different locations for isolation and identification of the pathogen associated with brown spot disease. The associated pathogen was isolated on PDA following the standard isolation technique. Then, the pure culture of all pathogens was established using single conidial isolation techniques, and further pathogens were identified using morpho-molecular characters.

Morpho-Molecular identification of the pathogens: Morphological features of all three pathogens were identified using a Camera assembled Binocular microscope fitted and connected to an image analyzer software. For molecular identification, DNA was extracted from the pure culture of all three pathogens using the CTAB method. Further, the ITS region was PCR amplified using ITS1 and ITS 4 primer pairs. The resultant PCR product was directly sequenced and analyzed for nucleotide identity through the BLAST search.

Pathogenicity test for different pathogens: Pure cultures of the isolated three pathogens was used for establishing Koch's postulates on a brown spot susceptible cultivar GNV-05-01. Inoculum suspension comprising Spore and mycelial bits was spray inoculated (until run-off) to the leaves of 30 days old seedlings of GNV-05-01, whereas water-inoculated plants served as control. The experiment was replicated thrice, and inoculated plants were covered with polythene covers until symptom development.

RESULTS

Upon isolation, we could generate the pure culture for 40 isolates of *B. oryzae*, 15 isolates of *C. lunata*, and three isolates of *S. rostrata*. Initially, *B. oryzae* produced grayish to black color colonies along the margins of inoculated leaf bits and formed the grayish radial mycelial colony. Mycelium was septate and light brown, on which conidiophores were produced. The conidiophores are thick and dark at the base and lighter towards the tip, and the conidia are 5-10 septate. Fully matured conidia are brownish; they germinate with two polar germ tubes. On PDA, *C. lunata*, after ten days of incubation, produced flattened blackish to grayish mycelial colonies with black pigmentation on the reverse side of the Petri Plate. The conidia were fusiform in shape, curved slightly at the second cell with three septations. Whereas the Mycelium of *S. rostrata* initially appeared as white and later became grey and finally converted into the black after 8-10 days. Cylindrical to ellipsoid-shaped conidia are formed at the apex of the conidiophores and are straight to slightly curved with 5–8 distoseptate and are darker in color towards the basal region. The conidial wall is darker in color except near the apex region and measures about 46.2-49.12 X 12-14.5 µm with characteristic protruding truncated hilum. Further, we amplified and sequenced the ITS region of all three pathogens, and a similarity check with BLAST analysis indicated the taxonomic identity as *B. oryzae, C. lunata,* and *S. rostrata*. The consensus sequences were deposited in the NCBI GenBank. Independent pathogenicity assays of all three pathogens (*B. oryzae*, *C. lunata,* and *S. rostrata*) indicated the typical disease symptoms on the inoculated leaves, whereas water-inoculated leaves remained symptomless. From the artificially inoculated symptomatic leaves, we isolated all three pathogens, which show similar characteristics to the original isolates, thus confirming Koch's postulates.

CONCLUSION

The present investigation provides conclusive evidence of the association of three fungal pathogens such as *B. oryzae*, *C. lunata,* and *S. rostrata*) in causing brown spot disease of rice in India. This study is very important for re-designing the brown spot research studies, which were otherwise focused only on *B. oryzae.*

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Silica induced resistance in rice against blast

***C. Gopalakrishnan and R. Logeshwari**

Department of Rice, Tamil Nadu Agricultural University, Coimbatore – 641 003, Tamil Nadu, India.
**Corresponding author: pcgopalagri@gmail.com*

Blast (C.O. *Magnoporthe oryzae*) is a devastating disease responsible for considerable yield loss in rice throughout the world. There are several hypotheses on how silicon confers or induces resistance against blast in rice. Understanding the mechanism of silica induced tolerance/resistance to blast in rice therefore forms basis for developing an appropriate management strategy. Hence, the present study was undertaken during 2021 using pre- release culture CB15714from Department of Rice, Tamil Nadu Agricultural University along with blast susceptible variety to understand the pattern of silica deposition and its effect on other anatomical parameters which contribute to the rice plants' resistance to blast.

METHODS

A promising pre-released culture namely CB15714 with blast tolerance along with susceptible variety namely CO 39 were used for the study. The seedlings were raised under glass house and the silica was applied as silixol (Orthosilicic acid) on 50 days after planting at 0.6% concentration and a control was maintained without silica application. The leaf samples were collected on 7days after silica application from silica treated plants and untreated plants and subjected to Scanning Electron Microscope analysis in addition to documenting physiological and anatomical parameters. The silica (Si) content was measured in leaves of two varieties by Energy Dispersive X-Ray Analysis (EDAX) under Scanning Electron Microscope (SEM). The physiological and anatomical characters were measured under Scanning Electron Microscope (SEM).

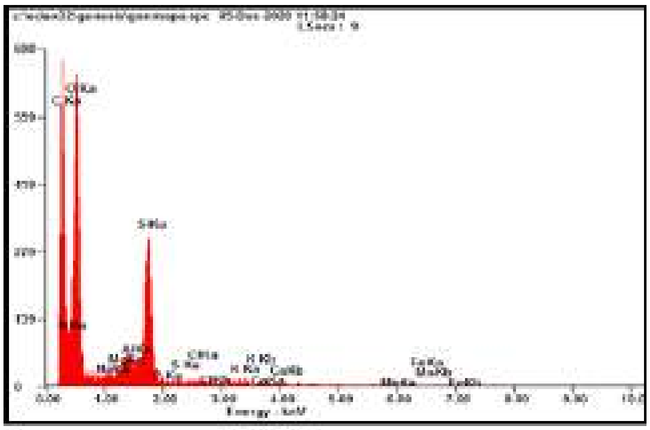
Effect of silixol on silica content and leaf thickness of rice

Genotypes	Leaf thickness (µm)		Silica content (%)	
	Treated	Control	Treated	Control
CB15714	82.6	64.3	8.37	3.15
CO 39	75.3	58.19	6.81	1.88

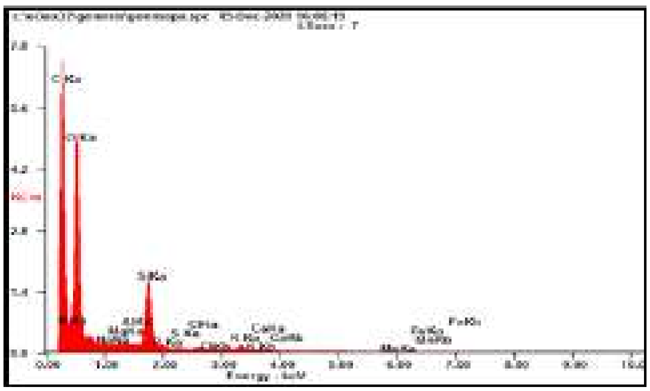
RESULTS

The results revealed that CB15714 registered the maximum silicon accumulation in foliar spray of silixol (8.37%) when compared to untreated control (3.15%), where as in CO39 it was 6.81

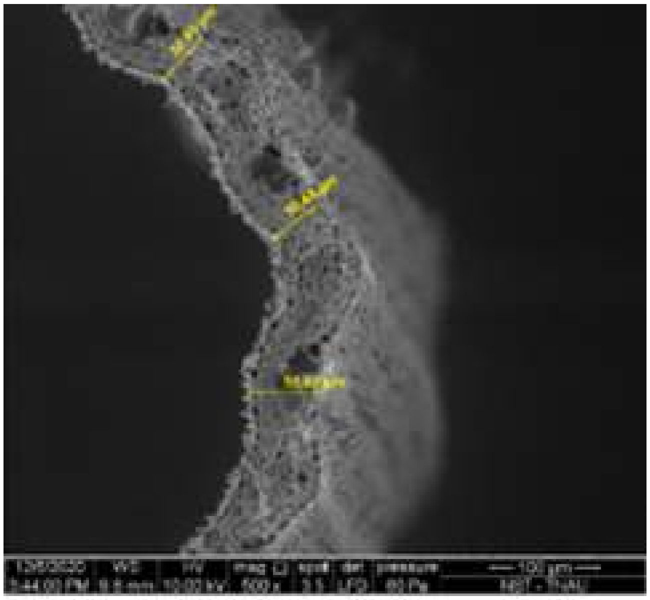
Silica content
CB15714 treated



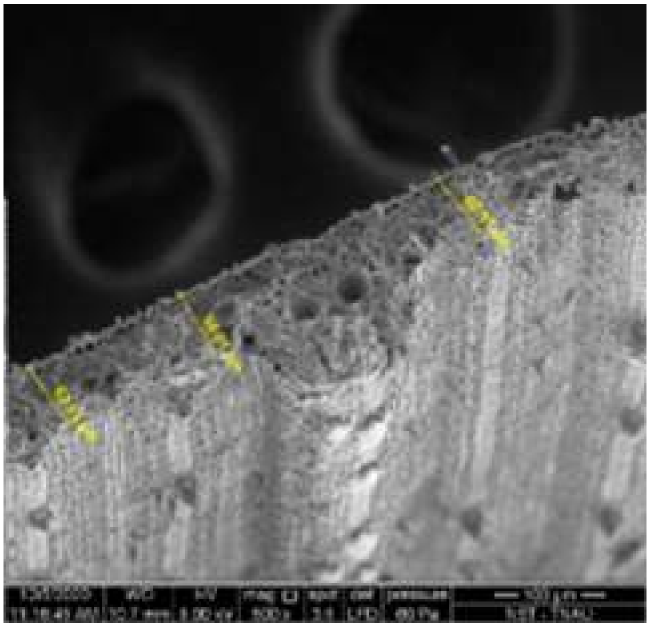
CB15714 treated



Pattern of silica deposition
CB15714 treated



CB15714 treated



and 1.88 % respectively. The CB15714 seedlings upon foliar spray with silixol at 0.6% showed more leaf thickness (82.6 µm) when compared to untreated control (64.3µm). The blast susceptible CO 39 upon foliar spray with silixol has recorded more leaf thickness (75.3)µm when compared to untreated seedlings (58.19 µm).The higher leaf thickness due to more accumulation of silica in the leaf epidermal cells, mesophyll cells and cuticle contributes to enhanced structural/physical defence against penetration of *Magnaporthe oryzae* infection peg.

CONCLUSION

The silica content of leaves of blast resistant culture was significantly higher when compared to blast susceptible variety. Exogenous application of silica during seedling stage significantly increases rice leaf thickness in both blast resistant and susceptible varieties.

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ARRW/SIRC/Theme III/13

Response of advanced rice genotypes towards yellow stem borer and brown plant hopper

SheelaVenugopal,[1]*Abdul Razak,[2]G.Srinivasan,[3]P.Anandhi,[4]K.Ganesan[5] & S.V. Krishnamoorthy[1]

[1] Dept. of Agrl. Entomology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India - 641003;
[2] Agricultural College and Research Institute (AC&RI), Killikulam; [3],AC&RI, Madurai;
[4] Tamil Nadu Rice Research Institute, Aduthurai; [5] Agricultural Research Station, Bhavanisagar, Tamil Nadu, India
Email: sheelavenugopal@tnau.ac.in

Rice (*Oryza sativa* L.) is the staple food of about 60 percent of the world population. India, the largest rice growing country, has the productivity of 2.58 t/ha which is very low when compared with China (6.71 t/ha), the country with highest productivity. One of the main reasons for low productivity is that majority of rice in India is grown in areas prone to high vagaries of weather *viz*., drought and flood. Another substantial reason for low productivity is the biotic stress caused especially by the monophagous pests *viz*., stem borers and plant hoppers right from seedling to maturity causing 30 and 20 % yield losses, respectively. These insect pests often become unmanageable using chemical control methods due to resurgence and concealed behavior of feeding, respectively. Host plant resistance is a useful alternate strategy that can be effectively incorporated with other eco-friendly methods of rice pest management. More than 30 potentially useful resistance gene loci and several major quantitative trait loci were identified for BPH in rice. However in case of YSB, studies on resistant genes are still in its infancy due to scanty source of resistance. In this context, 82 advanced rice entries were field screened for Yellow Stem Borer (YSB), *Scirpophaga incertulas*, at Coimbatore, Tirupathisaram, Ambasamudram, Killikulam, Madurai, Aduthurai, and Bhavanisagar centres of Tamil Nadu Agricultural University, during 2021-22 and artificial screened for Brown Plant Hopper (BPH), *Nilaparvatha lugens* at Coimbatore and Aduthurai.

MATERIALS AND METHODS

Field screening for stem borer resistance: Test entries (82 Numbers) were raised in nursery and then transplanted with a row of susceptible check, TN 1 for every 5 entries at Coimbatore, Tirupathisaram, Ambasamudram, Killikulam, Madurai, Aduthurai, and Bhavanisagar centres of Tamil Nadu Agricultural University, during Sep- Mar, 2021-22. Per cent dead hearts and white ear were observed on 50 DAT and prior to harvest, respectively, using the methodology enumerated by Heinrich *et.al.,* 1985.

Artificial screening for BPH resistance: Entries were sown in protrays @ 15 sprouted seeds per entry in each slot leaving two corner and middle

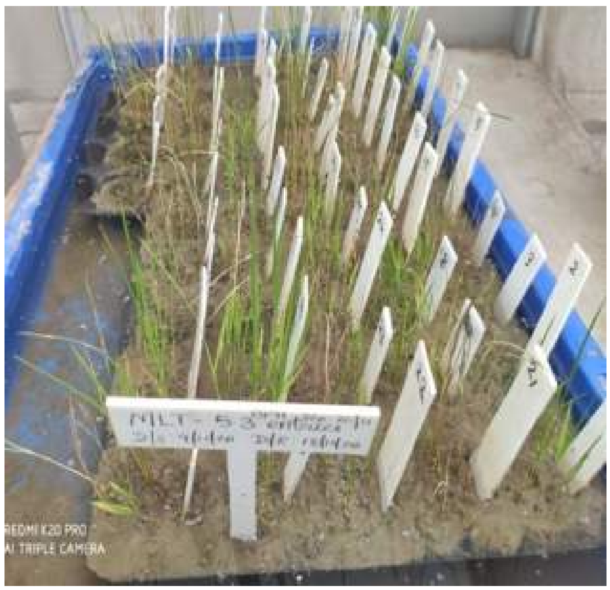

Fig. 1. Artificial screening against BPH

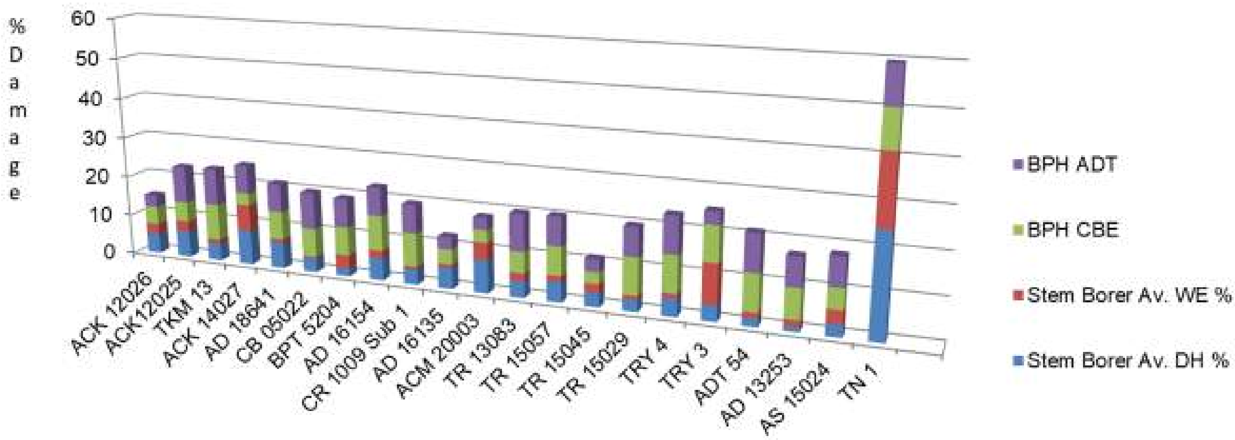

Fig. 2. Average damage by stem borer and BPH in selected entries under field and glass house screening

slots for TN1 and PTB 33/MO1, respectively. Seedlings were then inoculated with nymphs as per the procedure mentioned in SES, 2013 and damage score was taken.

RESULTS

The mean range of dead hearts caused by stem borer during field screening in the seven centres was 1.22-9.20% for entries while it was 21.94 % for TN 1 and the mean white ears was 0.39 – 9.68 % for entries and 16.69% for TN 1. AD 13252 and ADT 54 were found to be the resistant entries for YSB with scale 1 for both dead heart and white ear. Field screening experiments conducted during 2020-21 also revealed the resistance of ADT 54 to stem borer by registering low dead heart and white ear damage. BPT 5204 showed less dead heart (1.89%) but higher white ear (3.36%) incidence. Entries TKM 13, AD 18641, CB 05022, AD 16154, CR 1009 sub 1, AD 16135, TR 13083, TR 15057, TR 15029 & TRY 4 showed <2% white ear even after exhibiting higher dead heart incidence. Scores from artificial screening against BPH revealed that TR 15045 & ACM 20003 as highly resistant to BPH in both the locations whereas ACK 14027 & TKM 13 were highly resistant at Coimbatore and ACK 12026, AD 16135 & TRY 3 at Aduthurai. Entries ACK 12026 & AS 15024 showed moderate resistance to BPH at Coimbatore. Two of the 82 entries *viz.*, AD 16135 & TR 15035 showed resistance to both BPH and YSB.

CONCLUSION

Identification of a resistant genotype for rice stem borer is highly challenging due to the labour intensive and time consuming mass culture and screening protocols as well as the complex nature of inheritance of resistance. The variable reaction of the test entries to YSB at vegetative stage and reproductive stage, necessitates confirmation in YSB hotspot locations or by artificially inoculating with egg mass/ larva/adult in confined cages. Similarly resistance reaction towards hoppers have to be confirmed using modified seed box screening wherein the reaction of the test entry at tillering stage could be determined and compared with seedling screening. Studies on underlying inherent and induced resistant mechanisms is also suggested for the so-called confirmed entries which may in-turn accelerate the evolution of a resistant variety for these economic pests of rice.

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ARRW/SIRC/Theme III/14

Bioefficacy of new insecticide molecules against rice yellow stem borer, *Scirophaga incertulas* (Walker). (Pyralidae: Lepidoptera)

S. B. Kharbade, I.A.Ghonmode and A. J. Chormule

Government College of Agriculture, Karad, Mahatma Phule Krishi Vidyapeeth, Rahuri (MS)
Emails: adackarad@rediffmail.com

An investigation was undertaken with an objective to evaluate the relative bioefficacy of new insecticide molecules *viz*., flubendiamide 480 SC, indoxacarb 14.5 SC, fipronil 5 SC , imidacloprid 17.8 SL, lambda cyhalothrin 5EC, cartap hydrochloride 50 SP, along with *Metarhizium anisopliae* and *Bacillus thuringiensis* and granular insecticide *viz*., cartap hydrochloride 4 G, fipronil 0.3 G, ferterra 0.4 G carbofuran 3 G, lasenta 80 WG, Phorate 10 G, and chlorpyriphos 10 G against rice yellow stem borer, *Scirpophaga incertulas* (Walker) of rice.

All the new insecticide molecules treatments were observed to be effective in reducing stem borer infestation on rice crop. Among the evaluated new insecticide molecules fipronil 5 SC @ 30 g a.i./ha proved to be most effective against *Scirpophaga incertulas* (Walker) in which minimum dead hearts (4.08 per cent) were recorded at the time of first spraying and 3.13 per cent at the time of second spraying. Whereas 4.33 per cent white earheads were recorded at the time of third spraying. This treatment ultimately recorded hightest of 45.13 q/ha yield rice. The next best treatment in order of effectiveness were flubendiamide 480 SC@ 30 g a.i./ha, indoxacarb 14.5 SC @ 30 g a.i./ ha,cartap hydrochloride 50 SP@ 375 g a.i./ha, lambda cyhalothrin 5EC @ 25 g a.i./ha, imidacloprid 17.8 SL @ 25 g a.i./ha. The biopesticides *viz., M. anisopliae* and *Bt* were observed to be comparatively least effective against rice yellow stem borer. In case of insecticides lasenta 80 WG @ 250 g a.i./ha proved to be most effective against *S. incertulas* by recording lowest dead hearts 3.17 per cent at first application and 5.12 per cent at second application. This treatment ultimately recorded highest 43.30 q/ha yield of rice. The next best treatment in order of their effectiveness were ferterra 0.4 G @ 30 g a.i./ha, fipronil 0.3G @ 7.5g a.i./ha, cartap hydrochloride 4 G @ 750 g a.i./ ha, chlorpyriphos 10 G @1 kg a.i./ha, carbofuran 10 G 750 g a.i. /ha and phorate 10 G 750 g a.i. / ha.

The treatment with *M. anisopliae* and *Bt* were observed to be relatively safe to natural enemies. Whereas, the new insecticide molecules were also found to be moderately safe.

New insecticide molecules *viz*. flubendiamide 480 SC @ 30 g a. i./ha, indoxacarb 14.5 SC @ 30 g,a. i./ha, fipronil 5 SC @ 30 g,a. i./ ha, imidacloprid 17.8 SL@ 25 g,a. i,/ha, lambda cyhalothrin 5 EC @ 25 g,a.i,/ha, cartap hydrochloride 50 SP @ 375 g,a i,/ha, *M. anisopliae* and *Bt* and granular insecticides *viz*. cartap hydrochloride 4 G @ 750 g.a.i./ha, fipronil 0.3 G@ 7.5 g.a.i./ha, ferterra 0.4 G @ 30 g @ a.i./ha, carbofuran 3 G @ 750 g.a.i./ha, lesenta 80 WG @250 g.a.i./ha,, phorate 10 G @750 g.a.i./ha, and chlorpyriphos 10 G @ 1 kg g.a.i./ha did not exhibit any phytotoxicity symptom on rice crop.

ARRW/SIRC/Theme III/15

Nano-priming with biosynthesized silver nanoparticle protects rice plant against *Rhizoctonia solani* Kuhn causing sheath blight disease

S. Lenka[1], L. Behera[2], A. Mahanty[1], Raghu S[1] and P.C. Rath[1]

[1]*Crop Protection Division, ICAR-National Rice Research Institute, Cuttack (Odisha)-753006*
[2]*Department of Mycology and Plant Pathology, Institute of Agricultural Sciences, BHU, Varanasi (UP)- 221005*
Email: srikantalenka@yahoo.in

Sheath blight caused by the fungal pathogen *Rhizoctonia solani* Kuhn is among the most devastating diseases of rice. It is controlled by spraying fungicides like validamycin, carbendazim, propiconazole, iprodione etc. However, the rampant use of these chemicals has led to development of resistance towards this disease. Thus, it is necessary to look for newer chemical formulation to control the disease. The purpose of the study is to investigate the efficacy of biosynthesized silver nanoparticles (AgNPs) in management of rice sheath blight disease.

METHODOLOGY

AgNP was synthesized by using the culture supernatant of *Aspergillus niger.* The nanoparticle was characterized using UV-Vis spectrophotometer (SPR), dynamic light scattering (DLS), scanning electron microscopy (SEM), fourier transform infrared spectroscopy (FTIR).

RESULTS

The synthesis of AgNP was confirmed by a peak at 435 nm. SEM and DLS analysis showed that the AgNPs were found to be rod shaped with particle size of 42.41±2.18 nm. Zeta potential of the biosynthesized nanoparticles was found to be -41.2 Mv, which indicates high stability of the AgNPs. When used in different concentrations (0, 5, 10, 15, 30 and 50 ppm), AgNPs demonstrated antifungal action against *Rhizoctonia solani* Kuhn, an important pathogen of rice. In *in vitro* assay using poisoned food method showed that 50 PPM concentration of AgNPs emerged as the most effective treatment as per cent growth reduction was significantly maximum (73.52%). Similarly, *in vivo* assays under net house conditions also corroborated with the *in vitro*; 50 ppm concentration emerged as the most effective concentration with least disease index (25.93%) and was superior in all the morphological and yield attributes. Furthermore, the treatment of rice plants with AgNPs led to the induction of defense-related enzyme activities as PO, PPO, PAL, SOD, and APX.

CONCLUSION

Our research showed that plants treated with biosynthesized AgNPs were better able to deal with pathogen challenge, pointing to their broad implications in the control of plant diseases.

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ARRW/SIRC/Theme III/18

Efficacy of Chlorpyriphos 20 CS, a new Formulation against Major Sucking Pests of Rice

V.G. Mathirajan, M. Rajavel* and A.Velayutham

Agricultural College and Research Institute, Eachangkottai- 614 902, Tamilnadu, India

** Asst Professor (Agrl.Entomology) & Public Relation Officer , Tamil Nadu Agricultural University, Coimbatore, Tamilnadu*

Email: rjv6@tnau.ac.in

Rice is staple food in India. More than 100 species of insects are known as pests of this crop, out of which 20 are of major economic significance (Pathak and Dhaliwal, 1998). The overall yield loss due to these insect pests varies between 21-51 percent (Singh & Dhaliwal, 1998). The sucking pests*viz.,* brown planthopper (*Nilaparvata lugens* Stal.), white backed planthopper (*Sogatellafurcifera* Horvath) and green leafhopper (*Nephotettix virescens* Guenee) are of national important. Both nymphs and adults suck sap primarily from phloem tissues at the base of tillers, hence their presence goes undetected.To make pesticides environment friendly, molecules with novel mode of action are being synthesized and marketed. Chlorpyriphos (O,O- diethyl-(3,5,6-trichloro- 2-pyridylphosphorothioate) is the worlds leading insecticide in volume terms and is effective against a wide range of plant feeding, house hold and soil insects. It kills the insect by direct contact or ingestion and by disrupting the normal functioning of nervous system. The present study was taken up to evaluate the efficacy of new formulation CS and bio-safety to natural enemies and phytotoxicity in rice.

METHODOLOGY

Two season field trials were laid out with ADT 43 and CR 1009 rice varieties during *Kuruvai* 2014 (June'14-Sep'14) and *Samba* 2014(Aug'14-Jan' 15)at TRRI, Aduthurai in a randomized block design with 3 replications to evaluate the bio efficacy of Chlorpyriphos 20%CS at graded doses *viz.,* 125, 250, 375 and 500 g a.i/ha along with standard checks *viz.,*Imidacloprid 17.8 SL @ 25 g/ha, Fibronil 5% SC @ 75 g /ha and untreated control against Brown planthopper, White backed planthopper and Green leafhopper in rice, phytotoxicity on rice crop and bio safety to natural enemies. Two rounds of sprayings were given at 15 days interval starting from 40 days after transplanting using pneumatic knapsack sprayer with spray fluid of 500 litres/ha. Pre and post treatment counts of BPH / GLH no/ hill were observed from 10 randomly selected plants per plot (25 m^2) on 3,5,7 and 15 days after treatment spray. Percent reduction over control of BPH and GLH were calculated.Phytotoxicity symptoms like leaf injury, wilting, vein clearing, necrosis, epinasty and hyponasty on rice plants were observed as per CIB guidelines (0-10 rating scale) at 3,5,7 and 15 DAT (Days After Treatment). The plant and leafhopper population were transformed into square root transformation before statistical analysis. Grain yield was recorded at crop harvest and statistical analysis was carried out.

RESULTS

Maximum population reduction of BPH and GLH over control was observed Chlorpyriphos 20% CS @ 500ga.i/ha(97%), followed by Chlorpyriphos 20%CS@375g a.i/ha (94%), Chlorpyriphos 20% CS@ 250ga.i/ha (91%),Chlorpyriphos 20%CS @ 125g a.i/ha(86%). It is on par with Imidacloprid 17.8SL @ 25ga.i/ha(88%) and Fibronil 5%@ 75g a.i/ha(86%)at 15 DAT during *Kuruvai* season.

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ARRW/SIRC/Theme III/19

Exploration of potential bacterial strains against leaffolder, *Cnaphalocrosis medinalis*

Golive Prasanthi, Supriya Sahoo, Raghu S, Soumya Shephalika Dash, Anjan Kumar Nayak, Totan Adak, SD Mohapatra and Rath PC

Division of Crop Protection, ICAR- National Rice Research Institute, Cuttack 753006
**Email: prasanthi.golivi@gmail.com*

Insect pests in the rice agroecosystem, particularly the leaffolder*, Cnaphalocrosis medinalis* (Guenee) cause significant yield losses. The leaf folder larvae can damage several leaves while passing through different life stages. Due to heavy infestation, the field may look scorched which result in yield losses. If the damage is more than 25% at flag leaf stage, it results in 50% unfilled grains at flowering stage (Padmavathi *et al*., 2013). This pest generally managed by farmers with insecticides and a few biocontrol agents. As a component of IPM, biocontrol agents play a dynamic role in pest control. Therefore, an attempt was made to identify potential bacterial strains to control leaffolder.

