ISSN 2319-3670

Journal of Rice Research

Volume 15, No. 2 December 2022

Society for
Advancement of
Rice Research

Society For Advancement of Rice Research

(Regd. No.2175/2004 of A.P. Society Regn. Act. 2001)

The Society for Advancement of Rice Research is a registered society started with main objective of providing a platform for exchange of information and knowledge related to latest developments in rice research.

Aims and Objectives

- To advance the cause of rice research and development in the country.
- To disseminate knowledge on latest developments in rice research through publications, seminars, lectures and training programmes.
- To provide consultancy in rice production and development.
- To facilitate research and industry collaboration and public private partnership at national level.
- To honour outstanding achievers in rice research and development.
- To cooperate with other organizations having similar aims and objectives.
- To promote any other scientific/professional activities conducive for the advancement of science of rice and rice improvement.

Executive Council (2019-2022)

President : Dr. RM Sundaram, Director, ICAR-IIRR, Hyderabad
Vice - Presidents : Dr. ON Singh, Vice-Chancellor, Birsa Agril. University, Ranchi
Dr. Y Chandra Mohan, ARI, PJTSAU, Hyderabad
Secretary : Dr. R Mahender Kumar, ICAR-IIRR, Hyderabad
Joint Secretary : Dr. S Gopalakrishnan, ICAR-IARI, New Delhi
Treasurer : Dr. B Nirmala, ICAR-IIRR, Hyderabad
Zonal Councillors : Dr. VK Srivastava, BHU, Varanasi - North India
Dr. PB Patel, Navsari Agril. University, Gujarat – West India
Dr. Vijay Pal Bhadana, ICAR-IIAB, Ranchi – East India
Dr. BNVSR Ravi Kumar, RARS, Maruteru, Andhra Pradesh – South India

Journal of Rice Research is an official publication of Society for Advancement of Rice Research (SARR), ICAR-Indian Institute of Rice Research, Hyderabad - 500030 and published twice a year i.e., June and December. All correspondence related to SARR should be addressed to secretary, Dr. R M Kumar (kumarrm213@gmail.com).

Membership: Membership of the Society is open to all persons interested in furthering the aims and objectives of the Society and in the opinion of the executive committee, have the necessary qualification and experience.

Membership and Journal Subscription fee w.e.f August 2019

	Subscription price	
Membership category	**Annual**	**Life**
A. Individual membership		
Indian (Rs.)	500 (300*)	3000 (2000*)
Foreigner (US $ or its equivalent)	50	300
B. Corporate members/Patrons-one time (Rs.)	----	20,000
C. Libraries and Institutions (Annual)		
Indian (Rs.)	2500	
Foreign (US $ or its equivalent)	550	

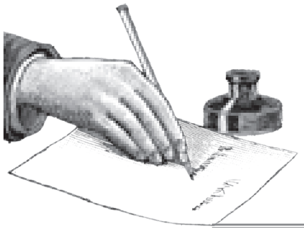
Admission fee of Rs. 100/- will be charged in addition to the above subscription fee;
*For Students
All remittances should be made in favour of Society for Advancement of Rice Research, Hyderabad with a mail to treasurer, Dr. B Nirmala (treasurersarr@gmail.com).

ISSN 2319-3670

Journal of Rice Research

Volume 15, No. 2 December 2022

Society for
Advancement of
Rice Research



Message from the outgoing Chief Editor

It has been a great honour and tremendous pleasure to serve as Chief Editor in the last four years, from 2019 to 2022. In line with our objective to improve the visibility and impact of JRR, the NAAS rating of the journal increased to 4.05 from 3.22 and efforts are continued to make it 6.0. I am glad to inform you that from June 2021 onwards, we got an internationally recognized Digital Object Identifier (DOI) for our research articles published in JRR through Cross-reference, the enabler. Another accomplishment is the publication of a special issue on Keynote and Lead lectures delivered at the International Conference on System of Rice Intensification (ICSCI 2022) in December 2022.

I am most indebted to the wonderful team of the Executive committee, Associate Editors, and reviewers for their dedicated services in selecting and publishing high-quality papers in JRR. I would like to thank all Associate Editors and reviewers who have answered my frequent calls to process the papers assigned to them in a timely fashion. I would also like to thank the authors for submitting their high-quality papers to JRR.

I am highly grateful to Dr. P Ananda Kumar, Production Editor from 2022 onwards, for his meticulous editing and providing suggestions for the improvement of the quality of manuscripts.

I am very thankful to Dr. RM Sundaram, President, SARR, and Dr. R Mahender Kumar, General Secretary, SARR for their constant support and cooperation in publishing the Journal.

I thank Dr. B Sailaja and her team, Gayathri Chamanthula, Sharon, and my young professional, Mounika Reddy for their help in updating the SARR website, uploading all the JRR issues, developing landing pages, uploading metadata files, and making it easy for downloading the articles.

It is a great pleasure to welcome Dr. SV Saiprasad as the new Chief Editor. I am sure he will work with the new editorial board members to take JRR to a new level of excellence in the coming years.

Padmavathi

(Dr. Ch Padmavathi)
Chief Editor
JRR

Journal of Rice Research

Volume 15 : Issue No. 2 December 2022

Contents **Page No.**

Contents	Page No.

REVIEW ARTICLE https://doi.org/10.58297/VZZH6068

Efficient Nitrogen Management Technologies for Sustainable Rice Production

Vijayakumar S[1]*, Lokesh Goud D[2], Hareesh Reddy CH[2], Mahender Kumar R[1] and Sundaram RM[1]

[1]ICAR-Indian Institute of Rice Research, Rajendranagar, Hyderabad, 500030
[2]Amity Institute of Organic Agriculture, Noida, Uttar Pradesh 201313
*Corresponding author's Email: vijayakumar@icar.gov.in, vijitnau@gmail.com

Received: 15th September 2022; Accepted: 18th November 2022

Abstract

The use of nitrogen (N) fertilizers in rice fields as a source of nutrition is the major source of emission of nitrous oxide (N_2O). Two key factors which control the flux of N_2O at the field level are the amount of N supplied and the efficiency at which it is absorbed by plants. To reduce the N_2O emissions, optimum N fertilizer application (in terms of input rate and time of application) and ideal fertilizer selection are crucial. Optimizing N-use efficiency (NUE) is crucial to sustain productivity and profitability. Depending on edaphic and climatic conditions, improved N management can dramatically cut greenhouse gases (GHGs) emissions. Producers must ensure that the kind, rate, and time of N application do not result in substantial losses owing to volatilization, leaching, or denitrification. Adoption of best nitrogen management practices like deep placement of urea, use of nitrification inhibitors, urease inhibitors, and slow-release nitrogen fertilizers will reduce the N loss and increase NUE. The goal of this review is to discuss in detail the various technologies that have been developed and refined to improve NUE and protect the environment.

Keywords: Nitrogen, Nitrification inhibitor, Urease inhibitor, Slow-release fertilizer, Brown manuring, LCC, GreenSeeker, SPAD

Introduction

Fertilizers boost agricultural productivity and encourage crop CO_2 uptake and decrease the need to cultivate new land (deforestation), resulting in fewer GHG emissions as a result of land use change. Nitrogen (N) is the most important element for the overall growth and development of rice plants (Subramanian *et al.,* 2020). The atmospheric N is not readily available to rice plants despite its high abundance in the air (around 79%). The proportion of fertilizer N in the total N input for crop production in India is increasing since the advent of the Green Revolution in the mid-1960s, but NUE has declined from 48 to 35% in 2018. There is a limited opportunity to achieve significant yield gains by applying more fertilizer N. Although optimal fertilizer use on agricultural crops reduces soil erosion, repeated applications of high N fertilizer doses may cause soil acidity, a negative soil health trait (Nayak *et al.,* 2020). Site-specific management strategies based on the principles of synchronizing crop N demand with N supply from all sources, including soil and fertilizer, have the potential to ensure high yields while also preserving soil health (Vijayakumar *et al.,* 2021). Soil organic matter (SOM) is the repository for soil N. Balanced nutrient application and integrated nutrient management using organic manures and mineral fertilizers also contributed to the preservation and improvement of soil health (Nayak *et al.,* 2020). Thus, fertilizer N, when applied in a balanced proportion to other nutrients and in conjunction with organic manures, if available to the farmer, maintains or improves soil health rather than being detrimental (Nayak *et al.,* 2022). The good soil structure improves NUE and reduces N_2O losses. The challenge ahead is to manage N fertilizers in such a way that not only food demands are met continuously, but soil and environment remain healthy to support adequate food production with minimal environmental impact (Gobinath *et al.,* 2021).

N is added to the agricultural lands through inorganic N fertilizer which contains N in three chemical forms *viz*., ammonium (NH_4^+), nitrate (NO_3), and urea (Hakeem *et al*., 2011). Globally, urea is the most preferred form of N in agriculture (Modolo *et al*., 2015). However, once applied to the soil, urea undergoes three microbial-mediated transformations *viz*., hydrolysis, nitrification, and denitrification. Nitrification and denitrification are key processes contributing to N_2O emissions from the soil (Cameron *et al.,* 2013; Guo *et al.,* 2018). In the ammonia oxidation process, N_2O is produced by the chemical decomposition of hydroxylamine (NH_2OH). The loss of externally added N leads to economic and environmental implications. One potential way to mitigate N_2O emissions is to use nitrification and urease inhibitors to slow down the rate of nitrification and reduce the availability of the substrate (NH_4^+) for nitrification. The use of nitrogen fertilizer for crop production has an impact on soil health primarily through changes in organic matter content, microbial life, and acidity. Similarly, the production of N fertilizer also causes environmental pollution through the emission of GHGs. CO_2 emitted during ammonia synthesis and N_2O emitted during the production of nitric acid are the two most important GHG emissions connected with the manufacture of N fertilizers. Increasing NUE is critical for maintaining productivity and profitability. Improved N management, depending on edaphic and climatic conditions, can significantly reduce GHG emissions (Chatterjee *et al.,* 2019).

Farmers must ensure that the type, rate, and timing of N application do not cause significant losses due to volatilization, leaching, or denitrification (Cameron *et al.,* 2013; Vijayakumar *et al.,* 2021a). Good soil structure decreases N_2O losses. Best nitrogen management practices such as deep placement of urea, the use of nitrification inhibitors, urease inhibitors, and slow-release N fertilizers will reduce N loss and increase NUE (Vijayakumar *et al.,* 2021a). Blanket recommendations do not account for the spatiotemporal variability in soil N supply capacity (Subramanian *et al.,* 2020). Variable-rate fertilizer applicators in large fields are used in developed countries to improve synchronization between crop N demand and N supply from various sources (Goud *et al.,* 2022). The goal of this paper is to go over in detail the various technologies that have been developed and refined to improve NUE and protect the environment. The management of fertilizer N has also been discussed in terms of providing adequate amounts of nutrients to crop plants and maintaining soil health.

Nitrification inhibitors

The microbial decomposition of N in soils, manures, and nitrogenous fertilizers produces N_2O, which is often exacerbated when available N exceeds plant requirements, especially in wet conditions. The use of NIs enhances NUE by extending the period of N available to the crop plants which leads to increased N uptake by crop plants due to the matching of soil available N with crop N demand (Huber *et al.,* 1977; Vijayakumar *et al.,* 2021a). Arresting nitrification could be a key strategy to improve N recovery and agronomic NUE in situations where the loss of N is significant. Nitrification inhibitors (NIs) selectively inhibit the microbial enzymes responsible for the conversion of NH_4^+ to NO_3^-. It reduces the risk of loss of N through leaching or denitrification and subsequently increases the NUE (Ruser and Schulz, 2015; Norton and Ouyang, 2019). The ammonia monooxygenase (AMO) is the first enzyme that is involved in the oxidation of NH_4^+ to NO in soils. The inhibition of the AMO by NIs directly decreases the nitrification rate and it reduces the NO concentration which serves as a substrate for denitrification. Hence, the two main pathways of N_2O production in soils are blocked or their source strength is at least decreased. NIs *viz.,* nitrapyrin (2-chloro-6-trichloromethyl pyridine) or N-Serve, AM (2-amino-4-chloro-6 methyl pyrimidine), dicyandiamide (DCD), Ammonium thiosulphate (ATS), Thiosulphoryl triamide (ZPTA), terrazole (etridiazole) and CMP (1-carbamoyle-3-methylpyrazole) slow down the nitrification process in soil and lower N_2O emissions by 10–15 percent (Malla *et al.,* 2005). However, few studies showed even a 30 to 50% reduction in N_2O emission (Sanz-Cobena *et al.,* 2017). The recommended dose of NI is 0.2-0.6 kg ai/ha. A synthetic NI *viz.*, Nitrapyrin reduces nitrate leaching, N_2O emissions, improves NUE, crop yields, and N uptake (Woodward *et al*., 2021). Dicyandiamide (DCD) is another effective NI found more suitable for the temperate region. DCD was found less effective if the temperature is above 20°C because of its rapid decomposition. NIs are effective in inhibiting the emissions of environmentally harmful N compounds from agriculture into the soil, water, and air. The use of NI in paddy soils leads to increased grain yields by 19%, N-recovery efficiency by 30-40%, and reduced N_2O emissions by 73% (Lan *et al*., 2013; Gaihre *et al*., 2020). The NIs *viz*., nitrapyrin and dicyandiamide (DCD) are the most effective inhibitors of nitrification/denitrification for the period of 2-6 and 12-14 weeks, respectively (Delgado and Follett, 2010). Dimethypyrazole phosphate (DMPP) is also effective in increasing soil NH_4^+-N content when combined with urea, organic and inorganic fertilizers and lower soil N_2O emissions in temperate environments (Yang *et al*., 2016). However, there is little evidence of its efficacy in sub-tropical or tropical environments where temperatures and rainfall intensities are typically higher (Rose *et al*., 2017). The application of urease inhibitors and NIs significantly reduced inorganic N leaching (48%), N_2O (44%), and NO emission (24%) (Burzaco *et al*., 2014; Qiao *et al*., 2015; Thapa *et al*., 2016) while increasing crop yield (7.5%) and NUE (12.9%) (Abalos *et al*., 2014). The inhibitor decreased the potential denitrification rate (PDR) at the rice heading stage but had little effect on the denitrifier gene abundance except for nitrapyrin, which decreased the *nirK* gene abundance (Meng *et al*., 2020). The list of NIs which are synthetically made and used in agricultural practices is presented in **Table 1**. Although several synthetic NIs are found very effective in inhibiting nitrification, their uses in agricultural land are limited due to high cost, limited availability, adverse influence on beneficial soil microorganisms, and above all, poor extension and promotional activities. Only a few inhibitors have got approval for commercial marketing. The increase in the cost of fertilization could be counterbalanced by an increment in crop productivity. Also, the potential improvement in crop NUE could minimize the rate of external N fertilizer application by reducing the losses, and thereby lowering fertilization costs (Abalos *et al*., 2014).

Table 1. Common synthetic nitrification inhibitors

N-Source	Base Compound	N-Process	Common Names	N-Content	Inhibition Duration (weeks)
Nitrapyrin	2-chloro-6-trichloromethylpyridine	Nitrification, denitrification	N-serve, stay-n 2000	12	2-6
DCD	Dicyandiamide	Nitrification	DCD, Ensan	1.6	4-8
DMPP	3,4-dimethypyrazoazole phospate	Nitrification	Entec , Dmpp	12-26	6-8

Source: Havlin *et al*., (2014)

Natural Nitrification Inhibitors (NNIs)

Natural NIs also known as botanical NIs encapsulate control water entry and rate of dissolution by providing a protective cover to the conventional soluble fertilizer which makes N release and availability more synchronized with plant requirements (Abbasi *et al.*, 2011). It also helps in improving soil health by reducing nitrification and N_2O emissions and enhancing crop productivity (Banik *et al.*, 2016). The usage of natural NIs like neem cake improves the N recovery efficiency of applied N in arable soil (Hala *et al*., 2014). The NNI like neem oil can inhibit the nitrification rate up to 20−50% in the soil, which is slightly lower than that of synthetic NIs like DCD (56−80%) (Raza *et al*., 2019). Another potential natural NI is Karanj (*Pongamia pinnata*) seed extract which minimizes N_2O emission from soil (Banik *et al*., 2016). It acts as a highly efficient NI (62−75% reduction in nitrification) as well as an N_2O mitigator (92−96% reduction in N_2O emission)

(Majumdar, 2002). The seed cake and extracts of Mahua contain alkaloids called saponin which slow down the N mineralization through nitrification inhibition. Based on the incubation study conducted on clay loam soil Kumar *et al.*, (2015) found that the nitrification inhibitory effect of mahua cake extract persisted only for 20 days. The advantages of NNI are easily available, cheap, and eco-friendly (Upadhyay *et al.*, 2011). Some natural NIs obtained from the different plants are enlisted in **Table 2.** The drawbacks of synthetic NIs like high cost, limited availability and adverse effect on beneficial soil microbes are solved through NNI. Therefore, it is necessary to develop and promote plant-based NIs (natural NIs) for augmenting NUE, crop productivity, and for safeguarding the environment.

While discovering a new NNI it is important to look for the following things. (i) *Specificity*: It should block the conversion of ammonium to nitrate, i.e. the activity of *Nitrosomonas*, and be non-toxic to other soil organisms, animals, and humans. (ii) *Persistence:* The material should stay active in the soil for an adequate period. Compounds subject to rapid degradation will not be useful. (iii) *Mobility:* It should move with the fertilizer and nutrient solution. Compounds with too high vapour pressure may move too fast and compounds easily absorbed are probably not very effective (iv) *Economy:* The chemical should be cheap as it is used as an additive to fertilizers (Slangen and Kirchhoff, 1984). In India, 100% of urea produced is neem (*Azadirachta indica*) oil coated. The chemical compound present in neem oil act as a nitrification inhibitor (NI) and also act as a physical barrier thereby slowing down the speed of urea solubility (Reddy and Prasad, 1975).

Table 2. Natural nitrification inhibitors

Common Name	Scientific Name	Alkaloids	Reference
Neem	*Azaridicta Indica*	Azaridictin	Slangen and Kerkhoff (1984)
Karanj	*Pongamia Glabra*	Karanjin, Glabrin, glabrosaponin	Modolo *et al*., (2015)
Mahua	*Madhuca longifolia*	Saponin	Bisht *et al*., (2018)

The ideal conditions where the use of NI is recommended

- Use of NIs may be advantageous in situations where the loss of N due to leaching and denitrification is accompanied by nitrification of fertilizer nitrogen.
- NIs are more effective in light-textured soils so their use may be more effective under these soil conditions as the effectiveness of these compounds decreases fast in heavy-textured soils.
- The application of NIs should be confined to the soil microsites where nitrification occurs rather than treating the entire soil volume so that the concentration of these compounds could be high enough for a reasonable period (Sahrawat and Mukerjee, 1977).

Urease Inhibitors (UIs)

Upon addition of urea to wet soil, it undergoes hydrolysis by the enzyme urease to generate ammonium carbonate, which is more prone to ammonia volatilization loss as carbonate increases the pH in the vicinity (Sahrawat, 1980). Urease enzyme is found both in the soil as well as in plant residues. UIs are chemical compounds that block the activity of the urease enzyme and reduce the rate of hydrolysis of urea to ammonium thereby it reduces the N loss through ammonia volatilization when urea is surface applied (Horta *et al.,* 2016). UIs gradually slow down the hydrolysis of urea for a period of 7 to 14 days by suppressing the activity of urease. The commonly known UIs are N-(n-butyl) thiophosphoric triamide (NBPT), and N-(n-propyl) thiophosphoric triamide (NPPT), PPD/PPDA (phenyl phosphorodiamide), TPT (tiophosphoryl triamide), PT (phosphoric triamide), HQ (hydrquinone). NBPT is sold in the trade name of Agrotain and Limus is new UI that contains two active ingredients (NBPT and NPPT). Among the numerous forms of UI, NBPT has seen the maximum commercial application (Sanz-Cobena *et al.,* 2008; Abalos *et al.,* 2014). UIs can reduce N_2O emissions by up to 80 percent (Sanz-Cobena *et al.,* 2017). UIs, can only be used in conjunction with urea or urea-containing fertilisers (including organic sources). Many factors like soil pH, the texture of soil, and N application rate influence the efficiency of UIs. The hydrolysis of urea is rapid in high soil PH, or soil which is poorly buffered against an increase in pH. Thus, among the soil type, in alkaline soils, the efficiency of UIs is found to be highest. Similarly, in coarse-textured soils and at high N fertilization rates, the efficiency is higher (Abalos *et al.,* 2014). Most of the inhibitors including NBPT are highly effective in neutral soil with a moderate amount of organic matter.

Urea treated with NBPT reduces NH_3 loss by around 53% and yield is gained by 6.0% and varies from 0.8 to 10.2% depending on crop species (Cantarella *et al*., 2018). UIs like NBPT have the potency to reduce ammonia volatilization and nitrite (NO_2) accumulation in the soil by altering the kinetic and thermodynamic behavior of the urease enzyme (Pan *et al.,* 2016). Thiousulfates can be used as UIs to reduce ammonia volatilization from urea or urea ammonium nitrate (UAN) fertilizer. Urea containing Ammonium Thiosulfate (ATS) has been shown to reduce NH_3 volatilization losses up to 11% as compared to UAN (Solan and Anderson, 1995). ATS by itself or in association with urea did not affect the soil microbial biomass pool. On the other hand, a field experiment performed with Canadian clay loam and fine sandy loam soils showed inconsistent results concerning urease inhibition by ATS (Modolo *et al*., 2018). Inhibitor N-(n-propyl) thiophosphoric triamide (NPPT) has shown a similar advantage of reducing ammonia volatilization losses from urea, and application of NBPT+NPPT mixture reduced NH_3 volatilization losses by 6% as compared to NH_3 losses of up to 25% in control (Li *et al*., 2017; Hull, 2018). The application of 12 kg Hydroquinine (HQ) on alluvial soil in conjunction with 120 kg Urea−N ha^{-1}, decreased N_2O emission by 5% in rice and 7% in wheat systems as compared to the crops grown solely in the presence of 120 kg urea N ha^{-1} (Modolo *et al*., 2018). Reduction in N_2O emission on the application of UIs along with urea ranged from 5% with hydroquinone to 31% with thiosulphate in rice. Contrary to the earlier finding, Malla *et al*., (2005) reported the combined application of UI (Hydroquinone and thiosulphate) and urea increased N_2O emission as compared to the application of urea alone. However, the global warming potential (GWP) was lower with the inhibitors (except hydroquinone) as compared to urea alone (Malla *et al*., 2005). In rice, the application of NBPT both in no−till and conventional tillage reduced the ammonia volatilization by delaying the conversion of N to NH_3. However, the magnitude of the effectiveness of inhibitors was associated with soil, season, climate, and cultivation system (Marchesan *et al.,* 2013). Another study conducted at IRRI, Philippines revealed the use of NBPT improve seed germination (from 9.32 to 16.22% for Apo and from 17.76 to 36.81% for Hanyou3) and plant growth and reduced ammonia volatilization (Qi *et al.,* 2012). The properties of various synthetic UIs are presented in **Table 3**.

Table 3. Properties of synthetic urease inhibitors

Source	Common Names	Base Compound	N Process	N Content (%)	Inhibition duration (Weeks)
NBPT	Agrotain, Super U	N−(n−butyl) thiophosphoric triamide	Volatilization	46	2 to 3
Thiousulphate	ATS, CaTS	Ammonium or Calcium thiosulphate	Volatilization, Nitrification	12	2 to 3
NPPT	Limus	N-(n-propyl) thiophosphoric triamide	Volatilization		
Hydroqunine	HQ	Hydroqunine	Volatilization		-

Source: (Havlin *et al*., 2014)

Natural Urease Inhibitors (NUIs)

These inhibitors are naturally found and obtained from plant parts and these chemical compounds block the activity of the enzyme urease thereby reducing the leaching losses. It has the potential to retard the loss of urea from agricultural soil and thus it may be used along with urea for improved utilization of the applied N by plants (Mathialagan *et al*., 2017). The NUIs obtained from various plant parts are presented in **Table 4.** Allicin, a plant derived inhibitor obtained from garlic (*Allium sativum* L.) has shown the potential to inhibit urease activity in the soil (Mathialagan *et al.,* 2017). However, its inhibition is about 75% lower than NBPT at steady state (Matczuk and Siczek, 2021). Tannin, a polyphenolic extract obtained from the bark of *Acacia decurrens* (Green wattle; Fabaceae) or seed coat of *Terminalia chebula* (Inknut; Combretaceae) inhibited both pure urease (urease tablets-BDH) and soil ureases to the same extent that did mercuric chloride and catechol, known urease inhibitors (Modolo *et al*., 2015). Indeed, with urea-polyphenol mixtures, NH_3 volatilization from the soil surface decreased upon soil fertilization. These results highlight the potential of tannin like polyphenols from green wattle and inknut as potent urease inhibitors (Fernando and Roberts 1976). In addition, some natural products such as phenolic compounds (methyl gallate, stilbenoids, and flavonoids) can suppress urease efficiency (Hussain *et al*., 2021).

Table 4. Natural urease inhibitors

Inhibitors	Obtained from	Reference
Allicin	Garlic	Matczuk and Siczek (2021)
Tannin (polyphenolics)	*Acacia decurrens* (Green Wattle)	Modolo *et al*., (2015)
Quercetin	*A. cepa*	Modolo *et al*., (2015)

Slow/Controlled Release Nitrogen Fertilizers

This is a granulated fertilizer that differs from regular fertilizers by releasing nutrients slowly or gradually into the soil. The fertilizer contains a plant nutrient in a form that extends its availability for plant uptake significantly longer than a reference fertilizer such as ammonium nitrate or urea, ammonium phosphate is commonly known as a slow-release fertilizer. Slow-release N fertilizers extend the period of N available to the crop plant by discharging the soluble N (NH_4 and NO_3) over several weeks/months and increase the amount of fertilizer uptake by the plant through synchronizing plant nutrient demand and soil N availability. This type of fertilizer is not readily water-soluble, which means it dissolves more slowly thereby it increases NUE and decreasing nutrient loss.

The demand for N increases gradually from germination to flowering. Usually, young plants have little demand while the demand for N increase from active tillering to the milking stage. The use of slow-release N-fertilizer ensures slow release of N to match crop demand. Slow-release N−fertilizers extend the period of N availability to crop plants as they release the N gradually and steadily in the soil solution thereby it increases NUE and decreasing its losses. The list of slow-release N-fertilizers is presented in **Table 5.** The slow-release N-fertilizers are classified into two categories *viz*., coated and uncoated. These products have been found to improve the recovery of applied N by 33% in cereal grains all over the world, and consequently decrease the external fertilizer applications rate. There are two types of slow-release N-fertilizers available in the market *viz.* coated (induced slow release) and uncoated products (inherently slow release).

Types of slow-release nitrogen fertilizers

Coated slow-release N fertilizers: The coated slow-release N fertilizers contain an external coating consisting of hydrophobic chemicals to provide a physical barrier against water. This type of fertilizer is not readily water-soluble, which means it dissolves more slowly. This promotes the gradual release of urea into the soil solution thereby it minimizes N losses and improves its uptake by crops (Akiyama *et al*., 2010). The release of N is primarily controlled by the external barrier that surrounds the N. Thus, it releases the N rapidly once the barrier is removed.

Examples of coated products are neem-coated urea, sulphur-coated urea, and polymer-coated urea. In neem-coated urea, 0.5 kg of neem oil is used per tonne of urea. Polymer-coated fertilizers are the most recent technology for controlling N release and reducing N losses by leaching, denitrification, and volatilization. Polymer-coated multi-nutrient fertilizers supply all three fertilizer elements (NPK) which are essential for plant growth and development. These polymer-coated fertilizers *viz*; Osmocote, Multicote, and Nutricote gradually release nutrients over extended periods (it can be shorter as three months and longer as eighteen months). Some commonly used coated N-fertilizers are listed in **Table 5**. The coated slow-release N fertilizers are comparatively cheaper than inherently slow-release N fertilizers as the products used for coating are easily available at low cost. In India, 100% urea manufactured is neem-coated urea.

Table 5. Coated N fertilizers

N-source	Base Compound	Common Name	N Content (%)	Inhibition Duration (Weeks)
Neem coated urea	Urea	NCU, NICU (Nimin−coated urea)	46	2-6
Polymer Sulphur-coated urea	Urea	Polyplus, Poly−S	38−42	6−16
Sulfur coated urea	Urea	Enspan, SCU	30−42	4−12
Polymer resin-coated urea	Urea	Polyon, Meister, Escote	38−44	8−14

Source: Havlin *et al*. (2014)

Inherently (uncoated) slow-release N fertilizers: Slow release is the inherent physical characteristic of uncoated products like isobutylidene diurea (IBDU) (31% N), urea form (35% N), and methylene urea (39-40% N) (Varadachari and Goertz, 2010). These are slightly soluble in soil solution, where the N release rate depends on microbial activity and hydrolysis. The inherently slow-release N fertilizers along with their N content and inhibition period are presented in **Table 6.**

Table 6. Slow-release N-fertilizer compounds

N−source	Base Compound	Common Names	N Content (%)	Inhibition Duration (weeks)
Urea Formaldehyde	Urea forms, Methylol urea	Nitamin, Nitroform, Folocorn	35−40	6−10
Isobutylidene Diurea	Isobutylidine urea	IBDU	31	10−16
Triazone	Triazoneƒurea	N−sure	28−33	6−10
Melamine	2,4,6−triamino−1,3,5−triazine	Nitrazine	50−60	6−12
Crotolidene Diurea	Urea Crotonaldehyde	Crotodur, Triabon	34	6−12

Source Havlin *et al*. (2014)

Brown manuring

Generally, brown manuring is the practice of growing *Sesbania spp*. and rice together. When these *dhaincha* plants overtake the rice plants in height at about 25 days of co−culture, a broadleaf herbicide *viz*., 2, 4−D (selective herbicide) is applied to kill *Sesbania* plants, not the rice plants. After 4−5 days of herbicide spraying, *Sesbania* leaves will fall on the ground and form mulch and help in smothering weeds. This is called the knocking down effect. The post-emergence herbicide spray on green manure leaves results in loss of chlorophyll in *Sesbania* leaves appear brown in colour and it is referred to as brown manuring.

Advantages of brown manuring

- Compete with weeds thus reducing their growth.
- Reduce the N requirement of plants as legumes fixed N from the atmosphere through bacteria present in their nodules.
- Prevent the loss of water due to evaporation and thus help in water conservation.
- Reduce the cost of cultivation by reducing the weed control cost and fertilizer N requirement.
- Increase soil organic carbon content and soil fertility.

The differences between green manure and brown manure are given in **Table 7**.

Table 7. Green manures VS Brown manures

Green Manures	Brown Manures
Moisture is necessary for incorporation and decomposition	Moisture is conserved during the practice
The risk of soil surface erosion is after incorporation	The plants are left standing to protect light texture soil from the risk of soil erosion
The microbial population is necessary for decomposition	Chemical desiccation will take place
It is the incorporation of a manure crop by tillage before seed set usually around flowering	It is a no-till version of green manuring, where herbicides are used to kill the manure crop and weeds

Source: Patil *et al*., (2020)

Sesbania is a live cover that offers interference to weeds during the pre-killing period and later as a dead residue mulch (at the post-killing period) offers weed suppression and stimulates rice crop growth by the addition of organic matter and nitrogen release. The knocking down of *Sesbania* by 2,4-D application hastens the decomposition and release of nutrients present in *Sesbania* as compared to *in situ* incorporation. Also, brown manure crops are grown between the lines of rice crops and no free space is available for weeds to germinate and spread as a result a minimum weed population is recorded in brown manuring. *Sesbania* could add C and N into the soil, which facilitates favourable microbial activity (Phukan and Bora, 2012). Other leguminous green manuring crops like sun hemp, cowpea, lentil, etc. are also potential brown manure crops for rice crops. Any pulse crop may be grown for brown manuring. Moreover, *Kharif* pulses which have good foliage and rapid growth are more suitable for this purpose. Nutrient content, Carbon-Nitrogen (C:N) ratio of green manure crops (**Table 8**), and the effect of brown manuring on soil organic carbon and post-harvest available N (**Table 9**) are highlighted below.

Table 8. Nutrient content and C: N ratio of major green manure crops

Crops suitable	Scientific name	Total N	C:N Ratio	Total P	Total K
Sun hemp	*Crotalaria juncea*	3.97	21:1	0.37	4.80
Dhaincha	*Sesbania aculeata*	1.90	44:1	0.34	3.60
Sesbania	*Sesbania speciosa*	2.71	40:1	0.53	2.21

Source: Iliger *et al*. (2017)

Table 9. Effect of brown manuring on soil organic carbon and post-harvest available nitrogen.

Year	Initial OC content of soil (%)	OC content after harvest (%)	% increase in organic carbon	Initial soil available nitrogen content (kg/ha)	Soil available N content after harvest (kg/ha)	% increase in soil available nitrogen
2014	0.54	0.69	0.15	283.0	320.2	13.7
2015	0.58	0.71	0.13	285.38	324.6	13.7
Mean	0.56	0.70	0.14	284.19	322.4	13.4

Source: Samant and Patra (2016). OC - Organic carbon.

More use of organic manures/green manures

The use of solid organic manure reduces the N_2O emission, however, it depends on the type of manure used (Webb *et al.,* 2010). While organic sources such as farmyard manure (FYM), green manure, and crop residues of rice and wheat increased the N_2O emission (Bhatia *et al.,* 2005). The incorporation of organic inputs, such as rice straw and green manure in rice soils promotes CH_4 emission (Van der Gon and Neue, 1995; Vijayakumar *et al.,* 2021). In Mediterranean systems use of solid manures significantly decreased N_2O emissions (23%) (Aguilera *et al.,* 2013) and has the potential to exacerbate long-term C sequestration (Ding *et al.,* 2012). Evidence from past experiments indicates that the technique of slurry application in agricultural soils is a crucial variable in regulating N_2O flux. Based on a meta-analysis study Hou *et al.,* (2015) reported that slurry injection could dramatically increase direct emissions as compared to broadcasting.

Manure, such as FYM, boosts CH_4 flux by providing organic carbon and nitrogen for microbial activities, as well as functioning as an electron source. In comparison to the application of a 100% recommended dose of N through urea, substituting 50% of inorganic N with FYM increased GHG emission by 172 percent (Pathak *et al.,* 2003). Crop residue incorporation/ retention also influences the CH_4 flux by increasing the organic matter availability. The CH_4 flux increased from 100 to 500 kg ha^{-1} yr^{-1} with the increase of rice straw incorporation from 0 to 7 t ha^{-1} (Sanchis *et al.,* 2012). The methane emissions were lowest in the unfertilized plot (28.4 kg ha^{-1}) and highest (41.3 kg ha^{-1}) when the total amount of N was applied by organic sources (Bhatia *et al.,* 2005). However, when compared to FYM, biogas slurry lowered emissions by 2-3 times, indicating that biogas slurry should be favoured over FYM for reducing CH_4 emissions (Debnath *et al.,* 1996). Composting, incorporation of organic manures/ crop residues during the off-season i.e. drained period, and application of fermented manures like biogas slurry instead of unfermented farmyard manure reduce methane emission (Pathak and Wassmann, 2007) thus, promoting aerobic degradation of organic manure which reduces methane emissions.

Leaf colour chart (LCC)

The LCC is used to determine the N fertilizer needs of rice crops by determining the greenness of the rice leaf as it is highly influenced by N content. It is an inexpensive, small size and easy-to-use tool (Bhavana *et al.,* 2020). The use of LCC ensures the precise application of N fertilizer to rice crops. It has four green strips (four to six), with colour ranging from yellow-green to dark green. LCC is a substitute for the chlorophyll meter (SPAD) to estimate rice leaf N status. LCC readings are taken once a week until the first flowering, starting from 14 days after transplanting for transplanted rice and 21 days after seeding for wet direct seeded rice. The topmost fully expanded leaf from each hill is selected and leaf colour is compared by placing the middle part of the leaf on LCC. N top dressing is recommended whenever the green colour of more than 5 out of 10 leaves is found equal to or below the critical value. The critical value is 3 for varieties with light green foliage and 4 for all other varieties and hybrids. If the critical value of the leaf falls below the threshold value, 35 kg N/ha during *kharif/kar/kuruvai/navarai* and 30 kg N/ha during *rabi/samba/thaladi/pishanam* season need to be applied. There is a considerable yield increase under LCC-based N management as N supply matches with the crop demand because of the timely supply of the optimum dose of N-fertilizer. The use of LCC leads to the saving of N fertilizers to the tune of 20 – 40 kg/ha (Sudhalakshmi *et al*., 2008). Although it has many advantages over other N management tools, still it has a few limitations like sunlight influences the readings if the measurements are not taken under the shade; deficiencies are identified after the symptoms are developed, and by this time crop might have been affected by the deficiency; LCC cannot give the exact values like the analysis done in the lab. Readings were taken in the morning (8-10 AM) under the shade of the body to avoid the influence of sunlight. The merits and demerits of LCC are presented below (**Table 10**).

Table 10. Merits and demerits of LCC tool

Merits of LCC	Demerits of LCC
LCC is an uncomplicated and easy-to-use tool for farmers to measure the nitrogen status of the leaf and to identify the instance for N top dressing.	LCC fails to specify minor variations in leaf greenness as the colour shades lie in between two shades.
LCC is cheap and portable thus, making it easy to carry to the field for estimating the N status of the leaf.	The comparative accuracy of LCC is relatively lower than the chlorophyll meter.
It is a non−destructive method and doesn't involve any laboratory analysis.	LCC developed for a particular region may not be appropriate for other regions. Similarly, the same LCC is not suitable for hybrid rice and HYV.
LCC can be better suited to a site-specific nutrient management approach.	LCC was used only to adjust the time of N top dressing not for basal N appliance.
Any specific knowledge or skill is not required for using LCC as it involves only comparing the leaf colour with a standard chart.	Though it does not require any specific skill to use, the user should be careful while taking the reading to avoid errors due to sunlight, time of observation, and selecting leaf for observation.

Source: Bhupenchandra *et al*., (2021).

Integrated Nutrient Management (INM)

INM is the judicious use of all possible nutrient sources to meet the plant nutrient requirement at an optimum level to sustain the desired crop productivity with minimal impact on the environment. In INM, the immediate nutrient requirement of the crop is met through chemical fertilizers. Thus, the rate and time of chemical fertilizer application should synchronize with the real-time need of the crop. The slow and long-term release of nutrients from organic sources helps in meeting the long-term need of the crop. The goal of INM includes (i) Optimization of the benefits from all possible sources of plant nutrients in an integrated manner to achieve a given level of crop production (ii) Maintenance of plant nutrient supplying capacity of soil to ensure sustainable crop productivity (iii) Ensuring higher nutrient use efficiency, minimization of nutrient loss and mitigation of harmful environmental impacts (iv) Minimizing the use of chemical fertilizers thereby reducing the cost of cultivation and enhancing profitability (Vijayakumar *et al.,* 2021a). The INM for different rice production systems is given below (**Table 11**).

Components of INM

Organic manures: Farmyard manure, compost, vermicomposting, biogas slurry, poultry manure, crop residues, and bio wastes like press mud, sugarcane baggages etc.

Green manures & Green leaf manures: Dhaincha (*Sesbania aculeata*), *Sesbania rostrata*, Sunhemp (*Crotalaria juncea*), *Pongamia globra*, *Leucaena leucocephala*, *Azadiracta indica* and all legume pulses except French bean.

Chemical fertilizers: Urea, Ammonium Sulphate, Ammonium Nitrate, Calcium Ammonium Nitrate (CAN), etc.

Table 11. The recommended INM for rice

S.No	Recommendation	Yield	Reference
1	100% recommended dose of N through green manure with 50 percent NPK	62.7 q ha^{-1}	Bhandarin *et al.,* (1992)
2	50% of N through green manure and the remaining 50% through chemical fertilizers	7.3 t ha^{-1}	Sharma and Subehia (2014)
3	Application of soil-based BGA biofertilizer at the rate of 10 kg ha^{-1} along with 90 kg urea	10 percent high yield	Mohanty *et al.,* (2019)

Green seeker

The Green Seeker is a hand-held optical reflectance sensor that uses active radiation from red and near-infrared bands independent of solar conditions. The sensor samples at a very high rate (approximately 1000 measurements per second) and averages measurements between outputs. This device delivers output *viz.,* NDVI, and ratio vegetation index (RVI) directly using the sensor readings at a rate of 10 readings per second with a travel speed of 0.5 m s^{1}. The integrated optical sensing and application system measures nitrogen status in the leaf and provides information on the right time, right place, and right amount of N application in real-time (Song, 2021). The sensor unit has self-contained illumination in both the red (656 nm with about 25 nm full-width half magnitude) and near-infrared (774 with about 25 nm FWHM) bands. Sensor readings (NDVI and RVI) were collected 0.5m above the rice canopy across each plot, except plot borders and the average values were used to represent each plot (Zhang *et al.,* 2017). Sensor readings were collected at five different stages *viz*., tillering, panicle initiation, booting, before heading, and heading stage. The original technology was developed for large farms; however, a small handheld version that costs (approximately Rs. 40,000) a fraction of the original technology is now commercially available (Yao *et al.,* 2012).

Soil Plant Analysis Development (SPAD) Meter

Soil Plant Analysis Development (SPAD) Meter or chlorophyll meter developed by Minolta Company is a simple, portable diagnostic tool that measures the greenness or relative chlorophyll content and is mainly used to identify the crop N status and relative chlorophyll contents (Yuan *et al.,* 2016). The SPAD meter measures the difference between the transmittance of red (650 nm) and infrared (940 nm) light through the leaf, generating a three-digit SPAD value (Uddling *et al.,* 2007). It enables users to measure potential photosynthetic activity quickly and easily, which is closely linked to leaf chlorophyll content, crop nitrogen status, and leaf greenness. SPAD readings indicate the plant N status and the amount of N to be applied. It is a non-destructive method of N status estimation thereby it saves time and money. SPAD readings are greatly influenced by the specific part of the foliage where the measurements are made, as chlorophyll is not evenly distributed along the leaf blade. Several factors such as plant growth stages, cultivars, specific leaf weight, leaf thickness, leaf position on the plant, measurement location on a leaf, environmental stress, and solar radiation could significantly affect chlorophyll meter readings (Yuan *et al.,* 2016). The chlorophyll meter is too costly (around one lakh rupees) which is very high for a small-scale farmer. Leaf area-based N concentration has a unique linear relationship with SPAD values of rice plants at all growth stages (Peng *et al*., 1995). SPAD values for different rice production systems are given below (**Table 12**).

Table 12. Critical SPAD values for different seasons, cropping conditions, and rice varieties

Crop establishment	Varietal group	Panicle density (m^2)	SPAD value	
			Dry season	Wet season
Transplanted rice	Traditional improved local aromatic rice	300-400	30-32	30
	Semi-dwarf indicia varieties	400-500	32-35	35-37
	Hybrid rice	400-500	32-35	35-37
Broadcast sown	All varieties	High -800	29-30	30
		Medium-400 to 500	32	35
Drum seeded	All varieties	High 600-650	32	32
		Medium 400-500	32-35	32-35

Source: Balasubramanian *et al.* (2000)

4R nutrient stewardship-based N application

Any technology which ensures a more precise application of N fertilizer based on soil, plant, and field characteristics will increase the NUE and reduce the N loss. 4R nutrient stewardship-based N application involves applying the right dose, right time, right source, and right place enhances NUE (Vijayakumar *et al.*, 2021). For example, the demand-driven application of N by using a leaf colour chart (LCC) reduced N_2O emission and GWP by about 11% (Bhatia *et al.,* 2010) thereby synchronizing the timing of N application with plant N demand and reducing N losses, including N_2O emissions. It also helps in saving fertilizer costs due to the saving of input N rate (Surjandari and Batte, 2003). Accurate estimation of external N requirements by considering indigenous supply, and target yield will reduce N loss by avoiding the excess N application and subsequent direct and indirect N_2O emissions, while saving energy and lessening other GHG emissions (e.g., associated with manufacturing N fertilizers). The optimized N application might cut N_2O flux by up to 50 percent compared to non-optimized practices in both irrigated and rain-fed Mediterranean agroecosystems (Sanz-Cobena *et al.,* 2017). However, multiple studies have found that direct N_2O emission is non-linear in response to N intake (Philibert *et al.,* 2012; Kim *et al.,* 2013; Shcherbak *et al.,* 2014), and other factors, such as cultural operations, method of fertilizer application, time of application, source of N fertilizer and climate plays a major role in direct N_2O emissions (Aguilera *et al.*, 2013). For rice and wheat, three split applications of N were found more efficient than two split applications. Several findings revealed that choosing the correct fertilizer could help reduce emissions. The use of nitrate (NO_3) based fertilizers significantly lowered the N_2O emissions than ammonium-based fertilizers (Bouwman *et al.,* 2002). N is mostly broadcast applied in India and other Asian countries. The broadcasting of urea and the ammonium-containing fertilizers is often associated with higher volatilization losses and it can be largely reduced by incorporating urea into the soil. This is done in the case of dry direct seeded rice and wheat in IGP regions. The use of seed cum fertilizer drills also enables incorporation of urea into the soil and this method is gaining importance in IGP for sowing zero-till wheat in RWCS.

Time of Application of Nitrogen Fertilizer

For better rice crop growth and development, the perfect time is required for the application of fertilizer. N is required in large amounts for rice plants and the Recommended Dose of Nutrients (RDN) application is advised to broadcast three times (1/3rd is applied before planting, incorporated in dry soil; 1/3rd at the mid-tillering stage and 1/3rd at panicle initiation stage) throughout its growing season. The effect of different times and methods of N application on rice crop is presented in **Table 13**.

Table 13. Time of application of fertilizer for rice crop

S.No	Method	Times of application	Yield	Reference
1	Direct seeded upland rice	3 splits 1/2 at 20 days,1/4th at tillering, 1/4th at panicle initiation	More than expected	Kaur and Kaur (2017)
2	Direct-sown rice under lowland conditions.	4 splits, 17% at 21 days after sowing, 33 at 35 DAS, 33% at panicle initiation and 17% at first flowering	4.18 t ha^{-1}	Thilagavathi and Ramanathan (2005)
3	Direct-sown rice under lowland conditions.	4 splits, 1/6th at 15 DAS,1/3rd at tillering, 1/3rd at panicle initiation, 1/6th at flowering	4.92 t ha^{-1}	Sathiya and Ramesh (2009)
4	Aerobic rice	4 splits – 1/6th at 15 DAYS, 1/3rd at tillering, 1/3rd at PI, 1/6th at flowering recorded higher tillers	2.82 t ha^{-1}	Sathiya and Ramesh (2009)

Deep placement of Urea

Under direct seeded rice (DSR), deep placement of urea reduced N_2O flux by 93% compared to broadcast urea and thereby increased NUE and grain yields (Gaihre *et al.,* 2020). This is most plausible as UDP might have stored much of the nitrogen as NH_4^+ in an anaerobic zone for a long time, where nitrification is less likely due to the lack of O_2. As a result, both nitrification and denitrification emissions of N_2O and NO could be lowered. Furthermore, UDP minimizes N loss through other processes such as NH_3 volatilization and surface runoff (Rochette *et al.*, 2013).

Decision support tool

Many decision support tools are now available for managing nutrient supply in different cropping systems. For example, the Nutrient expert decision support system (DSS) developed by the International Plant Nutrition Institute (IPNI) gives site-specific recommendations (SSNR) for hybrid maize genotypes. DSS was found effective tool under both conservation and conventional production system (Kumar *et al.,* 2014, 2015a, 2015b). DSS provides SSNR even in the absence of soil test values. It needs information that is easily given by the farmer/user. Similarly, for rice RiceXpert developed by ICAR-National Rice Research Institute (NRRI), Cuttack gives N recommendations to standing rice crops by capturing the N status of the plant. The farmer needs to take ten photos of standing rice crops randomly across the field using a smartphone. After uploading captured images, the output i.e. N recommendation immediately delivered to the farmer in terms of urea. Similarly, unmanned aerial vehicle (UAV) mounted sensors capable of detecting N stress in rice plants even before it produces visible visual symptoms (Vijayakumar *et al.*, 2020a). The spectral signature of multi-spectral and hyper-spectral sensors are highly correlated with the N status of the plant. However, at present, the higher cost of the UAV system hinders its application at the field level (Vijayakumar *et al.,* 2021b).

Conclusion

We have reviewed the field-specific N management strategies based on the leaf colour chart, chlorophyll meter (SPAD), and GreenSeeker for the need-based application of N fertilizers in rice. Chlorophyll meters (SPAD), GreenSeeker, and LCC have been standardized for applying N fertilizer to rice crops based on their needs. Farmers are increasingly using a simple and inexpensive LCC to practice field-specific N application in rice, which can increase agronomic efficiency by 5 to 16 kg grain per kg N over the farmers' fertilizer practice. Nutrient decision support tools that are computer, mobile, or web-based can also help manage fertilizer N in rice on a field-by-field basis (Vijayakumar *et al.,* 2022). To achieve higher NUE, farmers in India must significantly improve fertilizer N management by adopting technological innovations and avoiding N applications greater than the crop's need. Adoption of site-specific N management strategies has great potential; however, adoption of technologically advanced N options such as controlled release N fertilizers and nitrification and urease inhibitors will be dependent on the benefit:cost ratio of their use in India.

References

Abalos D, Jeffery S, Sanz-Cobena A, Guardia G and Vallejo A. 2014. Meta-analysis of the effect of urease and nitrification inhibitors on crop productivity and nitrogen use efficiency. *Agriculture, Ecosystems & Environment*, 189: 136-144.

Abbasi MK, Hina M and Tahir MM. 2011. Effect of *Azadirachta indica* (neem), sodium thiosulphate, and calcium chloride on changes in nitrogen transformations and inhibition of nitrification in soil incubated under laboratory conditions. *Chemosphere*, 82: 1629-1635.

Aguilera E, Lassaletta L, Gattinger A, Gimeno BS. 2013. Managing soil carbon for climate change mitigation and adaptation in Mediterranean cropping systems: a meta-analysis. *Agriculture, Ecosystems & Environment,* 168: 25–36.

Akiyama H, Yan X and Yagi K. 2010. Evaluation of effectiveness of enhanced-efficiency fertilizers as mitigation options for N_2O and NO emissions from agricultural soils: meta-analysis. *Global Change Biology*, 16: 1837-1846.

Balasubramanian V, Morales AC, Cruz RT, Thiyagarajan TM, Nagarajan R, Babu M, Abdulrachman S and Hai LH. 2000. Adaptation of the chlorophyll meter (SPAD) technology for real-time N management in rice: a review. *International Rice Research Notes*, 25: 4-8.

Banik M, Naorem A, Udayana SK and Kumar G. 2016. Efficiency of botanical nitrification inhibitors prepared from neem and karanj plant in suppressing nitrification and N_2O emission. (Progressive Research – An International Journal Print ISSN: 0973-6417, Online ISSN: 2454-6003 Volume 11 (Special-VII): 4912-4915

Bhandari AL, Sood A, Sharma KN and Rana DS. 1992. Integrated nutrient management in a rice-wheat system. *Journal of the Indian Society of Soil Science*, 40: 742-747.

Bhatia A, Pathak H, Jain N, Singh PK and Singh AK. 2005. Global warming potential of manure amended soils under rice-wheat system in the Indo-Gangetic Plains. *Atmospheric Environment,* 39: 6976–6984.

Bhatia A, Sasmal S, Jain N, Pathak H, Kumar R and Singh A. 2010. Mitigating nitrous oxide emission from soil under conventional and no-tillage in wheat using nitrification inhibitors. *Agriculture, Ecosystems & Environment,* 136: 247-253.

Bhatia A, Pathak H, Jain N, Singh PK and Singh AK. 2005. Global warming potential of manure amended soils under rice–wheat system in the Indo-Gangetic plains. *Atmospheric Environment,* 39: 6976-6984.

Bhavana B, Laxminarayana P, Latha AM, Anjaiah T. 2020. Judicious Nitrogen Management using Leaf Colour Chart for Enhancing Growth and Yield of Short Duration Transplanted Rice (*Oryza sativa* L). *International Journal of Current Microbiology and Applied Sciences*, 9: 2850-2856.

Bhupenchandra I, Athokpam HS, Singh NB, Singh LN, Devi SH, Chongtham SK, Singh LK, Sinyorita S, Devi EL, Bhagowati S and Bora SS. 2021. Leaf color chart (LCC): An instant tool for assessing nitrogen content in plant: A review. *The Pharma Innovation Journal,* 10: 1100-1104

Bisht V, Neeraj VK and Dalal N. 2018. Mahua an important Indian species: a review. *Journal of Pharmacognosy and Phytochemistry*, 7: 3414-3418.

Bouwman AF, Boumans LJM and Batjes NH. 2002. Emissions of N_2O and NO from fertilized fields; summary of available measurement data. *Global Biogeochemical Cycles*, 16: 1058–1070.

Burzaco JP, Ciampitti IA and Vyn TJ. 2014. Nitrapyrin impacts on maize yield and nitrogen use efficiency with spring-applied nitrogen: Field studies vs. meta-analysis comparison. *Agronomy Journal*, 106: 753-760.

Cameron KC, Di HJ and Moir JL. 2013. Nitrogen losses from the soil/plant system: a review. *Annals of Applied Biology*, 162: 145-173.

Cantarella H, Otto R, Soares JR and de Brito Silva AG. 2018. Agronomic efficiency of NBPT as a urease inhibitor: A review. *Journal of Advanced Research*, 13: 19-27.

Chatterjee D, Nayak AK, Vijayakumar S, Debnath M, Chatterjee S, Swain CK, Bihari P, Mohanty S, Tripathi R, Shahid M and Kumar A. 2019. Water vapor flux in tropical lowland rice. *Environmental Monitoring and Assessment*, 191: 550.

Debnath G, Jain MC, Kumar Sushil, Sarkar K and Sinha SK. 1996. Methane emission from rice fields amended with biogas slurry and farmyard manure. *Climatic Change*, 33: 97–109.

Delgado JA and Follett RF. 2010. Advances in nitrogen management for water quality. Soil and water conservation society, Ankeny, IA, pp.1-424.

Ding X, Han X, Liang Y, Qiao Y, Li L and Li N. 2012. Changes in soil organic carbon pools after 10 years of continuous manuring combined with chemical fertilizer in a Mollisol in China. *Soil and Tillage Research*, 122: 36–41.

Fernando V and Roberts GR. 1976. The partial inhibition of soil urease by naturally occurring polyphenols. *Plant and Soil*, 44: 81-86.

Gaihre YK, Singh U, Bible WD, Fugice Jr J and Sanabria J. 2020. Mitigating N_2O and NO emissions from direct-seeded rice with nitrification inhibitor and urea deep placement. *Rice Science*, 27: 434-444.

Gobinath R, Manasa V, Surekha K, Vijayakumar S and Bandeppa. 2021. New age nutrient carriers for rice based cropping systems. *Indian Farming*, 71: 12–15.

Goud RB, Tripathi R, Guru PK, Mohanty S, Kumar A, Khanam R, Munda S, Vijayakumar S, Debnath M, Sivashankari M, Kumar K, Mohapatra SD and Nayak AK. 2022. Advanced Techniques for Precision Farming in Rice. Pp 224-247. In Editors P Bhattacharyya, K Chakraborty, K A Molla, Annie Poonam, D Bhaduri, R P Sah, S Paul, P S Hanjagi, Basana-Gowda G, P Swain. Climate Resilient Technologies for Rice based Production Systems in Eastern India. ICAR-National Rice Research Institute, Cuttack-753006, Odisha, India. ISBN 818840902-2.

Guo L, Wang X, Diao T, Ju X, Niu X, Zheng L, Zhang X and Han X. 2018. N_2O emission contributions by different pathways and associated microbial community dynamics in a typical calcareous vegetable soil. *Environmental Pollution*, 242: 2005-2013.

Hakeem KR, Ahmad A, Iqbal M, Gucel S and Ozturk M. 2011. Nitrogen-efficient rice cultivars can reduce nitrate pollution. *Environmental Science and Pollution Research*, 18: 1184-1193.

Hala Y, Jumadi O, Muis A, Hartati H and Inubushi K. 2014. Development of Urea Coated with Neem (*Azadirachta indica*) to Increase Fertilizer Efficiency and Reduce Greenhouse Gases Emission. *Jurnal Teknologi*, 69. https://doi.org/10.11113/jt.v69.3195

Havlin JL Tisdale, Werner L Nelson and James D Beaton. 2014. Soil Fertility and Fertilizers: An Introduction to Nutrient Management. 6th Edition, Prentice Hall, Upper Saddle River, NJ.

Horta LP, Mota YC, Barbosa GM, Braga TC, Marriel IE, Fátima ÂD and Modolo LV. 2016. Urease inhibitors of agricultural interest inspired by structures of plant phenolic aldehydes. *Journal of the Brazilian Chemical Society*, 27:1512-1519.

Hou Y, Velthof GL and Oenema O. 2015. Mitigation of ammonia, nitrous oxide and methane emissions from manure management chains: a meta-analysis and integrated assessment. *Global Change Biology*, 21: 1293–1312.

Huber DM, Warren HL, Nelson DW and Tsai CY. 1977. Nitrification inhibitors—New tools for food production. *Bioscience*, 27: 523-529.

Hull N. 2018. Cover Crop Effects on Urease Inhibitors. Master's Thesis. Auburn University Auburn, Alabama. http://hdl.handle.net/10415/6338.

Hussain A, Jahan N, Jabeen Z, Rehman KU, Rafeeq H, Bilal M and Iqbal H. 2021. Synergistic Effect of Urease and Nitrification Inhibitors in the Reduction of Ammonia Volatilization. *Water, Air, and Soil Pollution*, 232: 1-7.

Iliger MD, Sutar R, Chogatapur SV and Parameshwarareddy R. 2017. Effect of brown manuring on soil properties, weed density, grain yield and economics of different crops. *Advances in Research*, 12: 1-10.

Kaur J and Kaur J. 2017. Appropriate Nitrogen Schedules in Direct Seeded Rice (*Oryza sativa* L.). *International Journal of Bio-resource and Stress Management*, 8: 242-246.

Kim DG, Hernandez-Ramirez G and Giltrap D. 2013. Linear and nonlinear dependency of direct nitrous oxide emissions on fertilizer nitrogen input: a meta-analysis. *Agriculture, Ecosystems & Environment*, 168: 53–65.

Kumar R, Parmar BS, Walia S and Saha S. 2015. Nitrification inhibitors: Classes and its use in nitrification management. In Nutrient Use Efficiency: from Basics to Advances. pp. 103-122. Springer, New Delhi.

Kumar V, AK Singh, SL Jat, CM Parihar, V Pooniya and S Sharma. 2015b. Nutrient uptake and fertilizer use efficiency of maize hybrids under conservation agriculture with nutrient expert based SSNM practices. *Annals of Agriculture Research*, 36: 160-166.

Kumar V, AK Singh, SL Jat, CM Parihar, V Pooniya, B Singh and S Sharma. 2015a. Precision nutrient and conservation agriculture practices for enhancing productivity, profitability, nutrient-use efficiencies and soil nutrient status of maize (*Zea mays*) hybrids. *Indian Journal of Agricultural Sciences*, 85: 926-930.

Kumar V, AK Singh, SL Jat, CM Parihar, V Pooniya, S Sharma and B Singh. 2014. Influence of site-specific nutrient management on growth and yield of maize (*Zea mays*) under conservation tillage. *Indian Journal of Agronomy*, 59: 657-660.

Lan T, Han Y, Roelcke M, Nieder R and Cai Z. 2013. Effects of the nitrification inhibitor dicyandiamide (DCD) on gross N transformation rates and mitigating N2O emission in paddy soils. *Soil Biology and Biochemistry*, 67: 174-182.

Li Q, Cui X, Liu X, Roelcke M, Pasda G, Zerulla W, Wissemeier AH, Chen X, Goulding K and Zhang F. 2017. A new urease-inhibiting formulation decreases ammonia volatilization and improves maize nitrogen utilization in North China Plain. *Scientific Reports*, 7: 1-9.

Majumdar D. 2008. Unexploited botanical nitrification inhibitors prepared from Karanja plant. http://hdl.handle.net/123456789/5647

Malla G, Bhatia A, Pathak H, Prasad S, Jain N and Singh J. 2005. Mitigating nitrous oxide and methane emissions from soil in rice–wheat system of the Indo-Gangetic plain with nitrification and urease inhibitors. *Chemosphere,* 58: 1410-1417.

Marchesan E, Grohs M, Walter M, Silva LS and Formentini TC. 2013. Agronomic performance of rice to the use of urease inhibitor in two cropping systems. *Revista Ciência Agronômica*, 44: 594-603.

Matczuk D AND Siczek A. 2021. Effectiveness of the use of urease inhibitors in agriculture: a review. *International Agrophysics*, 35: 197–208

Mathialagan R, Mansor N, Al-Khateeb B, Mohamad MH and Shamsuddin MR. 2017. Evaluation of allicin as soil urease inhibitor. *Procedia Engineering*, 184: 449-459.

Meng X, Li Y, Yao H, Wang J, Dai F, Wu Y and Chapman S. 2020. Nitrification and urease inhibitors improve rice nitrogen uptake and prevent denitrification in alkaline paddy soil. *Applied Soil Ecology*, 154: 103665.

Modolo LV, da-Silva CJ, Brandão DS and Chaves IS. 2018. A mini review on what we have learned about urease inhibitors of agricultural interest since mid-2000s. *Journal of Advanced Research*, 13: 29-37.

Modolo LV, de Souza AX, Horta LP, Araujo DP and de Fatima A. 2015. An overview on the potential of natural products as ureases inhibitors: A review. *Journal of Advanced Research*, 6: 35-44.

Mohanty S, Nayak AK, Tripathi R, Shahid M, Panda BB. Vijayakumar S, Mohapatra SD, Priyadarsini S, Saha S, Sarangi DR, Swain CK, Besra B, Nagothu US and Pathak H. 2019. Integrated Nutrient Management for Sustainable Rice Production. Technology Brief No. 2. ICAR-National Rice Research Institute, Cuttack-753006, Odisha

Nayak AK, Chatterjee D, Tripathi R, Shahid M, Vijayakumar S, Satapathy BS, Kumar A, Mohanty S, Bhattacharyya P, Mishra P, Kumar U, Mohapatra SD, Panda BB, Rajak M, Bhaduri D, Munda S, Chakraborty K, Priyadarsani S, Swain CK, Moharana KC, Nayak PK, Kumar GAK, Swain P, Tesfai M, Nagaothu US and Pathak H. 2020. Climate Smart Agricultural Technologies for Rice Production System in Odisha. ICAR-National Rice Research Institute, Cuttack, Odisha, 753006, India. pp 366. ISBN: 81-88409-14-6.

Nayak AK, Rahul Tripathi, Manish Debnath, CK Swain, B Dhal, Vijaykumar S, AD Nayak, S Mohanty, MD Shahid, Anjani Kumar, Manoj Rajak, KC Moharana, D Chatterjee, S Munda, P Guru, Rubina Khanam, B Lal, P Gautam, S Pattanaik, AK Shukla, Nuala Fitton, P Smith and H Pathak. 2022. Carbon and water footprint of rice, wheat and maize crop productions in India, *Pedosphere*, ISSN 1002-0160, https://doi.org/10.1016/j.pedsph.2022.06.045.

Norton J and Ouyang Y. 2019. Controls and adaptive management of nitrification in agricultural soils. *Frontiers in Microbiology*, 10: 1931.

Pan B, Lam SK, Mosier A, Luo Y and Chen D. 2016. Ammonia volatilization from synthetic fertilizers and its mitigation strategies: a global synthesis. *Agriculture, Ecosystems & Environment*, 232: 283-289.

Pathak H, Prasad S, Bhatia A, Singh S, Kumar S, Singh J and Jain MC. 2003. Methane emission from rice-wheat cropping system of India in relation to irrigation, farmyard manure and dicyandiamide application. *Agriculture, Ecosystems & Environment,* 97: 309–316.

Pathak H and Wassmann R. 2007. Introducing greenhouse gas mitigation as a development objective in rice-based agriculture: I. Generation of technical coefficients. *Agricultural Systems*, 94: 807-825.

Patil Chethan ND, Manjunatha SK and Bindu K Ramalingannanavar. 2020. Brown Manuring: A Tool for Integrated Nutrient Management. *Indian Farming*, 7: 701-704.

Peng S, Laza MRC, Garcia FV and Cassman KG. 1995. Chlorophyll meter estimates leaf area-based nitrogen concentration of rice. *Communications in Soil Science and Plant Analysis*, 26: 927-935.

Philibert A, Loyce C and Makowski D. 2012. Assessment of the quality of meta-analysis in agronomy. *Agriculture, Ecosystems & Environment*, 148: 72–82.

Phukan J, Bora P. 2012. Brown manuring. *AgriAllis*, 3 https://agriallis.com/wp-content/uploads/2021/03/BROWN-MANURING.pdf

Qi X, Wu W, Shah F, Peng S, Huang J, Cui K, Liu H and Nie L. 2012. Ammonia volatilization from urea-application influenced germination and early seedling growth of dry direct-seeded rice. *The Scientific World Journal*, 857472.

Qiao C, Liu L, Hu S, Compton JE, Greaver TL and Li Q. 2015. How inhibiting nitrification affects nitrogen cycle and reduces environmental impacts of anthropogenic nitrogen input. *Global Change Biology,* 3: 1249-1257.

Raza S, X Li, N Miao, M Ahmed, Z Liu and J Zhou. 2019. Dicyandiamide increased ammonia volatilization and decreased carbon dioxide emission from calcareous soil during wheat–maize rotation on the Loess Plateau. *Soil Research*, 57: 767-777.

Reddy RNS and Prasad R. 1975. Studies on the mineralization of urea, coated urea, and nitrification inhibitor treated urea in soil. *Journal of Soil Science*, 26: 304-312.

Rochette P, Angers DA, Chantigny MH, Gasser MO, MacDonald JD, Pelster DE and Bertrand N. 2013. Ammonia volatilization and nitrogen retention: how deep to incorporate urea? *Journal of Environmental Quality*, 42: 1635-1642.

Rose TJ, Morris SG, Quin P, Kearney LJ, Kimber S and Van Zwieten L. 2017. The nitrification inhibitor DMPP applied to subtropical rice has an inconsistent effect on nitrous oxide emissions. *Soil Research*, 55: 547-552.

Ruser R and Schulz R. 2015. The effect of nitrification inhibitors on the nitrous oxide (N_2O) release from agricultural soils—a review. *Journal of Plant Nutrition and Soil Science,* 178(2): 171-188

Sahrawat KL, Mukerjee SK. 1977. Nitrification inhibitors. *Plant and Soil.* 47: 27-36.

Sahrawat KL. 1980. Control of urea hydrolysis and nitrification in soil by chemicals—prospects and problems. *Plant and Soil*, 57: 335-352.

Samant TK and Patra AK. 2016. Effect of tillage and nutrient-management practices on yield, economics and soil health in rice (*Oryza sativa*)-green gram (*Vigna radiata*) cropping system under rainfed condition of Odisha. *Indian Journal of Agronomy*, 61: 148-153.

Sanchis E, Ferrer M, Torres G, Cambra-López M and Calvet S. 2012. Effect of water and straw management practices on methane emissions from rice fields: a review through a meta-analysis. *Environmental Engineering Science*, 29: 1-12.

Sanz-Cobena A, Lassaletta L, Aguilera E, del Prado A, Garnier J, Billen G, Iglesias A, Sanchez B, Guardia G, Abalos D and Plaza-Bonilla D. 2017. Strategies for greenhouse gas emissions mitigation in Mediterranean agriculture: A review. *Agriculture, Ecosystems & Environment*, 238: 5-24.

Sanz-Cobena A, Misselbrook TH, Arce A, Mingot JI, Diez JA and Vallejo A. 2008. An inhibitor of urease activity effectively reduces ammonia emissions from soil treated with urea under Mediterranean conditions. *Agriculture, Ecosystems & Environment*, 126: 243-249.

Sathiya K and Ramesh T. 2009. Effect of split application of nitrogen on growth and yield of aerobic rice. *Asian Journal of Experimental Sciences*, 23: 303-306.

Sharma U, Subehia SK. 2014. Effect of long-term integrated nutrient management on rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) productivity and soil properties in North-Western Himalaya. *Journal of the Indian Society of Soil Science*, 62: 248-254.

Shcherbak I, Millar N and Robertson GP. 2014. Global metaanalysis of the nonlinear response of soil nitrous oxide (N_2O) emissions to fertilizer nitrogen. *Proceedings of the National Academy of Sciences*, 111: 9199–9204.