OBJECTIVE

Identification of potential bacterial strains for the control of leaffolder, *Cnaphalocrosis medinalis*

METHODOLOGY

In this study, sixty-five diseased leaffolder *(Cnaphalocrosis medinalis*) larvae were collected from rice fields of ICAR-NRRI, Cuttack from which 25 different groups of bacterial strains were identified. The identified strains were tested against *C. medinalis* larvae, from which five bacterial strains were found as promising strains for leaffolder management. Physiological characters *viz.,* growth phase, NaCl sensitivity (1%-8%), temperature (28±1°C and 37°C), pH (3-10 range) of the bacterial isolates were examined on nutrient agar media. These were monitored by measuring the increase in optical density at 660nm using Thermo Scientific spectrophotometer.

The larvicidal activity of these five bacteria was evaluated against third instar of *C. medinalis* in petri plate assay and on whole plant assay (*Oryza* sativa var. TN1). Different concentrations such as $1x10^{-1}$, $1x10^{-2}$, $1x10^{-3}$,$1x10^{-4}$, $1x10^{-5}$ CFU/ml were tested against 3rd instar larvae of rice leaffolder. In petri plate assay, TN1 leaf bits (1 g) were dipped in different dilution of bacterial suspension for 15 minutes and kept in petri dishes lined with damp filter papers. Third instar larvae were released and kept in room temperature. The growth of the test insect on bacterial treated leaf bits were monitored and the larval mortality, pupal weight and adult emergence were recorded. Similarly, for whole plant assay, bacterial suspensions were sprayed in each pot containing three TN1 plants as replications at the maximum tillering stage and third instar larvae were released and covered with mylar cage. The observations on larval mortality, leaf area damaged were recorded.

RESULTS

Isolated strains were evaluated through extensive screening against leaffolder revealed that five bacterial strains were giving excellent larvicidal activity against leaffloder. Those were identified as *Cereibacter sphaeroides*, *Enterobacter cloacae, Bacillus thuringiensis, Ralstonia sp* and *Enterobacter hormaechei.*

In petri plate assay, the result of this study showed that 50% (LC_{50}) larval mortality of *C. medinalis* was observed after 7 days at $1×10^{-3}$ CFU/ml for *C. sphaeroides*, *E. cloacae*, *B. thuringiensis* and *Ralstonia sp* and in case of isolate *E.*

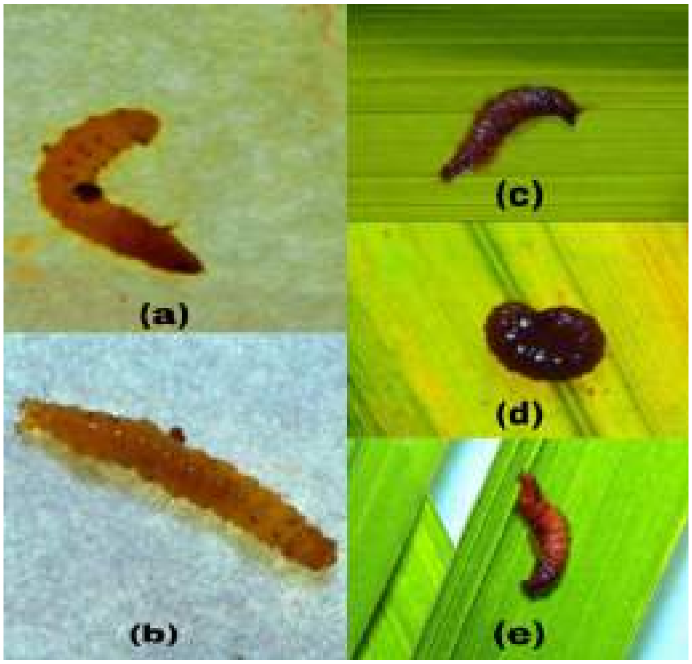

Fig. 1. (a) *C. sphaeroides* affected dead larvae of *C. medinalis* (b) *E. cloacae* affected dead larvae of *C. medinalis* (c) *B. thuringiensis* affected dead larvae of *C. medinalis* (d) *Ralstonia* sp affected dead larvae of *C. medinalis* (e) *E. hormaechei* affected dead larvae of *C. medinalis*

hormaechei, LC_{50} was 1×10^{-4} CFU/ml. In whole plant assay, *E. cloacae* and *B. thuringiensis* caused 50% larval mortality after 10 days of inoculation at concentration 3×10^{-3} and 2×10^{-3} CFU/ml, respectively, whereas for all other three isolates, it was at 1×10^{-3} CFU/ml. Adult emergence was significantly lower for the strains *viz*., *C. sphaeroides*, *E. cloacae*, *B. thuringiensis*, *Ralstonia sp* and *E. hormaechei* as compared to untreated control (90%).Symptoms caused by various bacterial strains on leaffolder larvae are indicated in fig.1.

Growth and survival of bacteria were also greatly influenced by the pH of the environment. The specific pH range for all the bacteria was between 7 to 8 for all the five potent strains. The isolates were also evaluated for their ability to withstand salt stress and revealed that all the strains can withstand 6% NaCl stress. They may not have any negative effect in salinity prone area. Maximum growth obtained in *B. thuringiensis* than other strains *viz*., *C. sphaeroides*, *E. cloacae*, *B. thuringiensis* and *Ralstonia sp* and *E. hormaechei*. All the effective bacteria strains *C. sphaeroides*, *E. cloacae*, *B. thuringiensis*, *Ralstonia sp* and *E. hormaechei* grown under the temperature 28°C and 37°C.

CONCLUSION

The bacterial strains namely *viz., C. sphaeroides, E. cloacae, B. thuringiensis, Ralstonia* sp and *E. hormaechei* are identified as potential bacterial strains against paddy leaffolder. Among them *B. thuringiensis, Ralstonia sp* and *E. hormaechei* were found to be highly virulent. Here a future thrust would be required to identify the mechanisms responsible for larvicidal activity of the identified strains.

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ARRW/SIRC/Theme III/20

Characterization of native rice landraces for leaf blast disease resistance

A Shanmugam[1*], Suresh R[1], Ramanathan A[2] and Sassikumar D[3]

[1] *Department of Genetics and Plant Breeding, Tamil Nadu Agricultural University, Coimbatore - 641003, Tamil Nadu, India.*
[2] *Agricultural Research Station, Tamil Nadu Agricultural University, Kattuthottam-613501, Thanjavur, Tamil Nadu, India.*
[3] *Sugarcane Research Station, Tamil Nadu Agricultural University, Cuddalore-607001, Tamil Nadu, India.*
**Email: ashanmugam1996@gmail.com*

Rice blast caused by an ascomycete fungus *Magnaporthe oryzae* is one of the most devastating fungal diseases affecting rice production globally. Severe incidence of this disease accounts for 70 to 80% yield losses which is equivalent to the feed value of 60 million people of the world. In India, blast disease is found throughout the rice growing regions, but predominantly visible in the areas where high humidity and low temperature are present. Cultural practices and chemical application are the major management practices for the control of rice blast disease. This leads to high production cost and environmental pollution. In addition, rapid emergence of the pathogen race makes it difficult to control rice blast by cultural practice. Therefore, identification of novel donors from the existing germplasms and development of resistant variety is one of the most durable and environment-friendly approaches to fend off the rice blast disease. Worldwide more than 100 blast resistant genes have been identified and reported (Shahriar *et al.,* 2020). Hence, the present study aimed to screen the diverse panel of native rice landraces to identify the novel resistant source against the leaf blast disease for utilization in future rice breeding programmes.

MATERIALS AND METHODS

A panel of 120 native rice landraces were collected from different parts of Southern India were screened for blast disease reaction under rice blast nursery at Hybrid Rice Evaluation Centre (HREC), Gudalur along with susceptible (CO39), moderately resistant (CO 51) and resistant check (Tetep). HREC located at a latitude of 11^{o} 30’N, longitude of 76^{o} 30’E and an elevation of 1317 m above MSL, Nilgiris, Tamil Nadu, which is a natural hotspot for leaf blast disease. The weather condition of this location is very much favourable for the blast incidence throughout the year and in winter and rainy season higher blast disease incidence is observed (Immanuel *et al*., 2011).

Genotypes along with checks were sown in single rows with a length of 100 cm and 10 cm gap between the successive rows. Entire uniform blast nursery bed was surrounded by a known susceptible check CO39, which are sown in a single rowfor the spread of blast fungal pathogen. Blast scoring was done following the IRRI standard evaluation system (SES) scale.

RESULTS

Screening of genotypes under natural disease incidence revealed that complete susceptibility of CO39 against Tamil Nadu isolate of blast pathogen. Blast symptom in the susceptible check CO39 was noticed on 18 days after sowing and severe symptom was observed on 45th day. CO51 and Tetep (containing *Pi54* gene) were found to exhibit moderate resistance against blast pathogen with score 3. Among the landraces studied, four genotypes (ADT-LR-52, 56, 57 and 108) were found to be resistant genotypes with score 1 at 45 days and seven genotypes (ADT-LR-34, 37, 40, 51, 53, 61, 74) were shown as moderately resistant with score 3. All other genotypes were fall under moderately susceptible, susceptible and highly susceptible groups.

CONCLUSION

Traditional rice varieties (land races) have been recognized as valuable genetic resources for improving the resistance level of modern rice cultivars against biotic diseases. Blast resistant genotypes identified in the present study could serve as a useful genetic resource for future breeding programmes to develop blast resistant high yielding rice varieties. Molecular confirmation and tagging of genes governing resistance in the identified donors would be ideal way to utilize these landraces in marker assisted breeding programmes.

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ARRW/SIRC/Theme III/21

Identification of rice genotypes for blast resistance under field and artificial conditions

R Sujitha[1], M Arumugam Pillai[2], R Kannan[3] and D Shoba[2]

[1]*Dept of Plant Breeding and Genetics, TNAU, Coimbatore-641 003, Tamil Nadu, India*
[2]*Dept of Plant Breeding and Genetics, AC & RI, Killikulam-628 252, Tamil Nadu, India*
[3] *Dept of Plant Pathology, TNAU, Coimbatore-641 003, Tamil Nadu, India*
Email: sujialr96@gmail.com

Rice (*Oryza sativa L.)* (2n = 24) is a prime food crop provides food for 90% of the world population. Considering global food production ninety percentage of world rice grown under Asian countries and among them India stands second position after China (Foreign agriculture service report 2021-22, USDA). The existing rice varieties were prone to several biotic and abiotic stresses which bring out breakdown of resistant capacity of the varieties and it leads to reduction in yield. One of the most consequential biotic stress influences the production and productivity of rice is Rice blast, which is effected by the filamentous ascomycete fungi, *Magnoporthe grisea.* It infects leaves, nodes, collar, panicles and roots from seedlings to adult plant stages (Manandhar *et al*., 1998). The evolution and disposition of rice varieties introgressed with crucial resistance genes is the most economical and eco-friendly approach to combat the menace of blast disease.

METHODOLOGY

The experiment was carried out in AC & RI, Killikulam, TNAU using one hundred and eight genotypes including Tetep and CO39 as resistant and susceptible checks. Blast screening was done under field condition without any artificial inoculation of blast pathogen and the periodical scoring was done at 47 and 79 days after transplanting (DAT) (Turaidar *et al*., 2018). Under controlled environment (glasshouse) blast inoculum was sprayed in 21 days old seedlings and scoring was done at 15 days after inoculation (DAI) using 0-9 scale (SES, 1996).

RESULTS

Out of 108 accessions screened under field conditions, 29 genotypes were identified as resistant including the check variety Tetep at 47 DAT. At 79 DAT, only two genotypes namely

Fig 1. Screening of rice genotypes under field and artificial conditions

Fig 2. Blast lesions observed in Tetep and CO39

Chandaicar and Thuyamalli were identified as resistant lines with low PDI value of 13.33% and 17.78% respectively as compared with CO39 (73.33%) while the genotypes Kalyani, Chomala and Uma were recorded high PDI values *viz.,* 73.3%, 71.11% and 70.1% which inferring that the susceptibility of the genotypes to the blast pathogen. None of the genotypes were recorded as highly resistant and highly susceptible in both the durations (Fig 1). Under artificial condition, the accessions Jaya and Virendra were recorded as resistant at 15 DAI with the lowest lesion length of 0.6 mm and 0.8 mm as compared with susceptible check CO39 (4.5 mm) (Fig.2). The lower lesion length conferred the resistant mechanism of genotype against pathogen and these genotypes were observed as moderately resistant under field conditions. The resistant genotypes under natural conditions were shown moderate resistance under artificial condition and it would be considered as the escape mechanism of genotypes to the pathogen under field conditions.

CONCLUSION

The enhancement of host plant resistance is one of the biological measures to control blast severity. Therefore, screening of germplasm plays a significant role in breeding program in order to assessing the diversity in the population. The genotypes Chandaicar, Thuyamalli, Jaya and Virendra were identified as resistant and moderately resistant lines under both the environments and they might be proposed for further analysis to unravel the genomic regions conferring blast resistance.

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ARRW/SIRC/Theme III/22

Tiny but magnificent warriors against rice pests in unsprayed rice fields

SheelaVenugopal,[1] N. Chitra[1], G. Preetha[1], S. Manonmani[2] & S.V. Krishnamoorthy[1]

[1] *Dept. of Agrl. Entomology,* [2] *Department of Rice, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu*

Email: sheelavenugopal@tnau.ac.in

Rice, the staple food crop of India, is infested by several insect pests and a significant portion of potential yield is lost to infestations by these pests. Insecticides are the first remedial measures sought by Indian rice farmers since ages and now the trend is shifting towards sustainable and zero input farming. Knowledge on potential of the innate warriors present in rice ecosystem would help appreciate the efforts taken towards their conservation. Rich communities of biological control agents *viz*., predators and parasitoids attack rice insect pests in the absence of chemical insecticides. The potential of biological control was observed to be surpassing any other management options during two fixed plot surveys conducted during 2021-22 in undisturbed rice ecosystem.

MATERIALS AND METHODS

Study was carried out at the Department of Rice, Tamil Nadu Agricultural University, Coimbatore, India during 2021-22. Fortnight surveys on fixed unsprayed rice fields focused on the incidence of dead heart and white ears and abundance of predators and parasitoids by making observations using sweep nets (25 sweeps per observation) and random collection of egg masses. These egg masses were kept separately in glass vials (10x 5 cm dia) provided with sufficient moisture to prevent desiccation of eggs and leaves. Egg masses were observed daily for emergence of wasp and % parasitization was calculated.

RESULTS

Diverse natural enemies *viz*., Spiders, Odonates, Mirids, Rove beetles *Ophionia* beetles, Hymenopteran wasps and Bristle flies were observed throughout the year except during May when there was no rice crop in the conducive stage. Among them, spiders *viz*., *Lycosa, Tetragnatha*, *Oxya* and *Argiope* spp, Odonates *viz*., damselflies and dragonflies, rove beetles, *Ophionea* beetles were generalist predators that were found

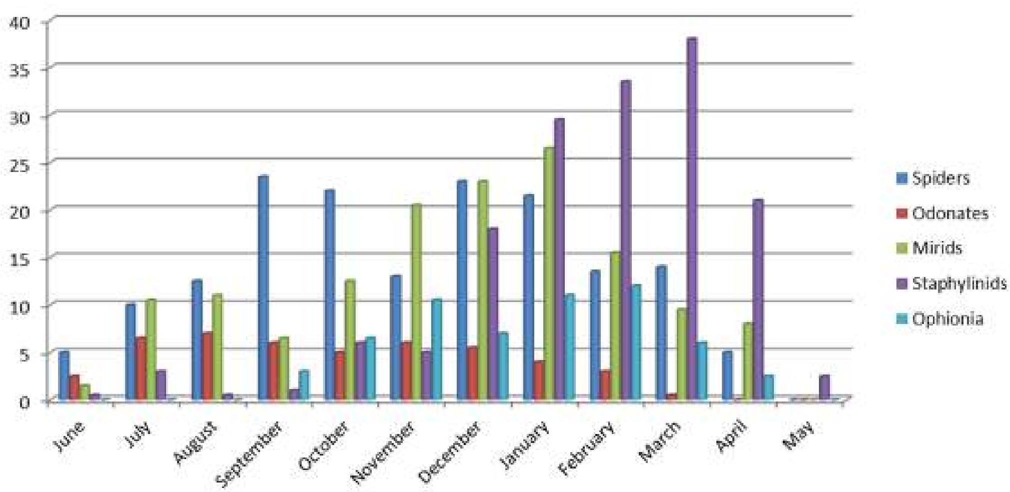

Fig.1 Incidence of generalist and specialist predators in rice during 2021-22 at TNAU, Coimbatore

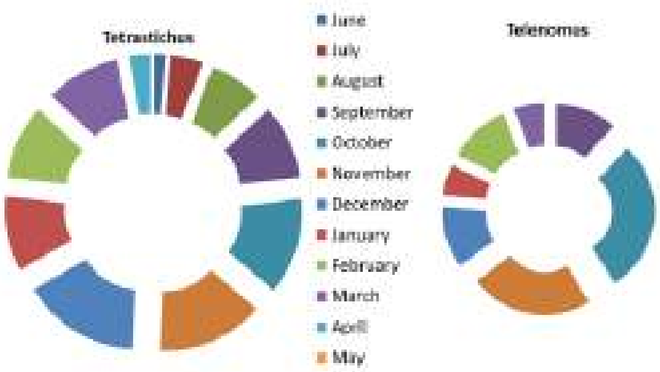

Fig. 2. Percent parasitism of YSB egg mass by *Tetrastichus* sp. and *Telenomus* sp. during 2021-22 at TNAU, Coimbatore

feeding on eggs, larva, nymphs and adults of rice pests *viz*., YSB, leaf folder, BPH *etc*. Rove beetles, *Paederus fusipes* was often seen inside each leaf roll infested by leaf folder. Specialist predator *viz*., Mirid bug, *Cyrtorrhinus lividipennis* was observed all though the year ranging from 1-30 per 25 sweeps and found to increase substantially with the build up of BPH in the rice canopy during November 2021- January 2022. Stem borer egg parasitism was upto 80 percent in the months of October and November by *Tetrastichus schoenobi* and *Telenomus sp*. and maximum parasitisation was due to *T. schoenobi*. Parasitoids *viz*., *Ischnojoppa*, *Stenobracon*, *Xanthopimpla*, *Amauromorpha*, *Pseudogonatopus* etc., were also frequently noticed in the unsprayed rice field.

CONCLUSION

The predator and parasite complex present in undisturbed rice ecosystems is diverse. At least 98 species of parasites have been reared from SB alone (Pathak and Khan, 1997). In addition, many species of generalist predators feed on the immature and adults of most pest species. Thus it was concluded that inspite of initial damage due to stem borer, leaf folder and sucking pests, their subsequent damage was observed to be significantly put under check in an unsprayed rice field and the rice crop could give an appreciable yield without any chemical intervention.

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ARRW/SIRC/Theme III/23

Molecular Mechanism of a Turmeric Based Biopesticide against sheath blight of rice

Swathi Chintala[1*], Nandita Sahana[1], Kumaresh Pal[1], Rosalin Laishram, Somnath Mandal[1]

[1]*Dept. of Biochemistry, Faculty of Agriculture, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India*
**Email : swathi.chintala95@gmail.com*

Rice (*Oryza sativa)* is one of the most important cereal crops in the world. India is the second largest rice producing country in the world and West Bengal takes the leading place in rice production amongst all the states. Rice sheath blight is a devastating fungal disease infecting rice worldwide and it can cause up to 50% yield loss under the most conducive environments. Search for effective biopesticides against sheath blight pathogen is of utmost importance to manage the disease on the field.

Turmeric (*Curcuma longa)* is known as the wonder crop of Indian subcontinent with countless benefits. It is one of the miraculous plants having antioxidant, antifungal and antibacterial properties. In the current study, a wide range of plant pathogenic fungi were tested using crude turmeric rhizome extracts for inhibitory actions. Concentrated turmeric extract exhibited more than 50% inhibition of the fungus, *Rhizoctonia solani* which causes sheath blight disease and affects rice cultivation globally.

METHODOLOGY

Green synthesis techniques were used to formulate a silver nano formulation (SNTPs) using turmeric rhizome extract. The SNTPs are characterized by using a UV-VIS spectrophotometer, Dynamic Light Scattering method (DLS), and scanning electron microscopy (SEM).Seed priming was done by using the SNTPs for 12 hours and was grown in seedling trays with *Rhizoctonia* inoculated soil media. All enzymatic assays of PAL, Peroxidase and Super oxide dismutase (SOD) have been performed by standard protocols using UV-VIS spectrophotometer. Gene expression study of 0, 5 and 10 days old seedlings has been performed with the help of RT-PCR studies.

RESULTS

The particle sizes of the SNTPs were determined to be less than 100nm. The presence of comparable chemical groups in turmeric crude extract and the in the synthesized SNTPs was confirmed by the Infrared spectrum generated by Fourier Transform Infrared spectroscopy (FTIR) where alkene, sulfoxide, anhydride and alcohol groups were found to be present. With a concentration of 100 ppm in PDA, the SNTPs were found to suppress *Rhizoctonia solani* up to 80%. Microscopic investigation of the fungus revealed increasing the ROS accumulation in SNTPs treated mycelia which reduces the mitochondrial membrane potential and ultimately damage the respiratory system. Quantitative RT-PCR studies revealed that SNTPs treated mycelia significantly increased the expression of different component of Electron Transport Chain (ETC) like Cytochrome oxidase 3 (*cox 3*) and NADH dehydrogenase 5 (*nad 5*) which may be due to compensating the hampered ATP synthesis in the treated mycelia. Under in vitro conditions, rice seeds were bio-primed with SNTPs for 12 hours and were grown in seedling trays with *Rhizoctonia* inoculated soil media. It was observed that treated seeds have a high level of immunity to the *Rhizoctonia* infection. Additional microscopic evidence suggested that the SNTP treated rice seedlings have a sturdy root system with increased callose accumulation surrounding the vascular tissues of the roots. Enzyme analysis revealed that the activities of anti-oxidative defense enzymes PAL, Peroxidase and SOD increased significantly in the treated plants. Real time PCR analysis of the PAL gene and PR gene expression in bio-primed seedlings showed an up regulation of the defense genes. These findings indicate that SNTPs enhances the resistance of the rice plants to withstand *Rhizoctonia* attack by suppressing the mycelial growth of the fungus and boosting their innate defense mechanisms. From the above findings it is indicating that the SNTPs are exhibiting double action phenomena during *R.solani*.

CONCLUSION

Priming of rice seeds with 100 PPM of SNTPs was highly effective in rice seedlings without hampering the germination and growth of the seedlings.

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Managing the Global Invasive Apple Snails in Rice: A New Food Security Threat to India

Ravindra Chandra Joshi

Senior Consultant, Philippine Rice Research Institute, Philippines; Associate CABI-SEA, Malaysia; Technical Advisor on invasive apple snails to DELTAMED (Asociación de Deltas del Mediterráneo), Amposta, Spain; Senior Adviser on Invasive Apple Snails, NEURICE Project-Funded by European Commission, Spain; Tropical Agriculture Association (UK); Paciûc Coordinator, Sustainable Agriculture, Food, and Energy (SAFE) Network.

E-mail: rcjoshi4@gmail.com

Originating from South America the freshwater invasive apple snail species of *Pomacea*, were deliberately introduced into many ASEAN countries with the intention of raising it for human consumption, aside from the aquarium trade. In addition, accidental introductions continue to occur in many countries around the globe because of the snail's ability to use multiple pathways and their biological characteristics. Not long after the snail introductions/invasions they quickly spread to most freshwater ecosystems, becoming one of the major invasive agricultural pests, notably in wetland direct-seeded rice, but also other aquatic crops (Joshi *et.al*, 2017). It is listed as one of the world's 100 worst invasive alien species (GISD, 2018).

Two species of *Pomacea* namely, *Pomacea canaliculata* and *Pomacea maculata* have been introduced and/or invaded many ASEAN Member States, Asia, Pacific, Caribbean, Africa from their native range. However, many publications prior to 2012, failed to distinguish *Pomacea canaliculata* and *Pomacea maculata*, until the advent of molecular approaches (Hayes et al., 2008). *P. maculata* was originally referred to as *Pomacea insularum*. Also, in the scientific literature many *Pomacea* spp. have commonly been referred to as "golden apple snails", or "GAS", often without clarifying speciûcally which species, was involved, or indeed simply assuming it to be *Pomacea canaliculata* (Cowie *et.al*, 2017). We propose that future researchers avoid this ambiguous common name designation.

Invasion apple snail invasions in wetlands and rivers pose high risk to the sustainability of the areas' native biodiversity and in particular, to the survival of endangered species such as the native aquatic plants, fish, amphibians, and birds. Occurrence of snails also reduce the macrophyte biomass through selective herbivory, seriously impacting the ecosystem services such as availability of fresh and good-quality water, thereby reducing the availability of plants and fish as food, and making recreation activities less attractive due to diminished bird and fish populations, and growth of algal bloom (Carlsson, 2017). It has also increased reliance on the use of synthetic molluscicides, include the misuse and abuse of agrochemicals in lowland rice fields. Aside from direct rice damage, they are also host to disease-causing trematodes and nematodes, including the endoparasite rat lungworm (*Angiostrongylus cantonensis*) which cause the disease Eosinophilic meningoencephalitis in humans; and intestinal ûuke (*Echinostoma ilocanum*) (CABI, 2014). Many farm workers can be exposed to such infections if they consume raw snails, and also in wetlands because of a lack of protective clothing.

Presently most of the snail management techniques could not be easily adopted by the wet direct-seeded rice farmers as these are labor-intensive, not economical, not eûective to reduce snail numbers at non-damaging levels, and not environment friendly (Joshi, 2007). Thus, new innovative approaches are needed for long-term control and containment to reduce ecological and economic losses.

The challenge for crop protection specialists is to prevent new invasions and manage the invasive apple snails in the changing climate, especially in the wet direct-seeded rice (DSR) under inbred and hybrid rice systems, and flood-prone areas. This is because currently there are no measures to eûectively prevent the growth, development and spread of *Pomacea* species. Therefore, international collaboration with snail invaded countries/ countries with high risk of invasions is needed for accurate species identiûcation, and for better understanding of invasion biology in order to develop eûective ecologically sustainable integrated snail management approaches. This is especially important for India to prevent any future invasions of *Pomacea* spp. from its neighbors where this snail had already invaded and is established. Thus, there is a need to develop the inter-country collaborative research, training and extension project for potential funding agencies/ organizations.

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ARRW/SIRC/Theme III/25

Characterization of endophytic microorganisms as biocontrol agents against major fungal diseases of rice (*Oryza Sativa* L.)

Shugufta Parveen, F. A. Mohiddin and Najeebur Rahman Sofi

MRCFC Khudwani, Sher-e-Kahmir University of Agricultural Sciences and Technology- Kashmir J&K-192102, India
Email: famohiuddin@skuastkashmir.ac.in

Rice (*Oryza sativa* L.) is the world's most widely consumed cereal crop, and more than 50 per cent of the world's population uses it as a staple food. More than 90 per cent of the world's rice is produced and consumed in Asian countries. It is affected by many diseases among which blast, brown spot and sheath blight are major diseases causing severe yield losses. Repeated use of chemical fungicides leads to the development of resistance in the fungi, environmental contamination and also affects non target microorganisms. Biological management by endophytic microbes is the most widely recognised and environmentally beneficial way for controlling any form of pest or disease, and it has no detrimental effects on the environment. So, the study was conducted to identify the most potent endophytes which not only prevents the rice plants from three major fungal diseases namely blast, brown spot, and sheath blight but also increases its production.

METHODOLOGY

Altogether one hundred twenty-five (125) endophytic microorganisms were isolated from roots, stem and leaves of four major cultivars of rice viz., C1039, SR3, SR4 and SR5. Among the isolated endophytes, total 18 (five fungal and thirteen bacterial) were found best performing for inhibition of growth of all the tested pathogens under *in vitro* conditions. They were evaluated for different invitro tests like chitinase production, siderophore production, hydrogen cyanide production and other plant growth promoting tests. All the eighteen endophytes were characterized by cultural, morphological and molecular means. Also, the endophytes were evaluated under green-house conditions.