Slangen JH and Kerkhoff P. 1984. Nitrification inhibitors in agriculture and horticulture: a literature review. *Fertilizer Research*, 5: 1-76.

Sloan JJ and Anderson WB. 1995. Calcium chloride and ammonium thiosulfate as ammonia volatilization inhibitors for urea fertilizers. *Communications in Soil Science and Plant Analysis*, 26: 2425-47.

Song D, Qiao L, Gao D, Li S, Li M, Sun H and Ma J. 2021. Development of crop chlorophyll detector based on a type of interference filter optical sensor. *Computers and Electronics in Agriculture,* 187: 106260.

Subramanian E, Aathithyan C, Raghavendran VB and Vijayakumar S. 2020. Optimization of nitrogen fertilization for aerobic rice (*Oryza sativa*). *Indian Journal of Agronomy* 65: 180-184.

Sudhalakshmi C, Velu V and Thiyagarajan TM. 2008. Leaf colour chart for nitrogen management in rice–A review. *Agricultural Reviews*, 29: 306-310.

Surjandari I and MT Batte. 2003. Adoption of Variable Rate Technology. Makara, *Teknologi*, December, 120-124.

Thapa R, Chatterjee A, Awale R, McGranahan DA and Daigh A. 2016. Effect of enhanced efficiency fertilizers on nitrous oxide emissions and crop yields: A meta-analysis. *Soil Science Society of America Journal*, 80: 1121-1134.

Thilagavathi T and Ramanathan S. 2005. Nitrogen management for direct wet-seeded rice. *International Rice Research Notes* 30: 44–45.

Uddling J, Gelang-Alfredsson J, Piikki K and Pleijel H. 2007. Evaluating the relationship between leaf chlorophyll concentration and SPAD-502 chlorophyll meter readings. *Photosynthesis Research*, 91: 37-46.

Upadhyay RK, Tewari SK and Patra DD. 2011. Natural nitrification inhibitors for higher nitrogen use efficiency, crop yield, and for curtailing global warming. *Journal of Tropical Agriculture,* 49: 19-24.

Van Der Gon HD and Neue HU. 1995. Influence of organic matter incorporation on the methane emission from a wetland rice field. *Global biogeochemical cycles*, 9: 11-22.

Varadachari C and Goertz HM. 2010. Slow-release and controlled release nitrogen fertilizers. In Singh B (ed.) ING Bulletins on Regional Assessment of Reactive Nitrogen. Bulletin No. 11. Scon-Ing, New Delhi. pp. 1–42.

Vijayakumar S, AK Nayak, Annie Poonam, Aravindan S and Rubina Khanam. 2020a. Unmanned aerial vehicle (UAV) and its application in Indian agriculture: A perspective. *Indian Farming*, 70: 34-37.

Vijayakumar S, Anil Kumar Choudhary, M. Deiveegan, R. Thirumalaikumar and R. Mahender Kumar. 2022. Android Based Mobile Application for Rice Crop Management. *Chronicle of Bioresource Management*, 6: 19-24.

Vijayakumar S, Aravindan S, Saravanane P and Sivashankari M. 2021b. Unmanned aerial vehicles policies evaluation and suggestion to boost its agriculture application in India. *Kerala Karshakan e-journal*, 8: 6-8.

Vijayakumar S, Dinesh Jinger, Saravanane P, Subramanian E and Prabhu Govindasamy May 2021a. Agricultural Waste to Wealth: Way for Sustainable Agriculture Development. *Indian Farming*, 71: 34–36.

Vijayakumar S, Dinesh Kumar, Dinesh Jinger, Bhargavi Bussa and BB Panda. 2021. 4R nutrient stewardship-based potassium management to improve the productivity of dry-direct seeded rice-wheat cropping system. *Indian Farming*, 71: 22-25.

Vijayakumar S, RubinaKhanam, AK Nayak, Aravindan S and Sivashankari M. 2020. Soil Health Card: A critical Review. *Kerala Karshakan e-journal*, 8: 27-29.

Vijayakumar S, SuchismitaPattanaik and Saravanane P. 2021a. Low Carbon technologies for agriculture. *Sabujima*, 29: 94-100.

Webb J, Pain B, Bittman S and Morgan J. 2010. The impacts of manure application methods on emissions of ammonia, nitrous oxide and on crop response—A review. *Agriculture, Ecosystems & Environment*, 137: 39-46.

Woodward EE, Edwards TM, Givens CE, Kolpin DW and Hladik ML. 2021. Widespread Use of the Nitrification Inhibitor Nitrapyrin: Assessing Benefits and Costs to Agriculture, Ecosystems, and Environmental Health. *Environmental Science & Technology*, 55: 1345-1353.

Yang M, Fang Y, Sun D and Shi Y. 2016. Efficiency of two nitrification inhibitors (dicyandiamide and 3, 4-dimethypyrazole phosphate) on soil nitrogen transformations and plant productivity: a meta-analysis. *Scientific Reports*, 6: 1-10.

Yao Y, Miao Y, Huang S, Gao L, Ma X, Zhao G, Jiang R, Chen X, Zhang F, Yu K and Gnyp ML. 2012. Active canopy sensor-based precision N management strategy for rice. *Agronomy for Sustainable Development*, 32:925-33.

Yuan Z, Cao Q, Zhang K, Ata-Ul-Karim ST, Tian Y, Zhu Y, Cao W and Liu X. 2016. Optimal leaf positions for SPAD meter measurement in rice. *Frontiers in Plant Science*, 7:719.

Zhang K, Ge X, Liu X, Zhang Z, Liang Y, Tian Y, Cao Q, Cao W, Zhu Y and Liu X. 2017. Evaluation of the chlorophyll meter and GreenSeeker for the assessment of rice nitrogen status. *Advances in Animal Biosciences*, 8: 359-363.

RESEARCH ARTICLE https://doi.org/10.58297/IZOZ6097

Exploration of Genetic Variability and Trait Association in High Protein Landraces of Rice (*Oryza sativa* L.)

Bhargavi B[1]*, Suneetha Y[2], Aravind Kumar J[3] and Sreenivasulu KN[4]

[1,2] Department of Genetics and Plant Breeding, Acharya N G Ranga Agricultural University, Andhra Pradesh, India.
[3] Department of Plant Breeding, ICAR-Indian Institute of Rice Research, Hyderabad, Telangana, India.
[4]Department Statistics and Computer Applications, Agricultural College
Bapatla-522101, Andhra Pradesh, India.
*Corresponding author's Email: bhargavi.sjvb@gmail.com

Received: 30th July 2022; Accepted: 30th August 2022

Abstract

The present investigation was carried out at the Indian Institute of Rice Research farm, ICRISAT, Hyderabad with 31 genotypes of rice in a randomized block design with three replications, and observations were recorded on grain yield, yield components and quality characters. Analysis of variance revealed significant differences among the genotypes for all characters studied. The studies on variability, heritability and genetic advance as per cent mean thus revealed high GCV and PCV for grains panicle^{-1} and iron content. High heritability coupled with high genetic advance as per cent mean was recorded for plant height, ear bearing tillers plant^{-1}, grains panicle^{-1}, grain yield plant^{-1} and iron content indicating, the effectiveness of simple selection for improvement of these traits. The results on character associations and path analysis revealed positive and significant association coupled with high positive direct effect for ear bearing tillers plant^{-1}, panicle length, grains panicle^{-1}, and amylose content indicating the effectiveness of direct selection for these traits in the improvement of grain yield plant^{-1}. However, for test weight, days to 50 percent flowering, plant height, head rice recovery (%), and zinc content, indirect effects seemed to be the cause of correlation, while for days to maturity, protein and iron content, the use of restricted simultaneous selection model is suggested with restrictions imposed for nullifying the undesirable indirect effects in order to make use of the high positive direct effect observed for these traits on grain yield plant^{-1}.

Keywords: Correlation, Path analysis, Grain yield, Nutritional quality

Introduction

In India, rice occupies an area of 457 lakh hectares producing 1243.7 lakh tons with average productivity of 2717 kg ha^{-1} (www.Indiastat.com, 2020-21). In Telangana, it occupies an area of 10.6 lakh ha, with a production and productivity of 24.58 lakh tons and 2384 kg ha^{-1}, respectively (AAP 2019-20, www.agri.telangana.gov.in). Protein malnutrition is a serious health threat in children of developing countries (Gearing 2015). In India, 80 percent of children under the age of five are malnourished, (Sahu *et al*., 2015). The recommended calorie intake for children is 1000-1400 calories per day (200-300g rice) with protein accounting for 150-450 calories (Faizan and Rouster, 2020). In this context, even a one percent increase in the grain protein content of rice would contribute significantly to the dietary protein, presenting an affordable solution to the epidemic problem of malnutrition, particularly, in countries consuming rice as a staple food. Twenty percent of dietary protein, 3 percent of dietary fat, and other essential nutrients are provided by rice. Further, rice protein is said to be the best among cereal proteins because it has a better balance of important amino acids and is easier to digest. Rice has a higher protein digestibility corrected amino acid score (PDCAAS) of 0.81 (Nitrayová *et al*., 2018) which shows the presence of essential amino acids and overall protein quality, compared to other popular cereals. However, the protein content of milled rice grains is typically 6-7 % (Baniwal *et al.*, 2021), which is the lowest among cereals such as wheat (12-14 %) and maize (8-9 %). Therefore, efforts are needed to develop high-protein rice genotypes with good yields.

In this context, information on the extent of variability in the experimental material along with heritability and genetic advance of the traits would aid in the formulation of effective selection strategies. Studies on correlation and path analysis would further aid in the identification of effective selection criteria for the improvement of grain yield along with grain quality. The present investigation was undertaken in this background to elucidate information on the variability, heritability, genetic advance, character associations, and path coefficients of grain yield, yield components, and quality characters to aid in the formulation of effective selection criteria for grain yield and quality improvement of high protein rice landraces.

Materials and Methods

The experimental material consisted of 31 rice genotypes (**Table 1**) collected from the Indian Institute of Rice Research (IIRR), Rajendranagar, Hyderabad. Among the 31 genotypes, 30 are landraces and one check (CR DHAN 310), a popular high protein content (10.4) variety with excellent cooking quality traits. All 31 genotypes were sown at IIRR Farm at ICRISAT, Hyderabad during *Kharif* 2021 on separate raised nursery beds. All recommended package of practices were adopted to raise a healthy nursery and 30 days old seedlings were transplanted in the main field laid out in Randomized Block Design (RBD) with three replications. Each genotype was transplanted separately in 5 rows of 4.5 m length by adopting a spacing of 20×15 cm. All recommended package of practices were adopted throughout the crop growth period to raise a healthy crop. Observations were recorded on five randomly selected plants for

Table 1. Details of the rice genotypes studied in the present investigation

S No.	Genotype	Pedigree	Origin	S No.	Genotype	Pedigree	Origin
1	JAK 14	Land race	West Bengal	16	JAK 377-3	Land race	Maharashtra
2	JAK 17	Land race	Jharkhand	17	JAK 390	Land race	Maharashtra
3	JAK 25	Land race	Jharkhand	18	JAK 400	Land race	West Bengal
4	JAK 90	Land race	Uttar Pradesh	19	JAK 423	Land race	Maharashtra
5	JAK 108	Land race	Jharkhand	20	JAK 424	Land race	Maharashtra
6	JAK 120	Land race	Uttar Pradesh	21	JAK 440	Land race	Uttar Pradesh
7	JAK 124	Land race	Maharashtra	22	JAK 453	Land race	Uttar Pradesh
8	JAK 153	Land race	Jharkhand	23	JAK 486	Land race	Uttar Pradesh
9	JAK 163	Land race	Uttar Pradesh	24	JAK 513-1	Land race	Jharkhand
10	JAK 247	Land race	West Bengal	25	JAK 519	Land race	Uttar Pradesh
11	JAK 248-3	Land race	West Bengal	26	JAK 552	Land race	West Bengal
12	JAK 287	Land race	West Bengal	27	JAK 595-1	Land race	Uttar Pradesh
13	JAK 341-2	Land race	Maharashtra	28	JAK 611	Land race	Jharkhand
14	JAK 355	Land race	West Bengal	29	JAK 625	Land race	West Bengal
15	JAK 374	Land race	West Bengal	30	JAK 638	Land race	Jharkhand
31	CR DHAN 310	Naveen xARC 10075	Cuttack				

grain yield plant^{-1}; yield component traits, namely, plant height, ear bearing tillers plant^{-1}, panicle length, grains panicle^{-1} and test weight and quality characters, namely, head rice recovery (%), protein content, iron content, zinc content, and amylose content were recorded. However, days to 50 per cent flowering and days to maturity were recorded on a plot basis. In contrast, observations for test weight and all the quality traits studied were obtained from a random grain sample drawn from each plot in each genotype and replication using standard procedures. The data collected was subjected to standard statistical procedures (Panse and Sukhatme, 1967). The genotypic and phenotypic coefficients of variability were computed as per the formula proposed by Burton and Devane (1953). Categorization of the range of variation was followed as per Subramanian and Menon (1973). Heritability in a broad sense was estimated as per Allard (1960) and characterized as suggested by Johnson *et al.* (1955). The genetic advance was estimated as per the formula proposed by Lush (1940). The range of genetic advances as per cent of the mean was classified as suggested by Johnson *et al.* (1955). The correlation was worked out using the formulae suggested by Falconer (1964) and partitioning of the correlation coefficients into direct and indirect effects was carried out using the procedure suggested by Wright (1921) and elaborated by Dewey and Lu (1959). Characterization of path coefficients was carried out as suggested by Lenka and Mishra (1973).

Results and Discussion

The mean performance of 31 landraces studied in the present investigation for grain yield, yield components, and quality characters along with the estimates of the phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2 broad sense) and genetic advance as percent of the mean (GAM) are presented in **Table 2**. A perusal of the results revealed a maximum range for grains panicle^{-1} (63-207). Grain yield plant^{-1} also exhibited wide variation ranging from 14.30g to 24.17g with a mean value of 20.21g. The nutritional

Table 2. Variability, heritability, and genetic advance as per cent of mean for grain yield, yield components and quality traits in rice

S. No.	Character	Mean	Range	Coefficient of variation		Heritability (%)	Genetic advance as per cent of mean
				PCV (%)	GCV (%)		
1	Days to 50 per cent flowering	103	90-119	9.58	8.18	73.04	14.41
2	Days to maturity	133	120-149	9.97	6.4	39.28	8.27
3	Plant height (cm)	108.16	71.00-143.67	17.99	17.54	95.01	35.22
4	Ear bearing tillers plant^{-1}	11	6-14	18.38	16.71	82.71	31.31
5	Panicle length (cm)	23.5	20.16-7.12	10.86	6.34	34.08	7.62
6	Grains panicle^{-1}	118	63-207	32.55	25.03	60.11	39.64
7	Test weight (g)	19.53	15.60-24.84	17.17	9.99	33.83	11.97
8	Grain yield plant^{-1} (g)	20.21	14.30-24.17	13	11.9	83.8	22.44
9	Head Rice Recovery (%)	63.37	45.50-72.40	11.08	9.89	79.76	18.2
10	Protein content (%)	9.77	8.50-10.70	7.87	6.61	70.56	11.44
11	Iron content (ppm)	1.9	1.10-2.90	32	31.52	96.97	63.96
12	Zinc content (ppm)	19.4	14.90-24.00	16.34	12.58	39	19.97
13	Amylose content (%)	22.39	19.94-26.31	20.05	13.82	47.54	19.63

parameter, protein content ranged from 8.50 to 10.70 with an overall mean value of 9.77, while zinc content varied from 14.9 to 24.0ppm with a mean of 19.4ppm. The amylose content of the experimental material was noticed to range from 19.94 -26.31. with a mean value of 22.39 percent, while iron content ranged from 1.10 to 2.90ppm with a mean value of 1.90ppm. The test weight of the landraces studied ranged from 15.60 to 24.84g with a mean value of 19.53g. Further, the landraces were observed to be of short to late duration and their days to maturity ranged from 120.00 to 149.00 days with a mean value of 133 days. The landraces studied were noticed to possess semi-dwarf to tall plant height and it varied from 71.00 to 143.67cm with a mean value of 108.16cm.

High GCV and PCV values (>20) were recorded for grains per panicle, and iron content, indicating the existence of sufficient variation and hence, the effectiveness of selection is better for these traits in the landraces studied. The results conform with the reports of Singh *et al*., (2020). Plant height, ear-bearing tillers plant^{-1}, grain yield plant^{-1}, and zinc content exhibited moderate GCV and PCV values (10-20), while, days to 50 percent flowering, days to maturity and protein content had recorded low PCV and GCV values (<10). The results are in broad agreement with the findings of Sameera *et al*. (2016) and Sudeepthi *et al*., (2020). The other traits, namely, panicle length (Singh *et al*., 2020), test weight (Swarnajit *et al*., 2015), head rice recovery (%) (Babu *et al*., 2012) and amylose content (Suman *et al*., 2020) had recorded variable values of PCV and GCV, similar to the findings of earlier workers.

High heritability (>60) coupled with high genetic advance as per cent mean (>20) was noticed for plant height, ear-bearing tillers plant^{-1}, grains panicle^{-1}, grain yield plant^{-1} (Sudeepthi *et al*., 2020), and iron content (Singh *et al*., 2020), indicating the effectiveness of simple selection for improvement of the traits. High heritability coupled with moderate genetic advance (10-20) was noticed for days to 50 per cent flowering, head rice recovery (%) (Singh *et al*., 2020), and protein content (Kumar *et al*., 2006). The traits, days to maturity (Sudeepthi *et al*., 2020), panicle length, test weight, and zinc content recorded moderate heritability (30-60). Genetic advance as per cent mean was also noticed to be moderate (10-20) for test weight, zinc, and amylose content, while, it was low (<10) for days to maturity (Saha *et al*., 2019) and panicle length (Singh *et al*., 2018).

The results on character associations between yield, yield components, and quality characters are presented in **Table 3**. A perusal of these results revealed a positive and significant association of grain yield plant^{-1} with the yield component traits, namely, ear bearing tillers plant^{-1}, panicle length, grains panicle^{-1} and test weight and the quality traits, namely, amylose content and zinc content, indicating scope for simultaneous improvement of yield and quality traits through selection. The results are in agreement with the reports of Gunasekaran *et al.,* (2017) for ear-bearing tillers plant^{-1}and panicle length; Singh *et al.* (2020) for grains panicle^{-1}, test weight, and zinc content; and Hasan *et al.* (2020) for amylose content. Positive and significant associations were also observed for days to 50 per cent flowering with days to maturity (Saha *et al.,* 2019); ear-bearing tillers plant^{-1} with test weight (Singh *et al.,* 2020) and amylose content (Ashok, 2015); panicle length with zinc content (Singh *et al.,* 2020); test weight with ear bearing tillers plant^{-1}, panicle length and grains panicle^{-1}(Vennela *et al.,* 2021); and iron content with zinc content (Archana *et al*., 2018) indicating scope for simultaneous improvement of these traits. Negative and significant associations of grain yield plant^{-1} with protein content (Chattopadhyay *et al*., 2011) and panicle length (Srivastava *et al*., 2017). However, negative and significant associations were observed for days to 50 per cent flowering with test weight (Singh *et al.,* 2020); plant height with grains panicle^{-1} (Vennela *et al.,* 2021); panicle length with protein content (Chattopadhyay *et al*., 2011); and grains panicle^{-1} with protein content, indicating the need for balanced selection while effecting simultaneous improvement of the traits.

The results of path coefficient analysis of yield components and quality characters concerning grain yield per plant are presented in **Table 4** and **Figure 1**.

Table 3. Correlation coefficients for grain yield, yield components and quality characters in rice

Characters	Days to maturity	Plant height	Ear bearing tillers plant^{-1}	Panicle Length	Grains Panicle^{-1}	Test Weight	Head Rice Recovery (%)	Amylose Content	Protein content	Iron content	Zinc content	Grain yield plant^{-1}
Days to 50 per cent flowering	0.951**	0.057	-0.146	-0.124	0.098	-0.341*	0.1504	0.082	-0.123	0.352	0.104	0.072
Days to maturity		0.194	-0.074	-0.103	-0.238	0.102	0.3043	-0.117	-0.229	0.261	0.086	0.102
Plant height			-0.045	0.0218	-0.527**	-0.351	-0.022	-0.105	0.038	0.189	-0.025	-0.317*
Ear bearing tillers plant^{-1}				-0.036	0.119	0.540**	0.169	0.471**	-0.291	-0.159	0.171	0.530**
Panicle Length					0.496**	0.369**	0.2771	-0.259	-0.641**	0.32	0.577**	0.527**
Grains Panicle^{-1}						0.464**	0.2283	-0.11	-0.452	0.202	0.29	0.562**
Test Weight							-0.01	-0.024	-0.246	-0.211	0.227	0.544**
Head Rice Recovery(%)								0.2655	-0.3229	0.2002	-0.0529	0.278
Amylose Content									-0.159	0.0324	-0.076	0.390*
Protein content										-0.194	-0.194	-0.403*
Iron content											0.529**	0.1618
Zinc content												0.472**

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

The residual effect of 0.469 was observed indicating that variables studied in the present investigation explained about 53.10 per cent of variability for grain yield plant^{-1} and therefore other attributes, besides the characters studied, are contributing to grain yield plant^{-1}. High positive direct effects of ear-bearing tillers plant^{-1} (Gunasekaran *et al.*, 2017), panicle length (Sudeepthi *et al*., 2020); grains panicle^{-1} (Archana *et al.*, 2018), and amylose content (Singh *et al.*, 2020) on grain yield plant^{-1} were noticed in the present study, similar to the results of earlier workers. These traits had also recorded high positive and significant association with grain yield plant^{-1}, indicating the effectiveness of direct selection for these traits in the improvement of grain yield plant^{-1}. Negative direct effects were, however, noticed for plant height, test weight (Lakshmi *et al.,* 2020), head rice recovery % (Ashok, 2015), and zinc content (Archana *et al.*, 2018), similar to the results of earlier workers. Plant height had also recorded a significant and negative association with grain yield plant^{-1}, while test weight and zinc content had recorded a significant and positive association with grain yield plant^{-1}. However, head rice recovery had recorded a non-significant association with grain yield plant^{-1}. Further, days to 50 per cent flowering had recorded positive and non-significant association along with low and positive direct effects, indicating indirect effects as the cause of the correlation. Hence, consideration of indirect causal factors is suggested simultaneously for these traits. Further, days to maturity and iron content had recorded non-significant association coupled with a high positive direct effect, while protein content had recorded negative and significant association with a high positive direct effect, indicating the need for use of a restricted simultaneous selection model with restrictions imposed for nullifying the undesirable indirect effects to make use of the positive direct effects observed for these traits on grain yield plant^{-1}. The results are in broad agreement with the reports of Archana *et al.*, (2018).

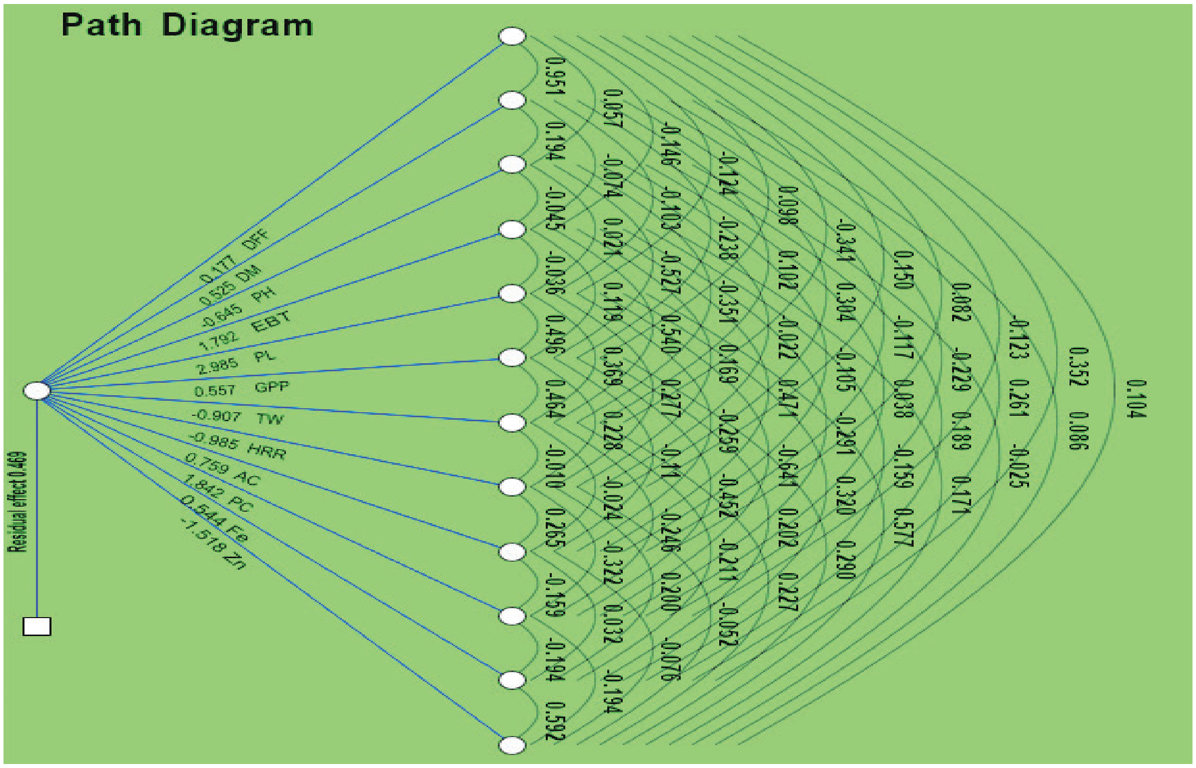


Figure 1: Path diagram of yield components and quality characters for grain yield plant^{-1}

DFF= Days to 50 per cent flowering, DM= Days to maturity, PH= Plant height, EBT=Ear bearing tillers plant^{-1}, PL= Panicle length, GPP= Grains panicle^{-1}, TW= Test weight, GYPP= Grain yield plant^{-1}, HRR=Head rice recovery %, AC=Amylose content, PC=Protein content, Fe = Iron content, Zn =Zinc content.

Table 4. Direct and indirect effects of yield components and quality characters on grain yield in rice

Characters	Days to 50 per cent flowering	Days to maturity	Plant height	Ear bearing tillers plant^{-1}	Panicle Length	Grains Panicle^{-1}	Test Weight	Head Rice Recovery (%)	Amylose Content	Protein content	Iron content	Zinc content	Grain yield plant^{-1}
Days to 50 per cent flowering	**0.177**	0.500	-0.037	-0.262	-0.372	0.055	0.292	-0.148	0.063	-0.227	0.192	-0.159	0.072
Days to maturity	0.168	**0.526**	-0.126	-0.133	0.309	-0.058	0.217	-0.300	-0.089	-0.422	0.142	-0.131	0.102
Plant height	0.010	0.102	**-0.646**	-0.081	0.065	-0.294	0.319	0.022	-0.080	0.071	0.103	0.039	-0.317*
Ear bearing tillers plant^{-1}	-0.026	-0.039	0.029	**1.792**	-0.109	0.066	-0.491	-0.167	0.358	-0.538	-0.086	-0.261	0.530**
Panicle Length	-0.022	0.054	-0.014	-0.065	**2.986**	0.277	-0.335	-0.273	-0.197	-1.181	0.174	-0.877	0.527**
Grains Panicle^{-1}	0.017	-0.054	0.341	0.213	1.481	**0.558**	-0.421	-0.225	-0.084	-0.833	0.011	-0.441	0.562**
Test Weight	-0.057	-0.126	0.227	0.969	1.103	0.259	**-0.907**	0.011	-0.019	-0.454	-0.115	-0.346	0.544**
Head Rice Recovery(%)	0.027	0.160	0.014	0.303	0.827	0.127	0.010	**-0.986**	0.202	-0.595	0.109	0.080	0.278
Amylose Content	0.015	-0.062	0.068	0.845	-0.773	-0.062	0.023	-0.262	**0.759**	-0.294	0.018	0.116	0.390*
Protein content	-0.022	-0.120	-0.025	-0.523	-1.914	-0.252	0.224	0.318	-0.121	**1.843**	-0.106	0.295	-0.403*
Iron content	0.063	0.137	-0.122	-0.285	0.959	0.011	0.192	-0.197	0.025	-0.359	**0.544**	-0.805	0.162
Zinc content	0.019	0.045	0.016	0.307	1.723	0.162	-0.207	0.052	-0.058	-0.358	0.288	**-1.519**	0.472**

*,**Significant at5 % and 1% levels, respectively

Conclusion

Grains panicle^{-1} exhibited high GCV, PCV, heritability, and genetic advance as per cent mean in addition to positive and significant correlation coupled with high positive direct effects and hence, is identified as effective selection criteria for improvement of grain yield plant^{-1} in the high protein landraces of rice. The study also revealed a negative correlation for grain yield plant^{-1} with protein content and hence, the need for balanced selection, while effecting simultaneous improvement for both traits.

Acknowledgments

The authors are thankful to the Director, ICAR-IIRR for providing research facilities and to all the staff of the Quality lab, ICAR-IIRR for their support.

References

Allard RW. 1960. Principles of Plant Breeding. John Wiley and Sons. Inc., New York. 485.

Archana R, Sudha M, Vishnu V and Fareeda G. 2018. Correlation and path coefficient analysis for grain yield, yield components and nutritional traits in rice (*Oryza sativa* L.). *International Journal of Chemical Studies*, 6: 189-195.

Ashok S. 2015. Genetic divergence studies for yield components and grain quality parameters in Rice (*Oryza sativa* L.). *M. Sc (Ag.) Thesis*. Acharya N.G. Ranga Agricultural University, Guntur, India.

Babu VR, Shreya K, Dangi KS, Usharani G, and Shankar AS. 2012. Correlation and path analysis studies in popular rice hybrids of India. *International Journal of Scientific and Research Publications,* 2: 2250-3153.

Baniwal P, Mehra R, Kumar N, Sharma S, and Kumar S. 2021. Cereals: Functional constituents and its health benefits. *The Pharma Innovation,* 10: 343-349.

Burton GW and Devane EM. 1953. Estimating heritability in tall Fescue (*Festuca arundinaceae*) from replicated clonal material. *Agronomy Journal*, 51:515-518.

Chattopadhyay K, Das A and Das SP. 2011. Grain protein content and genetic diversity of rice in northeastern India. *Oryza-An International Journal on Rice,* 48: 73-75.

Dewey DR and Lu KH. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agronomy Journal*, 5: 515-518.

Faizan U and Rouster AS. 2020. Nutrition and hydration requirements in children and adults. Stat Pearls Publishing, Treasure Island, Florida.

Falconer DS. 1964. An introduction to quantitative genetic and plant breeding. Oliver and Boyd. London. Pp. 312 – 324.

Gearing ME. 2015. Good as gold: Can golden rice and other biofortified crops prevent malnutrition? *Science in the News, Harvard University. http://sitn. hms. Harvard. edu*.

Gunasekaran K, Sivakami R, Sabariappan R, Ponnaiah G, Nachimuthu VV and Pandian BA. 2017. Assessment of genetic variability, correlation and path coefficient analysis for morphological and quality traits in rice (*Oryza sativa* L.). *Agricultural Science Digest,* 37: 251-256.

Hasan JM, Kulsum UM, Majumder RR and Sarker U. 2020. Genotypic variability for grain quality attributes in restorer lines of hybrid rice. *Genetika*, 52: 973-989.

Johnson HW, Robinson HE and Comstock RE. 1955. Estimation of genetic and environmental variability in soybean. *Agronomy Journal,* 47: 314-318.

Kumar S, Gautam AS and Chandel S. 2006. Estimates of genetic parameters for quality traits in rice (*Oryza sativa* L.) in mid hills of Himachal Pradesh. *Crop Research,* 32: 206-208.

Lakshmi VGI, Sreedhar M, Gireesh C and Vanisri S. 2020. Genetic variability, correlation and path analysis studies for yield and yield attributes in African rice (*Oryza glaberrima* L.) germplasm. *Electronic Journal of Plant Breeding,* 11: 399-404.

Lenka D and Mishra B. 1973. Path coefficient analysis of yield in rice varieties. *Indian Journal of Agricultural Sciences,* 43: 376-379.

Lush JL.1940. Intra-sire correlation on regression of off-spring on dams as a method of estimating heritability of characters. *Proceedings of American Society of Animal Production,* 33: 292-301

Nitrayová S, Brestenský M and Patráš P. 2018. Comparison of two methods of protein quality evaluation in rice, rye and barley as food protein sources in human nutrition. *Potravinarstvo,* 12: 762-766.

Panse VG and Sukhatme PV. 1957. Statistical methods for agricultural workers. Indian Council of Agricultural Research. New Delhi.

Saha SR, Hassan L, Haque A, Islam MM and Rasel M. 2019. Genetic variability, heritability, correlation and path analyses of yield components in traditional rice (*Oryza sativa* L.) landraces. *Journal of Bangladesh Agricultural University,* 17: 26–32.

Sahu SK, Kumar SG, Bhat BV, Premarajan KC, Sarkar S, Roy G and Joseph N. 2015. Malnutrition among under-five children in India and strategies for control. *Journal of Natural Science, Biology, and Medicine*, 6: 18

Sameera SK, Srinivas T, Rajesh AP, Jayalakshmi V and Nirmala PJ. 2016. Variability and path co-efficient for yield and yield components in rice. *Bangladesh Journal of Agricultural Research,* 41: 259-271.

Singh A, Manjri SDG, Kumar G, Dubey V, Rampreet KN and Dwivedi DK. 2018. Path coefficient analysis studies in Iron and Zinc containing rice varieties. *Journal of Pharmacognosy and Phytochemistry,* 7: 3729-3732.

Singh KS, Suneetha Y, Kumar GV, Rao VS, Raja DS and Srinivas T. 2020. Variability, correlation and path studies in coloured rice. *International Journal of Chemical Studies,* 8: 2138-2144.

Srivastava N, Babu GS, Singh ON, Verma R and Pathak SK. 2017. Appraisal of genetic variability and character association studies in some exotic upland rice germplasm. *Plant Archives,* 17: 1581-1586.

Subramanian PS and Menon PM. 1973. Genotypic and phenotypic variability in rice. Madras Agricultural Journal, 60: 1093-109

Sudeepthi K, Srinivas T, Kumar BNVSR, Jyothula DPB and Umar SkN. 2020. Assessment of genetic variability, character association and path analysis for yield and yield component traits in rice (*Oryza sativa* L.). *Electronic Journal of Plant Breeding,* 11: 144-148.

Suman K, Madhubabu P, Rathod R, Rao SD, Rojarani A, Prashant S, Subbarao LV, Ravindra babu V and Neeraja CN. 2020.Variation of grain quality characters and marker-trait association in rice (*Oryza sativa* L.). *Journal of Genetics,* 99: 1-12.

Swarnajit D, Senapati BK and Indrajeet P. 2015. Assessment of genetic parameters for quantitative characters in summer rice. *Environment and Ecology,* 33: 507-512.

Vennela M, Srinivas B, Reddy VR and Balram N. 2021. Studies on Correlation and Path Coefficient Analysis in Hybrid Rice (*Oryza sativa* L.) for Yield and Quality Traits. *International Journal of Bio-Resource and Stress Management,* 12: 496-505.

Wright S. 1921. Correlation and causation. *Journal of Agricultural Research,* 20: 557-585.

RESEARCH ARTICLE https://doi.org/10.58297/RQVQ6630

Evaluation of Salinity-Tolerant Backcrossed Inbred Lines (BILs) For Fertility Restoration Using Molecular Markers

Beulah P[1], Manasa Y[1], Nagaraju P[1], Veerendra J[1], Lohit R[1], Madhusudan N[1], Bhargava K[1], Revathi P[1], Kemparaju KB[1], Sruthi K[1], Hari Prasad AS[1], Sundaram RM[1], Ravindra Babu V[1], Krishna Satya A[2], Sudhakar P[2] and Senguttuvel P*[1]

[1]ICAR-Indian Institute of Rice Research, Hyderabad, India.
[2]Biotechnology department, Acharya Nagarjuna University, Guntur, India
*Corresponding author Email: senguttuvel@gmail.com

Received: 27th October 2022; Accepted: 20th November 2022

Abstract

Fertility restoration is a very important trait for the WA-CMS system in hybrid rice. Fifty-five BILs derived from KMR3 and FL478 cross combination possessing *Saltol1* generated through Marker Assisted Backcross Breeding (MABB) approach were screened using *Rf4* and *Rf3* markers during Rabi 2021. The use of molecular markers tightly linked with fertility restoration aided in identifying promising groups of restorers, maintainers, partial restorers, and partial maintainers. The presence of both *Rf4* and *Rf3* alleles among the nineteen BILs was 35% which showed a clear difference in the marker distribution among the BILs. The BILs namely TCP32, TCP34, TCP35, TCP36, TCP36-3, TCP37-2, TCP38, TCP13, TCP18, TCP19, TCP45, TCP46, TCP48, TCP54, TCP56, TCP57-1, TCP60, TCP61, TCP61-3 were identified as promising restorers possessing both *Rf4* and *Rf3* genes. The current study reflects that *Rf4 and Rf3* genes in combination help in the breeding of WA-CMS-based hybrids in *Saltol* introgressed restorers with better heterosis under various ecologies, especially coastal saline areas.

Keywords: WA-CMS, MABB, Rf3, Rf4, Saltol, Heterosis

Introduction

Rice is the largest consumed food grain in the world and its consumption was estimated to increase by 3% to 108 million tonnes (USDA, 2021; https://www.fas.usda.gov/ commodities/rice). The worldwide production of rice for 2021-2022 is estimated to be around 515.05 million tonnes, whereas India's production for the year 2021-22 was 126500 metric tonnes (https://www.worldagriculturalproduction.com/crops/rice.aspx). Achieving food security is the most important criterion to meet the food demands of the increasing global population and this is possible through adopting hybrid rice cultivation. Utilization of hybrid rice technology for greater heterosis is vital for increasing rice production all over the world (Anis, 2019). Identification of restorer lines (that restore the fertility of CMS lines) is the foremost step for superior-yielding heterotic rice hybrids (Venkanna *et al.,* 2022). The production of fertile pollen is supposed to be restored by a nuclear gene called the restorer of fertility (*Rf*) by modifying the male sterility effect (Katara *et al.,* 2017). Previous studies on fertility restoration were confirmed to be governed by two nuclear genes which are dominant and independent as well (Venkanna *et al.,* 2022). The two nuclear genes *Rf3* and *Rf4* on chromosomal locations 1 and 10 respectively were reported for the fertility restoration of the WA-CMS system (Katara *et al.,* 2017). The major locus for WA-CMS fertility restoration is identified as *Rf4* from previous studies (Balaji Suresh, 2012). RM6100 (Singh *et al.,* 2005) at 1,837,2167 bp for *Rf4* has been confirmed on Chromosome 10 of Nipponbare (NC_008403) while RM10313 for *Rf3* gene has been identified by Neeraja (2008) at a distance of 4.2 cM on the short arm of chromosome 1.

Markers for candidate genes have been developed and validated with the aid of marker-assisted breeding and molecular mapping (Suresh *et al*., 2012). Gene-based functional markers like RMS-PPR9-1 and RMS-SF21-5 for *Rf4* and *Rf3* respectively were developed by Pranathi *et al.,* (2016). A few of the reported markers for *Rf4* and *Rf3* are represented in **Table 1**. Screening for *Rf*3 and *Rf*4 fertility restoration genes based on markers fetch in quick identification of restorers within bulk genetic stock (Nagamani *et al.,* 2022). In the context of the identification of superior restorers along with fertility restorer genes, we have attempted to improve the parental line KMR3 whose genetic background has *Rf3* and *Rf4* to develop a salt-tolerant hybrid for saline-prone ecosystems. In the present study, an advanced BC_2F_4 population derived from KMR3 and FL478 (donor for *Saltol1*) using a marker-assisted breeding approach (MABB), was developed and these BILs were evaluated for the presence of *Rf3* and *Rf4* genes.

Materials and Methods

The backcrossed inbred lines (55 BILs) at BC_2F_4 generation derived using MABB approach for salt tolerance were evaluated for the presence of fertility restoration genes *Rf4* and *Rf3*. The recurrent parent KMR3 is a popular restorer, containing *Rf4* and *Rf3*, and APMS6B, a negative check for fertility restoration was used along with the BILs. 21-day-old healthy seedlings were raised in the nursery and transplanted to the field using a randomized complete block design (RCBD) with two biological replicates. The genomic DNA was isolated using the CTAB method from the leaves of the established BILs after 21-days after transplanting. The genotyping was done in the molecular laboratory, Crop improvement section, Hybrid Rice, Indian Institute of Rice Research, Hyderabad. The primers used for genotyping of the improved BILs were RM6100, DRCG-RF4-14, RMS-PPR-9-1 for *Rf4* and RM10313, DRRM-RF3-10, RMS-SF-21-5 for *Rf3* (**Table 1**). The PCR was run at 94°C for 5 min, 94°C for 30 secs, 55°C for 1 min, 72°C for 1 min, and 72°C for 10 minutes in a thermal cycler (*BIO-RAD, T100*^{TM} Thermal Cycler, USA); the amplified product was stored at 4°C. The components were resolved in the 3% agarose gel (*Seakem*$^{®}$*LE Agarose*) and visualized under the UV documentation system (IGENE $^{®}$LABSERVE) and scored accordingly.

Table 1. Molecular markers reported for *Rf3 and Rf4*

S.No.	Reported markers	Genes	Chromosome number	Reference
1	RM6100	*Rf4*	10	Singh *et al.,* 2005; Sheeba *et al.,* . 2009
2	RMS-PPR9-1	*Rf4*	10	Pranathi *et al.,* . 2016
3	DRCGRF4-14	*Rf4*	10	Balaji Suresh *et al.,* . 2012
4	DRCG-RF4-8	*Rf4*	10	Balaji Suresh *et al.,* . 2012
5	TMPPR3	*Rf4*	10	Balaji Suresh *et al.,* . 2012
6	RM10313	*Rf3*	1	Neeraja 2009
7	DRRM-RF3-5	*Rf3*	1	Balaji Suresh *et al.,* . 2012
8	DRRM-RF3-10	*Rf3*	1	Balaji Suresh *et al.,* . 2012
9	RMS-SF21-5	*Rf3*	1	Pranathi *et al.,* . 2016

Results and Discussion

Fifty-Five (55) BILs conferring salinity tolerance were genotypically screened for the presence/absence of fertility restoration genes *Rf4* and *Rf3*. The primers used for screening are RM6100, DRCG-RF4-14, RMS-PPR-9-1 for *Rf4* and RM10313, DRRM-RF3-10, RMS-SF-21-5 for *Rf*3. The genotypes were classified into four groups *viz*., restorers, partial restorers, maintainers, and partial maintainers based on the presence/absence of the desired allelic pattern.

The primer RMS-PPR9-1 for *Rf4* has a positive allele for restorer at 114 bp and a non-restorer had band size at 159 bp. Similarly, the candidate gene DRCG-RF4-14 had a positive allele at 782 bp for the R line and 887 bp for the B line. The functional marker for *Rf3*, RMS-SF21-5 had positive alleles at 172 bp and 127 bp for restorer and non-restorer respectively. The gel pictures for *Rf4* and *Rf3* screened were represented in **Figure 1**.

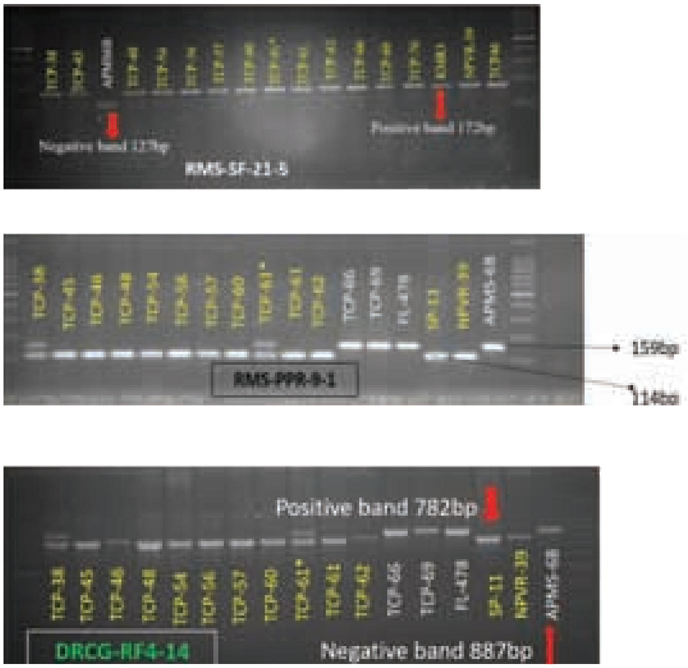


Figure 1: BILs screened for the presence of *Rf3* and *Rf4* a) functional marker for *Rf3,* RMS-SF-21-5; b) functional marker for *Rf4,* RMS-PPR9-1; c) candidate gene DRCG-RF4-14 for *Rf4*

Out of 55 BILs, nineteen BILs (19) were reported to be positive for both *Rf4* and *Rf3* considered as restorers along with the parental line KMR3 which are TCP32, TCP34, TCP35, TCP36, TCP36-3, TCP37-2, TCP38, MB13, MB18, MB19, TCP45, TCP46, TCP48, TCP54, TCP56, TCP57-1, TCP60, TCP61, TCP61-3. Thirty-three (33) were found to be positive for only *Rf4* allele which includes TCP32, 34, 35, 36,36-3, 37, 37-2, 38, 39, 11, 12, 13, 14, 15,16, 17, 18, 19, 45, 46, 47, 48, 30, 54, 55, 56, 57-1, 60, 61, 61-3, 62, 63 and 67 along with KMR3 and twenty-nine (29) positive for *Rf3* alone that are TCP32, 34, 35, 36, 36-3, 37-2, 38, 13, 18,19, 20, 21, 45, 46, 3, 48, 54, 56, 57-1, 72, 74, 58,59,60, 61, 61-3, 64 and 68. The percentage of *Rf4* contribution alone was 60% while *Rf3*s was 52.72%. Both *Rf4*+*Rf3* were present in 34.54% among the 55 BILs. The number of BILs positive for their respective markers was graphically represented in the clustered column in **Figure 2**.

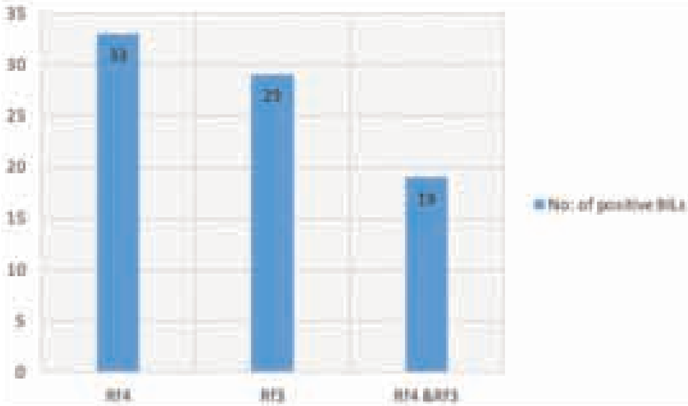


Figure 2: Clustered column of positive BILs against respective markers

The effectiveness of *Rf4* and *Rf3* markers genotypically was confirmed for fertility restoration based on various studies by the researchers. Screening of 310 NPT lines for fertility restoration targeting *Rf3* and *Rf4* using DRRM-*Rf3*-5 and DRRM-*Rf3*-10 and functional markers like RMS-SF21-5; RM6100 and functional marker RMS-PPR9-1 was reported by Shidenur *et al.,* (2020). Pranathi *et al.,* (2016) screened to distinguish 120 restorers and 44 non-restorers for fertility restoring ability genotypically and further developed functional markers for *Rf3* and *Rf4*. Similarly, a total of 51 genotypes were also screened for *Rf4* and *Rf3* and strong restorers and maintainers were identified using RM6100 and RM10313, respectively (Nath *et al.,* 2020). Nagamani *et al.,* (2022) screened 62 red-kernelled genotypes using RM6100, RMS-PPR9-1, and RMS-SF21-5 and identified restorer lines in combinations *Rf*3 and *Rf*4. Among the 24 genotypes screened by Rashid *et al.,* (2019) three genotypes were confirmed as complete restorers based on the screening with RM6100 and DRCG-RF4-14 for *Rf4* and DRRM-RF3-10 for *Rf3*. New markers (RM304, RM258 on Chromosome 10 and RM23598 on Chromosome 9) were found to be related to fertility restoration when screened with various SSR markers in an F2-derived population (Thakur *et al.,* 2021). Ramalingam *et al.,* (2020) screened *Pi54* introgressed BC_3F_2 lines for fertility restoration using DRRM-RF3-10, DRCG-RF4-8, and

RM6100 and identified potential restorers with *Pi54* target gene and the potential restorers were planned for hybrid development. Katara *et al.,* (2017) also screened 570 Indian-rice varieties for the identification of restorer genes using DRRM-RF3-10 and RM6100 and identified 40 potential restorers. In another study thirty-one (31) tropical *japonica-derived* rice hybrids were screened and distinguished into *Rf3, Rf4,* and *Rf3* + *Rf4* hybrids (Shidenur *et al.,* 2020).

Nagaraju *et al.,* (2021) also screened seventy-one (71) BILs derived from drought-tolerant parents for fertility restoration using *Rf4* and *Rf3* markers RM6100, RMS-PPR-9-1, DRCG-Rf4-14, for *Rf4* and DRRM-RF3-10, RM10313, and RMS-SF21-5 for *Rf3* respectively and identified ten restorers with *Rf4* and *Rf3* alleles in combination. Several other findings from various rice accessions screened for fertility restoration have reported the efficiency of *Rf4* and *Rf3* frequencies. Based on all the above outcomes these markers for *Rf4* and *Rf3* can be considered to speed up the breeding program of restorer lines in rice (Rashid *et al.,* 2019; Balaji Suresh *et al.,* 2012).

Conclusion

Based on genotyping for Saltol and fertility restoration the BILs TCP38, TCP45, TCP46, TCP48, TCP54, TCP56, TCP57-1, TCP60, and TCP61 were found to possess Saltol+*Rf4*+*Rf3*. Therefore, *Rf4* and *Rf3* were found to be the major fertility-restoring genes based on many research findings including our experiment. These genes were proved to restore complete fertility and play a major role in the three-line breeding of rice. The *Saltol* introgressed hybrids may confer salinity tolerance, especially in saline-prone rice ecosystems with superior yield heterosis.

References

Anis Galal Bakr. 2019. Assessment of Genetic Variability and Identification of FertilityRestoration Genes *Rf3, Rf4* of WA-CMS in RILs Population of Rice. *Journal of Applied Sciences,* 19: 199–209. https://www.scialert.net/abstract/?doi=jas.2019.199.209

Balaji Suresh, P, Srikanth B, Hemanth Kishore V, Subhakara Rao I, Vemireddy LR, Dharika N, Sundaram RM, Ramesha MS, Sambasiva Rao KRS, Viraktamath BC and Neeraja CN. 2012. Fine Mapping of Rf3 and Rf4 Fertility Restorer Loci of WA-CMS of Rice (Oryza sativa L.) and Validation of the Developed Marker System for Identification of Restorer Lines. Euphytica, 187: 421–35.

Katara JL, RL Verma, D Nayak, N Umakanta, S Ray, H Subudhi, L Bahera, Sanghamitra S, Ravi NR, ON Singh, T Mohapatra.2017. Frequency and Fertility Restoration Efficiency of *Rf3* and *Rf4* Genes in Indian Rice. *Plant Breeding,* 136: 74–82.

Nagaraju P, Beulah P, Manasa Y, Jaldhani V, Madhusudan N, Sundaram RM, Hari Prasad AS, Revathi P, Kemparaju KB, Sruthi K, Srinivas A, Prashant S, Someswar Rao S, Sheshu Madhav M, Senguttuvel P. 2021. Evaluation of improved drought-tolerant parental lines of KMR3R for fertility restoration by molecular analysis. *Journal of Rice Research,* 14: 1-7

Nagamani V, N Shivakumar, and T E Nagaraja. 2022. Marker-assisted selection of potential restorers among red kernel rice (*Oryza sativa* L .) genotypes and evaluation of test cross progenies for their pollen and spikelet fertility. *The Pharma Innovation Journal,* 11: 57–64.

Nath Anirban, Disharee Nath, Chand Kumar Santra, and Tapash Dasgupta. 2020. Identification of suitable restorers for WA-CMS lines of rice (*Oryza sativa* L.) through conventional and molecular breeding methods. *Agricultural Science Digest,* 40: 249–54.

Neeraja CN. 2008 Restorer fertility gene (*Rf3* and *Rf4*) reported marker RM10313. *DRR Annual Report,* 2008-2009.

Pranathi K, BC Viraktamath, CN Neeraja, SM Balachandran, AS Hariprasad, P Koteswara Rao, P Revathi, P Senguttuvel, SK Hajira, CH Balachiranjeevi, *et al.* 2016. Development and validation of candidate gene-specific markers for the major fertility restorer genes, *Rf4* and *Rf3* in rice. *Molecular Breeding,* 36:145. https://doi.org/10.1007/s11032-016-0566-8

Ramalingam J, Palanisamy S, Alagarasan G, Renganathan VG, Ramanathan A, and Saraswathi R. 2020. Improvement of stable restorer lines for blast resistance through functional marker in rice (*Oryza sativa* L.). *Genes,* 11: 1–13.

Rashid A, Sofi NR, Shikari AB, Khan GH, Waza SA, Sheikh FA, Parray GA, Bhat MA, Sofi M and Hussain A. 2019. Developing rice hybrids for temperate conditions using three line approach. *Indian Journal of Genetics and Plant Breeding,* 79: 25–33.

Shidenur S, Singh VJ, Vinod KK, Krishnan SG, Ghritlahre SK, Bollinedi H, Dixit BK, Ellur RK, Nagarajan M, Singh AK, Bhowmick PK. 2020. Enhanced grain yield in rice hybrids through complementation of fertility restoration by *Rf3* and *Rf4* genes as revealed by multilocation evaluation of tropical Japonica-derived rice (*Oryza Sativa*) hybrids. *Plant Breeding,* 139: 743–53.

Singh AK, Mahapatra T, Prabhu KV, Singh VP, Zaman FU, Mishra GP, Nandakumar N, Joseph M, Gopalakrishnan S, Aparajita G, Tyagi NK, Prakash P, Sharma RK, Shab US, Singh SK. 2005. Application of molecular markers in rice breeding: progress at IARI. Advances in marker-assisted selection workshop. Trainee's manual, Handouts and references.

Thakur VJS, Revathi P, Arum Kumar S, V Gouri Shankar, D Srinivasa Chary. 2021. Molecular tagging of *Rf* genes for the fertility restoration of WA-CMS system by bulk segregant analysis in rice. *Indian Journal of Genetics and Plant Breeding,* 81: 43–49.

USDA, 2021; https://www.fas.usda.gov/commodities/rice

Venkanna V, Y Hari, K Rukmini Devi, G Shravan and T Shasthree. 2022. Marker-assisted selection for two major fertility restorer genes in promising Warangal rice genotypes. *The Pharma Innovation Journal*, 11: 240-242.

RESEARCH ARTICLE https://doi.org/10.58297/CVTL7441

Assessment of Genetic Variability, Heritability and Genetic Advance for Grain Yield and Other Yield Attributing Traits in Elite Lines of Rice (*Oryza sativa* L.)

Sindhura NRH[1]*, Ravi Kumar BNVSR[2], Dayal Prasad Babu J[3] and Raju MRB[4]

[1]Department of Genetics and Plant Breeding, Agricultural College
Bapatla-522101, Andhra Pradesh, India
[2]Department of Genetics and Plant Breeding, RARS, Maruteru, 534122
West Godavari District, India
[3]Department of Genetics and Plant Breeding, ANGRAU, Lam, Guntur - 522034, India
[4]Department of Plant Pathology, RARS, Maruteru- 534122, West Godavari District, India
*Corresponding author's Email: ruthhepsisindhura@gmail.com

Received: 30th July 2022; Accepted: 20th August 2022

Abstract

The present investigation was carried out during *Kharif*, 2021 at Regional Agricultural Research Station (RARS), Maruteru, with an objective to study the genetic parameters and magnitude of variability for yield enhancement. The experimental material comprised of 88 elite lines including checks namely, Maruteru Samba (MTU 1224), Sravani (MTU 1239), Maruteru Mahsuri (MTU 1262), Improved Samba Mahsuri, Swarna, TN1 and Krishnaveni which were evaluated in alpha lattice design with two replications. Observations on days to 50 % flowering, plant height (cm), ear bearing tillers per m^2, panicle length (cm), number of grains per panicle, test weight (g), spikelet fertility (%) and grain yield per plant (g) were recorded. The analysis of variance among 88 elite lines revealed the presence of significant differences for all 8 characters indicating the existence of variability in the material. The mean performance of the elite lines studied for yield and yield components revealed that the lines AM885, AM891 and AM913 significantly outperformed the superior yield check Sravani for panicle length, ear-bearing tillers per m^2, number of grains per panicle, test weight, and grain yield per plant. The genetic parameters revealed that high heritability coupled with high genetic advance as per cent of mean for the traits days to 50% flowering, plant height, panicle length, test weight, spikelet fertility and grain yield per plant.

Keywords: Genetic variability, Heritability, Genetic advance, Elite lines, Grain yield

Introduction

Rice (*Oryza sativa* L. 2n=2x=24) is the most important food crop that provides a significant portion of carbohydrates to the world's population. The world's population growth has exceeded the growth rate in food-grain production. The demand for rice is still increasing in Asia as the consumption rate is at least 90% and it is globally projected that the demand for rice will rise to 650 million tonnes by 2050 (Chukwu *et al*., 2019).

The availability of sufficient variability and its proper use through breeding techniques are crucial for any successful crop improvement programme. Important factors in the genetic improvement of plant populations are the amount of genetic variability and the degree to which traits are heritable. The amount of variability present in the germplasm can be determined using genetic parameters like the genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV). Heritability estimates give accurate information about the consistency with which a specific genetic trait will be transmitted to succeeding generations. High heritability values suggest that the studied traits are less influenced by the environment.

Heritability coupled with genetic advance is a more reliable and useful genetic parameter in predicting genetic gain under selection than heritability values alone (Bhargavi *et al.*, 2021).

Material and Methods

The experimental material comprised 88 elite lines including checks namely, Maruteru Samba (MTU 1224), Sravani (MTU 1239), Maruteru Mahsuri (MTU 1262), Improved Samba Mahsuri, Swarna, TN1 and Krishnaveni were evaluated at Regional Agricultural Research Station (RARS), Maruteru, West Godavari district of Andhra Pradesh. It is located at 81.44^0 E longitude, 26.38^0 N latitude and 5 m above mean sea level, in Godavari Zone of Acharya N. G. Ranga Agricultural University. The present experiment was laid out in Alpha lattice design with two replications. All the 88 elite lines including checks were randomized in 11 blocks with a block size of eight *i.e.,* each block consists of eight genotypes. Observations were recorded on five randomly selected plants in each genotypewithout border effect as per the methodology given in SES, IRRI, (2014). The average values obtained for each character were subjected to statistical analysis.

Statistical analysis

Analysis of variance is a technique by which total variation present in data is divided into two components: variation due to assignable factors and variation due to non-assignable factors. The ANOVA of 88 elite lines including checks showed the presence of highly significant differences among the lines for all the characters studied *viz.*, days to 50% flowering, plant height (cm), ear bearing tillers per m^2, panicle length (cm), number of grains per panicle, test weight (g), spikelet fertility (%) and grain yield per plant (g) at 1% level denotes considerable variation in the material being studied (**Table 1**).

Table 1. Analysis of variance for yield and yield component traits

Source of variation	d.f	Mean sum of squares							
		Days to 50% flowering	Plant height (cm)	Ear bearing tillers per m^2	Panicle length (cm)	Number of grains per panicle	Test weight (g)	Spikelet fertility (%)	Grain yield per plant (g)
Replications	1	0.57	0.90	261.67	0.14	3.01	0.36	0.38	6.19
Treatments	87	193.69**	383.41**	2295.21**	18.73**	279.50**	7.63**	149.83**	21.86**
Blocks (b)	20	1.52	11.86	262.10	0.53	6.57	0.28	0.94	1.54
Experimental error	67	1.63	10.54	411.35	0.68	5.30	0.29	0.70	1.82
Total	175	197.40	406.71	3230.33	20.08	294.38	8.57	151.85	31.41

* Significance at 5% level, ** Significance at 1% level

Results and Discussion

Days to 50% flowering ranged from 81 days for AM855 to 114 days for AM902 with a mean value of 99 days. A total of 23 elite lines showed significantly fewer days to 50% flowering than the yield check Sravani. The plant height ranged from 94 cm (Improved Samba Mahsuri) to 156 cm (Sravani) with a mean of 132 cm. Ear-bearing tillers per m^2 ranged from 182 (AM924) to 360 (AM904), with a mean value of 274. Panicle length in the present study ranged from 21 cm (Nellore Mahsuri) to 35 cm (AM884) with a mean of 28 cm. The range for the number of grains per panicle was observed between 114 (AM865) to 162 (AM845) with a mean of 134.2. Test weight of the elite lines ranged from 15.0 g (AM853) to 23.5 g (AM924, AM896) with an overall mean value of 18.0 g (**Table 2**). The trait value ranged from 62.1% (BM549) to 94.5% (TN1) with a mean value of 83.0%. In the

Table 2. Mean performance of elite lines for yield and yield components

S. No.	Entry	DFF (days)	PH (cm)	EBT/m^2	PL (cm)	GP	TW (g)	SF (%)	YP (g)
1	AM 844	105	145	218	28	161	16.4	86.5	19.70
2	AM 845	104	146	195	32	162	17.0	68.0	22.00
3	AM 846	106	149	227	32	136	18.4	91.3	17.30
4	AM 847	96	133	206	28	159	17.1	79.9	19.59
5	AM 848	108	154	254	31	153	16.9	86.3	18.52
6	AM 849	98	141	244	29	154	17.0	86.2	18.55
7	AM 850	105	147	244	29	157	15.8	83.8	18.10
8	AM 852	92	133	261	29	146	15.3	66.0	15.15
9	AM 853	82	122	267	23	142	15.0	70.4	11.25
10	AM 854	82	130	274	24	142	15.3	68.9	16.15
11	AM 855	81	106	281	24	129	17.0	90.7	16.55
12	AM 856	81	118	248	26	130	16.7	85.0	13.42
13	AM 857	81	108	271	24	158	17.0	91.0	23.09
14	AM 858	82	118	273	23	146	16.3	81.2	15.82
15	AM 859	81	117	267	25	140	17.8	81.9	17.86
16	AM 860	92	122	267	26	143	15.3	71.0	17.36
17	AM 861	82	102	284	24	131	18.8	87.9	21.13
18	AM 863	84	112	274	25	122	17.2	89.2	12.17
19	AM 864	83	123	314	24	129	17.8	76.5	19.31
20	AM 865	82	107	228	26	114	19.0	86.1	12.04
21	AM 866	83	125	264	24	147	17.2	90.7	18.30
22	AM 867	84	118	267	27	144	17.1	93.8	19.66
23	AM 868	82	113	271	22	122	16.2	79.8	14.68
24	AM 869	89	115	231	28	132	16.9	83.3	13.87
25	AM 870	89	119	264	25	146	16.9	71.5	17.69
26	AM 871	88	115	281	27	145	17.5	63.7	22.68
27	AM 873	103	141	271	29	159	16.5	84.2	22.89
28	AM 874	100	143	261	32	149	16.2	64.0	15.24
29	AM 875	98	145	199	30	141	17.0	92.4	14.65
30	AM 876	102	136	310	26	147	16.6	91.3	23.84
31	AM 877	101	135	330	29	137	17.3	91.7	19.01
32	AM 879	104	148	254	27	155	16.5	85.8	17.81
33	AM 880	101	151	257	29	150	18.4	81.8	22.21
34	AM 881	98	149	251	28	152	17.3	90.3	20.03
35	AM 882	112	146	290	26	150	16.0	87.9	21.23
36	AM 883	84	131	274	30	134	19.4	75.8	26.47

S. No.	Entry	DFF (days)	PH (cm)	EBT/m^2	PL (cm)	GP	TW (g)	SF (%)	YP (g)
37	AM 884	98	119	248	35	125	19.5	88.2	15.65
38	AM 885	109	133	307	35	143	18.2	75.1	23.51
39	AM 886	100	127	248	30	120	19.7	85.7	13.09
40	AM 887	100	143	294	32	132	19.1	75.2	21.91
41	AM 888	109	145	272	34	135	18.5	84.5	20.57
42	AM 890	113	147	248	31	127	20.1	89.8	16.18
43	AM 891	102	134	317	31	138	18.5	91.1	24.38
44	AM 892	109	132	310	30	123	20.5	81.7	21.70
45	AM 893	113	142	248	26	121	20.8	92.6	15.91
46	AM 894	109	140	327	32	125	20.1	94.0	23.06
47	AM 895	100	132	287	31	129	19.9	88.1	19.42
48	AM 896	111	143	314	26	121	23.5	88.7	16.94
49	AM 897	109	146	310	30	132	18.9	90.6	18.20
50	AM 898	101	135	248	27	124	22.2	90.9	20.83
51	AM 900	109	141	271	30	126	21.4	85.8	19.26
52	AM 901	110	127	300	29	120	19.2	78.0	18.30
53	AM 902	114	140	287	30	138	17.5	65.0	19.09
54	AM 903	113	133	333	31	128	18.8	67.2	18.85
55	AM 904	110	142	360	31	126	18.0	75.9	21.85
56	AM 905	99	144	310	27	125	20.3	92.7	20.11
57	AM 906	108	137	248	30	128	18.8	71.0	15.51
58	AM 907	108	132	317	29	123	22.5	84.8	23.10
59	AM 908	110	110	231	25	122	20.6	81.5	16.73
60	AM 910	105	151	281	29	142	18.5	89.0	21.95
61	AM 911	108	127	248	28	123	20.5	83.7	18.95
62	AM 912	104	139	297	28	131	18.6	81.0	23.12
63	AM 913	104	144	310	34	138	18.3	91.7	23.45
64	AM 914	106	143	310	32	132	18.0	90.5	24.12
65	AM 915	99	136	317	31	124	18.0	94.1	17.23
66	AM 916	106	123	318	28	131	17.7	74.5	18.86
67	AM 918	105	148	294	29	130	18.1	78.2	19.44
68	AM 919	104	123	248	29	119	18.6	70.6	12.41
69	AM 920	99	143	304	32	122	20.5	80.6	22.56
70	AM 921	97	138	310	28	125	21.3	92.2	21.51
71	AM 922	98	135	292	30	126	20.5	89.8	21.79
72	AM 923	96	134	241	31	118	22.5	75.7	15.86
73	AM 924	92	139	182	33	114	23.5	74.7	11.00

S. No.	Entry	DFF (days)	PH (cm)	EBT/m^2	PL (cm)	GP	TW (g)	SF (%)	YP (g)
74	BM 519	98	138	257	31	136	18.5	86.5	20.51
75	BM 529	100	138	281	27	131	20.3	86.9	22.09
76	BM 530	102	139	235	31	119	21.0	71.9	16.44
77	BM 542	100	147	254	29	132	18.8	88.8	21.73
78	BM 544	99	133	267	31	139	18.8	84.2	20.59
79	BM 546	100	144	238	29	120	21.2	86.4	14.50
80	BM 549	109	130	267	26	134	17.3	62.1	16.98
81	Maruteru Samba (YC)	98	115	314	25	137	15.9	67.0	18.94
82	Sravani (YC)	96	156	281	29	133	16.8	94.3	21.22
83	Maruteru Mahsuri (YC)	108	136	269	29	137	17.1	81.1	19.18
84	Nellore Mahsuri	88	112	314	21	135	15.1	91.7	20.10
85	TN 1 (BSC)	85	118	292	24	123	20.9	94.5	19.30
86	Improved Samba Mahsuri (BRC)	96	94	314	22	133	16.0	88.5	17.35
87	Swarna (BRC)	110	118	314	24	125	18.3	91.8	19.30
88	Krishnaveni (BSC)	109	98	281	27	131	17.3	85.8	17.85
Minimum		**81**	**94**	**182**	**21**	**114**	**15.0**	**62.1**	**11.00**
Maximum		**114**	**156**	**360**	**35**	**162**	**23.5**	**94.5**	**26.47**
Mean		**99**	**132**	**274**	**28**	**134.2**	**18.0**	**83.0**	**18.84**
CV%		**1.3%**	**2.50%**	**7.40%**	**2.9%**	**1.70%**	**2.90%**	**1%**	**7.20%**
C.D. (0.05)		**2.51**	**6.54**	**38.59**	**1.59**	**4.7**	**1.06**	**1.72**	**2.63**

DFF-days to 50% flowering, PH - plant height, EBT - ear bearing tillers per m^2, PL - panicle length, GP - number of grains per panicle, TW - test weight, SF - spikelet fertility, YP - yield per plant, YC - Yield Check; BSC - BLB Susceptible Check; BRC - BLB Resistant Check , C.V % = Coefficient of variation per cent , C.D. = Critical Difference.

present study, the grain yield per plant ranged from 11.00 g (AM924) to 26.47 g (AM883) with an overall mean value of 18.84 g.

Moderate genotypic and phenotypic coefficient of variation was observed for the traits like plant height (GCV = 10.34, PCV = 10.63), ear-bearing tillers per m^2 (GCV = 11.30, PCV = 13.33), panicle length (GCV = 10.62, PCV = 10.99), test weight (GCV = 10.46, PCV = 10.86), spikelet fertility (GCV = 10.40, PCV = 10.46) and grain yield per plant (GCV = 16.84, PCV = 18.24) indicating that these traits can be improved by vigorous selection. Less variation between the GCV and PCV values indicates the environment's insignificant influence. Similar results were observed by Sandeep *et al*. (2018), Divya *et al*. (2020), Gupta *et al*. (2022) and Lavanya *et al*. (2022).

As suggested by Johnson *et al.* (1955), heritability in the broad sense is categorized into Low (0-30%), Moderate (31-60%) and High (More than 60%). High heritability along with high genetic advance as per cent of mean was recorded for the traits like days to 50% flowering (h^2 (bs) = 98.36%, GAM= 20.25), plant height (h^2 (bs) = 94.50%, GAM= 20.70), panicle length (h^2 (bs) = 93.36%, GAM = 21.14), test weight (h^2 (bs) = 92.71%, GAM = 20.74), spikelet fertility (h^2 (bs) = 90.00%, GAM = 21.33) and grain yield per plant (h^2 (bs) = 85.16%, GAM = 32.00). This provides evidence that this trait was under the control of additive gene effects and selection may be effective. Sandeep *et al*. (2018), Divya *et al*. (2020), Keerthiraj *et al*. (2020), and Lavanya *et al*. (2022) reported similar results. High heritability along with moderate genetic advance as per cent of mean was recorded for the traits like ear bearing tillers per m^2 (h^2 (bs) = 71.78%, GAM= 19.72) and number of grains per panicle (h^2 (bs) = 96.08%, GAM= 17.61) indicating the existence of additive and non-additive gene actions (**Table 3**). Simple phenotypic selection has no role in the genetic improvement of this character. Similar outcomes were reported by Islam *et al*. (2015) and Parimala and Devi (2019).

Table 3. Variability, heritability and genetic advance as per cent of mean for grain yield in rice

S. No.	Characters	Range		Mean	CV%	C.D. (0.05)	Coefficient of variation		Heritability	GAM
		Minimum	Maximum				GCV	PCV		
1	Days to 50% flowering	81	114	99	1.30%	2.51	9.91	9.99	98.36%	20.25
2	Plant height	94	156	132	2.50%	6.54	10.34	10.63	94.50%	20.7
3	Ear bearing tillers per m^2	182	360	274	7.40%	38.59	11.3	13.33	71.78%	19.72
4	Panicle length	21	35	28	2.90%	1.59	10.62	10.99	93.36%	21.14
5	No. of grains per panicle	114	162	134	1.70%	4.7	8.72	8.9	96.08%	17.61
6	Test weight	15	23.5	18	2.90%	1.06	10.46	10.86	92.71%	20.74
7	Spikelet fertility	62.1	94.5	83	1%	1.72	10.4	10.46	99.00%	21.33
8	Grain yield per plant	11	26.47	18.84	7.20%	2.63	16.84	18.24	85.16%	32.00

C.V % = Coefficient of variation per cent, C.D. = Critical Difference, PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, GAM = Genetic advance as per cent of mean.

Conclusion

The superior yield check Sravani with the highest spikelet fertility was outperformed by the lines AM 885, AM 891 and AM 913 for the traits panicle length, ear bearing tillers per m^2, number of grains per panicle, test weight and grain yield per plant. The traits such as days to 50% flowering, plant height, panicle length, test weight, spikelet fertility and grain yield per plant, which had high heritability and genetic advance, are controlled by additive gene action. Selection for these traits with high heritability and genetic advance will accumulate more additive genes, further enhancing their performance.

References

Bhargavi M, Shanthi P, Reddy VL, Reddy MD and Reddy RB. 2021. Estimates of genetic variability, heritability and genetic advance for grain yield and other yield attributing traits in rice (*Oryza sativa* L.). *The Pharma Innovation Journal*, 10: 507-11.

Chukwu SC, Rafii MY, Ramlee SI, Ismail SI, Oladosu Y, Okporie E, Onyishi G, Utobo E, Ekwu L, Swaray S and Jalloh M. 2019. Marker-assisted selection and gene pyramiding for resistance to bacterial leaf blight disease of rice (*Oryza sativa* L.). *Biotechnology & Biotechnological Equipment*, 33: 440-55.

Divya T and Pandey DP. 2020. Genetic variability for yield and quality traits in local germplasm of rice of Himachal Pradesh. *Journal of Cereal Research*, 12: 157-9.

Gupta H, Purushottam GY, Yadav SK and Singh S, Kumar S. 2022. Genetic variability, heritability and genetic advance for yield and its related traits in rainfed upland rice (*Oryza sativa* L.) genotypes. *The Pharma Innovation Journal*, 11: 2520-2524.

Islam MA, Raffi SA, Hossain MA and Hasan AK. 2015. Analysis of genetic variability, heritability and genetic advance for yield and yield-associated traits in some promising advanced rice lines. *Progressive Agriculture*, 26: 26-31.

Johnson HW, Robinson HF and Comstock RE. 1955. Estimation of genetic and environmental variability in soybean. *Agronomy Journal*, 47: 314-318.

Keerthiraj B and Biju S. 2020. Genetic variability, heritability and genetic advance of yield and lodging-related traits in rice (*Oryza sativa* L.). *Electronic Journal of Plant Breeding*, 11: 1093-8.

Parimala K and Devi KR. 2019. Estimation of variability and genetic parameters in indica and japonica genotypes of rice (*Oryza sativa* L.). *International Journal of Current Microbiology and Applied Sciences*, 8: 1138-42.

Sandeep S, Sujatha M, Subbarao LV and Neeraja CN. 2018. Genetic variability, heritability and genetic advance studies in rice (*Oryza sativa* L.). *International Journal of Current Microbiology and Applied Science*, 7: 3719-27.

Lavanya K, Suman K, Abdul Fiyaz R, Chiranjeevi MC, Ramamurthy S, Satya A, Sudhakar P and Subba Rao LV. 2022. Phenotypic assessment of rice landraces for genetic variability and diversity studies under heat stress. *Oryza,* 59: 31-38.

Standard Evaluation System for Rice (SES), International Rice Research Institute (IRRI), 2014.

RESEARCH ARTICLE https://doi.org/10.58297/BNWT2744

Genetic Analysis for Yield and Yield Attributing Traits in *Oryza glaberrima* Derived Introgression Line and O. *sativa* cv. Samba Mahsuri

Udaya V [1,2], Reddi Sekhar M[2], Laha GS[1], Reddy VLN[2], Sudhakar P[3] and Gireesh C[1]*

[1]ICAR-Indian Institute of Rice Research
[2]S. V. Agricultural College, Tirupati, Acharya N G Ranga Agricultural University (ANGRAU)
[3]Acharya N G Ranga Agricultural University (ANGRAU)
Corresponding author Email: giri09@gmail.com

Received: 2nd October 2022; Accepted: 5th December 2022

Abstract

Rice (*Oryza sativa* L.) is one of the most important staple food crops of the world and the yield of rice is stagnated for several decades because of a narrow genetic base. African cultivated species, *Oryza glaberrima*, is a potent source for broadening the genetic base of *O. sativa* cultivars. In this investigation, a total of 232 F_2 population derived from a cross between *O. glaberrima* derived introgression line and *O. sativa* cv. Samba Mahsuri was characterised by yield and yield-attributing traits. A great range of variability was noticed for the number of tillers, number of panicles, and yield per plant. The PCV values were on par with GCV for all yield and yield-attributing variables, indicating a low environmental influence. High heritability coupled with moderate to high GAM was recorded in all traits, indicating the presence of additive gene effect and direct selection of these characters might be effective. Panicle length (0.18**), the number of tillers (0.29**), and panicles (0.31**) found a significant positive correlation with yield per plant. The findings of the current study have demonstrated the usefulness of *O. glaberrima* germplasm and its potential for use in the genetic development of *indica* rice varieties, specifically for the yield-enhancing trait.

Keywords: *Oryza glaberrima, O. sativa*, Variability, Heritability, Hybridization

Introduction

Rice (*Oryza sativa* L.), is a major cereal crop, and roughly one-half of the world's population depends on rice. In India, 122.27 million tonnes of rice were produced in an area of 45.07 million hectares in the year 2021 (https://desagri.gov.in). It is also the most affordable source of carbohydrates and calories (Srijan *et al*., 2016; Lingaiah *et al*., 2020). The demand for rice production is rising along with the population. However, rice yield stagnated in the last several decades. In India, the yield of rice was 1901 kg/ha in 2000–21; it was 2239 kg/ha in 2010–11; and, was 2713 kg/ha in 2020–21 (https://desagri.gov.in), indicating low genetic gain over the period of time despite intensive breeding efforts. This could be mainly due to the narrow genetic base of parental lines in breeding programmes. So, it is imperative to broaden the genetic base of rice cultivars to break the yield ceiling limit in rice production to meet increasing rice demand.

African rice (*O. glaberrima*) is known to possess useful traits for the genetic enhancement of *indica* cultivars. However, *O. glaberrima* is not extensively utilised in *indica* improvement programs even after the successful story of NERICA (New Rice for Africa) in India, due to sterility barriers in interspecific hybridization, linkage drag and other challenges in interspecific crosses (Sarla and Swamy, 2005; Maji and Shaibu, 2012; Lakshmi *et al*., 2019). The *O. glaberrima* is used rarely in India to improve the genetics of indica rice. In this study, the F_2 population derived from the cross between *O. glaberrima* introgressed line and *O. sativa* cv. Samba Mahsuri was characterised by yield-enhancing traits. The study revealed selection parameters to be employed in the selection and promising plants for yield-enhancing traits.

The fundamental aim of the plant breeder is the development of a high-yielding and wide genetic base variety, in that context selection parameters play a crucial part in the introgression of useful traits during the breeding program. Key selection criteria for selecting superior varieties include genetic variability, correlation, heritability, genetic advance, and genetic advance over a mean (Ali *et al*., 2002). To maximise the utilisation of the relationships in the selection, it is essential to understand the link between yield and yield constituent qualities. (Sarawgi *et al*., 1997).

Samba Mahsuri (BPT-5204), a popular mega-variety of rice is grown extensively in India, especially in the southern belt. It is a medium-slender grain with outstanding cooking qualities. However, Samba Mahsuri yield levels plateaued (Basavaraj *et al*., 2020). The enormous genetic variability in the *Oryza* genus could aid in the improvement of rice varieties, and in this light, African rice would be a useful tool for *O. sativa* varietal improvement (Bharamappanavara *et al*., 2020). As a result, the current investigation sought to evaluate variability and identify a relationship between yield and yield constituting traits in the F_2 population of the cross between *O. glaberrima* introgressed line and *O. sativa* cv. Samba Mahsuri.

Materials and Methods

Plant material and population development

The present study was conducted at the ICAR-Indian Institute of Rice Research, Hyderabad in *Kharif* 2020, *Rabi* 2020-21, and *Kharif* 2021. Introgression line derived from IR64*1/*O. glaberrima* in BC_2F_4 was selected as the donor (male) parent and was crossed to *O. sativa* cv. Samba Mahsuri in *Kharif* 2020. *O. glaberrima* (EC861812) was used as a donor as it showed resistance to few biotic stresses over seasons and also has cross-compatibility with *O. sativa* cv. Samba Mahsuri. The true F_1 confirmed (**Figure 1**) by parental polymorphic SSR marker RM 169 (F: 5'-TGGCTGGCTCCGTGGGTAGCTG-3', R: 5'TCCCGTTGCCGTTCATCCCTCC-3'; Tm-58^0C; positive – 130 bp; negative – 169 bp) was selfed to develop F_2 seeds during *Rabi* 2020-21. The 232 F_2 seeds and parents were sown and transplanted with a single seedling per hill in an un-replicated design, spaced 20cm × 15cm apart in *Kharif* 2021 in an irrigated ecology. All the agronomic practices were followed as recommended by ICAR – IIRR (https://www.icar-iirr.org/index.php/en/) to raise the good crop.

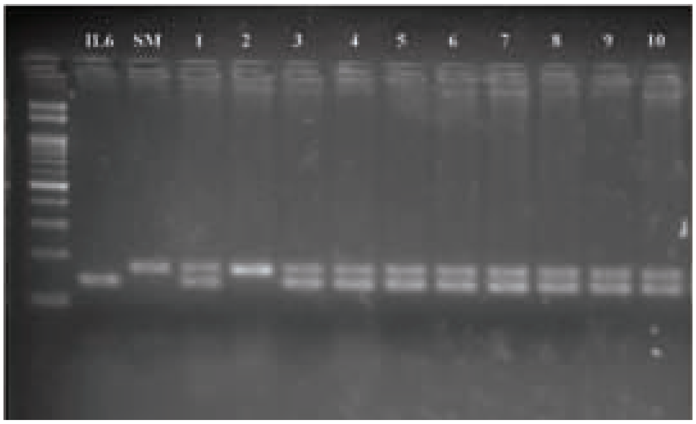


Figure 1: Hybrid confirmation of 10 F1 plants along with parents (IL6 and Samba Mahsuri) by SSR (RM169) marker

Observations and Statistical analysis

The observations were recorded at maturity stage for seven yield and yield constituent traits namely plant height (cm), panicle length (cm), number of tillers, number of panicles, flag leaf length (cm), flag leaf breadth (cm), and yield per plant (g). The collected F_2 data were subjected to different statistical analyses. The PCV and GCV were calculated according to Burton and Dewane (1953). Heritability was calculated following Falconer (1981). The genetic advance was calculated according to Johnson *et al*. (1955). Principal Component Analysis (PCA) and correlation coefficients were calculated using Past (v4.0). The transgressive index is the range of phenotypic differences between both the parents and the phenotypic range in the F_2 population. The index was calculated by the difference between the maximum and minimum values in the F_2 population by the parental (male and female) difference.

Results and Discussion

Genetic variability of yield and yield constitute traits

O. glaberrima, will serve as a donor for the identification and introgression of many economical traits for the genetic improvement of Asian cultivated species. However, utilization of *O. glaberrima*, in *O. sativa* breeding is hampered by high sterility in interspecific F_1 and could be overcome by repeated backcrosses (Bharamappanavara *et al*., 2020).

Any effective plant breeding programme depends on genetic variability. The most efficient way to create and preserve genetic variability is by crossing genetically diverse parents and selecting from the early generation. In the present experiment, the F_2 population derived from *O. glaberrima* introgression lines and popular *O. sativa* cv. Samba Mahsuri had shown high variability to yield and yield constitute traits (**Table 1** and **Figure 2**). The frequency distribution of yield and yield attributing traits that depicted the variation were presented in **Figures 3** and **4**.

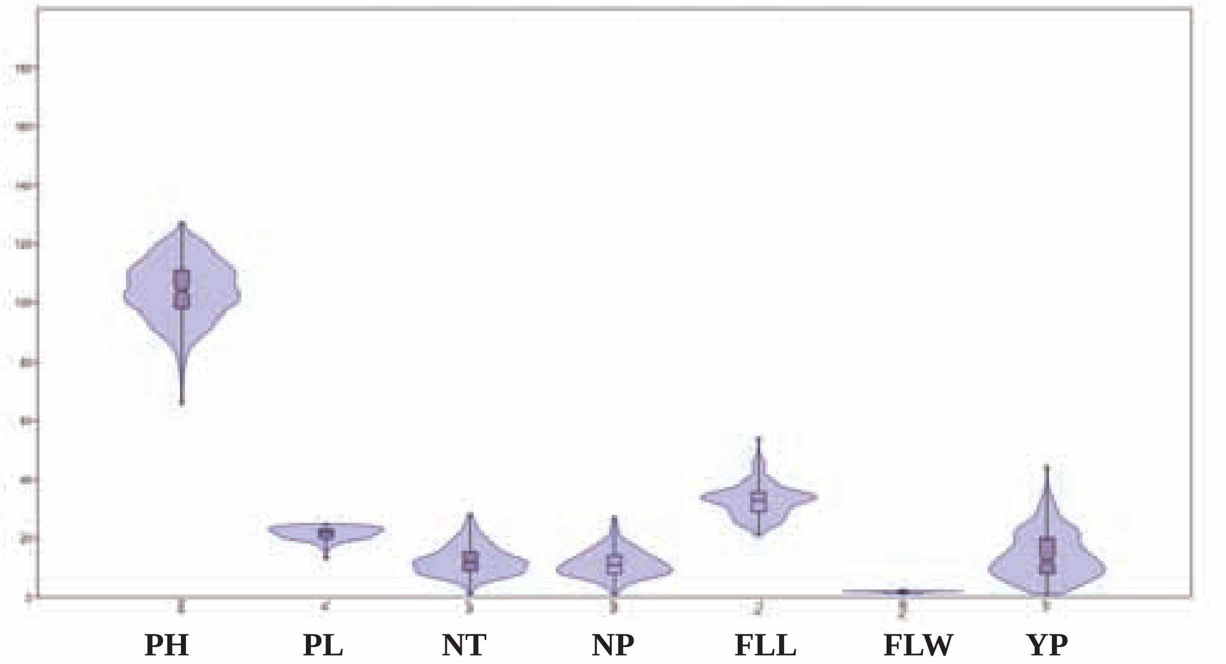
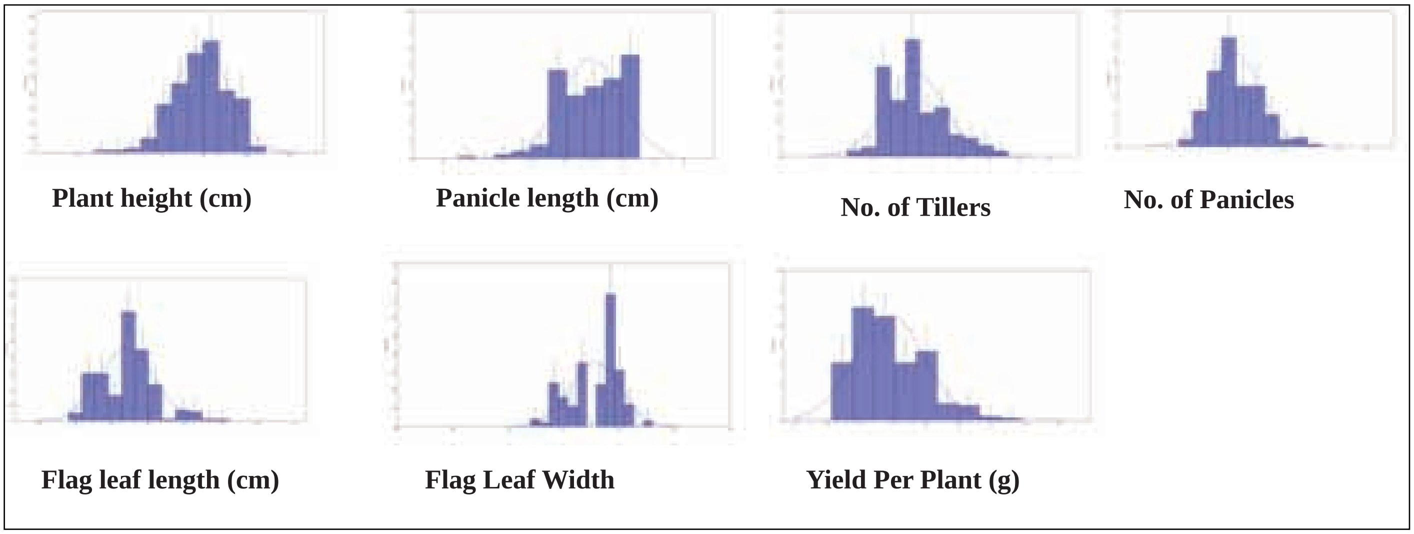


Figure 2: Violin and Box Plots for depicting genetic variability for yield and yield attributing traits in F_2 population derived from cross between IL 6 and Samba Mahsuri

PH- Plant height, PL-Panicle length (cm), NT-Number of tillers, NP-No. of panicles, FLL-Flag leaf length (cm), FLW-Flag leaf width (cm), YP- Yield Per plant (g)



Plant height (cm)

Panicle length (cm)

No. of Tillers

No. of Panicles

Flag leaf length (cm)

Flag Leaf Width

Yield Per Plant (g)

Figure 3: Frequency distribution of yield and yield attributing traits in F_2 population derived from cross between IL6 and Samba Mahsuri

Table 1. Genetic variability parameters for yield and yield attributing traits in F_2 population derived from cross between IL6 and Samba Mahsuri

Sl. No.	Trait		Range			PCV		GCV		$h^2_{(BS)}$		GA	GAM	
		Mean	Min.	Max.	SE	(%)	Category	(%)	Category	(%)	Category		(%)	Category
1	PH	103.984	66.000	127.000	0.652	9.570	Low	9.486	Low	98.20	High	20.141	19.369	Moderate
2	PL	21.796	13.000	25.000	0.135	9.458	Low	8.521	Low	81.20	High	3.447	15.814	Moderate
3	NT	12.475	1.000	28.000	0.329	40.235	High	37.958	High	89.00	High	9.203	73.767	High
4	NP	11.327	1.000	27.000	0.291	39.168	High	36.437	High	86.50	High	7.910	69.825	High
5	FLL	32.925	21.000	54.000	0.363	16.820	Moderate	16.058	Moderate	91.10	High	10.398	31.581	High
6	FLW	1.778	1.200	2.300	0.015	12.575	Moderate	12.282	Moderate	95.40	High	0.440	24.714	High
7	YP	14.232	1.000	44.250	0.526	56.375	High	55.618	High	97.30	High	16.088	113.033	High

PH-Plant height (cm), PL-Panicle length (cm), NT-Number of tillers, NP-No. of panicles, FLL-Flag leaf length (cm), FLW-Flag leaf width (cm) YP- Yield Per plant (g)

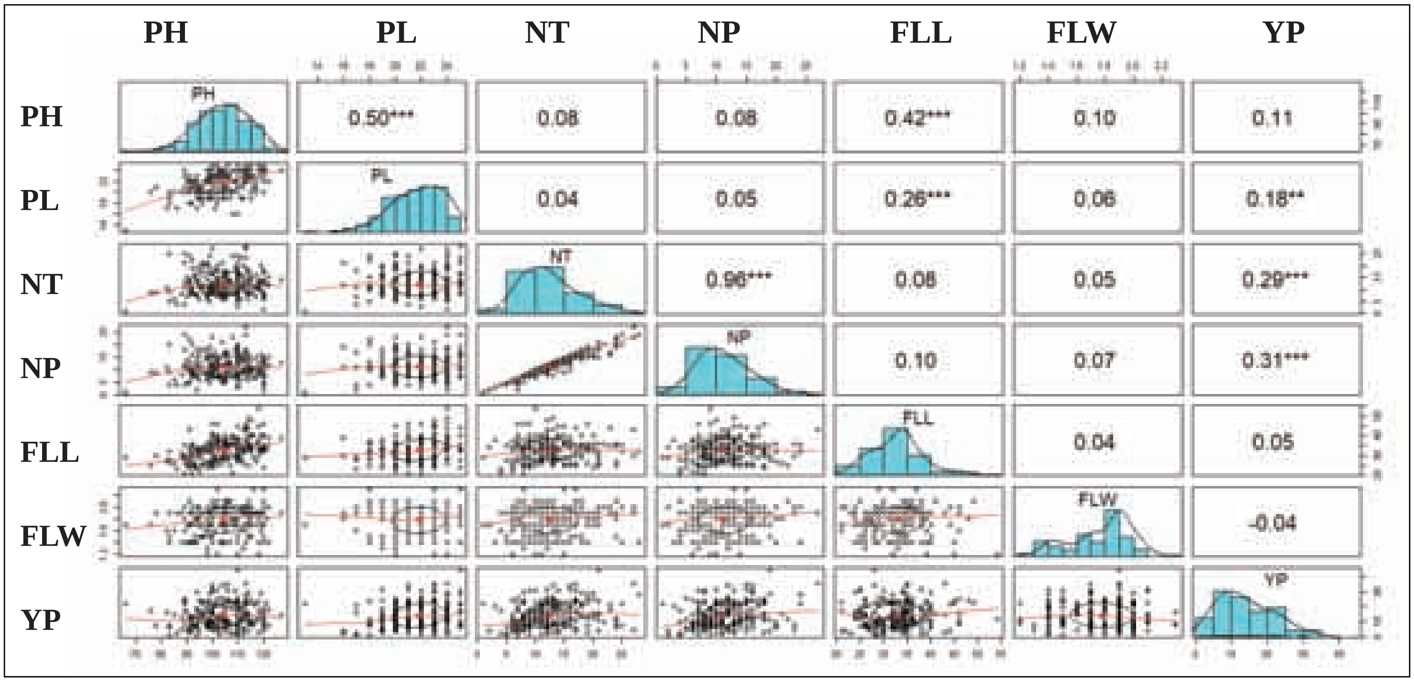


Figure 4: Frequency distribution, scatter diagram and correlation between yield and yield attributing traits in F_2 population derived from cross between IL 6 and Samba Mahsuri

PH- Plant height (cm), PL-Panicle length (cm), NT-Number of tillers, NP-No. of panicles, FLL-Flag leaf length (cm), FLW-Flag leaf width (cm) YP- Yield Per plant (g)

In the present study, plant height (cm) varied from 66.00 cm to 127.00 cm with a mean of 103.98 cm. Plant height is a significant factor influencing grain yield (Piao *et al.*, 2014). The majority of dwarf rice types are high yielding, do not lodge, and include the Dee-geo-woo-gen, semi-dwarfing gene, *sd1* (Poehlman and John, 1987). This characteristic has a modest phenotypic and genotypic variability (PCV- 9.570%, GCV- 9.486 %) indicating less variability for the trait. High broad sense heritability (98.20%) and virtually high genetic advance as a per cent of the mean (GAM -19.369%) were noticed in this case, showing the presence of additive gene activity for which selection is favourable in this case. The findings were consistent with those of Balakrishnan *et al.*, 2016 (GAM-3.18%, h^2 96.22%) and Basavaraj *et al.*, 2020 (GAM-34.50%, h^2-92.73%).

An important predictor of rice yield is panicle length. In rice, panicle length is a crucial factor in determining panicle architecture and grain yield (Liu *et al.*, 2016). The length of the panicle ranged from 13 to 25 cm with a mean value of 21.796 cm. There was less phenotypic and genotypic variability for panicle length (PCV- 9.458%, GCV-8.521%), indicating less variation for this character in the F_2 population. High heritability (81.20%) and moderate GAM (15.814%) were observed indicating additive gene action. This result was similar to the findings of Balakrishnan *et al.*, (2016) who reported GAM-2.20%, h^2 14.73% and Basavaraj *et al.*, (2020) with a GAM-32.56%, h^2-98.50%.

Because the number of tillers impacts the number of panicles, it is one of the most important features that can be exploited to obtain a high yield. Grain yield and biomass both have a strong relationship with the number of productive tillers (Basavaraj *et al.*, 2020). The number of tillers varied from 1 to 28 with a mean of 12.475. We found high phenotypic (PCV: 40.235%) and genotypic variation (GCV: 37.958%). High broad sense heritability (89.00%) was observed with high GAM (73.767%) indicating a predominance of additive gene action and advancing improvement through direct selection would be fruitful, which is in line with the conclusions of Edukondalu *et al.*, (2017; GAM-34.87%, h^2-95.00%) and Basavaraj *et al.*, (2020; GAM-67.58%, h^2-85.40%).

Grain yield is positively associated by the number of panicles (Balakrishnan *et al*., 2016). Tillers and panicles are typically numerous on *O. glaberrima* and its derived lines (Sarla and Swamy, 2005). In the current investigation, panicle counts ranged from 1 to 27, with a mean of 11.327. A high level of phenotypic (39.168%) and genotypic variability (36.437%) was noticed for this trait. For this character, high heritability (86.50%) and high GAM (69.825%) were observed which was similar to the findings of Abebe *et al*., (2017; GAM-4.10%, h^2-18.24%) and Basavaraj *et al*., (2020; GAM-67.58%, h^2-85.4).

The width and length of the flag leaf are crucial characteristics that affect rice grain output. Flag leaf breadth has a low range of variability (1.200 to 2.300 cm); however, flag leaf length has a high range of variability (21.000 to 54.000 cm), indicating the wide range of variation of this trait. Flag leaf length had high heritability (91.10%) and high GAM (31.581%) suggesting direct selection. We noticed high heritability (95.40%) and high GAM (24.714%) in flag leaf breadth as well, demonstrating the existence of additive gene action where pedigree selection can be used.

Yield per plant is a complex quantitative trait governed by multiple genes. The ultimate goal of plant breeders is high yield. The yield per plant values in the current study ranged from 1 to 44g with a mean of 14.232g and have substantial phenotypic and genotypic variation (PCV-56.375%, GCV-55.618%) along with high heritability (97.30%) and high GAM (113.033). The outcomes showed that the direct selection for this attribute would be quite successful. An identical set of results were reported by Abebe *et al*., (2017; GAM-27.77%, h^2-54.35%) and Basavaraj *et al*., (2020; GAM-89.27%, h^2-96.81).

Association study between yield and yield constitute traits

It is essential to understand the relationship between yield and its component parts in order to select the best genotype and identify the other contributing factors that influence yield. The length of the panicle (0.18**), the number of tillers (0.29**), and the number of panicles (0.31**) are all correlated with the grain yield (**Figure 4**). It was also interesting to note that flag leaf length had a significant positive association with panicle length (0.26**) and plant height (0.42**). The number of tillers has a significant positive association with the number of panicles (0.96**).

Through the selection of its yield-associated trait, which is indirectly and strongly connected, there is a chance of enhancing yield (Lakshmi *et al*., 2020, Basavaraj *et. al*., 2020). The results of the association study showed that panicle length, the number of tillers, and panicles can be used as criteria for choosing plants with higher yields as they were related to one another and showed a positive significant correlation (**Figure 4**). The current findings were in line with the findings of Thippeswamy *et al*., (2016) Priya *et al*., (2017) and Basavaraj *et. al*. (2020).

Principal component analysis

The first six main components in the current study accounted for 99.60% of the overall variability. PCA revealed PC1, PC2 and PC3 as important principal components with eigenvalues of 2.255, 1.692 and 1.020 which contributed to 71.00 per cent of the total variance for all the characters (**Table 2**) capturing important aspects of the data set. The component’s Eigen-values of less than one was disregarded because they are unlikely to be of any practical significance. Based on principal component 1, no. of tillers (0.565), no. of panicles (0.574) and yield per plant (0.344) had relatively higher contributions (32.200%) to the total morphological variability. While the second major component was responsible for 24.200% of the total morphological variability. In this plant height (0.551), panicle length (0.507), and flag leaf length (0.430) contributions more to variability. Principle component 3 contributes to 14.600 % of the total variation in which flag leaf width (0.899) contributes to the highest variation.

PCA analysis was done to assess the relationship among lines for characterization using the first, second and third principal components for the F_2 population. Selection of traits *viz.*, plant height, panicle length,

Table 2. Principal component analysis of yield and yield attributing traits in F_2 population derived from cross between IL6 and Samba Mahsuri

Parameter	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Eigenvalue	2.255	1.692	1.020	0.868	0.676	0.452	0.0373
Variance explained (%)	32.200	24.200	14.600	12.400	9.700	6.500	0.500
Cumulative (%)	32.200	56.400	70.900	83.400	93.000	99.500	100.000
Plant Height (cm)	0.300	0.551	0.010	0.053	-0.185	0.754	0.006
Panicle Length (cm)	0.267	0.507	-0.124	-0.308	-0.484	-0.572	-0.003
No. of Tillers	0.565	-0.353	0.075	0.172	-0.164	-0.015	-0.702
No. of Panicles	0.574	-0.344	0.079	0.148	-0.131	-0.026	0.711
Flag Leaf Length (cm)	0.252	0.430	0.013	0.547	0.599	-0.306	-0.012
Flag Leaf Width (cm)	0.087	0.091	0.899	-0.369	0.194	-0.04	-0.015
Yield Per Plant (g)	0.344	-0.057	-0.405	-0.645	0.539	0.088	-0.023

PC= Principal Component

flag leaf length and flag leaf width lying in these three principal components would **(Figure 5)** be beneficial in contributing to the total diversity. The results were in accordance with Worede *et al*., (2014) in 24 rice genotypes, with the first and second PCs accounting for 61.2% of the overall variability. In *O. glaberrima* accessions Lakshmi *et al*., (2019) described 54.752% of the total variance with the first two principal components.

Transgressive Segregants

Transgressive segregation results in phenotypes that are superior to those of the parents. As a result of segregation and recombination, such plants are created by the accumulation of favourable genes from both the parents. Extreme phenotypes brought on by transgressive segregation, in contrast to heterosis, are heritably stable. In the current study, out of 232 F_2 plants, we identified 172, 82, 65, 130, 119, and 62

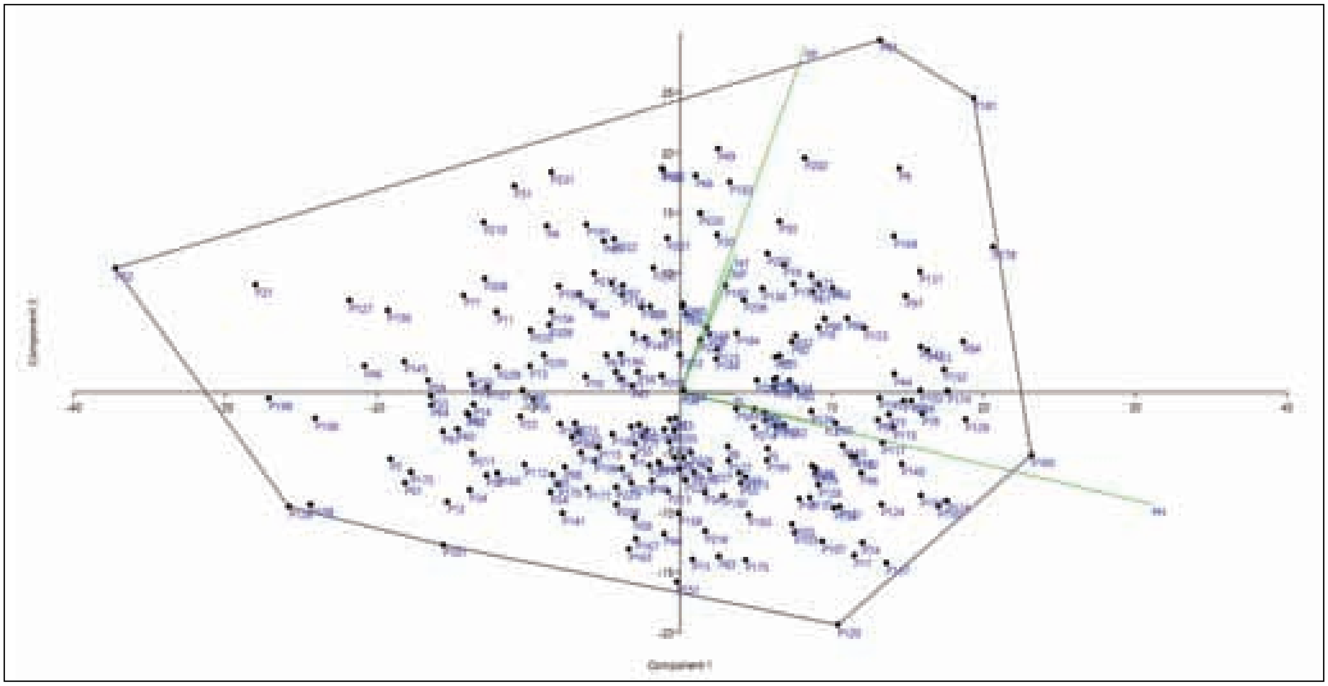


Figure 5: PCA biplot based on yield and yield attributing traits in F_2 population derived from cross between IL 6 and Samba Mahsuri

transgressive segregants for panicle length, tillers, panicles, flag leaf length, flag leaf width, and yield per plant respectively (**Table 3**). We have identified four F_2 plants (F_2-131, F_2-169, F_2-181 and F_2-231) which were transgressive segregants for all yield and yield attributing traits, which were highlighted in the **Supplementary Table 1**. Such transgressions may occur because certain F_2 populations have accumulated complimentary alleles from both parents at multiple loci (Tanksley,1993) and also unmasking of recessive deleterious genes due to inbreeding (Rick and Smith, 1953).

The transgressive index between IL6 and Samba Mahsuri for various yield and yield component traits was high, demonstrating that many plants from the F_2 generation outperformed their parents for various traits. Similar outcomes were noted by Koide *et al.,* (2019). This clearly shows that the parents had different genes governing yield and its component traits. Our study demonstrates that *O. glaberrima* contributes to yield-enhancing traits and could be employed as donor for genetic improvement of *O. sativa* cultivars for yield-enhancing traits. Hence, there is a lot of scope to introduce beneficial alleles from *O. glaberrima* into *O. sativa* cultivars through selection in later generations for yield and yield constituent traits.

Table 3. Transgressive segregants for yield and yield attributing traits in F_2 population derived from cross between IL6 and Samba Mahsuri

Sl. No.	Trait	Parents (Mean)		Range of F_2 population		Number of transgressive Segregants	Transgressive Index
		Samba Mahsuri	BRIL 6	Minimum	Maximum		
1.	Panicle Length (cm)	20.330	20.580	13.00	25.00	172.000	48.000
2	No. of Tillers	13.000	13.330	1.00	28.00	82.000	81.818
3.	No. of Panicles	13.000	12.380	1.00	27.00	65.000	41.935
4.	Flag Leaf Length (cm)	32.000	25.000	21.00	54.00	130.000	4.714
5.	Flag Leaf Width (cm)	1.700	1.800	1.20	2.30	119.000	11.000
6.	Yield Per Plant (g)	19.650	16.620	1.00	44.25	62.000	14.274

Conclusion

To break yield limitations in modern rice cultivars, related species of rice can be utilized to widen the genetic base. The present research showed that *O. glaberrima* could be utilised to genetically improve elite rice cultivars for increasing yield, and resulting transgressive segregants might be employed as pre-breeding material. The transgressive segregants can be assessed in subsequent generations, and the promising lines could be used in further breeding work. It is clear from the study that *O. glaberrima* has contributed to yield-enhancing traits and could be utilized as a donor for the genetic improvement of *O. sativa.*

Acknowledgments

The authors are thankful to the Director, ICAR-IIRR for providing the lab and field facilities for the successful conduct of this research. The first author extends his sincere thanks to the Director of Research, Associate Dean, and Head of the Genetics and Plant Breeding Department, S.V. Agricultural College, Tirupati, ANGRAU for allowing him to conduct his research at ICAR-IIRR, Hyderabad and also providing valuable suggestions during his research work.

References

Abebe T, Alamerew S and Tulu L. 2017. Genetic variability, heritability and genetic advance for yield and its related traits in rainfed lowland rice (*Oryza sativa* L.) genotypes at Fogera and Pawe, Ethiopia. *Advances in Crop Science and Technology,* 5: 272. DOI: 10.4172/2329-8863.1000272.

Agricultural Statistics at a Glance. 2021. Government of India Ministry of Agriculture & Farmers Welfare Department of Agriculture & Farmers Welfare Directorate of Economics & Statistics. https://desagri.gov.in

Ali Z, Khan AS and Asad MA. 2002. Salt tolerance in bread wheat: genetic variation and heritability. *Asian Journal of Plant Sciences*, 1:420-422.

Balakrishnan D, Robin S, Rabindran R and Joel AJ. 2016. Molecular and Morphological Characterisation of Back Cross Generations for Yield and Blast Resistance in Rice. *Rice Research: Open Access,* 4:169. Doi:10.4172/2375-4338.1000169.

Basavaraj PS, Gireesh C, Muralidhar B, Manoj A, Anantha MS and Raju CD. 2020. Genetic analysis of backcross derived lines of *Oryza rufipogon* in the background of Samba Mahsuri for yield-enhancing traits in rice. *Electronic Journal of Plant Breeding,* 11:1120-1127. https://doi.org/10.37992/2020.1104.181.

Bharamappanavara M, Siddaiah AM, Ponnuvel S, Ramappa L, Patil B, Appaiah M, Maganti SM, Sundaram RM, Shankarappa SK, Tuti MD and Banugu S. 2020. Mapping QTL hotspots associated with weed competitive traits in backcross population derived from *Oryza sativa* L. and *O. glaberrima* Steud. *Scientific reports,* 10: 1-13. https://doi.org/10.1038/s41598-020-78675-7.

Edukondalu B, Reddy VR, Rani TS, Kumari CA and Soundharya B. 2017. Studies on variability, heritability, correlation and path analysis for yield, yield attributes in rice (*Oryza sativa* L.). *International Journal of Current Microbiology and Applied Sciences,* 6: 2369-2376. doi: https://doi.org/10.20546/ijcmas.2017.610.279.

Falconer DS. 1981. An Introduction of Quantitative Genetics- Second edition. Oliver and Boyd, Edinburgh. 312-324.

Johnson HW, Robinson HF and Comstock RE. 1955. Estimates of genetic and environmental variability in soybeans. *Agronomy Journal,* 47:314-318.

Koide Y, Sakaguchi S, Uchiyama T, Ota Y, Tezuka A, Nagano AJ, Ishiguro S, Takamure I. and Kishima Y. 2019. Genetic properties responsible for the transgressive segregation of days to heading in rice. *G3: Genes, Genomes, Genetics,* 9:1655-1662. https://doi.org/10.1534/g3.119.201011.

Lakshmi VI, Sreedhar M, Vanisri S, Anantha MS, Rao LS and Gireesh C. 2019. Multivariate analysis and selection criteria for identification of African rice (*Oryza glaberrima*) for genetic improvement of indica rice cultivars. *Plant Genetic Resources,* 17:499-505. doi:10.1017/S1479262119000327.

Lingaiah N, Chandra BS, Venkanna V, Devi KR and Hari Y. 2020. Genetic variability and correlation studies in yield traits of elite rice (*Oryza sativa* L.) genotypes. *Indian Journal of Pure and Applied Biosciences,* 8: 359-363. doi: http://dx.doi.org/10.18782/2582-2845.8428

Liu E, Liu Y, Wu G, Zeng S, Tran, Thi TG, Liang L, Liang Y, Dong Z, She D, Wang H and Zaid IU. 2016. Identification of a candidate gene for panicle length in rice (*Oryza sativa* L.) via association and linkage analysis. *Frontiers in plant science,* 7: 596. https://doi.org/10.3389/fpls.2016.00596.

Maji AT and Shaibu AA. 2012. Application of principal component analysis for rice germplasm characterization and evaluation. *Journal of Plant Breeding and Crop Science,* 4:87-93.

Marri PR, Reddy LV and Siddiq EA. 2005. Identification and mapping of yield and yield-related QTLs from an Indian accession of *Oryza* *rufipogon*. *BMC Genetics*, 6:1-14. https://doi.org/10.1186/1471-2156-6-33.

Piao R, Chu SH, Jiang W, Yu Y, Jin Y, Woo MO, Lee J, Kim S and Koh HJ. 2014. Isolation and characterization of a dominant dwarf gene, Dh, in rice. *PLoS One*, 9(2). e86210. https://doi.org/10.1371/journal.pone.0086210.

Poehlman I and John M. 1987. Breeding Field Crops. Oxford and IBH Publishing. 2: 5-8.

Priya CS, Suneetha Y, Babu DR and Rao SV. 2017. Inter-relationship and path analysis for yield and quality characters in rice (*Oryza sativa* L.). *International Journal of Science, Environment and Technology*, 6:381-390.

Rick CM and Smith PG. 1953. Novel variation in tomato species hybrids. *The American Naturalist*, 87:359-373.

Sarawgi AK, Rastogi NK and Soni DK. 1997. Correlation and path analysis in rice accessions from Madhya Pradesh. *Field Crops Research*, 52:161-167.

Sarla N and Swamy BM. 2005. *Oryza glaberrima*: a source for the improvement of *Oryza sativa*. *Current science*, 89:955-963.

Shaikh S, Umate S, Syed AJ and Deosarkar DB. 2017. Study on genetic variability, heritability and genetic advance in rice (*Oryza sativa* L.) genotypes. *International Journal of Pure and Applied Bioscience*, 5: 511- 515.

Srijan A, Kumar SS, Raju CD and Jagadeeshwar R. 2016. Character association and path coefficient analysis for grain yield of parents and hybrids in rice (*Oryza sativa* L.). *Journal of Applied and Natural Science*, 8:167-172.

Thippeswamy S, Mohan CY, Srinivas B and Padmaja D. 2016. Selection of diverse parental lines for heterotic hybrid development in rice (*Oryza sativa* L.). *SABRAO Journal of Breeding and Genetics*, 48:285-294.

Worede F, Sreewongchai T, Phumichai C and Sripichitt P. 2014. Multivariate analysis of genetic diversity among some rice genotypes using morpho-agronomic traits. *Journal of Plant Sciences*, 9:14-24.

Supplementary Table 1. Mean values of F_2 Population (BRIL6 X SM) for yield and yield attributing characters during *Kharif*, 2021

Sl. No.	Plant Code	Plant Height (cm)	Panicle Length (cm)	No. of Tillers	No. of Panicles	Flag Leaf Length (cm)	Flag Leaf Width (cm)	Yield Per Plant (g)	BB Lesion Length (cm)
1.	F_2-1	100.00	22.00	27.00	23.00	30.00	2.00	4.57	1.52
2.	F_2-2	88.00	20.00	8.00	8.00	29.00	1.90	5.00	1.85
3.	F_2-3	99.00	23.00	11.00	11.00	26.00	1.70	23.38	2.30
4.	F_2-4	94.00	23.00	8.00	8.00	24.00	1.70	29.50	2.44
5.	F_2-5	110.00	25.00	16.00	16.00	36.00	1.70	7.70	1.90
6.	F_2-6	102.00	21.00	8.00	8.00	34.00	1.90	9.00	0.75
7.	F_2-7	104.00	21.00	8.00	8.00	29.00	2.00	10.42	4.75
8.	F_2-8	110.00	16.00	21.00	19.00	30.00	1.90	4.24	9.60
9.	F_2-9	113.00	25.00	28.00	24.00	32.00	1.40	28.31	3.70
10.	F_2-10	99.00	20.00	24.00	19.00	35.00	1.50	11.14	1.20
11.	F_2-11	92.00	22.00	19.00	16.00	26.00	1.40	13.27	2.62
12.	F_2-12	95.00	20.00	6.00	6.00	22.00	2.00	3.92	5.50
13.	F_2-13	96.00	19.00	11.00	11.00	26.00	1.50	14.20	2.92
14.	F_2-14	93.00	20.00	15.00	12.00	26.00	1.80	7.49	3.33
15.	F_2-15	110.00	22.00	9.00	9.00	30.00	2.00	1.55	2.85
16.	F_2-16	112.00	23.00	13.00	12.00	32.00	2.00	22.60	1.85
17.	F_2-17	120.00	23.00	8.00	8.00	32.00	2.00	6.10	1.00
18.	F_2-18	115.00	22.00	12.00	10.00	32.00	2.00	7.76	1.20
19.	F_2-19	109.00	22.00	9.00	8.00	30.00	1.70	30.65	0.55
20.	F_2-20	102.00	20.00	20.00	15.00	36.00	1.90	25.00	1.00
21.	F_2-21	76.00	20.00	9.00	9.00	25.00	1.70	17.19	0.75
22.	F_2-22	94.00	20.00	13.00	11.00	34.00	1.70	8.53	2.60
23.	F_2-23	102.00	21.00	13.00	13.00	27.00	1.90	20.60	2.66
24.	F_2-24	98.00	20.00	6.00	6.00	34.00	1.70	6.91	7.10
25.	F_2-25	104.00	20.00	11.00	11.00	26.00	1.90	20.15	1.50
26.	F_2-26	104.00	23.00	12.00	12.00	35.00	1.80	20.02	1.16
27.	F_2-27	100.00	22.00	9.00	9.00	46.00	2.00	9.01	1.05
28.	F_2-28	104.00	22.00	6.00	6.00	34.00	1.80	6.32	8.00
29.	F_2-29	105.00	24.00	8.00	7.00	34.00	1.70	11.46	5.25
30.	F_2-30	106.00	25.00	14.00	13.00	34.00	1.90	30.57	5.10
31.	F_2-31	89.00	21.00	21.00	18.00	30.00	2.00	23.58	8.00
32.	F_2-32	94.00	19.00	8.00	8.00	32.00	1.90	5.57	7.23

Sl. No.	Plant Code	Plant Height (cm)	Panicle Length (cm)	No. of Tillers	No. of Panicles	Flag Leaf Length (cm)	Flag Leaf Width (cm)	Yield Per Plant (g)	BB Lesion Length (cm)
33.	F_2-33	89.00	21.00	11.00	11.00	29.00	1.80	9.28	10.43
34.	F_2-34	92.00	22.00	8.00	7.00	35.00	1.70	4.15	11.54
35.	F_2-35	102.00	24.00	8.00	8.00	34.00	1.90	11.51	1.88
36.	F_2-36	102.00	22.00	14.00	13.00	32.00	1.90	8.79	7.00
37.	F_2-37	110.00	24.00	11.00	10.00	34.00	1.90	22.87	3.63
38.	F_2-38	102.00	22.00	15.00	14.00	29.00	1.90	13.19	1.00
39.	F_2-39	108.00	24.00	10.00	9.00	40.00	1.70	18.43	0.75
40.	F_2-40	96.00	21.00	18.00	18.00	31.00	1.90	21.69	1.86
41.	F_2-41	106.00	22.00	9.00	9.00	28.00	1.90	9.68	1.80
42.	F_2-42	102.00	21.00	14.00	13.00	34.00	1.90	20.80	1.70
43.	F_2-43	117.00	21.00	11.00	11.00	27.00	1.90	10.99	2.44
44.	F_2-44	116.00	21.00	11.00	10.00	40.00	1.90	21.53	3.44
45.	F_2-45	102.00	25.00	11.00	11.00	40.00	1.90	6.10	5.50
46.	F_2-46	85.00	20.00	6.00	6.00	26.00	1.60	14.47	0.47
47.	F_2-47	100.00	24.00	11.00	11.00	35.00	1.90	14.36	0.13
48.	F_2-48	104.00	21.00	9.00	8.00	34.00	1.40	14.16	0.34
49.	F_2-49	100.00	23.00	16.00	16.00	35.00	1.90	34.00	0.88
50.	F_2-50	110.00	21.00	16.00	16.00	39.00	1.80	23.81	8.08
51.	F_2-51	90.00	22.00	7.00	5.00	27.00	1.70	4.58	2.46
52.	F_2-52	92.00	18.00	11.00	10.00	30.00	2.00	8.84	2.60
53.	F_2-53	110.00	25.00	8.00	8.00	32.00	1.90	22.59	3.35
54.	F_2-54	110.00	23.00	10.00	10.00	27.00	1.90	7.09	1.88
55.	F_2-55	110.00	24.00	7.00	7.00	34.00	1.90	10.98	2.00
56.	F_2-56	95.00	21.00	11.00	10.00	32.00	1.80	11.53	1.50
57.	F_2-57	110.00	23.00	6.00	6.00	32.00	1.40	24.00	1.05
58.	F_2-58	110.00	21.00	24.00	20.00	27.00	1.80	6.17	1.62
59.	F_2-59	88.00	20.00	8.00	8.00	31.00	1.40	12.95	1.82
60.	F_2-60	91.00	18.00	10.00	10.00	32.00	1.40	7.64	2.73
61.	F_2-61	110.00	21.00	17.00	15.00	35.00	1.50	23.10	2.50
62.	F_2-62	66.00	13.00	1.00	1.00	29.00	1.70	22.00	3.00
63.	F_2-63	100.00	22.00	17.00	16.00	25.00	1.50	30.59	3.20
64.	F_2-64	91.00	20.00	8.00	5.00	24.00	1.70	11.92	5.00
65.	F_2-65	98.00	23.00	11.00	9.00	34.00	1.90	17.38	6.50
66.	F_2-66	99.00	24.00	19.00	19.00	35.00	1.70	28.73	1.00

Sl. No.	Plant Code	Plant Height (cm)	Panicle Length (cm)	No. of Tillers	No. of Panicles	Flag Leaf Length (cm)	Flag Leaf Width (cm)	Yield Per Plant (g)	BB Lesion Length (cm)
67.	F_2-67	110.00	25.00	21.00	19.00	28.00	1.90	44.25	1.72
68.	F_2-68	110.00	22.00	11.00	10.00	34.00	1.90	15.26	0.48
69.	F_2-69	104.00	22.00	7.00	5.00	29.00	1.90	26.00	0.60
70.	F_2-70	100.00	25.00	9.00	7.00	24.00	2.00	16.56	2.00
71.	F_2-71	90.00	20.00	15.00	14.00	25.00	1.40	16.49	3.38
72.	F_2-72	100.00	23.00	11.00	11.00	40.00	1.50	10.97	7.14
73.	F_2-73	104.00	24.00	12.00	11.00	34.00	1.70	12.00	1.95
74.	F_2-74	120.00	20.00	7.00	4.00	34.00	2.10	9.37	2.34
75.	F_2-75	118.00	25.00	11.00	10.00	34.00	1.80	17.68	2.76
76.	F_2-76	106.00	22.00	13.00	11.00	28.00	1.70	7.23	1.40
77.	F_2-77	104.00	19.00	9.00	8.00	30.00	1.90	12.10	1.33
78.	F_2-78	120.00	23.00	18.00	14.00	35.00	1.50	14.25	1.00
79.	F_2-79	93.00	22.00	8.00	8.00	24.00	1.40	13.52	0.85
80.	F_2-80	112.00	22.00	20.00	16.00	32.00	1.70	12.33	5.90
81.	F_2-81	93.00	21.00	16.00	10.00	25.00	1.50	6.85	2.95
82.	F_2-82	98.00	22.00	14.00	14.00	32.00	1.60	21.10	0.56
83.	F_2-83	110.00	24.00	7.00	7.00	35.00	1.40	3.80	2.25
84.	F_2-84	118.00	23.00	14.00	13.00	45.00	1.40	23.56	0.70
85.	F_2-85	98.00	23.00	6.00	6.00	32.00	1.20	8.48	1.65
86.	F_2-86	110.00	20.00	15.00	14.00	45.00	1.20	22.51	1.13
87.	F_2-87	91.00	20.00	14.00	13.00	28.00	1.40	4.39	1.33
88.	F_2-88	100.00	21.00	8.00	8.00	28.00	1.50	8.00	0.40
89.	F_2-89	96.00	20.00	20.00	18.00	34.00	1.70	14.63	0.80
90.	F_2-90	98.00	19.00	20.00	18.00	24.00	1.80	15.64	2.20
91.	F_2-91	102.00	24.00	11.00	10.00	39.00	1.20	11.42	5.85
92.	F_2-92	110.00	22.00	16.00	14.00	34.00	1.90	18.80	6.65
93.	F_2-93	117.00	22.00	16.00	15.00	36.00	1.90	13.16	7.38
94.	F_2-94	105.00	23.00	7.00	6.00	38.00	1.90	5.04	0.67
95.	F_2-95	112.00	24.00	12.00	12.00	43.00	1.90	14.55	1.13
96.	F_2-96	118.00	24.00	12.00	8.00	33.00	1.90	12.11	0.67
97.	F_2-97	113.00	25.00	23.00	17.00	44.00	2.00	21.35	0.56
98.	F_2-98	111.00	24.00	23.00	16.00	35.00	1.90	18.00	5.30
99.	F_2-99	110.00	20.00	18.00	17.00	34.00	1.90	13.34	1.36
100.	F_2-100	102.00	21.00	12.00	11.00	29.00	1.90	9.31	0.88
101.	F_2-101	94.00	17.00	7.00	2.00	29.00	2.00	1.00	2.50

Sl. No.	Plant Code	Plant Height (cm)	Panicle Length (cm)	No. of Tillers	No. of Panicles	Flag Leaf Length (cm)	Flag Leaf Width (cm)	Yield Per Plant (g)	BB Lesion Length (cm)
102.	F_2-102	120.00	25.00	17.00	15.00	32.00	2.30	16.30	2.40
103.	F_2-103	114.00	23.00	6.00	6.00	37.00	1.90	8.39	2.66
104.	F_2-104	103.00	24.00	8.00	8.00	38.00	1.70	12.36	6.83
105.	F_2-105	116.00	23.00	8.00	7.00	29.00	2.30	8.00	1.33
106.	F_2-106	99.00	22.00	9.00	9.00	37.00	1.90	8.35	0.75
107.	F_2-107	118.00	23.00	13.00	13.00	30.00	1.90	2.87	0.90
108.	F_2-108	83.00	19.00	9.00	9.00	26.00	1.90	6.36	0.57
109.	F_2-109	86.00	17.00	4.00	4.00	23.00	1.90	2.33	0.75
110.	F_2-110	99.00	19.00	10.00	8.00	32.00	1.90	10.69	3.00
111.	F_2-111	100.00	24.00	11.00	11.00	32.00	1.70	14.82	2.38
112.	F_2-112	98.00	20.00	8.00	7.00	26.00	1.30	7.76	1.75
113.	F_2-113	100.00	20.00	10.00	8.00	34.00	1.50	9.71	1.17
114.	F_2-114	118.00	24.00	10.00	9.00	54.00	1.20	11.69	0.64
115.	F_2-115	119.00	24.00	13.00	11.00	33.00	1.60	15.44	0.55
116.	F_2-116	113.00	24.00	8.00	7.00	46.00	1.60	15.32	1.00
117.	F_2-117	119.00	24.00	10.00	10.00	32.00	1.90	15.41	0.15
118.	F_2-118	100.00	22.00	16.00	13.00	26.00	1.80	19.88	2.28
119.	F_2-119	110.00	24.00	21.00	18.00	32.00	1.80	11.46	3.52
120.	F_2-120	120.00	24.00	2.00	2.00	34.00	1.70	4.00	3.50
121.	F_2-121	114.00	23.00	17.00	15.00	44.00	1.70	3.94	2.65
122.	F_2-122	115.00	24.00	15.00	14.00	40.00	1.90	10.00	2.05
123.	F_2-123	115.00	23.00	12.00	10.00	48.00	1.80	23.86	0.14
124.	F_2-124	120.00	25.00	13.00	8.00	33.00	1.40	9.25	2.38
125.	F_2-125	105.00	19.00	15.00	9.00	36.00	1.40	18.77	0.43
126.	F_2-126	83.00	18.00	5.00	4.00	28.00	1.50	1.20	0.20
127.	F_2-127	82.00	17.00	11.00	11.00	28.00	1.60	16.33	1.53
128.	F_2-128	115.00	25.00	12.00	11.00	34.00	2.00	8.95	3.50
129.	F_2-129	122.00	22.00	12.00	12.00	39.00	1.40	17.77	2.90
130.	F_2-130	111.00	24.00	6.00	6.00	28.00	2.00	10.26	4.50
131.	F_2-131	113.00	23.00	19.00	18.00	46.00	1.90	25.14	1.88
132.	F_2-132	110.00	22.00	3.00	3.00	38.00	1.40	20.00	0.77
133.	F_2-133	113.00	22.00	14.00	14.00	39.00	1.60	22.37	0.13
134.	F_2-134	113.00	23.00	10.00	10.00	34.00	1.60	16.73	0.13
135.	F_2-135	115.00	20.00	9.00	9.00	35.00	1.70	9.72	0.83
136.	F_2-136	83.00	20.00	25.00	20.00	32.00	1.40	7.21	3.30

Sl. No.	Plant Code	Plant Height (cm)	Panicle Length (cm)	No. of Tillers	No. of Panicles	Flag Leaf Length (cm)	Flag Leaf Width (cm)	Yield Per Plant (g)	BB Lesion Length (cm)
137.	F_2-137	110.00	24.00	14.00	13.00	29.00	1.80	7.78	2.40
138.	F_2-138	105.00	21.00	18.00	17.00	40.00	1.40	21.07	0.84
139.	F_2-139	120.00	23.00	6.00	5.00	24.00	1.90	11.93	2.38
140.	F_2-140	120.00	25.00	14.00	13.00	34.00	1.90	11.13	0.63
141.	F_2-141	99.00	20.00	5.00	5.00	35.00	1.90	6.02	0.35
142.	F_2-142	114.00	24.00	13.00	13.00	49.00	2.10	22.49	1.00
143.	F_2-143	114.00	24.00	9.00	9.00	40.00	1.90	15.00	0.88
144.	F_2-144	105.00	23.00	16.00	12.00	35.00	1.70	16.32	1.10
145.	F_2-145	89.00	21.00	4.00	4.00	21.00	1.60	17.27	4.50
146.	F_2-146	107.00	20.00	13.00	13.00	25.00	1.40	19.93	3.10
147.	F_2-147	120.00	22.00	7.00	7.00	40.00	1.90	6.86	5.67
148.	F_2-148	110.00	22.00	7.00	7.00	35.00	1.90	17.26	1.48
149.	F_2-149	100.00	21.00	13.00	12.00	35.00	1.90	17.93	2.06
150.	F_2-150	120.00	24.00	9.00	9.00	46.00	1.90	11.48	1.50
151.	F_2-151	110.00	24.00	5.00	4.00	28.00	1.40	2.55	1.63
152.	F_2-152	121.00	24.00	12.00	11.00	33.00	1.80	22.18	0.17
153.	F_2-153	110.00	22.00	12.00	12.00	30.00	1.50	26.43	1.00
154.	F_2-154	111.00	24.00	11.00	9.00	33.00	1.60	19.00	2.80
155.	F_2-155	91.00	22.00	12.00	9.00	29.00	1.40	12.37	3.00
156.	F_2-156	94.00	21.00	14.00	13.00	32.00	1.70	17.61	1.30
157.	F_2-157	92.00	21.00	10.00	9.00	31.00	1.90	12.38	3.10
158.	F_2-158	107.00	19.00	14.00	10.00	34.00	1.80	3.11	5.68
159.	F_2-159	105.00	20.00	11.00	9.00	37.00	1.90	8.68	6.00
160.	F_2-160	127.00	24.00	14.00	13.00	39.00	1.90	14.70	2.63
161.	F_2-161	99.00	22.00	12.00	12.00	33.00	1.90	6.50	1.50
162.	F_2-162	118.00	25.00	13.00	13.00	36.00	1.90	17.29	0.75
163.	F_2-163	103.00	23.00	9.00	7.00	38.00	1.40	1.72	0.86
164.	F_2-164	118.00	24.00	13.00	13.00	38.00	1.80	17.48	0.52
165.	F_2-165	100.00	21.00	16.00	15.00	25.00	1.40	31.49	0.64
166.	F_2-166	100.00	24.00	11.00	10.00	26.00	1.40	8.87	5.48
167.	F_2-167	105.00	24.00	6.00	5.00	32.00	1.60	4.79	5.13
168.	F_2-168	110.00	24.00	13.00	12.00	35.00	1.90	26.41	7.13
169.	F_2-169	114.00	24.00	18.00	16.00	34.00	2.00	29.02	0.23
170.	F_2-170	98.00	23.00	7.00	6.00	34.00	2.00	7.27	0.57
171.	F_2-171	109.00	22.00	19.00	18.00	36.00	1.80	22.55	1.50

Sl. No.	Plant Code	Plant Height (cm)	Panicle Length (cm)	No. of Tillers	No. of Panicles	Flag Leaf Length (cm)	Flag Leaf Width (cm)	Yield Per Plant (g)	BB Lesion Length (cm)
172.	F_2-172	92.00	21.00	8.00	8.00	21.00	1.70	4.28	1.00
173.	F_2-173	110.00	23.00	19.00	18.00	34.00	1.90	2.82	3.94
174.	F_2-174	120.00	20.00	14.00	12.00	40.00	1.50	19.20	2.88
175.	F_2-175	112.00	22.00	11.00	9.00	35.00	1.70	1.80	3.32
176.	F_2-176	105.00	20.00	10.00	9.00	37.00	2.00	10.20	2.77
177.	F_2-177	100.00	20.00	9.00	9.00	35.00	1.70	5.79	0.75
178.	F_2-178	119.00	24.00	20.00	16.00	40.00	1.70	29.30	1.50
179.	F_2-179	114.00	24.00	11.00	11.00	36.00	1.90	10.37	0.17
180.	F_2-180	91.00	21.00	13.00	11.00	43.00	1.90	2.76	1.83
181.	F_2-181	113.00	24.00	27.00	27.00	43.00	1.90	35.57	0.86
182.	F_2-182	112.00	21.00	12.00	10.00	33.00	1.90	14.16	2.50
183.	F_2-183	104.00	21.00	13.00	12.00	28.00	1.90	34.00	2.46
184.	F_2-184	106.00	22.00	8.00	8.00	35.00	1.70	23.81	1.50
185.	F_2-185	112.00	19.00	12.00	12.00	33.00	1.30	4.58	1.75
186.	F_2-186	115.00	19.00	14.00	14.00	33.00	1.50	8.84	1.25
187.	F_2-187	101.00	23.00	10.00	10.00	28.00	1.60	22.59	2.88
188.	F_2-188	94.00	20.00	19.00	15.00	32.00	1.40	7.09	0.90
189.	F_2-189	97.00	22.00	9.00	9.00	33.00	1.50	10.98	1.25
190.	F_2-190	98.00	24.00	21.00	15.00	36.00	1.90	11.53	1.63
191.	F_2-191	95.00	19.00	17.00	16.00	30.00	1.50	24.00	0.80
192.	F_2-192	112.00	23.00	15.00	14.00	26.00	1.70	6.17	9.50
193.	F_2-193	114.00	23.00	8.00	8.00	25.00	1.50	12.95	2.50
194.	F_2-194	122.00	22.00	15.00	15.00	35.00	2.00	7.64	3.00
195.	F_2-195	117.00	20.00	7.00	7.00	36.00	1.70	21.80	2.65
196.	F_2-196	111.00	19.00	16.00	14.00	29.00	2.00	11.99	1.60
197.	F_2-197	104.00	21.00	15.00	15.00	35.00	1.80	22.53	5.50
198.	F_2-198	78.00	21.00	9.00	9.00	30.00	1.90	7.10	1.80
199.	F_2-199	96.00	20.00	21.00	18.00	25.00	1.70	15.47	2.00
200.	F_2-200	104.00	23.00	21.00	21.00	26.00	1.80	15.36	2.50
201.	F_2-201	100.00	23.00	12.00	12.00	41.00	2.10	15.16	12.50
202.	F_2-202	106.00	23.00	17.00	15.00	35.00	1.70	35.00	1.95
203.	F_2-203	106.00	21.00	17.00	17.00	35.00	1.70	24.81	2.34
204.	F_2-204	102.00	23.00	8.00	8.00	35.00	2.00	5.58	10.50
205.	F_2-205	106.00	21.00	13.00	13.00	29.00	2.00	9.84	12.50
206.	F_2-206	107.00	20.00	13.00	12.00	31.00	1.80	23.59	1.30

Sl. No.	Plant Code	Plant Height (cm)	Panicle Length (cm)	No. of Tillers	No. of Panicles	Flag Leaf Length (cm)	Flag Leaf Width (cm)	Yield Per Plant (g)	BB Lesion Length (cm)
207.	F_2-207	108.00	20.00	24.00	23.00	36.00	1.90	8.09	2.50
208.	F_2-208	91.00	18.00	24.00	22.00	25.00	2.10	11.98	2.80
209.	F_2-209	94.00	19.00	19.00	18.00	33.00	1.90	12.53	0.75
210.	F_2-210	89.00	23.00	13.00	12.00	26.00	1.80	25.00	11.75
211.	F_2-211	92.00	21.00	8.00	8.00	33.00	1.90	7.17	1.33
212.	F_2-212	102.00	24.00	18.00	15.00	36.00	2.10	13.95	2.70
213.	F_2-213	102.00	21.00	7.00	7.00	46.00	1.90	8.64	6.50
214.	F_2-214	110.00	22.00	9.00	8.00	33.00	2.00	15.20	4.60
215.	F_2-215	102.00	18.00	15.00	13.00	37.00	2.30	8.49	7.50
216.	F_2-216	108.00	16.00	12.00	11.00	39.00	1.80	2.55	2.00
217.	F_2-217	96.00	18.00	12.00	11.00	33.00	1.90	23.60	4.80
218.	F_2-218	106.00	23.00	12.00	12.00	36.00	2.00	7.10	0.90
219.	F_2-219	102.00	19.00	7.00	7.00	38.00	2.00	8.76	1.40
220.	F_2-220	100.00	19.00	12.00	10.00	38.00	2.10	31.65	2.20
221.	F_2-221	102.00	23.00	10.00	7.00	25.00	2.10	30.57	2.20
222.	F_2-222	98.00	23.00	17.00	15.00	26.00	1.90	23.58	13.50
223.	F_2-223	98.00	23.00	17.00	16.00	32.00	2.00	5.57	9.20
224.	F_2-224	106.00	23.00	8.00	8.00	35.00	2.10	9.28	3.00
225.	F_2-225	102.00	21.00	12.00	12.00	34.00	2.10	4.15	1.40
226.	F_2-226	106.00	23.00	9.00	8.00	34.00	2.00	11.51	4.90
227.	F_2-227	107.00	23.00	11.00	10.00	36.00	2.10	8.79	1.80
228.	F_2-228	108.00	22.00	8.00	7.00	21.00	2.00	22.87	2.40
229.	F_2-229	91.00	23.00	12.00	10.00	34.00	2.10	13.19	2.80
230.	F_2-230	94.00	22.00	7.00	7.00	34.00	1.80	18.43	11.50
231.	F_2-231	89.00	24.00	25.00	24.00	35.50	2.00	21.69	2.50
232.	F_2-232	92.00	18.00	22.00	20.00	36.00	2.00	9.68	10.40
233.	F_2-233	101.00	17.00	18.00	17.00	29.00	2.00	20.80	2.60
234.	F_2-234	105.00	23.00	17.00	16.00	30.00	2.10	10.99	9.40
235.	SM(P_1)	73.00	20.33	13.00	13.00	32.00	1.70	19.65	9.20
236.	BRIL6(P_2)	83.25	20.58	13.33	12.38	25.00	1.80	16.62	1.50
Min		66.00	13.00	1.00	1.00	21.00	1.20	1.00	0.13
Max.		127.00	25.00	28.00	27.00	54.00	2.30	44.25	13.50

RESEARCH ARTICLE https://doi.org/10.58297/PDTR9988

Studies on Genetic Variability, Heritability, Genetic Advance for Yield, and Yield Components in Rice Landraces

Pravallika Y[1]*, Ravi Kumar BNVSR[2], Aravind Kumar J[3] and Anand Kumar ADVSLP[4]

[1]Agricultural College-Bapatla, Acharya N.G. Ranga Agricultural University, Guntur 522101, India
[2]Department of Genetics and Plant Breeding, Regional Agricultural Research Station, Maruteru, 534122, India
[3]Department of Genetics and Plant Breeding, ICAR-Indian Institute of Rice Research, Rajendranagar, 500030, India
[4]Department of Entomology, Regional Agricultural Research Station, Maruteru, 534122, India
*Corresponding author's Email: pravallikashetty8991@gmail.com

Received: 30th July 2022; Accepted: 25th August 2022

Abstract

An investigation was carried out to study the variability, heritability, and genetic advance as per cent of mean for yield and yield components in 100 rice landraces along with four checks at Regional Agricultural Research Station, Maruteru during *Kharif*, 2021. Analysis of variance revealed significant differences among the landraces for all the characters indicating sufficient genetic variation in the experimental material under study. The studies on variability, heritability, and genetic advance as per cent mean revealed small differences between GCV and PCV that were recorded for all the characters studied, indicating less environmental influence on these characters. Moderate levels of PCV and GCV, high heritability coupled with high genetic advance as per cent of mean were recorded for plant height, panicle length, grain yield, plant, and test weight indicating the effectiveness of simple selection in the improvement of these traits.