RESULTS

The highest growth inhibition among fungal isolates was shown by *Trichoderma harzianum* (91%) followed by *Aspergillus flavus* (90%). Similarly, among the bacterial isolates, highest growth inhibition was shown by *Ureibacillus massiliensis* (75.47%) followed by *Ochrabactrum rhizosphaerae.* All the five fungal and ten bacterial endophytes were able to solubilise phosphorous. Highest phosphorous solubilisation was observed by *Aspergillus flavus* (88.45 μmgl^{-1}) while as lowest solubilisation was found by *Trichoderma harzianum* (34.28 μmgl^{-1}). All the endophytes (5 fungal and 13 bacterial) were able to produce IAA and gibberellic acid ranging from 34-88 μmgl^{-1}, 7-97 μgml^{1} and 1-49 μgml^{-1} respectively. Highest auxin production was observed by isolate *Enterobacter cloacae* (99.77 μmgl^{-1}) while as lowest was found by *Penicillium rubens* (7.14 μmgl^{-1}). Eleven endophytes showed chitinase activity with highest chitinase activity by *Bacillus licheniformis* while as lowest chitinase activity was shown by *Stenotrophomonas maltophilia* (1.32 units). Thirteen isolates were able to produce ammonia ranging from 13μg ml^{-1} produced by *Bacillus licheniformis* to 83 μg ml^{-1} produced by *Enterobacter cloacae*, fourteen isolates showed siderophore production with highest siderophore production of 57 percent by *Aspergillus flavus* and lowest production of 10 percent by *Stenotrophomonas rhizophila.* Only three bacterial isolates were found positive for HCN production with highest HCN production of 54 μg ml^{-1} by *Bacillus flexus*. Under greenhouse conditions, the highest disease control was shown by *Aspergillus flavus* in case of blast and sheath blight with disease control of 79 and 80 per cent respectively, while as in case of brown spot, highest disease control was shown by endophyte *T. harzianum* with disease control of 78 per cent. The endophyte *Enterobacter cloacae, Bacillus cereus, Aspergillus flavus* were showing highest root length, root wet weight and root dry weight while as *Stenotrophomonas maltophilia* and *Aspergillus flavus* were best performing for increasing shoot length, shoot wet and dry weight under greenhouse conditions.

CONCLUSION

Among the fungal and bacterial endophytes *Trichoderma harzianum*, *T. afroharzianum*, *Aspergillus flavus*, *Bacillus licheniformis*, and *Stenotrophomonas rhizophila,* were able to manage all the three diseases. *Enterobacter cloacae, Bacillus cereus* and *Aspergillus flavus* were best in promoting root growth while as *Enterobacter cloacae, Stenotrophomonas maltophilia* and *Aspergillus flavus* were found best in promoting shoot growth. Formulation of both fungal and bacterial endophytes can be evaluated under field conditions and Integrated disease management programme should be explored to integrate fungicides with endophytes to achieve better and eco-friendly disease control. Also, bio-formulation of these endophytes can be taken forward as a potential biofertilizer for sustainable cultivation of *Oryza sativa* in Kashmir Himalayas.

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ARRW/SIRC/Theme III/26

Evolutionary dynamics of rice tungro virus from eastern India and development of recombinase polymerase amplification (RPA) based rapid diagnostic

Chandu A[a], Amrita Banerjee[b*], GP Pandi[c], Somnath Roy[b], S Mandal[c], MK Bag[c], N.P. Mandal[b]

[a] Division of Plant Pathology, ICAR-Indian Agricultural Research Institute, New Delhi 110012, India
[b]Central Rainfed Upland Rice Research Station, ICAR-National Rice Research Institute, Hazaribag 825301, Jharkhand, India
[c]ICAR-National Rice Research Institute, Cuttack 75 006, Odisha, India
**Email: amrita.banerjee@icar.gov.in; amrita.ars@gmail.com*

Rice tungro disease, the most important viral disease of rice, is caused by the simultaneous infection of *Rice tungro bacilliform virus* (RTBV) and *Rice tungro spherical virus* (RTSV). Tungro outbreaks generally occur in the epidemic form in a cyclic pattern and its presence is endemic in India. The latest outbreak of RTD was noticed during *Kharif* 2007 in northern Telangana, India (Krishnaveni *et al*., 2011). However, in Odisha major tungro outbreak has been reported long back during 1990-1991. The field survey conducted during *Kharif* 2020 at the experimental farm of ICAR-National Rice Research Institute, Cuttack revealed widespread occurrence of tungro. Most of the tungro isolates from eastern India have been collected and characterized ten years back during 2010-11. Therefore, it would be interesting to know the present molecular features of RTBV and RTSV from eastern India for a better understanding of evolutionary dynamics. Moreover, the available diagnostic techniques are unable to detect the virus from crude sap. Therefore, in this study attempts were made to reveal the present genomic status of tungro isolate from eastern India and to develop Recombinase Polymerase Amplification (RPA) based rapid diagnostics of RTD directly from plant sap.

METHODOLOGY

The symptomatic plant (variety Bina 8) was assayed for presence of RTBV and RTSV through polymerase chain reaction (PCR). The PCR confirmed plant was used as the virus source (isolate Cuttack-2020). The RTBV-Cuttack-2020 was characterized based on complete large intergenic region (LIGR) and RTSV-Cuttack-2020 was characterized based on partial coat protein 3 (CP3) gene following PCR-based fragment amplification, cloning and sequencing. The DNA sequence data of RTBV-LIGR and RTSV-CP3 of Cuttack-2020 isolate was compared with the LIGR and CP3 sequences of previously reported isolates available in NCBI database.

To develop RPA based diagnostic assay, three pairs of RPA primer were designed were designed based on highly conserved RT/RNaseH gene sequences of RTBV to function both in RPA and in PCR. Both the total DNA and crude leaf extract from RTBV positive sample was used as template. RPA was performed with all the three pairs of primers using TwistAmp® Basic Kit (TwistDx, Cambridge, UK) following manufacturer's instructions with a few modifications. The specificity and sensitivity were evaluated. Finally, the developed assay was validated on samples collected from Odisha and ICAR-IIRR, Hyderabad.

RESULTS

Molecular characterization : The nucleotide sequence of complete LIGR (819 nucleotide) of RTBV-Cuttack-2020 showed 95.42-97.23% identity with SA isolates, while only 79.40-80.19% identity with SEA isolates**.** The phylogenetic analyses also revealed the grouping of present isolate (RTBV-Cuttack-2020) within SA cluster having previously reported Indian isolates. The multiple alignment of LIGR of RTBV-Cuttack-2020 with SA isolates (Fig. 1) revealed that TATA box

Fig. 1. Nucleotide sequence alignment of LIGR of RTBV-Cuttack-2020 with previously reported Indian RTBV isolates. The green arrows indicate the relative position of E fragment of the promoter and the red arrow indicates the predicted transcription start site. RTBV-Cuttack-2020 is indicated by * mark.

consensus, small ORF1 (sORF1), poly A signal, tRNA primer binding site and shunt landing site of LIGR remained conserved in the present isolate including other RTBV isolates reported from India (Banerjee et al., 2012). The partial nucleotide sequence (848 bp) of CP3 of RTSV-Cuttack-2020 showed 92.53-98.47% identity with previously reported SA isolates, while only 88.64-89.79% identity with SEA isolates. But, the derived amino acid sequence of partial CP3 (282 amino acid) of present isolate showed 95.37-99.29% identity reported RTSV isolates irrespective of its origin. The phylogenetic analyses based on amino acid sequence of CP3 grouped the present isolate within SA cluster and showed its close association with WB isolates.

Development of diagnostic : The developed RPA assay efficiently detected RTBV from both genomic DNA and crude sap incubating at an isothermal condition of 39! for 30 min. The specificity of the developed assay using all three sets of primers were tested and none of the primer pair showed cross reactivity with other rice pathogens or rice DNA. The optimized RPA assay using primer pair RTBV-RPA F3/R3 was found to be highly sensitive than PCR in detecting RTBV from both DNA and crude sap. Moreover, it was able to detect RTBV from frozen crude sap stored for three months in deep freezer (-20 p C). Further, the developed RPA assay was validated on field samples collected from Cuttack and Hyderabad, India.

CONCLUSION

Overall, the molecular characterization of the new tungro isolate (Cuttack-2020) from eastern India confirmed its homology with previously reported Indian isolates. This in turn confirmed that the genomic features of the isolates remain conserved over the period of more than ten years. To the best of our knowledge, this is the first report of detection of RTBV using crude sap by RPA. In future, the developed RPA assay coupled with lateral flow-strip could be useful for early on-site detection of RTBV infection under field condition.

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Depiction of spatio-temporal dependence of yellow stem borer damage in coastal rice ecology using geostatistical method

Kiran Gandhi Bapatla

ICAR- NRRI, Regional Coastal Rice Research Station, Naira - 532186, Andhra Pradesh, India

Rice (*Oryza sativa* L.) is one of the most important staple crops for many people in the world. Unfortunately, rice is also a target for pests. One of these is the yellow stem borer (YSB), *Scirpophaga incertulas* Walker (Lepidoptera: Crambidae). The YSB attack at the vegetative stage and reproductive stage of the plant growth produces symptoms called 'Deadhearts (DH)' and 'Whiteheads (WH)', respectively. The manifestation of both DH and WH in rice resulted in up to 30% yield loss (Yunus, 2018). Biological variables exhibit spatial heterogeneity, for example, certain places have high insect pest incidence. Therefore, geostatistical tools were applied to characterize the spatio-temporal distribution of YSB infestation, DH in coastal rice ecology.

METHODOLOGY

Fixed plot surveys for YSB damage symptom DH were carried out in 10 rice fields located at Eastern Plateau and Hills agro-climatic zone of India for two crop seasons (*kharif* 2021 and 2022) from 35 to 42 meteorological standard weeks (MSWs). Spatial dependence and the relationship between sample values and distance and directions were determined by plotting variogram plots. Nugget-to-sill ratios define the extent of YSB damage aggregation, where ratios of <0.25, 0.25-0.75, and>0.75 indicate strong, moderate, and weak aggregation, respectively (Reay-Jones, 2017). The ordinary kriging interpolation models viz., spherical, gaussian and exponential were employed to develop the prediction maps of YSB damage (DH) in rice, which were generated in RStudio and QGIS 3.12 software. To evaluate the prediction, the values of metrics like co-efficient of determination and Root Mean Squared Error values were considered.

RESULTS

In total, 1762 DH were sampled from all the locations and MSWs for two cropping seasons (2021 and 2022). Across the locations, the YSB

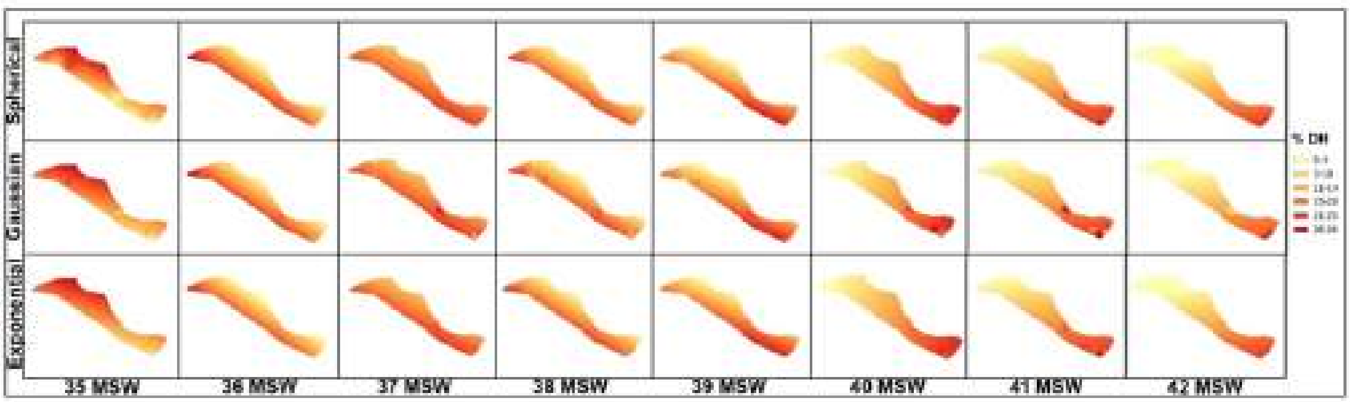

Fig. 1. Illustrating kriging interpolated map showing predicted values of yellow stem borer damage in the experimental area for different sampling weeks

damage (DH) in rice not varied significantly between MSWs ($F_{79,7}$ = 1.101, p<0.05). The highest DH was observed in: the first sampling week (35 MSW) compared to the last sampling week 42 MSW (approximately threefold). It was noticed that a 32% DH declined from the first (35 MSW) to the last sampling week (42 MSW). Tillering and internode elongation phenophase (35 MSW) of rice favoured the initial YSB damage. A very strong spatial dependence of YSB damage was noticed during 35, 36, 37, 40, 41 and 42 MSWs, whereas in 38 and 39 MSW, a moderate level of dependence was characterized. The range value of the variogram revealed that the average spatial dependence value of YSB damage was measured to be 1135.78m.

CONCLUSION

A geostatistical tool, a variogram was employed to characterize the spatio-temporal variation in YSB damage (DH). This study witnessed moderate to strong spatial dependency of the YSB damage in the experimental area. A comprehensive sampling plan and gradual distribution maps of YSB damage were achieved through variograms and kriging estimates, respectively. The interpolated maps may bring out the possibility of designing detailed prophylactic management strategies for YSB in rice.

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ARRW/SIRC/Theme III/28

Study on virulence behaviour of *Rhizoctonia solani* Kuhn on different rice cultivars

Santosh Kumar* **and Md. Mahtab Rashid**

Department of Plant Pathology, Mandan Bharti Agricultural College, Agwanpur, Saharsa-852201, Bihar, India (Bihar Agricultural University, Sabour, Bhagalpur, Bihar).

** Corresponding author mail: santosh35433@gmail.com*

INTRODUCTION AND OBJECTIVES

Sheath blight disease, caused by the fungus *Rhizoctonia solani* Kuhn, is one of the devastating rice diseases with a worldwide impact. It is quite a challenge to manage this disease owing to the broad host range and high genetic variability. Initial symptoms of this disease appear as water-soaked chlorotic patches usually on leaf sheaths or culms just above the water level. These patches are ellipsoid or ovoid somewhat irregular and of greenish-grey colour. The damage due to this disease start as partial infection on the lower sheath portion. This renders a negative impact on grain filling and premature death under extreme conditions resulting in the reduction of grain yield and quality. Complete resistance against sheath blight has not been observed while screening thousands of rice cultivars collected from various growing regions (Molla *et al.*, 2020). The mechanism of interaction of this pathogen is different for a tolerant and a susceptible host. The objective of the present study is to document the virulence behaviour of *R. solani* pathogen against tolerant and susceptible rice cultivars.

METHODOLOGY

The virulence behaviour of *R. solani* was studied among 5 rice cultivars. Pure culture of this fungus was obtained by hyphal tip method on Potato Dextrose Agar medium after incubation at 28! ± 1! for 6 days. The experiment was carried out at 28! ± 3°C in a glasshouse at Mandan Bharti Agricultural College, Agwanpur, Saharsa. Surface sterilized rice seeds of different cultivars were sown H”1 cm deep, in plastic pots (15 cm diameter) containing partially sterilized soil amended with required fertilizers. Five seedlings of each cultivar were grown and maintained in each pot. Each rice seedling was inoculated with a mycelial ball obtained from three days old culture of *R. solani* on the leaf sheath. The virulence behaviour was recorded in terms of a relative number of lesions/plant (unit), relative lesion length (after eight and fifteen days of inoculation) and relative lesion height to plant height (%), which was observed when the plant height is 64.25 cm. The severity of sheath blight disease was also observed and expressed in a disease rating scale of 0-9 (based on relative lesion

Table 1. Virulence behaviour of *R. solani* in the different rice cultivars

Variety	Average number of lesions per plant	Average length of lesion at 7 DAI (cm)	Average length of lesion at 15 DAI (cm)	Relative lesion length to plant height (%)	Disease rating scale
Rajendra Sweta (S)	8.28	5.47	6.17	9.61	3
Sabour Sampan T	4.33	4.16	4.97	7.74	1
Rajendra Mansuri (S)	9.10	6.35	7.58	11.80	3
Swarna sub 1 (T)	3.27	3.35	3.93	6.11	1
Sabour Surbhit (T)	2.58	2.16	3.57	5.56	1
CD (P=0.05)	2.97	0.642	0.70	–	–

S= Susceptible, T=Tolerant

Fig. 1. Disease rating scale for sheath blight of rice

height to plant height) (Ahn and Mew, 1986) (Figure 1). Relative lesion height was determined using the following formula.

Relative lesion length(%) =

$$\frac{\text{Total lesion length}}{\text{Total length of plant}} \times 100$$

RESULT

An effective assessment of the virulence behaviour of *R. solani* in susceptible and tolerant rice cultivars is a critical component for the quantification of resistance level against the pathogen. The result showed a significant incidence of disease in susceptible cultivars in comparison to tolerant cultivars with respect to the number of lesions and lesion length (Table 1). Additionally, the same pathogen showed non-significant disease incidence in tolerant cultivars. The maximum number of lesions and lesion length at 8 and 15 days after inoculation (DAI) were observed with the susceptible cultivar Rajendra Mansuri. However, the minimum was found with Sabour Surbhit.

CONCLUSION

The overall observations from this study indicate that the virulence behaviour of *R. solani* is distinctly different in the susceptible and tolerant cultivars of rice. The differential behaviour resulted in the disease affecting the susceptible host to a much greater extent, leading to almost ten times more necrotic lesions than the tolerant one.

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Introgression of bacterial blight and brown planthopper resistance in susceptible popular indica rice variety Naveen

Pritiranjan Sahoo, Mridul Chakraborti, Meera Kumari Kar, Guru Prasanna Pandi G, Arup Kumar Mukherjee, Pankajini Samal, Mayabini Jena, Prakash Chandra Rath and Lambodhar Behera

ICAR- National Rice Research Institute, Cuttack-753006, Odisha, India

Cultivation of rice in a wide range of ecology with diverse environmental conditions affects the various yield and quality parameters due to several biotic and abiotic stresses. Bacterial blight (BB) and hopper burn are among major biotic constraints causing severe yield loss. BB caused by *Xanthomonas oryzae* pv. *oryzae* causes either leaf blight or wilting syndrome known as 'Kresek' and the insect pest Brown planthopper (BPH) caused by *Nilaparvata lugens* Stal damages the rice crop by directly sucking the phloem sap resulting in 'hopper burn' and it also serves as a vector for grassy stunt and ragged stunt viral diseases. Till date 46 genes conferring resistance to BB have been identified. Popular varieties in India have mostly been pyramided with *Xa21*, *xa13* and/or *xa5* genes in last 20 years. Introgression of *Xa4* gene improves the lodging resistance of the rice plants (Hu et al. 2017). The *Xa7* gene, besides providing resistance under normal temperature, also prevents the exploitation of *SWEET14* gene by *Xoo* under high temperature and drought through competitive binding of TAL effectors AvrXa7 and PthXo3 (Dossa et al. 2020). For BPH, 41 majorresistance genes and many QTLs have been reported worldwide. Two novel QTLs, *qBph4*.3 and *qBph4*.4 associated with BPH resistance in 'Salkathi', a local landrace from Odisha was found to be highly tolerant to BPH biotype 4. Naveen, a popular semidwarf *indica* rice variety of medium duration suitable for irrigated ecosystem released from NRRI, Cuttack is extremely popular with the farmers. However, this variety is highly susceptible to BB and BPH making it an important variety for the introgression of BB and BPH genes/QTLs. The present study deals with combining five BB resistant genes (*Xa4*, *xa5*, *Xa7*, *xa13* and *Xa21*) and two QTLs (*qBph4.3* and *qBph4.4)* for BPH resistance into a single background of the popular rice variety 'Naveen' by marker assisted backcross breeding approach.

METHODOLOGY

'Naveen', susceptible to both brown planthopper and bacterial blight, was chosen as recurrent parent. For introgression of BB resistance genes, a donor line IRBB 66 which is a NIL of elite indica rice cultivar IR24 carrying five resistance genes (*Xa4*, *xa5*, *Xa7*, *xa13* and *Xa21*) was used. A resistant pre-breeding line, CR3006-8-2 which is a derivative of the cross between Pusa44 and a landrace 'Salkathi' carrying the BPH resistance QTLs *qBph4.3* and *qBph4.4* was taken as the donor. The recipient parent was crossed with each of the donors to produce F_1 plants with BB resistant genes and BPH resistant genes/ QTLs respectively. Tightly linked/Flanking/ Functional markers were used for foreground selection. Background selection was performed by >100 polymorphic SSR markers in both cases. The lines with highest RPG recovery having different gene combinations were screened through standard leaf clipping method and scored based on standard evaluation system. In BC_2F_2, homozygous NILs for both QTLs and recombinants between and within QTLs were identified and advanced further. The *Xoo* isolate, NR-*Xoo*-P-05 was used for screening BB resistance. Standard Seed Box Screening Test (SSST) was used to evaluate level of *N. lugens* resistance in the rice genotypes. A detailed bioassay was conducted for estimating damage percentage, nymphal survival, honeydew excretion and feeding marks on each genotype. The bacterial blight resistant NIL with five resistance genes (CR 4345-23-8-1-1) was used as recurrent parent and a BPH resistant NIL (CR 4331-85-1-1-1) was used as donor to combine the two BPH resistant QTLs and five BB resistant genes.

RESULTS

Among the bacterial blight resistant NILs, the two best performing lines, one carrying all five genes for *Xoo* resistance (CR-4345-23-8-1-1) and another having four genes (*xa5, Xa7, xa13 and Xa21)*, designated as CR-4345-13-7-2-1 were developed. Both the NILs showed disease score of '1' compared to '9' of Naveen (wet seasons of 2019 and 2020) against NR-*Xoo*-P-05. All the NILs with *Xa4* gene showed substantially enhanced lodging resistance over the NILs lacking *Xa4*. The NILs with *Xa7* performed better in summer showing the effectiveness of *Xa7* gene under high temperature. The susceptibility of recurrent parent Naveen increased substantially in summer in comparison to wet season. All 12 homozygous recombinants for the BPH QTLs and the three lines carrying both QTLs identified in BC_2F_2 generation were advanced till BC_2F_7 generation. Only the three lines (CR 4331-74-2-2-1, CR-4331-84-3-2-1, and CR-4331-85-1-1-1) carrying both the QTLs showed resistance at par with Salkathi or CR-3006-8-2. Other lines were either susceptible or partially resistant. The NILs showed substantial reduction in plant damage and nymphal survival percentage, besides honeydew excretion length when compared with the recurrent parent Naveen. Three plants (designated as BBPH-1, BBPH-2 and BBPH-3) with all the five genes for *Xoo* resistance and two QTLs in homozygous condition were identified with minimal residual background. Average single plant yield of all the three lines were better than Naveen and the two bacterial blight resistant near isogenic lines. Lodging incidence was rare in plants of all the three lines. All the three genotypes showed at par response to *Xoo* inoculation when compared with CR 4335-23-8-1-1. BBPH-2 and BBPH-3 showed best response against BPH (SES Score 2.7 and 2.1, respectively), compared to BBPH-1 (SES Score: 3.8). Thus, it was possible to combine both bacterial blight and brown plant hopper resistance through introgression of five genes with highly diverse mechanisms and two complementary epistatic BPH resistant QTLs in the popular rice variety 'Naveen'.

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ARRW/SIRC/Theme III/30

Population structure and genetic diversity of brown planthopper, *Nilaparvata lugens* (Stål.) in India

[1]Soumya Bharti Babu, Guru-Pirasanna-Pandi Govindharaj, Parameswaran C, [1]Jayaraj Padhi, Basana Gowda, Naveen Patil, Annamalai M and PC Rath

ICAR-National Rice Research Institute, Cuttack – 753 006
[1]Odisha University of Agriculture & Technology, Cuttack – 753 006

Among the rice insect-pests, the brown planthopper, *Nilaparvata lugens* is the major sucking pest causes 70-100% yield losses in the Asian subcontinents (Pandi et al., 2018). So far, four *N. lugens* biotypes have been identified in the world, of which biotype-4 is most damaging one, predominantly found in India. This biotype has been documented to express differential reaction to resistant rice varieties and various insecticide groups in different geographic locations of India. A sound understanding of the genetic diversity, migration patterns, and the environmental adaptability of *N. lugens* is essential to design better pest management strategies; which is unfortunately lacking in India. Hence, this study was designed to explore genetic structure and diversity of *N. lugens* from distinct geographic areas of India using genomic markers.

MATERIAL AND METHODS

N. lugens populations were sampled from 22 hotspot regions that represent different agroclimatic zones of India (north, south, east and west zones) during three consecutive years 2020-22. Genomic DNA extraction of *N. lugens* populations was done by cetyltrimethyl ammonium bromide (CTAB) method. After quantification PCR amplification was done with 30 SSR markers. The SSR bands were analysed for population genetics by using DARwin, POWER MARKER, STRUCTURE, GenAlEx and Mantel test.

RESULT AND DISCUSSION

Results revealed that mean genetic diversity was 0.399 and polymorphic information content (PIC) was 0.337 in the 30 selected SSR markers. Similar

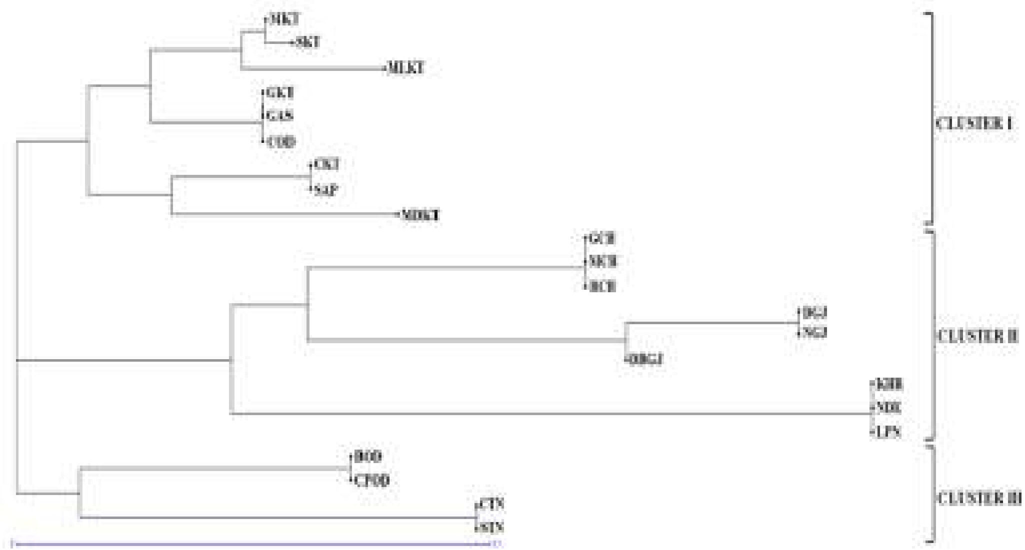

Fig. 1. Unrooted neighbor-joining (NJ) tree representing three clusters of 22 *N. lugens* populations

results were reported by earlier researchers in genetic diversity analysis of *N. lugens* biotypes, with the average allele per locus ranged from 2.3±0.1 (biotype 1) to 4.5±0.2 (biotype Y) (Jing et al., 2012). Further, molecular variance (AMOVA) revealed only 2% variation among population and 98% within the populations. Tyagi et al. (2022) has also reported low genetic differentiation (2.84%) among the Indian *N. lugens* populations. In cluster and population structure analysis, all the 22 population were sub-grouped into three groups (Fig. 1). Interestingly, north and west Indian population showed high genetic similarity and assembled into one cluster in cluster analysis. The east and south Indian populations were evenly segregated into rest two clusters. Similarly, north and west Indian population again deemed to be occupied same compartment in Principal coordinate analysis (PCoA) (Jing et al., 2012).