Keywords: Variability, Heritability, Rice, Landraces

Introduction

Rice (*Oryza sativa* L.) is an important cereal crop belonging to the Gramineae family and serves as a staple food for more than 60% of the world's population (Singh and Singh, 2008). Landraces harbour the great genetic potential for rice improvement. Landraces maintained by farmers are enriched with tremendous genetic variability when compared with high-yielding varieties (whose variability is constrained due to homozygosity) since they are not subjected to subtle selection over a long period. This aids in the adaptation of landraces to wide agroecological niches and they contain qualitative traits. It is, however, necessary to know the extent, magnitude, and pattern of rice diversity for a successful rice-breeding programme (Singh *et al*., 2016).

Grain yield is a complex quantitative character that is governed by polygenes. While making a selection, it is essential to take into account genotypic variation in yield and its component traits. Heritability is the measure of transmission of characters from generation to generation and the estimates of heritability will be of great use to the breeder in choosing superior individuals for a desired trait. Genetic advance measures the difference between the mean genotypic values of the selected population over the original population from which these were selected. Johnson *et al*., (1955) proposed that heritability coupled with genetic advance would be more useful than heritability estimates alone in predicting genetic gain under selection. Keeping in view the above prospects, the present investigation is carried out with the objective of estimating the genetic variability for yield, yield components, heritability, and genetic advance which would help in the selection and further improvement of rice genotypes.

Material and Methods

Experimental material and experimental design

The present investigation was carried out using 100 rice landraces along with four checks (BM 71, TN 1, Chandra, and Sri Dhruthi) grown in augmented block design during *Kharif*, 2021 at Regional Agricultural Research Station, Maruteru. Each genotype was grown in a single row of 3.75 m in length with a spacing of 20 cm between rows and 15 cm between plants within the row. Observations were recorded on five randomly selected plants in each genotype for days to 50% flowering, plant height (cm), number of ear bearing tillers/m^2, panicle length (cm), number of grains/panicle, spikelet fertility%, grain yield/plant (g) and test weight (g).

Statistical analysis

Analysis of variance was worked out by the method suggested by Federer (1956, 1961) and was elaborated by Federer and Raghavarao (1975) and Peterson (1985). Genotypic and phenotypic variances were estimated by the method suggested by Burton and Devane (1953) and heritability (broad sense) as the ratio of genotypic to phenotypic variance by Allard (1960). The genetic advance was estimated as per the formula proposed by Lush (1940). The data analysis was carried out using the software, Windostat version 4.2.0 from R Studio.

The GCV and PCV are classified as low (<10%), moderate (10-20%) and high (>20%) as suggested by Sivasubramanian and Madhavamenon (1973). Heritability was estimated by the formula given by Johnson *et al*. (1955) and they classified the heritability as low (below 30%), moderate (30-60%), and high (more than 60%). The range of genetic advance as per cent of the mean was classified as low (<10%), moderate (10-20%), and high (>20%) as suggested by Johnson *et al*. (1955).

Results and Discussion

The ANOVA for augmented design consisting of 100 landraces along with four checks pertaining to eight quantitative characters was shown in **Table 1**. The results showed significant differences among the entries, genotypes, and checks for eight characters *viz.*, days to 50% flowering, plant height (cm), number of ear-bearing tillers/m^2, panicle length (cm), number of grains/panicle, spikelet fertility (%), grain yield/plant (g) and test weight (g) except the number of ear bearing tillers/m^2 under checks. The mean sum of squares for checks vs genotypes showed significant differences for all the traits except the number of ear-bearing tillers/m^2 and grain yield/plant. Thus, the results revealed the presence of significant variability among the landraces.

The PCV estimates were slightly higher than the corresponding GCV estimates for the characters studied (**Table 2** and **Figure 1**) indicating that the characters were less influenced by the environment. Therefore, phenotypic selection would be effective for the improvement of these traits. Low PCV and GCV values were recorded for the traits *viz.,* days to 50% flowering (7.39, 7.32), number of ear bearing tillers/m^2 (9.45, 8.33) number of grains/panicle (8.87, 7.22)

Table 1. Analysis of variance for yield and yield components

Source of variation	d.f.	Days to 50% flowering	Plant height (cm)	Number of ear bearing tillers/m^2	Panicle length (cm)	Number of grains/ panicle	Spikelet fertility%	Grain yield/ plant (g)	Test weight (g)
		Sum of squares							
Block	4	5.12 *	56.01	243.25	2.96 *	127.43	4.33 *	7.08 **	1.16*
Entries	103	59.78 **	384.71 **	816.76 **	9.74 **	627.82 **	65.25 **	12.52 **	12.41**
Genotypes	99	50.87 **	292.35 **	830.34 **	9.49 **	243.73 *	37.4 **	12.86 **	12.55 **
Checks	3	311.25 **	245.34 **	556.18	11.48 **	1222.93 **	11.58 **	5.45 *	8.28 **
Checks vs genotypes	1	188.16 **	9947.08 **	254.8	29.28 **	3870.96 **	2984.1 **	0.72	10.72 **
Error	12	0.96	17.26	184.18	0.7	82.06	1.29	1.26	0.28

* Significant at 5% level; ** Significant at 1% level

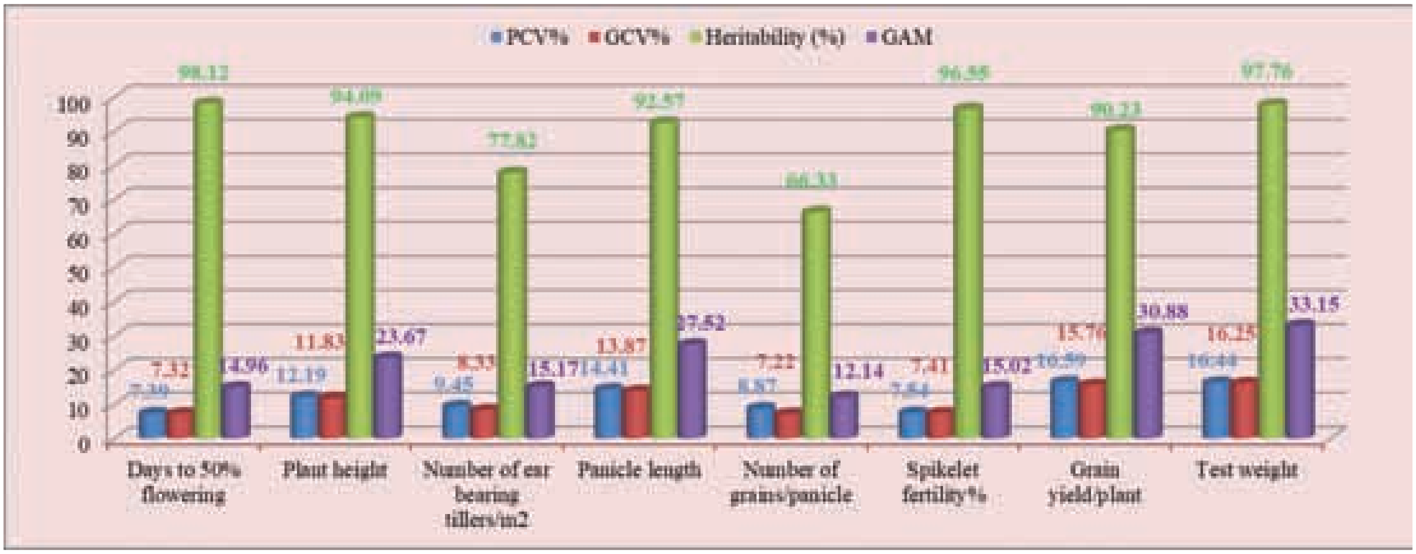


Figure 1: Variability, heritability, and GAM for eight characters in 100 landraces along with four checks

Table 2. Variability, heritability and GAM for yield and yield components

S. No.	Character	Coefficient of variation		Heritability (%)	Genetic advance	Genetic advance as per cent of mean
		PCV (%)	GCV (%)			
1.	Days to 50% flowering	7.39	7.32	98.12	14.44	14.96
2.	Plant height (cm)	12.19	11.83	94.09	33.19	23.67
3.	Number of ear bearing tillers/m^2	9.45	8.33	77.82	46.26	15.17
4.	Panicle length (cm)	14.41	13.87	92.57	5.88	27.52
5.	Number of grains/panicle	8.87	7.22	66.33	21.36	12.14
6.	Spikelet fertility%	7.54	7.41	96.55	12.18	15.02
7.	Grain yield/plant (g)	16.59	15.76	90.23	6.67	30.88
8.	Test weight (g)	16.44	16.25	97.76	7.14	33.15

and spikelet fertility% (7.54, 7.41) indicating presence of less variability among the landraces for these traits. Similar findings were reported by Sudeepthi *et al*., (2020) and Gbenga *et al*., (2021) for days to 50% flowering; Singh *et al*., (2018) and Devi *et al*., (2019) for the number of ear-bearing tillers/m^2; Bhim *et al*., (2018) and Swapnil *et al*., (2020) for number of grains/panicle and Lamichhane *et al*., (2021) for spikelet fertility%. Moderate levels of PCV and GCV were recorded for plant height (12.19, 11.83), panicle length (14.41, 13.87), grain yield/plant (16.59, 15.76) and test weight (16.44, 16.25) indicating the existence of comparatively moderate variability for these traits and provide scope for improvement through selection in further generations. The results are similar to the findings of Edukondalu *et al*., (2017) and Rachana *et al*., (2018) for plant height; Anup *et al*., (2020) and Bhor *et al*., (2020) for panicle length; Bhor *et al*., (2020) and Sudeepthi *et al*., (2020) for grain yield/ plant and Lakshmi *et al*., (2021) and Lamichhane *et al*., (2021) for the test weight.

High heritability coupled with moderate genetic advance as per cent of mean for days to 50% flowering (98.12%, 14.96), number of ear bearing tillers/m^2 (77.82%, 15.17) number of grains/panicle (66.33%, 12.14) and spikelet fertility% (96.55%, 15.02) indicating the presence of additive and non-additive gene action in the expression of these traits. Hence, the improvement of these characters would be easier through mass selection, varietal or hybrid development, or any other modified selection procedure aiming to make use of additive gene effects rather than simple selection. Similar results were reported by Lamichhane *et al*., (2021) and Nihad *et al*., (2021) for days to 50% flowering; Parimala *et al*., (2019) and Bhor *et al*., (2020) for the number of ear-bearing tillers/m^2; Nayak *et al*., (2016) and Hari *et al*., (2018) for the number of grains/panicle and Sudeepthi *et al*., (2020) and Swapnil *et al*., (2020) for spikelet fertility%. High heritability coupled with high genetic advance as per cent of mean for plant height (94.09%, 23.67), panicle length (92.57%, 27.52), grain yield/plant (90.23%, 30.88), and test weight (97.76%, 33.15) indicating the presence of additive gene action in the inheritance of these traits and effectiveness of simple selection for improvement of these characters. The results are similar to the findings of Lakshmi *et al*., (2021) and Lamichhane *et al*., (2021) for plant height; Parimala *et al*., (2019) and Anup *et al*., (2020) for panicle length; Sudeepthi *et al*., (2020) and Lakshmi *et al*., (2021) for grain yield/plant; Nihad *et al*., (2021) for the test weight.

Conclusion

Moderate PCV, GCV, and high heritability coupled with high genetic advance as per cent mean were observed by plant height, panicle length, test weight, and grain yield/plant indicating the effectiveness of simple selection in the inheritance of these traits.

References

Allard RW. 1960. *Principles of Plant Breeding*. John Wiley and Sons Inc., New York. 485.

Anup D, Shishir S, Amrit P and Ankur P. 2020. Variability and heritability estimate of 30 rice landraces of Lamjung and Tanahun districts, Nepal. *Indonesian Journal of Agricultural Science,* 21: 1-10.

Bhim NA, Bishnu JP, Jiban S and Naba BR. 2018. Genetic variability, heritability, genetic advance and correlation among yield and yield components of rice (*Oryza sativa* L.). *Journal of Agriculture and Natural Resources*, 1: 149-160.

Bhor TJ, Kashid K and Kadam SM. 2020. Genetic variability, character association and path analysis studies for yield component traits in promising rice (*Oryza sativa* L.) genotypes. *Journal of Pharmacognosy and Phytochemistry,* 9: 1953-1956.

Burton GW and Devane EW. 1953. Estimating heritability in tall fescue (*Festuca arundinaceae*) from replicated clone material. *Agronomy Journal,* 45: 478-481.

Devi KR, Chandra BS, Venkanna V and Hari Y. 2019. Variability, correlation and path studies for yield and quality traits in irrigated upland rice (*Oryza sativa* L.). *Journal of Pharmacognosy and Phytochemistry,* 8: 676-684.

Edukondalu B, Ram VR, Shobha TR, Aruna ChK and Soundharya B. 2017. Studies on variability, heritability, correlation and path analysis for yield, yield attributes in rice (*Oryza sativa* L.). *International Journal of Current Microbiology and Applied Sciences,* 6: 2369-2376.

Federer WT and Raghavarao D.1975. On augmented design. *Biometrics*. 31: 29-35.

Federer WT. 1956. Augmented designs. *Hawaiian Planter's Record*. 55: 191-208.

Federer WT. 1961. Augmented designs with one-way elimination of heterogeneity. *Biometrics,* 17: 447-473

Gbenga OA, Salami AE, Aluko M, Olajide OO and Afolab MS. 2021. Genetic and heritability estimates of landrace upland rice accessions grown in rainforest agroecological zone of Nigeria. *Journal of Pure and Applied Agriculture,* 6: 18-25.

Hari RKB, Satyanarayana PV, Babu DR, Chamundeswari N, Srinivasa VR and Krishnam SR. 2018. Genetic variability estimates for yield and yield component traits and quality traits in rice (*Oryza sativa* L.). *International Journal of Current Microbiology and Applied Sciences,* 7: 34-48.

Johnson HW, Robinson HF and Comstock RE. 1955. Estimates of genetic and environmental variability in soybean. *Agronomy Journal,* 47: 314-318.

Lakshmi MS, Suneetha Y and Srinivas T. 2021. Genetic variability, correlation and path analysis for grain yield and yield components in rice genotypes. *Journal of Pharmacognosy and Phytochemistry,* 10: 1369-1372.

Lamichhane S, Adhikari NR, Bishwas KC and Thapa S. 2021. Estimating variability, heritability and genetic advance of rice genotypes in mid-hills of Nepal. *Indonesian Journal of Agricultural Science,* 22: 92-101.

Lush JL. 1940. Intra-sire correlation on regression of offspring on dams as a method of estimating heritability of characters. *Proceedings of American Society of Animal Production,* 33: 292-301.

Nayak R, Singh VK, Singh AK and Singh PK. 2016. Genetic variability, character association and path analysis of rice genotypes. *Annals of Plant and Soil Research,* 18: 161-164.

Nihad SAI, Manidas AC, Hasan K, Hasan MdI, Honey O and Latif MA. 2021. Genetic variability, heritability, genetic advance and phylogenetic relationship between rice tungro virus resistant and susceptible genotypes revealed by morphological traits and SSR markers. *Current Plant Biology,* 25: 100194.

Parimala K and Devi KR. 2019. Estimation of variability and genetic parameters in Indica and Japonica genotypes of rice (*Oryza sativa* L.). *International Journal of Current Microbiology and Applied Sciences,* 8: 1138-1142.

Rachana B, Eswari KB, Jyothi B and Raghuveer PR. 2018. Variability, heritability and genetic advance for yield and its component traits in NPT core set of rice (*Oryza sativa* L.). *Electronic Journal of Plant Breeding,* 9: 1545-1551.

Singh Y and Singh US. 2008. Genetic diversity analysis of rice germplasm using agro-morphological traits. *Journal of Plant Genetic Resources,* 21: 32-37.

Singh N, Choudhury DR, Tiwari G, Singh AK, Kumar S, Srinivasan K, Tyagi RK, Sharma AD, Singh NK and Singh R. 2016. Genetic diversity trend in Indian rice varieties: an analysis using SSR markers. *BMC Genetics,* 17: 1-13.

Singh SK, Monika S, Prudhvi RV, Singh DK, Shubhra NK and Dinesh Kumar. 2018. Studies on genetic variability, heritability and genetic advance for yield and yield components in drought tolerant rice (*Oryza sativa* L.) landraces. *International Journal of Current Microbiology and Applied Sciences,* 7: 299-305.

Sivasubramanian S and Madhavamenon P. 1973. Combining ability in rice. *Madras Agricultural Journal*, 60: 419-421.

Sudeepthi K, Srinivas T, Kumar BNVSRR, Jyothula DPB and Umar SKN 2020. Assessment of genetic variability, character association and path analysis for yield and yield component traits in rice (*Oryza sativa* L.). *Electronic Journal of Plant Breeding,* 11: 144-148.

Swapnil Prasad K, Chakraborty M, Singh DN, Kumari P and Priya JE. 2020. Correlation and path coefficient analysis among grain yield and kernel characters in rice (*Oryza sativa* L.). *Electronic Journal of Plant Breeding,* 6 : 288-291.

RESEARCH ARTICLE **https://doi.org/10.58297/OWFQ8879**

Estimation of Genetic Diversity by Principal Component Analysis of Yield Attributing Traits in Katarni Derived Lines

Divya Mahto[1], Singh PK [2], Rabiya Parveen[3], Sareeta Nahakpam[4] and Mankesh Kumar[5]*

[1, 3 &5]Department of Plant Breeding and Genetics, Bihar Agricultural University, Sabour, Bhagalpur, Bihar
[2]Director, Seed and Farms, Bihar Agricultural University, Sabour, Bihar
[4]Department of Plant Physiology and Biochemistry, Bihar Agricultural University, Sabour, Bihar
*Corresponding author's Email: drmankeshkumar@gmail.com

Received: 12th September 2022; Accepted: 30th October 2022

Abstract

Katarni is a non-basmati traditional aromatic rice cultivar being grown in the Bhagalpur, Banka, and Munger districts of Bihar. However, it is weak-strawed, tall, prone to lodging, and late maturing. Attempt was made to develop a semi-dwarf and early maturing lines of Katarni by crossing with three semi-dwarf high-yielding cultivars and was advanced to F_5 generation. In this study, 54 derived lines of Katarni were studied on the basis of 14 morphological traits. Five principal components (PCs) were observed which contributed 70% of cumulative variability and exhibited Eigenvalues> 1. The first PC (23.31%) and the second PC (35.59%) showed a cumulative variation of 63.90%. On the basis of genotype by trait biplot analysis, flag leaf length, plant height, and fragrance were found to be strongly positive. Genotypes biplot study revealed diverse genotypes like KIR-46 KIR-48, KRS-39, KRS-43, KRS-15, KRS-19, KRS-8, KRS-25, and KMTU-52 which can be further exploited for varietal development.

Keywords: Eigenvalue, Hybridization, Katarni, Principal component

Introduction

Rice (*Oryza sativa* L.) is a staple food for more than 2.7 billion people (Tannidi *et al.,* 2016) around the world, and about 32- 59% of the dietary energy and 25-44% of the dietary protein is obtained from rice in more than 39 countries (Prabhu *et al.,* 2017). According to Nagaraju *et al*., (2002), the aromatic Basmati lies in a separate group between *indica* and *japonica* in which the traditional Basmati and evolved Basmati varieties represent a major component of the Basmati gene pool of the Indian subcontinent. Katarni is a non-basmati traditional aromatic rice cultivar of the Bhagalpur district of Bihar. This rice is one of the famous fine-grained aromatic rices of India which is renowned for its unique aroma, special grain, and cooking qualities. Its flowering occurs between the end of October to the beginning of November and matures in the month of December. Plant height ranges from 140 to 160 cm (Smriti *et al.,* 2016). In view of its uniqueness, Katarni rice has been granted geographical indication in April 2018. However, the available Katarni is a poor yielder (25-30 t/ha), weak strawed, traditionally tall type, easily prone to lodging and late maturing (Kumar *et al.,* 2018). Principal component analysis (PCA) is generally used to estimate the relative contribution of various traits for total variability and a small number of factors that account for maximum variability can be identified easily. It also shows the pattern of similarity of the traits and relation among the traits. Further, PCA identifies the minimum number of components, which can explain the maximum variability out of the total variability (Anderson 1972), and also ranks genotypes on the basis of PC scores. Several researchers have characterized rice germplasm including the landraces, varieties, and advanced materials of diverse nature for morphological and physicochemical quality parameters (Bollinedi *et al.* 2020; Madhubabu *et al*. 2020), and reported a wide range of variability. Considering the importance of PCA, the present experiment was laid out to identify diversified genotypes with short stature and early maturity with high-yielding ability in the segregating population generated by crossing Katarni with R. Sweta, IR-64, and MTU-7029. Among the derived lines, principal component analysis was carried out to identify diversified lines which can be utilised for future breeding programmes.

Materials and methods

The experimental material comprised 54 Katarni-derived families, four parental checks i.e. Katarni, R. Sweta, IR-64, MTU-7029, and two aromatic checks Sabour Surbhit and Rajendra Suwasini. The derived families of Katarni were in F_5 generation and were grown in alpha lattice design with two replications at Rice Section, Bihar Agricultural university, Sabour, Bhagalpur during *Kharif* 2018. For convenience, the genotypes of Katarni x Rajendra Sweta, Katarni x IR64, and Katarni x MTU7029 were denoted as KRS, KIR, and KMTU, respectively. The crop was raised following recommended package of practices. Observations were recorded on five randomly tagged plants of each genotype per replication. Data were recorded on fourteen quantitative and quality traits.

Principal Component analysis is a very important tool to minimize the large data set into a new set of uncorrelated variables (known as principal components) by a linear transformation of original variables. In the present study, genotypic means were used to determine genetic variability for the traits in PCA. The data analysis was conducted using SAS (Statistical Analysis System) version 9.2. For PCA, eigenvalues were calculated first which define the amount of total variation that was displayed on the PC axis. Then, loading values were standardized in such a way that the sum of squares of loadings within a PC was equal to one. The loading values depicted the contribution of each trait in the respective principal component.

Result and Discussion

The analysis of variance studied revealed the presence of significant variability for the traits which indicated diversity among the genotypes. Principal component analysis was performed to trace out major components and their contributing traits as well as genotypes in respective components. The PCA revealed up to seven principal components (PC1 to PC7). Among seven PCs, five components contributed 70% of cumulative variability and exhibited Eigenvalues > 1, i.e. PC1 (3.26), PC2 (2.28), PC3 (1.77), PC4 (1.25), PC5 (1.24), PC6 (0.94) and PC7 (0.73). The first PC (23.31%) and second PC (35.59%) showed for cumulative variation of 63.90%. Principal components, Eigenvalues, factor loading values, the percentage contribution of every variable to overall variance, and major contributing characteristics for each major component are described in **Tables 1** and **2**. The important characters and major contributors to variability in PC1 were kernel length, length and breadth ratio, thousand-grain weight, and panicle length. Whereas in PC2, important characters were flag leaf length, plant height and panicle length, and kernel breadth. Gelatinization temperature and number of tillers per plant in PC3 (**Table 3**); the number of tillers per plant and amylose content in PC4; fragrance, days to 50% flowering, and plant height in PC5 were major contributors to variability. Traits with high variability are essential during crop improvement program (Nachimuthu *et al.,* 2014). Therefore, the selection of kernel length, length and breadth ratio, plant height, number of tillers per plant, and panicle length can be used in the choice of diverse genotypes from the specific principal component. The outcomes of the current study were consistent with the findings of Sao *et al.,* (2019), Ojha *et al.,* (2017), and Gaur *et al.,* (2017). The factor loading value was found to be maximum for kernel length (0.88) in PC1, flag leaf length (0.75) in PC2, kernel breadth (0.71) in PC3, amylose content (0.79) in PC4, fragrance (0.65) in PC5, grain yield per plant in PC6 and PC7.

Maximum variability in PC1 was contributed by genotype KIR-46 (9.49%) followed by KIR-48 (7.21%) and KRS-39 (6.16%) (Table 3), whereas in PC2, maximum variability was contributed by KRS-43 (12.42%) followed by KRS-15 (8.58%) and KRS-19 (5.30%). In PC3, KRS-25 (11.99%) was followed by KRS-8 (11.97%) and KRS-4 (9.49%), in PCA4 KMTU-53 (11.94%) was followed by KRS-7 (11.38%) and KRS-39 (6.04%), were the major variability contributors. The highest contribution

Table 1. Eigen value, percentage of variance and eigenvector of Katarni derived lines

PCA **Components**	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**
Eigenvalue	3.26	2.28	1.77	1.25	1.24	0.94	0.73
Variability (%)	23.31	16.28	12.67	8.95	8.85	6.72	5.24
Cumulative %	23.31	39.59	52.26	61.21	70.06	76.78	82.02
Component matrix	**Factor Loading Value**						
PH	-0.03	0.67	0.05	0.20	0.31	0.34	-0.15
DOF	-0.59	-0.06	0.07	0.19	0.46	0.02	-0.31
FLL	-0.03	0.75	0.00	0.08	-0.36	-0.11	0.25
PL	0.46	0.65	0.29	0.12	0.01	-0.14	0.00
NOT	-0.11	-0.52	0.35	0.57	-0.09	-0.37	-0.05
GPP	-0.76	0.29	-0.18	-0.10	-0.05	0.14	0.15
GW_100	0.71	0.05	0.10	-0.22	0.27	0.39	-0.08
GY	-0.05	-0.52	0.30	0.15	-0.01	0.49	0.55
ASV	0.17	0.15	0.64	-0.24	-0.52	-0.02	-0.10
AMY	0.32	0.25	0.11	0.79	0.02	0.15	0.05
FRAG	0.00	0.22	0.27	-0.19	0.65	-0.45	0.43
KL	0.88	-0.17	-0.28	0.02	0.06	-0.09	0.02
KB	0.41	-0.19	0.71	-0.17	0.15	0.03	-0.13
L/B	0.73	-0.10	-0.59	0.08	-0.01	-0.11	0.06

Table 2. Contribution of each trait in different principal components

PCA **Traits**	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**
PH	0.02	19.98	0.16	3.11	7.87	12.44	2.87
DOF	10.67	0.17	0.31	2.91	17.42	0.03	13.23
FLL	0.02	24.59	0.00	0.53	10.50	1.39	8.67
PL	6.46	18.61	4.79	1.23	0.00	2.17	0.00
NOT	0.37	11.68	6.80	25.52	0.69	14.23	0.38
GPP	17.59	3.62	1.79	0.76	0.23	2.06	2.95
GW_100	15.42	0.12	0.62	4.01	5.74	15.93	0.90
GY	0.08	11.73	5.06	1.69	0.01	25.56	41.26
ASV	0.84	1.03	23.03	4.52	21.49	0.05	1.49
AMY	3.11	2.85	0.66	49.83	0.03	2.28	0.39
FRAG	0.00	2.20	4.25	2.96	33.88	21.69	24.84
KL	23.99	1.32	4.35	0.03	0.34	0.77	0.05
KB	5.15	1.67	28.46	2.40	1.78	0.08	2.42
L/B	16.29	0.44	19.71	0.51	0.02	1.31	0.54

Table 3. Contribution of each genotype in different principal components

Sl. No.	Genotypes	PCA1	PCA2	PCA3	PCA4	PCA5	PCA6	PCA7
1.	KIR-44	0.74	0.31	0.06	0.09	2.80	4.89	0.80
2.	KIR-45	4.07	2.36	0.75	0.04	3.37	0.30	2.83
3.	KIR-46	9.49	1.25	0.96	2.80	0.12	6.59	4.87
4.	KIR-47	3.02	0.25	2.75	0.00	0.34	0.08	11.60
5.	KIR-48	7.21	0.00	0.48	0.95	0.00	0.02	2.98
6.	KIR-49	5.38	0.10	0.56	1.24	6.31	5.79	2.62
7.	KMTU-50	1.13	0.70	0.11	0.57	0.14	0.68	0.53
8.	KMTU-51	0.99	0.94	0.59	0.20	0.22	0.26	0.42
9.	KMTU-52	2.70	0.07	0.20	1.27	1.98	0.25	10.56
10.	KMTU-53	1.19	1.06	2.00	11.94	0.17	0.11	0.11
11.	KMTU-54	0.41	1.56	0.49	5.62	12.94	0.69	3.35
12.	KRS-1	0.02	0.44	1.34	0.76	0.18	0.90	0.05
13.	KRS-10	2.36	1.61	0.80	4.84	2.53	0.02	0.83
14.	KRS-11	0.77	0.23	3.15	0.13	1.26	7.23	0.00
15.	KRS-12	0.22	0.00	3.48	0.16	0.79	0.18	1.18
16.	KRS-13	0.66	1.05	2.59	4.26	0.05	0.39	1.38
17.	KRS-14	0.89	1.43	2.00	0.00	0.79	0.00	0.30
18.	KRS-15	0.30	8.58	0.03	2.36	0.29	0.12	0.03
19.	KRS-16	0.06	4.20	0.08	0.33	0.80	0.51	3.52
20.	KRS-17	0.59	3.66	0.03	0.02	0.53	0.03	0.03
21.	KRS-18	0.03	2.14	1.12	0.90	3.31	3.85	0.03
22.	KRS-19	0.24	5.30	0.32	0.24	0.61	0.01	1.10
23.	KRS-2	0.00	0.80	0.20	2.26	1.05	1.89	0.92
24.	KRS-20	0.11	1.20	3.06	0.31	0.04	0.54	0.28
25.	KRS-21	0.67	1.08	0.08	0.37	1.29	1.85	1.52
26.	KRS-22	0.04	4.40	0.09	0.58	0.15	0.21	0.03
27.	KRS-23	0.21	0.15	0.20	0.02	0.31	0.99	0.24
28.	KRS-24	0.06	0.24	0.52	1.83	0.94	9.09	5.84
29.	KRS-25	1.34	1.78	11.99	0.00	2.38	0.25	8.79
30.	KRS-26	0.14	0.51	0.19	0.11	0.12	0.50	0.97
31.	KRS-27	0.54	0.30	2.65	0.08	1.58	2.25	0.45
32.	KRS-28	0.01	0.12	1.86	2.10	1.42	4.13	0.09
33.	KRS-29	2.73	0.12	0.54	0.73	0.52	0.04	1.85
34.	KRS-3	2.45	0.35	0.95	0.12	3.39	5.54	0.43
35.	KRS-30	5.46	0.52	0.00	0.03	0.22	1.17	1.83
36.	KRS-31	0.97	0.74	8.82	3.89	0.16	6.78	1.18
37.	KRS-32	4.26	0.52	2.27	3.83	0.00	0.76	0.70

Sl. No.	Genotypes	PCA1	PCA2	PCA3	PCA4	PCA5	PCA6	PCA7
38.	KRS-33	1.03	0.00	4.23	2.31	0.00	0.03	0.22
39.	KRS-34	1.80	1.12	1.46	0.12	0.24	0.61	0.71
40.	KRS-35	2.01	0.21	0.05	0.25	0.00	0.13	0.67
41.	KRS-36	0.16	0.06	0.02	0.04	1.21	0.03	0.23
42.	KRS-37	0.90	0.00	4.23	0.83	0.22	2.25	0.66
43.	KRS-38	0.68	0.45	1.30	3.65	3.28	0.33	0.09
44.	KRS-39	6.16	0.19	0.01	6.04	1.34	1.32	0.05
45.	KRS-4	0.08	0.42	9.49	3.39	0.42	0.03	3.93
46.	KRS-40	3.16	1.70	0.00	0.00	2.90	0.01	1.69
47.	KRS-41	0.02	1.77	0.50	0.05	0.05	2.70	0.71
48.	KRS-42	0.91	0.27	0.01	0.73	6.90	1.12	1.86
49.	KRS-43	0.46	12.42	0.04	1.52	9.47	7.78	2.48
50.	KRS-5	0.06	3.49	1.54	0.18	0.40	0.63	0.01
51.	KRS-6	0.01	4.26	0.02	0.11	0.82	4.45	0.14
52.	KRS-7	0.90	0.45	0.00	11.38	1.24	0.07	0.93
53.	KRS-8	0.06	0.27	11.97	2.20	0.83	2.48	0.06
54.	KRS-9	4.06	0.40	1.12	1.46	0.83	0.07	2.80
55.	MTU7029	0.44	1.32	0.50	0.00	0.09	2.94	2.38
56.	IR-64	4.42	2.18	0.49	0.96	1.22	1.23	0.12
57.	Katarni	2.01	14.75	1.59	8.52	9.81	1.00	1.35
58.	R. Sweta	0.22	1.35	1.98	0.63	1.47	0.80	1.17
59.	R. Suwasini	4.02	2.66	1.49	0.35	4.12	0.12	2.63
60.	S. Surbhit	4.97	0.19	0.64	0.29	0.00	0.98	0.81

PH: Plant height, DOF: Days to 50% flowering, FLL: Flag leaf length, PL: Panicle length, NOT: Number of tillers/hill, GPP: Number of grains/panicle, GW-100: 1000-grain weight, ASV: Alkali spreading value, AMY: Amylose content, FRAG: Fragrance, KL: Kernel length, KB: Kernel breadth, LB: L/B ratio and GY: Grain yield/plant

for variability in PC5 was contributed by genotypes KMTU-54 (12.94%) followed by KRS-43 (9.47%) and KIR-49 (6.31%). Among the checks, Katarni (14.75%) was the major variability contributor in PCA2. The derived information of PCA on F_5 lines of Katarni would be very useful to select potential and diverse breeding lines for future rice improvement programmes.

Scree plot explained the percentage of variation by plotting a graph between eigenvalues and cumulative variability (%) on the Y axis and the mean value of 14 characters under study on the X axis (**Figure 1**). The scree plot explained the percentage of variation by each PC and its eigenvalues. As depicted in the graph majority of variations were contributed by the first three PCs. The distribution of the scores for the 14 different characters in the scree plot indicated the presence of large diversity.

Comparison of genotypes on the basis of measured multiple variables are possible by Genotype by Trait (GT) biplot which identifies those genotypes that are particularly superior in certain traits. The GT biplot can be effectively used as an independent selection criterion of genotypes on the basis of yield (Yan and Rajcan, 2002). The distance to the biplot origin, known as the vector length of a trait is indicative

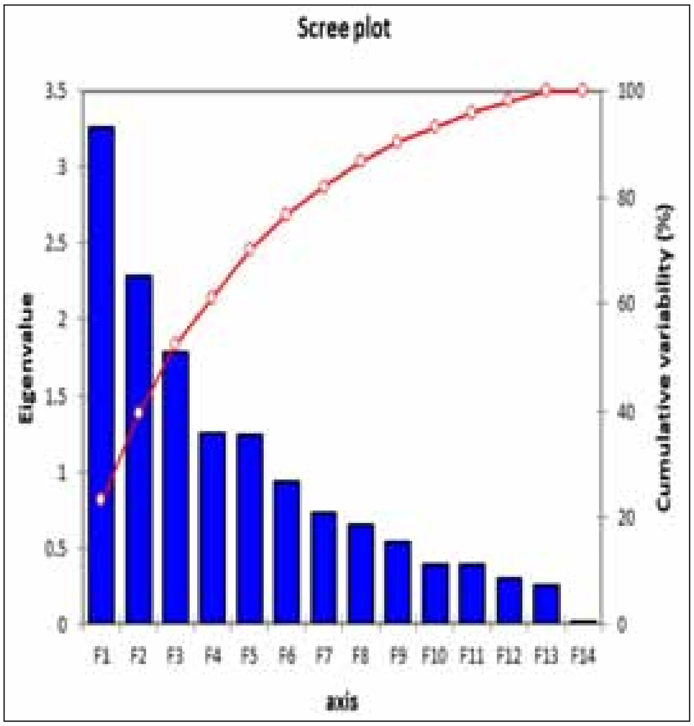


Figure 1: Scree plot of different components with Eigen values

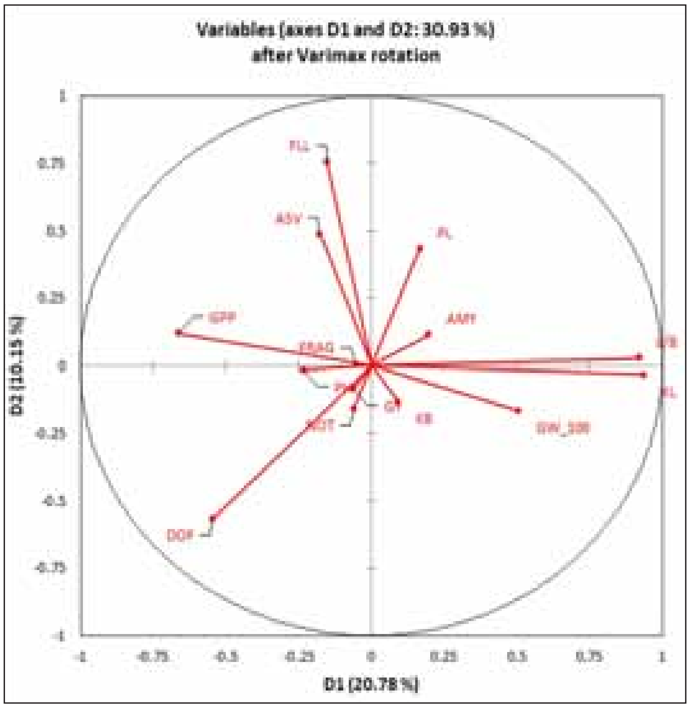


Figure 2: Biplot of 14 different morphological characters

of the trait representation in the biplot. A relatively short vector indicates that the variation of the trait across genotypes is either small or not well presented in the biplot due to its weak or lack of correlation with other traits (Yan and Fregeau-Reid, 2018). PC1 and PC2 variables in biplot analysis showed both positive and negative associations among the traits. Flag leaf length, plant height, and fragrance were strongly positively correlated as the axes recorded an angle less than 90^0 (**Figure 2**). Similarly, panicle length with gelatinization temperature and amylose content; length/ breadth ratio with kernel length and kernel breadth, and number of tillers per plant with grain yield per plant were positively correlated as these traits showed axes angle less than 90°. A few traits like the number of grains per panicle with kernel breadth and thousand seed weight with days to 50% flowering were negatively associated as these traits are placed at approximately 180° angle on PC1 and PC2 axes. Similarly, the genotypes biplot study (**Figure 3**) revealed that entries KIR-46 KIR-48, KRS-39, KRS-43, KRS-15, KRS-19, KRS-8, KRS-25, KMTU-52, and Katarni are distantly placed from the origin of axes indicating their diversity with respect to other genotypes under study. Therefore, the selection of kernel length, length and breadth ratio, plant height, number of tillers per plant, and panicle length can be used in the selection of diverse genotypes and a

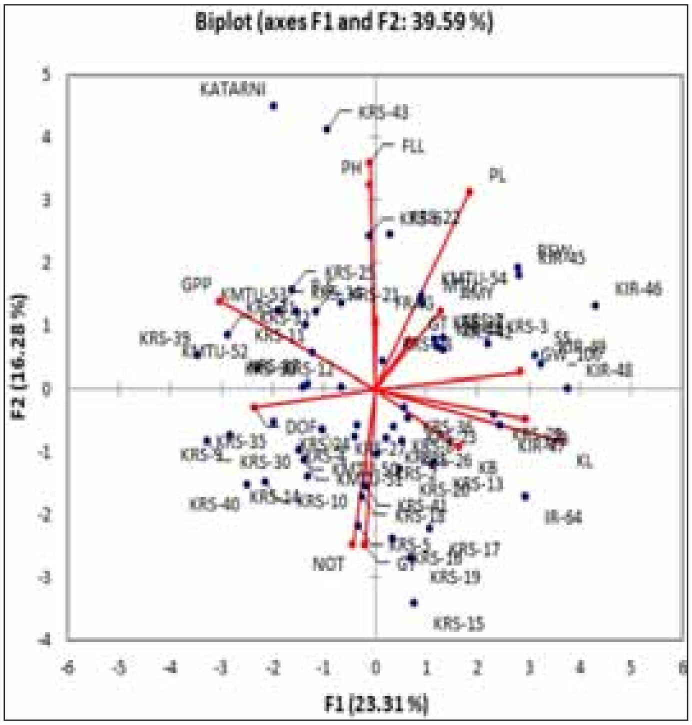


Figure 3: Biplot of 60 genotypes including checks

hybridization breeding program can be initiated by using the diverse genotypes obtained in the present study.

Acknowledgements

We sincerely acknowledge the grants received from the SERB, DST, New Delhi (Sanction no. SB/YS/LS-81/2013) and BAU, Sabour (State plan code: SNP/CI/2017-2). Research Article bears BAU communication no. 1218/220722.

References

Anderson TW. 1972. Principal Components. P. 459-483. In An introduction to multivariate analysis: Wiley Eastern Private Limited, New Delhi, Third Edition.

Bollinedi H, Vinod K, Bisht K, Chauhan A, Krishnan SG, Bhowmick PK, Nagarajan M, Rao DS, Ellur RK and Singh AK. 2020. Characterising the diversity of grain nutritional and physico-chemical quality in Indian rice landraces by multivariate genetic analyses. *Indian Journal of Genetics*, 80: 26-38.

Gour L, Maurya SB, Koutu GK, Singh SK, Shukla SS, Mishra DK. (2017. Characterization of rice (*Oryza sativa* L.) genotypes using principal component analysis including scree plot & rotated component matrix. *International Journal of Chemical Studies*, 5:975-83.

Kumar M, Satyendra, Singh SP, Kumar A, Smriti, Shashikant, Singh PK and Sohane RK. 2018. Characterisation of Katarni rice for its geographical indication in Bihar, India. *Journal of AgriSearch,* 4: 223-229.

Madhubabu P, Surendra R, Suman K, Chiranjeevi M, Fiyaz RA, Rao DS, Chaitanya U, Lella VSR, Babu VR and Neeraja CN. 2020. Assessment of genetic variability for micronutrient content and agro-morphological traits in rice (*Oryza sativa* L.). *Indian Journal of Genetics,* 80: 130-139.

Nachimuthu VV, Robin S, Sudhakar D, Raveendran M, Rajeswari S, Manonmani S. 2014. Evaluation of rice genetic diversity and variability in a population by principal component analysis. *Indian Journal of Science and Technology*, 7: 1555-1562.

Nagaraju J, Kathirvel M, Kumar RR, Siddiq EA and Hasnain SE. 2002. Genetic analysis of traditional and evolved Basmati and Non-Basmati rice varieties by using fluorescence-based ISSR-PCR and SSR markers. *Proceedings of the National Academy of Sciences,* U. S. A. 99: 5836-5841.

Ojha GC, Sarawgi AK, Sharma B, Parikh M. 2017. Principal component analysis of morpho-physiological traits in rice germplasm accessions (*Oryza sativa* L.) under rainfed condition. *International Journal of Chemical Studies,* 5:1875-1878.

Prabhu S, Ganesan NM, Jeyaprakash P, Selvakumar R and Prabhakaran NK. 2017. Assessment of genetic variability studies among the backcross populations in Rice (*Oryza sativa* L.). *International Journal of Pure & Applied Bioscience,* 5:368-372.

Sao R, Saxena RR, Sahu PK. 2019. Assessment of genetic variation and diversity in rice genotypes based on principal component analysis. *Journal of Plant Development Sciences,* 11:725-730.

Smriti, Deepti, Chattopadhyay T, Satyendra, Singh SP and Kumar M. 2016. Characterization and purity analysis of a few aromatic indigenous rice genotypes of Bihar using an aroma-specific marker. *International Journal of Environmental Science and Technology*, 5: 1167-1176.

Tannidi S, Govintharaj P, Ameenal M, Manonmani S and Robin S. 2016. Improving blast resistance in parental line of rice hybrid through marker assisted selection. *International Journal of Agricultural Science Research,* 6: 339-346.

Yan W and Rajcan I. 2002. Biplot analysis of test sites and trait relations of Soybean in Ontario. *Crop Science,* 42:11-20.

Yan W, Frégeau-Reid J. 2018. Genotype by Yield*Trait (GYT) Biplot: A Novel Approach for Genotype Selection based on Multiple Traits. *Scientific Reports*, 8:8242. doi: 10.1038/s41598-018-26688-8.

RESEARCH ARTICLE https://doi.org/10.58297/KVJD5357

Varietal Improvement and Weed Management for Aerobic Rice Cultivation in the Drought-Prone Jharkhand State

Ekhlaque Ahmad[1], Ashok Kumar Singh[2]*, Krishna Prasad[1], Manoj Kumar Barnwal[3], Binay Kumar[4], Varsha Rani[5] and Saha PB[6]

[1]Department of Genetics and Plant Breeding; [2]Department of Agronomy, [3]Department of Plant Pathology, [4]Department of Entomology, [5]Department of Crop Physiology, [6]Department of Soil Science, Birsa Agricultural University, Ranchi, Jharkhand-834006, India

*Corresponding author Email: aksinghbau65@gmail.com

Received: 25th November 2022; Accepted: 20th December 2022

Abstract

Aerobic rice varietal and weed management trials under direct seeding were carried out at Birsa Agricultural University Rice Experimental Area, Kanke, Ranchi in the wet seasons of 2017 and 2018. Efforts were made to select better high-yielding varieties and improved production technology for aerobic rice cultivation. Dhaincha (*Sesbania aculeata*), Cowpea (*Vigna unguiculata*), and urd bean (*Vigna mungo*) were grown along with direct seeded rice, uprooted and used as a green mulch, 25 days after seeding. Six varietal trials were conducted under aerobic conditions during the 2017 and 2018 wet seasons in which the entries RP 6191-HHZ1-Y4-Y1-Y1 (6.90 t ha^{-1}), PA 6129 (hybrid) (6.45 t ha^{-1}), RP 6273-HHZ4-DT3LI1-LI1 (6.10 t ha^{-1}), CR Dhan 201 (5.185 t ha^{-1}), US 380(hybrid) (5.28 t ha^{-1}), NVSR 2107 (4.73 t ha^{-1}), IIRRH 124 (hybrid) (4.70 t ha^{-1}) with early maturity were found promising. In varietal trials, intermediate plant height (100 to 110 cm), non-lodging and high yield (>4.0 t ha^{-1}) were major criteria for selection. Two to three irrigations were applied as per the requirement. Naveen variety under aerobic conditions produced maximum yield with 125 kg N per hectare in both years. Among weed control methods, rice+ dhaincha+ pre-emergence application of pendimethalin @ 0.75 g a.i. per hectare in 2017 and rice+ dhaincha+2,4 D @ 0.8 kg a. i. per hectare as post-emergence application produced maximum yield with weed control efficiency of 61.4% in 2018.

Keywords: Aerobic rice, Variety, Weed control, Plant height, Pre-emergence, Post-emergence

Introduction

Rice (*Oryza Sativa* L.) is one of the major staple crops of Asian countries. Two-third of Asian population are dependent on rice for daily calories (Rahman and Masood, 2012). Rice contributed 40 % to the total food grain production in India thereby occupying a pivotal role in food and livelihood security of the people. In terms of area, rice crop grown in about 43 million hectares (mha) in the country, which is the largest acreage in the world. The last sixty years have seen a paradigm shift from subsistence agriculture to technology driven intensive farming which has taken the country from the days of food deficit to an era of self sufficiency. In Asian countries, rice is grown by manual transplanting of seedlings into puddled soil. Puddling and transplanting operations consume a significantly large quantity of water, which is around 30 % of total rice crop requirement (Chauhan, 2012). The rising concern about water availability for rice production is leading the farmers of many Asian countries to shift from manual transplanting to DSR system.

The Jharkhand state is rich in natural resources and dense forests. The state is full of biodiversity but deficient in self sufficiency of food grains because of meagre irrigation facilities i.e. 12-13% in kharif and around 5-6% in rabi. The majority of the farmers in the state are marginal and sub-marginal (**Table 1**) and the land is deficient in major nutrients due to its acidic nature (**Table 2**). Crop production is closely related to the onset of monsoon hence success or failure is linked with rainwater. Currently, monsoons are a gamble with rice cultivation in Jharkhand due to changes in precipitation patterns, the number of rainy days, and the shrinking monsoon period due to climate change. Jharkhand has a net sown area of around 28.0 lakh hectares which is 35.13% of the total geographical area. The cropping intensity of the state is around 125%. At the time of separation, the state was producing only 23.0 lakh metric tonnes of rice from 15.2 lakh hectare but in the year 2021, 48.0 lakh tonnes was produced from an area of 17.63 lakh hectares.

Table 1. Typology land holding in Jharkhand, India

Landholding (ha)	Typology	Percentage (%)
0	Landless	9.3
Up to 0.4	Sub marginal	49.8
0.41-1	Marginal	22.8
1.01-2	Small	12.5
2.01-4	Medium	4.4
>4	Large	1.2
	Total	**100**

Table 2. Soil Profile of Jharkhand

Indicator	Unit (%)	Land typology
Soil with phosphorus deficiency	66.0	Upper, middle and lower portion of toposequence
Acid upland soil	71.0	Upper part of toposequence
pH(<5.5)	49.0	Mainly upper pst of toposequence, forest soils
Soil type :ph(5.5-6.0)	22.0	upper and middle part of toposequence
Red and lateritic (Tanr 2 and 3 and Don 3)	78.0	upper and middle part of toposequence
Alluvium (Don 1 and 2)	19.0	Lower part of toposequence

Jharkhand is a drought-prone state in eastern India. Sometimes, rainfall is adequate throughout the country, but Jharkhand as a whole or in part is always affected by drought. The rice area and productivity are strongly influenced by rainfall patterns and the amount of rain during the wet season. Around 88% of the rice area is rainfed. The state has undulating terrain. Less rain in June-July reduces the rice area, whereas mid–season drought in August and September affects production and productivity. Research on aerobic rice cultivation by direct seeding of fertilizer-responsive high-yielding varieties with supplementary irrigation is a possible option.

Based on the success of direct-seeded rice with sprinkler irrigation in Brazil, and with surface irrigation in China, research on direct-seeded rice with modern varieties, irrigation, and higher fertilizer inputs as compared with rainfed upland, low-yielding direct-seeded rice has been carried out on a small scale since 2006 in Ranchi. Systematic trials in collaboration with the All India Coordinated Rice Improvement Programme (AICRIP) on aerobic rice began in India in 2009. In Brazil, higher yields were obtained with improved plant types under direct-seeded aerobic rice areas using input-responsive drought–tolerant and pest-resistant varieties with sprinkler irrigation or in regions with favourable rainfall distribution (Stone *et al.*, 1990; Guimaraes and Stone, 2000, Pinheiro *et al.*, 2006). In northern China also in water-deficit environments, aerobic rice cultivation has been successful (Wang *et al*., 2002; Yong *et al*., 2005). In India, research has been carried out at the University of Agricultural Sciences (UAS), Bangalore; National Rice Research Institute (NRRI), Cuttack; and Indian Agricultural Research Institute (IARI), New Delhi, for the past 10 years. In the USA, drought screening was part of a strategy to develop aerobic rice cultivars, whereas, at other locations, only varietal evaluation was being carried out.

At BAU, Ranchi, weed management and varietal trials have been conducted. The rice crop is direct-seeded in non-puddled soil like wheat, bunds are made to harvest rainwater, and a higher dose of NPK as with high-yielding varieties (HYV) is being recommended to obtain higher yield. Direct seeding in uplands is common in Jharkhand, but the yield is low because of tall, non-input-responsive varieties. Aerobic rice can be cultivated in the upper, middle, and lower parts of the toposequence, and accordingly, varieties of different maturity duration are needed. Supplementary irrigation is provided through surface irrigation when no rain and moisture stress are visible during any period of crop growth. In direct-seeded rice, weeds are a major problem, so varieties of intermediate height with good seedling vigor are preferred for demonstration. Generally, rains begin in the third week of June and nursery sowing starts for rainfed transplanted crops. In the first fortnight of July, when soils are saturated and rainfall of about 50 mm occurs on a single day, water harvesting through bunds was done and the fields are puddled and transplanted. Growing rice in unpudddled aerobic soil, with the use of external inputs such as supplementary irrigation and fertilizer and aiming for high yield under tropical conditions have also been proposed at IRRI (Bouman *et al.,* 2005). The main driving force behind aerobic rice is economical with water use and timely sowing. As insufficient and delayed rain reduces rice area, and production in transplanted rice cultivation a fundamental approach to reduce water inputs in rice is growing the crop like an irrigated upland crop, such as wheat or maize. Instead of trying to reduce water input in lowland paddy fields, the concept of having the field flooded or saturated is abandoned altogether (Bouman and Tuong, 2001). In direct seeding, weeds are hardy and have a profuse root and shoot growth habit; they grow faster than rice thereby checking the growth of rice plants by severe weed-crop competition. This can be managed by weedicides or with legume crops as mulch.

Materials and Methods

Birsa Agricultural University, Kanke, Ranchi, is situated at 23^0 17' north latitude, $85^0$19' east longitude, and an altitude of 625 m above mean sea level. This location has a subtropical sub-humid climate characterized by hot and dry summer, cold winter, and moderate annual rainfall. The experimental plot represents midland having red loam type of soil, which belongs to the "red, yellow-light gray" group representing the major soil order Alfisols of Jharkhand. The soils are well aggregated with high permeability and low water retention capacity due to the presence of hydrated oxides of iron and aluminum. Soil test values of 100 experimental plots indicated that the soil was sandy loam in texture (Sand 63%, silt 22% and clay 15%), slightly acidic in nature, and moderately fertile, being low in organic carbon, low in available nitrogen, high in available phosphorus, and medium in available potassium.

Two types of experiments were carried out with the Rice Research Unit, Kanke, Ranchi, at BAU during the 2017 and 2018 wet season (WS); One on varietal trials to select higher-yielding, drought-tolerant, disease-resistant varieties; and the other on weed management in aerobic rice.

Varietal evaluation for aerobic rice

Varietal yield trials from AICRIP, Hyderabad, began in 2009 to select better-yielding varieties for midlands. Three yield trials, namely, Initial Varietal Trial (IVT), and two Advance Varietal Trials (AVT-1 &AVT-2), were conducted in the 2017 WS, and three trials in the 2018 WS in Kanke, Ranchi. The IVT was grown in two replications and the AVTs in three replications. The trials were direct seeded in the first week of July with a row-to-row distance of 20 cm and applied 80:60:40 NPK ha^{-1}. A full dose of P and K was applied as basal application while N was applied as top-dressing in two equal splits as urea at 25 and 50 days after seeding. The top dressing was done after hand weeding. Two irrigations were given as and when drought symptoms were visible in the field during the drought spell period.

Weed management in aerobic rice

Weeds are a major problem in direct seeded rice (**Table 3**). A legume crop such as dhaincha (*Sesbania aculeate*), Cowpea (*Vigna unguiculata*), and urd bean (*Vigna mungo*) as green mulch with different nitrogen and weedicide treatments was used in Kanke during 2017 and 2018 wet season with objectives to find the effects of nitrogen rates and weed management on growth, grain yield attributes, grain and straw yield, and weed control efficiency. During 2009 WS, three treatments comprising three nitrogen rates (N_1=75, N_2=100, and N_3=125 kg ha^{-1}) in the main plots and five

Table 3. Major weeds present in the experimental field of rice

Botanical name	English	Family
GRASSES		
Echinochloacolona	Water grass	Poaceae
Digitariasangunalis	Large crab grass	Poaceae
Eleusineindica	Goose grass	Poaceae
Paspalumdistichum	Knot grasss	Poaceae
Brachiariamilliformis	Signal grass	Poaceae
BROAD LEAF WEEDS		
Ludwigiaparviflora	Water purslane	Onagraceae
Sphelenthusacmella	Toothache plant	Spehenocleacae
Eclipta alba	False daisy	Asteraceae
Commelinabenghalensis	Day flower	Commelinaceae
SEDGES		
Cyperusiria	Flat sedge	cyperaceae
Fimbristylismiliaceae	Fimbristylis	cyperaceae
Kyllingabravifolia	Kyllinga	cyperaceae
Cyperusdifformis	Nut sedge	cyperaceae

treatments in the sub-plots (W_1=dhaincha in between rice rows + Pendimethalin at 0.75 kg a.i. ha^{-1}, W_2= rice + Pendimethalin at 0.75 a.i., W_3= Cowpea in between rice rows + Pendimethalin at 0.75 a.i., W_4= weed-free check (two mechanical weedings at 20 and 40 DAS), and W_5= unseeded check). During 2010 WS, sub-plots with seven weed control methods were used: W_1= dhaincha in between rice row + Pendimethalin at 0.75 a.i. ha^{-1}, W_2= rice + Pendimethalin at 0.75 kg a.i., W_3= dhaincha between rice rows + Pendimethalin at 0.75 kg a.i. + 2,4D (0.8 kg a.i.) at 25 DAS, W_4= urd bean rice row + Pendimethalin at 0.75 kg a.i. , W_5= Urd bean in between rice row + Pendimethalin at 0.75 kg a.i. + 2,4D (0.8 kg a.i.) at 25 DAS, W_6= weed free check and W_7= unweeded check. In W_1, W_3 and W_5 treatments, dhaincha, cowpea, or urd bean was uprooted and left in between rows as a green mulch. The experiment was laid out in a split-plot design with three replications. The soil was slightly acidic (pH 6.2), Sandy loam in texture, organic carbon (0.46%) and available nitrogen (228 kg ha^{-1}), high in available phosphorus (35.3 kg ha^{-1}), and medium in available potassium (157.1 kg ha^{-1}). During the 2009 WS, 40 kg P and 20 kg K and in the 2010 WS, 60 kg P and 40 kg K were applied as basal dose in all the treatments. N was applied as DAP (18% N and 46% P_2O_5) as basal dose, and Urea (urea 46% N) as top dressing. P and K were applied through DAP and muriate of potash (60% K_2O). The plot size was 20 cm^2 each.

Results and Discussion

Varietal evaluation for aerobic rice yield trials

2017 yield trials: Three trials, an initial varietal trial aerobic (IVT aerobic), advance varietal trial-1 aerobic (AVT aerobic), and advance varietal trial 2 aerobic (AVT 2 aerobic), were evaluated. The IVT aerobic had 64 entries and was evaluated in two replications. CR Dhan 201 was the national check and Birsa Vikas Dhan 201 was the local check (**Table 4**). Days to 50% flowering varied from 86 to 114 days, Plant height from 80 to 118 cm, and grain yield from 2.30 to 6.90 t ha^{-1}. Late- duration varieties were affected by drought with 55% to 69% grain sterility. Varieties with 110 to 120 cm plant height under direct seeding had better weed competitive ability, and varieties with 115 to 120 days duration were desirable for midland. RP 6191-HHZl-Y4-Y1-Y1 yielded a maximum of 6.90 t ha^{-1} compared with 4.65 t ha^{-1} by CR Dhan 201.

Table 4. Initial Varietal Trial- Aerobic (IVT -Aerob) in 2017 WS at BAU, Kanke, Ranchi

Entries	Yield ($t\ ha^{-1}$)	Days to 50% flowering	Plant height (cm)	No. of panicle m^{-2}
CR 3721-1-3-1-1-1-2.	2.55	99	105	259
BPT 2601	2.85	114	94	323
RP Bio 4918-B-B-1425	3.15	108	91	365
RP 6273-HHZ4-DT3-L11-L11	6.10	88	105	241
IDP-1-1-1695	2.95	91	102	131
11KR 15-4-1R 99784-255-91-1-5	4.20	87	100	243
TRC-2017-20	4.30	86	96	336
PAU 7554-1-1-1 (EH 214-Y7-Y1-FT-2)	5.40	88	92	274
CR 3721-1-3-1-1-1-2.	4.10	109	114	169
BPT 2601	3.80	91	93	275
RP Bio 4918-B-B-1425	2.55	98	108	253
RP 6273-HHZ4-DT3-L11-L11	2.35	95	103	241
JDP-1-1-1695	3.80	86	100	210
HKR 15-4-1R 99784-255-91-1-5	3.55	91	100	271
CR Dhan 201 (NC)	4.65	90	106	316
RDR-1158	5.35	95	97	335
CR 3996-331-1-2	3.55	88	109	293
Rewa 1113	3.00	92	90	243
US 335 Hybrid	3.85	99	100	323
RP 5934-73-2	3.35	92	99	258
KPH-468 Il,bri	5.65	92	91	226
PAU 6508-273-13-20-6-2	2.30	108	93	290
RP 5594-410-12-6-3	4.15	95	108	211
BPT 2611	2.25	118	98	190
RP 5943-68-17-6-3-1-1-1	4.70	88	128	217
TRC-2017-21	3.70	102	106	333
NWGR-13031	5.40	87	97	220
OR 2567-3	4.80	87	88	305
RP 6222-GSR IRI-12-Y4-D 1 -Y3	5.20	90	100	268
CR 4002-1324-2-2	4.55	95	115	249
PA 6129 (HC)	6.45	90	105	231
CR 4043-1-2-1-1-1-IR95796	3.85	91	102	211
BRR 2085	3.10	91	111	260
HURS 17-9-1R 95836-14-3-1-2	4.75	87	107	232
CR4043-1-2-l-1-l	4.05	90	100	268

Entries	Yield (t ha^{-1})	Days to 50% flowering	Plant height (cm)	No. of panicle m^{-2}
CB 14756	3.95	90	90	297
YRH 2007 (Hybrid)	2.50	99	109	291
CR Dhan 202 (ZC)	4.70	86	96	188
CR 3983-53-1-2-1-2-R95786	5.00	91	82	245
RP Bio 4918-B-B-2215	2.40	109	100	249
RP 6226-GSR IRI-11-YI O-D3-Y3	4.15	90	98	264
HKR 15-3-1R 91326-19-2-1-2	4.25	86	102	188
RP 5933-123-2	3.55	109	99	216
RP Bio 4918 B-B-166SW	2.55	100	114	283
CR 4006-564-3-1-4	3.85	87	97	261
UPR 3976-24-1-1-1	3.85	107	89	271
RP 6275-GSR IRI-15-D4- Dl -YI	4.60	88	80	239
RP Bio 4918 B-B-248L	2.15	107	96	330
UPR3961-6-1-2-1	3.30	107	92	294
R 1700-2247-1-2313-1	3.90	87	98	365
HURS 17-10-IR 93827-27-1-1-2	5.25	88	104	314
CR 3848-1-1-2-1-1	4.00	89	98	301
RP 6112-MS-14-3-9-8-5-4-2	3.40	102	118	288
RCPR 36-1R84899-B-185-8-1-1-2	4.75	86	97	292
RP 5988-78-25-18-5-99-6-70-220	2.65	100	99	288
Rewa 1187	2.75	84	118	254
NVSR -2147	5.00	86	99	241
RP 6191-HHZl-Y4-Y1-Y1	6.90	90	101	242
BRR 2077	3.15	88	102	313
NVSR-2107	5.40	86	101	224
RCPR 25-1R 88964-24-2-1-4	4.00	88	100	334
RP 6263-GSR IRI-5- Y3-Y1-Dl	2.80	100	98	207
CB 14530	3.25	91	102	298
Birsa Dhan 201 (LC)	4.15	99	105	369
CD at 5%	**1.31**			
CV%	**14.66**			

In AVT 1 aerobic, 23 entries were evaluated in three replications (**Table 5**). CR Dhan 201 and Birsa Dhan 201 were used as checks. Grain yield varied from 2.20 to 5.29 t ha^{-1}. The three top-yielding entries were US 380 (5.29 t ha^{-1}), MEPH-134 (5.02 t ha^{-1}), and RP 5601-283-14-4-1 (4.87 t ha^{-1}). CR Dhan 201 out yielded Birsa dhan 201 with 3.29 t ha^{-1}, 3.20 t ha^{-1}, respectively. The plant height of Birsa dhan 201 (112 cm) was also higher and more appropriate than that of CR dhan 201(101 cm).

Table 5. Advance Varietal Trial 1 Aerobic (AVT 1-Aerobic) in 2017 WS at BAU, Kanke, Ranchi

Entries	Yield ($t\ ha^{-1}$)	Days to 50% flowering	Plant height (cm)	No. of panicle m^{-2}
CR 3997-8-IR91648-B-89-B-5-1	2.93	87	98	259
Rewa 1121-475-15-1-1	2.92	87	83	198
OR 2568-4	2.88	81	96	307
BPT 2671	3.38	111	97	206
IR 95812-CR3948-1-2-1-2	3.89	88	103	227
CR Dhan 201 (NC)	3.29	86	101	365
US 380 (hybrid)	5.29	108	101	242
MEPH 134 (hybrid)	5.02	82	98	264
CR 3947-9-25-3-2	3.40	109	98	128
TRC 2015-5	4.00	86	99	168
CB 14932	3.20	74	62	308
AAGP 9412	3.16	79	93	366
CR 3996-11-240-3-1	3.58	86	101	225
RP 5601-283-14-4-1	4.87	90	99	287
RP 5591-123-16-2	3.98	87	95	336
RP 5587-B-B-B-210-1	3.02	86	87	344
CR Dhan 202	3.42	88	101	218
RP 5594-410-53-4-2	2.24	107	102	129
R 1882-306-4-243-1	3.16	89	98	258
RP 5477-N22 SM -162	3.51	112	105	152
PA 6129 (HC)	2.36	86	98	201
RP 5593-83-12-3-1	3.80	88	100	269
Birsa Dhan 201 (LC)	3.04	84	91	457
CD at 5%	**1.08**			
CV%	**12.78**			

In AVT 2 aerobic, 18 entries were evaluated in three replications **(Table 6**). CR Dhan 201 and Birsa Dhan 201were used as checks. Grain yield varied from 3.27 to 6.67 $t\ ha^{-1}$. The entry RP 5955-15-1-1-1-1 gave maximum yield (6.67 $t\ ha^{-1}$) followed by RP 5943-421-16-1-1-B (5.60 $t\ ha^{-1}$). CR Dhan 201 out yielded Birsa dhan 201 yielded 4.33 $t\ ha^{-1}$, 3.20 $t\ ha^{-1}$, respectively.

Table 6. Advance Varietal Trial 2 Aerobic (AVT 2-Aerob) in 2017 WS at BAU, Kanke, Ranchi

Entries	Yield (t ha^{-1})	Days to 50% flowering	Plant height (cm)	No. of panicle m^{-2}
R 1986-296-2-86-1	4.00	88	110	228
PAU-2K 10-23-53-14-52-20-0-4	5.00	100	97	295
PCPR-20-IR83929-B-B-291-2-1-1-2	4.93	82	107	235
TRC-2015-15	4.33	81	103	248
CR Dhan 201 (NC)	4.33	82	103	337
CR 948-2-1-2-2-2-1	3.87	82	102	361
OR 2529-1	3.27	111	98	203
R 1973-206-2-86-1	5.00	83	97	310
UPR 3841-8-1	2.93	89	101	104
CR Dhan 202	5.27	80	104	240
PCPR-21-IR84887-B-158-7-1-1-4	4.80	78	105	234
TRC-2015-12	5.33	86	106	165
CR 3848-1-1-1-6	3.67	82	105	288
PCPR-22-IR848899-B-183-20-1-1-1	4.67	82	115	247
RP 5943-421-16-1-1-B	5.60	84	108	171
OR 2537-1	4.00	107	107	294
RP 5955-15-1-1-1-1	6.67	81	105	246
Birsa Dhan 201(LC)	3.67	76	100	223
CD at 5%	**1.27**			
CV%	**12.54**			

2018 yield trials: In IVT-aerobic, 64 entries were evaluated in two replications (**Table 7**). Two entries namely IIRRH 124 (hybrid; 4.70 t ha^{-1}), and PA 6129 (hybrid; 4.52 t ha^{-1}) yielded maximum. These genotypes were early maturing, duration of 106 days, as compared with other entries of 120 days duration. It was also taller (109 cm) to better compete with weeds.

In AVT-1 aerobic, 16 entries were evaluated in two replications (**Table 8**). CR dhan 201 and Birsa Dhan 201 were the checks. Four entries, *viz.*, NVSR 2107 (4.93 t ha^{-1}), PA 6129 (4.81 t ha^{-1}), HURS 17-10-IR 93827-27-1-1-2 (4.72 t ha^{-1}), and RP 6273-HHZ4-DT3-LI1-LI1 (4.66 t ha^{-1}) were higher yielding than check CR dhan 201 (3.44 t ha^{-1}). The plant height of NVSR 2107 was 87 cm and HURS 17-10-IR 93827-27-1-1-2 was 85 cm. All four selected entries are of medium duration (120 to 131 days).

In AVT-2 aerobic, 17 entries were evaluated in three replications (**Table 9**). Two entries, PA6129 (hybrid; 5.36 t ha^{-1}) and MEPH 134 (5.02 t ha^{-1}) were top yielders. These entries also belong to the medium maturity group, with a plant height of 91 to 101 cm.

All six yield trials during 2017 and 2018 showed wide variability for grain yield, its components, plant height, maturity, and resistance to the natural

Table 7. Initial Varietal Trial- Aerobic (IVT -Aerob) in 2018 WS at BAU, Kanke, Ranchi

Entries	Yield (t ha^{-1})	Days to 50% flowering	Plant height (cm)	No. of panicle m^{-2}
OR 25254-1	2.25	103	56	95
Pusa 1827-12-55	2.80	82	73	109
RCPR 57-1R 84898-B-165-9-1 -1	3.15	85	91	163
RP 5977-MS-112-1-9-4-2-35-8-6	3.15	93	109	146
RP6313-GSR IRI-D Q 126-L15-Y1	2.95	85	83	205
R 1532-1101-1-119-1	2.95	88	76	197
RP 5973-20-9-8-24-6-3	2.55	93	69	148
RP 5678-465-544-3	2.45	92	83	189
CR 4160-2-IR 93329:61-B-21-1221-1RGA-2RGA-ı-B-B	3.35	88	85	100
OR 2520-4-1	3.30	85	89	228
IIRRH 124 (Hybrid)	4.65	78	101	195
MSN 101 (DH4)	3.00	81	100	117
TRC 2018-8	3.35	89	86	77
HKR 16-2-IR 9578043-1-1-1	2.80	78	83	104
NVSR 396	2.25	76	87	213
CR 4114-2-1-1-1-1	2.65	88	81	160
US341 (Hybrid)	2.70	92	79	188
CR dhan 201 (C)	2.95	86	70	148
CR 4007-547-1 1-2-1-2-3-3	3.15	83	93	238
NVSR 2285	3.65	86	71	156
NVSR 399	3.05	78	104	160
PAU 5563-23-1-1	2.55	93	84	150
CR 4116-3-2-1-1-1	2.35	100	93	145
NWGR 14071	2.45	92	80	126
YRH716 (Hybrid)	3.10	87	86	143
HURŞ 18-2-11198976-20-1-2-2	3.80	78	80	188
PAU 5563-23-1-1	2.70	82	90	98
CR dhan 202	2.45	91	86	73
CR 4114-1-2-1-2-2-1	3.15	86	92	223
NVSR 391	2.70	86	72	130
HHZ 3-SAL 13-Y2-DT1 (RYT 3578)	2.20	98	83	151
RP 61 12-MS-8-6-5-9-1-3-4-7	3.35	84	82	225
RP 5938-75-6-7-3-1	3.35	92	92	218
CR 4161-4-1R14L 572	2.70	96	70	110
Pusa 1827-12-14	2.85	89	93	173

RP Bio 4918 B-B-166-30	2.00	87	80	71
RP 5401-B-184-2-1-1-1	2.75	84	71	173
RCPR 56-1R 93827-29-1-1-4	2.90	90	86	114
RP 6301-189-17-2	2.70	86	93	263
CR4115-2-1-2-1-1	2.80	84	80	261
CR 3999-377-2-1-2	4.05	79	76	93
PA 6129 (HC)	3.90	75	103	257
CR 4011-8-3-GSRIR1-DQ136-Y8-Y1	3.45	81	73	189
NVSR 395	3.85	90	76	118
YRH721 (HYBRID)	3.30	88	96	161
R 1912-172-2-111-1	3.15	87	72	203
MSN 102	3.00	86	87	107
JGL 24423	2.85	92	77	178
CR 4113-1-1-2-1-1	3.15	85	81	168
NVSR 2112	3.25	85	88	121
CR 4010-8-3- GSR IRI-DQ122Y5-Y1	2.85	97	69	93
JDP 1817 (IR14L594)	2.35	88	81	155
RP 6112-MS494-1 -3-5-2-7-9	3.50	78	80	180
RP 6314-GSR IRI-D	3.10	82	83	193
RP 6307-GSR IR 1-DQ136-Y8-Y1	2.95	84	72	298
CR 4112-2-1-3-2	2.70	85	78	102
TRC 2018-5	2.50	86	90	211
RP 6306-GSR IRI-23-S15-Y1-Y1-D1	3.15	80	84	260
CR 4006-564-3-1-14-3	3.20	73	100	188
RP 5972-13-1-6-67-129-268	3.70	92	92	218
Birsa Dhan 201 (LC)	3.25	96	100	210
CD at 5%	**1.38**			
CV%	**12.56**			

Table 8. Advance Varietal Trial 1 Aerobic (AVT 1-Aerob) in 2018 WS at BAU, Kanke, Ranchi

Entries	**Yield ($t\ ha^{-1}$)**	**Days to 50% flowering**	**Plant height (cm)**	**No. of panicle m^{-2}**
CR 3983-53-1-2-1-2-IR95786	3.69	83	326	305
NWGR 13031	2.33	84	273	274
RP 6191-H11Z1-Y4-Y1-Y1	3.11	90	298	285
RP 5977-MS-M42-1-94-2-35-8-6	3.67	92	229	265
TRC 2017-20	3.42	94	236	288
CR Dhan 201 (NC)	3.44	101	208	271
NVSR 2107	4.93	95	325	304
HURS 17-10-IR 93827-27-1-1-2	4.72	90	292	329
CR Dhan 202 (ZC)	3.84	106	234	247

Entries	Yield (t ha^{-1})	Days to 50% flowering	Plant height (cm)	No. of panicle m^{-2}
NVSR 2147	3.38	92	245	274
RCPR25-1R 88964-24-2-14	3.67	91	228	265
PA 6129 (HC)	4.81	88	229	285
CR4043-1-2-1-1-l	2.82	89	316	322
RDR 1158	2.42	89	235	228
RP 6273-HHZ4-DT3-LI1-LI1	4.86	87	229	258
Birsa Dhan 201 (LC)	3.87	88	358	310
CD at 5%	**0.79**			
CV%	**13.56**			

Table 9. Advance Varietal Trial 2 Aerobic (AVT 2-Aerob) in 2018 WS at BAU, Kanke, Ranchi

Entries	Yield (t ha^{-1})	Days to 50% flowering	Plant height (cm)	No. of panicle m^{-2}
OR 2568-4	4.24	81	81	248
TRC2015-5	3.60	87	94	151
RCPR 20-1R83929-B-B-291-2-1-1-2	3.93	86	96	183
RI) 5601-283-14-4-1	3.16	95	88	200
CR Dhan 201 (nc)	3.11	86	92	274
RCPR 22-1R84899-B-183-20-1-1-1	3.82	86	100	169
MEPH 134	4.36	80	99	196
US 380 H,brid)	4.42	95	86	247
CR Dhan 202	3.22	86	92	143
RP 5591-123-16-2	3.31	85	91	238
CR 3996-11-240-3-1	4.18	86	91	227
RP 5943-421-16-I-I-B	3.60	86	105	194
PA 6129 (HC)	4.86	91	88	203
BPT 2671	3.12	97	72	157
R 1882-3064-243-1	3.02	88	86	207
RP 5593-83-12-3-1	3.69	81	95	196
Birsa Dhan 201(LC)	4.09	79	99	285
CD at 5%	**0.69**			
CV%	**12.99**			

infestation of leaf blast and brown spot. Many entries out-yielded the local or national checks, Birsa Dhan 201 and CR Dhan 201. Varieties such as Birsa Dhan 201 were primarily developed for the irrigated ecosystem, and their height decreases in the direct-seeded rainfed ecosystem because of the occurrence of drought spells. There is consistency in the yield superiority of certain entries in both the years. Several varieties have already been released in India, the Philippines, and Nepal (Pradhan *et al.,* 2016). This shows their wide adaptation to the aerobic system of cultivation. These varieties were developed through screening for drought tolerance. This shows that, for developing varieties for aerobic conditions, especially for rainfed environments, drought tolerance is one of the important traits. All other high-yielding varieties should be evaluated in multi-location trials and in farmers' fields through participatory varietal selection. The entries susceptible to blast and the brown spot should be discarded.

Weed Management

Weed management experiments revealed that grain and straw yield were significantly higher at 125 kg N than at 75 and 100 kg N (**Tables 10, 11** and **12**). The increase in grain yield arose mainly from an increase in values for yield components, that is, effective panicles m^{-2}, fertile grains per panicle, and 1000 grain weight. Weed dry matter (g m^{-2}) at harvest

Table 10. Nitrogen x Weed control method (N x W) interaction for grain yield (t ha^{-1}) of aerobic rice variety Naveen during 2017 WS at Kanke, Ranchi

Treatment	N1:75kgN ha^{-1}	N2:100kgN ha^{-1}	N3:125kgN ha^{-1}	Mean
W1: rice+ dhaincha (1:1)+pend. at 0.75 kg a.i.ha^{-1}	3.81	4.23	4.40*	4.15
W2: pend. at 0.75 kg a.i.ha^{-1} + 1 H.W. at 60 DAS	3.41	3.83	3.98	3.74
W3: rice + cowpea (1:1) + pend. at 0.75 kg a.i.ha^{-1}	3.82	4.16	4.27*	4.08
W4: two mechanical weedings (20 and 40 DAS)	3.42	3.79	3.93	3.71
W5: unweeded check	2.84	3.18	3.31	3.11
Mean	**3.46**	**3.84**	**3.98**	
N at same level of W	SEm = 0.15; CD (P=0.05) - NS			
W at same level of N	SEm = 0.17; CD (P=0.05) - NS			

Table 11. Nitrogen x Weed control method (N x W) interaction for weed dry matter (g/m^2) of aerobic rice variety Naveen during 2017 WS at Kanke, Ranchi

Treatment	N1:75kgN ha^{-1}	N2:100kgN ha^{-1}	N3:125kgN ha^{-1}	Mean
W1: rice+dhaincha (1:1)+pend. at 0.75 kg a.i.ha^{-1}	21.6*	23.1	26.5	23.7
W2: pend. at 0.75 kg a.i.ha^{-1} + 1 H.W. at 60 DAS	56.2	72.2	79.7	69.4
W3: rice + cowpea (1:1) + pend. at 0.75 kg a.i.ha^{-1}	26.8	25.2	28.7	26.9
W4: two mechanical weedings (20 and 40 DAS)	54.03	67.5	85.3	69
W5: unweeded check	103.2	108.4	111.2	107.6
Mean	**52.42**	**59.27**	**66.28**	
N at same level of W	SEm= 3.64; CD (P=0.05) = 11.19			

Table 12. Effect of nitrogen doses and weed control methods on grain yield, yield attributes, and weed dry matter of aerobic rice during 2018WS at Kanke, Ranchi

Treatment	Effective panicles m^{-2}	Fertile grains panicle^{-1}	1000-grain weight(g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Weed dry matter (gm^{-1}) at harvest*	WCE (%)
Main plot :N level							
N1:75kgN ha^{-1}	234	86.1	23.17	3.53	5.00	26.26 (709.6)	49.2
N2:100kgN ha^{-1}	256	90.5	23.58	3.74	5.52	27.34 (769.6)	44.9
N3:125kgN ha^{-1}	266	95.4	23.72	3.90	5.78	28.86 (850.7)	39.1
CD (P=0.05)	9.6	6.8	0.39	0.11	0.20	0.97	-
Subplot: weed control method							
W1: rice+dhaincha (1:1)+pend. at 0.75 kg a.i.ha^{-1}	284	96.6	24.0	4.30	5.99	24.14 (583.9)	58.2
W2: pend. at 0.75 kg a.i.ha^{-1}+ 1 H.W. at 60 DAS	227	85.2	23.5	3.42	4.96	28.32 (803.7)	42.4
W3: W1+2,4D at 0.8 kg a.i.ha^{-1} at 25 DAS	295	98.1	24.0	4.37	6.17	23.16 (538.9)	61.4
W4: rice + urd bean (1:1) + pend. at 0.75 kg a.i.ha^{-1}	253	90.6	23.1	3.73	5.34	26.82 (721.3)	48.3
W5: W4+2,4D at 0.8 kg a.i.ha^{-1} at 25 DAS	256	91.9	23.5	3.78	5.41	26.2 (689.6)	50.6
W6: weed – free check, H,W at 20 and 40 DAS	257	92.0	23.3	3.94	5.97	26.47(702.9)	49.6
W7: unweeded check	192	80.5	23.2	2.53	4.20	37.31(1396.3)	-
LSD (0.05)	**25.5**	**4.6**	**0.79**	**0.30**	**0.37**	**1.35**	
CV (%)	**9.5**	**5.2**	**4.2**	**8.4**	**7.0**	**5.16**	

was significantly higher at 125 kg N but decreased significantly in treatments with dhaincha, cowpea, and urd bean grown in between rows. The use of pendimethalin at 0.75 kg a.i. in 2017 and 2018 and /or 2,4D at 0.8 kg a.i. ha^{-1} in addition to pendimethalin also reduced weed flora and weed mass. The weed flora in the trial is given in **Table 3**. In the 2017 WS, grain yield biomass was maximum (4.4 t ha^{-1}) in W1 (rice + dhaincha (1:1 interrow) with pendimethalin) (**Table 9**). Weed dry matter was also low in rice+dhaincha or rice+cowpea plots compared with other treatments. Pendimethalin alone with rice was not able to reduce weed biomass (**Table 10**). In the 2018 WS, WCE was maximum 61.4% in W3, the combination of dhaincha in between rice rows + pendimethalin at 0.75 a.i. + 2,4-D at 0.8 kg a.i. ha^{-1}) followed by W1 (dhaincha between rows + pendimethalin at 0.75 kg a.i. ha^{-1}) (Sunil *et al.*, 2018). The use of dhaincha was better than urd bean (**Table 11**). This shows that dhaincha should be preferred, but if it is not available then urd bean that is widely grown as a grain legume crop, can also be used effectively as line mulch or browning through spraying of 2,4-D. Dry matter of weeds at harvest and WCE were higher in interrow crops of dhaincha or urd bean than in mechanically weeded plots.

Conclusion

From the different varietal trials on aerobic rice for two years, it was observed that CR Dhan 201, US 380 (hybrid), and PA 6129 (hybrid) are found to be high yielding than Naveen, selected based on duration and plant type. Naveen was found to be susceptible to leaf blast and brown spot. These varieties can be tested in multi-location trials and in farmers' fields for wide adoption. New high-yielding varieties with tolerance to major diseases and pests must continue to evolve. In weed management trials, the rice variety Naveen grown under aerobic conditions with 125 kg N ha^{-1} was productive and profitable. Planting dhaincha in between rice rows + Pendimethalin at 0.75 a.i. ha^{-1} + 2,4D at 0.8 kg a.i. ha^{-1}at 25 DAS (W_3) suppressed weed density, and weed dry matter accumulation, provided maximum weed control efficiency, and resulted in higher productivity of rice. In the absence of dhaincha seed availability, cowpea and urd bean can also be grown as an intercrop or mixed crop.

Future outlook

The research on aerobic rice in India and drought-prone states such as Jharkhand and others is quite limited. In the era of climate change, and shifts in rainfall patterns, it is essential that systematic research on aerobic rice varietal development and screening for drought tolerance and other location-specific biotic and abiotic stresses should be carried out through multidisciplinary team efforts. Singh and Chinnusamy (2007) have also demonstrated the potential of this technology in farmers' fields of western Uttar Pradesh and the amount of water saved through the adoption of this technology. Globally, Prasad (2011) reviewed the problems, potential, and possibilities in the different countries of the world. In collaboration with IRRI, varietal screening, and agronomic experiments have begun at NRRI, Cuttack and variety Apo was released in 2012 in Odisha. Earlier work at UAS, Bangalore, also lead to the release of Sharada for Karnataka State. If rains are delayed or fail, aerobic rice demonstration through Krishi Vigyan Kendra and on-farm demonstration should be carried out. The extension system of the Department of Agriculture should be involved in the training and dissemination of technology on a large scale.

References

Bouman BAM, Toung TP. 2001. Field water management to save water and increase productivity in irrigated rice. *Agricultural Water Management*, 49:11-30.

Bouman BAM, Peng S, Castaneda AR, Visperes RM. 2005. Yield and water use of irrigated tropical aerobic rice systems. *Agricultural Water Management*, 74:87-105

Chauhan BS. 2012. Weed Management in direct-seeded rice systems. Los Banos (Philippines): International Rice Research Institute, pp.20.

Guimaraes EP, Stone LF. 2000. Current status of high yielding aerobic rice in Brazil. High yielding aerobic rice,7-8 September 2000. Los Banos (Philippines): International Rice Research Institute. 12p.

Pinheiro BS, Castro EM, Guimaraes CM. 2006. Suitability and profitability of aerobic rice production in Brazil. *Field Crops Research*, 97:34-42.

Prasad R. 2011. Aerobic rice system. *Advances in Agronomy,* 111:207-247. https://doi. org/10.1016/B978-0-12-387689-8.00003-5.

Pradhan SK, Mall AK, Ghosh A, Singh S, Samal P, Dash SK, Singh, ON, Kumar A. 2016. Aerobic rice perspectives in India: progress and challenges. Regional: Development and Dissemination of Climate-Resilient Rice Varieties for Water-Short Areas of South Asia and Southeast Asia, 48.

Rahman MM, Masood M. 2012. Aerobic System: A Potential water saving Boro Rice Production technology. Adaptation of aerobic system for Boro rice cultivation in farmer's field for saving irrigation water and attaining food Security-Project pp:1-2

Singh AK, Chinnusamy V. 2007. Aerobic rice: a success story. *Indian Farming,* 57:7-10

Stone LF, Pinero B da S, Silvera PM. 1990. Sprinkler irrigated rice under Brazilian conditions. In: Proceedings of the 17th International Commission, Goiania, Brazil. *International Rice Newsletter,* 39:36-40.

Sunil CM. 2018. Weed Management Practices in Aerobic Rice – A Review. *International Journal of Agriculture Sciences,* 10:5401-5405

Wang H, Bouman BAM, Zhao D, Wang C, Moya PF. 2002. Aerobic rice in northern China: opportunities and challenges. In: Water wise rice production (Eds. Bouman BAM, Hengsdijk H, Hardy B, Bindraban PS, Toung TP, Ladha JK). Proceedings of the International Workshop on Water Wise Rice production, 8-11 April. Los Banos (Philippines), International Rice Research Institute. Pp. 143-154.

Yang X, Bouman BAM, Wang H, Wang Z, Zhao J, Chen B. 2005. Performance of temperate aerobic rice under different water regimes in North China. *Agricultural Water Management,* 74:107-122.

RESEARCH ARTICLE https://doi.org/10.58297/DKUN5024

Adoption Status of Improved Paddy Varieties and Fertilizer Use in Moga District of Punjab

Sangeet Ranguwal*[1] and Mavi HK[2]

[1]Agricultural Economist, Department of Economics and Sociology, Punjab Agricultural University, Ludhiana, Punjab.
[2]Scientist (Agricultural Marketing), Department of Economics and Sociology,
Punjab Agricultural University, Ludhiana, Punjab
*Corresponding author's Email: sangeet@pau.edu

Received: 30th November 2022; Accepted: 20th December 2022

Abstract

Paddy is a major food crop having significance for millions of farmers. It is grown under paddy-wheat cropping system on a vast area in India. In Punjab state continuous need is felt to increase area under short duration (SD) paddy varieties for better crop yield and to save irrigation water. Thus, adoption of these SD varieties and optimal fertilizer use are major factors that can contribute to enhanced paddy productivity in short time span. The present study was carried out in district Moga of Punjab state for five consecutive years i.e., 2017-18 to 2021-22 using the interview method for data collection from 30 respondents from each of the five blocks of the district. Analysis revealed that paddy cultivation is diversified in the district as basmati and non-basmati types along with different varieties that are being cultivated here. The area under recommended varieties has increased significantly among non-basmati paddy, unrecommended long duration variety Pusa 44 is the most preferred throughout the study period followed by Dogar Pusa due to high yield. SD varieties occupy only about 18 per cent paddy area. Only about 2 to 4 per cent of the total paddy area was transplanted before 10th of June each year except during 2020-21 Covid 19 pandemic period. Further, excessive use of fertilizer-Nitrogen by farmers in the form of urea was observed. A rise in the proportion of farmers (69% to 73%) in a span of five years which discontinued the practice of applying phosphorus to the paddy crop was also observed. The data on adoption status may help the extension agencies to focus on bridging the gap to enhance the yield of paddy and basmati and thus, income of farmers along with conservation of natural resources.

Keywords: Fertilizers, Recommended, Paddy, Short duration, Variety

Introduction

Developing and promoting the adoption of yield increasing crop varieties in a sustainable manner helps to improve the livelihood of rural farmers (Asfaw *et al.*, 2012) by improved crop production (Singh *et al.*, 2018; Adeyemi *et al.*, 2020) and thus higher per capita monthly household expenditure (Bannor *et al*., 2020). Education along with implementation of suitable policies enhances farm productivity in the case of adopters of modern technology (Paltasingh and Goyari, 2018). Varietal characteristics, extension activities, package of practices of a variety and marketing are important factors in adoption of a newly released variety in a particular area (Ghimire *et al.*, 2015, Manan *et al.*, 2018, Campenhout, (2021). Thus, the adoption of recommended improved varieties and production technologies is of utmost importance.

Paddy productivity varies widely depending on climatic conditions, water availability, soil fertility, fertilizers applied and other technological factors. This emphasizes the need for more agricultural information for farmers concerning the advantages of using good agricultural practices in paddy production (Oo and Usami, 2020). Along with improved paddy varieties, fertilizer use is one of the key factors for increasing the paddy production. Paddy is one of the input intensive crops in the world and input of nutrients contributes approximately 20–25 per cent to the total input costs of paddy (Shankar *et al.,* 2021). At present paddy production alone consumes nearly 24.7 Mt of fertilizer which accounts for approximately 14 per cent of total global fertilizer consumption in a year. Scientists have predicted that a hike of at least 60 per cent in paddy yield is essential in order to ensure food and nutritional security of 9 billion populations that are expected to inhabit the globe by 2050. With increasing demand for food production, demand for nutrients is likely to increase further.

Paddy, the largest crop industry in South Asia has special significance and economic importance in agricultural development and poverty reduction (Gumma *et al.*, 2011). In India, paddy (*Oryza sativa L.*) is the staple food crop for more than 70 per cent of people and accounts for 40-45 per cent of the total area covered by cereal crops. Paddy is grown in a paddy-wheat cropping system and this cropping system occupies more than 26 million hectares of cultivated land in the Indo-Gangetic Plains of India (Singh *et al.,* 2019). Therefore, increasing paddy productivity and production is essential to ensure national food security, reduce poverty, and safeguard against the volatility of the paddy market.

Punjab with 3.1 million hectares of land under paddy during the *kharif* season accounts for nearly seven per cent of the total area under paddy cultivation in India. The state comprising only 1.5 percent of the total geographical area of country contributes 13-14 percent towards the total food grain production of the country and has annual contributions of around 36 per cent of wheat and 26 per cent of paddy to the national pool (Anonymous, 2020). Paddy is sown in about 31 lakh hectares in Punjab and controlling the use of urea could result in saving nearly Rs 200 crore. Urea consumption registered for the same is about 10 lakh tonnes which is 3.15 lakh tonnes over and above the recommended quantity (BS, 2018). The data on adoption status may help the extension agencies to focus on bridging the gap to enhance the yield of paddy and basmati and thus, income of farmers along with conservation of natural resources. In this backdrop, the present study was conducted to assess the adoption status of improved varieties and fertilizer use practices in Punjab.

Materials and Methods

District Moga from the Western agro-climatic zone of Punjab state having 1.81 lakh Ha under paddy was selected for the study. Data were collected using the interview method for five consecutive years i.e., 2017-18 to 2021-22 from 30 respondents selected by simple random sampling method from each of the five blocks of the district namely Moga-I, Moga-II, Kot-Ise-Khan, Bagha Purana and Nihal Singh Wala. Thus, total sample consisted of 150 respondents for each year. Using a pre-tested questionnaire, data were collected regarding different paddy varieties grown, area under the varieties, variety-wise transplanting dates and fertilizer use (N, P_2O_5) was collected from the selected farmers for five years. Further, the data was analyzed using simple statistical tools like averages, percentages etc.

Results and Discussion

A. Socio-personal characteristics of the farmers: The results of the study revealed that the majority of the farmers (51.5%) were above the age of 45 years. About one-third of the respondents (35.3%) were educated up to middle followed by matriculation (29.4%), senior secondary (11.8%), graduation (6.5%) while about six per cent were unable to read and write. The family size of the majority (60.0%) was 5-8 members, however, about one third (29.7%) were having family size with more than 8 members. In most of the sampled farmers, the family members involved in farming were two **(Table 1)**.

Table 1. Social-personal characteristics of the selected respondents

S. No.	Particulars	No. of respondents	Percentage
1.	**Age (years)**		
	< 25	5	3.6
	25-35	18	12.1
	35-45	48	32.3
	>45	78	52
2.	**Family size**	150	
	1 to 4	15	10.3
	5 to 8	90	60.0
	>8	45	29.7
3.	**Family members involved in agriculture**		
	One	41	27.1
	Two	66	44.1
	Three	43	28.8
4.	**Education**		
	Illiterate	8	5.3
	Upto middle	53	35.3
	Upto matric	44	29.4
	Senior secondary	18	11.8
	Graduation	10	6.5

B. Adoption status of recommended practices

Area under recommended paddy varieties

The study revealed that among different varieties, the maximum area during the entire study period i.e., 2017-18 to 2021-22 remain occupied by long duration variety Pusa 44 (51 % in 2017-18 to about 41 % in 2021-22) due to comparatively high yield than other varieties though it needs more water, fertilizer and pesticides and is not recommended by PAU. Also, easy availability of ground water, coupled with the government's policy of supplying free electricity are the contributing factors to this finding. The private benefits obtained from higher yields of Pusa 44 compared to other varieties, far exceed its immediate costs, as the use of ground water resources is easy and inexpensive (Joshi *et al.*,2018) The next preferred variety was again unrecommended non-basmati Dogar Pusa which occupied 16.1 to 11.8 per cent of the paddy area during the study. Another major observation was that the area under unrecommended non-basmati paddy varieties has declined with time i.e., from 70.6 per cent in 2017-18 to 57.2 per cent in 2021-22 **(Table 2)**. Among recommended non-basmati varieties, PR 114 (8.8%) and PR 126 (8.3%) were the most preferred ones during 2021-22 though it was so for PR 122 (9.2%) during 2019-20. It was also observed that with time, the area under short duration (SD) varieties which require comparatively less time to mature and give farmers 20-25 days to clear the field in October-November after the kharif season harvest remained almost constant i.e., 18 per cent during the study period though it varied among different SD varieties. It was so as the yield for the SD varieties is comparatively less than Pusa 44 and Dogar Pusa in Moga district.

The area under recommended basmati varieties has almost doubled from 4.5 per cent in 2017-18 to 7.9 per cent in 2021-22 though only 0.2 per cent were under unrecommended basmati variety Muchhal during 2019-20. Among basmati paddy varieties, Pusa 1121 remained the most preferred one and it had a share of about 6 per cent in the total paddy area during 2021-22 (**Figure 1**).

Transplanting

Transplantation time for paddy starts in mid-June. The survey results indicated that only about 2 to 4 per cent of the total paddy area was transplanted before 10th of June each year (**Figure 2**) except during 2020-21 when about 9 per cent of the area was transplanted before 10th June. This happened because of the prevailing Covid-19 pandemic which forced the farmers to manage with available local labour. Across different farm operations, transplanting of paddy is the only operation in which 62.9 per cent farmers prefer migrant labour to local labour as it is manual operation to be performed well in time to avoid loss in productivity thus leading to manifold rise in demand for short-term migrant labour (Kaur *et al*., 2011). Further, during *kharif* 2021, the farmers resorted to the use of casual migrant labour which arrived in

Table 2. Trend in the area under recommended paddy varieties in Moga district of Punjab (%)

S. No.	Variety	2017-18	2018-19	2019-20	2020-21	2021-22
1.	**Recommended non-basmati varieties**					
	PR 111	0.0	0.0	0.2	0.8	0.2
	PR 112	0.0	0.0	0.0	0.0	0.7
	PR 114	3.5	2.3	6.7	7.8	8.8
	PR 118	2.6	4.3	3.3	3.6	6.4
	PR 121	6.8	5.5	2.8	1.7	2.2
	PR 122	4.1	10.0	9.2	6.6	5.7
	PR 123	0.0	0.0	0.4	0.0	0.0
	PR 124	0.0	0.0	0.0	1.4	0.0
	PR 124	2.5	1.2	2.8	0.0	1.4
	PR 126	5.3	6.7	5.5	7.7	8.3
	PR 127	0.0	0.7	1.6	0.8	0.0
	PR 128	0.0	0.0	0.0	0.7	0.4
	PR 129	0.0	0.0	0.0	0.8	0.8
	Sub total A	24.9	30.8	32.3	32.8	34.9
2.	**Unrecommended non-basmati varieties**					
	Pusa 44	51.1	34.6	47.6	45.2	40.6
	Dogar Pusa	16.1	21.4	8.3	11.1	11.8
	LR 212	0.0	0.0	0.0	0.0	2.7
	Supreme 110	0.0	0.0	0.0	0.0	0.2
	P 65	0.0	0.0	0.0	0.0	0.8
	Neelam	0.0	0.0	0.0	0.0	0.3
	SV/Sawa 27	0.7	0.4	0.5	0.2	0.0
	202	2.0	2.5	1.7	2.5	0.2
	Super 212	0.0	0.0	0.6	0.0	0.7
	777	0.7	0.4	0.2	0.0	0.0
	Sub total B	70.6	59.3	58.9	59.0	57.2
3.	**Recommended Basmati varieties**					
	Pusa Basmati 1121	3.3	6.9	7.8	5.1	6.0
	Punjab Basmati 5	1.2	0.4	0.0	0.0	0.2
	Pusa Basmati 1509	0.0	1.4	1.0	1.7	1.2
	Basmati 1718	0.0	0.8	0.0	1.0	0.4
	Pusa Basmati 1637	0.0	0.2	0.0	0.4	0.0
4.	**Unrecommended basmati (Mucchal)**	0.0	0.0	0.2	0.0	0.0
	Sub total C	4.5	9.8	8.8	8.2	7.9
	Total (A+B+C)	100.0	100.0	100.0	100.0	100.0

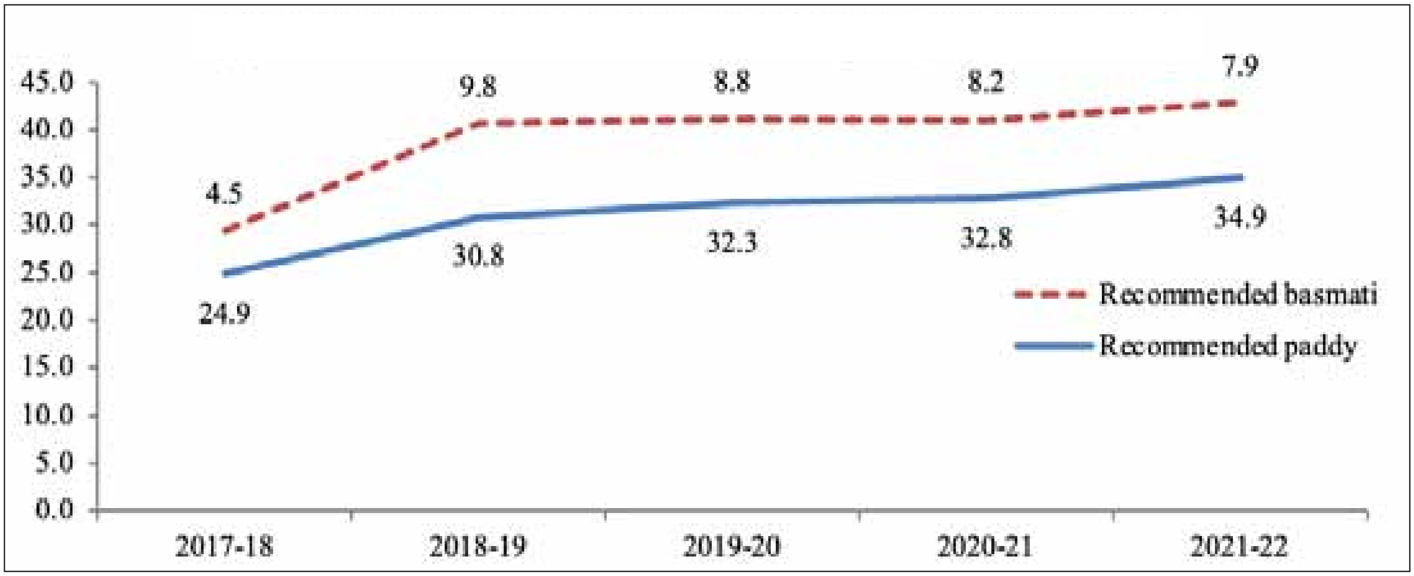


Figure 1: Trend in the area under recommended paddy varieties in Moga

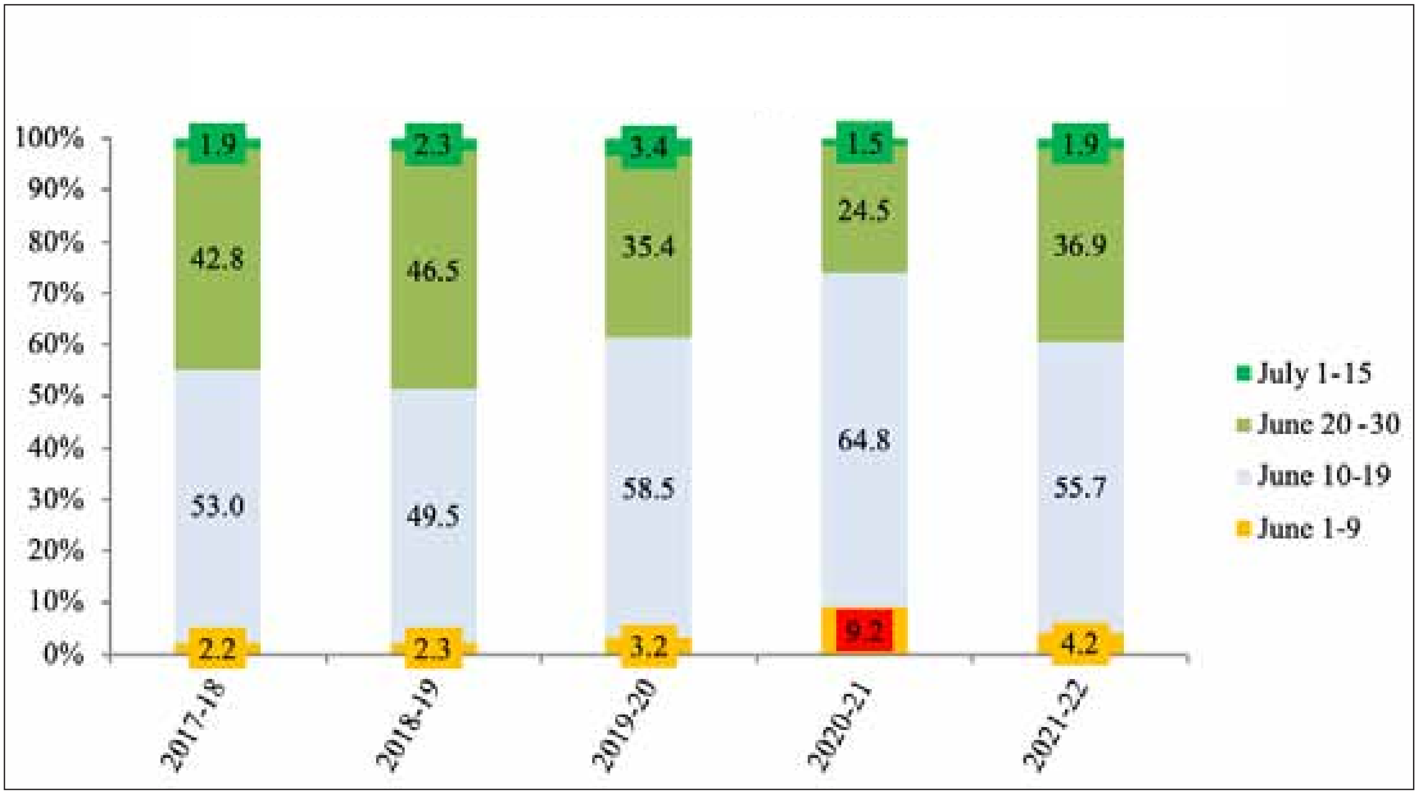


Figure 2: Paddy area transplanted during different time intervals (% share)

huge numbers in *kharif* 2021 along with use of family labour in place of highly waged local labour.

Punjab government had passed the Punjab Preservation of Sub-Soil Water Act in 2009 under which it was mandated to start paddy transplantation from June 20th to conserve subsoil water which fulfils 85 per cent of irrigation needs in the state. During *Kharif* 2020, due to the pandemic, the government relaxed these norms and advanced the paddy sowing and transplantation dates (ET, 2020). The paddy nursery sowing and transplantation operations commenced on May 10th and June 10th, respectively which also helped the farmers in the timely completion of paddy transplanting. A large share of area under paddy (50 to 65%) was transplanted between 10-19th of June followed by about 25 per cent (2020-21) to 47 per cent in 10-20th June and the rest about 2 to 3 per cent in the beginning of July (1-5th July).

The majority of the farmers had also adopted the recommended transplantation time i.e., second fortnight of June except during *Kharif* 2020. The highest area was transplanted between 1-15th of July in case of basmati during 2017-18 (39.9%) to (67.7%) in 2021-22 (**Figure 3**).

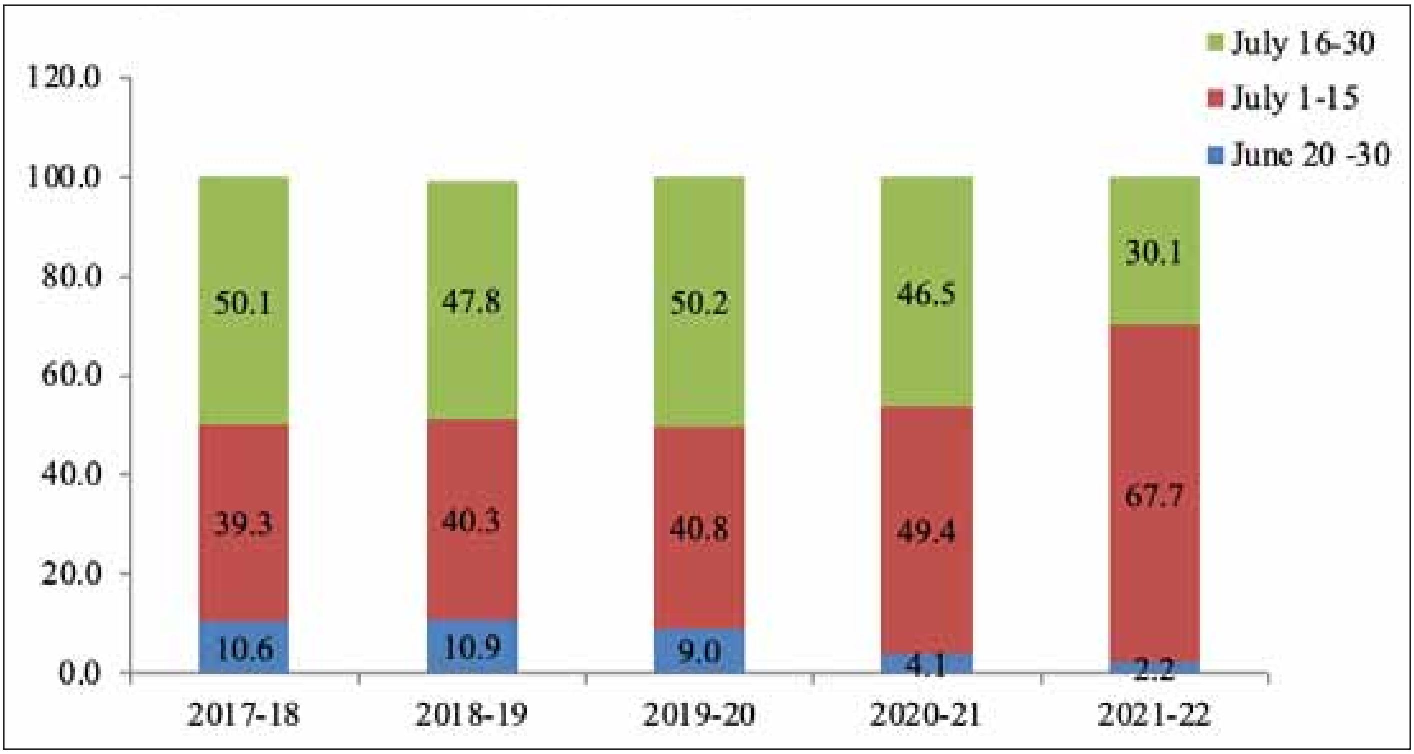


Figure 2: Basmati area transplanted during different time intervals (% share)

Fertilizer use

Punjab state ranks third at the national level for fertilizer consumption per hectare (224.49 kg/ha) with average consumption per hectare being almost one and a half times as compared to the national level of 133.12 kg/ha during 2018-19 (Anonymous, 2019). In the present study, it was found that the majority (39-44%) of the paddy farmers were applying fertilizer N in the range of 137.5-162.5 kg N/ha during different years of the survey period, while 31-37 per cent of the farmers were applying fertilizer in the range of 112.5-137.5 kg/ N/ha. The application of fertilizer N in the case of basmati paddy was in the range of 87.5-112.5 kg N/ha for a majority of the farmers. The majority of the farmers were applying fertilizer N in excess to basmati during the initial years of the survey though it has declined over the years (**Table 3**). It may be mentioned here that Integrated Nutrient Management (INM) practices lead to a significant increase in grain and straw yield of rice (Rahale, 2019) but about three-fourths of the farmers in South-Western Punjab have the second highest energy expenditure on fertilizers specifically N content after irrigation (Singh *et al.*, 2019).

Table 3. Distribution of farmers according to extent of nitrogen fertilizer use in paddy and basmati paddy in the Moga district of Punjab

Extent of nitrogen use in non-basmati paddy					
Dose of Nitrogen (Kg/Ha)	**Percentage of farmers**				
	2017-18	**2018-19**	**2019-20**	**2020-21**	**2021-22**
62.5 to 87.5	4	5	7	7	6
87.5 to 112.5	15	14	17	13	11
112.5 to 137.5	31	35	35	37	35
137.5 to 162.5	44	43	39	40	43
162.5 to 187.5	7	3	3	3	5
Extent of nitrogen use in basmati paddy					
Dose of Nitrogen (Kg/Ha)	**Percentage of farmers**				
37.5 to 62.5	11	12	13	14	13
62.5 to 87.5	33	31	35	31	33
87.5 to 112.5	39	42	42	46	47
112.5 to 137.5	17	15	10	9	7
37.5 to 62.5	11	12	13	14	13

It was evident from the data (**Table 4**) that there was a rise in proportion (69% to 73%) of farmers in a span of five years who discontinued the practice of applying phosphorus to the paddy crop. During 2021-22, there was 10 per cent of farmers applied 12.5 - 37.5 kg P_2O_5 /ha. Only 6 percent of the farmers were applying P in the range of 37.5-50 kg/ha. Kaur and Sharma (2017) reported that small farmers were using fertilizers more optimally than medium and large farmers in the state. In the case of the basmati crop, discontinuance of the practice of applying phosphorus in the span of five years increased in proportion from 38 per cent of the farmers to 49 per cent during the study period. The proportion of farmers applying fertilizer-P up to 50 kg/ ha was 12 per cent only. The use of fertilizer-K in paddy crop is recommended based on soil test reports as this nutrient is generally found available in soils to meet crop needs and none of the selected farmers was doing so. Thus, the majority of farmers were following recommended practices with respect to fertilizer use. This shows that extension efforts were successful in convincing farmers to skip the dose of fertilizer-P in case recommended dose has already been applied to *rabi* season crop.

Table 4. Distribution of farmers according to extent of phosphorus fertilizer use in paddy and basmati paddy in Moga district of Punjab

Extent of phosphorus use in paddy					
Dose of Phosphorus (Kg/Ha)	**Percentage of farmers**				
	2017-18	**2018-19**	**2019-20**	**2020-21**	**2021-22**
Nil	69	70	73	77	73
12.5 to 25	5	2	0	7	10
25 to 37.5	18	21	20	10	6
37.5 to 50	8	7	7	7	11
Extent of phosphorus use in basmati paddy					
Dose of Phosphorus (Kg/Ha)	**Percentage of farmers**				
Nil	38	40	58	51	49
12.5 to 25	19	9	0	3	6
25 to 37.5	33	30	26	31	33
37.5 to 50	10	21	16	15	12

Conclusions

The data collected regarding area shift, varieties and cultivation practices in paddy revealed that the paddy cultivation is diversified in district Moga as basmati and non-basmati types along with different varieties are being cultivated here. Pusa 44 due to its high yield is the most preferred paddy variety in the district. Policy intervention is important in this setup where the natural resource cost is not fully realized, and growing environmentally unsustainable Pusa 44 is resulting in negative externalities. On the other hand, the area under recommended varieties has increased during 2017-18 to 2020-21 and the reason behind this increase in the area could be the government policy for sowing paddy after 10th June which encourage farmers to sow short-duration varieties rather than long-duration varieties. Also, continuous extension programmes led by Punjab Agricultural University, Ludhiana, and Krishi Vigyan Kendras for creating awareness among farmers regarding short-duration and water-saving varieties and technologies like tensiometer help in adopting the recommended varieties. Only about 2 to 4 per cent of the total paddy area was transplanted before the 10th of June each year except during 2020-21 when the prevailing covid19 pandemic forced the farmers to manage paddy transplanting quickly with available local labour to tackle the high scarcity of casual labour. Excessive use of Nitrogen fertilizer by farmers in the form of urea was observed during the time period. The farmers were found to be using excessive fertilizers for paddy against the recommendation of the researchers of the PAU. Development of an appropriate management strategy for enhancing nutrient use efficiency and ensuring the environmental sustainability of the paddy production system is a priority area of research. Therefore, there is a need for an intensified extension for disseminating the technology for efficient nutrient management among the paddy growers, e.g. leaf colour chart (LCC) developed by PAU for its' wider adaptability. Fertilizer application by adopting the 4R rule, that is, the right source, rate, time, and place for enhancement of efficiency of nutrients applied by increasing yield must be adopted. By conducting regular surveys and monitoring, the adoption of new varieties, techniques, and input use can be monitored regularly, and policies can be framed accordingly by the government, universities, and extension agencies. In a study from Nepal (Pokhrel *et al.*, 2021), the results revealed that membership in an agriculture group, advice from agriculture technicians, training, visit of extension workers, and paddy-cultivated land had a positive and significant effect on the adoption of various production practices. The same can be followed for better management and adoption of recommended paddy varieties and recommended fertilizer input use. Therefore, the significant role played by extension agencies, increased emphasis on information dissemination, field demonstration, and farmers' participatory research and training programs are required.

References

Adeyemi AA, Omotara OA, Adeyemo AA and Oludele AS. 2020. Impact of improved paddy varieties' adoption on sustainable paddy productivity among farmers in Southwestern Nigeria. *International Journal of Advanced Research in Biological Sciences*, 7: 69-78.

Anonymous 2019. *Agricultural Statistics at A Glance*, Government of India, Ministry of Agriculture and Farmers Welfare Department of Agriculture Cooperation and Farmers Welfare Directorate of Economics and Statistics, 335p.

Anonymous 2020. *Statistical Abstract of Punjab,* Government of Punjab Economic and Statistical Organisation, Chandigarh, 785p.

Asfaw S, Shiferaw B, Simtowe F and Lipper L. 2012. Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. *Food Policy*, 37: 283– 95.

Bannor RS, A Gupta, K Kumar, HO Kyeremeh and CA Wongnaa. 2020. Adoption and Impact of Modern Paddy Varieties on Poverty in Eastern India. *Rice Science*, 27: 56-66.

BS 2018. Punjab to help farmers cut down urea usage. https://www.business-standard.com/article/newsians/punjab-to-help-farmers-cut-down-urea-usage-118071700869_1.html (accessed on 13th January, 2022).

Campenhout BV. 2021. The Role of information in agricultural technology adoption: Experimental evidence from paddy farmers in Uganda. *Economic Development and Cultural Change*, 69:1239-72.

ET 2020. Punjab government advances paddy sowing transplantation. Available at https://economictimes.indiatimes.com/news/economy/agriculture/punjab-govt-advances-paddy-sowing-transplantation-dates/articleshow/75648104.cms?utm_source=contentof interest&utm_medium=text&utm_camp (accessed on 19th July 2021).

Ghimire R, Wen-chi H and Shrestha RB 2015. Factors affecting adoption of improved paddy varieties among rural farm households in central Nepal. *Rice Science*, 22: 35-43.

Gumma M K, Gauchan D, Nelson A, Pandey S, Rala A 2011. Temporal changes in paddy-growing area and their impact on livelihood over a decade: A case study of Nepal. *Agriculture Ecosystems and Environment*, 142: 382–392.

Joshi K, Joshi PK, Khan MT, Kishore A. 2018. Sticky Paddy: Variety Inertia in a Technologically Progressive State of India, 30th International Conference of Agricultural Economists at 28th July to 2nd August, 2018 at Vancouver.

Kaur A and Sharma M. 2017. Adoption level of recommended agricultural practices by Punjab farmers. *Journal of Krishi Vigyan,* 6: 1-9

Kaur B, Singh JM, Garg B R, Singh J and Singh S. 2011. Causes and impact of Labour Migration: A case study of Punjab agriculture. *Agricultural Economics Research Review,* 24: 459-466.

Manan J, Sharma M and Jaidka M. 2018. Factors affecting the adoption of paddy varieties in Kapurthala district of Punjab, India. *International Journal of Current Microbiology and Applied Sciences*, 7: 3014- 3020.

Oo SP, Usami K. 2020. Farmers' Perception of Good Agricultural Practices in Rice Production in Myanmar: A Case Study of Myaungmya District, Ayeyarwady Region. *Agriculture*, 10:249. *https://doi.org/10.3390/agriculture10070249.*

Paltasingh KR, Goyari P. 2018. Impact of farmer education on farm productivity under varying technologies: case of paddy growers in India. *Agricultural and Food Economics*, 6:1-19.

Pokhrel A, Dhakal S, Kafle R. 2021. Adoption status of improved production technology in paddy cultivation in Kanchanpur, Nepal. *Archives of Agriculture and Environmental Science,* 6: 178-185.

Rahale SC. 2019. Long term effect of fertilization on rice (*Oryza sativa*) yield, nutrient uptake, economics and soil fertility under 25 years old rice-rice cropping system in vertisol of Tamil Nadu. *Journal of Rice Research*, 12: 36-44.

Shankar T, Banerjee M, Malik GC, Dutta S, Maiti D, Maitra S, Alharby H, Bamagoos A, Hossain A, Ismail IA. 2021. The productivity and nutrient use efficiency of Paddy–Paddy–Black Gram cropping sequence are influenced by location specific nutrient management. *Sustainability,* 13: 3222. https://doi.org/10.3390/ su13063222

Singh G, Singh P and Sodhi GPS. 2018. Status of crop management practices for paddy and basmati cultivation in South-Western Punjab. *Journal of Community Mobilization and Sustainable Development,* 13: 457-462.

Singh P, Singh G and Sodhi GPS 2019. Energy auditing and optimization approach for improving energy efficiency of paddy cultivation in south-western Punjab, India. *Energy* 174: 269-279.

RESEARCH ARTICLE https://doi.org/10.58297/REOJ2415

Morphological Characterization of Advanced Coloured Rice Genotypes

Tushara M[1]*, Krishna Veni B[2] and Sambasiva Rao N[3]

Agricultural Research Station, Bapatla, ANGRAU, Guntur, Andhra Pradesh
*Corresponding author's Email: M.thushara@angrau.ac.in

Received: 30th November 2022; Accepted: 27th December 2022

Abstract

Morphological characterization of 12 advanced coloured rice genotypes was carried out using 39 morphological descriptors during Kharif, 2021 at Agricultural Research Station, Bapatla and the results revealed that 20 out of 39 characters showed variation. Estimates of Shannon weaver diversity indices for the characters studied ranged from 0 to 0.81. The highest diversity index of 0.81 was exhibited by the Flag leaf: attitude of the blade (late observation). Cluster analysis revealed that BPT2858 from cluster I was unique when compared to other cultures. DUS characterization of advanced rice genotypes helps the plant breeder to maintain the cultures with 100 % genetic purity and the cultures can also be used as parents in the breeding programmes based on the objective.

Keywords: Coloured rice, Phenotypic diversity, Shannon weaver diversity index and cluster

Introduction

Most of the population in developing countries is suffering from diabetes, malnutrition, and chronic diseases where white rice is the major staple food (Dipti *et al*., 2012). Coloured rice varieties, on the other hand, are alternative healthy foods that contain high antioxidants and other nutrients (protein, vitamins, minerals, phenolic and low glycemic index) that have a significant benefit on human health. Antioxidants play an important role in reducing the risk of cancer and other diseases (Sani *et al*., 2018). Hence, a better understanding of the distribution and extent of morphological diversity among the coloured rice cultures is crucial to assist plant breeders in the selection of parents.

DUS testing is a way of determining whether a newly bred variety differs from existing varieties (the Distinctness part), whether the characteristics used to establish Distinctness are expressed uniformly (the Uniformity part), and whether these characteristics do not change over subsequent generations (the stability part). The development of a new cultivar is the result of genetic improvement and its identification should be possible through morphological traits by Distinctiveness, Uniformity, and Stability (DUS). Morphological characterization provides an identity for each genotype through the use of a series of descriptors that indicate genetic variability and distinguishability compared to the other genotypes. These traits, called morphological descriptors, must be heritable, and controlled by a few genes, and their expression should be uniform in all environments. The selection of the most discriminating traits is especially important for all the crops (Khadivi-Khub and Anjam, 2014). Morphological descriptors remain the first step in the conservation process of the plants (Podgornik *et al*., 2010) and the most suitable tool for genetic diversity (Darjazi, 2011). With the above background and scope a study was conducted to characterize 12 coloured rice advanced cultures developed at ARS, Bapatla. If genotypes with similar morphological traits are repeatedly bred together, the benefits resulting from crossing may be limited. This is because the resulting offspring will have similar genetic makeup and may not exhibit as much genetic gain (Chimello *et al*., 2017) as those produced from diverse genotypes. Therefore, it is important for breeders to select genotypes with diverse genetic backgrounds to maximize the benefits of breeding programs and achieve greater genetic gain.

Materials and Methods

The experimental material was comprised of 12 advanced cultures of coloured rice grown in *Kharif*, 2021 at Agricultural Research Station, Bapatla. Data was recorded on 39 DUS descriptors following guidelines from Protection of Plant Varieties and Farmer's Rights Authority (PPV & FRA). The characters include Coleoptile - Colour, Basal-Leaf sheath colour, Leaf-Anthocyanin colouration, Leaf sheath anthocyanin colouration, Leaf- pubescence of blade surface, Leaf-auricles, Leaf-Length of blade, Leaf- Width of blade, Time of heading, Flag leaf-Attitude of blade (early observation), Spikelet-density of pubescence of lemma, Male sterility, Lemma-Anthocyanin colouration of keel, Lemma-Anthocyanin colouration of area below apex, Lemma-Anthocyanin colouration of apex, Spikelet-colour of stigma, Stem-Length, Stem-anthocaynin colouration of nodes, Stem-anthocyanin colouration of internodes, Panicle-Length of main axis, Flag leaf-attitude of blade (late observation), Panicle curvature of main axis, Panicle-number per plant, Spikelet-colour of tip of lemma, Lemma and Palea colour, Panicle-awns, Panicle-exertion, Time of Maturity, Sterile Lemma-colour, Grain- weight of 1000 fully developed grains, Grain length, Grain width, Decorticated-grain length, Decorticated-grain width, Decorticated-grain shape, Decorticated-grain colour, Endosperm-presence of amylose, Endosperm-content of amylose and Decorticated grain-aroma.

Shannon Diversity Index: Estimates of Shannon Weaver Diversity Indices reveals the phenotypic diversity shown by the cultures. Shannon diversity indices (H^{l}) were calculated to study the phenotypic diversity for each character in the entire germplasm as described by Perry and McIntosh (1991) is given as:

$$H^{1} = 1- \sum_{i=1}^{n} p_i \log_e p_i$$

where p_i is the proportion of accessions in the i^{th} class of an n-class character and n is the number of phenotypic classes for a character. The indices are standardized by dividing each value of H' by loge_n to keep the value in a range of 0 to 1 in order to estimate the importance of phenotypic diversity. Analysis was done by using MS EXCEL. An arbitrary scale of diversity indices was adapted from Rabara *et al*., (2014) to categorize the computed indices into high (H' = 0.76–0.99), moderate (H' = 0.46–0.75), and low diversity (0.01–0.45). Cluster analysis was done by using Minitab software.

Results and Discussion

Phenotypic frequencies and genotypes distribution

The frequency distribution of 12 advanced coloured rice genotypes for 39 morphological descriptors are represented in **Table 1**.

Table 1. Frequency distribution of 12 coloured rice advanced cultures for 39 morphological descriptors

S. No.	Character	Phenotypic class	No. of genotypes under each class	Frequency Distribution (%)	Genotypes under each class
1	Coleoptile: Colour	Colorless	12	100	All the genotypes
2	Basal: Leaf sheath colour	Green	12	100	All the genotypes
3	Leaf: Anthocyanin colouration	Absent	12	100	All the genotypes
4	Leaf sheath anthocyanin colouration	Absent	12	100	All the genotypes
5	Leaf: pubescence of blade surface	Absent	12	100	All the genotypes
6	Leaf:auricles	Presence	12	100	All the genotypes

S. No.	Character	Phenotypic class	No. of genotypes under each class	Frequency Distribution (%)	Genotypes under each class
7	Leaf: Length of blade	Medium (30-45 cm)	4	33	BPT2848, BPT3136, BPT3143, BPT2841
		Long (> 45 cm)	8	67	BPT2858, BPT3182, BPT3137, BPT3111, BPT3141, BPT3140, BPT 3145, BPT 3178
8	Leaf: Width of blade	Medium (1-2 cm)	11	92	BPT2848, BPT3136, BPT3143, BPT3182, BPT3137, BPT3111, BPT2841, BPT3141, BPT3140, BPT 3145, BPT 3178
		Broad (> 2 cm)	1	8	BPT2858
9	Time of heading	Early (71-90 days)	6	50	BPT2848, BPT3136, BPT3137, BPT2841, BPT3141, BPT3140
		Medium (91-110 days)	3	25	BPT3111, BPT 3145, BPT 3178
		Late (111-130 days)	3	25	BPT2858, BPT3143, BPT3182
10	Flag leaf: Attitude of blade (Early observation)	Erect	12	100	All the genotypes
11	Spikelet: density of pubescence of lemma	Absent	8	67	BPT2858, BPT2848, BPT3136, BPT3143, BPT3182, BPT3137, BPT3111,BPT 3145
		Weak	1	8	BPT 3178
		Medium	3	25	BPT2841, BPT3141, BPT3140
12	Male sterility	Absent	12	100	All the genotypes
13	Lemma: Anthocyanin colouration of keel	Absent	12	100	All the genotypes
14	Lemma: anthocyanin colouration of area below apex	Absent	12	100	All the genotypes
15	Lemma: anthocyanin colouration of apex	Absent	12	100	All the genotypes
16	Spikelet: colour of stigma	White	11	92	BPT2858, BPT2848, BPT3136, BPT3143, BPT3182, BPT3111, BPT2841, BPT3141, BPT3140, BPT 3145, BPT 3178
		Purple	1	8	BPT3137
17	Stem: length	Very short (< 91 cm)	1	8	BPT2858
		Medium (111-130 cm)	11	92	BPT2848, BPT3136, BPT3143, BPT3182, BPT3137, BPT3111, BPT2841, BPT3141, BPT3140, BPT 3145, BPT 3178
18	Stem: anthocyanin colouration of nodes	Absent	12	100	All the genotypes
19	Stem: anthocyanin colouration of internodes	Absent	12	100	All the genotypes

S. No.	Character	Phenotypic class	No. of genotypes under each class	Frequency Distribution (%)	Genotypes under each class
20	Panicle; Length of main axis	Medium (21-25 cm)	3	25	BPT3136, BPT3143, BPT3140
		Long (26-30 cm)	7	58	BPT2858, BPT2848, BPT3182, BPT3137, BPT2841, BPT3141, BPT 3145
		Very long (>30 cm)	2	17	BPT3111, BPT 3178
21	Flag leaf: attitude of blade (late observation)	Erect	6	50	BPT3136, BPT3143, BPT3182, BPT3111, BPT2841,BPT 3178
		Semi-erect	1	8	BPT2848
		Horizontal	4	33	BPT2858, BPT3137, BPT3140, BPT 3145
		Deflexed	1	8	BPT3141
22	Panicle curvature of main axis	Semi-straight	1	8	BPT3182,
		Deflexed	5	42	BPT2848, BPT3143, BPT3137, BPT 3145
		Drooping	7	58	BPT2858,BPT3136, BPT3111, BPT2841, BPT3141, BPT3140, BPT 3178
23	Panicle: number per plant	Few (<11)	4	33	BPT2858, BPT3182, BPT3141, BPT 3145
		Medium (11-20)	8	67	BPT2848, BPT3136, BPT3143, BPT3137, BPT3111, BPT2841, BPT3140, BPT 3178
24	Spikelet: colour of tip of lemma	White	11	92	BPT2858, BPT2848, BPT3136, BPT3143, BPT3137, BPT3111, BPT2841, BPT3141, BPT3140, BPT 3145, BPT 3178
		Purple	1	8	BPT3182
25	Lemma and Palea colour	Straw	12	100	All the genotypes
26	Panicle: awns	Absent	12	100	All the genotypes
27	Panicle: Exertion	Mostly exerted	6	50	BPT3136, BPT3143, BPT3182, BPT3111, BPT2841, BPT 3145
		Well exerted	6	50	BPT2858, BPT2848, BPT3137, BPT3141, BPT3140, BPT 3178
28	Time of Maturity	Early (101-120)	6	50	BPT2848, BPT3136, BPT3137, BPT2841, BPT3141, BPT3140
		Medium (121-140)	3	25	BPT3111, BPT 3145, BPT 3178
		Late (141-160)	3	25	BPT2858, BPT3143, BPT3182,
29	Sterile lemma: colour	Straw	12	100	All the genotypes
30	Grain: weight of 1000 fully developed grains	Very low (< 15g)	6	50	BPT2858, BPT2848, BPT3137, BPT3111, BPT2841, BPT3141,
		Low (15-20 g)	5	42	BPT3136, BPT3143, BPT3182, BPT3140, BPT 3178
		Medium (21-25g)	1	8	BPT 3145

S. No.	Character	Phenotypic class	No. of genotypes under each class	Frequency Distribution (%)	Genotypes under each class
31	Grain Length	Medium	10	83	BPT2858, BPT2848, BPT3136, BPT3143, BPT3137, BPT3111, BPT2841, BPT3141, BPT3140, BPT 3145
		Long	2	17	BPT3182, BPT 3178
32	Grain Width	Narrow (< 1 cm)	8	67	BPT2858, BPT2848, BPT3143, BPT3182, BPT3137, BPT3111, BPT2841, BPT3141
		Medium	4	33	BPT3136, BPT3140, BPT 3145, BPT 3178
33	Decorticated: grain length	Medium	10	83	BPT2858, BPT2848, BPT3136, BPT3143, BPT3137, BPT3111, BPT2841, BPT3141, BPT3140, BPT 3145
		Long	2	17	BPT3182, BPT 3178
34	Decorticated: grain width	Narrow (< 2mm)	8	67	BPT2858, BPT2848, BPT3143, BPT3182, BPT3137, BPT3111, BPT2841, BPT3141
		Medium (2-2.5mm)	4	33	BPT3136,BPT3140, BPT 3145, BPT 3178
35	Decorticated grain: shape	Short slender	1	8	BPT2858
		Short bold	1	8	BPT3140
		Medium slender	8	67	BPT2848, BPT3136, BPT3143, BPT3137, BPT3111, BPT2841, BPT3141, BPT 3145
		Long bold	1	8	BPT3182
		Long slender	1	8	BPT 3178
36	Decorticated grain colour	Light red	1	8	BPT3141
		Red	6	50	BPT2858, BPT3143, BPT3182, BPT3111, BPT3140, BPT 3178
		Variegated purple	2	17	BPT3136, BPT 3145
		Purple	1	8	BPT2848
		Dark purple	2	17	BPT3137, BPT2841
37	Endosperm: presence of Amylose	Present	12	100	All the genotypes
38	Endosperm: content of Amylose	Medium (20-25%)	12	100	All the genotypes
39	Decorticated grain: Aroma	Absent	12	100	All the genotypes

Leaf characters

Among the leaf traits, all the genotypes exhibited colour-less coleoptiles colour, green basal leaf sheath colour, lack of anthocyanin colour in both leaf and leaf sheath, absence of leaf pubescence of blade surface, presence of leaf auricles and erect flag leaf attitude of blade (early observation). For the length of the leaf blade, 33 % of genotypes exhibited medium length (30-45 cm) and 67 % exhibited long (> 45 cm) length of the blade. Medium width (1-2 cm) of the leaf blade was exhibited by 92 % of genotypes and 8 % of genotypes exhibited a broad (> 2 cm) width of the leaf blade. In the case of Flag leaf attitude of the leaf blade, all the genotypes exhibited erect flag leaf in early observation but in the case of late observation, 50 % of genotypes exhibited erect flag leaf attitude, 33% horizontal, 8% semi-erect and remaining 8 % exhibited deflexed flag leaf attitude.