CONCLUSION

In this study, the population structure and genetic diversity of twenty- two *N. lugens* populations from different geographic locations in India was analysed and our result revealed the presence of two genetic groups, North and West India & East and South India, as well as genetic homogeneity within the groups. Our analysis and results can be useful for optimizing Integrated Pest Management methodologies that will target the genetic traits shared by different *N. lugens* populations of India.

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Investigation of Sheath blight tolerance of CR 1014 through Proteomics and Transcriptomics analysis

Pankajini Samal, Archana Bal, Meera K. Kar, Arup K. Mukherjee, Kutubuddin A. Molla, Mridul Chakraborti

ICAR- National Rice Research Institute, Cuttack-753006, Odisha, India

Sheath blight (ShB) of rice has emerged as a serious threat to rice cultivation for the Indian subcontinent. The introduction of semi-dwarf high-yielding varieties (HYV) of rice has brought revolution in rice production in India. However, HYV and related cultural practices have invited several problems, including increasing susceptibility to diseases and pest. The sheath blight, caused by *Rhizoctonia solani* (Kuhn) (perfect stage *Thanatephorus cucumeris*), was once a minor disease has turned out to be a serious threat to rice cultivation in many countries. The estimated yield loss due to this disease is 5.2 to 50 percent depending upon the environmental conditions. The major problem to tackle the disease is that no resistance source has been identified so far to combat the disease through resistance breeding. However, some partial resistance has been reported elsewhere. Due to the lack of a proper resistance source, the basic understanding of the host-pathogen interaction was not also unravelled in detail. Therefore, breeding for sheath blight resistance is not so successful to date. In the present study, we have identified CR 1014 as a source of resistance to ShB disease (Bal et al., 2020). To study the mechanism of resistance in CR1014, we have performed comparative transcriptomics and proteomics analysis. This study intended to examine the differential defense response of tolerant and susceptible rice genotypes infected with *Rhizoctonia solani* at gene expression level. Based on the RNA seq data and proteomics data, validated by qPCR, the study gives a remarkable insight into how CR 1014 defends better against the pathogen than the susceptible genotype Swarna-Sub1 and what are the putative candidate genes responsive to the disease.

METHODOLOGY

Field and net house screening were performed for the rice varieties reported to have tolerance against sheath blight using artificial inoculation with a highly virulent strain CRRI-RS-8 (MTCC12232, IMTech, Chandigarh) of *Rhizoctonia solani*. The transcriptome profiles of Swarna-Sub1 and CR 1014 infected with ShB pathogen were compared using high throughput RNA Seq on Illumina Hiseq 2500 Ltd. For this, the leaf samples were collected after 3 days of inoculation for studying early expressed genes and then after 9 days of inoculation when the disease was fully expressed in the susceptible check for studying late expressed genes.

For proteomic analysis, the leaf samples were collected at 0-hour post inoculation (HPI), 12HPI, 24HPI, 48HPI, 72HPI and 96HPI with *Rhizoctonia solani*. From both transcriptome and proteome profiling of the two genotypes, a list of up regulated and down regulated genes and proteins was prepared according to their fold change. For validating these differentially expressed genes found from both the studies, quantitative real time PCR were performed. Real time PCR primers were designed through Primer3 software. The total RNA was isolated using Qiagen RNAeasy plant mini kit from preserved leaf samples of both the infected and control plant of SwarnaSub1 and CR1014. cDNA of respective RNA samples was prepared using cDNA synthesis kit and used in quantitative real time PCR for further validation.

RESULT

The transcriptome study revealed the basis of tolerance in CR 1014 by exploring the disease responsive differentially expressed transcriptome and comparing them with that of a susceptible variety, Swarna-Sub1. A total of 815 and 551 genes were found to be differentially regulated in CR 1014 and Swarna-Sub1, respectively at two different time points. The result shows that the ability to upregulate genes for glycosyl hydrolase, secondary metabolite biosynthesis, cytoskeleton and membrane integrity, the glycolytic pathway, and maintaining photosynthesis make CR 1014 a superior performer in resisting the ShB pathogen (Samal et al., 2022). The qPCR analysis using 20 primers showed resemblance of expression with that of transcriptomic analysis. It was interesting to observe that two genes (*terpene synthase*, *NBS-LRR* disease resistance protein) showed higher expression in both the control and infected plants of CR 1014 in comparison to Swarna-Sub1 resulting in a significant variation in the fold change. Again *NBS-LRR disease resistance protein* was validated in the resistant and susceptible RILs and NILs developed from the cross of Swarna-Sub1 and CR 1014. Altogether these validations showed a strong evidence that CR 1014 can be a strong source of resistance carrying a probable candidate gene *NBS-LRR* disease resistance protein.

The comparative proteomics study of resistant and susceptible genotypes revealed many differentially expressed proteins such as peroxidase precursor, pentatricopeptide, glycosyl hydrolases, glutathione S-transferase, stress-responsive protein, OsSCP40-Putative Serine Carboxypeptidase homologue, ubiquitin activating enzyme, plastocyanin-like domain containing protein, glucose-6-phosphate isomerase, Leucine Rich Repeat family protein etc. Those proteins and their pathways shed light on the host-pathogen interaction. The results of the proteomics study confirmed our earlier transcriptome study.

CONCLUSION

The present study, for the first time, revealed the basis of ShB tolerance in the germplasm CR 1014 and should prove to be particularly valuable in understanding molecular response to ShB infection. The knowledge could be utilized to devise strategies to manage the disease better and also the genotype can be used in resistance breeding programme for developing ShB resistant variety.

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ARRW/SIRC/Theme III/32

Marker-Trait association analysis of brown planthopper, *Nilaparvata lugens* resistance in indigenous rice genotypes of India

***Guru-Pirasanna-Pandi G, Aashish Kumar Anant, Soumya Bharati Babu, Annamalai M, Basana-Gowda G, Naveenkumar Patil, and PC Rath**

Division of Crop Protection, ICAR-National Rice Research Institute, Cuttack – 753006, India.

**Corresponding author Email: guru.g@icar.gov.in*

The brown planthopper (BPH), *Nilaparvata lugens* (Stål) is one of the major insect pest of rice in Indian subcontinent. Being the world's second largest producer of rice, India suffers a severe loss due repetitive outbreaks of *N. lugens* in many parts of the country. *N. lugens* has the capability of damaging rice cultivation from vegetative stage to reproductive stage and its infestation leads to "hopper burn" symptom (Pandi et al., 2018). The present study attempted to understand the marker-trait association of brown planthopper, *Nilaparvata lugens* resistance in indigenous rice genotypes of India.

METHODOLOGY

A total of 900 indigenous varieties were screened and subsequently 200 panel were genotyped using 93 molecular markers linked to 34 different *N. lugens* resistance genes for marker-trait association using the general linear model and mixed linear model. Major allele frequency, allele per locus, gene diversity, heterozygosity, polymorphism information content (PIC) value of the markers was determined (Anant et al., 2021).

RESULTS

Present study identified new resistance donors against *N. lugens*. Further, genotypic analysis revealed that 8-10 % variance among the populations. Population structure and cluster analysis results revealed that rice landraces were grouped into three major genetic clusters with a clear genetic difference between resistance and susceptible genotypes (Fig. 1). Resistant, moderately resistant and susceptible genotypes occupied separate quarters in principal coordinate analysis (PCoA). Significant marker trait association was found in the following markers viz., RM463 (*bph2*), RM586 (*bph4*), RM6997 (*Bph6*), RM28449 (*Bph17*), RM28472 (*Bph18*), RM6308 (*bph19*), RM28561 (*Bph21*), RM5479 (*Bph25*), RM309 (*Bph26*), RM222 (*Bph30*), RM19291 (*Bph30*), RM17006 (*Bph33*), RM551 (*Bph33*), RM7 (*Qbph3)* and RM5633 (*Qbph4.4)* with different phenotypic parameters.

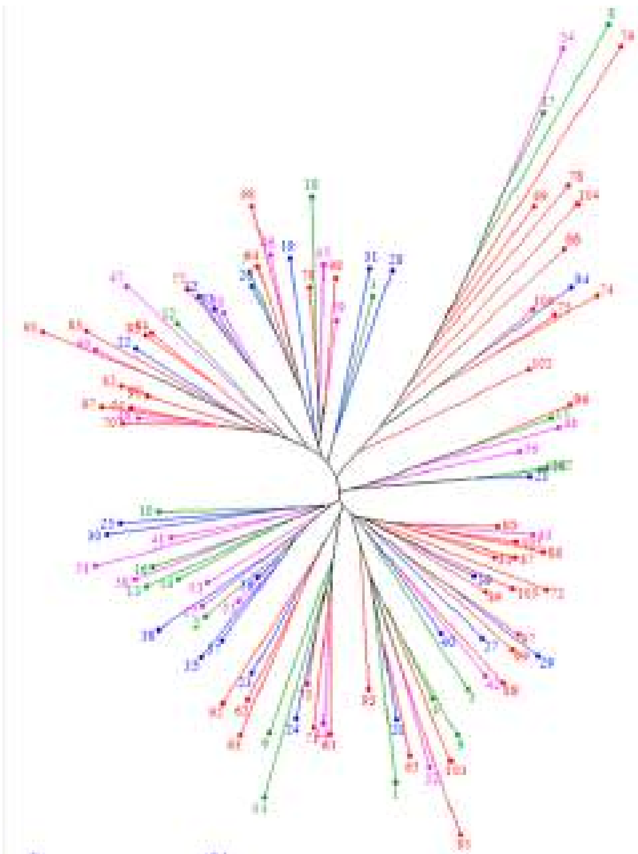

Fig 1. Unrooted neighbor-joining tree based on molecular markers linked to BPH resistance in indigenous rice varieties. These vaarieties are represented corresponding to BPH resistance reaction (resistant, green; moderately resistant, blue; susceptible, red)

CONCLUSION

The reported resistance genes could be introgressed into popular varieties, either alone or in combination, to generate robust resistant rice varieties against *N. lugens*.

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Identification of mating type of Indian isolates of *V. virens*, the causal pathogen of rice false smut disease of rice

M. K. Bag*, P. Masurkar, Raghu S, Prabhukartikeyan SR, L. Behera

ICAR- National Rice Research Institute, Cuttack, Odisha, India, 753006

**Email : manas.bag@gmail.com; Manas.Bag@icar.gov.in*

Rice false smut disease caused by the ascomycetes fungi *Villosiclava virens* (Anamorph: *Ustilaginoidea virens*). This is an emerging grain-infecting disease that infect spikelets and slowly convert the whole grains to smut ball like structure. Colour of the smut ball initially whitish and later transform from yellow to orangish-yellow to greenish-black. Sexual reproduction and development in ascomycetes fungus is controlled by a single locus called mating-type locus 1 (MAT1), which has two idiomorphs, MAT1-1 and MAT1-2 (Turgeon and Yoder 2000; Yu et al. 2015). At the MAT1 locus, heterothallic strains have either MAT1-1 or MAT1-2 idiomorphs, whereas homothallic strains have both idiomorphs with different configurations (Yu et al. 2015). The objective of the study is to understand the mating type of Indian isolates.

METHODOLOGY

Twenty (20) isolates from different part of north and north-eastern states of India were collected and cultured following standard isolation and purification method (Bag et. al., 2021). DNA extraction was done following Nakada et al., (1994) protocol. Two sets of primers MAT1-1-1 and MAT1-2-1 were used for identification. PCR was done following standard protocol.

RESULTS AND DISCUSSIONS

The amplification of the mating type genes was observed at 250 and 220 bp for MAT1-1-1 and

Table 1: Mating type of some of the *V. virens* isolates

Isolates	District/Block, State	Latitude	Longitude	Collected from rice variety	MAT1-1-1	MAT1-2-1
Uv1	Deoria, UP	26.3158	83.9936	NatiMansuri	+	+
Uv15	Deoria, UP	26.3141	84.0008	BPT 5204	-	+
Uv16	Mirzapur, UP	25.1468	82.5852	Chintu	-	+
Uv19	Varanasi, UP	25.2568	82.9915	HUR-917	+	+
Uv29	Chandauli, UP	25.2367	83.2535	Sonam	-	+
Uv31	Chandauli, UP	25.2079	83.2610	Moti	-	+
Uv32	Pantnagar	29.0229	79.4880	Pusa RH-10	-	+
Uv35	Kangra, HP	32.1109	76.5363	LakhaMandal	+	+
Uv36	Jabalpur, UP	23.2292	79.9630	JRH 19	-	+
Uv37	Varanasi, UP	25.2613	82.8295	HUBR-917	-	+
Uv49	Banuri, HP	32.1029	76.5566	HPR 1068	-	+
Uv50	Deoria, UP	26.3165	84.0047	Pusa Basmati	+	+
Uv53	Cuttack, Odisha	20.4800	86.1731	CR311	-	+
Uv55	Navasari farm, Gujrat	20.9245	72.9073	GAR-13	-	+
Uv61	Jeypore, Odisha	18.9080	82.5875	Moudamani	+	+
Uv63	Boudh, Odisha	20.8585	84.2296	Swarna Sub-1	-	+
Uv64	Howdah, WB	22.4110	88.2940	Swarna	+	+
Uv69	24 parganas, WB	22.2460	88.6649	Pankaj	-	+
Uv70	Cuttack, Odisha	20.6213	84.7352	Janauli	+	+
Uv71	Navasari, Gujrat	20.9245	72.9073	GAR-13	+	+

MAT 1-2-1 respectively. Both the MAT 1-2-1 and MAT 1-1-1 genes were present in isolate nos. Fsm-1, 19, 35, 50, 61, 64, 70, and 71. The results clearly indicate the collected isolates were homothallic and heterothallic both nature. It means that these isolates are homothallic in nature. They contain both genes in a single cell and results enabling combine MAT1-1-1 and MAT 1-2-1 expression by single individual. The MAT 1-1-1 gene of 220bp is absent in isolates no. 15, 16, 29, 31, 32, 36, 37, 49, 53, 55, 63, and 69. This indicated that these isolates lack MAT 1-1-1 gene and only one allele is present i.e. MAT 1-2-1 and are heterothallic in nature (Table 1). This finding highlighted the presence of both mating type of false smut pathogen in those regions and might be one of the possible reasons of genetic diversities present in Indian isolates as reported by bag et al., 2021 and Masurkar et al., 2022. Sharanabasav et al., (2020) also reported the presence of heterothallic isolates in southern states of India.

CONCLUSION

Indian isolates particularly from north and north-eastern parts showed mix of heterothallic and homothallic strains which showed the variable nature of sexuality within the defined regions.

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ARRW/SIRC/Theme III/34

Seasonal incidence and damage variation of yellow stem borer (*Scirpophaga incertulas* walker) in boro rice under different cultivation practices of West Bengal

Arka Manna*, Lakshman Chandra Patel, Kusal Roy, Anirudhha Pramanik, Dipak Hazra

Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, W.B. 741252
Presenting Author's Email: arkamanna1997@gmail.com

Rice (*Oryza sativa* L.) is one of the most important and leading cereal crops in the world. India covers an area of about 47 million hectares and produces around 129.66 million tonnes of rice with yield level around 4.1 tonnes per hectare. India is the second largest producer of rice only next to China. The leading rice producing states are West Bengal, Uttar Pradesh, Punjab, Odisha, Andhra Pradesh, Bihar and Chhattisgarh. West Bengal ranks first in area and production in the country. About 78% of total area under rice in the state is concentrated under high and medium productivity groups, which accounts for nearly 84% of total production of rice in the State with production of 131.68 lakh tons in 58.30 lakh ha area. In India, approximately 100 insect species feed on rice and 20 of these are considered to be major pests of which yellow stem borer, *Scirpopagha incertulas* Walker is the dominant and most destructive pest occurring throughout the country causing yield loss of about 10-60 per cent. The insect causes "Dead hearts" at vegetative stage and "White ear head" at reproductive stage. The extent of borer induced yield losses have been estimated to range from 30 to 70% in outbreak years and from 2 to 20% in non-outbreak years in India. While yield loss due to *S. incertulas* is typically 5 to10%, it can be as high as 20% in certain regions and on particular varieties.

METHODOLOGY

A field experiment was conducted at the Research Farm, College of Agriculture, BCKV, Burdwan, West Bengal during rabi season of 2021-22, where 4 cultivation practices (zero tillage, direct seeded rice, system of rice intensification and conventional transplanted) act as main plots with sub plots having 2 varieties Satabdi (IET 4786) and Khitish (IET 4094) along with sub-sub plots having 2 chemical managements (C1: Chlorantraniliprole 0.35+Fipronil 0.35 GR @10kg/ha, C2: Emamectin Benzoate 0.25+Cartap Hydrochloride 7.5 GR @7.5kg/ha) replicated 4th times in Split-split-plot design with 2m^2 each plot size maintaining spacing 25cm×25cm. Two chemicals were applied twice at the time of vegetative stage and reproductive stage and during those stages Dead Hearts % & White

Table 1. Percentage White Earhead at reproductive stage caused by YSB during 2021-22 in boro rice

Chemical Management (C)	Cultivation Systems (A)								Mean
	ZT		DSR		SRI		CT		
	Variety(B)								
	Satabdi	Khitish	Satabdi	Khitish	Satabdi	Khitish	Satabdi	Khitish	
C1	19.14(25.89)*	16.38(23.40)	17.39(24.36)	13.22(21.08)	9.87(18.21)	6.73(14.84)	6.86(15.05)	4.68(12.37)	11.78
C2	22.68(28.31)	19.43(26.05)	11.98(20.18)	12.26(20.10)	8.93(17.28)	6.97(15.17)	8.62(16.78)	8.1(16.27)	12.37
	A	B	C	A×B×C					
SEm	0.891	0.690	0.571	1.615					
CD	2.84	NA	NA	NA					

Earhead % data were taken from 5 hills per plot. 4 pheromone traps were installed in 4 cultivation practices separately to determine male YSB moths population. Weather data was taken throughout the season.

RESULTS

YSB adult male moth population is positively correlated with max temp, min temp and rainfall for all four cultivation practices except with relative humidity i.e., negatively correlated for zt, dsr, sri practices. Minimum DH% (0.158) was observed in ZT for Khitish cultivar with C1 chemicals and max dh% (2.435) in SRI for Satabdi with C1 chemicals. Overall C2 chemicals had given good result.

Table 1 revealed that white earhead % was more (22.68) in ZT with C2 chemicals for Satabdi variety and low (4.68) in CT with C1 chemicals for Khitish . Overall C1 had given good result to supress YSB population. Table 1 showed that max yield (1326.25) came from CT as well as Khitish for C1 chemicals and min yield (267.5) from ZT for C2 chemicals in also Khitish cultivar. Average good yield came from C1 chemicals and C2 was at par.

CONCLUSION

It can be concluded that C1 chemicals performed well rather than C2 in terms of ysb pest suppression as well as yield. Conventional Transplanted method provided more yield than all three practices and Khitish ranks first. So C1 (Chlorantraniliprole 0.35+Fipronil 0.35 GR @10kg/ha) can be recommended for farmers.

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Life table analysis and population parameters of *Nilaparvata lugens* (Stål.) (Homoptera: Delphacidae)

[1,2]Swagatika Sahoo*; [1]Guru-Pirasanna-Pandi Govindhraj and [2]Debabrata Panigrahi

[1]*ICAR-National Rice Research Institute, Cuttack- 753 006*

[2]*Odisha University of Agriculture and Technology, Bhubaneswar 751 003*

**Email: swagatikasahoo81@gmail.com*

Rice cultivation in recent years witnessed severe brown plant hopper, *Nilaparvata lugens* (Stal.) infestation in India, resulting in serious yield loss to the tune of 70-100%. Though several studies addressed the biology of this in different parts of the country, yet better understanding is required on the influence of climatic factors, particularly, temperature and relative humidity on biological parameters of *N. lugens,* that can enable us to predict distribution and abundance, which is evidenced by changes in the number of generations a year, increasing survival rates in winter, or the earlier appearance during the cultivation. Hence, the present study aimed to construct the life tables that will facilitate for formulation of effective management strategies against this pest.

MATERIALS AND METHODS

The brown planthopper *Nilaparvata lugens* (Stål) was reared on potted rice plant cultivar TN-1 inside the insect growth chamber. One pair of adults was released over the plant in each pot with 5 replications, then covered with a mylar cage. Females of each cohort were reared at 25±1°C temperature and 70±5% relative humidity (RH). The life table parameters were studied for four successive generations. The Procedures adopted for computations of various life parameters were as specified by Southwood (1978).

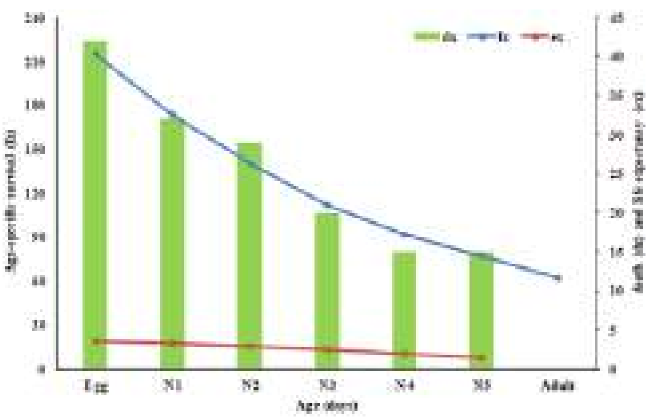

Fig. 1. Age-specific life table of brown planthopper (*N. lugens*)

RESULT AND DISCUSSION

It was revealed that *N. lugens* required an average of 28 days (egg to adult) to complete its generation at 25±1°C and 70±5% RH. The number of live individuals entering the next developmental stage (I_x) decreases from the egg to adult stage (Fig. 1). Life expectancy (e_x) was found to be declined from the egg to the adult stage. About 28.83% out of 215 eggs survived to adulthood and the highest survival rate within the stage was found in the fourth instar nymph (83.70%). Earlier reports (Htet et al., 2021) concordance with our results, 26.4% of eggs developed up to the adult stage. The total nymphal period was of 16±0.24 days and the developmental duration of smaller (I+II) nymphal instars were comparatively less than larger (III+IV+V) ones. The hatching period and average adult life span was 11.28 ± 0.47 and 11.47 ± 1.18 days, respectively. Htet et al. (2021) also noted that 25±1°C considered as most favorable temperature for all the life stages of *N. lugens* development.

CONCLUSION

The life table data obtained in this study can provide insight into the demographics of planthopper populations and will be needful in making predictions about the growth or decline of planthopper populations in the future. It is a preliminary study and further life table analysis on the effect of different constant temperatures influencing *N. lugens* development are in progress.

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ARRW/SIRC/Theme III/36

Host stage preference and suitability of *Goniozus triangulifer* Kieffer (Hymenoptera: Bethylidae), a parasitoid of rice leaffolder *Cnaphalocrocis medinalis* (Guenée) (Lepidoptera: Pyralidae)

Soumya Shephalika Dash[1], Golive Prasanthi[1*], Anjan Kumar Nayak[1], Rajasekhar Rao Korada[1], and P C Rath[1]

[1]*ICAR-National Rice Research Institute, Cuttack*
**Email : prasanthigolivi@gmail.com*

Goniozus triangulifer Kieffer is a gregarious external parasitoid of leaffolder, *Cnaphalocrocis medinalis* (Guenee) on rice. In the process of parasitism, host suitability is related with the successful development and emergence of the parasitoid (Mackauer & Sequeira, 1993) which results to the successful parasitism. The larval stage and size of the host also directly influences the parasitoid's survival and rate of development. Thus, to maximize the parasitization, hosts should be at such age (or stage or instar) that is most suitable for parasitoid survival and development.

OBJECTIVE

Determination of the host stage preference of different *Cnaphalocrocis medinalis* larval instars by *Goniozus triangulifer*

METHODOLOGY

The experiment was conducted at Division of Entomology, NRRI, Cuttack in 2022. Larvae of *Cnaphalocrocis medinalis* were maintained on potted rice plants placed in transparent plastic rearing cages of size 40 x 40 x 40 cm. To guarantee a continuous source of parasitoids, females of *G. triangulifer* were collected from field and released in the cages. Adult parasitoids were collected within 24 h of their emergence from the parasitized larvae and released separately in glass tubes (20 x 4 cm) and were provided with 20 per cent honey solution in cotton swab as food. This procedure was continued during the experimental period.

Host stage preference (No-choice experiment)

The third, fourth and fifth instars of the host were tested to know the susceptibility of the host larvae to *G. triangulifer*. Ten leaffolder larvae of the same instar were shifted onto rice leaves and kept in separate long tubes. Same day, a single mated female of *G. triangulifer* was transferred individually into the tube containing leaffolder. After 24 h of introduction of the parasitoid, parasitized host larvae were collected and transferred to separate tubes. The number of leaffolder larvae parasitized and the percent parasitization were observed from each respective instar. For each instar, ten replications were exposed to different individual *G. triangulifer* females in this manner.

Host stage preference (Choice experiment)

Mixed population of first, second, third, fourth and fifth instars of *C. medinalis* in equal ratio (five leaffolder larvae of each stage) were shifted to rice leaf and placed in a long glass tube. A mated female of *G. triangulifer* was released into each experimental set up for 24 h. Such ten replications were exposed to different individual *G. triangulifer* females in this manner and percent parasitization were recorded.

Statistical analysis

Parasitization percentage data were arc sine transformed. Data of host preference (choice and non-choice experiment) were subjected to one-

Table 1. Host stage acceptance and preference by *G. triangulifer* in no-choice and choice experiments for different stages of *C. medinalis*. For each host stage, ten individuals were exposed to one female parasitoid for 24 h.

Host stage	No-choice experiment		Choice experiment	
	Mean no. hosts parasitized	Parasitization % (±SD)	Mean no. hosts parasitized	Parasitization % (±SD)
3rd instar	3.50	35.82±2.61	2.60	30.47±1.42
4th instar	5.40	47.31±1.55	4.20	40.31±1.69
5th instar	1.30	19.83±2.54	0.90	16.58±1.84
C.D. value	-	6.68	-	4.85

Values are means ± SD, N = 10

way ANOVA (CRD). Values are specified as mean ± standard deviation (SD).

RESULTS

In case of choice and non-choice experiments, the results (Table 1) suggested that the 4th instar larvae of leaffolder were the most preferred stage for the oviposition of *G. triangulifer* as compared to 3rd instar larvae. The 5th instar larvae were less preferred by the parasitoid as compared to 3rd and 4th instar hosts. In host preference choice experiment, *G. triangulifer* completely ignored 1st and 2nd instars. This might be due to the smaller body size of the host for development of parasitoid.

CONCLUSION

From this study it is clear that *G. triangulifer* is primarily a parasitoid of rice leaffolder. This information is also important for mass rearing of *G. triangulifer* and for evaluating it in a biological control programme against *C. medinalis* by maximising the host parasitization.

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Synthesis of biogenic magnesium oxide nanoparticle for decontamination of pesticides from water

Abhijit Kar[1,2*], Sonali Deole[2], Basana Gowda Gadratagi[1], Naveenkumar Patil[1], Govindharaj Guru-Pirasanna-Pandi[1] and Totan Adak[1#]

[1]*ICAR-National Rice Research Institute, Cuttack, Odisha, India-753006*
[2]*Indira Gandhi Krishi Vishwavidyalaya, Krishak Nagar, Raipur, Chhattisgarh 492012*
** Presenting author: abhijitkar0101@gmail.com*
 # Corresponding author : Totan.Adak@icar.gov.in & totanadak@gmail.com

Nanomaterials can be utilized as adsorbents for their varied structural forms, high surface area, optical properties, and biological and chemical durability. Magnesium oxide nanoparticles (MgO NP) have extremely high surface area and transparent morphologies and could be utilized to remove contaminants from water. Green extraction of metal oxide nanoparticles is eco-friendly, and biological molecules present in plant extracts can transform metal salt into nanoparticles. Many reports on biogenic synthesis of MgO NP are published, but none of them utilized rice as the plant source. Purple coloured rice genotype (popularly known as *Crossa*) was used for biogenic synthesis of MgO NP. The nanoparticles were used to remove three pesticides namely, thiamethoxam, chlorpyriphos and fenpropathrin from water.

METHODOLOGY

Biomolecules from *Crossa* leaves were extracted in hot water. Plant extract and $Mg(NO_3)_2$ were reacted in presence of NaOH solution to yield $Mg(OH)_2$, which was then calcined at 550 ºC for 5 h in a muffle furnace to obtain MgO NP (Nguyen *et al.*, 2021). Characterization of nanoparticles were done using SEM-EDX, DLS analyzer, zeta potential analyzer and FT-IR. Decontamination experiment was carried out and pesticides were analyzed in Ultra high-performance liquid chromatograph equipped with autosampler (UHPLC-Ultimate 3000, Thermo Fisher Scientific Inc., Germany).

RESULTS

The nanoparticles were primarily made up of Mg (33.72%) and O (59.23%) elements. Presence of

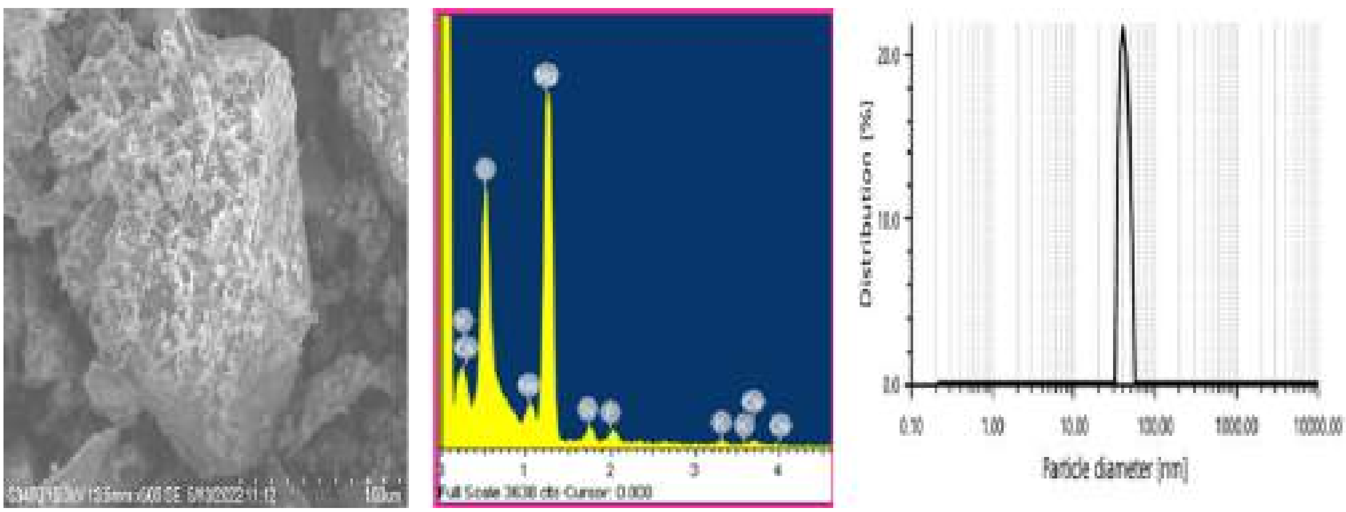

Fig 1. Characterisation of MgO NP (a. SEM, b. EDX, c. DLS)

other elements in SEM-EDX analysis and adsorption bands in FTIR spectra of nanoparticles indicated the role of biomolecules from *Crossa* leaf extract in MgO NP synthesis (Fig 1). The average particle hydrodynamic diameter was 35.57 nm, PDI value was 0.16 and mean zeta potential was -16.2 mV, indicating a stable nanoparticle formation. The sorption study was performed to know the potential of MgO NP to remove three pesticides. It was observed that 40 mg dose resulted in 56.32, 78.50 and 77.39 removal of thiamethoxam, chlorpyriphos and fenpropathrin, respectively. Adsorption was increased with increase in pH. Pseudo first order (PFO) model was the best fitted kinetic model. Sorption data of thiamethoxam and chlorpyriphos best fitted in Langmuir and Frendulich models indicating involvement of monolayer as well as multilayer adsorption. The maximum adsorbent capacity of MgO NP was 87.660 µg/mg. Such higher adsorption capacity of MgO NP proves it to be an excellent adsorbent of pesticides from water.

CONCLUSIONS

An indigenous, ecofriendly method for MgONP synthesis was standardized. MgO NP had high adsorbent capacity and could be recommended in water treatment plants for pesticide removal.

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In- vivo evaluation of fungicides for management of blast of rice

M. K. Barnwal*[1], Ekhlaque Ahmad[2] Ashok Kumar Singh[3], Varsha Rani[3], Binay Kumar[4] and Krishna Prasad[2]

[1] *Deptt. of Plant Pathology,* [2] *Deptt. of Genetics & Plant Breeding* [3] *Deptt. of Agronomy,* [4] *Deptt. of Entomology,*
Birsa Agricultural University, Kanke, Ranchi, Jharkhand 834 006 (India)
**Email: barnwalbau@gmail.com*

Rice blast of caused by *Pyricularia grisea* is one of the most severe problems particularly in Jharkhand state. Two foliar spray of Tebuconazole (0.15%) *i.e.,* at initiation of disease and 2nd spray at ten days interval recorded lowest mean leaf blast disease severity of 8.0%, neck blast incidence of 6.0%. The above treatment also recorded highest grain yield of 5330.45 kg/ha and increase in grain yield over control (IGYOC) of 27.2%. This treatment was followed by two foliar spray of Kitazin (0.1%) recorded leaf blast disease severity of 13.4%, neck blast incidence of 8.6%, grain yield of 5193.46 kg/ha and IGYOC of 24.0%. The next best treatment *i.e.*, Two foliar spray of Kasugamycin (0.2 %) recorded mean leaf blast disease severity of 15.4%, neck blast incidence of 8.5%, grain yield of 5087.98 kg/ha and IGYOC of 21.4%.

INTRODUCTION

Rice is one of the most widely cultivated important food crops in the world and over half of the world population relies on it. Rice production in India has increased from 82.5 m tons during the period of 1997-98 to 114 m tons in 2018-19 (Anonymous, 2019). But projected figures for future indicate that the present level of production is not sufficient to feed the population of the country. The low productivity of rice in India is due to attack of several biotic and abiotic factors. Among biotic factors diseases like Blast, Bacterial leaf blight, Sheath blight, False smut etc. are severe, wide spread and economically important. In recent decades, Blast of rice is one of the most destructive diseases affecting rice production worldwide, which caused an economic loss up to 65% yield in susceptible cultivars (Li *et al*., 2007). Losses are dependent on the growth stage of the plant at which infection occurs, level of resistance and prevailing environmental conditions. It occurs more frequently in rain-fed areas in wet season due to high dose of nitrogenous fertilizers, close plant spacing and wide spread of HYV and favourable environmental conditions such as cloudy days and high relative humidity etc. Now-a-days blast of rice caused by *Pyricularia grisea* is one of the most severe problems particularly in Jharkhand State. Therefore the present investigation was conducted at Rice Research Farm, Birsa Agril. University, Ranchi during *Kharif*, 2020-21 and 2021-22 for the management of blast of rice.

MATERIALS AND METHODS:

Field trials were conducted in randomized block design with four replications for two consecutive crop seasons (Kharif, 2020 and 2021) at Rice Research Farm, BAU, Ranchi. Twenty days old seedlings (Var.- Pusa Sugandha-3) were transplanted in last week of July in main field of rice The plot size was 5.4 m X 3.8 m with spacing of 20 cm x 15cm using one seedling per hill The trials was laid out Med land (Don II) in RBD with four replications. The Plots were fertilizered with FYM@ 1 ton ha^{-1} and Fertilizers NPK @ 100:60:40 kg ha^{-1} respectively. Nitrogen was applied in three split doses *i.e.*, 30, 35and 35 kg ha^{-1}at seedling, tillering and panicle initiation stage of crop. Phosphorus and pottassic fertilizers were applied @ 60 and 40 kg ha^{-1} as basal. Plots were inoculated with spores of *Pyricularia grisea* (2X 10^{7} spore/ml water) taken from 25 days old culture at 30 days after transplanting. When the environmental conditions were favourable for development of the disease during above crop seasons. All possible care was taken to prevent the pest attack by spraying suitable insecticides accordingly to the necessity. First foliar application of fungicides was

Table 1. Evaluation of fungicides for management of Blast of rice (Mean of *Kharif*, 2020-21 and 2021-22)

Treatments	Dosage /L	Leaf blast disease severity (%)			Neck blast (%)			Grain Yield (Kg/ha)			Increase in yield over control (%)
		*2020-21	*2021-22	Mean	*2020-21	*2021-22	Mean	*2020-21	*2021-22	Mean	
T1- Difenoconazole 25% EC	0.5 ml	30.3 (33.3)	20.4 (30.1)	25.4 (31.7)	12.5 (19.5)	17.8 (24.9)	15.2 (22.2)	3833.25	4720.04	4276.65	2.1
T2- Isoprothiolane 40% EC	1.5 ml	26.8 (31.8)	26.1 (32.0)	26.5 (31.9)	11.3 (18.8)	24.5 (29.7)	17.9 (24.3)	3866.58	4823.72	4345.15	3.7
T3- Kasugamycin 3% SL	2.0 ml	15.8 (21.9)	15.0 (22.5)	15.4 (22.2)	7.5 (15.8)	9.5 (17.9)	8.5 (16.9)	4575.00	5600.96	5087.98	21.4
T4- Kitazin 48% EC	1.0 ml	12.1 (20.3)	14.6 (20.3)	13.4 (20.3)	5.8 (13.7)	11.3 (19.6)	8.6 (16.7)	4708.33	5678.59	5193.46	24.0
T5- Propineb 70% WP	3.0 g	21.5 (27.5)	32.0 (35.9)	26.8 (31.7)	9.5 (17.6)	22.3 (28.1)	15.9 (22.9)	4191.69	5007.98	4599.84	9.8
T6- Tebuconazole 25.9% EC	1.5 ml	9.6 (18.0)	6.4 (14.4)	8.0 (16.2)	5.0 (12.7)	7.0 (15.1)	6.0 (13.9)	4891.67	5769.23	5330.45	27.2
T7- Thifluzamide 24% SC	0.8 g	18.0	21.7 (24.1)	19.9 (26.6)	8.3 (25.4)	13.5 (16.6)	10.9 (21.5)	4349.92 (19.1)	5336.54	4843.23	15.6
T8- Control		33.5 (35.4)	36.2 (36.9)	34.9 (36.2)	18.3 (25.2)	30.8 (33.5)	24.6 (29.4)	3683.34	4695.51	4189.43	-
CD at 5%	9.9	4.95	7.35	13.65	4.8	10.6	768.4	676.1	699.2		
CV (%)	16.4	12.3	15.3	16.55	13.7	14.8	12.3	18.8	15.8		

. Mean of four replications Figures in parentheses are transformed arc sine values.

given at 4 days after artificial inoculation of the pathogen and 2nd spray was given after 10 days of first spraying of fungicides. Untreated plots were served as control. Severity of leaf blast was recorded after 8 days of last spray. Observation of leaf blast disease severity was recorded 8 days of last week by randomly taken 50 leaves/plot (IRRI, 2013). neck blast incidence was recorded seven days before harvest by panicles taken per m-^{2} per plot. Grain yields were recorded for each plot after threshing and sun drying for seven days. Increase in grain yield over control were also worked out.

RESULTS

Two foliar spray of Tebuconazole (0.15%) *i.e.*, at initiation of disease and 2nd spray at ten days interval recorded lowest mean leaf blast disease severity of 8.0%, neck blast incidence of 6.0%. The above treatment also recorded highest grain yield of 5330.45 kg/ha and increase in grain yield over control (IGYOC) of 27.2%. This treatment was at with T4 and T3. The treatment, T4. *i.e.,* Two foliar spray of Kitazin (0.1%) recorded leaf blast disease severity of 13.4%, neck blast incidence of 8.6%, grain yield of 5193.46 kg/ha and IGYOC of 24.0%. The next best treatment was T3. *i.e.,* Two foliar spray of Kasugamycin (0.2 %) recorded mean leaf blast disease severity of 15.4%, neck blast incidence of 8.5%, grain yield of 5087.98 kg/ha and IGYOC of 21.4%. whereas, the control plots recorded leaf blast disease severity of 34.9%, neck blast of 24.6%, grain yield of 4189.43 kg/ha. (Table1)

CONCLUSION

Two foliar spray of Tebuconazole (0.15%) *i.e.*, at initiation of disease and 2nd spray at ten days interval could be recommended as curative measure for blast outbreak as ad-hoc decision making component of integrated disease management strategy.

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Biological control of sheath rot disease of rice by antibiotic producing *Bacillus* spp.

S. R. Prabhukarthikeyan *, U. Keerthana, S. Raghu, Manas K Bag

ICAR-National Rice Research Institute, Cuttack, India
**Corresponding: prabhukarthipat@gmail.com*

Among the various rice diseases, sheath rot disease caused by *Sarocladium oryzae* (Syn. *Acrocylindrium oryzae* Sawada) is the most ubiquitous and destructive in all rice cultivating areas, reducing the economic and commercial value of rice. Although chemical fungicides have been shown to be effective in treating sheath rot disease, phytotoxicity and fungicide residues are serious issues that pollute the environment and pose health risks to humans. As a result, the need for alternate approaches to the management of sheath rot disease has become vital. The biocontrol approach is the most environmentally friendly and long-term disease management strategy.

METHODOLOGY

Bacillus species were isolated from the different rice-cultivating areas of Odisha using serial dilution method (McPherson *et al.* 2018) on Nutrient Agar medium (NA). The dual culture method was used to test biocontrol efficacy against *S. oryzae* under *in vitro* (Dhingra and Sinclair, 1995). Native bacterial isolates were characterized based on standard biochemical tests (Hildebrand *et al*., 1992). Bacterial DNA was extracted for molecular characterization. The universal primer pair pA F (5'-AGAGTTTGATCCTGGCTCAG-3') and pH R (5'-AAGGAGGTGATCCAGCCGGA-3') was used to amplify 16S rRNA region (1500 bp) in a thermal cycler (BIO-RAD, USA). The PCR products (50–100 ng/ ìl) were purified using PCR Clean-Up System (Promega, Fisher Scientific, cat# PR-A9281, Toronto, Canada) and sent to Agrigenomics pvt. Ltd., Cochin, India, for sequencing. The antibiotic genes of bacilysin, bacillomycin, iturin, surfactin, subtilin, subtilosin, mersacidin, ericin, mycosubtilin and fengycin were amplified using respective gene-specific primers.

RESULTS

We tested the antagonistic potential of forty *Bacillus* spp. against *Sarocladium oryzae* under *in vitro*. Based on their antagonism, ten effective strains against *S. oryzae* were selected among them and characterized at molecular level. The antibiotic biosynthetic genes responsible for the production of bacillomycin, bacilysin, iturin, surfactin, subtilin, mersacidin, subtilosin, ericin, mycosubtilin and fengycin from the effective strains were detected by PCR analysis. Among the strains, BS5 exerted higher mycelial growth inhibition (80.33%) of the pathogen and possesses the maximum number (9) of antibiotic genes as well. In this study, we evaluated the efficacy of liquid formulation of the strains BS5, BS6 and BS39 against *S. oryzae* under glasshouse conditions. Glasshouse studies illustrate significant reduction in the sheath rot disease index (75.25%) on rice crop with the combined application of seed treatment + seedling dip + foliar spray of BS5 liquid formulation.

CONCLUSION

Application of liquid formulation of BS5 reduced the sheath rot disease severity under *in vitro* and *in vivo* conditions. Moreover, the current study has given the scope for better management of sheath rot disease of rice in a sustainable manner.

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ARRW/SIRC/Theme III/40

Determination of false smut resistance in rice genotypes through molecular markers

Swagatika Biswal, Mathew S Baite*, Elssa Pandit, Sharat K Pradhan, Manas K Bag, Raghu S, Prabhukarthikeyan SR, Keerthana U

ICAR- National Rice Research Institute, Cuttack 753006, Odisha, India
** Corresponding author: mathew.baite@gmail.com*

False smut is an emerging threat to rice production in many rice growing regions of the world. The causal organism of the disease is *Ustilaginoidea virens*. Infection by the fungus convert rice grains into a yellowish smut ball and later to greenish black colour. The disease can cause 2–81% yield loss depending on the weather factors, genotype and intensity (Yang et al. 2012). Control of the disease through deployment of resistant genes is a promising strategy and also safe to the environment.

MATERIALS AND METHODS

The 96 rice genotypes consisted of both resistant and susceptible genotypes reported. The genomic DNA was extracted from the 95 rice genotypes following modified CTAB method (Murray and Thompson 1980). The plant DNAs were suspended in 100 µl of 1X TE buffer and stored in -20p C till further use. DNA amplification was performed in a Gradient Thermal Cycler following standard procedure. A set of 22 flanking markers linked to false smut resistance were used.

Data were analyzed and similarity matrix was constructed from binary data with Jaccard's coefficients and cladogram was generated with unweighted pair group method arithmetic average (UPGMA) algorithm using Free Tree software and the cladograms were visualized by Tree view 32 software.

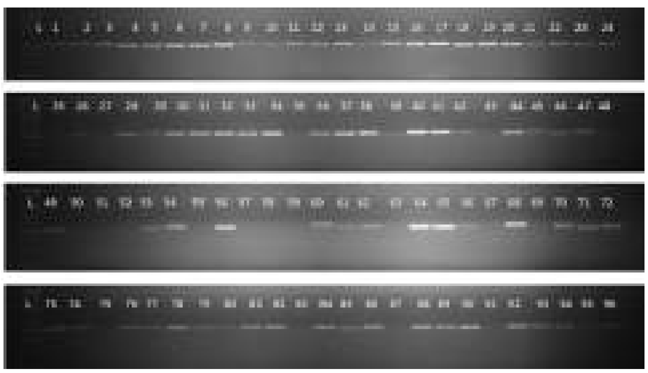

Fig. 1. Amplification obtained with RM222 marker

Table 1. False smut resistance specific alleles obtained with various linked markers.

Primer Name	Size of allele (bp)	Name of resistant genotypes
RM216	170	Sitabhog, Geetanjali
RM222	210	Purnendu, Pankaj, IR 36, Maichikan, Rajamani, Rangi, CSR30, Geetanjali
RM6374	250	Maichikan, ASD 8 ,
RM 307	150	Geetanjali, Maichikan
RM 5699	210	Geetanjali

RESULTS

The genomic DNA from 96 rice genotypes were extracted and quantified to range from 100 to 200ng/µl. All the markers used in the study were polymorphic. A total of 54 alleles were amplified (Fig. 1). Few false smut resistance genotype specific alleles were obtained (Table 1).

CONCLUSION

False smut resistance specific alleles were obtained from the following genotypes, Sitabhog, Geetanjali, Purnendu, Pankaj, IR36, Maichikan, Rajamani, Rangi, CSR30, Maichikan and ASD8. Geetanjali was the most promising variety for possible identification of false smut resistance genes.

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ARRW/SIRC/Theme III/41

Blast disease resistance phenotyping and molecular profiling of rice germplasm lines from the Indian mid-Himalayas

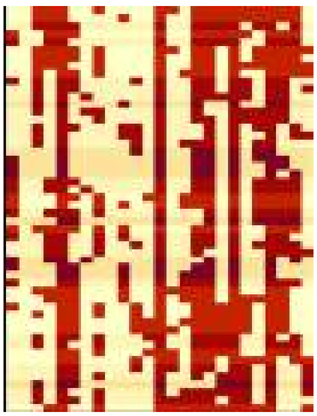
Jeevan B[1,2] *, Raghu S[1], Rajashekara H[2], Rupak Jena[1] and KK Mishra[2]

Division of Crop Protection, ICAR- National Rice Research Institute, Cuttack, Odisha, India
Division of Crop Protection, ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora, Uttarakhand, India
**For correspondence. E-mail: jeevan.bscag@gmail.com*

Rice (*Oryza sativa* L.) blast disease, caused by filamentous fungus *Magnaporthe oryzae* (anamorph *Pyricularia oryzae*) remains a potential threat to global rice production This pathogen can be found in all developmental stages of the plant, and substantially reduce the grain yield up to 90% under conducive environmental conditions. Exploitation of host resistance (*R* genes) is the most economical and ecologically viable approach for the rice blast control. Marker-assisted selection (MAS) has emerged as powerful technology, which accelerated the rice breeding program for blast disease resistance. Indian rice germplasm collection has got abundant genetic diversity. Therefore, the present study has been carried out to evaluate and identify the blast disease resistant sources and the genes significantly associated with blast disease resistance.

MATERIALS AND METHODS

A set of 52 rice accessions, were evaluated for their reactivity against leaf and neck blast. For genotyping, PCR reactions were carried out using 25 molecular markers for the presence of major blast resistance genes. Further, genetic analyses like Population structure, diversity, Principal coordinate analysis, analysis of molecular variance, different alleles per locus (Na), the number of effective alleles per locus (Ne), Shannon's Information Index (I), and Expected Heterozygosity (H_E) were carried out. Subsequently, genetic association of markers, with leaf and neck blast disease was also performed.



RESULTS

Of 52 rice genotypes, evaluated for their reaction to leaf and neck blast, 29 (58 %) and 22 (42 %) entries were found highly resistant, 18 (36 %) and 29 (57 %) were moderately resistant and 05 (6 %) and 01(1%) were highly susceptible to leaf and neck blast respectively. The genetic frequency of 25 major blast resistance genes ranged from 32% to 60%, with the frequency of *R*-gene positive alleles ranging from 0% to 100%. Based on the association analysis, we identified that two markers (RM5647 and K39512), which correspond to the blast-resistant genes *Pi36* and *Pik*, respectively, were significantly associated with the neck blast disease, whereas three markers (Pi2-i, Pita3, and k2167), which correspond to the blast-resistant genes *Pi2, Pita/Pita2,* and *Pikm*, respectively, showed a significant association to the leaf blast disease.

CONCLUSION

The identified resistant rice accessions with diverse genetic background, can be used as a potential source of donors, in future breeding programs. Subsequently, these resistant accessions could be tested for presence of novel functional genes/ alleles, so as to use them in rice improvement program as per the need of agricultural systems.

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ARRW/SIRC/Theme III/42

Isolation and characterization of bacterial biocontrol agents from rice Rhizosphere of Assam

R Jena[1]*, SR Prabhukartikeyan[1], Raghu S[1], S Gogoi[2], G. Bandaru[3] and A. Chatterjee[4]

[1]*ICAR- NRRI, Cuttack, Odisha, 753006, India*

[2]*Ph.D. Scholar, Plant Pathology, Assam Agricultural University, Jorhat, Assam, 785013, India*

[3]*Scientist, Nematology, ICAR- NRRI, Regional Station (Naira),765024, AP, India*

[4]*M.Sc. Scholar, Plant Pathology, Assam Agricultural University, Jorhat, Assam, 785013, India*

Rice (*Oryza sativa*), has always been an elemental food crop to the world's socioeconomic scenario. Rice covers a major share of the food plate for about 800 million people of India fulfilling 43% calorie requirement and also contributing nearly 40% and 55% to the countries food grain and cereal production respectively (Pathak *et al*, 2020). Over 210 species of plant parasitic nematodes are reported to be associated with rice crop. The economically important nematodes associated with the crop are *Meloidogyne graminicola, Dictylenchus angustus, Heterodera oryzicola, Aphelenchoides besseyi, and Hirschmanniella spp*. Considering the benefits of the biocontrol agents and negative impact of chemicals to the environment a study was undertaken with the objective- Isolation and characterization of various native bio control agents from rice rhizosphere of Upper Assam.

METHODOLOGY

A roving survey was conducted and 110 soil samples (100gms each) were collected from the rhizosphere of rice plants from areas like Alengmora, Sibsagar, Titabor, Jorhat, Golaghat of Upper Assam. The isolation of bacterial bio agents from soil involved the use of serial dilution procedures. The soil samples were plated and after 24 hrs, the morphologically different bacterial colonies were selected and were repeatedly streaked to achieve pure bacterial colonies.

RESULTS

A total of 11 potential bacterial microorganisms and were isolated and pure cultures were maintained. The strains coded as BTS 4, BTS5, BSH8 and BJA15 after morphological and biochemical tests were subjected to molecular identification by 16S rDNA and were identified as *Bacillus velezensis*, *Alcaligenes faecalis*, *Bacillus subtilis* and *Rhizobium pusense*. Amruta *et al*. (2016) isolated a total of 60 bacterial strains from the rice rhizosphere of plants grown under submerged conditions by serial dilution method. Haque *et al*. (2018) in his investigations had characterized twelve strains of biocontrol isolates including *Aspergillus niger, Trichoderma harzianum, T. viride, P. lilacinus, B. subtilis, P. fluorescens* and *P. putida*

BTS4 (*Bacillus velezensis*) BTS5 (Alcaligenes faecalis) BSH8 (Bacillus subtilis) BJA15 (Rhizobium pusense)

from the rice rhizosphere of Aligarh. The strains were further incubated to be tested against various nematode pests on rice in *invitro* conditions.

CONCLUSION

The rhizospheric soils in rice are rich in micro organisms and the native strains *B. velezensis, A. faecalis, B. subtilis* and *R. pusense* were isolated The native strains provides encouraging insight into integrated nematode management with synergistic impact on environmental sustainability.

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Effect of different levels and mode of application of nutrients on the incidence of major insect pest of rice

Binay Kumar[1]*, Rabindra Prasad[1] Manoj Kumar Barnawal [2], Ashok Kumar Singh[3], Ekhlaque Ahmad[4], Krishna Prasad [4] and Varsha Rani [4]

*[*1]Department of Entomology, Birsa Agricultural University, Ranchi, Jharkhand, India-834006.*
Corresponding author: binayento@yahoo.co.in

Rice (*Oryza sativa* L.) is one of the most important staple food crops of India. Insect pests infesting rice are considered as one of the important yield limiting factors. Optimization of NPK dose and their mode of application with more emphasis of the use of potassic fertilizer may be effective in significant reduction of the incidence of pest attack. But no information are available on these aspects particularly in the state of Jharkhand.

OBJECTIVES

Hence, the present experiment was conducted with prime objective to determine the effect of different level and mode of application of major plant nutrients (NPK) on the incidence and abundance of YSB, hispa and leaf folder infesting rice and their ultimate impact on yield of the crop.

MATERIALS AND METHODS

The present experiment was conducted on rice (Var: IR 64) was conducted for two consecutive kharif seasons(i.e 2021 & 2022) in the research farm of BAU, with eight treatments (Table-1) in four replications using RBD with varying levels of quantity of NPK and their different mode of applications.

Table 1. Effect of different levels and mode of application of nutrients on the incidence of major insect pest of rice (Based on pooled years, 2021 & 2022)

Treatment no	Treatments: Nutrients dose & mode of their application	Incidence of major insects pests of rice & yield of grains				
		Incidence of YSB		Incidence of	Leaf folder	Yield of rice
		DH (%)	WEH (%)	hispaLDH (%)	LDLF (%)	grains(q/ha)
T_1	N,P,K @ 80,40,30 Kg/ha (N & K in 2 splits: P as basal)	3.24 (10.32) *	3.00 (9.98)*	3.15 (10.16) *	3.77 (11.09)*	38.20
T_2	N,P,K @ 80,40,30 Kg/ha (N & K in 3 splits: P as basal)	2.55 (9.11)	2.65 (9.29)	1.78 (7.49)	2.18 (8.46)	42.70
T_3	N,P,K @ 80,40,30 Kg/ha+FYM @ 5 t/ha (P, K as basal, N in 3 Splits)	5.50 (13.56)	5.70 (13.81)	4.20 (11.83)	7.80 (16.29)	46.20
T_4	N,P,K @ 120,60,45 Kg/ha+FYM @ 5 t/ha (N & K in 2 splits: P as basal)	6.20 (14.43)	7.30 (15.68)	5.80 (13.95)	4.33 (11.98)	53.50
T_5	N,P,K @ 120,60,45 Kg/ha (N & K in 3 splits: P as basal)	2.46 (9.28)	2.76 (9.47)	2.80 (9.63)	3.26 (8.53)	48.40
T_6	N,P,K @ 120,60,45 Kg/ha (P,K as basal, N in 3 splits)	7.60 (16.02)	8.80 (17.28)	6.50 (14.78)	8.80 (17.27)	38.40
T_7	N,P,K @ 80,40,Ko (Farmers Practice) (N in 3 splits: P as based)	12.40 (20.63)	14.30 (22.24)	11.50 (19.82)	16.70 (15.02)	30.40
T_8	No,Po,Ko (Untreated Control)	5.22 (13.19)	4.50 (12.27)	3.20 (10.31)	3.76 (11.09)	18.20
C.D (P=0.05)		(0.56)	(0.86)	0.67	(1.73)	4.36
C.V (%)	(9.85)	(11.76)	(10.53)	(9.67)	9.33	

DH- dead heart due to YSB; WEH-White ear head to YSB; LDH-Leaf damage due to hispa;, LDLF-Leaf damage due to leaf folder
*Figures under the parentheses are angular transformed value

RESULTS AND DISCUSSION

It was found that N and K applied both @ 80, 40, 30, and 120, 60 and 45 kg/ha in 2 to 3 splits significantly reduced the incidence of major insect pests viz, YSB, hispa and leaf folder which, in turn, could be responsible for limiting the realization of yield potential of rice as compared to those of basal application of N and K. Application of K @ 30 and 45 kg/ha applied in soil in 2 to 3 splits resulted to the substantially lesser incidence of all the three insect pest species as compared to that with the basal application of K. Basal application of FYM @ 5 t/ha along with application of N and K applied @ 120 and 45 Kg/ha, respectively in 3 split doses resulted in almost lower incidence of the pest species with realization of the highest grains yield of 53.5 q/ha followed by application of 150 percent RDF i.e., N,P,K @ 120,60 and 45 Kg/ha with N&K applied in 3 splits which gave 48.4 q/ha grain yield whereas N and K applied @ 80 and 40 kg/ha (Farmers practice) received highest incidence of the pest species with significantly lower yield (30.40 q/ha). It would be worthwhile to mention here that the rice plants receiving zero quantity of N,P,K from outside source received the minimum incidence of the pest species probably on account of very poor growth of rice plants with minimum yield of rice (18.20 q/ha). Findings of Prasad et.al. (2008) are almost in agreement with the results of present experimentation.