Spikelet characters

Awns were absent in all the genotypes and exhibited straw coloured lemma and palea. 67 % of genotypes exhibited absence of spikelet density of pubescence of lemma, 7 % showed weak pubescence, and the remaining 25 % medium density of pubescence of lemma. Though all the genotypes evaluated in the present study are coloured genotypes, absence of anthocyanin colour in three parts of the lemma *viz.*, Lemma anthocyanin colouration of the keel, lemma anthocyanin colouration of the area below the apex and anthocyanin colouration of the apex was observed. White-coloured stigma was observed in almost all the genotypes except BPT3137 where purple-coloured stigma was seen.

Stem characters

The stem anthocyanin colouration of nodes and internodes was absent in all the genotypes. For stem length, almost all the genotypes exhibited medium stem length ranging from 111 to 130 cm except BPT2858 which exhibited very short stem length of less than 91 cm.

Panicle characters

Long panicle length of the main axis was observed in 58 % of genotypes, whereas 25 % of genotypes exhibited medium and 17 % of genotypes showed very long panicle length of the main axis. For panicle curvature deflexed type was observed in 42 % of genotypes, drooping in 58 % and 8 % of genotypes showed a semi-straight pattern. Medium panicle numbers range from 11-20 in 67 % of genotypes, whereas 33 % of the genotypes showed few panicle numbers per plant. Mostly exertion type of panicle was seen in 50 % of genotypes and the remaining 50 % showed a well-exerted type of panicle.

Grain characters

The grain weight of 1000 fully developed grains was found to be very low (< 15 g) in 50 % of genotypes, 42 % of genotypes exhibited low grain weight and 8 % showed medium grain weight. The grain length was found to be medium in 83 % of genotypes and long grain length was observed in BPT 3182 and BPT3178 genotypes. Narrow grain width was seen in 67 % of genotypes and 33 % showed medium grain width. Medium slender type of decorticated grain shape was observed in 67 % of genotypes and the remaining genotypes showed short slender, short bold, long bold, and long slender types of grain shape. A lot of variation was observed in the character decorticated grain colour, where 50 % of genotypes (BPT2858, BPT3143, BPT3182, BPT3111, BPT3140, and BPT3178) exhibited red colour, 17 % of genotypes (BPT3136 and BPT3145) showed variegated purple colour, 17 % of genotypes (BPT3137 and BPT3841) showed dark purple colour and the remaining 8 % (BPT2848) showed purple coloured grain colour (**Figure 1**). All the genotypes contain medium amylose content in endosperm, while grain aroma was absent in all the genotypes.

Figure 1: Variation in decorticated grain colour among 12 coloured rice advanced cultures

Shannon weaver diversity analysis

The estimates of Shannon weaver diversity indices (**Table 2**) revealed the extent of phenotypic diversity showed by 12 rice advanced cultures in a particular trait. Shannon weaver diversity indices in the present study for 39 morphological descriptors ranged from 0 to 0.81. The traits were grouped into three categories based on the index values *viz*., high diversity (0.76-0.99), Moderate diversity (0.46 to 0.75), and Low diversity (0.01 – 0.45). Out of 39 characters studied only 20 characters exhibited phenotypic diversity. The Shannon weaver diversity index values ranged from 0.81 to 0.16. The highest diversity index value of 0.81 was observed in Flag leaf: attitude of the blade (late observation). Similar results of high diversity index value for the flag leaf attitude of the blade were reported by Rawte and Saxena, 2018. Moderate index values were exhibited by spikelet: density of pubescence of lemma(0.51), decorticated grain shape (0.56), grain: weight of 1000 fully developed grains (0.57), decorticated grain width (0.58), panicle number per plant (0.58), leaf: length of the blade (0.58), panicle: length of the main axis (0.6), decorticate grain colour (0.62), panicle exertion 0.63), panicle curvature of the main axis (0.64), time of maturity (0.65) and time of heading (0.65). Similar results of moderate index value for panicle curvature of the main axis were reported by Rao *et al*., (2021) and Rabara *et al.*, 2014 reported for Panicle exertion, panicle length of the main axis, and length of the leaf blade. Low diversity index values were exhibited by the spikelet colour of the tip of the lemma (0.16), stem length (0.18), spikelet colour of stigma (0.18), leaf width of the blade (0.26), decorticated grain length (0.28), grain length (0.28) and grain width (0.4). Lemma and Palea colour exhibited a 0 index value, similar results were also reported by Hein *et al*., (2007).

The genotypes were grouped into five major clusters based on similarity index (**Figure 2**) cluster I consists of only one genotype i.e., BPT 2858 which has unique characters than other genotypes *viz*., broad leaf width, very short stem length and short slender grain shape. Cluster II consists of three genotypes, BPT2848, BPT3137 & BPT3145 with 94 % similarity. Cluster III consists of four genotypes BPT 3136, BPT3111, BPT2841, and BPT3178 with 95 % similarity. Cluster IV consists of two genotypes BPT 3143 and BPT3182 with 96 % similarity. Cluster V consists of two genotypes that are 97 % similar to each other.

Table 2. Estimates of Shannon weaver diversity indices for 39 morphological descriptors studied

S.No.	Character	Shannon Weaver Diversity Index
High Diversity (0.76-0.99)		
1	Flag leaf: attitude of blade (late observation)	0.81
Moderate Diversity (0.46-0.75)		
2	Time of heading	0.65
3	Time of Maturity	0.65
4	Panicle: curvature of main axis	0.64
5	Panicle: Exertion	0.63
6	Decorticated grain colour	0.62
7	Panicle: length of main axis	0.6
8	Leaf: length of blade	0.58
9	Panicle: number per plant	0.58
10	Decorticated: grain width	0.58
11	Grain: weight of 1000 fully developed grains	0.57
12	Decorticated grain shape	0.56
13	Spikelet: density of pubescence of lemma	0.51
Low Diversity (0.01-0.45)		
14	Grain width	0.4
15	Grain Length	0.28
16	Decorticated: grain length	0.28
17	Leaf: width of blade	0.26
18	Spikelet :colour of stigma	0.18
19	Stem: length	0.18
20	Spikelet:colour of tip of lemma	0.16
In variant		
21	Coleoptile: Colour	0
22	Basal: Leaf sheath colour	0
23	Leaf: Anthocyanin colouration	0
24	Leaf sheath anthocyanin colouration	0
25	Leaf: pubescence of blade surface	0
26	Leaf: auricles	0
27	Flag leaf: Attitude of blade (Early observation)	0
28	Male sterility	0
29	Lemma: Anthocyanin colouration of keel	0
30	Lemma: anthocyanin colouration of area below apex	0
31	Lemma: anthocyanin colouration of apex	0
32	Stem: anthocyanin colouration of nodes	0
33	Stem: anthocyanin colouration of internodes	0
34	Lemma and Palea colour	0
35	Panicle: awns	0
36	Sterile lemma: colour	0
37	Endosperm: presence of amylose	0
38	Endosperm: content of amylose	0
39	Decorticated grain: Aroma	0

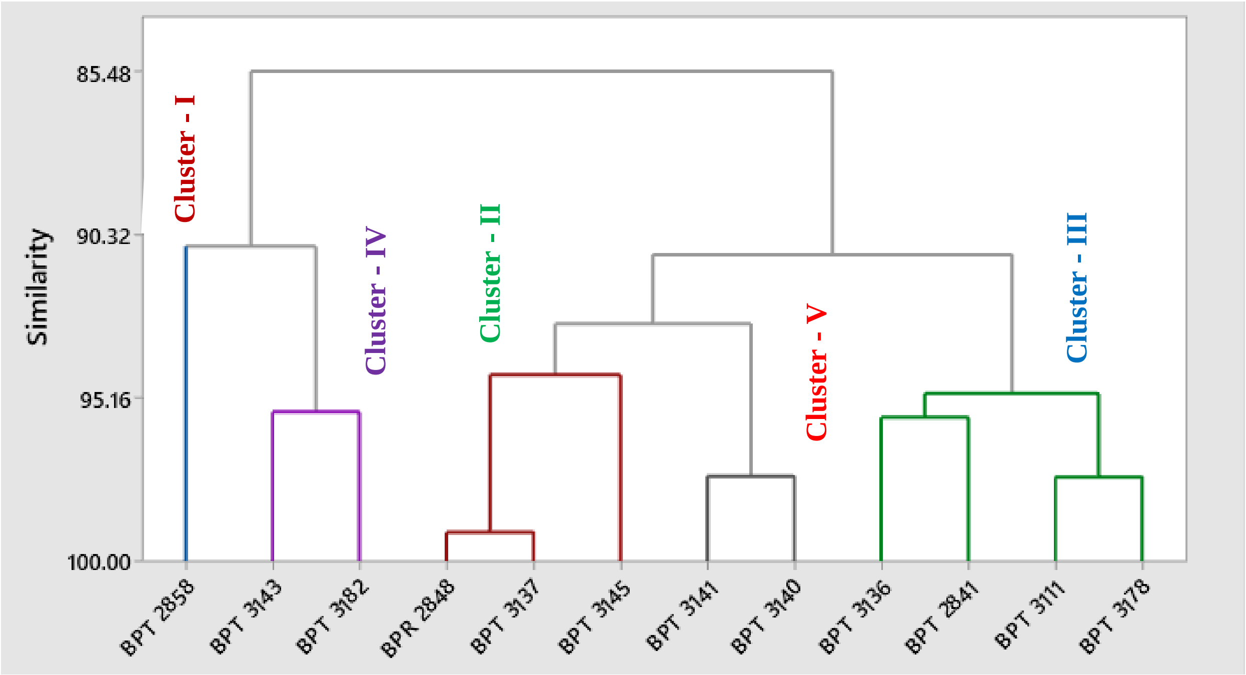


Figure 2: Dendrogram of 12 advanced coloured rice genotypes based on 39 morphological descriptors

Conclusion

The present study revealed a significant amount of variation in the decorticated grain colour trait. Rice genotypes possessing purple or red grain colour are known to be abundant in antioxidants, which have been shown to lower the risk of cancer and other diseases. Till now coloured varieties are rarely developed but coloured landraces are being cultivated in some areas with problems like lodging and not having consumer preference due to bold grains. The colored rice advanced cultures analyzed in this study exhibited leaf characteristics similar to those of currently available white rice cultivars, with no anthocyanin coloration, having a non-lodging growth habit, and mostly slender to medium-slender grains. Thus, by evaluating the yield-related parameters of these advanced cultures, they can be released directly as new varieties or used as parental stock in breeding programs aimed at developing colored rice varieties.

References

Chimello, Antonio Marcos, Jesus JG, Teodoro Paulo, Rossi Ana, Araújo KL, Marostega TN, Neves LG and Barelli Marco. 2017. Morphological descriptors and ISSR molecular markers in the evaluation of genetic variability of *Tectona grandis* genotypes. *Genetics and Molecular Research*, 16. 10.4238/gmr16029665.

Darjazi BB. 2011. Morphological and pomological characteristics of fig (*Ficus carica* L.) cultivars from Varamin, Iran. *African Journal of Biotechnology*, 10: 19096-19105.

Dipti SS, Bergman C and Indrasari SD. 2012. The potential of rice to offer solutions for malnutrition and chronic diseases. *Rice,* 5:161-18.

Hein NL, Sarhadi WA, Oikawa Y and Hirata Y. 2007. Genetic diversity of morphological responses and the relationships among Asia aromatic rice (*Oryza sativa* L.) cultivars. *Tropics*, 16: 343-355.

Khadivi-Khub A and Anjam K. 2016. The relationship of fruit size and light condition with number, activity and price of *Blastophaga psenes* wasp in caprifigs**.** *Trees*, 30: 1855-1862

Podgornik M, Vul I, Vrhovnik I and Mavsar DB. 2010. A survey and morphological evaluation of fig (*Ficus carica* L.) genetic resources from Slovenia. *Scientia Horticulturae*,125: 380-389.

Naga Durga Rao N, Roja V, Tushara M, Satyanarayana Rao V and Srinivasa Rao V. 2021.Characterization and diversity analysis of Rice germplasm. *Biological Forum – An International Journal*, 13: 170-179.

Perry MC and McIntosh MS. 1991. Geographical patterns of variation in the USDA soybean germplasm collection: International Morphological traits. *Crop Science*, 31: 1350–1355.

Rabara RC, Ferrer M, Diaz CL, Newingham MCV and Romero GO. 2014. Phenotypic diversity of farmers' traditional rice varieties in the Philippines. *Agronomy,* 4: 217-241.

Rawte S and Saxena R. 2018. Phenotypic diversity and correlation analysis for agro morphological traits in 100 landraces of rice from Chhattisgarh. *International Journal of Pure and Applied Biosciences*, 6: 345 – 353.

Sani NA, Sawei J and Ratnam W. 2018. Physical, antioxidant and antibacterial properties of rice (*Oryza sativa* L.) and glutinous rice (*Oryza sativa* var. glutinosa) from local cultivators and markets of Peninsular, Malaysia. *International Food Research Journal*, 25: 2328–2336.

RESEARCH ARTICLE https://doi.org/10.58297/RZMP1870

Assessment of Sodicity Tolerance in Rice (*Oryza sativa* L.) Germplasm

Shiv Prakash Shrivastav[1]*, Verma OP[1], Kanhaiya Lal[2] and Subhash Mishra[1]

[1]Department of Genetics and Plant Breeding, Acharya Narendra Deva University of Agriculture and Technology, Narendra Nagar (Kumarganj), Ayodhya -224 229 (U.P.), India.
[2]Department of Genetics and Plant Breeding, CSA University of Agriculture and Technology, Kanpur (U.P.), India.
*Corresponding author's Email: ms.shiv92@gmail.com

Received: 15th July 2022; Accepted: 30th August 2022

Abstract

The experiment on 113 genotypes (aromatic and non-aromatic rice) including three checks *viz.,* Sarjoo 52, FL 478, and CSR 10 of rice (*Oryza sativa* L.) was conducted to work out the identification of elite genotypes based on grain yield and their various yield attributing traits. The grain yield per plant ranged from 8.898g for NDRK 50047 to 24.658g in the case of IR 13 T 141 with a general mean of 16.464g. Out of 113 genotypes, thirty-six genotypes produced significantly higher grain yield per plant than the general mean. The best ten genotypes for higher grain yield per plant were IR 13 T 141, IR 11 T 230, IR 13 T 145, IR 12 T 147, IR 11 T 171, IR 11 T 132, IR 11 T 205, IR 12 T 193, AT 401, and CSR 43. Similarly, the genotypes showed that very high mean performance in the desired direction for various characters; may also be used as donors for improving the characters for which they had high mean performance in yield and yield contributing traits. The availability of large genetic variability, as well as the nature of heritability and gene actions, are all important factors in the success of selection in improving plant traits. The basic material for a plant breeding programme is genetic diversity, which is used to generate superior genotypes through selection.

Keywords: Rice, *Oryza sativa*, Elite genotypes, Grain yield, Yield components Salt tolerance

Introduction

Rice (*Oryza sativa* L.) has chromosome number 2n = 24 (n=12) and basic chromosome number x=5 and is a member of the Gramineae (Poaceae) family. Rice belongs to the genus *Oryza*, and there are approximately 24 kinds found in tropical, sub-tropical, and warm temperate regions around the world. The *Oryza sativa* and *Oryza glaberrima* are the two most often cultivated species. The *Oryza sativa* plant is classified into three subspecies: *Indica*, *Japonica,* and *Javanica*.

Rice (*Oryza sativa* L.) is the most important staple food crop in the world. Asia is the leader in rice production accounting for about 90% of the world's production. India has the world's largest rice-growing area (43.78 million hectares), accounting for 28.26% of all rice-growing land, and ranks second in overall production (118.40 million tonnes) after China, with an average yield of 2705 kg/hectare (Anonymous, 2019-20). Asia covers around 140.036 million hectares and produces 5.32 tonnes per hectare (Anonymous, 2017-18). More than 80% of our population eats rice as their major meal and staple diet, either entirely or partially. Uttar Pradesh is a major rice-growing state in India. Rice is grown on 6.45 million hectares and produces 18.251 million tonnes in Uttar Pradesh (UP), with an yield of 4.95 tonnes per hectare (Uttar Pradesh Directorate of Agricultural Ministry, 2017-18). Agriculture is the most important occupation in UP because around 80% of the population lives in rural areas and 75% of the total workforce is engaged in cultivation/farming, which accounts for 27% of the state's GDP. Families in the state rely on agriculture as their primary source of income.

Although India's average rice productivity is substantially lower than the global average, the development of high yielding, broadly adapted pure-line rice varieties, combined with advances in production technology, has enabled to meet the demand for rice to a satisfactory level over the last four decades. However, fast-rising demand, owing to India's ever-growing population, has compelled us to look for another quantum leap in rice yield. To solve this challenge, the creation of improved high-yielding pure line and hybrid rice varieties appropriate for harsh conditions (salt-affected soil) will be a key strategy. Inland salinity areas in UP are primarily found in the districts of Raibareilly, Azamgarh, Sultanpur, Faizabad, Lucknow, Unnao, and Pratapgarh.

Aromatic rice is a small but unique sub-group of rice that is prized for its superior quality. Aromatic rice has been grown for generations in the traditional territories of the Indian subcontinent's northwestern regions. Aromatic rice emits a specific aroma in the field at the time of flowering, harvesting, in storage, milling, cooking, and eating (Efferson, 1985). Aroma development is influenced by both genetic factors and environmental factors. Mostly, a single recessive gene has been reported to control aroma, but there are also reports of a dominant gene, and multiple factors/polygenes, controlling aroma (Singh *et al.*, 2000). Aroma is due to certain chemicals present in the endosperm and such chemicals are also found in the vegetative parts, which emit aroma in the standing crop in some cases even at early stages of growth. The biochemical basis of aroma was identified as the compound 2-acetyl-1-pyroline. The compound is known to be present in raw grain as well as in plants. There are 100 more volatile molecules associated with the fragrance development in rice, including hydrocarbons, acids, alcohols, aldehydes, ketones, esters, phenols, and other substances, in addition to 2-acetyl-1-pyroline. (Singh *et al*., 2005).

Germplasm is the most useful natural resource for creating successful variations since it possesses all the necessary characteristics. (Hawkes, 1981). Breeders can recombine favourable phenotypes of diverse qualities to generate superior genotypes capable of providing high and steady yields due to the availability of acceptable variability in germplasm collections. With the use of genetic parameters like coefficients of variation, heritability, and genetic progress, the existing variability in a population can be partitioned into heritable and non-heritable components to serve as a basis for selecting some outstanding genotypes over existing ones.

Although yield is a complicated character that appears through multiplicative interactions of other characters known as yield components, identifying factors responsible for high yields has proven difficult (Grafius, 1959).

The soil sodicity is a major factor that adversely affects the growth and yield of crop plant. Approximately one-third of the land area on which rice is grown is affected by salinity. Approximately 10% of the world's total land area (950 million ha), 20% of the world's arable land (300 million ha) and 50% of the total irrigated land (230 million ha) are affected by soil salinization. Further, it is expected to influence 50% of total cultivated land in 2050 at a dis-quieting rate. Every year almost 12 billion US$ are globally lost due to salt stress that significantly affects the agricultural production (Shrivastav *et al.*, 2022).

The number of salt-affected areas is growing every day because of excessive irrigation water use combined with poor drainage and irrigation water of poor quality. The only way to boost productivity is to develop cultivars for sodic soil. As a result, adapting high-yielding rice varieties to a variety of stress environments, such as sodic and salt-affected soil, would be a significant technique for addressing this problem.

The rice breeding scenario has progressed in recent years. Few important achievements have been addressed in this area. Changes in climatic circumstances, in addition to biotic and abiotic challenges, pose a serious danger to rice production sustainability, making it challenging for rice molecular breeders to improve production and productivity under these stress conditions.

Materials and Methods

The study's goal was to determine the status of elite genotypes based on grain yield and various yield attributing traits among 113 genotypes (aromatic and non-aromatic rice) in a field experiment at the A.N.D. University of Agriculture and Technology's Main Experimental Station in Narendra Nagar (Kumarganj), Ayodhya, India, during the *Kharif* of 2018 under natural sodic soil with the pH, EC and ESP were 9.5, 3.2 dSm-1 and 45%, respectively. Geographically, experimental site is located between

24° 47¢ and 26° 56¢N latitude, 82° 12¢ and 83° 98¢E longitude and at an altitude of 113 m above mean sea level. This area falls in sub-tropical climatic zone. The study's experimental materials are 113 genotypes that included three check varieties: Sarjoo 52, FL 478, and CSR 10. The experiment was designed with an augmented design. Days to 50% flowering, chlorophyll content, leaf nitrogen, leaf temperature, flag leaf area (cm), plant height (cm), panicle bearing tillers per plant, panicle length (cm), spikelets per panicle, grains per panicle, spikelet fertility (percent), biological yield per plant (g), harvest-index (percent), 1000-grain weight (g), and grain yield per plant were among the sixteen grain yield traits observed. Federer's (1956) analysis of variance for Augmented Design.

Results and Discussion

The results of an analysis of variance for augmented design for sixteen characters to see if there were any significant changes between the various treatments (checks) are provided. With the exception of chlorophyll content and panicle bearing tiller per plant, mean squares due to checks were extremely significant for all fourteen characters, whereas mean sum of squares due to blocks were highly significant for all fifteen characters except panicle bearing tiller per plant. Only for panicle bearing tillers per plant did the mean squares due to blocks exhibit significance as presented in **Table 1**.

Table 1. Analysis of variance of augmented design for 16 characters in rice genotypes

S. No.	Characters	Sources of variation		
		Blocks	**Checks**	**Error**
	Degree of freedom	10	2	20
1	Days to 50% flowering	87.60012**	717.07638**	0.31352
2	Chlorophyll content	7.70623**	0.02150	0.10558
3	Leaf nitrogen	0.03307**	0.03496**	0.00065
4	Leaf temperature	7.79106**	3.28954**	0.39504
5	Flag leaf area (cm^2)	177.50943**	1198.80388**	3.84368
6	. Plant height (cm)	227.34473**	374.80927**	49.17389
7	Panicle bearing tillers/plant	3.03571*	3.08501	0.95376
8	Panicle length (cm)	30.52569**	41.93319**	0.10494
9	Spikelets/panicle	6793.52427**	6131.31184**	3.14637
10	Grains/panicle	5226.46163**	8570.66888**	3.77866
11	Spikelet fertility (%)	27.26834**	321.56878**	0.80395
12	Biological yield/plant (g)	375.23544**	532.99278**	0.54627
13	Harvest index (%)	27.42357**	75.34074**	0.66473
14	L/B ratio	0.29320**	2.15928**	0.03811
15	1000- grain weight (g)	2.95271**	44.24653**	0.02777
16	Grain yield/plant (g)	46.88795**	38.77322**	0.14937

*, ** Significant at 5% and 1% probability levels, respectively.

The mean performance of 113 diverse rice genotypes including 3 checks (Sarjoo 52, FL 478, and CSR 10) for 16 characters is presented in **Table 2** and the most desirable lines for different characters are listed in **Table 3**. A very wide range of variation in the mean performance of genotypes was observed for all the sixteen characters under study. The comparison of the mean performance of 113 genotypes for sixteen traits using the least significant differences revealed the existence of a very high level of variability in the germplasm collections evaluated in the present study.

Table 2. Mean, range, coefficient of variation (CV) and least significant differences (LSD) for 16 characters in rice

S. No	Genotypes	Days to 50% flowering	Chlorophyll content	Leaf Nitrogen	Leaf temperature	Flag leaf area (cm^2)	Plant height (cm)	Panicle bearing tillers/ plant	Panicle length (cm)	Spikelets/ panicle	Grains/ panicle	Spikelet fertility (%)	Biological yield/ plant (g)	Harvest index (%)	L/B ratio	1000 grain weight (g)	Grain yield/ plant (g)
1	Jallahri	117.219	7.022	0.444	37.944	39.095	92.600	8.993	24.372	139.018	104.069	75.064	32.445	37.021	2.447	23.178	12.092
2	Kalanamak	116.219	7.772	0.494	33.754	37.165	99.030	8.263	25.732	157.118	115.609	73.696	41.065	34.240	2.587	21.978	14.352
3	CSR-27	96.219	11.192	0.414	34.944	30.855	83.400	7.393	24.932	103.248	88.599	86.184	47.085	37.405	2.787	19.878	18.092
4	Improved PB-1	111.219	7.692	0.444	38.214	31.145	93.990	7.023	25.722	116.938	93.669	80.413	45.655	29.298	2.497	14.678	13.752
5	NUD-2008	102.219	8.472	0.464	34.384	30.965	93.230	7.563	22.762	105.928	100.069	94.716	41.875	33.398	2.227	21.778	14.292
6	NUD-2009	95.219	10.202	0.564	37.754	29.845	85.060	7.963	24.802	133.228	85.499	64.514	52.045	33.792	2.597	23.278	18.172
7	CSR-23	98.219	7.782	0.474	36.404	40.815	87.190	9.263	22.362	142.528	118.379	83.169	38.655	38.524	2.997	19.778	15.152
8	CSR-30	108.219	10.172	0.584	38.074	43.965	80.440	7.373	24.012	156.048	119.069	76.401	46.605	36.208	2.817	24.078	17.332
9	CSR-36	105.219	10.182	0.564	34.104	29.045	97.200	8.063	24.972	168.898	123.589	73.237	39.675	39.239	3.057	26.878	15.862
10	Jaya	101.219	12.472	0.514	37.454	28.785	88.200	10.183	23.112	160.518	129.339	80.621	53.075	35.228	2.997	15.278	19.322
11	NDRK 5062	104.349	13.262	0.654	36.914	30.368	103.597	10.409	26.615	197.951	159.875	80.801	44.138	40.866	3.037	22.328	17.955
12	NDRK 5099	99.349	12.912	0.704	34.354	33.538	104.047	9.819	26.365	194.711	169.655	87.215	46.248	42.642	3.217	25.148	19.605
13	NDR 2064	95.349	13.412	0.794	35.574	33.908	103.567	9.509	27.045	191.161	173.545	90.896	44.238	40.026	3.157	22.758	17.635
14	NDRK 5038	94.349	12.762	0.784	36.284	33.668	102.567	9.169	25.725	180.181	166.755	92.678	45.548	37.387	3.077	30.358	16.985
15	NDRK 5047	104.349	12.202	0.714	34.744	35.758	104.594	9.919	26.725	209.711	190.925	91.150	44.488	41.303	2.657	28.938	18.285
16	NDRK 5042	105.349	13.652	0.604	35.024	35.398	102.687	10.269	25.645	242.401	197.025	81.323	39.658	41.723	2.557	24.808	16.475
17	CSR 28	109.349	12.812	0.594	38.244	46.698	104.047	10.439	28.665	191.901	161.655	84.300	50.048	40.792	2.777	23.928	20.305
18	Pusa Basmati 1	99.349	13.552	0.644	36.544	32.668	109.377	8.089	29.275	198.881	161.725	81.358	41.728	36.197	3.257	17.278	15.095
19	NDRK 5026	98.349	15.252	0.724	37.774	32.768	119.707	7.829	28.385	172.411	129.465	75.077	44.158	35.433	3.137	25.598	15.635
20	FL 449	92.349	13.792	0.744	34.044	33.798	105.557	5.909	22.215	170.611	149.525	87.733	49.598	30.027	3.537	24.738	14.925
21	SambhaMahsuri	109.755	13.049	0.568	36.537	30.745	71.520	5.409	21.878	182.318	151.099	82.707	47.152	41.781	3.257	21.341	19.738
22	PNR 381	92.755	12.529	0.518	36.077	22.315	103.170	5.489	22.308	181.258	148.769	81.923	44.132	40.952	2.697	24.881	18.068
23	IR11T265	83.755	13.459	0.578	32.427	24.485	96.590	7.579	23.218	179.438	145.729	81.082	40.492	40.183	2.477	23.871	16.218
24	IR11T159	90.755	12.829	0.628	34.727	25.235	102.610	8.129	24.838	169.518	141.539	83.364	42.932	42.840	2.357	25.321	18.408
25	IR11T255	86.755	12.649	0.718	28.827	23.335	95.570	6.909	24.108	170.568	145.729	85.268	42.602	41.632	2.787	23.671	17.728
26	CSR 28	92.755	13.729	0.708	36.397	32.355	104.760	7.429	24.228	152.848	138.829	90.630	45.972	33.066	2.717	26.801	15.078
27	NDRK 50031	91.755	11.429	0.588	32.427	22.595	100.900	6.519	24.078	170.218	136.799	80.287	45.172	38.829	2.197	24.321	17.508
28	NarendraUsar 3	96.755	12.799	0.638	32.427	22.495	104.080	7.369	23.938	166.258	135.439	81.382	45.862	38.525	2.397	23.351	17.638
29	NDR 510	85.755	12.099	0.568	35.777	23.595	117.900	8.619	23.068	105.338	87.719	83.567	40.262	38.383	3.287	20.871	15.368
30	USAR 1	92.755	13.299	0.528	34.427	20.185	125.760	8.249	22.518	130.188	109.679	84.307	35.642	40.356	3.197	21.781	14.288
31	NDRK 50005	96.275	13.502	0.624	35.610	30.781	98.010	7.939	21.755	151.391	136.629	90.081	58.682	34.923	2.803	25.681	20.488

S. No	Genotypes	Days to 50% flowering	Chlorophyll content	Leaf Nitrogen	Leaf temperature	Flag leaf area (cm^2)	Plant height (cm)	Panicle bearing tillers/ plant	Panicle length (cm)	Spikelets/ panicle	Grains/ panicle	Spikelet fertility (%)	Biological yield/ plant (g)	Harvest index (%)	L/B ratio	1000 grain weight (g)	Grain yield/ plant (g)
32	IR 45427-2B-2-2B-1-1	93.275	15.152	0.564	33.050	18.341	63.830	6.199	18.835	125.821	100.609	79.864	43.022	36.985	2.523	19.991	15.818
33	NDRK 50039	102.275	12.202	0.664	34.980	21.001	87.110	7.499	19.465	110.351	88.639	80.198	38.032	38.063	3.193	24.051	14.358
34	NDRK 50052	98.275	13.122	0.604	33.440	22.171	90.400	8.529	24.015	141.431	111.499	78.768	33.162	40.194	2.733	21.661	13.198
35	NDRK 50045	96.275	12.332	0.574	33.720	19.881	87.300	7.609	20.235	119.741	84.799	70.822	37.512	39.418	3.723	21.011	14.678
36	Narendra User 2	94.275	14.202	0.524	33.980	23.451	106.110	8.919	26.045	155.431	139.509	89.599	58.682	29.255	3.523	22.921	17.108
37	IR 12 T 193	100.275	13.642	0.594	34.030	20.481	107.370	7.399	24.805	164.821	136.229	82.570	57.492	39.463	3.543	19.201	22.718
38	IR 13 T 141	102.275	14.362	0.574	36.940	21.241	96.500	10.639	25.985	163.811	135.529	82.651	60.822	40.439	3.503	18.541	24.658
39	NDR 359	101.275	13.192	0.674	35.300	21.471	101.670	10.699	27.245	184.251	145.999	79.200	61.732	34.227	3.133	26.271	21.138
40	IR 74095 AC 5	96.275	13.062	0.704	35.410	34.241	80.910	8.359	29.565	144.001	119.899	83.152	54.592	36.627	2.763	25.261	19.978
41	Deepak	106.319	16.262	0.648	37.750	20.928	89.210	10.899	27.528	137.278	113.585	82.687	56.978	37.270	2.880	24.484	21.058
42	Narendra 6093	101.319	14.052	0.728	37.090	33.198	100.000	10.389	29.638	150.288	116.185	77.242	63.948	31.568	2.830	24.844	20.028
43	IR 12 T 195	100.319	14.512	0.678	36.160	45.728	99.310	12.699	29.658	150.848	124.275	82.392	57.488	33.389	2.890	23.754	19.108
44	PusaSugandha 4	105.319	15.722	0.678	36.610	25.918	90.310	9.359	28.918	146.518	126.175	86.158	46.918	38.541	3.160	22.374	18.058
45	Pusa 1121	100.319	13.482	0.698	35.880	24.458	95.280	10.569	29.148	155.918	132.155	84.822	55.738	38.153	2.780	21.554	21.088
46	Sugandha 3	103.319	13.292	0.668	37.710	23.478	89.740	8.659	26.338	149.078	130.185	87.397	39.078	44.123	2.840	22.904	17.218
47	Moti Gold	105.319	14.352	0.708	36.510	22.858	88.200	12.689	26.388	210.638	186.675	88.887	58.718	35.299	2.700	21.184	20.568
48	NDRK 5070	89.319	14.852	0.358	37.410	25.058	100.230	10.169	23.758	180.818	154.435	85.565	41.058	44.859	3.370	22.554	18.338
49	NDRK 5049	87.319	14.922	0.468	37.300	17.558	119.990	8.869	24.048	123.468	106.705	86.350	40.248	40.684	2.900	22.834	16.418
50	NDRK 5027	97.319	14.782	0.408	37.520	27.058	114.300	10.839	23.648	158.118	124.375	78.649	38.078	50.162	3.220	23.544	18.938
51	NDRK 50035	90.292	12.852	0.404	32.144	15.781	89.430	5.646	21.125	79.181	65.222	81.711	21.352	42.167	2.797	19.448	8.998
52	NDRK 5092	95.292	10.942	0.484	31.994	17.181	111.540	10.806	21.365	88.471	74.752	83.817	20.822	51.858	3.167	22.288	11.108
53	NDRK 50032	91.292	11.652	0.444	33.374	30.881	95.510	9.276	21.345	135.131	131.532	96.509	49.022	35.045	3.067	23.368	17.148
54	KashturiChandauli	102.292	13.212	0.544	34.474	20.131	85.610	7.316	22.225	148.741	136.912	91.571	52.852	39.941	2.497	23.748	21.268
55	NDRK 50047	96.292	12.282	0.534	30.744	16.571	105.510	6.706	20.215	59.321	47.092	78.624	22.062	40.571	3.307	22.978	8.898
56	NDRK 50036	100.292	11.182	0.504	33.304	19.101	86.520	6.576	20.795	130.511	110.232	84.195	55.572	31.911	3.247	23.698	17.648
57	NDRK 5036	95.292	12.482	0.494	32.144	10.981	94.960	5.846	19.185	80.841	67.312	82.564	25.642	38.431	3.077	20.718	9.758
58	NDRK 50053	100.292	12.362	0.464	35.004	21.121	98.110	7.876	22.395	132.131	119.522	89.920	50.572	41.180	3.307	22.238	21.008
59	IR 12 T 147	98.292	15.632	0.434	34.284	31.881	86.690	8.176	21.585	137.341	103.632	75.640	55.452	42.940	3.407	23.748	24.088
60	NDRK 50028	91.292	11.972	0.464	35.404	13.801	112.210	7.206	19.715	86.751	69.222	79.421	24.052	44.365	3.167	22.428	10.758
61	NDRK 5083	91.359	11.679	0.494	34.577	25.258	95.437	10.756	20.098	68.285	57.332	84.211	27.132	48.277	3.660	23.404	13.128
62	NDRK 5007	89.359	11.939	0.504	33.817	23.148	95.767	7.336	21.598	91.625	66.792	73.492	31.312	43.109	3.240	24.654	13.478
63	NDRK 5014	94.359	12.879	0.564	34.937	14.728	105.447	7.346	19.238	90.885	70.362	77.805	31.322	41.962	2.240	19.234	13.108
64	NDRK 5067	104.359	14.179	0.594	34.917	17.528	99.537	9.166	20.668	66.755	61.982	92.545	24.622	45.551	2.570	22.044	11.198

S. No	Genotypes	Days to 50% flowering	Chlorophyll content	Leaf Nitrogen	Leaf temperature	Flag leaf area (cm^2)	Plant height (cm)	Panicle bearing tillers/ plant	Panicle length (cm)	Spikelets/ panicle	Grains/ panicle	Spikelet fertility (%)	Biological yield/ plant (g)	Harvest index (%)	L/B ratio	1000 grain weight (g)	Grain yield/ plant (g)
65	NDRK 5019	89.359	12.309	0.524	34.927	19.728	119.577	7.926	20.058	96.835	79.872	82.588	37.122	43.056	3.130	23.304	15.988
66	NDRK 50033	92.359	10.889	0.504	33.357	21.038	106.447	7.206	17.138	103.065	82.942	80.631	28.032	43.546	3.160	22.674	12.178
67	NDRK 5017	102.359	13.309	0.544	33.617	33.428	108.737	12.086	22.968	142.285	119.392	83.783	42.142	35.616	2.860	21.724	14.938
68	NDRK 5089	80.359	13.639	0.674	33.667	27.128	110.467	10.166	23.608	93.395	77.052	82.627	37.632	39.252	3.360	22.234	14.728
69	NDRK 50056	86.359	12.909	0.694	33.847	23.728	108.717	9.186	19.628	120.625	99.552	82.519	44.492	40.010	2.660	24.504	17.798
70	NDRK 5011	97.359	13.479	0.664	34.087	17.628	95.447	9.176	19.398	90.775	76.082	83.894	26.442	42.211	2.460	22.944	11.108
71	NDRK 50019	99.172	14.692	0.568	38.907	20.535	106.693	10.316	22.662	99.818	86.775	86.993	29.575	44.531	3.440	23.218	13.125
72	NDRK 5087	86.172	12.062	0.758	37.267	14.135	120.713	7.266	20.262	75.678	65.475	86.463	27.725	42.395	3.580	21.958	11.755
73	CST 7-1	97.172	12.062	0.408	37.377	24.435	119.003	9.856	25.352	80.288	59.995	74.021	29.235	43.190	3.760	22.708	12.605
74	Pokkali (Acc 108921)	105.172	14.102	0.518	37.247	27.735	165.593	6.516	25.272	110.538	93.845	84.902	41.425	37.254	3.080	21.948	15.425
75	IR 86731-1-1-1-3-3-2-1	94.172	13.932	0.458	37.047	19.235	109.473	13.986	20.192	78.008	66.185	84.702	23.555	43.034	3.870	22.718	10.155
76	IR 87856-1AJAY1-B	113.172	13.892	0.468	36.587	22.735	107.593	9.696	20.962	135.558	106.165	78.164	35.905	37.459	3.670	22.058	13.475
77	IR 64527-2B-2-1-1	98.172	12.852	0.548	35.657	20.235	109.803	14.056	21.002	171.198	151.885	88.938	40.125	38.255	3.450	22.638	15.335
78	IR 85920-11-2-1AJAY1-2-B	114.172	13.702	0.508	36.107	16.435	98.683	7.986	20.192	83.558	65.165	77.504	30.725	47.947	3.500	21.928	14.625
79	IR 85921-9-2-1AJAY1-1-B	94.172	13.092	0.608	35.377	20.235	92.973	6.076	19.062	75.968	63.905	83.923	26.295	47.076	3.480	22.568	12.315
80	Kalanamak 3	110.172	15.262	0.598	37.207	32.735	109.713	9.656	26.642	96.178	68.535	70.569	29.945	45.193	3.640	21.518	13.475
81	Sundari	96.205	15.889	0.624	36.884	21.461	94.510	12.953	23.015	95.628	71.102	72.458	28.705	35.684	2.377	23.644	10.665
82	IR 45427-2B-2-2B-1-1	80.205	15.759	0.584	36.844	37.591	109.820	10.433	24.575	86.088	73.932	84.869	35.995	40.373	3.077	22.494	14.695
83	IR 71866-3 R -1-2-1-B	94.205	14.179	0.574	37.744	21.141	103.410	9.793	25.625	128.278	100.682	77.821	39.605	37.862	3.117	21.624	15.145
84	IR 65427-2B-2-2	83.205	15.859	0.544	37.634	20.441	98.740	12.193	23.315	116.048	95.902	82.065	29.705	45.469	2.937	22.714	13.675
85	NDRK 50050	109.205	16.389	0.594	37.854	17.341	97.580	7.753	21.085	116.628	97.082	82.726	29.165	42.910	2.807	22.054	12.755
86	NDRK 50055	105.205	15.049	0.514	36.944	21.141	99.810	8.543	20.835	128.308	95.312	73.311	44.715	41.260	2.817	23.594	18.415
87	NDRK 50057	90.205	14.639	0.544	36.794	23.841	90.710	10.603	23.395	114.258	100.722	88.000	43.265	40.084	2.817	24.234	17.365
88	NDRK 5003	106.205	15.989	0.634	35.544	28.841	117.540	6.783	22.805	183.608	167.052	91.625	40.535	43.253	3.917	22.124	17.535
89	NDRK 5034	96.205	15.549	0.664	39.054	22.841	90.630	9.563	20.535	104.348	91.412	87.229	26.155	41.819	3.187	21.774	11.265
90	IR 86341-B-AJAY1-B	97.205	15.799	0.594	38.104	31.181	104.010	10.533	22.975	97.888	77.712	78.074	36.225	43.067	2.607	24.754	15.695

S. No	Genotypes	Days to 50% flowering	Chlorophyll content	Leaf Nitrogen	Leaf temperature	Flag leaf area (cm^2)	Plant height (cm)	Panicle bearing tillers/ plant	Panicle length (cm)	Spikelets/ panicle	Grains/ panicle	Spikelet fertility (%)	Biological yield/ plant (g)	Harvest index (%)	L/B ratio	1000 grain weight (g)	Grain yield/ plant (g)
91	NDRK 50029	88.892	12.862	0.544	35.237	27.885	138.633	7.643	23.715	93.551	82.232	88.361	39.962	41.896	2.277	23.708	16.678
92	AT 401	98.892	13.312	0.744	38.097	40.195	94.653	7.243	22.985	145.621	120.522	82.850	64.472	33.952	2.977	25.958	21.818
93	NDRK 50044	102.892	14.102	0.684	38.387	28.755	86.323	8.783	24.855	124.341	101.442	81.783	49.622	43.651	2.767	22.778	21.588
94	IR 11 T 183	97.892	14.812	0.634	37.377	28.645	88.193	10.893	23.815	214.911	186.822	86.804	61.692	33.630	3.467	20.098	20.678
95	IR 11 T 171	97.892	14.012	0.764	38.497	29.425	83.933	6.813	19.645	99.661	72.372	73.002	53.382	44.348	3.437	19.208	23.598
96	IR 11 T 230	96.892	14.302	0.714	36.037	37.665	106.753	6.933	24.605	168.541	144.742	85.877	59.652	41.129	2.367	24.958	24.458
97	NDRK 50046	93.892	14.312	0.714	35.277	35.665	101.193	7.373	24.145	154.371	122.632	79.487	40.632	47.399	2.737	24.118	19.188
98	NDRK 50030	95.892	14.312	0.734	36.397	24.995	102.633	7.483	21.065	111.951	92.582	82.984	51.952	33.667	2.797	27.108	17.428
99	NDRK 5095	106.892	15.772	0.704	36.377	21.565	90.213	9.483	18.775	181.711	163.372	89.865	41.762	38.335	3.167	24.488	15.948
100	NDRK 5093	87.892	16.252	0.554	36.387	24.405	122.473	9.173	22.945	112.071	93.362	83.591	28.562	44.247	3.267	22.268	12.578
101	IR 86376-47-3-1-B	93.162	12.586	0.728	34.867	13.575	95.990	10.476	19.795	121.651	100.749	83.040	29.892	42.854	3.237	24.198	12.835
102	IR 55179-3B-11-3	89.162	11.426	0.378	34.137	21.655	101.490	10.366	19.055	76.691	60.219	79.274	25.732	43.964	3.097	23.418	11.355
103	IR 11 T 205	99.162	11.976	0.488	35.967	32.315	95.290	10.416	22.415	161.811	138.329	85.485	63.002	36.840	2.797	22.778	23.095
104	IR 11T 208	94.162	13.296	0.428	34.807	15.945	94.750	9.256	19.725	111.761	91.439	82.119	28.652	41.578	3.037	21.468	11.945
105	IR 11 T 213	91.162	13.896	0.438	34.767	19.455	101.340	10.126	21.045	106.261	88.179	83.339	36.622	32.270	3.527	23.838	11.825
106	IR 12 T 210	88.162	12.376	0.518	35.667	19.525	93.300	9.606	22.865	141.771	106.159	74.966	40.442	34.314	3.127	22.518	13.865
107	IR 13 T 144	92.162	11.346	0.478	35.557	20.825	86.990	10.116	20.885	99.461	80.749	81.611	35.122	39.518	2.797	21.758	13.885
108	IR 13 T 145	96.162	14.406	0.578	35.777	20.725	85.410	10.946	20.655	110.801	97.539	88.348	52.762	46.122	2.627	22.958	24.255
109	IR 11 T 132	99.162	13.976	0.568	34.867	20.725	85.410	10.676	20.505	111.951	98.419	88.220	49.802	47.112	2.597	21.868	23.395
110	CSR 43	97.162	13.826	0.528	37.197	45.465	89.750	10.606	24.045	192.561	164.699	85.418	54.432	39.950	2.427	23.048	21.665
1	Sarjoo 52©	103.524	13.506	0.662	35.929	43.655	92.103	9.215	24.701	177.463	155.197	87.440	48.493	35.975	2.662	25.291	17.465
2	FL 478 ©	88.690	13.537	0.556	35.954	33.935	88.665	9.633	21.867	142.865	111.901	78.328	53.808	30.799	3.161	22.356	16.584
3	CSR 10©	101.633	13.594	0.575	36.888	22.793	80.722	8.581	20.957	132.335	103.028	77.841	62.294	32.714	2.277	21.455	20.185
Mean		97.468	13.202	0.581	35.630	26.121	99.589	8.905	23.184	135.224	112.264	82.695	42.205	39.614	3.026	22.856	16.464
Std. Dev.		7.365	1.811	0.100	1.839	7.708	13.094	1.798	2.811	38.558	34.316	5.514	11.033	4.534	0.486	2.239	3.714
Std. Error		0.693	0.170	0.009	0.173	0.725	1.232	0.169	0.264	3.627	3.228	0.519	1.038	0.427	0.046	0.211	0.349
C. V. %		7.556	13.718	17.268	5.161	29.509	13.148	20.194	12.125	28.514	30.567	6.668	26.142	11.447	16.049	9.797	22.556
Range	Lowest	80.205	7.022	0.358	28.827	10.981	63.830	5.409	17.138	59.321	47.092	64.514	20.822	29.255	2.197	14.678	8.898
	Highest	117.219	16.389	0.794	39.054	46.698	165.593	14.056	29.658	242.401	197.025	96.509	64.472	51.858	5.133	30.358	24.658
LSD$_1$		0.4980	0.2890	0.0226	0.5590	1.7438	6.2372	0.8686	0.2881	1.5777	1.7290	0.7975	0.6574	0.7252	0.1736	0.1482	0.3438
LSD$_2$		1.6518	0.9586	0.0751	1.8541	5.7835	20.6865	2.8810	0.9557	5.2327	5.7344	2.6451	2.1803	2.4052	0.5759	0.4916	1.1401
LSD$_3$		1.9073	1.1068	0.0867	2.1410	6.6782	23.8867	3.3267	1.1035	6.0422	6.6215	3.0542	2.5176	2.7772	0.6650	0.5677	1.3165
LSD$_4$		1.4086	0.8175	0.0640	1.5812	4.9322	17.6415	2.4569	0.8150	4.4624	4.8903	2.2557	1.8594	2.0511	0.4911	0.4192	0.9723

Table 3. The most desirable genotypes identified for high mean performance for 16 characters under sodic soil

S.No.	Characters	Genotypes
1	Days to 50% flowering	IR 45427-2B-2-2B-1-1 (80.205), NDRK5089 (80.359 days), IR65427-2B-2-2 (83.205 days), IR11T265 (83.775 days), NDRK 510 (85.775 days), NDRK 5087 (86.172 days), NDRK 50056 (86.359 days), IR11T255 (86.775 days), NDRK 5049 (87.319 days) and NDRK 5093 (87.892 days)
2	Chlorophyll content	NDRK 50050 (16.389), Deepak (16.262), NDRK 5093 (16.252), NDRK 5003 (15.989), Sundari (15.889), IR 65427-2B-2-2 (15.859), IR 86341-B-AJAY1-B (15.799), NDRK 5095 (15.772), IR 45427-2B-2-2B-1-1 (15.759) and Pusa Sugandha 4 (15.722).
3	Leaf nitrogen	NDR 2064 (0.794), NDRK 5038 (0.784), IR 11 T 171 (0.764), NDRK 5087 (0.758), AT 401 (0.744), FL 449 (0.744), NDRK 50030 (0.734), IR 86376-47-3-1-B (0.728), Narendra 6093 (0.728) and NDRK 5026 (0.724)
4	Leaf temperature	NDRK 5034 (39.054), NDRK 50019 (38.907), IR 11 T 171 (38.497), NDRK 50044 (38.387), CSR 28 (38.244), Improved PB-1 (38.214), IR 86341-B-AJAY1-B (38.104), AT 401 (38.097), CSR-30 (38.074) and Jallahri (37.944)
5	Flag leaf area (cm^2)	CSR 28 (46.698 cm^2), IR 12 T 195 (45.728 cm^2), CSR 43 (45.465 cm^2), CSR-30 (43.965 cm^2), CSR-23 (40.815 cm^2), AT 401 (40.195 cm^2), Jallahri (39.095 cm^2), IR 11 T 230 (37.665 cm^2), IR 45427-2B-2-2B-1-1 (37.591 cm^2) and Kalanamak (37.165 cm^2)
6	Plant height (cm)	IR 45427-2B-2-2B-1-1 (63.830 cm), Sambha Mahsuri (71.52 cm), CSR-30 (80.44 cm), IR 74095 AC 5 (80.91 cm), CSR-27 (83.4 cm), IR 11 T 171 (83.933 cm), NUD-2009 (85.06 cm), IR 13 T 145 (85.41 cm), IR 11 T 132 (85.41 cm) and KashturiChandauli (85.61 cm)
7	Panicle bearing tillers/ plant	IR64527-2B-2-1-1 (14.056), IR86731-1-1-1-3-3-2-1 (13.986), Sundari (12.953), IR12T195 (12.699), Motigold (12.689), IR65427-2B-2-2 (12.193), NDRK 5017 (12.086), IR13T145 (10.946) and Deepak (10.899), IR11T183 (10.893)
8	Panicle length (cm)	IR 12T195 (29.658 cm), Narendra 6093 (29.638 cm), IR74095AC5 (29.565 cm), Pusa Basmati (29.275 cm), Pusa 1121 (29.148 cm), Pusa Sugandha 4 (28.918 cm), CSR 28 (28.665 cm), NDRK 5026 (28.385 cm), Deepak (27.528 cm) and NDRK 359 (27.245 cm)
9	Spikelets/panicle	NDRK 5042 (242.401), IR11T183 (210.629), Motigold (210.638), NDRK 5047 (209.711), Pusa basmati 1 (198.881), NDRK 5062 (197.951), NDRK 5099 (194.711), CSR 43 (192.561), CSR 28 (191.901) and NDRK 2064 (191.161)
10	Grains/panicle	NDRK 5042 (197.025), NDRK 5047 (190.925), Motigold (186.675), NDR 2064 (173.545), NDRK 5099 (169.655), NDRK5003 (167.052), NDRK 5038 (166.755), CSR 43 (164.699), NDRK 5095 (163.372) and CSR 28 (161.655)
11	Spikelet fertility (%)	NDRK 50032 (96.509%), NUD 2008 (94.716%), NDRK 5038 (92.678%), NDRK 5067(92.545%), NDRK 5003 (91.625%), Kashtirichandauli (91.571%), NDRK 5047 (91.15%), NDR 2064(90.896%), CSR 28 (90.630%) and NDRK 50005 (90.810%)
12	Biological yield/plant (g)	AT 401 (64.472g), Narendra 6093 (63.948g), IR 11T 205 (63.002g), NDR 359 (61.732g), IR 11T 183 (61.692g), IR 13T141 (60.822g), IR 11T230 (59.652g), Motigold (58.718g) NDRK 50005 (58.682g), and Narendra Usar 2 (58.682g)
13	Harvest index (%)	NDRK 5092 (51.858%), NDRK 5027 (50.162%), NDRK 5083 (48.277%), IR 85920-11-2-1AJAY1-2-B (47.947%), NDRK 50046 (47.399%), IR 11 T 132 (47.112%), IR 85921-9-2-1AJAY1-1-B (47.076%), IR 13 T 145 (46.122%), NDRK 5067 (45.551%) and IR 65427-2B-2-2 (45.469%)
14	L/B ratio	NDR 359 (5.133), NDRK 5038 (5.077), NDRK 5003 (3.917), IR 86731-1-1-1-3-3-2-1 (3.870), CST 7-1 (3.760), NDRK 50045 (3.723), IR 87856-1AJAY1-B (3.670), NDRK 5083 (3.660), Kalanamak 3 (3.640) and NDRK 5087 (3.580)
15	1000-grain weight (g)	NDRK 5038 (30.358g), NDRK 5047 (28.938g), NDRK 50030 (27.108g), CSR-36 (26.878g), CSR 28 (26.801g), NDR 359 (26.271g), AT 401 (25.958g), NDRK 50005 (25.681g), NDRK 5026 (25.598g) and IR11T159 (25.321g)
16	Grain yield/plant (g)	IR 13 T 141 (24.658g), IR 11 T 230 (24.458g), IR 13 T 145 (24.255g), IR 12 T 147 (24.088), IR 11 T 171 (23.598g), IR 11 T 132(23.395g), IR 11 T 205 (23.095g), IR 12 T 193(22.718g), AT 401(21.818g) and CSR 43 (21.665g)

The mean performance of sixteen characters is described character-wise in the following. Days to 50% flowering varied from 80.205 (IR 45427-2B-2-2B-1-1) to 117.219 days (Jallahari) with a general mean of 97.468 days. Out of 110 genotypes, nineteen entries were significantly earlier for days to 50% flowering over the general mean. The best ten genotypes for early flowering were IR 45427-2B-2-2B-1-1 (80.205), NDRK5089 (80.359), IR65427-2B-2-2 (83.205), IR11T265 (83.775), NDRK 510 (85.775), NDRK 5087 (86.172), NDRK 50056 (86.359), IR11T255 (86.775), NDRK 5049 (87.319) and NDRK 5093 (87.892). NDRK5089 was statistically *at par* with the earliest flowering genotype IR 45427-2B-2-2B-1-1. The lowest and highest means for chlorophyll content were recorded for Jallahri (7.022) and NDRK 50050 (16.389), respectively. The general mean for chlorophyll content was 13.202. Thirty-six genotypes showed significantly high chlorophyll content over the general mean and the best ten genotypes among them were NDRK 50050 (16.389), Deepak (16.262), NDRK 5093 (16.252), NDRK 5003 (15.989), Sundari (15.889), IR 65427-2B-2-2 (15.859), IR 86341-B-AJAY1-B (15.799), NDRK 5095 (15.772), IR 45427-2B-2-2B-1-1 (15.759) and Pusa Sugandha 4 (15.722). The lowest and highest means for leaf nitrogen were recorded for NDRK 5070 (0.358) and NDR 2064 (0.794), respectively. The general mean for leaf nitrogen was 0.581. Forty-two genotypes showed significantly higher leaf nitrogen over the general mean and best ten genotypes among them were NDR 2064 (0.794), NDRK 5038 (0.784), IR 11 T 171 (0.764), NDRK 5087 (0.758), AT 401 (0.744), FL 449 (0.744), NDRK 50030 (0.734), IR 86376-47-3-1-B (0.728), Narendra 6093 (0.728) and NDRK 5026 (0.724).

The lowest and highest means for leaf temperature were recorded for IR11T255 (28.827) and NDRK 5034 (39.054), respectively. The general mean for leaf temperature was 35.630. Twenty-nine genotypes showed a significant leaf temperature over the general mean and best ten genotypes among them were NDRK 5034 (39.054), NDRK 50019 (38.907), IR 11 T 171 (38.497), NDRK 50044 (38.387), CSR 28 (38.244), Improved PB-1 (38.214), IR 86341-B-AJAY1-B (38.104), AT 401 (38.097), CSR-30 (38.074) and Jallahri (37.944). The general mean for the flag leaf area was 26.121 cm^2. The lowest and highest mean for flag leaf area were recorded in the case of NDRK 5036 (10.981cm^2) and CSR 28 (46.698 cm^2), respectively. Twenty-eight genotypes possessed significantly greater flag leaf area over the general mean. The best ten genotypes for higher flag leaf area were CSR 28 (46.698 cm^2), IR 12 T 195 (45.728 cm^2), CSR 43 (45.465 cm^2), CSR-30 (43.965 cm^2), CSR-23 (40.815 cm^2), AT 401 (40.195 cm^2), Jallahri (39.095 cm^2), IR 11 T 230 (37.665 cm^2), IR 45427-2B-2-2B-1-1 (37.591 cm^2) and Kalanamak (37.165 cm^2). Plant height ranged from 63.830 cm (IR 45427-2B-2-2B-1-1) to 165.593 cm (Pokkali (Acc 108921)) with a general mean of 99.589 cm. Twenty-nine, out of 110 genotypes had significantly shorter plant stature than the general mean. The best ten genotypes for shorter plant height were IR 45427-2B-2-2B-1-1 (63.830 cm), Samba Mahsuri (71.52 cm), CSR-30 (80.44 cm), IR 74095 AC 5 (80.91 cm), CSR-27 (83.4 cm), IR 11 T 171 (83.933 cm), NUD-2009 (85.06 cm), IR 13 T 145 (85.41 cm), IR 11 T 132 (85.41 cm) and Kashturi Chandauli (85.61 cm). None of these was found statistically *at par* with the shortest genotype, IR 45427-2B-2-2B-1-1 (63.830 cm). The general mean for panicle bearing tillers per plant was 8.905. Panicle-bearing tillers ranged from 5.409 (Samha Mahsuri) to 14.056 (IR64527-2B-2-1-1). Out of 110 entries, thirty-four entries exhibited significantly higher panicle bearing tillers per plant than the general mean. The best ten genotypes for higher mean performance for this character were IR64527-2B-2-1-1 (14.056), IR86731-1-1-1-3-3-2-1 (13.986), Sundari (12.953), IR12T195 (12.699), Motigold (12.689), IR65427-2B-2-2 (12.193), NDRK 5017 (12.086), IR13T145 (10.946) Deepak (10.899) and IR11T183 (10.893). IR64527-2B-2-1-1 constituted the top non-significant group for this trait alone because none of the remaining entries were statistically *at par* with it.

The lowest and highest means for panicle length were recorded for NDRK 50033 (17.138 cm) and IR 12T195 (29.658 cm), respectively. The general mean for panicle length was 23.184 cm. Forty-three genotypes showed significantly longer panicle length over the general mean and best ten genotypes among them were IR 12T195 (29.658 cm), Narendra 6093 (29.638 cm), IR74095AC5 (29.565 cm), Pusa Basmati (29.275 cm), Pusa 1121 (29.148 cm), Pusa Sugandha 4 (28.918 cm), CSR 28 (28.665 cm), NDRK 5026 (28.385 cm), Deepak 27.528 cm) and NDRK 359 (27.245 cm). Only IR 12T195, constituted the top non-significant group for panicle length. The general mean for spikelets per panicle was 135.224 with the range of 59.321 (NDRK50047) to 242.401 (NDRK 5042). Out of 110 entries, fourty one genotypes exhibited significantly greater number of spikelets per panicle than the general mean. NDRK 5042 (242.401), IR11T183 (210.629), Motigold (210.638), NDRK 5047 (209.711), Pusa Basmati 1 (198.881), NDRK 5062 (197.951), NDRK 5099 (194.711), CSR 43 (192.561), CSR 28 (191.901) and NDRK 2064(191.161) emerged as the best genotypes for higher mean performance for spikelets per panicle. The general mean for spikelets per panicle was 112.264 with the range of 47.92 (NDRK 50047) to 197.025 (NDRK 5042). Out of 110 entries, twenty-three genotypes exhibited significantly greater number of spikelets per panicle than the general mean. NDRK 5042 (197.025), NDRK 5047 (190.925), Motigold (186.675), NDR 2064 (173.545), NDRK 5099 (169.655), NDRK5003 (167.052), NDRK 5038 (166.755), CSR 43 (164.699), NDRK 5095 (163.372) and CSR 28 (161.655) emerged as the best genotypes for higher mean performance for spikelets per panicle. The spikelet fertility (%) varied from 64.514 % (NUD 2009) to 96.509 % (NDRK 50032) with a general mean of 82.695 %. Thirty-four out of 110 genotypes exhibited higher spikelet fertility than the general mean. The best ten genotypes for higher fertility percentage were NDRK 50032 (96.509%), NUD 2008 (94.716%), NDRK 5038 (92.678%), NDRK 5067(92.545%), NDRK 5003 (91.625%), Kashtirichandauli (91.571%), NDRK 5047 (91.15%), NDR 2064(90.896%), CSR 28 (90.630%) and NDRK 50005 (90.810%). NUD 2008, NDRK 5038, NDRK 5067, constituted the top non-significant group for this trait along with NDRK 50032.The general mean for biological yield per plant was 42.205g. The entry NDRK 5092 recorded lowest mean (20.822g) for biological yield whereas, highest mean (64.472g) was observed in case of AT 401.

Out of 110 entries, twenty-six produced significantly higher biomass than the general mean. The best ten genotypes for higher biomass production were AT 401 (64.472g), Narendra 6093 (63.948g), IR 11T 205 (63.002g), NDR 359 (61.732g), IR 11T 183 (61.692g), IR 13T141 (60.822g), IR 11T230 (59.652g), Motigold (58.718g), NDRK 50005 (58.682g), and Narendra Usar 2 (58.682g). The top non-significant group for higher biological yield per plant comprised of four genotypes *viz*., AT 401, Narendra 6093, IR 11T 205 and NDR 359.The lowest and highest means for harvest–index were observed for Narendra Usar 2 (29.255%) and NDRK 5092 (51.858%), respectively. The general mean for harvest–index was 39.614%. Out of 110 genotypes, forty five genotypes exhibited significantly better partitioning of photosynthates than the general mean. The best ten genotypes which also possessed harvest-index statistically *at par* were NDRK 5092 (51.858%), NDRK 5027 (50.162%), NDRK 5083 (48.277%), IR 85920-11-2-1AJAY1-2-B (47.947%), NDRK 50046 (47.399%), IR 11 T 132 (47.112%), IR 85921-9-2-1AJAY1-1-B (47.076%), IR 13 T 145 (46.122%), NDRK 5067 (45.551%) and IR 65427-2B-2-2 (45.469%).The L:B ratio varied from 2.197 (NDRK 50031) to 5.133 (NDR 359) with general mean of 3.026mm. Out of 110 entries, fifty six genotypes exhibited significantly higher L:B ratio than the general mean. The best ten lines were NDR 359 (5.133), NDRK 5038 (5.077), NDRK 5003 (3.917), IR 86731-1-1-1-3-3-2-1 (3.870), CST 7-1 (3.760), NDRK 50045 (3.723), IR 87856-1AJAY1-B (3.670), NDRK 5083 (3.660), Kalanamak 3 (3.640) and NDRK 5087 (3.580). The one genotypes, NDRK 5038 constituted top non- significant group of higher L:B ratio along with NDR 359.The 1000- grain weight ranged from 14.678g in case of Improved PB-1 to 30.358g for NDRK 5038 with a general mean of 22.856g. Out of 110 entries, twenty-eight genotypes had significantly higher 1000–grain weight than the general mean and the best ten genotypes among them were NDRK 5038 (30.358g), NDRK 5047 (28.938g), NDRK 50030 (27.108g), CSR-36 (26.878g), CSR 28 (26.801g), NDR 359 (26.271g), AT 401 (25.958g), NDRK 50005 (25.681g), NDRK 5026 (25.598g) and IR11T159 (25.321g). The grain yield per plant ranged from 8.898g for NDRK 50047 to 24.658g in case of IR 13 T 141with a general mean of 16.464g. Out of 113 genotypes, thirty-- six genotypes produced significantly higher grain yield per plant than the general mean. The best ten genotypes for higher grain yield per plant were IR 13 T 141 (24.658g), IR 11 T 230 (24.458g), IR 13 T 145 (24.255g), IR 12 T 147 (24.088), IR 11 T 171 (23.598g), IR 11 T 132(23.395g), IR 11 T 205 (23.095g), IR 12 T 193(22.718g), AT 401(21.818g) and CSR 43 (21.665g).

Similarly, the genotypes showing very high mean performance in desirable direction for various characters listed in **Table 4**, which may also be used as donors for improving the characters for which they had high mean performance.

Table 4. The mean performance of high yielding genotypes in aromatic and non-aromatic group in sodic soil for other characters

S. No.	Genotypes	High mean performance of grain yield per plant (g)	High mean performance for other characters
1	IR 13 T 141	24.658	BY/P
2	IR 11 T 230	24.458	FLA, BY/P
3	IR 13 T 145	24.255	PH, PBT/P, HI
4	IR 12 T 147	24.088	-
5	IR 11 T 171	23.598	LN, LT, PH
6	IR 11 T 132	23.395	PH, HI
7	IR 11 T 205	23.095	BY/P
8	IR 12 T 193	22.718	-
9	AT 401	21.818	LN, LT, FLA, BY/P, 1000-GW
10	CSR 43	21.665	FLA, S/P, G/P

DF=Days to 50% flowering, CC=Chlorophyll content (SPAD value), LN= Leaf nitrogen (SPAD value), LT= Leaf temperature (SPAD value), FLA=Flag leaf area (cm^2), PH=Plant height (cm), PBT/P=Panicle bearing tillers / plant, PL=Panicle length (cm), S/P=Spikelets / panicle, G/P= Grains per panicle, SF=Spikelet fertility (%), BY/P= Biological yield / plant (g), HI=Harvest index (%), L/B=L/B ratio, 1000-GW=1000- grain weight (g) and GY/P=Grain yield / plant(g)

The availability of large genetic variability, as well as the nature of heritability and gene action, are all important factors in the success of selection in improving plant traits. The basic material for a plant breeding programme is genetic diversity, which is used to generate superior genotypes through selection. The phenotypic, genotypic, and environmental coefficients of variation can be used to assess and compare the nature and magnitude of variability present in breeding materials for various traits. In a general sense, heritability refers to the proportion of heritable genetic variance in total phenotypic variance, whereas in a more specific meaning, it refers to the ratio of fixable additive genetic variance to total phenotypic variance. Estimates of heredity aid in predicting expected selection progress. By taking into consideration the character's genetic variability and heritability, the genetic advance in percent of mean provides an indicator of expected selection response.

The estimates of direct selection parameters, coefficients of variation, heritability and genetic advance in per cent of mean were computed for sixteen characters of 113 germplasm lines including 3 checks (**Table 5**). The high estimates (>20%) of phenotypic (PCV) and genotypic (GCV) coefficients of variation were recorded in case of grains per panicle, spikelets per panicle, flag leaf area, biological yield per plant and grain yield per plant. These similar results have also been reported by earlier scientists (Khedikar *et al.*, 2003; Saxena *et al.*, 2005; Singh and Singh, 2005; Dhanwani *et al.*, 2013; Gyawali *et al.*, 2018 and Parimala and Devi, 2019).

Table 5. Estimates of coefficient of variation, $h_{(bs)}^2$ (broad sense) and genetic advance in per cent of mean for 16 characters in rice

S. No.	Characters	Range	Mean	Coefficient of variation		Heritability in broad sense (%)	Genetic advance in per cent of mean
				PCV	GCV		
1	Days to 50% flowering	80.205-117.219	97.468	6.672	6.647	99.26	13.6421
2	Chlorophyll content	7.022-16.389	13.202	10.106	9.801	94.06	19.5807
3	Leaf nitrogen	0.358-0.794	0.581	15.403	14.766	91.90	29.1598
4	Leaf temperature	28.827-39.054	35.630	3.756	3.315	77.92	6.0288
5	Flag leaf area (cm^2)	10.981-46.698	26.121	26.199	25.084	91.67	49.4721
6	Plant height (cm)	63.830-165.593	99.589	11.564	9.191	63.17	15.0485
7	Panicle bearing tillers/plant	5.409-14.056	8.905	17.037	13.031	58.50	20.5318
8	Panicle length (cm)	17.138-29.658	23.184	10.470	10.377	98.22	21.1853
9	Spikelets/panicle	59.321-242.401	135.224	26.220	26.187	99.75	53.8776
10	Grains/panicle	47.092-197.025	112.264	28.201	28.147	99.62	57.8734
11	Spikelet fertility (%)	64.514-96.509	82.695	6.115	6.018	96.86	12.2015
12	Biological yield/plant (g)	20.822-64.472	42.205	23.935	23.870	99.46	49.0373
13	Harvest index (%)	29.255-51.858	39.614	9.882	9.667	95.70	19.4808
14	L/B ratio	2.197-5.133	3.026	14.141	12.593	79.31	23.1016
15	1000- grain weight (g)	14.678-30.358	22.856	8.679	8.649	99.29	17.7534
16	Grain yield/plant (g)	8.898-24.658	16.464	21.375	21.245	98.79	43.4988

High estimates of broad sense heritability (> 75%) were recorded for spikelets/panicle, grains/panicle, biological yield/plant, 1000-grain weight, days to 50% flowering, grain yield/plant, panicle length, spikelet fertility, harvest index, chlorophyll content, leaf nitrogen, flag leaf area, L/B ratio and leaf temperature.

The high estimates of genetic advance in per cent of mean (>20%) were recorded for grains/panicle, spikelet's/panicle, flag leaf area, biological yield/plant, grain yield/plant, leaf nitrogen, L/B ratio, panicle length, panicle bearing tillers/plant. The high to very high estimates of direct selection parameters for above mentioned nine characters indicated that these would be ideal traits for improvement through selection in context of materials evaluated owing to existence of high genetic variability represented by high coefficients of variation and high transmissibility denoted by high heritability for them. The high estimates of direct selection parameters observed for the above characters are broadly in agreement with earlier reports in rice (Thakur *et al.*, 1999; Kumar *et al.*, 2001; Roy *et al., 2001;* Mohammad and Deva, 2002; Nayak *et al.*, 2002; Yadav *et al.*, 2002; Chaudhary *et al*., 2004; Shukla *et al*., 2004; Mall *et al*., 2005; Suman *et al*., 2005; Singh *et al*., 2006; Panwar *et al*., 2007; Babar *et al*., 2009; Anjaneyulu *et al*., 2010; Dhanwani *et al*., 2013; Lingaiah *et al*., 2014; Gyawali *et al*., 2018; Parimala and Devi, 2019). Panicle length with moderate PCV and GCV values and high heritability resulted in strong genetic advance, implying that due to high transmissibility, even if variability is moderate, a reasonable response to selection may be attained for this trait. Despite high heritability in the broad sense, days to 50% flowering resulted in low genetic progress due to low variability, as measured by low PCV and GCV values, indicating that improving trait through selection in the context of current material would be difficult due to a lack of genetic variability. The availability of large genetic variability, as well as the nature of heritability and gene action, are all important factors in the success of selection in improving plant traits. The basic material for a plant breeding programme is genetic diversity, which is used to generate superior genotypes through selection.

References

Anjaneyulu M, Reddy DR and Reddy KHP. 2010. Genetic variability, heritability and genetic advance in rice (*Oryza sativa* L.). *Research on Crops,* 11: 415-416.

Anonymous. 2017-18. Directorate of economics and statistics, dept. of agriculture and co-operation. Ministry of agriculture. Government of India.

Anonymous. 2019-20. Directorate of economics and statistics, dept. of agriculture and co-operation. Ministry of agriculture. Government of India.

Babar M, Khan AA, Arif A, Zafar Y and Arif M. 2009. Path analysis of some leaf and panicle traits affecting grain yield in double haploid lines of rice (*Oryza sativa* L.). *Journal of Agricultural Research,* 45: 245-252.

Chaudhary M, Sarawgi AK and Motiramani NK. 2004. Genetic variability of quality, yield and yield attributing traits in aromatic rice *(Oryza sativa* L.*). Advances in Plant Sciences*, 17: 485-490.

Dhanwani RK, Sarawgi AK, Solanki A and Tiwari JK. 2013. Genetic variability analysis for various yield attributing and quality traits in rice (*O. sativa* L.). *The Bioscan,* 8: 1403-1407.

Efferson JN. 1985. Rice quality in world markets. In: Rice Grain Quality and Marketing. (IRRI, Los Banos, Philippines), pp. 1-13.

Federer WT. 1956. Augmented designs. *Hawaiin Planters Record,* 55: 191-208.

Fiaz S, Shakeel A, Mehmood AN, Xiukang W, Afifa Y, Aamir R, Adeel R and Fahad A. 2019. Applications of the CRISPR/Cas9 system for rice grain quality improvement: perspectives and opportunities. *International Journal of Molecular Sciences,* 20, 888; doi:10.3390/ijms20040888.

Grafius JE. 1959. Genetic and environmental relationship of components of yield, maturity and height in F_2-F_3 soybean populations. *Iowa State College Journal of Science,* 30: 373-374.

Gyawali S, Poudel A and Poudel S. 2018. Genetic variability and association analysis in different rice genotypes in Mid-Hill of Western Nepal. *Acta Scientific Agriculture,* 2: 69-76.

Hawkes JG. 1981. Germplasm collection, preservation and use. In: Plant Breeding II. Ed. K.J. Frey. Iowa State Univ. Press, Iowa, pp 57-84.

Huang BE, Klara LV, Arunas PV, Chitra R, Vikas KS, Pooran G, Hei L, Rajeev KV and Colin RC. 2015. MAGIC populations in crops: current status and future prospects. *Theoretical and Applied Genetics,* 128:999–1017.

Khedikar VP, Bharose AA, Sharma D and Khedikar YP. 2003. Study on genetic parameters in scented rice genotypes. *Journal of Soils and Crops,* 13: 338-342.

Kumar B, Thakur R, Mishra SB and Singh DN. 2001. Variability studies in segregating population of rice (*O. sativa* L.). *Annals of Biology*, 17: 43-45.

Lingaiah N, Venkanna V and Cheralu C. 2014. Genetic Variability Analysis in Rice (*Oryza sativa* L.). *International Journal of Pure and Applied Bioscience,* 2: 203-204.

Mall AK, Babu JDP and Babu GS. 2005. Estimation of genetic variability in rice. *Journal of Maharashtra Agricultural University*, 30: 166-168.

Mohammad S and Deva JB. 2002. Genetic variability and other relevant parameters in rice. *Journal of Maharashtra Agricultural University,* 22: 110-113.

Nayak AR, Chaudhary D and Reddy JN. 2002. Genetic variability, heritability and genetic advance in scented rice. *Indian Agriculturist*, 46: 45-47.

Panwar A, Dhaka RPS and Kumar V. 2007. Genetic variability and heritability studies in rice. *Advances in Plant Sciences*, 20: 47-49.

Parimala, K. and Devi, R.K. 2019. Estimation of Variability and Genetic Parameters in Indica and Japonica Genotypes of Rice (*Oryza sativa* L.), *International Journal of Microbiology and Applied Sciences,* 8: 1138-1142.

Roy B, Hossain N and Hossain F. 2001. Genetic variability in yield components of rice. (*O. sativa* L.). *Environment and Ecology*, 19: 186-189.

Saxena RR, Saxena RR, Motiramani NK, Nichal SS and Sahu RK. 2005. Studies on variability, heritability and genetic advance in scented rice germplasm accessions. *Journal of Inter-Academicia*, 9: 487-489.

Shabir G, Kashif A, Abdul RK, Muhammad S, Hamid M, Sibgha N, Mueen AK, Muhammad B, Muhammad S, Shahid MS and Muhammad A. 2017. Rice molecular markers and genetic mapping: Current status and prospects. *Journal of Integrative Agriculture*, 16: 60345-7.

Shrivastav SP, Verma OP, Lal K, Singh V and Srivastava K. 2022. Genetic divergence analysis in rice (*Oryza sativa* L.) germplasms under sodic soil. *Indian Journal of Agricultural Research,* DOI: 10.18805/IJARe.A-5976.

Shukla V, Singh S, Singh SK and Singh H. 2004. Analysis of variability and heritability in new plant type tropical *Japonica* rice (*Oryza sativa* L.). *Environment and Ecology*, 22: 43-45.

Singh RK and Singh O. 2005. Genetic variation for yield and quality characters in mutants of aromatic rice. *Annals of Agricultural Research,* 26: 406-410.

Singh RK, Singh US, Khush GS and Rohilla R. 2000. Genetics and biotechnology of quality traits in aromatic rice. In: *Aromatic rice*, pp. 47-69.

Singh RV, Maurya JV, Dwivedi JL and Verma OP. 2005. Combining ability studies on yield and components using CMS line in rice. *Oryza*, 42: 306- 309.

Singh SP, Singh RP, Srinivasulu K and Prasad JP. 2006. Studies on genetic variability, character association in diverse lines of international irrigated observation nursery of rice (*Oryza sativa* L.). *Research on Crops*, 7: 714-719.

Suman A, Sankar VG, Rao LVS and Sreedhar N. 2005. Variability, heritability and genetic advance in rice. *Crop Research*, 30: 211-214.

Thakur SK, Choubey SK. and Sharma NP. 1999. Genetic variability and character association in F2 (Anupama x IR 36) population in rice. *Agricultural Science Digest*, 19: 187-190.

Yadav PN, Chauhan MP and Singh RS. 2002. Genetic variability, heritability and expected genetic advance for certain qualitative characters in rice. *New Agriculturist,* 13: 84-94.

Yang Y, Li D, Hengchuan X, Keming Z, Haijun L and Keping C. 2013. Protein profile of rice (*Oryza sativa*) seeds. *Genetics and Molecular Biology,* 36: 87-92.

Yang Z, Lingling J, Haitao Z, Shaokui W, Guiquan Z and Guifu L. 2018. Analysis of epistasis among QTLs on heading date based on single segment substitution lines in rice. *Scientific Reports,* 8:3059 DOI:10.1038/s41598-018-20690-w.

RESEARCH ARTICLE https://doi.org/10.58297/XQHH9504

Assessment of Genetic Variability Parameters Among the F_2 Population of a Cross Between Jaya × Isogenic Line of MTU1010 for Yield and its Component Traits in Rice

Dileep Kumar GD[1, 2], Abdul Fiyaz R[1]*, Viswanatha KP[2], Subba Rao LV[1], Chimote VP[2], Raghuwanshi KS[3], Amolic VL[2], Chaithanya K[1], Shivani D[4], Bharat Kumar[4], Rapaka Percy VS[1], Satvik B[1] and Sundaram RM[1]

[1]ICAR-Indian Institute of Rice Research, Hyderabad 500030
[2]Mahatama Phule Krishi Vidyapeeth, Rahuri, Maharashtra 413 722
[3]Agricultural Research Station, Lonavala, Maharashtra 410401
[4]Professor Jayashankar Telangana State Agricultural University, Hyderabad 500030
* Corresponding author's Email: *fiyaz.ra@icar.gov.in*, *genefiyaz@gmail.com*

Received: 30th November 2022; Accepted: 28th December 2022

Abstract

An experiment was carried out during *Rabi* 2021-22 at the experimental plot of ICAR-Indian Institute of Rice Research, Hyderabad. Two diverse elite indica lines of rice (Jaya and isogenic line of MTU1010) were used to generate the F_2 population to study genetic variability parameters, heritability, and expected genetic advance under selection. Higher GCV, PCV, and heritability coupled with high genetic advance were estimated for the number of productive tillers, panicle weight, number of filled grains, and single plant yield, which indicated that heritability of these traits was under the control of additive gene action. Stringent selection for such traits will be rewarding.

Keywords: Variability, Jaya, MTU1010 (IL), GCV, PCV, Expected genetic advance, Rice

Introduction

Rice (*Oryza sativa* L.) is the most preferable staple cereal crop around the world. More than 90% of the world's rice is produced and consumed in Southeast Asia and tropical Latin America. It accounts for almost 35-60% of the calories consumed by more than 3 billion Asians. India is the largest rice-growing country, while China is the largest producer of rice (Fiyaz *et al*., 2022). To meet the growing demand of nearly 5.0 billion consumers with an annual average population growth of ~1.5% and estimated per capita consumption of about 250g of rice per day, the demand for rice is expected to increase to 40% by 2030 (Khush, 2005). Yield is one of the important complex traits influenced by environmental, agronomical, and genetic factors. Yield-related traits are mostly governed by several additive loci which always show continuous variation. Basically, for any crop improvement strategy, the availability of genetic variability is a must criterion. With the available genetic variation, knowing the inheritance pattern and adopting appropriate selection techniques together gives good results in crop improvement (Rani *et al*., 2016). The higher heritability values generally are the reflection of the closed value of respective phenotypic and genotypic variances and indicate that selection of this character is useful in improving plant type. Heritability by itself does not indicate the amount of genetic progress that would result from selecting the best individuals, rather it depends on the amount of genetic variance. Therefore, genetic advance and genetic advance over mean gain importance in providing an idea of the amount of progress that can be achieved by selection. Among the segregating populations, the F_2 generation is more vital for improving plant types because of its highly variable population structure. Heritability coupled with genetic advance would provide a clear-cut approach to the selection of desirable traits (Shet *et al*., 2012). Hence, the present study aims to estimate genetic variability parameters among the diverse cross of Indica rice varieties. Genetic parameters' effectiveness is determined by genetic parameters that include gene action, the number of genes controlling the trait, the magnitude of genetic variability, heritability, and genetic advance (Fisher *et al*.,1932).

Materials and Methods

The experimental study was carried out in the experimental plots of ICAR-Indian Institute of Rice Research, Rajendranagar, Hyderabad during *Rabi* 2021-22. Single seedlings per hill were maintained at a spacing of 20 × 15 cm and all cultural practices were followed as per the recommended package of practices. In F_2, a total of 257 plants were selected randomly and observations were recorded on plant height, number of productive tillers per plant, panicle length, panicle weight, number of filled grains per panicle, number of unfilled grains per panicle, 1000 grain weight and single plant yield. The phenotypic and genotypic coefficient of variation was computed by the method reported by Burton and De Vane (1953). Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were classified as suggested by Sivasubramanian and Menon (1973) that are, low (<10 %), moderate (10 - 20%) and high (>20 %). The heritability percentage was classified as low (0-30%), moderate (30–60%), and high (>60%) by Robinson *et al*. (1949). The genetic advance was computed by using the formula given by Robinson *et al*. (1949) and the genetic advance over the mean was calculated by the given formulas below.

Phenotypic variance

The individual observation made for each trait on the F2 population is used for calculating the phenotypic, genotypic, and environmental variance.

Phenotypic variance (σ^2p) = Var F_2

Where, Var F_2 = variance of F_2 population

Genotypic variance

Genotypic variance (σ^2g) = $\sigma^2p - \sigma^2e$

σ^2p = Phenotypic variance

σ^2e = Environmental variance

Environmental variance

The average variance of parents and their corresponding F1 is used as the environmental variance for single crosses.

Where,

σ^2p1 = Variance of parent P1

σ^2p2 = Variance of parent P2

σ^2F1 = Variance of cross F1

$$\text{Environmental variance } (\sigma^2e) = \frac{(\sigma^2p1) + (\sigma^2p2) + (\sigma^2F1)}{3}$$

The genetic advance as per cent mean was categorized as low up to 10 per cent, 10 to 20 per cent consider as moderate and more than 20 per cent noticed as high (Johnson *et al.,* 1955).

$$\text{Genetic advance over mean} = \frac{\text{Genetic Advance}}{\text{Mean}} \times 100$$

Broad-sense heritability ($h^2 b$) was calculated as

$$h^2b = V_G / V_P$$

Where V_G is genetic variance and V_P is phenotypic variance

Results and Discussion

Genetic variability is a prerequisite for any crop improvement program. The pedigree method of selection from F_2 onwards from the cross-between genetically diverse parents has been known to be one of the effective means of generating and maintaining genetic variability. The present study attempted to evaluate genetic variability, heritability, and GAM in the F_2 population derived from the cross of two popular indica rice varieties, Jaya, and an isogenic line of MTU1010. Statistical analysis revealed the presence of a considerable level of genetic variability for all the characters in this study (**Table 1**). Statistically, the range is a difference between the highest and lowest, breeders generally used to know the existing range of variability for interested traits in the working population. Single plant yield recorded the range from 21.06-84.6g, number of filled grains (116-320), number of unfilled grains (1-63), panicle weight (3.56-11.3g), 1000 grain weight (18-27.71g), panicle length (21-32cm), plant height (93.5-107cm) and number of productive tillers (5-30).

Table 1. Genetic variability parameters in F2 population of across Jaya × MTU1010 (IL)

Sl. No.	Traits	Mean	GCV (σ^2g)	PCV(σ^2p)	ECV (σ^2e)	Heritability (h^2)	GA	GAM
1	PH	108.52	5.42	6.04	0.62	80.41	10.87	10.02
2	NPT	15.42	32.76	33.14	0.38	97.7	10.3	66.8
3	PL	25.84	6.68	7.13	0.45	87.84	3.34	12.92
4	PW	5.71	20.2	20.67	0.47	95.51	2.33	40.72
5	TW	22.44	9.92	10.17	0.25	95.22	4.48	19.97
6	NFG	191.97	21.05	21.32	0.27	97.47	82.31	42.87
7	NUFG	16.96	52.28	56.87	4.59	84.52	16.82	99.16
8	SPY	43.09	29.45	29.76	0.31	97.93	25.91	60.11

PH- Plant Height; NPT- Number of Productive Tillers; PL- Panicle Length; PW- Panicle Weight; TW- Thousand Grain Weight; NFG- Number of Filled Grains; NUFG- Number of Unfilled Grains; SPY- Single Plant Yield; GCV- Genotypic coefficient of variation; ECV- Environment coefficient variance; PCV- phenotypic coefficient of variation; GAM- Genetic advance over mean; GA- Genetic advance

Of the 257 F_2 plants, 57 plants recorded higher yield than F_1 (44.4 g/plant), plant number F-103 recorded the highest 84.6 g (90.54% superior over F_1), followed by F-252 recorded 83.98 g (89.14 % more than F_1), F-67 recorded 81.1 g (82.65% more than F_1) and F-114 shown 70.7 g (59.23% greater than F_1). These results confirmed that genetic variation can be created through hybridization between diverse parents. There were many reports available on this aspect, the most related study by Savita and Usha (2015) reported the presence of a wide range for single plant yield (21.46-61.15g) in 200 F_2 population of a cross IR72 × Veeradangan.

The coefficients of variation expressed in percentage at phenotypic and genotypic levels (PCV and GCV) have been used to compare the variability observed among the different characters. The number of productive tillers (33.14), panicle weight (20.67), number of filled grains (21.32), number of unfilled grains (56.87), and single plant yield (29.76) recorded higher PCV (>20%), whereas 1000 grain weight (10.17) recorded moderate PCV (10-20%), but plant height (6.04) and panicle length (7.13) recorded low PCV (<10%). Similarly, for GCV, the number of productive tillers (32.76), panicle weight (20.2), number of filled grains (21.05), number of unfilled grains (52.28), and single plant yield (29.45) recorded higher GCV, whereas plant height (5.42), panicle length (6.68) and 1000 grain weight (9.92) shown less GCV. In the present investigation, the Phenotypic Coefficient of Variation (PCV) was greater than the Genotypic Coefficient of Variation (GCV) for all traits studied in the F2 population, representing the magnitude of environmental influence (**Table 1**). The narrow difference between the genotypic coefficient of variation and phenotypic coefficient of variation indicates that characters were less affected by the environment, and the comparison between GCV and PCV is depicted in **Figure 1**.

The number of productive tillers, panicle weight, number of filled grains, number of unfilled grains, and single plant yield recorded higher PCV and GCV which were in accordance with the results of Rani *et al*., (2016). Plant height and panicle length recorded low PCV and GCV, similar results were earlier reported by Sala *et al*., (2015) and Rani *et al*., (2016). Only one character *i.e.,* 1000 grain weight had recorded moderate PCV along with low GCV, and the observed result found similar to that reported by Dhanwani *et al*., (2013).

Heritability (h^2) is a ratio of genotypic to the phenotypic variance that indicates the effectiveness with which the selection of genotypes can be based on phenotypic performance. Heritability of different traits was classified as high (>60%), moderate (30-60%), and low (<30%) (Robinson *et al.,* 1949). High heritability was reported for all the traits in the present

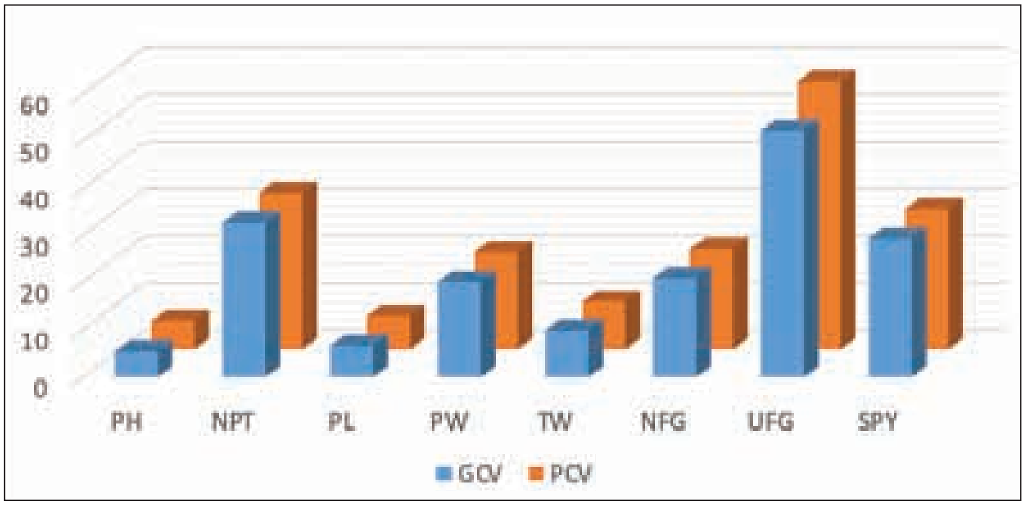


Figure 1: Comparison between PCV and GCV for yield and its component traits

study (**Table 1**). Similar results were reported by many researchers. The study by Seneega *et al.*, (2019) reported higher heritability for plant height, panicle length, panicle weight, number of productive tillers per plant, number of filled and unfilled grains per panicle, and single plant yield.

Heritability estimates along with genetic advance over mean will be more useful in predicting the outcome of selecting the best individuals. The high GAM (>20 %) was observed for different traits *viz.*, Number of productive tillers (66.8), panicle weight (40.72), number of filled grains (42.87), and single plant yield (60.11) Similar results were reported for the number of productive tillers per plant, number of filled grains per panicle, single plant yield by Seneega *et al.*, (2019) in F_2 population of the cross CO 52 × CR Dhan 310. Moderate GAM (10-20%) was observed for plant height (10.02), panicle length (12.92), and 1000 grain weight (19.97). Similar results were reported by many researchers, a more relevant study by Shet *et al.*, (2012) reported moderate GAM for plant height and 1000-grain weight. Comparison among heritability, genetic advance, and genetic advance over mean is depicted in **Figure 2**.

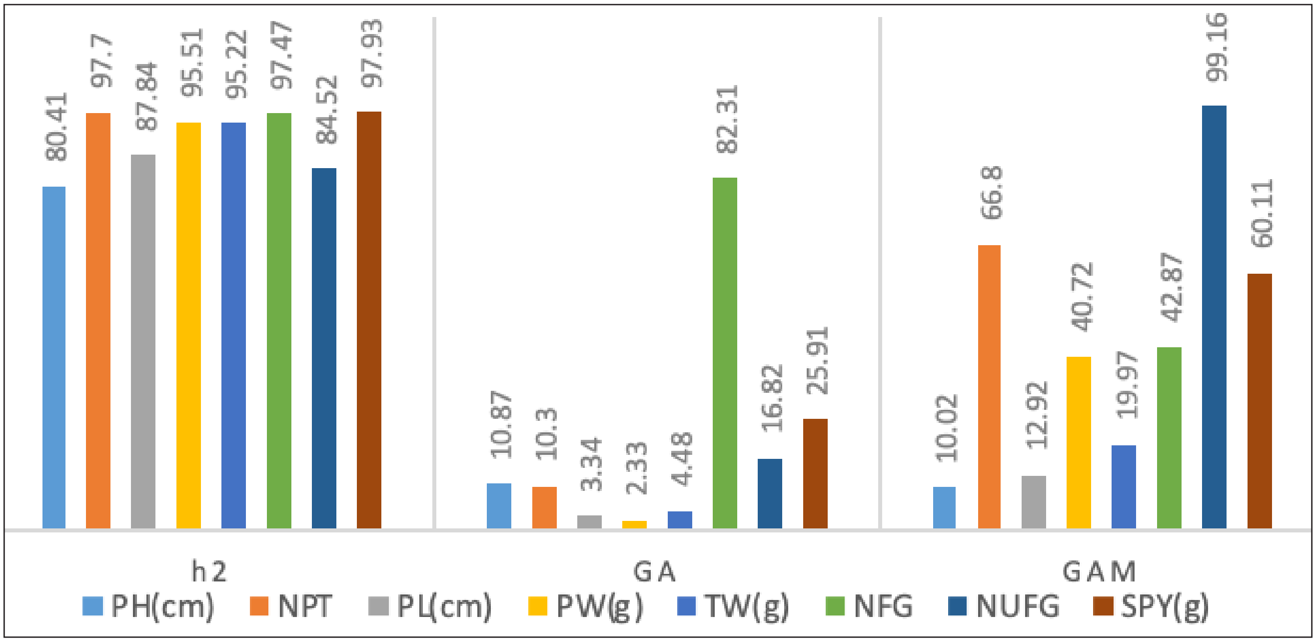


Figure 2: Comparison among heritability (h2), genetic advance (GA), and GAM for yield and its component traits

Conclusions

High heritability coupled with high genetic advance indicates the presence of additive gene effect and it inferred that simple selection may be effective for the improvement of these traits. In our study, higher heritability along with a high genetic advance over the mean observed for a number of productive tillers per plant, panicle weight, number of filled grains, and single plant yield. These results indicate high chances of recovery of transgressive segregants for yield and its related characters in the forwarded generations, hence selection for these traits leads to better results for selecting high-yielding lines among the forwarded generation from the cross Jaya × isogenic line of MTU1010.

Acknowledgments

The first author acknowledges the fellowship support received from ICAR-SRF during his Ph.D. study (2019-2022). The authors are thankful to the Director, ICAR-IIRR for providing research facilities. The authors acknowledge the support given by ICAR-Indian Institute of Rice Research, Hyderabad, and Mahatama Phule Krishi Vidyapeeth, Rahuri, Maharashtra.

Authors' contribution

The study was timely planned and analyzed by DGD, RAF; supervised by KPV, LVS, VPC, KSR, VLA and DGD, KCR, BK, SD, RPVS, and SB helped in the collection and interpretation of data; the manuscript was critically edited by RAF and KPV.

References

Burton GW and Devane EW. 1953. Estimating heritability in tall fescue (*Festuca arundinacea*) from replicated clonal material. *Agronomy Journal*, 45: 478- 481.

Dhanwani RK, Sarawgi AK, Solanki A and Tiwari JK. 2013. Genetic variability analysis for various yield attributing and quality traits in rice (*Oryza sativa L.*). *The Bioscan,* 8: 1403-1407.

Fiyaz RA, D Shivani, K Chaithanya, K Mounika, M Chiranjeevi, GS Laha, BC Viraktamath, LV Subba Rao, RM Sundaram. 2022. Genetic Improvement of Rice for Bacterial Blight Resistance: Present Status and Future Prospects. *Rice Science,* 9: 118-132.

Fisher RF, Immer and O Tedin. 1932. The Genetical Interpretation of Statistics of The Third Degree in The Study of Quantitative Inheritance. *Genetics,* 17: 107–124.

Johnson HW, Robinson HF, and Comstock RE. 1955. Estimation of genetic and environmental variability in soybean. *Agronomy Journal,* 47: 314-318.

Khush GS. 2005. What will it take to feed 5.0 billion rice consumers in 2030? *Plant Molecular Biology,* 59: 1–6.

Rani CS, Anandakumar CR, Raveendran M, Subramanian KS and Robin S. 2016. Genetic variability studies and multivariate analysis in F2 segregating populations involving medicinal rice (*Oryza sativa L.*) Cultivar Kavuni. *International Journal of Agricultural Sciences*, 8: 1733- 1735.

Robinson HF, Comstock RE and Harvey VH. 1949 Estimation of heritability and degree of dominance in corn. *Agronomy Journal,* 41: 353-359.

Sala M. 2012. Rice breeding for biofortification with high iron and zinc content in segregating populations. M.Sc. (Ag.) Thesis. TNAU, Madurai.

Savitha P and Kumari RU. 2016. Genetic variability studies in segregating generation for grain and nutritional quality traits in rice (*Oryza sativa L.*). *Journal of Applied and Natural Science*, 8: 63-68.

Seneega TA, Gnanamalar RP, Parameswari C, Vellaikumar S and Priyanka AR. 2019. Genetic variability and association studies in F2 generation of rice (*Oryza sativa* L.). *Electronic Journal of Plant Breeding*, 10: 512-517.

Shet RM, Rajanna MP, Ramesh S, Sheshshayee MS and Mahadevu P. 2012. Genetic variability, correlation, and path coefficient studies in F2 generation of aerobic rice (*Oryza sativa* L.). *Electronic Journal of Plant Breeding*, 3: 925- 931.

Sivasubramanian S and M Menon. 1973. Heterosis and Inbreeding Depression in Rice. *Madras Agricultural Journal*, 60: 1139–1144.

RESEARCH ARTICLE https://doi.org/10.58297/GISL2194

Enhancing Soil Health Through Microbial Inoculation and Changing Cultivation Methods in Rice-Wheat Cropping System

Amit Anil Shahane[1]* and Yashbir Singh Shivay[2]

[1]College of Agriculture (CAU, Imphal), Kyrdemkulai, Ri-Bhoi District, Meghalaya, India
[2]Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi, India
*Corresponding author Email: amitiari89@gmail.com

Received: 12th September 2022; Accepted: 20th October 2022

Abstract

India's rice-wheat cropping system (RWCS) is going through a paradigm shift to address resource degradation and sustainability issues. The increasing level of soil degradation has made soil biological health an important aspect of managing the problems of RWCS through understanding the role of microbes in enhancing soil health and by increasing the adoption of conservation agriculture-based practices. Our two-year study revealed that soil biological health, as measured by soil acetylene reductase activity (ARA), soil chlorophyll, microbial biomass carbon (MBC), soil dehydrogenase enzyme activity, and soil alkaline phosphatase activity (APA), was significantly impacted by the rice and wheat cultivation methods. The system of rice intensification (SRI) and zero tillage wheat (ZTW) system had significantly higher values for all the studied microbial parameters. The application of *Anabaena-Pseudomonas* biofilm formulation along with 75% recommended dose of nutrients (RDN) (90 kg N/ha and 19.35 kg phosphorus (P/ha) significantly improved all studied microbial parameters in both rice and wheat. The microbial properties such as dehydrogenase enzyme activity, alkaline phosphatase activity and microbial biomass carbon (MBC) had significantly higher values in treatment with RDN over 75% RDN indicating the role of optimal fertilization in soil biological health maintenance. A significant improvement in ARA and soil chlorophyll in inoculated treatment showed superior performance of inoculated microbes over inherent soil microbes in nitrogen fixation. The study of a combination of different rice and wheat cultivation methods and their influence in the long run on soil biological health in RWCS emphasizes the need for soil biological health maintenance considering its significant role in the system's sustainability.

Keywords: Cultivation methods, Nutrient management options, RWCS, Soil health

Introduction

The rice–wheat cropping system (RWCS), which is being followed on 10.2 million ha area, has played and is still playing a major role in food security of India. This cropping system is an outcome of the green revolution, which was initially based on three to four major pillars: crop improvement, use of chemical fertilizers, irrigation and agrochemicals for biotic stress management, including weeds. Due to the use of these purchased inputs in large areas for over 5-6 decades, RWCS has a higher contribution to total inputs and energy used in India. These technologies are associated with ill effects on soil health which arise due to the imbalanced use of chemical fertilizers, excessive dependence on agrochemicals and defective irrigation management strategies. Soil health is defined as an integrative property that reflects the capacity of soil to respond to agricultural intervention, so that it continues to support both agricultural production and the provision of other ecosystem services (Kibblewhite *et al*., 2008). Considering the three major groups of soil properties, soil health can also be defined in terms of soil physical, chemical and biological properties. The major problems related to soil chemical health in RWCS can be addressed through efficient nutrient management strategies like the use of secondary and micronutrients (sulphur zinc and iron), site-specific nutrient management and integrated nutrient management (SSNM and INM), accompanied by reduced use of agrochemicals and suggestions to use of biopesticides. In the case of soil physical health, alternative crop establishment methods, use of resource conservation technologies and following conservation agriculture principles can be useful.

The biological health is defined as the ability of soil to support large and diverse microbial communities, suppress pathogens and support healthy crop development (Brackin *et al*., 2017). The soil microbial population and diversity and conducive conditions of soil for the growth of microorganisms will decide the soil biological health. The soil microbial population and diversity are enhanced by periodic and need based inoculation with microorganisms having desirable characteristics such as nitrogen fixation, nutrient solubilisation, nutrient mobilization, and antagonism towards soil borne disease causing microorganisms. Considering this, an attempt was made to study the soil biological health as influenced by the addition of nitrogen-fixing and phosphorus solubilizing microbial consortia and by evaluating their performance under different cultivation methods. Soil acetylene reductase and alkaline phosphatase activity were measured to study the effect of inoculation on nitrogen fixation and phosphorus solubilisation, indicating the functional diversity of microbes. Dehydrogenase activity and microbial biomass carbon show changes in soil microbial population due to different crop establishment methods and microbial inoculation. Therefore, measuring these properties helps quantify soil biological health besides their role in crop growth improvement and nutrition.

Materials and Methods

The field experiment was conducted successively for two years at ICAR–Indian Agricultural Research Institute, New Delhi, India, located at a latitude of 28°38' N, longitude of 77°10' E and altitude of 228.6 m above mean sea level. The experiment was conducted in split plot design in rice–wheat cropping system involving two major factors: cultivation methods and rate and sources of crop nutrition as subplots. The three cultivation methods each of rice and wheat as the main plot, and nine combinations of nutrient sources and rates (chemical fertilizers, microbial inoculations and zinc fertilization) as subplots were studied in the present investigation (**Table 1**). For application of nutrient management treatments in rice for puddled transplanted rice (PTR) and SRI, phosphorus (P), potassium (K) and Zinc (Zn) were incorporated just before transplanting while broadcasting of N was

Table 1. **Treatment details**

Cultivation methods (Main plot treatments)
Puddled transplanted rice (PTR) followed by conventional drill-sown wheat (CDW)
System of rice intensification (SRI) followed by system of wheat intensification (SWI)
Aerobic rice system (ARS) followed by zero tillage wheat (ZTW)
Nutrient management options (Sub-plot treatments)
T1: Control (No nutrient application)
T2: Application of 120 kg N ha^{-1}, 25.8 kg P ha^{-1} (Recommended dose of nutrients (RDN)
T3: PDN + Zn (5 kg Zn ha^{-1} through ZnSO4.7H2O)
T4: 75% RDN
T5: 75% RDN + Zn
T6: *Anabaena sp.* (CR1) + *Providencia sp.* (PR3) + 75 % RDN
T7: *Anabaena sp.* (CR1) + *Providencia sp.* (PR3) + 75 % RDN + Zn
T8: *Anabaena-Pseudomonas* (An-Ps) biofilmed formulation+ 75 % RDN
T9: *Anabaena-Pseudomonas* (An-Ps) biofilmed formulation+ 75 % RDN + Zn

Zn**: Soil applied 5 kg Zn ha^{-1} through Zinc sulphate heptahydrate; Potassium was applied uniformly @ 49.8 kg K/ha in all plots (including control).

done in three equal splits at 5, 25 and 45 days after transplanting (DAT). In aerobic rice system (ARS), the whole quantity of P, K and Zn were applied as per the treatments during sowing by drilling below the seed. For N, 1/3rd N was applied at the time of sowing by drilling below the seed, and the remaining 2/3rd N was applied as top dressing (broadcasting) equally at 30 and 60 days after sowing (DAS). For wheat, 1/3rd N, the complete dose of P, K, and Zn were applied by drilling below the seed at the time of sowing in all cultivation methods while the remaining 2/3rd nitrogen was applied equally at 30 and 60 DAS. Zn was soil applied at the time of sowing/transplanting @ 5 kg Zn/ha through zinc sulphate heptahydrate ($ZnSO_4.7H_2O$) in each crop. Potassium was applied uniformly (49.8 kg K /ha/crop) in all plots (including control) before transplanting in rice and when sowing in wheat.

All treatments were replicated thrice, and rice variety '*Pusa Sugandh5*' and wheat variety '*HD2967*' were planted in the experiment. Two microbial cultures were used in the study *viz*., *Anabaena-Pseudomonas* (An-Ps) biofilmed formulation and *Anabaena sp.* (CR1) + *Providencia sp.* (PR3) consortia. For preparation of microbial inoculations, a mixture (1:1) of vermiculite (hydrous phyllosilicate mineral): compost (paddy straw compost with C/N 16.22 and humus 13.8% (pH 7.34) was used as carrier. The cyanobacterial, fungal, and bacterial colony forming units in the formulations were 10^4, 10^5, and 10^8 per gram of carrier, as reported by Prasanna *et al*. (2015) and Adak *et al*. (2016). A thick paste of inoculants was made in carboxyl methyl cellulose for inoculation. Rice seedlings were inoculated by dipping roots in a paste of respective culture for half an hour before transplanting in PTR and SRI. For ARS, pre-soaked seeds were treated with culture mixed in carboxyl methyl cellulose. In wheat, seeds were treated before sowing with thick paste of respective inoculations made in carboxyl methyl cellulose. The microbial inoculants were applied for their nitrogen fixation ability and phosphorus solubilization capacity.

Standard recommended management practices were followed for all cultivation methods. The data obtained were analyzed using F-test (Gomez and Gomez, 1984) and the least significant difference were used for comparing treatment means for their statistical difference. For the determination of soil microbial properties in rice, bulk soil samples were collected from each plot after 100 days in all three cultivation methods; while for wheat, bulk soil samples collected at 90 DAS were used for analysis. The soil microbial properties were analyzed following standard procedures (**Table 2**).

Table 2. Procedures for measurements of soil microbial properties

Soil microbial properties	**Procedure**	**References**
Nitrogenase enzyme activity	Acetylene reductase activity	Prasanna *et al.* (2003)
Soil chlorophyll	Chlorophyll extraction using organic solvents	Nayak *et al.* (2004)
Dehydrogenase activity	Triphenyl tetrazolium chloride incubation	Casida *et al.* (1964)
Microbial biomass carbon	Fumigation method	Nunan *et al.* (1998)
Alkaline phosphatase activity	p-nitrophenyl phosphate hydrolysis method	Tabatabai and Bremner (1969)

Results and Discussion

Acetylene reductase activity (ARA) and soil chlorophyll

The nitrogenase enzyme is responsible for biological nitrogen fixation and reduces nitrogen (N_2) from the atmosphere to ammonia (NH_3). This enzyme also reduces the acetylene to ethylene and this principle is used to determine the biological nitrogen fixation potential of cyanobacteria using gas chromatography and expressed as acetylene reductase activity (ARA) in unit of nmole ethylene/g soil/h. The ARA in rice and wheat was significantly affected due to cultivation methods as well as due to application of microbial inoculation (**Figure 1** and **Table 3**, respectively). In rice, the highest ARA activity was observed in SRI (7.99 nmole ethylene/g soil/h), which was significantly higher than PTR (7.71 nmole ethylene/g soil/h) and ARS (6.88 nmole ethylene/g soil/h). Among the nutrient management treatments, the highest ARA was recorded in 75% RDN + MI2 (11.20 nmole ethylene/g soil/h) which was significantly higher than 75% RDN + MI1 (10.18 nmole ethylene/g soil/h). This indicates the positive effect of inoculation on biological nitrogen fixation by improving population of inoculated microbes. In wheat, ZTW had the highest ARA, which was significantly higher than other methods. The ARA was significantly higher in all treatments with application of microbial inoculation, with the highest value in 75% RDN + MI2 + Zn in both years. The increase in ARA with microbial inoculation was 4.63 to 5.77 n mole ethylene/g soil/h in rice at 100 DAS and 2.60 to 2.91 n mole ethylene/g soil/h in wheat at 90 DAS.

The soil chlorophyll extracted with the help of organic solvent (Dimethyl sulphoxide and acetone) was measured as an indicator of the growth of applied cyanobacteria. The soil chlorophyll in rice (0.47 – 2.57 μg/g) was higher than wheat. The soil chlorophyll in SRI and PTR was significantly higher than ARS which might be due to saturated condition of soil in both methods. In wheat, ZTW recorded the highest soil chlorophyll content, which was significantly superior over CDW and SWI. Among the nutrient management treatments, the trend remained the same as that of ARA, with the highest value in 75% RDN + MI2. This variation in soil ARA and soil chlorophyll across the crop establishment methods and nutrient rates indicate the impact of change in soil microclimate on soil microbial properties and suggest their role as indicators of soil biological health (Prasanna *et al.*, 2015, and Adak *et al.*, 2016); while improvement in both properties with application of inoculations (treatment T6 to T9) indicates their role in enhancing soil biological health (Shivay *et al.*, 2022).

Dehydrogenase activity, microbial biomass carbon (BMC) and alkaline phosphatase activity

The dehydrogenase activity was significantly increased due to microbial inoculation and applying chemical fertilizers (**Table 3** and **Figure 1**). The increase in

Table 3. Effect of microbial inoculations in combination with chemical fertilizer on soil microbial parameters in different cultivation methods of wheat at 90 days after sowing (data pooled over two years)

Treatment	Acetylene reductase activity (ARA) (n mole ethylene g/soil/h)	Soil Chlorophyll (μg/g)	Dehydrogenase activity [μg triphenyl formazan (TPF)/g soil/h)	Microbial biomass carbon (mg/kg)	Alkaline phosphatase activity (APA) (μg PNP/g soil/h)
Cultivation methods					
CDW	4.04	1.56	43.2	337.8	76.9
SWI	4.06	1.59	43.4	338.8	79.1
ZTW	4.36	1.76	46.2	342.7	82.1
SEm±	0.03	0.02	0.40	0.54	0.37
CD (*P* = 0.05)	0.14	0.10	1.57	2.11	1.44
Nutrient management options					
Control (no fertilizer application)	1.20	0.24	20.2	183.7	25.9
RDN*	3.15	1.38	44.4	349.3	81.9
RDN + Zn**	3.20	1.39	45.1	350.2	82.6
75% RDN	3.13	1.35	44.1	347.8	80.8
75% RDN + Zn	3.15	1.37	44.2	348.5	81.0
75% RDN + MI1	5.73	2.16	48.9	367.1	88.0
75% RDN + MI1 + Zn	5.77	2.18	49.0	367.8	89.0
75% RDN + MI2	6.00	2.31	50.8	371.2	92.2
75% RDN + MI2 + Zn	6.06	2.31	51.4	372.0	92.6
SEm±	**0.08**	**0.06**	**0.67**	**1.12**	**0.87**
CD (*P* = 0.05)	**0.21**	**0.17**	**1.90**	**3.18**	**2.47**

CDW, Conventional drill-sown wheat; SWI, System of wheat intensification; ZTW, Zero tillage wheat; RDN*, Recommended dose of nutrients (120 kg N/ha and 25.8 kg P/ha); Zn**, Soil applied 5 kg Zn/ha through zinc sulphate heptahydrate; MI1: *Anabaena sp.* (CR1) + *Providencia sp* (PR3); MI2: *Anabaena-Pseudomonas* biofilmed formulation).

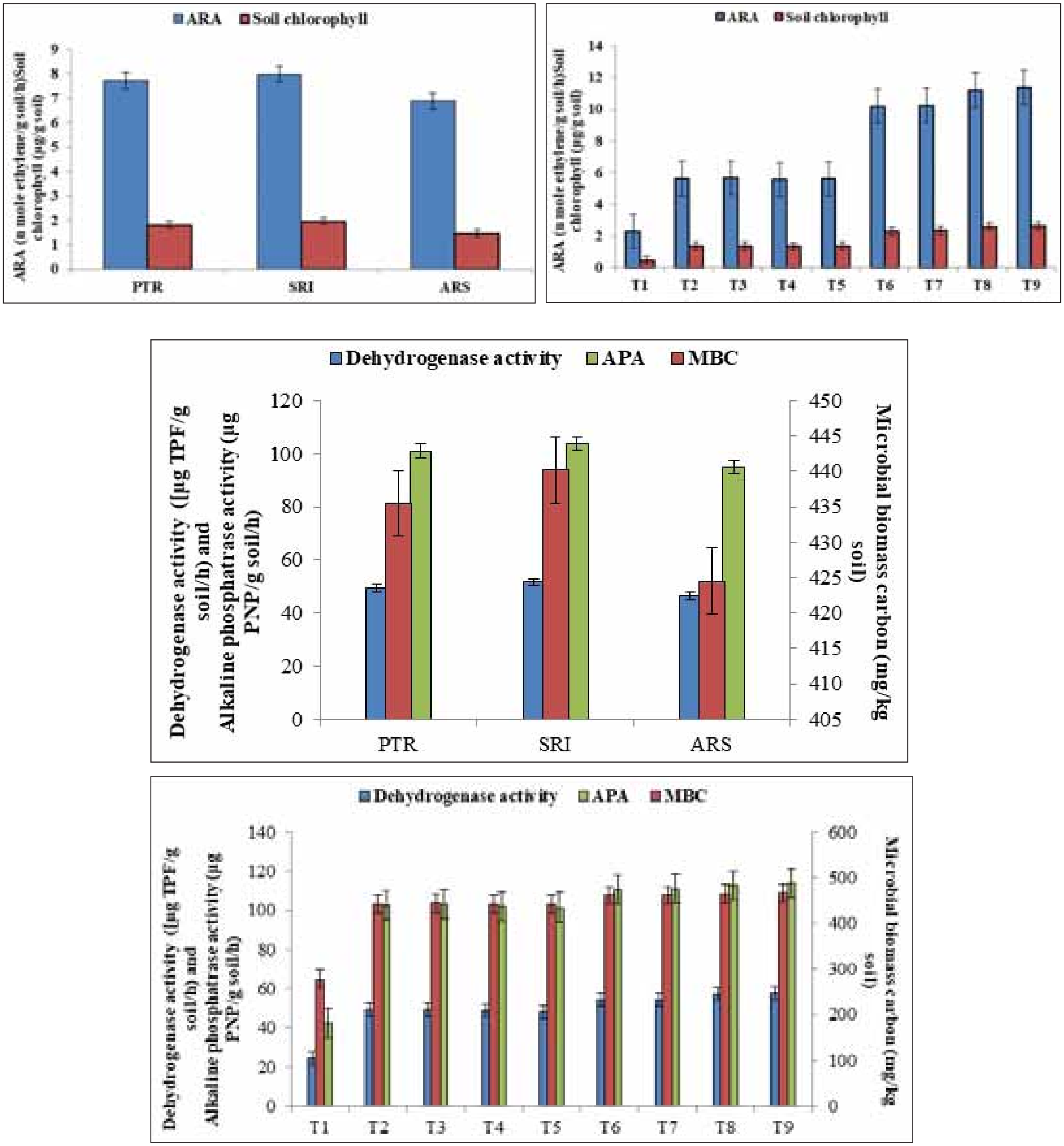


Figure 1: Effect of crop cultivation methods and nutrient management on soil microbial properties in rice field (soil) at 100 days after sowing (Data pooled over two years)

T1: Control (no fertilizer application), T2: RDN*, T3: RDN + Zn**, T4: 75% RDN, T5: 75% RDN + Zn, T6: 75% RDN + MI1, T7: 75% RDN + MI1 + Zn, T8: 75% RDN + MI2 and T9: 75% RDN + MI2 + Zn; PTR: Puddled transplanted rice; SRI: system of rice intensification; ARS: Aerobic rice system; RDN*, Recommended dose of nutrients (120 kg N/ha and 25.8 kg P/ha); Zn**, Soil applied 5 kg Zn/ha through zinc sulphate heptahydrate; MI1: *Anabaena sp.* (CR1) + *Providencia sp* (PR3); MI2: *Anabaena-Pseudomonas* biofilmed formulation enzyme activity over control due to the application of RDN was 24.6 µg triphenylformazan (TPF)/g soil/h in rice at 100 DAS, and in wheat, the increase was 24.2 µg TPF/g/soil/h at 90 DAS over control. Microbial inoculation increased the dehydrogenase activity over RDN and control by 5.1–8.7 and 29.8–33.3µg TPF/g soil/h respectively in rice, while in wheat, the increase was 4.5–7 and 28.7–31.2µg TPF/g/h, respectively. Among cultivation methods, SRI was found significantly superior to both PTR and ARS; while in wheat, ZTW was significant. This signifies that microbial inoculations and optimal dose of chemical fertilizers had a significant and positive effect on enhancing soil microbial activities (Mader *et al*., 2011; Nath *et al*., 2011). At the same time, increased dehydrogenase activity in non-inoculated treatment indicates the role of inherent soil microbial population in maintaining biologically active soil.

The microbial biomass carbon (MBC) is the most sensitive fraction of the total soil organic carbon to change in management practices and input addition and has a high turnover rate. Considering its sensitivity, MBC is one of the important soil property used in soil quality analysis (Onwosi *et al*., 2020). Hence its measurement as affected by a change in crop cultivation methods and input addition in different crops is important for evaluating the impact of crop cultivation on soil health. The MBC varies between 278–466.3 mg/kg soil at 100 DAS in rice, while in wheat, it varied between 183.7–372.0 mg/kg soil (**Table 3** and **Figure 1**). In our study, the order of significance of applied treatment in affecting MBC was nutrient application (RDN)>microbial inoculations>cultivation methods >Zn fertilization in both rice and wheat. This order indicates that both inherent soil microbial populations triggered by fertilization and inoculated microbes have a major role in increasing MBC. Therefore fertilization and application of microbial inoculation improve soil biological health besides their impacts on crop growth and yield (Zhang *et al*., 2022). The alkaline phosphatase activity (APA), an indicator of P solubilization capacity of microbes, was found to be significantly higher in SRI in rice and ZTW in wheat, indicating their superiority in enhancing soil microbial health (Swarnalakshmi *et al*., 2013). Microbial inoculation increased the APA by 8.6–11.0 µg PNP/g soil/h in rice and 7.2–11.4 µg PNP/g soil/h in wheat. The interaction effect was found significant for all the five soil microbial properties studied, which indicates the sensitivity of selected parameters to changes in soil, water and plant management (Prasanna *et al.*, 2015; Adak *et al*., 2016).

Our study concluded that SRI system of cultivation in rice and ZTW in wheat had a positive and significantly better impact on soil biological health. The use of *Anabaena-Pseudomonas* biofilmed formulation showed promise in improving all the studied soil biological parameters thereby contributing to soil biological health improvement.

References

Adak A, Prasanna R, Babu S, Bidyarani N, Verma S, Pal M, Shivay Y S and Nain L. 2016. Micronutrient enrichment mediated by plant-microbe interactions and rice cultivation practices. *Journal of Plant Nutrition*, 39: 1216–1232.

Brackin R, Schmidt S, Walter D, Bhuiyan S, Buckley S and Anderson J. 2017. Soil biological health—What is it and how can we improve it? *Proceeding of Australian Society of Sugarcane Technologist,* 39: 141–154.

Casida L E J, Klein D A and Santaro T. 1964. Soil dehydrogenase activity. *Soil Science*, 98: 371–376.

Gomez KA, Gomez AA. 1984. Statistical procedures for agricultural research. An international rice research institute book, 2nd edn. Wiley, New York

Kibblewhite M G, Ritz K and Swift M J. 2008. Soil health in agricultural system. *Philosophical Transactions of Royal Society* B, 363: 685–701.

Mader P, Kaiser F, Adholeya A, Singh R, Uppal H S, Sharma A K, Srivastava R, Sahai V, Aragno M, Wiemken A and Johri B N. 2011. Inoculation of root microorganisms for sustainable wheat–rice and wheat–black gram rotations in India. *Soil Biology and Biochemistry*, 43: 609–619.

Nath D J, Ozah B, Baruah R, Barooah R C and Borah D K. 2011. Effect of integrated nutrient management on soil enzymes, microbial biomass carbon and bacterial populations under rice (*Oryza sativa*)-wheat (*Triticum aestivum*) sequence. *Indian Journal of Agricultural Sciences*, 81:1143–1148.

Nayak S, Prasanna R, Pabby A, Dominic T K and Singh P K. 2004. Effect of urea and BGA-Azolla bio-fertilizers on nitrogen fixation and chlorophyll accumulation in soil cores from rice fields. *Biology and Fertility of Soils*, 40: 67–72.

Nunan N, Morgan M A and Herlihy M. 1998. Ultraviolet absorbance (280 nm) of compounds released from soil during chloroform fumigation as an estimate of the microbial biomass. *Soil Biology and Biochemistry*, 30: 1599–1603.

Onwosi C O, Odimba J N, Igbokwe V C, Nduka F O, Nwagu T N, Aneke C J and Eke I E. 2019. Principal component analysis reveals microbial biomass carbon as an effective bioindicator of health status of petroleum-polluted agricultural soil. *Environmental Technology*, 41: 3178– 3190.

Prasanna R, Adak A, Verma S, Bidyarani N, Babu S, Pal M, Shivay Y S and Nain L. 2015. Cyanobacteria inoculation in rice grown under flooded and SRI modes of cultivation elicits differential effects on pant grown and nutrient dynamics. *Ecological Engineering*, 84: 532–541.

Prasanna R, Tripathi U, Dominic T K, Singh A K, Yadav A K and Singh P K. 2003. An improvised technique for measurement of nitrogen fixation by Blue-Green Algae and Azolla using intact soil cores. *Experimental Agriculture*, 39:145–150.

Shivay Y S, Prasanna R, Mandi S, Kanchan A, Kaur S, Nayak S, Baral K, Sirohi M P and Nain L. 2022. Cyanobacterial inoculation enhances nutrient use efficiency and grain quality of basmati rice in the system of rice intensification. *ACS Agricultural Science and Technology*, 2: 742–453

Swarnalakshmi K, Prasanna R, Kumar A, Pattnaik S, Chakravarty K, Shivay Y S, Singh R and Saxena A K. 2013. Evaluating the influence of novel cyanobacterial biofilmed biofertilizers on soil fertility and plant nutrition in wheat. *European Journal of Soil Biology*, 55: 118–126.

Tabatabia M A and Bremner J M. 1969. Use of p-Nitrophenyl phosphate for assay of soil phosphatese activity. *Soil Biology and Biochemistry*, 1: 301–307.

Zhang C, Zhao Z, Li F and Zhang J. 2022. Effects of Organic and Inorganic Fertilization on Soil Organic Carbon and Enzymatic Activities. *Agronomy*, 12: 3125; https://doi.org/10.3390/agronomy12123125.

RESEARCH ARTICLE https://doi.org/10.58297/YTGE7776

Comparison of Rice Cultivars (*Oryza sativa.* L.) under SRI and Normal Transplanting Method for Resource Conservation and Productivity Enhancement in Irrigated System

Srinivas D[1]*, Mahender Kumar R[1], Sreedevi B[1], Mangal Deep Tuti[1], Aarti Singh[1], Soumya Saha[1], Sudhakara TM[1], Thirupathi I[2], Sandhyarani A[1], Vijaya Kumar S[1], Arun MN[1] and Venkatanna B[1]

[1]*ICAR-Indian Institute of Rice Research, Hyderabad, Telangana, India – 500030.*
[2]*KVK-Bellampalli, PJTSAU.*
*****Corresponding author Email: *seenu290@gmail.com*

Received: 1st December 2022; Accepted: 22nd December 2022

Abstract

An experiment was conducted at the Indian Institute of Rice Research (IIRR) farm, ICRISAT for three consecutive *kharif* and *rabi* seasons from 2016 to 2018 to evaluate varieties under System of Rice Intensification (SRI) and Normal Transplanting (NTP) method. A total of 46 cultivars including hybrids (10), High yielding varieties (HYVs) (28) and elite cultures (8) were tested. Data pooled over years and seasons indicated that SRI was significantly superior in terms of number of tillers, number of panicles per square meter, days for 50% flowering and grain yield with low inputs *viz*; energy, man power and irrigation. Hybrids, HYVs and elite culture recorded a grain yield of 6.54 t/ha, 5.65 t/ha and 5.50 t/ha under SRI as compared to 5.13, 4.59 and 4.58 t/ha, respectively under NTP, thereby indicating that SRI excelled NTP in grain yield. Pooled data of six seasons, three years among the cultivars indicated that SRI recorded higher grain yield (5.90 t/ha) over NTP (4.77 t/ha) with mean percent grain yield increase of 23.4%. Intensification method was also promising over conventional transplanting in terms of energy use efficiency (SRI 10.17% over NTP 6.20%) and economy parameters (B:C ratio 2.0 in SRI and 1.20 in NTP). Water productivity was higher in SRI (7.08 kg/mm/ha) than NTP (3.93 kg/mm/ha).

Keywords: System of Rice Intensification (SRI), Normal Transplanting (NTP), Water saving, Water productivity.

Introduction

Rice is the most important staple food crop in the world. More than 50% of world population's daily energy requirement is fulfilled by rice and its derived products. System of Rice Intensification (SRI) is a set of ideas that comprises the use of younger seedlings, planting of single seedling with wider spacing, adopting intermittent irrigation, weeding by conoweeder during crop growth for four times during vegetative growth of crop which facilitates for aerobic conditions at rhizosphere zone of plants and use of organic fertilizers (Stoop *et al*., 2002; Uphoff, 2007). According to FAO report (FAOSTAT, 2020), global rice requirement by 2025 will be 800 mt. At current pace of growth, it will be less than 600 mt and hence, there will be deficit of 200 mt, which has to be produced by increasing productivity per unit area against the diminishing resources. Under these circumstances, SRI holds promise to save water and environment with less emissions of greenhouse gases (GHG). System of Rice Intensification (SRI) is best understood as an agronomic practice for small and marginal farmers to sustain with available resources such as organic fertilizers, water and man power. This has been found to be productive, resource conserving and environmentally benign in most of the countries when compared to normal transplanting method (Namara *et al*., 2008; Sato and Uphoff 2007; Sinha and Talati, 2007). In this context, the present experiment was conducted for three consecutive years (six seasons) to compare rice cultivars under SRI and NTP method for higher yield and resource conservation.

Methodology

A total of 46 cultivars including hybrids, high-yielding varieties and elite cultures were evaluated under SRI in comparison with NTP during three k*harif* and *rabi* seasons at the Indian Institute of Rice Research farm located in ICRISAT, Hyderabad (**Table 1**). The soils were sandy loam with pH 7.6, E.C. 0.26, organic carbon of 0.49% and with available N:P: K of 225: 42.5:323 kg ha^{-1}. The experimental design was a split plot with establishment methods (SRI and NTP) as main plots and cultivars as subplots with three replications and with a plot size of 6.0m x 1.8m. The recommended dose of fertilizer was 120:60:40 of N: P: K kgha^{-1}was applied, P and K as basal and N applied in splits of 50%, 25% & 25% as basal, at maximum tillering and panicle initiation, respectively. Twenty-five per cent of N was applied from an organic source (Vermicompost @ six tonnes per hectare) in the SRI method. Manual weeding was performed for NTP whereas in SRI conoweeder used in SRI method three to four times with a time interval of one week, from 12 days after transplanting to the maximum tillering stage. Alternate wetting and drying method was followed for irrigation in the SRI method up to the panicle initiation stage whereas in NTP saturation condition was maintained thorough out the crop period (**Table 2**). Total irrigation was 834 mmha^{-1} for the SRI method and 1218 mmha^{-1} for the NTP method. Water productivity was calculated by taking into account irrigation water supplied and the contribution from rainwater. The total yield is divided by the total water applied. Water productivity was expressed in kg ha mm^{-1}. (Water productivity = Grain yield (kg ha^{-1})/ total irrigation (Irrigation + effective rainfall) (mm).

Table 1. List of germplasm evaluated

Hybrids	High yielding varieties			Elite cultures
PA-6129	Shanti	Phalguna	Aditya	Improved-Chitti muthyalu
PA-6201	Dhanarasi	Jaya	Ravi	Vasumati
PA-6444	RP Bio-226	Rasi	Ajaya	Sugandamati
KRH-2	Akshayadhan	Swarna-Dhan	Nidhi	Kasturi
DRRH-3	Varadhan	Vikas	Triguna	PB1121
DRRH-2	Sampda	Sonasali	Krishna Hamsa	Taroari Basmati
US 305	Dhan - 38	Vikramarya	MTU1010	
US 312	Dhan - 39	Prasanna	RNR15048	
US 314	Mandhya vijaya	Suraksha	Swarna	
US 382	Sasyasree	Tulasi	BPT 5204	

Table 2. Details of the methods of cultivation under SRI and NTP

S.No.	Practice	SRI method	Normal Transplanting
1	Nursery	Raised bed nursery	Flat bed nursery
2	Seedling age for transplanting	8-12 days	25-30 days
3	Seedlings	Single seedling was planted	Average of three seedlings were planted
4	Spacing	25 x 25 cm wider spacing	20 x 15 cm spacing
5	Weeding	4 weeding by cono weeder 12 DAT with one week to 10 days interval	Hand and manual weeding at 20 and 35 DAT
6	Water management	Alternate wetting and drying irrigation from 12 DAT to panicle initiation stage	Saturation through the crop
7	Fertilizers	Use of organic manure- vermi compost/ FYM upto 25% of Recommended Dose of Fertilizer (RDF)	100% RDF as inorganic

Growth parameters *viz*; plant height, number of tillers were recorded at 30, 60, and 90 DAT. Yield attributes- panicle number, panicle length, panicle weight, test weight; physiological data – SPAD and days for 50% flowering and irrigation data were recorded. Plants in the net plot area were harvested, separately in each plot, threshed and grains were dried under the sun before recording the grain yield per plot. The yield was standardised at 13% moisture. From this, yield per plot was computed and expressed as t ha-1.

The data obtained on the different growth and yield parameters and yield was analysed statistically by the method of analysis of variance as per the procedure outlined for split-split plot design given by Gomez and Gomez (1984). Statistical significance was tested by F value at 0.05 level of probability and the critical difference was worked out where ever the effects were significant.

Results and discussion

SRI method of cultivation is significantly promising over NTP in terms of yield attributes in the *kharif* and *rabi* seasons of three years. SRI recorded significantly higher number of tillers and panicles per square meter in all seasons and years among hybrids, HYVs and elite cultures (**Table 3**). Pooled data of three years indicated that day to 50% flowering was 97 days for SRI and 108 days for NTP. This can be ascribed to the fact that transplanting younger seedlings without disturbing the rhizosphere soil of the seedling might have supported fast establishment in the field, which in turn resulted in the reduction of days for crop maturity (**Figure 1**).

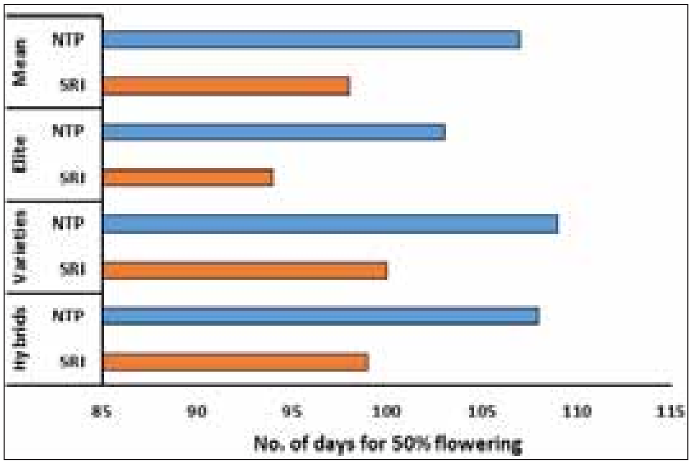


Figure 1. Days for 50% flowering as influenced by SRI vs NTP

Table 3. Effect of SRI method on yield attributes

Number of Tillers/m2												
Method	**Hybrids**				**High Yielding Varieties**				**Elite cultures**			
	2016	**2017**	**2018**	**Mean**	**2016**	**2017**	**2018**	**Mean**	**2016**	**2017**	**2018**	**Mean**
SRI	368	408	507	**428**	365	407	500	**424**	350	394	541	**428**
NTP	320	341	383	**348**	319	320	360	**333**	363	317	386	**355**
CD(0.05)	23.96	14.58	32.95		41.16	5.35	16.03		NS	18.42	67.45	
CV(%)	5.25	3.5	5.97		11.88	2.26	4.25		5.86	3.9	9.26	
Number of Panicles/m2												
Method	**Hybrids**				**High Yielding Varieties**				**Elite cultures**			
	2016	**2017**	**2018**	**Mean**	**2016**	**2017**	**2018**	**Mean**	**2016**	**2017**	**2018**	**Mean**
SRI	364	388	462	**405**	346	383	455	**394**	331	371	490	**397**
NTP	299	311	353	**321**	274	292	331	**299**	277	287	356	**307**
CD(0.05)	33.46	11.59	65.23		24.1	6.71	32.5		21.73	8.78	45.66	
CV(%)	7.6	2.99	12.88		7.67	3.05	9.41		3.52	2.01	6.87	

Panicle length (cm)

Method	Hybrids				High Yielding Varieties				Elite cultures			
	2016	2017	2018	Mean	2016	2017	2018	Mean	2016	2017	2018	Mean
SRI	24.71	24.32	23.90	**24.31**	25.41	24.32	23.23	**24.32**	27.06	24.45	24.04	**25.18**
NTP	23.01	22.37	22.75	**22.71**	23.09	22.39	21.77	**22.42**	24.47	22.07	22.60	**23.05**
CD(0.05)	0.94	1.07	0.40		1.52	0.88	0.79		NS	0.41	NS	
CV(%)	2.98	4.13	1.38		6.16	5.81	4.00		5.40	1.34	4.94	

Panicle weight (g)

Method	Hybrids				High Yielding Varieties				Elite cultures			
	2016	2017	2018	Mean	2016	2017	2018	Mean	2016	2017	2018	Mean
SRI	4.84	4.79	4.00	**4.54**	3.74	4.04	3.18	**3.65**	3.90	4.10	2.57	**3.52**
NTP	4.2	3.70	3.80	**3.90**	3.52	3.33	3.10	**3.32**	3.62	3.37	2.46	**3.15**
CD(0.05)	0.41	0.26	NS		NS	0.26	0.08		0.09	0.57	NS	
CV(%)	6.79	5.56	6.09		8.65	10.77	2.72		1.12	11.56	5.07	

Test weight (g)

Method	Hybrids				High Yielding Varieties				Elite cultures			
	2016	2017	2018	Mean	2016	2017	2018	Mean	2016	2017	2018	Mean
SRI	21.22	21.28	21.31	**21.27**	20.71	22.22	18.99	**20.64**	20.09	20.18	22.75	**21.01**
NTP	19.66	19.78	20.18	**19.87**	20.53	20.14	18.20	**19.62**	16.34	18.47	22.26	**19.02**
CD(0.05)	0.3	NS	1.06		NS	0.66	NS		1.59	NS	NS	
CV(%)	1.09	11.45	4.11		9.55	4.75	9.5		4.29	9.11	7.23	

The SRI method was promising over NTP with higher yield parameters and yield with decreased days to 50% flowering and inputs **(Table 4)**. Hybrids due to their heterotic potential *viz*; KRH2, DRRH3, PA6129, PA6444 & US312 were found promising with higher grain yield (6.25 to 6.90 t/ha) under SRI and also excelled NTP by a margin of 19.37% to 34.5% along with reduced water application. Srinivas *et al*., (2017) observed that system of rice intensification method with alternate wetting and drying irrigation could be adopted for hybrid rice cultivation for those areas with fewer irrigation facilities. Among varieties, the per cent grain yield increase was to the tune of 17.2% to 31.9% and the promising varieties identified was RP Bio 226, Akshayadhan, Vardhan, Sampada, IR 64 and Krishnahamsa, which matured early and reduced seed rate and water requirements to a greater extent (80% in seed and 30% in water input) with SRI method of cultivation. Among the elite varieties, the per cent grain increase found in SRI over NTP ranged from 8.98% to 32.97% and promising elite cultures were Chittimuthyalu, Kasturi and Taroari basmati in terms of grain yield. It indicated that the elite and scented could be grown with the SRI method to enhance the productivity and profitability of these cultivars. Mean over the three years, the grain yield was significantly higher in SRI method over NTP (Hybrids: 6.54 t/ha; HYV; 5.65 t/ha and Elite; 5.50 t/ha) and the per cent grain yield increase was found to be higher in SRI over NTP i.e., 27.40% for hybrids, 22.93% for varieties and 20.0% for elite cultures **(Figure 2)**. Rice intensification and transplanting procedures were found to be more efficient in minimizing weed infestation and nitrogen removal by weeds, resulting in improved yield characteristics and yield (Singh *et al*., 2021). Kumar *et al*., (2021) observed that all growth and yield parameters were highest in the SRI. SRI practices create conditions for beneficial soil for microbes to prosper, saving irrigation water, and increasing grain yield (Subramanian *et.al*, 2013). The pooled data over the seasons and years indicates that the SRI method with less cost of cultivation (Rs.35555) and less energy input (14963 MJ/ha) recorded higher energy output (173.7 GJ/ha over NTP 141.7GJ/ha), Energy productivity (0.9 kg grain/MJ energy over NTP 0.6 kg grain/MJ), energy intensity MJ/Rs. (SRI 5.2: NTP 3.1) and B: C Ratio (SRI 2.0 vs NTP 1.21) (**Table 5**).