CONCLUSION

It may be conclude that split doses of N & K with some higher quantity of K was found to be significantly effective in reducing the extent of intensity of attack of the pest species viz YSB, hispa and leaf folder which, in turn realized higher grain yield of rice.

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Study on the spectral characteristics of the rice infested by brown plant hopper using hyperspectral remote sensing

Shyamaranjan Das Mohapatra[1*], Radhakrushna Senapati[1], Rahul Nigam[2]

[1]*ICAR-National Rice Research Institute, Cuttack - 753006, Odisha, India*
[2]*Space Application Centre, ISRO, Ahmedabad-380015, Gujarat, India*
**Corresponding Author: sdmento73@gmail.com*

The global agricultural sector is facing increasing challenges posed by a range of stresses, which includes a rapidly growing population, depletion of natural resources, biotic stresses and climate change. A promising strategy to solve these issues is precision agriculture, which aims to improve farming methods and reduce environmental impacts. To solve this more practically, the use of Hyperspectral Remote Sensing (HRS) technique is used which can identify spectral signatures of different insect pests and diseases which subsequently, provides spectral data for site-specific management. The development of HRS over the past few decades offers an alternate way of assessing crop health and growth with reduced human effort. It has thousands of bands that can capture detailed spectral response; hence it is more capable of detecting any variations in crop physiological characteristics. This raises the problem of reducing the number of bands from thousands to a significant spectral band width and also identifying the central band, which has been a considerable challenge for the agricultural community. In order to distinguish between healthy and stressed crops, the Space Applications Centre in India is working with ICAR centres to conduct various ground-based investigations. As a result, an experiment was conducted to use hyperspectral data to distinguish healthy and damaged rice plants by Brown Plant Hoppers (BPH) at different phenological stages and damage levels.

METHODOLOGY

Field experiments were carried out during the Rabi season (2019-20) in an experimental rice field at ICAR-NRRI, Cuttack, Odisha, located at 20.45 °N, 85.93 °E. Rice seedlings of Taichung Native 1 (TN 1) were sown in a field with four treatments in completely randomized design (CRD) with two replications. To obtain different BPH damage levels (Level 5, 7, 9 as per International Rice Research Institute, Standard Evaluation System, 2013), 45-days old rice seedlings were infested with differential numbers of brachypterous females and winged males and were covered with nylon netting. The reflectance data was recorded for healthy and affected BPH samples at different damage levels. The atmospheric perturbated bands (1350-1450, 1780-2000 and 2350-2500) nm were removed in order to get a smoothened curve as shown in Figure 1. The Economic Threshold Level (ETL) of BPH was correlated with Pearson's correlation and the reflectance value with its corresponding derivatives, to identify the spectral sensitive regions. The sensitive region which was common to both first and second derivatives with the correlation coefficient value greater than 0.6 were considered as sensitive regions. Besides, derivative approach the continuum removal (CR) using ENVI software package and sensitivity analysis (SA) were also used to identify peaks and dips in the sensitive region. The central band of the sensitive region and the peaks and dips obtained from CR and SA were considered as sensitive bands which were further undergone a statistical test to check its significance. Feature selection study was further carried out using MATLAB by the Random Forest Elimination tool to reduce the dimensionality of the spectral data. This study employs accuracy-based selection of bands from the sensitive bands using different combinations.

RESULTS AND DISCUSSION

Under field conditions, the rice crop's spectral reflectance changed throughout the wavelength due to differential BPH damage. Healthy samples had a higher spectral reflectance than BPH samples. It was found that BPH damage is directly correlated with the reflectance of BPH samples in the visible (VIS) and near infrared region (NIR), where the reflectance value increased with a decrease in damage from around 400 nm to the red edge shoulder around 670 nm. (Tan et al., 2019).

The ETL value of BPH was correlated with the reflectance value and its corresponding derivatives. It was found that the correlation coefficient 'r' was -0.2 when correlated with reflectance value, but when it was correlated with its derivatives the 'r' value increased to 0.9 as shown in Figure 2b (Huang et al., 2015). Hence, three regions (495–520, 678–730 and 788–816) nm that were common to both first and second order derivatives with 'r' value more than 0.6 were identified as sensitive spectral regions. Bands 519 and 718 nm exhibited significant peaks and bands 786 and 812 nm resulted significant dips which were eventually confirmed as sensitive bands for BPH.

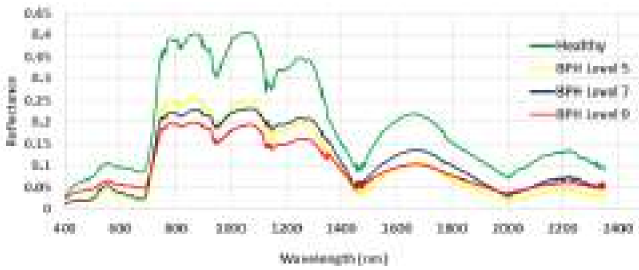

Fig 1. Spectral curve for Healthy vs BPH at different damage level

Sensitivity Analysis and CR analysis were performed simultaneously in the VIS and the NIR region and it was found that there was a dip at 543 nm in the green region (520-580) nm and a peak was observed at 670 nm in the red region (600-670) nm very close to the red edge region as shown in Figure 2a. (Zhao et al., 2012). Hence, the bands 519, 543, 670, 718, 786 and 812 nm were considered as a central bands and were finally termed as sensitive bands for BPH.

To lessen the dimensionality of the spectral data, a feature selection was further carried out using MATLAB and the Random Forest Elimination tool. This study uses several combinations to accurately choose bands from the sensitive bands. When combining sensitive bands, the RELIEFF

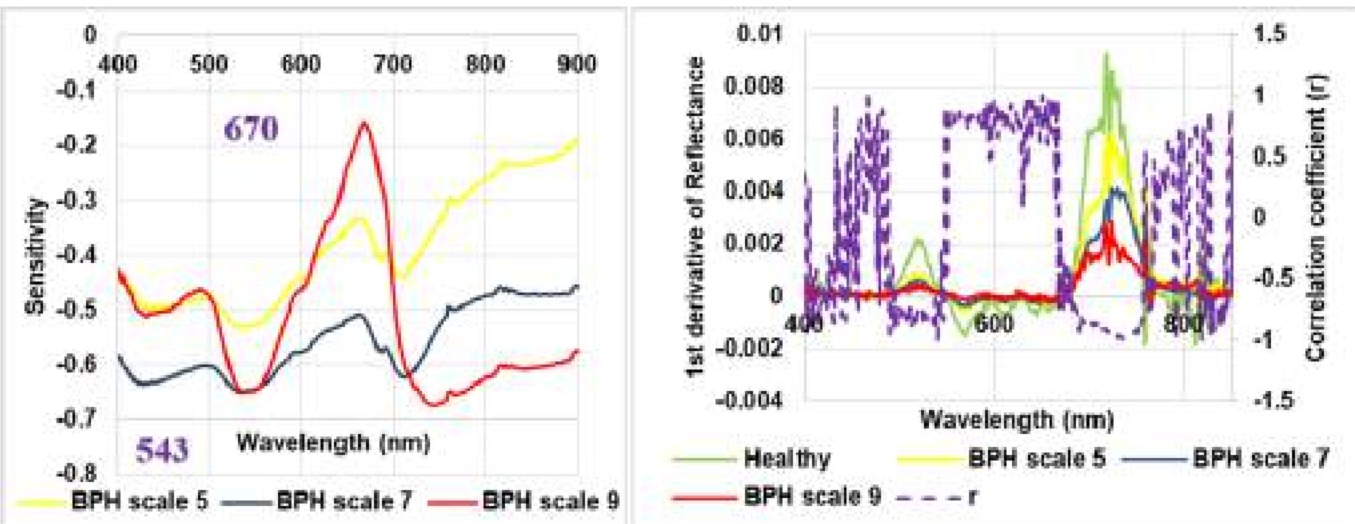

Fig. 2. (A) Sensitivity Analysis of BPH damage (B) Correlation coefficient between 1st derivative of reflectance and ETL value of BPH.

method was found to be the best above all other machine learning algorithms in terms of accuracy. The maximum accuracy of 83.6 per cent was obtained at 519, 670, and 718 nm, indicating that the green, red, and red edge regions were mostly responsible of BPH detection in rice.

CONCLUSION

Early and quick detection of BPH in rice crops during the vegetative stage might protect the projected losses and lower the cost of cultivation. The ability to distinguish between a healthy and BPH-infested rice crop using hyperspectral data with the high spectral resolution was demonstrated without damaging agricultural field sampling. The findings of the current study may be used to monitor BPH damage to rice that is being grown in the field at various vegetative stages. The sensitive bands 519, 543, 670, 718, 786 and 812 nm are mainly from the VIS and the NIR region. Future research can employ hot spots to identify the presence of BPH damage in rice samples using satellite data gathered from aircraft or satellite platforms with various resolutions. Therefore, farmers will benefit from using appropriate control measures to reduce losses caused by BPH, minimizing pesticide application, and applying site-specific pesticide application.

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Effect of elevated ozone levels on emerging disease, bakanae on different rice genotypes under controlled conditions

Raghu Shivappa[1], Jeevan B[1], Anjani Kumar[2], Prashanthkumar S Hanjagi[3], Mathew S Baite[1], Prabhukarthikeyan SR[1], Gurupirasanna Pandi G, Manas Kumar Bag[1] and Amaresh Kumar Nayak[2]

1. Crop Protection Division, ICAR- National Rice Research Institute, Cuttack, Odisha, India
2. Crop Production Division, ICAR- National Rice Research Institute, Cuttack, Odisha, India
3. Crop Physiology and Biochemistry Division, ICAR- National Rice Research Institute, Cuttack, Odisha, India
Email for correspondence: raghurm531@gmail.com

Changing climatic conditions especially, temperature, Carbon dioxide and Ozone can cause significant reduction in rice yield and also may lead to outbreak of many insect pest and diseases. Number of minor diseases can emerge as major problem in addition to existing diseases. Among the emerging diseases of rice, bakanae also called as foolish seedling is emerging as major problem in basmati growing regions of North and North Western India leading to crop losses of 15-50% (Bashyal et al., 2013). But, from past few years, the disease is emerging as major challenge in Eastern Indian States like Odisha, West Bengal and Assam. Most popular varieties becoming highly susceptible to the disease (Raghu et al., 2018, 2021). As mentioned above changing climatic conditions may be playing some role in disease incidence and losses. Therefore we investigated the effect of elevated Ozone (O_3) concentration on four popular rice varieties with different level of resistance under open top chambers (OTCs). For the first time, we attempted this experiment as no published research work is carried out earlier.

MATERIAL AND METHODS

The Experiment was conducted for two seasons under controlled conditions of open top chambers (OTCs) at ICAR-national Rice Research Institute, Cuttack. Four rice varieties namely, Pooja (Highly susceptible), Pusa Basmati-1121 (Highly susceptible), Naveen (Resistant) and Chandana (Moderately resistant) were used for the experiment. A total of 100 seeds were surface disinfected with 1% sodium hypochlorite (NaOCl) for 2 min and rinsed thrice in sterilized distilled water. A total of 100 seeds in three replication were soaked initially in water for 24 h followed by soaking in 100 mL of pathogen spore suspension (1 X 10^2 spores/mL) for 24 h. The seeds were then air dried for 30 min and sown in plastic pots (2 kg w/v). The pots were placed in OTCs and normal environmental conditions. Three sets of experiment were laid out *i.e.,* Elevated O_3-1 (40 ppb), Elevated O_3-2 (65 ppb), and ambient conditions. Optimum water level was maintained by irrigating pots. Daily observation was made for complete germination. Plant and disease parameters such as percent germination, dead seedlings, and elongated seedlings were recorded and percent disease incidence was assessed.

RESULTS

The experimental results indicated that, elevated O_3 levels do not increased the disease incidence as compared to significant disease incidence and crop loss. No visible symptoms of bakanae disease such as abnormal elongation, seedling death, root rot, stunting or chlorotic leaves were observed during the period. Although different genotypes showed contrasting response for the growth, and physiological responses. Hence, it may be concluded that, elevated ozone levels do not have any observable increase in bakanae disease.

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Genetic dissection of brown plant hopper, *Nilaparvata lugens* (Stål), resistance in rice landraces

[1]Chanchala Meher, Guru-Pirasanna-Pandi Govindharaj, Parameswaran C, [1]Tribikram Samal, Basana Gowda G, Naveenkumar Patil, Annamalai M and PC Rath

ICAR-National Rice Research Institute, Cuttack – 753 006
[1]Odisha University of Agriculture & Technology, Cuttack – 753 006

Rice is the staple food for people in 39 countries and a source of calories for one-third of the world's population which include 2.70 billion people in Asia alone. It has been attacked by more than 100 insect species, of which20 are major pests. Among insect pests, the brown planthopper, *Nilaparvata lugens* is the major pest that sucks the phloem sap from leaves, stems, and mainly from leaf sheath, which results in yellowing, browning, drying, and wilting of the rice, termed as "hopper burn", which leads up to 70–100% yield loss (Jena *et al.,* 2018; Pandi *et al.,* 2018). The present study was done on purpose to characterize *N. lugens*-resistant genes/ sources in Indian landraces by assessing through phenotypic evaluation and genetic analysis. This will help in the identification of new resistant donors and the development of durable resistant rice varieties against *N. lugens.*

MATERIAL AND METHODS

A total of 191 rice landraces have been screened in two consecutive seasons during 2021-22. The level of *N. lugens* resistance in selected landraces of rice has been evaluated as per the standard Seed Box Screening Test. Further, phenotypic parameters like nymphal survival study, honey dew test, and feeding mark study were also carried out. Marker-trait association study was done with 81 SSR molecular markers and analysis was conducted by using DARwin, POWER MARKER, STRUCTURE and GenAlEx software's.

RESULT AND DISCUSSION

Results revealed that mean genetic diversity was 0.165and the polymorphic information content (PIC) was 0.145 in the 81selected markers. Further, molecular variance (AMOVA) revealed only 13 % variation among population and 41% within the populations. Population structure analysis of 191 rice genotypes in present research recorded a peak value of 63.167 for Ä*K* at *K* = 2 with two sub-genetic groups (Fig. 1).Sub-population I consisting of 99 rice genotypes, while Sub population-II consist of 89 genotypes and remaining 3 rice genotypes found as admixtures. Maximum proportion of resistant genotype

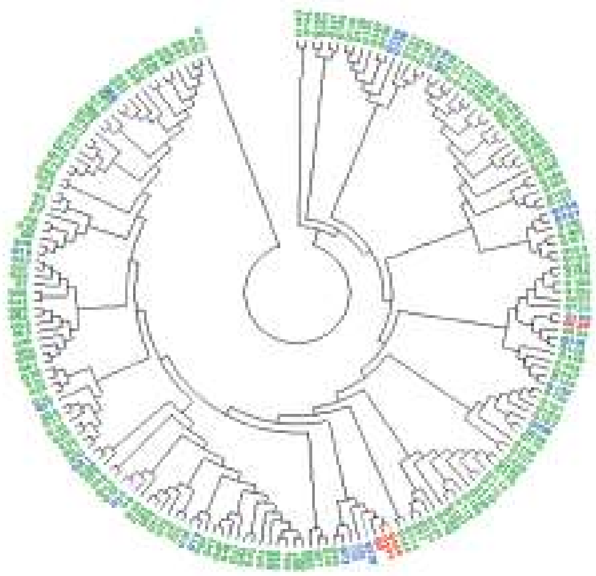

Fig. 1. Unrooted neighbor-joining (NJ) tree of 191 panel population based on 81 molecular markers interrelated to *N. lugens resistance* genes. These genotypes representing two subpopulations (green-susceptible; blue-moderately resistant; red-resistant).

present in Sub-population I, moderately resistant genotype was scattered in all 3 subpopulations. Marker-trait association study revealed seven SSR markers such as RM6732, MS10, RM314B, RM8213, RM218, RM500 and RM7102 were associated with different *N. lugens* phenotypic parameters.

CONCLUSION

These identified resistant germplasm and genes in rice landrace will serves as the source for development of durable resistant variety against *N. lugens* and useful for optimizing Integrated Pest Management strategies.

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ARRW/SIRC/Theme III/47

Multigenerational exposure of sublethal imidacloprid improves functional response in an egg parasitoid, *Trichogramma chilonis* Ishii

Basana Gowda G[2*], Aishwarya Ray[1,2], Neeraj Budhlakoti[3], Dhanendra Kumar Rana[1], Totan Adak[2], Prakash Chandra Rath[2], S. D. Mohapatra[2]

[1]*Department of Entomology, College of Agriculture, Indira Gandhi Krishi Vishwavidyalaya, Raipur 492001, Chhattisgarh,*
[2] *Crop Protection Division, ICAR-National Rice Research Institute, Cuttack 753006, Odisha, India*
[3] *Division of Agricultural Bioinformatics, ICAR-Indian Agricultural Statistics Research Institute, PUSA, New Delhi - 110 012*
Corresponding author: basanagowda.g@icar.gov.in

Recently, the phenomenon of using bio-control agents in reducing the menace of noxious pest has gained momentum, but the predominance of chemical management in conventional agriculture remains. In the approach to achieve a balanced ecosystem, the compatibility between the applied insecticides and bio-control agents is a matter of great concern (Martinou et al., 2015). The predilection of using insecticides non-judiciously has cost natural enemies. Hence, appraising the effects of insecticides (both lethal and sublethal), to evaluate the impact on bio-control agents is imperative (Desneux et al., 2007).

METHODOLOGY

The multigenerational effect ($F_1$to F_5) of different concentrations (LC_5, LC_{30}, LC_{50}) of imidacloprid along with acetone (control) was carried out following the protocol of Ray et al. 2022 with 20 surviving genitors (*n*=20) in each generation. Each generation was extended by genitors treated with designated concentrations of imidacloprid and offered with UV-sterilized *C. cephalonica* eggs. All the functional response analysis is carried out using 'frair' R package (Pritchard et al., 2017).

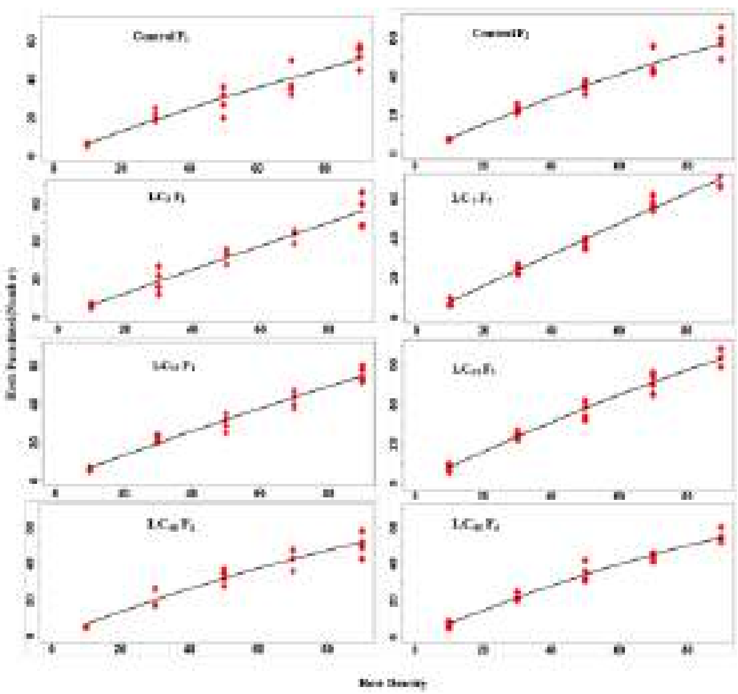

Fig. 1. Functional response of *Trichogramma chilonis* to different densities of *Corcyra cephalonica* eggs in control and different concentrations of imidacloprid at F_1 and F_5 generations. Each data value indicates the observed number of eggs parasitized.

RESULTS

The multigenerational effect of different concentrations of imidacloprid on the functional response of *T.chilonis* at different host densities is shown in Fig 1. In each treatment, the rate of parasitization increased with increase in host densities (Fig. 1.). The outcomes revealed a type II functional response for the F_5 generation of LC_{30}, both the generations (F_1 and F_5) of LC_{50} and control. A type I functional response was exhibited for F_1 generation of LC_{30} and both the generations of LC_5. A shift in the type of functional response did not alter (decrease) the attack rate over the host eggs treated with LC_5 and LC_{30} concentrations in comparison to the control. A significant increase in the searching efficiency (*a*) was observed in the later generation (F_5) under the exposure of LC_5 and LC_{30} imidacloprid concentrations. A lower handling time (T_h) in both the generations of the LC_5 followed by LC_{30} treated individuals was observed juxtaposing the control and LC_{50} concentration. The per capita parasitization efficiency ($1/T_h$) along with rate of parasitization per handling time (a/T_h) were also considerably high in both the generations of LC_5 and LC_{30} than in the control and LC_{50}, thereby implying positive effects of imidacloprid on the parasitization potential of *T. chilonis*.

CONCLUSION

Altogether, these multigenerational outcomes on the functional response of *T. chilonis* could be leveraged to annihilate the intractable lepidopteran pests under the mild exposure of imidacloprid in IPM programmes as well as in the mass rearing of the parasitoid, *T. chilonis*.

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INVITED LECTURE

Non-invasive early detection of rice blight disease using a sensitive volatile based sensor technology

Debabrata Sircar [a*] and Pawan Kumar Agrawal [b]

[a] *Department of Biosciences and Bioengineering; Indian Institute of Technology Roorkee, Roorkee 247 667, India.*
[b] *ICAR Headquarters, New Delhi*
** E-mail : debabrata.sircar@bt.iitr.ac.in*

Rice (*Oryza sativa*) is an important staple crop consumed in Indian and worldwide. During plant growth, rice plants are susceptible to a number of devastating diseases caused by fungi and bacteria. Among rice diseases, bacterial blight (BB) is one of the most serious destructive rice diseases in India caused by the bacterium *Xanthomonas oryzae* pv. oryzae (*Xoo*). Due to the non-availability of robust resistant cultivars, the management of BB primarily relies on chemical control. Early detection (asymptomatic stage) of this disease will help farmers to apply proper disease management and control strategies.

In this work, we have developed a low-cost and portable sensor technology coupled with machine learning algorithm-models for early detection of bacterial blight in rice. First, by using headspace SPME gas chromatography-mass spectrometry (GC-MS) based comparative volatilomics, we have identified signature volatile organic compounds (S-VOCs) emitted by the blight-susceptible rice plants upon *Xoo* infection. Those S-VOCs are unique to early signs of blight infection. Based on the chemical signature of S-VOCs, the corresponding metal oxide imprinted transducer was coated on a flexible substrate. Transducer reacts with S-VOCs to generate electrical signal changes. Electrical signals were processed through a processor by incorporating artificial intelligence and then the output was visualized on LCD screen. Results showed that the developed sensor can predict the occurrence of bacterial blight disease in rice at an early stage (asymptomatic) with an overall accuracy of 92.6%. Farmers, in this current mobile phone generation, can easily adopt this sensor technology as an early warning system for the detection of blight disease in rice. The proposed technological solution has huge economic significance.

Theme - IV

Socio-extension approaches in rice farming to address global food security issues

ARRW/SIRC/Theme IV/01

Promoting Gender equity through accessing Agri-innovations for ensuring Livelihood and Nutrition in Rice-based Cropping System

Lipi Das, Gayatri Moharana, Ankita Sahu and R.S.Panda

ICAR- Central Institute for Women in Agriculture, Bhubaneswar-751003, Odisha, India
Email: lipi.ciwa@gmail.com

Women farmers are pivotal drivers of Indian agriculture. Their magnitude of participation though un-quantified but manifests profoundly when retrospected in terms of quantum operations carried both on-farm and off-farm. Constituting an enormous segment of Indian agricultural workforce, farm women represent a paradoxical, highly heterogeneous and complex entity (Wodon *et al*. 2018).

Accessing and percolating agri-innovations among the farming community through gender-sensitive extension model could be an effective approach to promote gender equity in addition to improving livelihood, reducing drudgery and ensuring food and nutritional security. Creation of a congenial women friendly agro-ecosystem by addressing their issues and improving their accessibility to agricultural resources will enable in unlocking their threshold potential, enhance their efficiency and improve productivity in farming (Ianchovichina *et al*. 2019).

Improving livelihood and ensuring nutritional security are the fundamental pillars of developmental programme and addressing such issues requires sustainable gender equitable approaches with concerted gender-centric institutional support and technical backstopping. Hence, a 'Gender Sensitive Agri-Horti Cropping System Model' was designed and implemented through participatory action research to promote inclusive development of women farmers of the region. The model is based upon an integrated approach of addressing the basic needs of livelihood to meeting their unfelt needs towards nutrition security along with triggering a need in them to upscale their existing farming practices into a commercial venture.

METHODOLOGY

The study was conducted in a cluster comprising of two villages *viz*., Sankilo and Tentalpur under Nischintakoili block of Cuttack district of Odisha. The selection of villages was done on the basis of gender-sensitiveness of the locale and interest of the farm households for action research. For the purpose of study, out of a cluster of 400 farm families, 40 farm families were selected proportionately and a baseline survey was conducted. The gender-centric approach was adopted in familiarizing the households with the project activities through concurrent meetings, gender sensitization programmes, gender gap analysis and PRA studies by involving both male and female key informants separately. The gender gaps were identified using a SHEET module (Social, Health and Nutrition, Economic, Environmental and Technological). On the basis of gender gaps identified, a 'Gender Sensitive Agri-Horti Cropping System Model' was formulated to enhance nutritional status and farm families' income by increasing the production potential of crops and improving their socio-economic conditions.The feasibility of the model was worked out on the basis of their existing circumstances and obtainable resources. Under this Model, demonstrations of HYVs and bio-fortified varieties were conducted among the adopted farm women of the cluster.

RESULTS

The major areas of gender gap identified as per SHEET module were disparity in terms of wage rate(82.5%), poor health of farm women as evident from lower BMI (92.5%), limited accessibility to institutional credit (87.5%), lower accessibility to natural resources like land and water (72.5%) and poor technological knowledge in production and post-production activities (57.5%).

Under Livelihood Enhancement Model, high yielding rice varieties such as CR-Dhan 312, CR-Dhan 409, CR-Dhan 407 and bio-fortified varieties like CR-Dhan 311, CR-Dhan 315 were evaluated in the fields of adopted women farmers (40 nos.) in a contiguous patch of 10.5 ha. The model demonstrated the highest average yield of 6.68 t/ha, obtained in rice variety CR-Dhan 312, followed by CR-Dhan 409 (Pradhan Dhan) and CR-Dhan 407 (Maudamani),which registered a yield of 6.21 t/ha and 6.15 t/ha, respectively. The varietal replacement with high yielding rice varieties manifested an improvement in livelihood by enhancing the average net return to ₹ 1,09,020/- and gross return to ₹ 1,22,410/- per ha. On an average, 55.40% yield advantage and 136.84% increase in income was recorded under demonstrations of HYVs with improved production practices when compared with existing farmers' variety and traditional cultivation practice. Highest B:C ratio was also obtained in var. CR-Dhan 312 (2.40) followed by var. Pradhan Dhan (2.23) and var. Maudamani (2.20).This economic improvement was attributed to improved production potential of rice varieties along with scientific package of practice adopted by active participation of women farmers in both the villages (Das *et al*. 2022).

Similarly, the commercially viable vegetables of the region were also popularized as a subsidiary to rice which is the main crop of the region. As a result, an increase in average gross return from ₹ 1,16,923/- to ₹ 3,15,005/- and net return from ₹ 50,107/- to ₹ 1,89,955/- per annum was achieved. A yield advantage of about 45.51-68.93% and incremental income of 155-203% was also obtained. The highest B:C ratio was observed in cowpea (3.37) followed by bitter gourd (3.19) and okra (3.02). In addition, the introduction of high yieldingshort duration fruit crops, also resulted inyield advantage of about 47.85-49.52% with an incremental income of 69.74-119.30% (Das *et al*. 2022).

To augment the nutrition of farm families, bio-fortified rice varieties (CR Dhan 311 and CR Dhan 315) were introduced under the 'Nutritional Security Model', which ensured a nutrition gain in the existing dietary pattern of farm families, by adding an additional protein yield of 3.26 q/ha and 3.30 q/ha, respectively. In addition to protein, these rice varieties also contained 20-22ppm zinc, which 'supplemented the micronutrient availability to the existing diet. The Nutri-farm trials as a component of 'Nutritional Security Model', generated a lot of awareness and sensitization among the women group towards nutrition knowledge and motivated them to increase the incorporation of Nutri-rich vegetables and fruits in their daily diet.

As drudgery is a major issue of farm women, the perceived rate of exertion by farm women in rice-based model was estimated by using Borg scale (Rating 1-10), which revealed that more than 95% had exertion range of 6-9, which indicated really hard work in case of activities like uprooting, thinning, weeding, ridge making, transplanting, harvesting, threshing and winnowing. The effectiveness of demonstrated drudgery reducing farm tools and implements were assessed by using Drudgery Assessment Module. It was revealed that during rice cultivation, 69% saving in time could be obtained by using cono weeder and dry land weeder for weeding. Similarly, 68% saving in time could be by using seed treatment drum and mandwa weeder for seed treatment and weeding and 54% saving in time could be observed by using fertilizer broadcaster for fertilizer application. During vegetable cultivation, 70% saving in time could be observed by using dry land weeder and hand cultivator for weeding, 58% saving in time could be observed by using hand ridger for ridge making, 56% and 55% saving in time could be observed by using secateurs and battery-operated sprayer for cutting/pruning and spraying, respectively. The demonstrated farm tools improved the work efficiency, work output and decreased drudgery and health hazards of the farm women (Das *et al*. 2022).

CONCLUSION

The gender-centric approach to promote agri-innovations through the developed model enabled in creating a gender friendly atmosphere, which promoted active participation of women farmers. Additionally, the model ensured improvement in livelihood and enhancement in nutrition. The socio-economic status of women in the region and their access to resources were also improved. The women farmers were more empowered to take farm related decisions. Conclusively, the inception of the agri-innovations synthesized a kind of awakening among the farm women of the region and created a motivation among them to upscale their farming to a new dimension and serve as a catalyst to empower other unreached farm women. The model could be instrumental for other stakeholders and extension beneficiaries who aim to address the 3E concept of women empowerment i.e., promoting entrepreneurship, bringing gender equity and realization of empowerment.

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ARRW/SIRC/Theme IV/02

Economics of Ferti-Irrigation in *Kharif* paddy

D.S. Navadkar, R.R. Hasure and S.B. Kharbade

Government College of Agriculture, Karad, Mahatma Phule Krishi Vidyapeeth, Rahuri (MS)
Emails: adackarad@rediffmail.com, dsnchangbhal@gmail.com

A field experiment entitled "Study the Efficacy of Ferti-Irrigation For Paddy Crop" was conducted at PG Research Farm of MPKV, Rahuri -413722 (MS) India during *kharif* seasons of the year 2013, 2014 and 2015 in Randomized Block Design (RBD) on Broad Bed Furrows (BBF) in medium deep Soil having 0.90 m top and 1.20 m bottom at spacing of 0.15 x 0.15 m. Recommended fertilizer dose @ 120:60:60 of NPK (kg/ha) was applied. Nine treatments (based on sources i.e. Water Soluble (WSF) and Conventional fertilizer (CF) at 100, 80 & 60% levels as per schedule) were laid i.e. **T_{1}**- Drip (DI) with 100 % Recommended Dose (RD) of WSF as per schedule , **T_{2}**- DI with 100% RD of WSF as per schedule + 3 foliar sprays of 2 per cent urea phosphate (at 30, 45 & 60 Days After Sowing (DAS)) , **T_{3}**- DI with 80% RD of WSF as per schedule , **T_{4}**- DI with 60% RD of WSF as per schedule, **T_{5}**- DI with 100% RD of CF (N & K through drip and P through soil), **T_{6}**- DI with 100% RD of CF (N, P, K through soil), **T_{7}**- DI with 00 % RD of WSF as per schedule , **T_{8}**- Surface Irrigation (SI) with 100% CF as **Control** and **T_{9}**-SI with 100% CF+ 3 foliar sprays of 2% urea phosphate (30, 45 & 60 DAS), replicated thrice, with objectives to study the efficacy of ferti-irrigation for paddy crop, to standardize optimum dose and schedule of Water Soluble Fertilizers (WSF) for paddy crop and to study the economics of fertigation for paddy crop with variety: Sahyadri-4 using WSF .

The average water use by paddy revealed that the drip method of irrigation resulted into lowest water use (536.97 mm) as compared to surface method (922.37 mm) and thus resulted into 41.78% water saving. The treatment T_2 100% RD of WSF through drip method of irrigation + 2% three foliar sprays at 30, 45 and 60 DAS gave 74% increase in yield with 41.78% water saving with higher water use efficiency of 11.96 kg/ha mm as compared to surface irrigation (3.94 kg/ ha.mm). The drip irrigation with 60% RD of fertigation (T_4) also resulted in 41.78% water saving and 40% fertilizer saving. The drip irrigation (without fertigation) resulted into 26.15% decrease in yield as compared to conventional method.

The maximum benefit-cost (B-C) ratio of 1.66, significantly maximum net seasonal income at Rs.40159 per ha, net extra income of Rs. 26503 per ha, total net income Rs. 69889 and productivity of Rs. 150 per mm of water was obtained in treatment T_2 (100% fertigation with foliar sprays), which remained at par with T_1 as regards (B-C ratio of 1.56, total net income at Rs.59374, net extra income of Rs. 20493 per ha and productivity of Rs 136 per mm of water as compared to surface irrigation with conventional fertilizer (total net income of Rs. 14045 and productivity of Rs. 22 per mm of water).

It can be concluded that the drip fertigation with recommended dose (120 : 60: 60 NPK kg/ha) of water soluble fertilizers in 12 weekly splits as per schedule is recommended for higher yield and net returns, efficient water and nutrient use for paddy in medium deep soils of Maharashtra.

ARRW/SIRC/Theme IV/04

Impact Assessment of Manually Operated Paddy Drum Seeder Using Economic Surplus Method*

KP Saha and Dushyant Singh

ICAR-Central Institute of Agricultural Engineering, Bhopal - 462038 (M.P.)

Paddy (*Oryza sativa* L.) is the main food-grain crop grown in India covering an area of about 45 million hectares (about 35 per cent of area under food-grains) during 2020-21 with an average yield of 2.7 tonnes per hectare. During the same period, the weighted average cost of production for paddy was Rs. 1245 per quintal mainly due to high wages of human labourers engaged in transplanting and harvesting operations. Manual transplanting is a labour consuming operation, which requires approximately 25 per cent of the total labour requirement of the crop (Sahoo *et al*., 1994). Farmers are also facing problems like shortage of labour as well as hike in labour wages during peak period for transplanting (Visalakshi and Sireesha, 2016; Sudharani *et al*., 2019). To overcome this situation, direct seeding of pre- germinated paddy seeds on puddled field by manually operated drum seeder was introduced in India, which also reduces human drudgery involved in manual transplanting. Several ICAR institutions and state agricultural universities worked on this equipment based on IRRI, Philippines design and popularized it among marginal and small paddy farmers in traditional paddy growing regions. Currently a number of manufacturers are manufacturing and supplying it to the users in large numbers every year. The popularity of the equipment is due to a number of benefits reported by many researchers such as, reduced crop duration by 7 -15 days (Wang and Sun, 1990), higher net returns of Rs. 9886.00 per acre (Sreenivasulu *et al*., 2013) and increase in grain yield by 13 to 28 per cent (Prasad *et al*., 2014). Keeping these factors in view, an attempt was made to analyse the economic impact due to adoption of this technology by paddy farmers. Economic surplus method (ESM), a powerful tool for impact analysis was applied for this study because the developed model needs less information to establish the benefits of agricultural research (Wander *et al*. 2004). The study revealed that total number of manually operated lightweight 8-row paddy drum seeder in operation has grown up to ninety-two thousand units approximately from about fifteen thousand units during a period of eight years from 2012 to 2019 in the sates of Assam, West Bengal, Odisha, Chhattisgarh, Andhra Pradesh, Telangana, Tamil Nadu and Kerala. On average, this technology saved about Rs. 745 crores per annum in cost of cultivation, contributed Rs. 7,716 crores annually from additional paddy produced and sold in markets, generated an average income of about Rs. 39 crores per annum to processors and about Rs. 23 crores per annum to the retailers from additional production generated by this technology. Furthermore, the consumers of processed fine rice on average were also benefitted by an amount of about Rs. 224 crores annually. Overall, the total impact on economy was about Rs. 8,747 crores per annum in current prices, equivalent to Rs. 7,869 crores per annum approximately in constant (base year 2011-12) prices.

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ARRW/SIRC/Theme IV/05

Assessment of Consumption of Rice in Odisha

Nitiprasad Namdeorao Jambhulkar* and Biswajit Mondal

ICAR-National Rice Research Institute, Cuttack, Odisha – 753006 India

**corresponding authors email: nitiprasad1@gmail.com*

Rice is the staple food for about half of the world population and more than two thirds of the Indian population. India ranks first in rice area and second in rice production next to China. Rice accounts for 40% of the total food grain production occupying 35% of the food grain area of the country.

Odisha is the fifth largest producer of rice in India during 2020-21 with the production of 8810 thousand tons of rice in 4038 thousand hectare area. But, the consumption of rice is not available in literature. Hence, an attempt has been made to estimate the consumption of rice in Odisha for different classification of age.

MATERIALS AND METHODOLOGY

The secondary data has been collected from the Food and Agriculture Organization of United Nations and Ministry of Health and Family Welfare, Government of India. In this study, the age has been categorized into five classed viz. Class I: 0 to 10 years; Class II: 10 to 20 years; Class III: 20 to 50 years; Class IV: 50 to 70 years and Class V: more than 70 years age. The rice consumption has been estimated for three year 2011, 2016 and 2021 for each of the five classes of age. More than five thousand samples were used in the analysis to estimate the consumption of rice in Odisha.

RESULTS

The consumption of rice in Odisha was 4052, 4245 and 4412 thousand tons in 2011, 2016 and 2021 respectively. The consumption of rice in Odisha during 2011 for Class I, Class II, Class III, Class IV and Class V were estimated to be 435, 775, 2141, 626 and 112 thousand tons respectively. During 2016, the rice consumed by different age classes Class I, Class II, Class III, Class IV and Class V were 407, 771, 2297, 713 and 141 thousand tons respectively. The consumption of rice in 2021 by Class I, Class II, Class III, Class IV and Class V were 386, 733, 2431, 817 and 171 thousand tons respectively.

CONCLUSION

The consumption of rice increased in Odisha over the years. In class I (0 to 10 years) and class II (10 to 20 years) consumption of rice decreased over the years. While in class III (20 to 50 years), class IV (50 to 70 years) and class V (> 70 years) rice consumption were increased over the years. This study will helpful to the policy makers and other rice stakeholders of the Odisha state to plan and reorient the rice related policies of the state.

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Initiative for enhancing farmer's and rural youth incomes by practicing hybrid paddy seed production in Bihar

Ravi Kant[1], VK Choudhary[1], C S Choudhary[2], S S Prasad[3], R K Choudhary[4] and V K Sharma[5]

Department of Genetics and Plant Breeding[1]; Department of Plant pathology[2]; Department of Soil Science[3]; Department of Agricultural Statistics[4] and Department of Agricultural Biotechnology & Molecular Biology[5].
Dr. Rajendra Prasad central Agricultural University, Pusa Samastipur, Bihar-843121.
Email: ravikantrau@gmail.com

In Bihar hybrid paddy is currently grown in about 6 lakh hectares and demand of hybrid paddy seed among farmers is enhancing day by day. As per Bihar Agricultural Road Map 2017-2022, for hybrid paddy seed distribution program, physical and financial target fixed was 60775 quintals and Rs. 6077.53 (in lakh) respectively during 2021-22 but commercially no hybrid paddy seed production is being undertaken either by public or by private sector. Many private seed sector companies are encasings the opportunity by providing a wide range of hybrid paddy seed. These private companies usually produce these hybrids in different state and sell in Bihar Agri-sector markets. This causes manifold losses in terms of both face value and economical fronts to Bihar.

Taking above facts in mind, one project entitled "Standardization of Seed Production Practices and Participatory Seed Production Program of Hybrid Paddy" has been submitted and finally gets sanctioned during last month of 2019 for period of two years by RKVY *Raftar* with the theme to standardize hybrid paddy seed production techniques and to popularize hybrid seed production under Farmers Participatory mode in Bihar. Standardization of seed production techniques was undertaken for three hybrid paddy genotypes (two experimental hybrid genotypes developed in RPCAU, Pusa, namely, RRH-1 & RRH-2 and one commercial hybrid variety received from IIRR, Hyderabad, namely, DRRH-2) followed by farmer's participatory Hybrid Paddy Seed Production in four districts of Bihar during *Kharif-21 and 22* seasons. First Famer's Seed Producing Organization (FPO) was started at Samastipur during *kharif -22* under banner of Morand Desh Foundation (NGO) established by rural youth during *kharif*-22.

Parental lines seeds were sown in the nursery by adopting staggered planting approach. Twenty days old seedlings were transplanted to hybrid seed production plot. During transplanting 5 female (A): 1 male (R) row ratios were adopted. Spacing for female (A) and male parental (R) lines was maintained as 15 X 10 cm and 15 x 15 cm, respectively. Foliar application of Giberellic acid (GA_3) was done twice during appropriate time between panicle initiations to panicle emergence. Supplementary pollination was done by rope pulling during throughout flowering period.

Results of Hybrid Paddy Seed Production at more than 25 acres during *Kharif* -21 & 22 were quite encouraging. Productivity of above 25 q/ha recorded for all three hybrid paddy genotypes seed production against national average of 15 q/ha. Economies of seed production was worked out for both pureline and hybrid paddy seed production. Bihar farmers have now opportunity to enhance their income more than two times in comparison to production of pureline seed of same duration. Rural youth of Bihar has another remunerative option to establish hybrid seed production venture.

Based on results and to undertake this farmer's participatory Hybrid Paddy Seed Production on large scale, Government of Bihar has recommended under RKVY new project entitled "Motivation and Training for Participatory Hybrid Paddy Seed Production in Bihar" during-2022 for sanction.

ARRW/SIRC/Theme IV/07

Farmer Producer Organisation (FPO): the lighthouse for entrepreneurial revolution in farm sector

Saumyesh Acharya[1*], S.K. Acharya[2], T.K. Mandal[3] & B.K. Mohanty[4]

[1] *Ph.D. Research Scholar, Department of Agricultural Extension, Institute of Agriculture, Visva-Bharati University, Sriniketan- 731235, West Bengal, India*

[2] *Professor,* [3] *Associate Professor, Department of Agricultural Extension, BCKV, Mohanpur, Nadia- 741252, West Bengal, India*

[4]*Associate Professor, Department of Agricultural Extension& Communication, Faculty of Agricultural sciences (IAS), S'O'A Deemed to be University, Bhubaneswar-751030, Odisha , India*

**E-mail : acharyasaumyesh@gmail.com*

Farmer Producer Organizations (FPOs) have immense potential to deliver an organized chain of services to various stakeholders involved with agriculture and allied sectors. The FPOs provides a desirable platform for the farmers to take collective decision regarding their farm enterprises in an institutionalized manner. Various stakeholders of farming ecosystem are the direct beneficiaries of FPOs which tend to have various micro-sociological implications on them. With these background the following have been the specific objectives of the study:

(i) To study the entrepreneurial communication behaviour of FPO members.

(ii) To estimate the inter and intra level of interaction between sets of predicted and predictor variables as accommodated in the study.

(iii) To generate policy at micro-level for farmers upskilling and upgradation of the entrepreneurial behaviour of study.

METHODOLOGY

Following snowball sampling method, 100 respondents were selected for data collection. Appropriate statistical tools have been used to carry out the study viz, Correlation coefficient, Step wise regression analysis and path analysis. 24 Independent variables (x_1-x_{24}) were selected for the study and Dependent variable selected for the study was entrepreneurial communication behaviour (y).

RESULTS

The results of stepwise regression analysis revealed that the 7exogenous variables-no. of male workers, materials possessed, marketed surplus, no. of fragments, crop yield, family labour and size of homestead land have been retained at the last step and has substantially contributed to the consequent variable entrepreneurial communication behaviour (y). The r^2 value being 68.70%, these 7 variables have together contributed to 95.15 % of the total 72.20% variance of explicated variables to vindicate their distinctive contribution in characterizing entrepreneurial communication behaviour.

CONCLUSION

Farmer Producer Organisations (FPOs) are evolving as discernible alternatives to classical farming by inviting elements to entrepreneurship and providing a company status to farmer conglomerations. A market linked agriculture is possible only through FPOs which maybe of immense application for generating income, livelihood and empowerment for millions of farmers across India.

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ARRW/SIRC/Theme IV/08

Does Access to Formal Agencies Improve Price Realization and Farmers' Income in Odisha?

Sunil Naik[1], S. K. Srivastava[2], Prabhat Kishore[2], Mrinmoy Ray[3], Nithyashree M. L.[1] and Kingsly I. M.[2]

[1]*Division of Agricultural Economics, ICAR – Indian Agricultural Research Institute (IARI), New Delhi-110012, India*
[2]*ICAR-National Institute of Agricultural Economics and Policy Research (NIAP), New Delhi- 110012, India*
[3] *ICAR-Indian Agricultural Statistics Research Institute (IASRI), New Delhi- 110012, India*

Although crop productivity in India has increased manifold over time, it has not translated into improved economic well-being of the farmers. In addition to productivity, factors such as cost of cultivation, efficient marketing networks and remunerative prices for the produce are important in determining a farm family's income. An efficient marketing system is necessitated to guarantee a fair price for farmers' produce and to increase farm income (Chand, 2017). Farmers generally have several choices to dispose their produce in the market, and prices vary greatly with these destinations. Farmers selling their produce to the formal agencies obtain higher prices as compared to the informal destinations (Negi et al., 2018). This study has identified factors affecting farmer's decision to choose a formal agency as his primary disposal destination and assessed impact of such choice on price receipt and household income in Odisha.

METHODOLOGY

The study is based on the data from the Situation Assessment Survey of Agricultural Households and Land and Livestock Holdings of Households in Rural India, 2019, conducted by the National Sample Survey Office (NSSO). We have used data of 866 paddy growing households in Odisha who sold paddy to a single agency in the market. There are mainly four primary destinations in the market (absorbing more than 95% of the output), which are aggregated into formal (cooperative and government agencies) and informal (local market and input dealers) agencies. *Two-stage Heckman procedure* has been used to nullify the effect of selection bias. The impact of choosing formal agencies on price and income realization (outcome equation) has been jointly estimated along with the determinants of price and income realization (selection equation). The binary choices of farmers marketing agencies are specified as the probit model in the first stage. Second stage of the analysis estimates the effect of formal agency selection. Further, Inverse Probability Weighting (IPW) treatment effect model is used to estimate the average effect of selecting formal agencies over informal agencies on price receipt and farmer's income.

RESULTS

Local market has emerged as the predominant destination for the paddy in Odisha. About 72% of the farmers chose local market to sell major portion of their produce in 2018-19. The government agencies are the second major destination. Relatively higher proportion of farmers in Odisha sold their produce to co-operative societies (8%) as compared to the national average of 4%. Relatively better access to cooperative and government agencies for disposing paddy could be on account of the state-run Paddy Procurement Automation System (P-PAS). Further, farm size wise disposal pattern of paddy showed that the share of farmers selling to the government agencies and cooperatives increases with the increase in farm size. The probit model estimates (first stage of Heckman selection model) showed that factors such as land size, marketed surplus of paddy, awareness about MSP, insurance of the crop, access to institutional organizations, educational attainment of the household head, social status of the household and access to technical advice from government extension agent or ATMA and electronic media (TV, radio, etc.) are positively and significantly associated with formal agencies sale (cooperatives and govt. agencies). Formal agency sale has the potential to improve both price realization of and farmers' income of paddy farmers. Income from diversified sources like income from livestock, wages and salaries, and income from non-farm business has positive impact on the total income of the farmers. Operational land holding, marketed surplus of paddy, awareness about MSP, educational attainment of the household head, and social status of the household has significant impact on the income. IPW treatment effect model showed that paddy output disposal to formal agencies increases the price realization by Rs.3.31 /kg. over an average of Rs.13.94 /kg. and annual income of farmers by Rs. 16,518 over an average of Rs. 67,047, which could have been obtained if none of the farmer had sold to formal agencies. In other words, the impact of choosing formal agencies is 23.74% on price realization and 24.63% on farmers' income.

CONCLUSIONS

The study has identified factors affecting a farmer's decision to choose a formal agency (government and cooperatives) as his primary disposal destination and assessed the impact of selecting these formal agencies on price and income realisation. The evidences have established a positive effect of choosing a formal output disposal destination on price realization and income of the farmers. The choice of formal agencies depends on several factors such as land size, marketed surplus, awareness about MSP, education, social status and access to technical advice. Small and marginal farmers are mostly dependent on informal agencies for their sale despite the fact that they can get higher price from the formal agencies. It is necessary to expand outreach of P-PAS system to the small and marginal farmers (accounts for 93% in the state) for enabling them to get a higher price for their produce and subsequently improve their household income.

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Behaviour change strategies for popularisation of high zinc rice varieties among farmers in Telangana state, India

Amtul Waris, Jyothi Badri and Arun Kumar

ICAR-Indian Institute of Rice Research, Hyderabad-500073

In order to achieve the UN's Sustainable Development Goal number 2 to 'End hunger, achieve food security and improve nutrition and promote sustainable agriculture' by 2030 efforts are being made by various stakeholders including researchers. Nutritional security is also being paid attention too as a vast majority of infants in India are malnourished. In India, iron and zinc deficiency among children is high (NFHS4, 2017). Rice varieties with high zinc and protein have been released to address malnourishment among vulnerable population (Yadava et al., 2020). Popularization of these varieties for large scale cultivation by farmers is very important. The objective of the present study was to popularise high zinc rice variety, DRR Dhan 48 under the nutrition smart interventions among farmers of selected villages in Telangana state.

METHODOLOGY

This study is making an attempt to test the COM-B model for behaviour change communication for the popularization of high zinc rice variety DRR Dhan 48**.** The COM-B Model was developed by Susan Michie, Maartje van Stralen, and Robert West in 2011 and cites Capability (C), Opportunity (O), and Motivation (M) as three key factors capable of changing behaviour (B). Crop demonstrations on high zinc rice variety, DRR Dhan 48 were taken up on fields of 94 farmers in Manchal Village of Ranga Reddy district, Telangana during *kharif* 2021. DRR Dhan 48(high Zn -brown-27 ppm; polished-24 ppm) were taken up on farmers' fields as nutrition smart interventions. Seed production of DRR Dhan 48 was taken up on farmer's field in Ranga Reddy district Telangana. Nutrition information campaign and posters were designed to emphasize upon the importance of zinc in the cognitive development of children.

RESULTS

Demonstrations on high zinc rice variety, DRR Dhan 48 were taken up on fields of 94 farmers and an average yield of 24 q/acre was recorded. About 22% of the farmers retained the grain for own consumption and rated it to be good in taste. The variety was evaluated to be non lodging, tolerant to diseases and appreciated for the full panicle exertion. Seed production of DRR Dhan 48 was taken up on farmers and sold@Rs.26/kg. Horizontal spread of the technology is very encouraging and farmers' rated the taste as good and consumer acceptability study is to be undertaken.

CONCLUSION

The COM-B model was tested to undertake behaviour change interventions to popularise the cultivation of high zinc rice by farmers. Demonstrations on high zinc rice variety, DRR Dhan 48 were taken up on fields of 94 farmers and an average yield of 24 q/acre was recorded. About 22% of the farmers retained the grain for own consumption and rated it to be good in taste.

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ARRW/SIRC/Theme IV/10

Mapping Rice Research in India (2003-2022): An Analysis of Research Productivity

S.K. Mohanty[1*], H.K. De[1], D.P. Rath[1], Manoj Nayak[2] and B. Mondal[2]

[1]*ICAR-Central Institute of Freshwater Aquaculture, Kausalyaganga, Bhubaneswar-751002*
[2]*ICAR-National Rice Research Institute, Cuttack-753006*
[*]*Email:mohanty.sisir@gmail.com*

Rice is a principal food crop in the world in general and Asia in particular. Asia accounts for 90% of the global rice production and consumption and total rice demand will continue to rise in Asia. To assess the research priority and productivity. The present study employs the bibliometric techniques to examine the Indian research output and its citation impact in rice research during the period of 2003-2020. The present study focuses on the scientific output of rice research in India during 2003-2022 on different parameters including growth, global publication share, international collaboration, most productive authors and institutions, funding agencies and pattern of research communication in most productive journals, funding agencies, etc.

METHODOLOGY

The source data for the present study were acquired from the online edition of Scopus published by Elsevier. Publications with keywords "Rice" OR "Oryza Sativa" OR "Dhan" OR "Paddy" OR "Chawal". The search was limited to the year 2003-2022 and affiliation country "India". The data were collected and further analyzed using bibliometric techniques. As many as 25562 research publications were contributed during the study period.

RESULTS

The research productivity has recorded seven-fold increase during 2003-2022, i.e. from 422 publications in 2003, it has gone up to 2807 in 2022. The publication pattern has been steadily increased from 2003-2011 and showed a noteworthy increase from 2012 onwards. Eighty-five percent of the publications were research articles, whereas reviews, conference papers, book chapters, notes, letters etc. constitute the rest. Dr. A.K. Singh is the top ranked author with 171 publications followed by Dr. N.K. Singh with 149 publications, Dr. R.M. Sundaram with 132 publications and Dr. A.K. Nayak with 122 publications. ICAR-Indian Agricultural Research Institute (IARI) published highest number of publications (1773) followed by Punjab Agricultural University (PAU), Tamil Nadu Agricultural University (TNAU) and ICAR-National Rice Research Institute (NRRI). Indian Journal of Agricultural Sciences emerged as the most preferred journal by the researchers with 671 publications appeared during the period 2003-2022 followed by Indian Journal of Agronomy with 476 publications, Electronic Journal of Plant Breeding with 347 publications & Plant Archives with 334 publications, respectively. The highly cited publications and funding agencies have also been identified.

CONCLUSION

With the trend observed during the study period, publication productivity in rice research is slated for touching new heights by 2030. Research publications in NAAS rated journals and others having high impact factor has also witnessed upward growth. The study also reveals that private funding for rice research is negligible with public agencies providing funding support for most of the research.

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Diffusion of NRRI Varieties in Eastern and Northeastern Parts of India: A Micro-level Assessment

Sudipta Paul*, GAK Kumar and Biswajit Mondal

ICAR – National Rice Research Institute, Cuttack

**Corresponding author: E-mail id: Sudipta.Paul@icar.gov.in*

The ICAR-National Rice Research Institute (NRRI), Cuttack has a glorious history of developing improved rice varieties for different ecologies of the country. The institute so far has released 154 high yielding varieties including 5 hybrids (Anon. 2021), and holds a share of about 13% in overall paddy variety release in the entire country (Pathak et al. 2019). The NRRI varieties are quite popular in the eastern states of the country. In the present study, we made a structured effort to estimate the diffusion of NRRI varieties in several Eastern and Northeastern states.

METHODOLOGY

Three popular ways of estimating varietal diffusion are evident in literature: (1) based on breeder seed indents placed by the states to the Department of Agriculture and Farmers Welfare, Government of India; (2) based on computing the total sale of certified seeds by the state departments of agriculture; and (3) based on sample survey. The present study was based on extraction and analysis of household survey based primary cross-sectional data recorded in the NEMA (Network Project on New Extension Methods and Approaches) surveys conducted across the country by the Division of Agricultural Extension, ICAR during 2017-21. The analysis has been restricted to six randomly selected Eastern and Northeastern states, namely, Assam, Bihar, Chhattisgarh, Jharkhand, Odisha, and Tripura with a total sample size of 1464 rice farmers (n=1464).

RESULTS

The results of the study reveal that 28.42% of the sampled farmers adopted at least one NRRI variety. Share of NRRI varieties is the highest in the state of Odisha (65.97%), followed by Jharkhand (45.79%), Tripura (21.1%), Assam (1.16%), and Bihar (0.21%). The average acreage of NRRI varieties in the adopter farmers' fields was the highest in the state of Jharkhand (3.15 acre), followed by Odisha (2.81 acre), Assam (1.13 acre), Bihar (1 acre), and Tripura (0.7 acre). Pooja was found to be the most popular variety, adopted by 12.16% of the farmers in the sample, followed by Lalat (6.08%), Sahabhagidhan (3.55%), Sarala (3.14%), and Savitri (2.94%). Pooja had the highest share in varietal replacement (36.25%), followed by Lalat (18.13%), and Sahabhagidhan (10.59%). The farmers' field level yield was the highest for Gayatri (56.19 q/ha.), followed by Panidhan (43.84 q/ha), and Swarna sub1(43.64 q/ha.).

CONCLUSION

Given the higher extent of diffusion of the comparatively older varieties, and the meagre extent of adoption of the newly released varieties, we conclude that farmers' perspectives need to be understood well in the process of variety development for faster diffusion.

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ARRW/SIRC/Theme IV/12

Module-based Interventions in Farmer-FIRST Programme: An Impactful Approach for Livelihood Enhancement

Biswajit Mondal[1*], SK Mishra[2], BS Satapathy[2], Sudipta Paul[1], S. Lenka[1], Sonali Jethi[1] & Krutibas Jena[1]

[1]*ICAR-National Rice Research Institute, Cuttack 753 006, Odisha, India*
[2]*ICAR-Indian Institute of Water management, Bhubaneswar, Odisha, India*
[*]*E-mail: bisumondal@rediffmail.com*

The Farmer FIRST Programme of ICAR-NRRI, Cuttack started during 2016-17 by adopting four villages namely, Satyabhamapur, Biswanathpur, Laxminarayanpur and Ganeswarpur in Cuttack district of Odisha aiming increase in farm yield and sustain the rice-based production system. Out of 1762 farm families, 800 were chosen randomly following proportionate sampling of which 90 percent are marginal and small farmers. During 2021-22 four new villages namely, Purusottampur, Ganapur, Malihata & Gopinathpur in Cuttack, Odisha out of 1100 farm families' 250 farmers were adopted.

METHODOLOGY

A preliminary survey was conducted and based on findings, need based technological interventions were carried out along with continuous capacity building activities through four modules, namely (I) *crop-based module* (rice, pulses, mechanization), (II) *horticulture-based module* (vegetables, fruits, poly house, mulching technology, nylon net trellis), (III) *animal husbandry module* (poultry, duckery & fishery), and (IV) *enterprise-based module* (mushroom, vermi-composting, honey bee keeping).

RESULTS

Important visible and comprehensive impacts are: (I) Eleven popular high yielding varieties and hybrids namely, CR Dhan 307 (Maudamani), CR Dhan 304, Rajalaxmi (hybrid), Pooja, CR Dhan 701 (hybrid), and CR Dhan 409 (Pradhandhan), Swarna *Sub-1*, CR Dhan 1009 (*Sub-1*), CR Dhan 312, CR Dhan 507 & CR Dhan 508 replaced earlier grown varieties with 30-60 percent increment in yield and 50-300 percent increase in income. (II) Under horticulture-based module, innovative ways of growing five commercial vegetables through relay cropping in trellis system using local materials helped to earn about Rs.6.75 lakhs/ha/annum benefitting about 50 farm families. (III) In animal husbandry module, introduction and adoption of dual purpose poultry breed 'Vanaraja' and 'Khaki Campbell' duck yielded three-times of their investment for over fifty families. (IV) Under enterprise-based module, six young entrepreneurs incubated and promoted in mass production and marketing of oyster mushroom and paddy straw mushroom and one entrepreneur as fish fingerlings grower and supplier.

CONCLUSION

Overall, there was significant increase in knowledge, skill and awareness of farmers, farmwomen and youths observed in the cluster about new crops, vegetables, animals, fisheries, use of farm implements, and related crop-stress management practices apart from substantial increase in income and livelihoods.

Multi-dimensional approach to developing a dynamic agro-advisory and its dissemination through a converged single window system for optimization in resources use and greater impact in agriculture

Bidhan Kumar Mohapatra, Prakashan Chellattan Veettil and Ashok Kumar

International Rice Research Institute

Agricultural sciences and technologies are developing at a good pace but it's still observed that there is a huge knowledge gap at the farmer/ user level resulting in under-productivity and profitability in agriculture in eastern India. An appropriate agricultural extension system supported by policy can only bridge such a knowledge gap. In this regard, agro-advisory plays a major role. If so, then it's high time to critically review the present system of agro-advisory. Agro-advisory in India is not new. Although it started more than two decades, still the impact of agro-advisory has not been that significant or has not created much visible impact on the farming system in the country. The main reason behind this fact may be the content of the so-called agro-advisories is not organized and integrated considering the impactive factors in the locally based agriculture system. The contents are not dynamic, particularly to have decisions in contingent field ecologies. In the present scenario, the content of the agro-advisory messages may be too heavy to be accepted by the end users. Also, the messages are mainly institutional-specific. Agro-advisories on the same topic/issue are being sent by many sources making the end users very confused about which one he/she should use. Hence, collaborative efforts can provide an opportunity to bring all the stakeholders in one platform to organize an integrated approach to synthesize the dynamic model of the agro-advisory system in the agriculture domain in the country.

For an effective agro-advisory system, we need to properly understand its need, target group, process execution, customisation, impact factors, etc. This can be well explained through "5 Ws" of agro-advisory. W_1: What is Agro-advisory? Farm decisions (BMPs & CRPs) are taken in response to information and technological knowledge gaps and changing weather. Farm decisions include agronomics, pest and disease, water and input management. The agro-advisory is taken in response to past, current and future weather changes. W_2: Why agro-advisory is required? This is required to reduce crop losses, sustain crop productivity and enhance profitability, increase input efficiency, and bridge the knowledge gap, and capacity building (information and technology adoption). W_3: When it is most useful? It's useful in normal agricultural operations for BMPs a regular time intervals. Moreover, as and when the situation demands due to biotic & abiotic stresses/events. W_4: Where it is required? The targeted groups and areas could be any farmer in a rice-based or rice-wheat-based cropping system of indo-gangetic plain, in monsoon-dominant regions, and also where the weather is mostly unstable. W_5: For whom it is required? It's required for farmers and agri-entrepreneurs, farmers' farm-based industries, livestock feed makers, agricultural marketing, government to take policy decisions, etc.

Now questions come what are the challenges in agro-advisory systems for which it's not delivering the desired impact? The problem in current agro-advisory looks like algorithms for developing advice are often underdeveloped or insufficiently driven by real-time data, information is supplied at scales too coarse to permit actionable management decisions, and information is not conveyed in simple formats that are readily understood by end users. There are challenges like accessibility to quality data at scale, challenges to get the field or farmer-specific crop management information and customising accordingly, there is higher short distance field to field variation in eastern IGP which makes difficult the design the advisory management zones, the lack of enthusiasm in the NARES partner for sharing the data which they are holding is another challenge. Its development and deployment are also big challenges.

Every problem has a solution. Variable factors which could have an impact on system productivity must be dynamic in decision-making. The contents of agro-advisory may be classified into the following groups. 1) Time of crop establishment: weather data needs to be correlated with the time of establishment; historical weather data can play a vital role in determining decisions of crop establishment time that are favourable for getting higher returns; to figure out the impact of weather forecasting and the onset of monsoon on the timing of crop establishment. 2) Nutrient management: the approach will be tools simplification focussing on very critical information, sensitivity analysis, work on attainable yield logic, and harmonising the recommendation based on digital soil mapping. 3) Pest management: as per DoA surveillance data two most damaging insect pests and diseases in Odisha are – i) stem borer and brown plant hopper, ii) blast and bacterial leaf blight; development of an automated diagnostic tree from IVR (Interactive voice response); insect-pest and disease forecast model verification by comparing existing data with surveillance data. 4) Market information and AI: updated market information; critical data harvesting and acquisition through IVR. 5) Climate resilient agro-advisory: besides regular intervals or during agricultural activities as and when urgently required due to biotic/abiotic stresses messaging needs to be passed to the affected farmers and stakeholders with an exclusive strategy.

The emerging opportunities in this regard are dynamic agro-advisories. New recommendations based on farmer typologies are being devised using modern data analytics approaches using relevant data. The validation trials on crop management variables like sowing date, establishment practice, varieties, nutrition management, irrigation management, etc. Developing and testing the data-driven algorithm to support agro advisory ecosystem in India to provide accurate rice planting date decisions based on multi-criteria assessments that couple irrigation availability, investment costs, risk, and the reliability of forecast information towards cropping systems optimization is what is required. "Co-developing digital architecture and data systems for sustained delivery of planting date advisories" would be one output which will help to lay the foundation for data-driven advisory systems and encourage the partners to mutually share the data.

It's very important to disseminate the agro-advisory to properly targeted groups and through a proper channel. Nowadays one farmer is getting number of messages on the same topic/issue and sometimes the timing is also not relevant to the actual field situation. In this scenario the solution could be one platform developing the agro-advisories in consensus and disseminating through a dedicated single window system. In brief, the steps in this regard would be like below. 1) strengthening the foundations of agro-advisory through knowledge organization and data integration. 2) by leveraging crop modelling, remote sensing, and weather forecast information, etc.. 3) The synergistic partnership under the Convergence Platform (CP) may be established in the state level to develop consensus on proven technologies in the state. 4) Stakeholders working in agriculture have their own mandate and plans to reach out to farmers based on their objectives. While each one of them is involved in strategic planning for improving the lives of farmers in the state, it also becomes important for them to share good practices with each other to achieve maximum impact at the ground level. 5) The regular planning meetings of Convergence Platform members for discussing and sharing synergistic approaches and outcomes have started creating trust in communicating mutually agreed interventions for farmers in each upcoming season through "Single Window Agro Advisory".

The dissemination platforms should be distinguished at national, state and district levels. The mode of dissemination like billboards, newspaper announcements, SMS messages, video messages, IVR, etc. However, it's simply not sending messages on better management practices (BMPs). Achieving impact, we see an opportunity to strengthen the EiA (excellence in agronomy) use cases. In a broader sense, achieving greater impact through mature and promising technologies or innovations that need to be co-developed by stakeholders/ convergence platform members and transformation of knowledge and skill to ensure wider adoption; transforming institutions and policies to increase effectiveness and efficiency through data-based intelligence systems, convergence platforms and evidence-based policy decisions; and supporting digital agriculture for digital farmer services, primarily at State-level, through data-integration and co-development/sharing of analytics, tools and know-how.

The coverage and impact of such agro-advisory development and dissemination would be very much targeted and productive. This will help in bridging the knowledge gap on technologies with tailored BMPs/CRPs, ensure large-scale adoption of landscape-specific technologies and crops with higher productivity and profitability leading to higher income and better life, open up a diversified food choice and ensure nutritional security, and last but not least reduce environmental footprint for a healthier society.

ARRW/SIRC/Theme IV/14

Impacts of Small-Scale Water Management Interventions on Crop Production and Livelihood in Odisha Agro-Ecologies

M. K. Sinha[1]*, P.S.B Anand, R.K. Mohanty and S. Mohanty

ICAR- Indian Institute of Water Management, Bhubaneswar-751023

[1] ICAR-Agricultural Technology Application Research Institute, Garbhuchak, Jagdeo path, Patna-14

Corresponding author email: mukeshwtc@gmail.com

The paper assessed the impact of water management technological interventions created by Indian Institute of Water Management (IIWM), Bhubaneswar in different agro-ecosystems of Odisha state.

METHODOLOGY

Questionnaire based farmer's response and focus group discussion at the intervention site of tank cum well system in high rainfall area, sub surface water harvesting structure in coastal area and two stage rain water harvesting techniques in mid table land areas was the basis for impact analysis.

RESULTS

Mixed and diverse response observed in terms of physical status of irrigation structures, their present-day utilization and existing crop production practices. On the basis of farmers' responses at tank cum well system intervention site under sloppy land situation, the benefit obtained due to dug wells and water harvesting structures was initially up to 68% higher rice yield (from 2.25 to 3.80 t/ha), which at present is still 15% higher (2.60 t/ha) with 33% increased cropping intensity. Dug wells are found maintained better as compared to water harvesting structures. Results of the two stages rain water harvesting study reveals that the benefit gained by the farmers due to utilization of additional water resources was quite good and the sustainability of the lowland pond is significant. The farmer getting benefit of rice yield from 1.6 to 3.5 t/ha, 119% increase from pre-adoption period by the farmers is found persistent. The field assessment of sub surface water harvesting structures revealed that the created structures are still maintained even after 12 years of withdrawal and benefits in *rabi* rice yield is about 7.1% (from 6.7 to 7.18 t/ha) with 108% (from 0.28 to 0.58 t/ha) increase in fish yield compared to pre-adoption period. The technology has also expanded in other fields and impact of the structures on increasing productivity of *rabi* and summer crops, cropping intensity and generating supplemental income through pisciculture is found evident. Further, livelihood also measured based on the assets pattern over the pre-adoption period and are measured based on a 5-point continuum scale. Assets pattern among beneficiary shown an impressive improvement from 52 to 86% across the study village. Maximum gain was recorded at sub-surface water structure, where 86% improvement recorded, leads to further investment in farm pond for fish farming.

CONCLUSION

The watershed technology intervention has considerable impact towards increasing productivity of *rabi* and summer crops, cropping intensity and generating supplemental income through pisciculture improving livelihood of the beneficiary farmers. Repairing of structure, technical guidance, financial support is essential to boost the morale of farmers and the technological intervention to carry forward in the field.

Historical trends and projected rice situation for India till 2032-33

Jaiprakash Bisen[1&3], Shiv Kumar[2], Biswajit Mondal[1], GAK Kumar[1], Utkarsh Tiwari[3], NN Jabhulkar and Asit Kumar Pradhan[1]

[1] *ICAR-National Rice Research Institute, Odisha-753006 (India)*
[2] *ICAR-National Institute for Agricultural Economics and Policy Research, New Delhi- 110012 (India)*
[3] *ICAR-Indian Agricultural Research Institute, New Delhi-110012 (India)*

Rice is one of the keys to address human hunger and ensure food security to the millions of hungry stomachs. India at the fulcrum of global rice market has massive responsibility to feed its growing population amidst growing production challenges. Hence, planning for most appropriate future course of actions requires lessons from the historical experiences and idea about futuristic situations. This study was undertaken with the objective of drawing meaningful lessons from the history of rice markets situations in India and provide inputs for the future policies based on the projected rice demand and supply situations.

METHODOLOGY

The study is based on secondary data on components of aggregate demand and supply of rice and employed growth analysis tools to access historical trends in it. Further, we used NITI Aayog's projections on demand and supply of rice under different growth scenarios to get idea about the future rice situation in the country.

RESULTS

The all India historical trends in area, production and yield of rice indicates that despite a positive and increasing trend in the area, production and yield in past 50 years (1970-2019), the rice cultivation area and its yield have grown compound annually by 0.30 and 1.79 per cent, respectively. The area growth remained below one per cent in all the past five decade and further decreased from 0.47 per cent (during 1970-79) to 0.18 per cent (during 2010-19). The declining growth in area under rice signifies the limitation in possibility of area expansion under rice crop in future. Contrary to it, the decadal growth in yield of rice has increased from -0.44 per cent (1970-79) to 1.97 per cent (2010-19) during the same period. The domestic production of rice has increased at the CAGR of 2.09 per cent in last five decades It indicates that, the productivity growth of rice was the force to drive up the production growth and it need to be maintained

Table: Rice situation in India during 2021-22 to 2032-33 (Based on NITI Aayog)

	Simplistic approach#			Behaviouralist approach#					
				@ 6% GDP growth rate			@ 8% GDP growth rate		
	2021-22	2028-29	2032-33	2021-22	2028-29	2032-33	2021-22	2028-29	2032-33
All India Exp. GR in supply for 10 years	9.12	16.12	20.36	29.61	40.64	47.69	30.84	42.79	50.40
All India Exp. GR in supply for 15 years	9.71	17.73	22.66	30.20	42.25	49.99	31.43	44.40	52.70
State level Exp. GR in supply for 25 years	8.46	14.64	18.50	28.95	39.16	45.83	30.18	41.31	48.54
State level Exp. GR in supply for 35 years	11.44	22.86	30.36	31.93	47.38	57.69	33.16	49.53	60.40
Supply trends in Exp. GR of Pre-Lib period*	12.6	22.90	29.10	33.09	47.42	56.43	34.32	49.57	59.14
Supply trends in Exp. GR of Po-Lib period*	15.8	30.20	39.20	36.29	54.72	66.53	37.52	56.87	69.24

*Supply projections based on three stage least square estimates; #Approaches for demand projections: GR: Growth rate
Note: Additional surplus under the behaviouralist approach is because the demand is exclusive of seed, feed, wastage (SFW) and other use demand
Source: Author's calculation based on NITI Aayog's projections

amidst growing challenges which requires higher investments in R&D and robust extension system. The historical trends in Indian rice trade indicates the independence of Indian food policy for the import point of view while on exports front it got closely linked with the global rice market.

On the demand side, for all the time in past five decades, the total demand of rice the food demand has a significant share followed by seed demand and losses. The export and processing demand of rice has picked up significantly during 1990s which is a positive signal for industrial development in the rice sector. Further, the food demand of rice grains has grown by an average CAGR of two per cent while the processing, seed and the exports demand has grown by an average CAGR of 4.31, 6.67 and 13.41 per cent respectively. The future rice situation suggests positive supply-demand balance and which opens opportunities for crop diversification towards high value commodities and nutrition sensitive crops like pulses, oilseeds and millets.

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Challenges and prospects for application of drone technology in agriculture

Asit Kumar Pradhan[1], Dilip Kumar[2], Jaiprakash Bisen[1], Biswajit Mondal[1], GAK Kumar[1]

[1] *ICAR-National Rice Research Institute, Odisha-753006 (India)*

[2] *ICAR-National Institute for Agricultural Economics and Policy Research, New Delhi- 110012 (India)*

The mainstay of India's economy is agriculture. Agriculture continues to be the main source of income for the majority of rural households. Agriculture-related goods, which account for a substantial portion of India's exports, are also vitally important to its economy. Today in technological world, technology can improve the productivity and efficiency of work in agricultural sector. Drone is one of the emerging technologies and has potential to play a significant role to help Indian farming community. Industry-leading drones make it possible to acquire a thorough picture of the landscape and crops that is not visible to the naked eye, improving crop health and yield. Now a day, drone is familiar to everyone but there are some information gaps, financial constraints, technological limitations, etc. in the agriculture industry. In this study the constraints of adoption of this technology by Indian farmers has been depicted. In current scenario application of drone (UAVs) in Indian agricultural sector is minimum. As Government of India has started many initiatives in this direction it may help Indian farming community to adopt this technology in agriculture sector.

***Keyword**: Drone, Indian Agriculture, Unmanned Aerial Vehicles (UAVs)*

INTRODUCTION

Agriculture drones are spray drone-enhanced unmanned aerial vehicles (UAVs) that are used to increase crop yield, crop monitoring, and the efficiency of agricultural operations. Farmers may get a more in-depth view of their land thanks to drone sensors and digital photography capabilities. The agricultural industry's expansion, which is integrating technical advancements into agricultural operations, will continue to be a driving force behind the development of agriculture drones. Due to its advantages, drone technology that combines remote sensing, machine learning, and artificial intelligence (AI) is growing in popularity. With their online Digital Sky Platform, the central government has acknowledged the importance of unmanned aerial vehicles (UAVs), Machine Learning, and Artificial Intelligence, which is anticipated to augment drone adoption in the country's agriculture sector during the forecast period. There are few major applications of this drone technology in various fields of agriculture like soil and field analysis, crop spraying, crop monitoring, irrigation, plant health assessment and monitoring growth and livestock management etc.

METHODOLOGY

The study is based on collecting feedback/ suggestions from experts in different sectors related to agricultural technology. The data has been collected from 500 different service sector

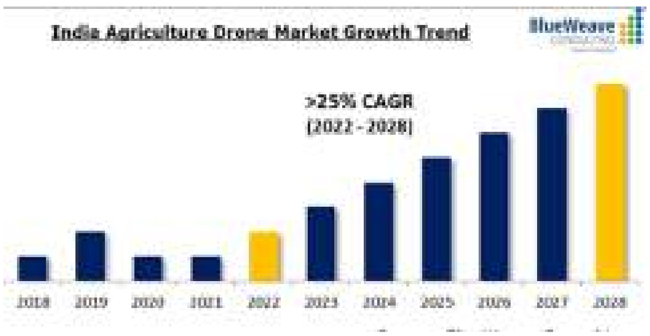

Fig. 1. Growth trend of Indian agriculture drone market (*Source*: Blueweave Consulting)

Table 1. Factors and affecting rate of adoption of drone technology

Factors	Affecting adoption rate(%)	Initiatives
Government policy	65	DGCA to simplify the rules
Training	95	Remote Pilot License required
Awareness	90	Agri drone project and drone yatra by startups
Purchasing cost	95	Subsidy to FPO and CHCs
Official interventions	90	Demonstrations are being carried out through various schemes

experts like farmers, students, agricultural scientists, professors, private sectors and so on. On the basis of feedback, challenges/constraints of adoption of drone technology by farming community has been depicted here.

RESULTS

According to data gathered by specialists, more than 90% of people desire sufficient training for drones used in agricultural agriculture, and more than 65% of people believe that government policies have an impact on how these drones are used. According to the feedback report, 90% of respondents believe that drone start-ups are beneficial to the expansion of drone use in agriculture. Experts have learned that the growth of drone start-ups in agro sector and new enterprises is beneficial for the use of drones in agriculture. Taking cost factor into constraint, 95% of the participants agree that purchasing cost of drones affect the level of drone application in agriculture.

CONCLUSION

In this study the challenges and prospects for application of drone technology in agriculture are presented. In current scenario application of drone (UAVs) in Indian agricultural sector is minimum. The Indian government has launched several initiatives to promote the use of drones in agriculture. One of the key initiatives is the "National Drone Policy" which was released in 2018. Government has taken initiatives through DGCA to simplify the policy provides guidelines for the use of drones in agriculture, such as obtaining necessary permits, following safety and privacy regulations, and utilizing drones for crop mapping, crop spraying, and other agricultural tasks. The government has also established drone testing and training centres to provide remote pilot license across the country, as well as launched pilot projects like Agri Drone Project to demonstrate the potential benefits of drone technology in agriculture. Besides government is giving subsidy to Farmers Producer Organisation (FPOs) and Custom Hiring Services (CHCs) to procure drones. Additionally, the government is partnering with private companies to develop and deploy drone solutions for farmers through Drone Yatra and other beneficial schemes.

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ARRW/SIRC/Theme IV/03

Extent of adoption of recommended cultivation practices of rice (*Oryza sativa*) in the state of Nagaland

Z. Khuvung[1], P. Mishra[2], P. Saikia[3], N. Kharjana[3], B.J. Naik[3]

[1] *PhD Scholar, Department of Extension Education, AAU, Jorhat-13*
[2] *Professor and Head, Department of Extension Education, AAU, Jorhat-13*
[3] *PhD Scholar, Department of Extension Education, AAU, Jorhat-13*
Email: zujankhuvung07@gmail.com

Nagaland is a small state in the north-eastern part of India where majority of the population depends on agriculture serving as the backbone of its economy. Cereals occupies more than two-third of the total cultivable area in the state where rice, maize and millet being the major variants cultivated. Two methods of cultivation are mainly practiced in the state namely, jhum (shifting cultivation) and terrace cultivation, which jointly makes about 86 per cent of the total cultivable area. In the recent years, a high surge in population coupled with high demand of food grains is seen which is of great concern for global food security. Therefore, there ascends a need for sustainable agricultural growth for achieving global food security which can only be unraveled by putting into practice modern and innovative agricultural practices which are sustainable in the long run. A study was carried out in six selected districts of Nagaland with a sample size of 300 respondents to find out the extent of adoption of recommended cultivation practices of rice. Data was collected through personal interview method by administering a structured schedule. Findings revealed that majority (60.67%) of the farmers had moderate level of adoption for recommended cultivation practices of irrigated rice and majority (60.00%) of the respondents had moderate level of adoption for recommended cultivation practices of upland rice.

INVITED LECTURE

Innovative Extension Approaches to Transform Towards Sustainable Agriculture and Food Systems: Experiences and Reflections

R. N. Padaria, J.P.S. Dabas, R. R.Burman, V.Sangeetha, Misha Madhavan, L. Muralikrishnan and Subhashree Sahu

Division of Agricultural Extension, ICAR-IARI, New Delhi

The ICAR-Indian Agricultural Research Institute has contributed immensely to the rice centric national extension systems through continuously working towards generating innovative extension models, tailoring them to developmental programmes, and disseminating them through regional stations, universities, state extension systems, Not for Profit Organizations (NGOs) and Volunteer Organizations (VOs). The recent models are broadly based on Innovative Extension linkages, ICT-based and market linkage models. IARI-SAUs/ICAR Institutes and Voluntary Organizations Partnership Extension Models disseminate IARI technologies in partnership with the partner SAUs/ICAR Institutes and VOs. IARI-Post Office Linkage Extension Model utilized the post office as medium of technology delivery and branch postmasters as para extension officers for farm technology dissemination. Community based and social learning extension models were found effective in promotion of climate resilient technology (Zero-tillage, DSR, and IPM). Agri-Nutri Smart (A2NS) village model has been devised, demonstrating nutri-rich crop varieties in farmers' fields and enhanced rural women's skills in preparing value added nutri-products through capacity development programmes and Community Agri-Nutri Security Centers (CANSCs). A convergence model involving the synergism of varied strengths of all stakeholders from technology generation, financial institutions, state line departments, KVKs, ATMA and grassroots organizations was found effective to promote climate resilient technologies. Under the ICT based models, Pusa mKRISHI was developed by IARI in collaboration with Innovation Lab, Tata Consulting Services, Mumbai in order to provide customized as well as weather based advisory to farmers. *Pusa Samachar* is an IARI initiative on YouTube platform, showcasing time specific crop management practices, experts' advice, and success stories of innovative farmers, *Pusa* WhatsApp salah and weather forecast. Under the market-linkage model, the *Pusa Kisan Mall* has been established at IARI Campus to facilitate farmers' initiatives towards value addition to their farm produce and selling them directly to consumers. It is an initiative to facilitate farmer entrepreneurs with adequate training, hand-holding and infrastructure support system for marketing. The successful farmers from different parts of India are being felicitated annually as the 'IARI-Fellow' and "Innovative Farmers", during *Pusa Krishi Vigyan Mela*, who later become partners in extension programme of the Institute for spreading Agricultural technologies among the larger farming community. The models promote client and location-specific research and technology assessment, refinement and transfer through participatory approaches. Still there is a huge potential to transform the rice production systems of the country through adoption of bottom-up innovative extension approaches with information and communication connectivity.

Author Index

Organizer

Association of Rice Research Workers
Cuttack, Odisha, India

Collaborator

Indian Council of Agricultural Research, New Delhi
National Academy of Agricultural Sciences, New Delhi
International Rice Research Institute, Philippines
ICAR-National Rice Research Institute, Cuttack
ICAR-Indian Institute of Rice Research, Hyderabad
Society for Advancement of Rice Research, Hyderabad

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