Table 4. Grain yield of Hybrid, HYVs and Elite cultures as influenced by SRI over NTP

Cultures/Method		Pooled Grain Yield (t/ha)			Mean Grain Yield (t/ha)
		2016	2017	2018	
Hybrids	**SRI**	6.25	6.90	6.47	6.54
	NTP	4.85	5.13	5.42	5.13
	CD(0.05)	0.2	0.12	0.29	
	CV(%)	2.78	1.74	3.99	
Varieties	**SRI**	5.11	6.04	5.79	5.65
	NTP	4.29	4.58	4.91	4.59
	CD(0.05)	0.15	0.21	0.27	
	CV(%)	3.24	6.13	5.78	
Elite	**SRI**	4.75	6.17	5.58	5.50
	NTP	3.99	4.64	5.12	4.58
	CD(0.05)	0.28	0.24	0.20	
	CV(%)	3.16	3.41	2.39	

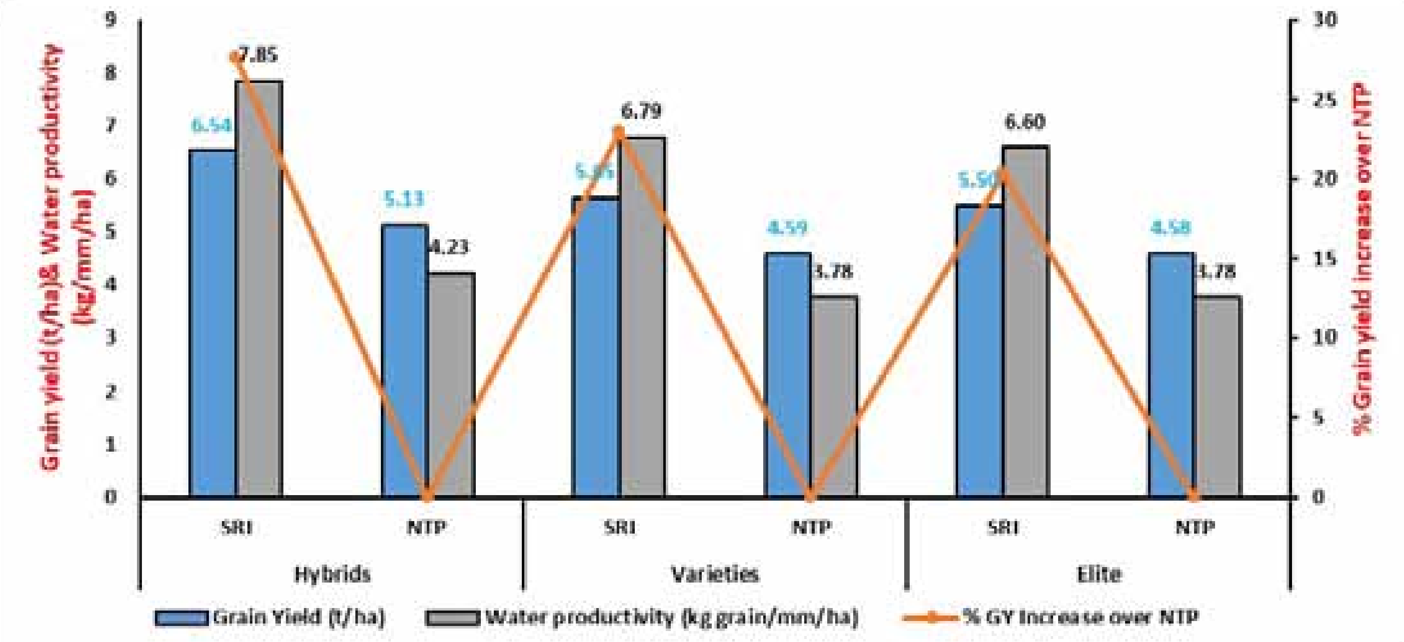


Figure 2: Grain Yield, and Water productivity in SRI method over NTP

Table 5. Energy and Economics as influenced by SRI vs NTP method

Method	Cost of cultivation (Rs/ha)	Energy Input (MJ/ha)	Total Energy Output (GJ/ha)	Net Energy (GJ/ha)	Energy Productivity (kg/MJ)	Energy intensity (MJ/Rs)	Energy use efficiency (%)	Gross returns (Rs/ha)	Net returns (Rs/ha)	Benefit: Cost ratio
SRI	35555	14963.0	173.7	158.7	0.9	5.2	10.6	101709	68154	2.0
NTP	45231	18451.0	141.7	123.2	0.6	3.1	6.7	79696	34101	1.21

It was observed that the paddy crop utilises up to 5000 litres of water per one-kilogram grain production in the conventional method whereas as SRI method of practice requires up to 3000 litres of water. Significant differences were observed between the varieties under SRI vs NTP (Kumar *et al*., 2017). The water productivity (kg grain produced per mm water applied) was significantly superior in SRI (7.08 kg/mm/ha) method over NTP (3.93 kg/mm/ha) in all the seasons for Hybrids, High yielding varieties and Elite and scented cultivars. Across the years, the water productivity ranged from 3.16 to 8.18 kg/mm/ha **(Table 6)** Irrespective of cultivars, SRI method saved 32% of water input **(Figure 3)** over NTP with increased output energy and 24% higher grain yield, with reduced manpower & input energy. The system of rice intensification improved the yield of crops and water productivity (Deelstra *et al*., 2018). Similar results of saving about 40% of irrigation water and increasing land productivity by about 46% while reducing the cost of cultivation by 23% over the conventional inundation method was reported by Naranayamoorthy and Jothi (2019). The percentage of water saved was 33.57% in 2016, 29.10% in 2017 and 31.84% in 2018 over NTP method. Further, most of the cultivars were found promising and recorded higher grain yields with SRI method with reduced resources (seed, water & labour). Hybrid cultivars *viz*; KRH2, DRRH3, PA6129, PA6444 & US312 were found promising with higher grain yield. Among varieties, the per cent grain increase found in SRI over NTP was to the tune of 17.2% to 31.9% and the promising varieties identified were RP Bio 226, Akshayadhan, Vardhan, Sampada, IR 64 & Krishnahamsa, which matured early and reduced seed rate and water requirements to a greater extent (80% in seed and 30% in water input. Among the elite varieties, the per cent grain increase in SRI over NTP ranged from 8.98% to 32.97% and the identified promising elite cultures were Chittimuthyalu, Kasturi and Taroari basmati in terms of grain yield. It indicated that the elite and scented could be grown with the SRI method to enhance the productivity of these cultivars. Local and elite cultures' yield could also be increased with the adoption of the SRI method. By adopting the SRI technique, the farmer can save the existing land from deterioration by reducing the use of chemical fertilizers and getting the highest yields.

Table 6. Water productivity (kg grain/mm/ha)

Cultures		Water productivity (kg grain/mm/ha)			Mean
		2016	**2017**	**2018**	
Hybrids	**SRI**	7.45	8.18	7.91	7.85
	NTP	3.84	4.32	4.52	4.23
	CD(0.05)	0.22	0.17	0.31	
	CV(%)	2.94	2.48	4.01	
Varieties	**SRI**	6.1	7.17	7.09	6.79
	NTP	3.4	3.85	4.09	3.78
	CD(0.05)	0.16	0.24	0.29	
	CV(%)	3.35	6.76	5.93	
Elite	**SRI**	5.66	7.32	6.82	6.60
	NTP	3.16	3.9	4.27	3.78
	CD(0.05)	0.21	0.21	0.16	
	CV(%)	2.33	2.84	1.78	

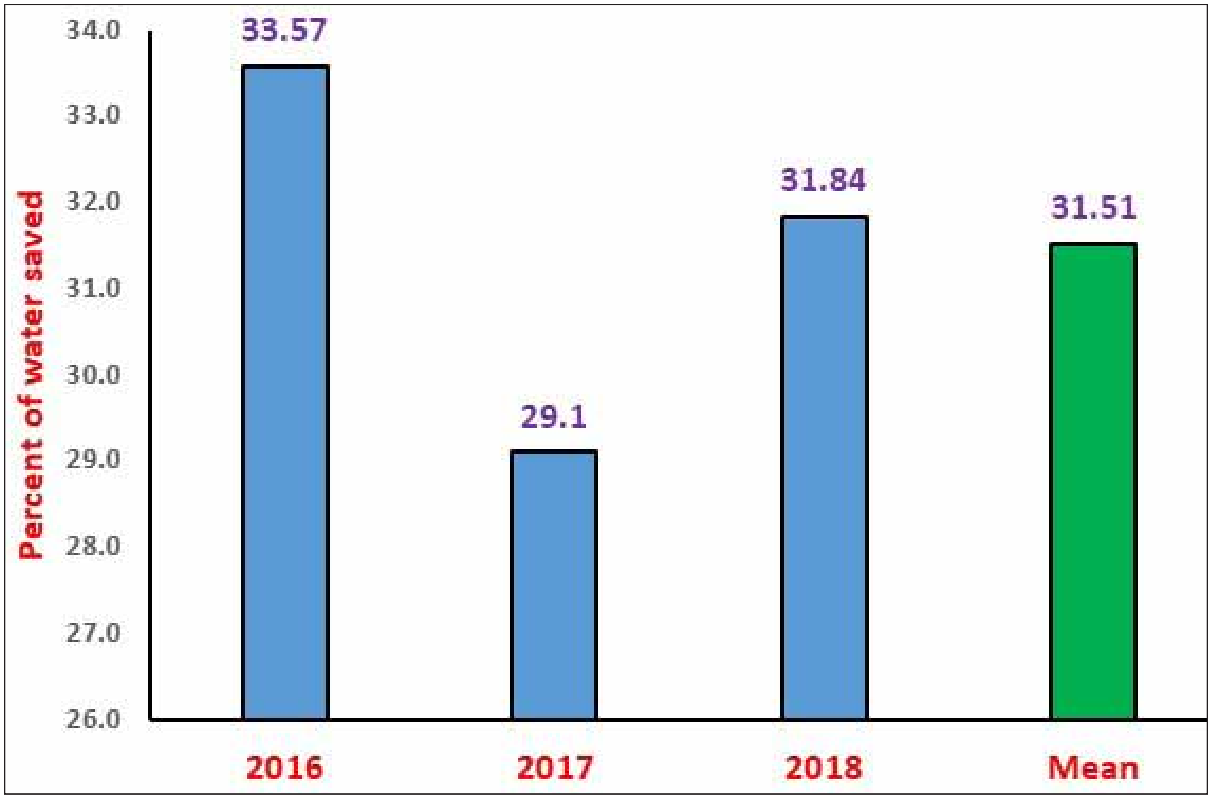


Figure 3: Percentage of water saved in SRI method over NTP

Conclusion

SRI method of cultivation was promising over NTP in terms of grain yield, energy output, net returns and Benefit: Cost Ratio. All the cultivars recorded higher yield in SRI method. Among the cultivars, hybrids (6.54 t/ha) performed better than HYVs (5.65 t/ha) and elite cultures (5.50 t/ha). The identified hybrids, cultivars and elite cultures could be promoted in SRI method for higher grain yield with lesser inputs especially seed (80%) and water (31%) which can be utilized for the increase of paddy cultivation area and other rice-based crops.

References

Deelstra J, Nagothu US, Kakumanu KR, Kaluvai YR, Kallam SR. 2018. Enhancing water productivity using alternative rice growing practices: a case study from Southern India. *Journal of Agricultural Science*, 156:673-679.

FAOSTAT. 2020. Food and Agriculture Organization, Rome, Italy. (http://faostat.fao. org).

Gomez KA and Gomez AA. 1984. *Statistical Procedures for Agriculture Research*. John Wiley and Sons Publishers, New York. Pp. 357-423.

Kumar R, Raj M, Lal K, Ranjan A. 2021. Impact of SRI Components on Growth and Productivity of Conventional Transplanted Rice. *Biological Forum – An International Journal*, 13:196-199.

Kumar RM, K Surekha, B Sreedevi, Ch Padmavathi, D Srinivas, T Vidhan Singh, B Nirmala, PC Latha, P Muthuraman, MD Tuti, N Somashekar, MBB Prasad Babu, MN Arun and LV Subba Rao. 2017. SRI method- a water-saving technology in rice – present status and future prospectives. *The Journal of Research*. PJTSAU, 45: 1-19.

Namara R, Bossio D, Weligamage P and Herath I. 2008. The practice and effects of the System of Rice Intensification (SRI) in Sri Lanka. Quarterly *Journal of International Agriculuture*, 47:5-23.

Naranayamoorthy A and Jothi P. 2019. Water saving and productivity benefits of SRI: a study of tank, canal and groundwater irrigated settings in South India. *Water Policy,* 21: 162–177.

Sato S. and Uphoff N. 2007. A review of on-farm evaluation of system of rice intensification (SRI) methods in eastern Indonesia. In: *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources. Wallingford: Commonwealth Agricultural Bureau International*, 54: 12 -26

Singh AK, Yadav RS, Kumar D, Kumar S, Kumar G. 2021. Outcomes of yield attributes, yield and economics of Rice (*Oryza sativa* L.) through applied the various planting methods and weed management practices. *The Pharma Innovation Journal,* 10: 1135-1139.

Sinha SK, and Talati J. 2007. Productivity impacts of the system of rice intensification (SRI): A case study in West Bengal, India. *Agricultural Water Management,* 87: 55-60.

Srinivas D, Kumar R Mahender, Karthik AV, Saha S, Venkatanna B, Arun MN, Reddy B Dhanunjaya and Sandhyarani A. 2017. Evaluation of rice (*Oryza sativa* L.) hybrids for system of rice intensification (SRI) with limited water input. *Agriculture Update,* 12 (TECHSEAR-9): 1-8.

Stoop WA, Uphoff, N and Kassam A. 2002. A review of agriculture research raised by the system of rice intensification (SRI) from Madagascar: Opportunities for improving farming systems for resource-poor farmers. *Agriculture Systems,* 71:249-274

Subramaniam Gopalakrishnan, R Mahender Kumar, Pagidi Humayun, V Srinivas, B.RatnaKumari, R Vijayabharathi, Amit Singh, K Surekha, Ch Padmavathi, N.Somashekar, P Raghuveer Rao, P C Latha, L V Subba Rao, V R Babu, B C Viraktamath, V.Vinod Goud, N Loganandhan, BikshamGujja, Om Rupela. 2013. Assessment of different methods of rice (*Oryza sativa*. L) cultivation affecting growth parameters, soil chemical, biological, and microbiological properties, water saving, and grain yield in rice–rice system. *Paddy and Water Environment,* 12: 79-87.

Uphoff N. 2007. The System of rice intensification: Using alternative cultural practices to increase rice production and Profitability from existing yield potentials. International Rice Commission Newsletter, No. 55. Rome: U.N. Food and Agriculture Organization.

RESEARCH ARTICLE https://doi.org/10.58297/SNZZ6760

Comparative Analysis of Different Nitrogen Treatments on Yield and Its Attributes in SRI and Conventional Cultivation

Venkatanna B, Latha PC, Srinivas D and Mahender Kumar R*

Indian Institute of Rice Research (ICAR-IIRR), Hyderabad-500030
*Corresponding author Email: kumarrm21364@gmail.com

Received: 20th November 2022; Accepted: 28th December 2022

Abstract

The current study reveals the effect of inconsistent nitrogen treatments on yield and yield attributes in the System of Rice Intensification (SRI) and conventional practices when compared during *Kharif* 2018 and 2019. Growth parameters like plant height, tillers per plant, yield attributes *viz;* length of panicle, number of filled and unfilled grains per panicle, test weight, straw yield, and harvest index were compared under both conventional and SRI methods. Subplots comprising four nitrogen management practices like control (N_1), 100% organic (N_2), 50% organic+50% inorganic (N_3) 100% inorganic (N_4) were taken. The maximal yield was recorded in SRI (5265 kg ha^{-1}) than conventional cultivation i.e., Normal Transplanting (4168 kg ha^{-1}). Among the nitrogen management practices 50% inorganic + 50% organic treatments (N_3) showed better performance when compared to 100% inorganic (N_4), followed by 100% organic (N_2) and control (N_1). The pooled analysis of grain yield was observed to be highest in the N_3 treatment (5551 kg ha^{-1}), followed by N_4 (5185 kg ha^{-1}), N_2 (4988 kg ha^{-1}), and control N_1 (3142 kg ha^{-1}). A similar pattern was also seen pertaining to the yield attributes.

Keywords: Rice, SRI, Conventional, Nitrogen management, Organic and inorganic.

Introduction

Rice *(Oryza sativa* L.*)* is an ancient crop cultivated in 117 nations worldwide and hence named “global grain”. It is by far the oldest domesticated crop known to humankind. Rice is always an important crop and a good source of energy for over one-third of the world’s citizenry. India has a productivity of 2.7 tons per hectare over an area of 45 million hectares with a production of 123.7 million tons (CMIE, 2021). Rice production currently faces constraints like declining net cultivable land, lowering the water table, and other climate change issues like increasing temperature, carbon sequestration, and methane emission that are causing a decline in yields. Water is a restraining factor in rice grain production**.** Future predictions of the scarcity of water limiting agricultural production estimated that by 2025 about 15-20m ha^{-1}in Asia’s grain fields will suffer from the water shortage in drought season. Especially 45 to 90% of the freshwater is used for irrigating total agricultural crops (Tuong and Bouman, 2003).

The conventional method is the most important and common practice of crop establishment methods under irrigated lowland rice, which not only consumes extra water but also results in water wastage and subsequently results in the degradation of land. To overcome this problem, many techniques evolved and amongst them is the System of Rice Intensification (SRI). This technique has emerged as an aqua-saving technology that has shown enhanced yield with a controlled supply of water. SRI system has been documented to produce higher rice grain yields with less irrigation and without the need for costly improved seeds or expensive chemical fertilisers. This additional extended rice will have to be produced on much less land with less water usage, labour and chemicals (Zheng *et al*., 2004). The combined use of organic and inorganic fertilizers helps in maintaining yield stability in addition to improving soil physicochemical and biological properties. Among the nutrients, nitrogen is crucial and limiting element in rice growth (Jayanthi *et al*., 2007).

Materials and Methods

The field experiments were carried out during *kharif* 2018 and 2019 at ICRISAT farm Patancheru, Hyderabad, Telangana, India. The geographic site of the farm is at 17°53'N latitude, 78°27'E longitude, and 545 m altitude above mean sea level. The experimental soil was clay loam black, neutral in reaction (pH 6.98) with non-saline (EC 0.692 d/Sm^{-1}). The experimental soil contains 1.004 % high organic carbon, 202 kg ha^{-1} of available Nitrogen, 40 kg ha^{-1} of available Phosphorus and 305 kg ha^{-1} of available Potassium. Akshayadhan (DRR Dhan 35), a high yielding, resistant-to-blast, semi-dwarf rice variety with a duration of 135 days and yield potential of 5.5t ha^{-1} was selected for the present study.

The experiment was carried out in split plot design with two main plots consisting of two establishment methods of cultivation, *i.e.*, System of Rice Intensification (SRI) and Normal Transplanting (NTP). The subplots comprising of four nitrogen management practices, *viz.*, control (N_1), 100% organic (N_2), 50% organic + 50% inorganic (N_3), 100% inorganic (N_4). The total subplot treatments sum up to 12 treatment combinations and 3 replicates. The experimental field was provided with irrigation channels and the discrete plots were demarcated by bunds in both methods. The recommended fertilizer doses 120:60:40 Kg ha^{-1} of N: P_2O_5: K_2O were applied as single super phosphate (SSP) and muriate of potash (MOP). Nitrogen was applied in the form of urea in three equal splits, half as basal, one-fourth at maximum tillering and one-fourth at panicle initiation stage in all the treatments of 100% inorganic treatment.

During flowering stage, three plants from each treatment were selected randomly and plant height was measured from base to flag leaf. The number of tillers per plant was also recorded. Ten panicles were selected to record the panicle length randomly. It was measured from the base of the primary rachis to top most spikelet and the average length was expressed in centimetres (cm).

After counting the filled and chaffy grains of a single panicle, the filled grain percentage and spikelet sterility percentage were determined with the following formula:

Filled grain percentage = (Number of filled grains/ Total number of grains) x 100

Spikelet sterility percentage = (Number of unfilled grains /Total number of grains) x100

Test weight was calculated by weighing a thousand grains obtained from three randomly selected hills and denoted in grams (g).

Plants in the net plot area were harvested separately in every plot, seeds separated after threshing and cleaning followed by drying under sunlight and the grain yield per plot was recorded, computed and expressed as kg ha^{-1}.

Results and Discussion

The plant height was significantly high in SRI (105,106 and 106.1cm during 2018, 2019 and pooled means, respectively) over NTP (99, 98 and 99.1 cm during 2018, 2019 and pooled means, respectively). Plant height was superior in the SRI method when compared to the conventional method of rice cultivation (Uphoff, 1999). Among the nitrogen treatments, maximum plant height was attained with 50% organic + 50 %, inorganic (N_3) (109,111 and 110.8 cm during 2018, 2019 and pooled means, respectively) followed by 100% Inorganic (N_4) and 100% Organic (N_2) treatments (**Table 1**). The lowest plant height was found in control (N_1) (93, 92 and 93.5 cm during 2018, 2019 and pooled means, respectively). The treatment with SRI practice was with higher plant height mainly because of wider spacing between rice plants, which allows the plant to get more light, nutrients and air. Usage of organic + inorganic nitrogen gives a better plant growth response than inorganic fertilizers due to the more sustained supply of nutrients by the favourable growth of soil biota. Satynarayana *et al.*, (2007) reported similar results.

The number of tillers was significantly high in the SRI (396, 411 and 403 m^{-2} in 2018, 2019 and pooled means, respectively) over NTP (336,346 and 341 m^{-2} in 2018, 2019 and pooled means, respectively) (**Table 1**). This may be due to the SRI cropping strategy, shorter length of phyllocorns and enhanced tillering. Mulu (2004) also reported similar results. In nitrogen treatments, the maximum tiller number (464, 461 and 462 in 2018, 2019, and pooled, respectively) was attained with 50% organic +50 % inorganic (N_3) nitrogen treatment. This was followed by 100% Inorganic (N_4) and 100% Organic (N_2) treatments. All the treatments were significantly superior to the control (N_1) during the two years of study. The lowest tiller number was found in control (N_1) (256, 262 and 259 m^{-2} in 2018, 2019 and pooled means, respectively). However, the interactions between main plots and subplots were not-significant. There is a continuous supply nutrient throughout the crop growth period in 50% organic +50% inorganic (N_3). Gopalakrishnan *et al.*, (2013) also reported that tillers in SRI-cultivated plants were higher when compared to the conventional method. The reasons for higher tiller density in SRI could be that the younger seedlings having higher vigour to produce more tillers and an additional number of days, even a radically reduced number of plants can produce more tillers per unit area. This was complemented by low competition between plant-to-plant and soil churning by cono weeder has a specific positive effect on the tillering in SRI.

Table 1. Plant height and number of tillers as influenced by planting methods and nitrogen treatments

Treatments	Plant height (cm)			No. of tillers (m^2)		
	2018	2019	Pooled	2018	2019	Pooled
Mean values of main treatments (M)						
M1-System of rice Intensification (SRI)	105	106	106.1	396	411	403
M2-Normal Transplantation (NTP)	99	98	99.1	336	346	341
S.Em±	0.4	0.9	0.62	4.3	5.9	3.07
C.D at 5%	2.7	5.9	4.06	28.3	38.9	20.1
Mean values of sub treatments						
N_1-Control	93	92	93.5	256	262	259.1
N_2-100% Organic	100	100	100.5	352	378	365.3
N_3-50% Organic + 50% Inorganic	109	111	110.8	464	461	462.6
N_4-100% Inorganic	106	105	105.8	392	413	402.6
S.Em±	0.7	0.7	0.56	9.2	10.8	8.6
C.D at 5%	2.2	2.3	1.76	28.6	33.7	27

Panicle length was also significantly higher in SRI (27.1, 27.2, and 27.1cm in 2018, 2019 and pooled, respectively) as compared to NTP (22.4, 22.9 and 22.6 cm and pooled, respectively). The observed panicle length in SRI when compared with normal method reached 19%. It was associated with various phenotypical alterations such as longer panicles, more open plant architecture with more erect and larger leaves, more light interception, high leaf chlorophyll content at the ripening stage, delayed senescence, higher photosynthesis rate and lower transpiration (Thakur *et al*., 2009). The higher value of panicle length was observed in N_3 (29.8 cm) followed by N_4 (26.9cm), N_2 (23.4 cm) and N_1 (**Table 2**) Application of organic and inorganic nitrogen supply 50% organic+50% inorganic (N_3) nitrogen treatment results in continuous supply of nutrients throughout the growth period of the crop (Damodaran *et al.*, 2012). These characteristics were associated with longer panicle length with greater number of grains and with enhanced grain filling in widely spaced hills compared with closely spaced hills. Similar results were also reported earlier by Latif *et al.,* (2005) and Menete *et al.,* (2008).

Establishment methods influenced the test weight of rice significantly with the highest in SRI (22.1, 21.7 and 21.9g in 2018, 2019 and pooled, respectively) as compared to NTP (19.7,18.9 and 19.3g in 2018, 2019 and pooled, respectively). This might be due to alternate wetting and drying (AWD) with wider spacing that promotes more profuse growth of roots and tillers, and more space (below and aboveground) per hill for access to nutrients, water and light. These changes improved the root growth and function with open canopy structure and prolonged leaf greenness, light utilization for higher photosynthetic rates during reproductive and grain filling stages. Due to this, a higher number of panicles and the number of grains per panicle, and lower spikelet sterility are easily noticeable. Significant variation was observed in test weight due to the nitrogen treatments. The higher average value of test weight was seen in N_3 (24.8 and 24.1g during 2018 and 2019, respectively) followed by N_4 and N_2. The minimal test weight was recorded in N_1 (16.1 and 16.5g during 2018 and 2019, respectively). Higher test weight in N_3 treatment was recorded in the present investigation due to the nitrification process by bacteria which increases nitrogen availability. Kronzucker *et al*., (1999), also reported similar results.

Table 2. Panicle length and test weight influenced by planting methods and nitrogen treatments

Treatments	Panicle length (cm)			Test weight (g)		
	2018	2019	pooled	2018	2019	Pooled
Mean values of main treatments (M)						
M1-System of rice Intensification (SRI)	27.1	27.2	27.1	22.1	21.7	22.1
M2-Normal Transplantation (NTP)	22.4	22.9	22.6	19.7	18.9	19.3
C.D at 5%	1.48	0.86	1.13	1.29	2.00	0.82
Mean values of sub treatments						
N_1-Control	19.2	19.5	19.4	16.1	16.5	16.3
N_2-100% Organic	23.2	23.6	23.4	20.5	19.6	20.0
N_3-50% Organic + 50% Inorganic	29.5	30.1	29.8	24.8	24.1	24.5
N_4-100% Inorganic	27.0	26.9	26.9	22.3	21.0	21.6
C.D at 5%	1.73	1.14	0.91	1.43	1.29	0.91
TXM	NS	NS	0.28	NS	NS	NS
MXT	NS	NS	0.87	NS	NS	NS

There was a remarkable effect of the method of establishment on grain filling percentage of rice, during both the years of study. A higher percentage of grain filling was recorded in SRI (179.8 and 179.9 %) compared to NTP in 2018 and 2019, respectively (**Table 3**). This was because of recommended management practices during the early ripening stage, higher biomass production in SRI as supported by more leaf area, longer length of panicles and more grains which was a major source of carbohydrate production. This positively improved the grain filling percentage in SRI. These results are in corroboration of the findings of Thakur *et al.*, (2013). Application of nitrogen through N_3 treatment recorded significantly higher percentage of grain filling over other nitrogen treatments during both the years of study. In $N_{3,}$ the percentage of grain filling was significantly maximum, 180.8 and 182 g during 2018 and 2019, respectively compared to N_4 and N_2. The minimal test weight was recorded in the N_1 treatment (Control). Split application of Nitrogen through 50% Inorganic + 50% Organic increases available nitrogen to the crop, thus providing better nitrogen uptake and a greater number of filled grains panicle lead to greater dry-matter production and its translocation to sink. Prabhakarsetty *et al*., (2007) also reported similar results.

The SRI method registered a significantly lower percentage of spikelet sterility (5.5 and 6.0%) as compared to NTP (10.5 and 10.5 %) during 2018 and 2019, respectively. The possible reason could be higher photosynthetic rates and lower inter and intra-tiller competition and wider spacing during dry matter integration under NTP. Rajendran *et al*., (2013) have supported these results. Application of nitrogen through treatment N_3 recorded a significantly lower percentage of spikelet sterility (5.1 and 5.3%) compared with other nitrogen treatments. The N_1 treatment registered a higher percentage of spikelet sterility (11.6 and 12.5%) during 2018, 2019 and in pooled means, respectively (**Table 3**). Application and combination of organic manures, besides supplying essential nutrients, will add to the favourable conditions for soil microbes by being the source of carbon for them, sustained the plants green even at the time of maturity. Hence, the contribution of carbohydrates from the current photosynthetic activity and the efficient translocation into the grain has resulted in an increased number of filled grains and reduced the unfilled grains per panicle. These results were in agreement with Wijebandara *et al.,* (2009).

Table 3. Influence of planting methods and nitrogen treatments on grain filling and spikelet sterility

Treatments	**Grain filling (%)**			**Spikelet sterility (%)**		
	2018	**2019**	**pooled**	**2018**	**2019**	**Pooled**
Mean values of main treatments (M)						
M1-System of rice Intensification (SRI)	179.8	179.9	182.4	5.5	6.0	6.0
M2-Normal Transplatation (NTP)	145.5	144.3	148.5	10.5	10.5	10.9
S.Em±	0.2	0.3	0.4	0.5	0.1	0.3
C.D at 5%	1.7	2.1	3.0	3.2	1.0	2.3
Mean values of sub treatments						
N_1-Control	143.8	142.5	147.1	11.6	12.5	12.3
N_2-100% Organic	156.3	157.1	158.8	8.1	8.3	8.6
N_3-50% Organic + 50% Inorganic	180.8	182.0	183.3	5.1	5.3	5.6
N_4-100% Inorganic	169.8	166.8	172.6	7.1	7.0	7.3
S.Em±	1.4	1.3	0.98	0.3	0.2	0.2
C.D at 5%	4.3	4.0	3.06	1.0	0.8	0.8
TXM	NS	NS	NS	NS	NS	NS
MXT	NS	NS	NS	NS	NS	NS

There was a significant increase in per cent grain yield in SRI was 28.1, 24.5 and 26.3over NTP during 2018, 2019 and their pooled means, respectively (**Table 4**). System of rice intensification creates a different environment for the rice plant's favourable growth such as physiological functioning, better soil aeration, wider spacing and less competition for higher root growth. Soil environment plays a major role in root activity, and nutrient availability, capturing all the essential nutrient elements important for all plant growth and thereby leading to higher tillering and more dry matter production as reported by Thigyarajan *et al.,*(2002). The influence of SRI biological and nutrient dynamics appears to enhance the response to higher grain yield of plants.

Yield attributes such as reduced intra-hill competition favoured the development of more lateral roots and root growth. Grain yield in rice was determined by the number of panicles per unit area, panicle length, filled grains per panicle and panicle weight, which were observed to be higher in SRI method than NTP. which was responsible for the increased grain. Based on nitrogen application, 50% organic +50% inorganic (N_3) treatment was found to have significantly greater grain yield during both years of study. The grain yield of rice is highest in 50% organic + 50%

inorganic (N_3) (5547, 5554and 5551 kg ha^{-1}) followed by 100% inorganic (N_4) (5128, 5242 and 5185 kg ha^{-1}) and 100% organic (N_2) (4974, 5002 and 4988 kg ha^{-1}) treatments, respectively. The lowest grain yield observed in Control (N_1) (3094, 3189 and 3142 kg ha^{-1}).

The higher availability of nitrogen in 50% organic + 50% inorganic (N_3) treatment resulted in higher grain yields as higher availability of nitrogen determined integration of chlorophyll molecule, lead to corresponding optimization of photosynthetic activity and photosynthetic assimilates. These conditions enhance the effective root oxidizing activity higher and better root distribution in the soil, more perpendicular and larger leaves, more light interference high chlorophyll content because of longer panicles, higher grain filling and finally improve the grain yield (Thakur *et al.,* 2009).

The Straw yield of rice was significantly higher in SRI (5884 and 5787 kg ha^{-1}) than in NTP (4936 and 4872 kg ha^{-1}) in 2018 and 2019, respectively. It could be because of more dry matter production, and more grain weight per unit nutrient taken up. SRI root system absorbs more nutrients from the soil and then supplies them to the plant. There is delayed senescence and the higher LAI (Leaf Area Index) presents higher nitrogen in the leaves after flowering in SRI plants compared to the NTP planting method (Mahender Kumar *et al.*, 2009). Application of nitrogen based on N_3 treatment had shown significantly higher straw yield (6119 and 6069 kg ha^{-1} during 2018 and 2019, respectively). N_4 treatment was statistically at par with N_3 but these nitrogen treatments were significantly superior to N_2 treatment. This might be because of an adequate supply of nitrogen throughout the crop growth period that led to higher dry matter production (Alam *et al.*, 2013). N_1 treatment recorded lower straw yield (3928 and 3845 kg ha^{-1} during 2018 and 2019 respectively).

The harvest index of rice was not significantly different among the planting methods and nitrogen treatments, and also the interaction effect during the two years of study (**Table 4**) Significant difference was however observed among pooled means observed in SRI (47.2%) compared to NTP (45.7%). The maximum harvest index was observed in N_3 (47.6%) and the lowest was recorded in N_1 (44.6%). Increased

Table 4. Grain yield, straw yield and harvest Index (%) influenced by planting methods and nitrogen treatments in rice

Treatments	Grain yield(kg/ha^{-1})			Straw yield(kg/ha^{-1})			Harvest index(%)		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
Mean values of main treatments (M)									
M_1	5264	5266	5265	5884	5787	5836	47.0	47.4	47.2
M_2	4107	4228	4168	4936	4872	4904	45.1	46.3	45.7
S.Em±	21.3	32.9	17.7	38.1	13.7	12.4	0.27	0.24	0.08
C.D.5%	139.9	215	116.5	249.7	90.2	81.8	1.80	NS	0.57
Mean values of subtreatments (N)									
N_1	3094	3189	3142	3928	3845	3887	43.9	45.3	44.6
N_2	4974	5002	4988	5689	5544	5617	46.4	47.3	46.8
N_3	5547	5554	5551	6119	6069	6094	47.5	47.8	47.6
N_4	5128	5242	5185	5904	5860	5882	46.4	47.1	46.7
S.Em±	53.6	40	25.7	91	99.8	61.7	0.51	0.49	0.25
C.D.5%	167.2	124.8	80.2	283	311	192	1.6	1.5	0.79
TXM	NS	NS	NS	NS	NS	NS	NS	NS	NS
TXM	NS	NS	NS	NS	NS	NS	NS	NS	NS

harvest index in the SRI system and N_3 treatment (50% Organic + 50% Inorganic) has shown that perhaps even a radically lesser number of plants can produce more tillers per unit area, and the panicles usually have more number of grains, total dry matter production, grain and yield parameters (**Figure 1**).

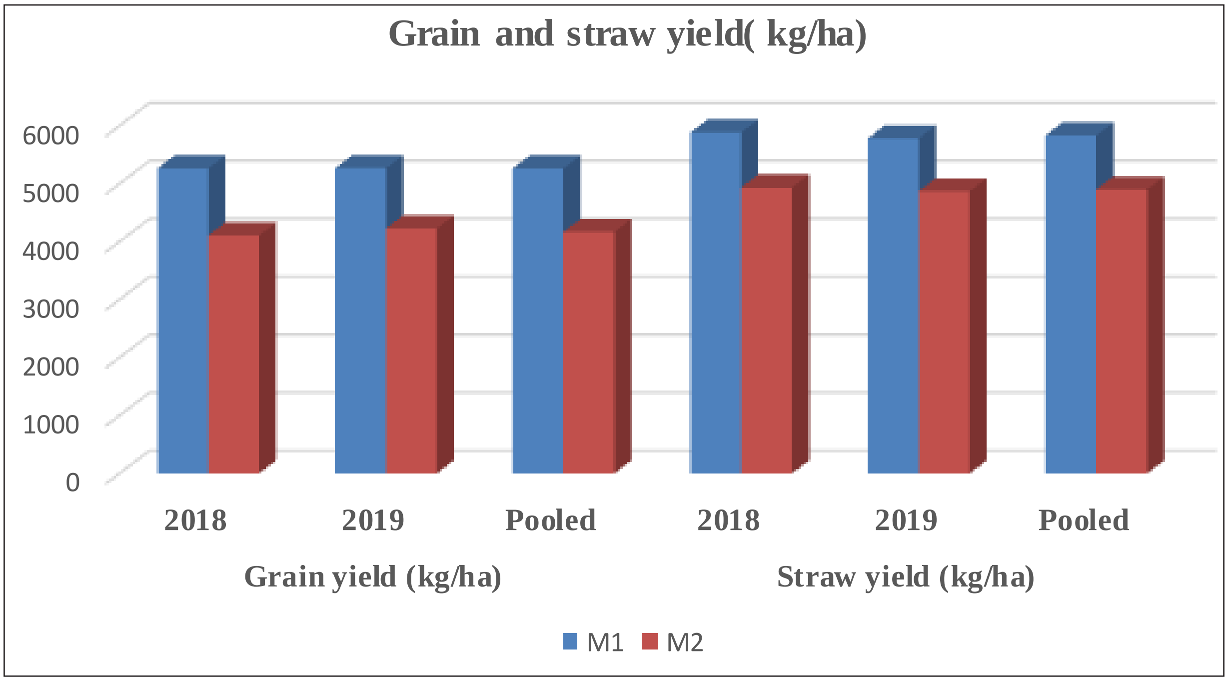


Figure1. Grain yield, and Straw yield influenced by planting methods and nitrogen treatments in rice

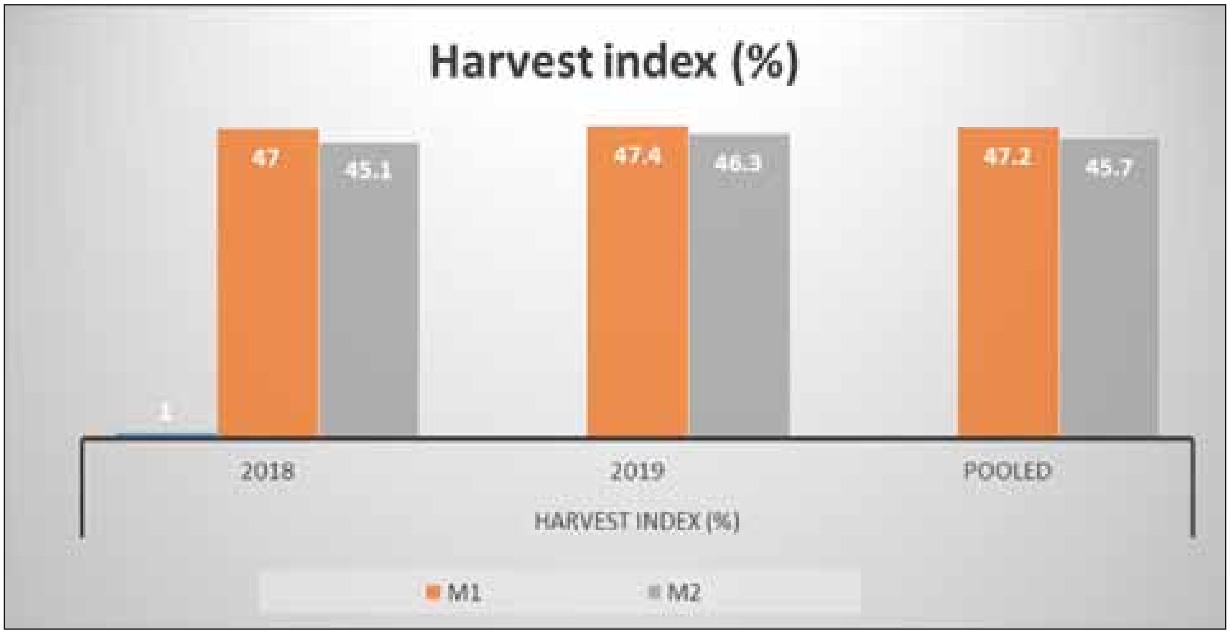


Figure 2. Harvest index influenced by planting methods and nitrogen treatments in rice

Conclusion

SRI showed significantly higher yield parameters like the number of tillers, panicle length, grain weight, and the number of grains per panicle. Therefore, there is a significant grain yield increase of 24.6% under SRI over NTP. Treatment 50% organic + 50% Inorganic has shown an increased percentage of filled grains and test weight compared to other treatments. Among the nitrogen treatments, 50% organic + 50% Inorganic showed 76.0% enhanced yield over control in both the years of pooled means. From the above results, it can be concluded that the SRI method was more promising than NTP and treatment with 50% organic + 50% inorganic was found promising over the other nitrogen treatments.

References

CMIE. 2021. Centre for Monitoring Indian Economy (CMIE).

Damodaran V, Saren BK, Ravisanker N and Bommayasamy N. 2012. Influence of time of planting, spacing, seedling number and nitrogen management practices on productivity, profitability and energetic of rice *(Oryza sativa)* in island ecosystem. *Madras Agricultural Journal,* 99:538-544.

Jayanthi T, Gali SK, Chimmad VP, and Angadi VV. 2007. Leaf colour chart based N management on yield, harvest index and partial factor productivity of rainfed rice. *Karnataka Journal of Agricultural Sciences,* 20: 405-406.

Kronzucker HJ, Siddiqi MY, Glass ADM, and Kirk GJD. 1999. Nitrate-ammonium synergism in rice a subcellular flux analysis. *Journal of Plant Physiology*, 119:1041–1046.

Latif MA, Islam MR, Ali MY, and Saleque MA. 2005. Validation of the system of rice intensification (SRI) in Bangladesh. *Field Crops Research,* 93:281-292.

Menete MZL, van HM, Es RML, Brito, SD De Gloria, and Famba S. 2008. Evaluation of system of rice intensification (SRI) component practices and their synergies on salt–affected soils . *Field Crops Research,* 109:34-44.

Mahender Kumar R, Surekha K, Padmavathi Ch, SubbaRao LV, Latha PC, Prasad MS, Ravindra Babu V, Ramprasad AS, Rupela OP, Vinod Goud V, Somashekar N, Ravichandran S, and Viraktamath BC. 2009. Research experiences on System of Rice Intensification and future directions. *Journal of Rice Research*, 2: 61-74.

Prabhakarasetty TK, Bandi AG, Satnam Singh, and Sanjay MT. 2007. Influence of Integrated nutrient management on growth and yield of hybrid rice under System of Rice Intensification (SRI) and Aerobic method of cultivation. In SRI *India 2007 Second National Symposium on 'System of Rice Intensification(SRI) in India- Progress and Prospects'.*Papers and Extended Summaries, 3-5 October, Agartala Tripura, India.82-84.

Singh RS, Gos DC and Srinivastava VC, 1991. Studies on production factors limiting yield attributes and yield of upland rainfed rice. *Indian Journal of Agronomy*, 36:159-164

Sinclair TR. 2004. Agronomic UFOs. *Field Crops Research*, 88:9-10.

Satyanarayana A, Thiygarajan TM, Uphoff N. 2007. Opportunities for water saving with higher yield from the system of rice intensification. *Irrigation Science*, 25:99-115.

Subramaniam Gopalakrishnanan, Mahendrakumar R, Humayaun P, Srinivas V, Ratnakumari B, Vijayabharathi R, Amit Singh, Surekha K, Padmavathi Ch, Somashekar N, RaghuveerRao P, Latha PC, Subbarao LV, Babu VR, Viraktamath BC, Vinod goud V, Loganandhan N, Biksham Gujja and Om Rupela. 2013. Assessment of different methods of rice (Oryza sativa L.) cultivation affecting growth parameters soil chemical biological and microbiological properties water saving and grain yield in rice – rice system. *Paddy and Water Environment*, 12: 79-87.

Thakur AK, Chaudhari SK, Singh R, and Kumar A. 2009. Performance of rice varieties at different spacing grown by the system of rice intensification in eastern India. *Indian Journal of Agricultural Science,* 79:443-447.

Thakur, AK, Rath S, and Mandal KG, 2013.Differntial responses of system of rice intensification (SRI) and conventional flooded rice management methods to application of nitrogen fertilizer. *Plant and Soil,* 370:59-71

Thakur AK, Rath S, Patil DU and Kumara A. 2011. Effects on rice plant morphology and physiology of water and associated management practices of the system of rice intensification and their implications for crop performance. *Paddy and Water Environment,* 9: 13-24.

Thiyagarajan TM, Velu V and Bindrabam PS. 2007. Effect of SRI practice on rice in Tamil Nadu *IRRI Report, 26.*

Tuong TP, and Bouman BAM. 2003. Rice production in water scarce environments. In LW Kijne, R Barker, and DMolden,eds. Water productivity in agriculture Limits and opportunities for improvement. The Comprehensive Assessment of Water Management in Agriculture Series. Wallingford, UK, CABI Publishing. 1: 13- 42.

Uphoff N. 1999. Agroecological implications of the System of Rice Intensification (SRI) in Madagascar Envioronment. *Development and Sustainability*, 1:231-297.

Wijebandara, DMDI, Dasog GS, Patil PL and Hebber M. 2009 Response of rice to nutrients and biofertilizers under conventional and system of rice intensification methods of cultivation in Tungabhadra command of Karnataka, *Karnataka Journal of Agricultural Sciences,* 22:741-750.

Zheng JG, Lu XJ, Jiang XL and Tang YL. 2004. The System of Rice Intensification for super high yields of rice in Sichuan basin. In T Fischer *et al*., (ed) New Directions for a Diverse planet. Proceedings of the 4th International Crop Science Congress, 26 September -01 October, 2004. Brisbane, Australia.

RESEARCH ARTICLE https://doi.org/10.58297/MYEA7162

Modified Mat Nursery and SMSRI -A Climate Smart Mechanization Practice in Rice

Shekar K

AICRP Sorghum, ARS, Tandur, PJTSAU
Corresponding author Email: kaluvalashekar333@yahoo.com

Received: 3rd November 2022; Accepted: 3rd December 2022

Abstract

The conventional method of transplanting rice is labour-intensive, requires more water, and involves drudgery. Keeping this in view, large-scale front-line multi-location demonstrations of a modified mat nursery followed by mechanized rice transplanting under a slightly modified system of rice intensification (SMSRI) was conducted in the erstwhile Karimnagar District of Telangana to overcome the problem of labour, saving time and cost. The demonstrations recorded the highest grain yield (7512 kg ha^{-1}) than the conventional method (7029 kg ha^{-1}). This method saved around Rs. 4500 – 6250 ha^{-1} on nursery raising and transplanting. Timely transplanting was carried out during peak periods of labour shortage. Therefore, there is a need to develop small self-propelled transplanters with suitable power weeders as a national strategy to increase the area under mechanization.

Keywords: Mat type nursery, SMSRI, Economics, Rice transplanting, Conventional method

Introduction

Rice *(Oryza sativa L.)* is one of Asia's major food crops. The crop area under rice in Telangana State covers 25,81,827 hectares (Department of Agriculture, Government of Telangana, 2022). Direct seeding of rice and transplanting are the two common methods of rice establishment (Kumar *et al*., 2016, 2017). The conventional way of rice transplanting is labour-intensive, involves drudgery and requires high energy (Verma, 2010). To overcome these problems in rice, a modified mat nursery followed by mechanized rice transplanting under a slightly modified system of rice intensification (SMSRI) was found cost-effective and time-saving. It helps in maintaining soil physical properties and is better from a crop management and productivity point of view. Despite having the edge over conventional transplanting, the adoption rate of mechanized transplanting is low due to high initial investment and lack of knowledge in growing modified mat-type nurseries. Field demonstrations were conducted on modified mat nurseries followed by mechanized rice transplanting in farmers' fields. Modified mat type nursery and transplanting under SMSRI method recorded the highest grain yield (7512 kg ha^{-1}) over the conventional method of rice establishment (7029 kg ha^{-1}) and saved cost (₹ 4500-6250 ha^{-1}) over the conventional method of rice establishment.

Imparting technical knowledge, ensuring timely availability, and encouraging custom hiring through rural youth may increase India's rice area under mechanical transplanting. Large-scale Front Line Multi-Location Demonstrations were conducted in the erstwhile Karimnagar District of Telangana to overcome the problem of labour, to save the cost, time and to impart the skill by popularizing the technology in raising modified mat nursery and machine transplantation in rice among the rural youth to spread the cost-effective technology **(Figure 1)**.

Methodology

Cluster front-line demonstrations were conducted in erstwhile Karimnagar districts covering Peddapalli, Rajanna Sircilla, Jagtial and Karimnagar of Telangana State during 2019, 2020 and 2021. The treatments are Demo: Raising of modified mat nursery followed by

Transplanting with rice transplanters under a slightly modified system of rice intensification (SMSRI) and Check: Farmer practice (Conventional transplanting) with Recommended Fertilizer dose of 120: 60: 40 N, P_2O_5 and K_2O kg ha^{-1} in 25 farmer's fields under unit Plot size of 0. 40 ha in each farmer's field. The soil types were light textured red loamy soils. Before the operation, the fields were puddled uniformly and left for 24 hours to allow the puddle to settle down completely and to avoid soil flow for better seedling establishment (Kumar and Kumar, 2012; Singh and Vatsa, 2006). The total demonstrations were 25 in the farmers' fields.

Results and Discussion

The results indicated that raising of a modified mat nursery followed by transplanting with rice transplanters under a slightly modified system of rice intensification (SMSRI) recorded the highest grain yield (7512 kg ha^{-1}) than the conventional method of rice establishment (7029 kg ha^{-1}) (**Table 1**). These results were in conformity with the findings of Haytham *et al.,* (2010) who developed a long mat-type nursery using the rice straw seedbed and found the method cost-effective compared to the conventional mat preparation method. The mean rice yield recorded was 6.8 % higher than the conventional method of rice establishment (Kamboj *et al.,* 2013). This method saved costs of ₹ 4500-6250 ha^{-1} on nursery raising and transplanting. The highest cost-benefit ratio was found in demonstration treatments compared to the conventional method (**Table 2**). Timely transplanting was carried out during peak periods of labour shortage (5-6 acres' per day). Earlier

Table 1. Yield and economics of rice under modified mat nursery followed by SMSRI method of establishment

Treatments	Plot Area (ha)	Year	Yield (kg ha^{-1})		Yield increase (%)	Net returns (₹ ha^{-1})		C: B Ratio	
			Demo	Check		Demo	Check	Demo	Check
Demo: Raising of modified mat nursery f/b Transplanting with Rice Transplanters	0.4	2020	7725	7300	5.8	93531	83534	01:02.8	01:02.6
Check: Farmer practice (Manual transplanting)	0.4	2019	7600	7077	7	104054	92722	01:03.8	01:03.5
	0.4	2018	7211	6710	7.5	91498	84357	01:03.8	01:03.7
Mean			**7512**	**7029**	**6.8**	**96361**	**86871**		

Table 2. Operation-wise economics of demonstrations

S. No.	Name of the operation	Mat nursery followed by machine planting method	Conventional Rice Transplantation
1	Seed Rate (kg/Acre)	20	30
2	Seed Cost (₹/Acre)	600	750
3	Land Preparation Cost (₹/Acre)	5000	5000
4	Transplanting Cost (₹/Acre)	350	3000
5	Herbicide cost (₹/Acre)	250	250
6	Manual Weeding (₹/Acre)	750	1000
7	Fertilizer Cost (₹/Acre)	2750	2750
8	Pesticide Cost (₹/Acre)	0	0
9	Labor cost for fertilize & pesticide application (₹/Acre)	0	0
10	Cost of Harvesting (₹/Acre)	7500	7500
11	Cost of Cultivation per Acre	17200	20250

trays became difficult for them, as the modified mat is very useful in saving nursery raising costs. Under the impact of this FLD, young rural farmers purchased the machinery. With the interventions in these districts, approximately more than 56,000 acres of the new area under mechanization was covered under modified mat nursery followed by machine planting newly in Rajanna Sircilla, Jagtial and Karimnagar Districts of Telangana State.

Figure 1: Mat nursery preparation, rolling and transplanting

Conclusions

Mechanical paddy transplanter is one of the possible options to get rid of labour shortage in farm operations. However, the adoption is slower due to poor response from stakeholders because of the cumbersome process of growing paddy nurseries in trays and mats. Providing proper hands-on training to the stakeholders about the operating procedure of nursery raising and handling transplanters would enhance the adoption rate of the presently available transplanters. Therefore, there is a need to develop small self-propelled transplanters with suitable power weeders as a national strategy to increase the area under mechanization. By conducting FLDs under Crop Production with our interventions in the operational area, more than 21,750 acres of the area under modified mat nursery followed by machine transplanting under SMSRI in rice was covered newly in Rajanna Sircilla, Karimnagar, Jagtial and Peddapalli Districts.

References

Haytham ME, Hassaanein MK, Zahoor A and Kotamy TM. 2010. Rice straw-seedbed for producing rice seedling mat. *International Journal of Sustainable Agriculture*, 2: 26-33.

Kamboj BR, Yadav DB, Yadav A, Goel N K, Gill G, Malik RK and Chauhan BS. 2013. Mechanized transplanting of rice (*Oryza sativa* L.) in non-puddled and no-till conditions in the rice-wheat cropping system in Haryana, India. *American Journal of Plant Science*, 4: 2409-2413.

Kumar U and Kumar A. 2012. Performance evaluation of manually operated four-row rice transplanter in Jharkhand, India. *SKUAST Journal of Research*,14: 59-66.

Kumar A, Nayak AK, Mohanty S and Das BS. 2016. Greenhouse gas emission from direct seeded paddy fields under different soil water potentials in Eastern India. *Agriculture Ecosystem, Environment*, 228: 111- 123.

Kumar A, Nayak AK, Pani DR and Das BS. 2017. Physiological and morphological responses of four different rice cultivars to soil water potential-based deficit irrigation management strategies. *Field Crops Research*, 205: 78-94.

Reports on seasonal conditions, Department of Agriculture, Government of Telangana. 2022. https://agri.telangana.gov.in/content.php?U=19.

Singh S and Vatsa DK. 2006. Performance evaluation of PAU manual paddy transplanter in hills of Himachal Pradesh. *Agricultural Engineering Today*, 30: 19-25

Verma A. 2010. Modeling for mechanization strategies of rice cultivation in Chhattisgarh, India. *Agriculture Mechanization in Asia, Africa and Latin America*, 41: 20-26.

SHORT COMMUNICATION https://doi.org/10.58297/MDJQ7071

DRR Dhan 57 (IET 26171) - an Aerobic Rice Variety

Senguttuvel P*, Sundaram RM, HariPrasad AS, Subbarao LV, Anantha MS, Gireesh C, Suneetha Kota, Abdul Fiyaz R, Divya Balakrishnan, Revathi P, Sai Prasad SV, Mangrauthia SK, Sruthi K, Kemparaju KB, Swamy AVSR, Padmavathi G, Sreedevi B, Sheshu Madhav M, Neeraja CN, Kumar RM, Prasad MS, Brajendra Parmar, Mangaldeep Tuti, Nirmala B, Muthuraman P, Sadath Ali M, Koteshwar Rao P, Chaitanya U, Jaldhani V, Beulah P and Nagaraju P

ICAR-Indian Institute of Rice Research (ICAR-IIRR), Rajendranagar, Hyderabad-500030

*****Corresponding author Email: senguttuvel@gmail.com

Received: 10th December 2022; Accepted: 25th December 2022

Abstract

DRR Dhan 57 [IET 26171 (RP 5601-283-14-4-1)], an aerobic rice variety was developed from BPT5204/Azucena cross combination. It was evaluated in AICRIP multi-location aerobic rice trials during the wet seasons of 2016 to 2020. DRR Dhan 57 consistently outperformed the check varieties in Eastern Zone (Zone III) and Central Zone (Zone V) with a mean grain yield of 4782 kg/ha, which is 13%, 17% and 16 % higher than the National, Zonal and Local checks, respectively. In addition, it exhibited moderate resistance to leaf blast and Neck blast; and to gall midge and rice thrips, and moderate resistance to planthoppers and whorl maggot. DRR Dhan 57 has a mid-early duration of 120 days (seed to seed) and possesses desirable grain and cooking quality parameters. It was released for cultivation in aerobic ecosystems of Jharkhand (Zone III), and Chhattisgarh (Zone V) states through Central Sub-committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops; vide S.O. 8(E) dated 24th December 2021[CG-DL-E-04012022-232406].

Keywords: Aerobic rice, Grain yield, Cooking quality

Introduction

Rice (*Oryza sativa* L.) is cultivated on 22 million hectares of area under irrigated ecology, accounting for about 50% of India's total area under rice production. In view of climate change, limiting water and human resources, aerobic rice is the need of the hour for substantial and stabilized crop returns. Indian Institute of Rice Research (ICAR-IIRR) has placed emphasis on aerobic rice, and with concerted efforts that started in 2011 with the crossing of BPT5204/Azucena, the segregating populations were evaluated under direct seeded aerobic conditions. The promising line RP 5601-283-14-4-1 was identified and nominated in AICRIP Aerobic 2016 trial. Subsequently, the entry performed very well in all the three years and released as a direct seeded aerobic rice variety DRR Dhan 57 through the Central Sub-committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops vide S.O. 8(E) dt. 24th Dec 2021[CG-DL-E-04012022-232406] suitable for cultivation in Jharkhand State of the eastern zone (Zone III) and Chhattisgarh State of the central zone (Zone V). The overall mean grain yield of DRR Dhan 57 in Zone III and V was 4782 kg/ha, which was 13, 17 and 16 % higher than the National, Zonal and Local checks, respectively. The mean grain yield in Zone III was 4771 kg/ha, which was 13, 13, and 17% higher than the National, Zonal and Local checks, respectively. The mean grain yield in Zone V was 4800 kg/ha, which was 12, 23, and 13 % higher than the National, Zonal and Local checks, respectively. The weighted mean grain yield was 3617 kg/ha in Jharkhand, which was > 8% higher than the best check. In Chhattisgarh state, the weighted grain yield mean was 4546 kg/ha and out yielded the national, regional, and local checks by 16, 16 and 13 %, respectively **(Table 1).**

Table 1. Yield performance of DRR Dhan 57 in Zone III and Zone V regions

Zone/State	MeanGrain Yield (Kg.ha^{-1})	Superiority over checks		
		National Check (%)	Zonal Check (%)	Local Check (%)
Z-III & Z-V	4782	13	17	16
Z-III	4771	13	13	17
Z-V	4800	12	23	13
Jharkhand	3617	40	8	17
Chhattisgarh	4546	16	16	13

It exhibited resistance to major insect pests and diseases such as leaf blast, neck blast, gall midge and rice thrips; moderate resistance to plant hoppers and whorl maggot. It has good hulling (79%), milling (69.30%) and head rice recovery (60%) in comparison with the checks and qualifying varieties. It possesses intermediate amylose content (23.4 %), medium alkali spreading value (4.0), medium gel consistency (53 mm), short bold (SB) grain type (KL- 5.21 mm; KB- 2.22 mm) and other desirable grain and cooking quality parameters **(Figure 1).**

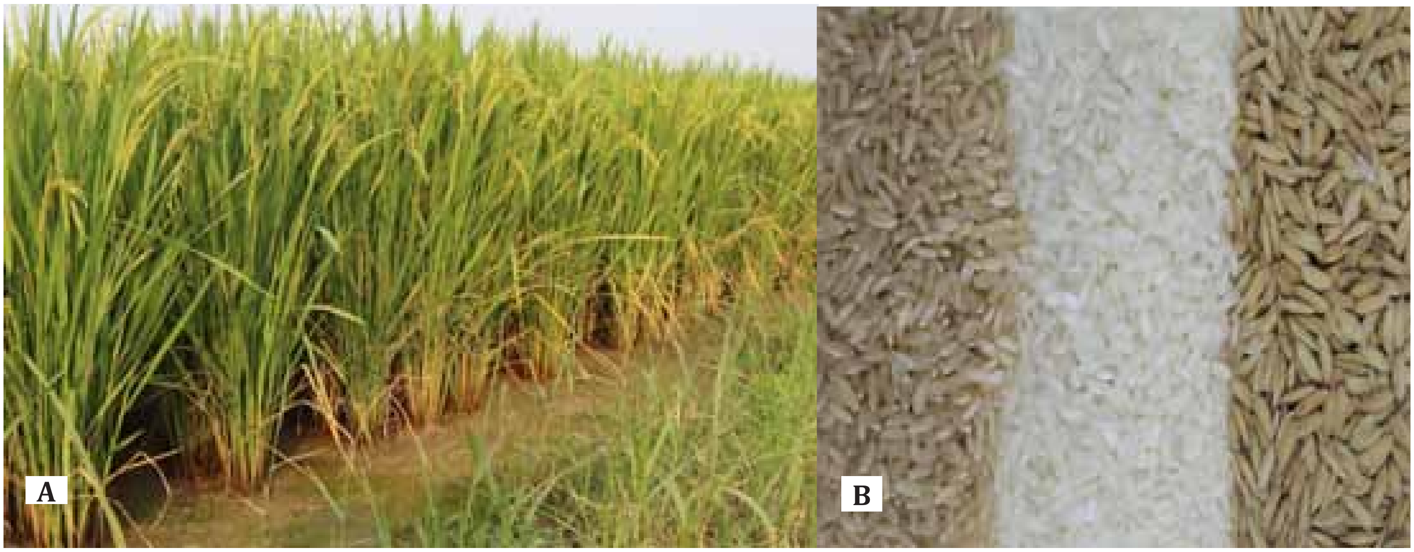


Figure 1A: Field view of DRR Dhan 57, 1B. Paddy, Brown rice and Polished rice of DRR Dhan 57

The variety DRR Dhan 57 is highly suitable for dry direct-seeded aerobic conditions with intermittent irrigation. Dry direct seeding is preferable from the second week of June to the second week of July (with the onset of rain or pre-sowing irrigation). Immediately after sowing, life-saving irrigation should be ensured for uniform germination and crop establishment. Weed management is a big menace in aerobic rice. To resolve this, Pendimethalin herbicide @1 kg per hectare at field capacity moisture is applied within three days of sowing. Further, it is recommended to apply Post Emergence broad-spectrum systemic herbicide like Bispyribac Sodium 10% SC (Nominigold) @50ml per hectare at field capacity moisture within 5-15 days of sowing. One intermittent weeding is recommended (two if there are more weeds) during the crop growth. Need-based irrigation should be followed up to physiological maturity. The DRR Dhan 57 has an advantage of 10-15 days (115-120 seed-to-seed duration) in comparison with transplanted rice and can yield up to 5-5.5t/ha subject to use under the area of adoption and recommended climate conditions and adoption of package and practices. It is suitable for direct seeding of both early *Kharif* (wet) and *Rabi* (dry) seasons.

SHORT COMMUNICATION https://doi.org/10.58297/HMCM2151

Screening of Rice Genotypes for Resistance to Leaf Folder, *Cnaphalocrocis medinalis* Guenee

Krishna Veni B[1]*, Rama Rao CV [1], Padmavathi Ch[2], Suneetha Y[1],
Sambasiva Rao N[1] and Tushara M[1]

[1]Agricultural Research Station, Bapatla, ANGRAU, Andhra Pradesh
[2]ICAR-Indian Institute of Rice Research, Hyderabad
*Corresponding author Email: b.krishnaveni@angrau.ac.in

Received: 10th November 2022; Accepted: 10th December 2022

Abstract

In recent years, leaf folder incidence has been increasing in all rice ecosystems and is abundant during the wet season. Presently farmers are dependent on the use of toxic chemical pesticides alone for their management. Hence, an attempt was made to nominate genotypes developed at Agriculture Research Station, Bapatla for screening against leaf folder under the AICRIP entomology program. Of the 16 genotypes evaluated at multi-locations during the *Kharif* season for two years, 2020 and 2021, BPT 2699 was found promising in 2-8 locations. BPT 3034 and BPT 3059 were promising in 2-6 locations, four entries BPT 2677, BPT 2954, BPT 3049 and BPT 2932 were promising in 3- 5 locations. The majority of these entries consistently outperformed the check variety (TN1) for leaf folder resistance and can be used as donors in future breeding programmes.

Keywords: Genotypes, Screening, Resistance, Rice, Breeding, Test

Introduction

Leaf folders occur in all rice environments and are more abundant during the rainy season. They are commonly found in shady areas and areas where rice is heavily fertilised with nitrogen. In tropical rice areas, they are active year-round, whereas in temperate countries, they are active from May to October. Chitra *et al.,* (1998) reported that growing resistant cultivars would reduce the pest load and pesticide usage and thus can be of greater value for an eco-friendly future. Heinrichs *et al.,* (1985) opined the need to develop resistant varieties to combat this pest in Asia. Thereafter, identifying sources of resistance against this pest became the primary objective of various research workers (Heinrichs, 1986; Khan and Joshi, 1990; Singh and Dhaliwal, 1985). Recently, the leaf folder incidence has increased in various rice ecosystems. Keeping this in view, an attempt was made to screen rice genotypes developed at Bapatla against the rice leaf folder.

Sixteen rice genotypes developed at Agricultural Research Station, Bapatla, were nominated for screening against leaf folder under AICRIP testing. These entries were evaluated in three replications at 13 locations spread over 12 states during *Kharif*, 2020 (**Table 1**). Analysis revealed that four entries, *viz*., BPT 2932, BPT 2677, BPT 2954 and BPT 3049, were found promising at 4 locations. BPT 3081, BPT 3034, BPT 3029 and BPT 2824 were promising at three locations.

During *Kharif* 2021, the same entries were evaluated at 12 locations spread over 11 states (**Table 2**). Analysis revealed that BPT 2699 was promising at 8 valid field tests, while BPT 3034 and BPT 3059 were promising at 6 locations. Four entries, BPT 2677, BPT 2954, BPT 3081 and BPT 2935, were promising in 5 valid tests. Five entries, BPT 3049, BPT 3032, BPT 2953, BPT 3157 and BPT 3115, were promising at 4 locations/ tests. Other entries were promising in 2-3 locations.

Thus, in both the years, the entry BPT 2699 was found promising in 2-8 locations, BPT 3034 and BPT 3059 were promising in 2-6 locations, four entries BPT 2677, BPT 2954, BPT 3049 and BPT 2932, were

Table 1. Performance of nominations from Bapatla against leaf folder in LFST, *Kharif* 2020

Designation	Parentage	ADT	BPT	CHT	CHN	JDP	KRK	LDN	MLN	NVS	NWG	PTB	RNR	KUL	NPT
BPT 2677	MTU 2077/Ajay/MTU 2077	30.1	14.8	12.5	9.1	7.5	43.0	33.5	24.0	7.6	24.4	19.8	6.4	28.0	4
BPT 2954	NLR 34449/Annada/NLR 34449	29.7	13.5	13.2	5.4	6.2	42.1	32.2	25.6	7.9	18.9	26.9	6.1	32.8	4
BPT 3049	MTU 1010/IR 50	29.3	11.2	17.1	5.4	9.0	50.6	24.7	23.0	1.0	23.6	27.4	8.5	23.2	4
BPT 2932	BPT 5204/MTU 1075	31.7	16.0	12.1	9.0	9.8	46.3	25.5	25.3	5.4	22.9	26.4	4.7	21.6	4
BPT 3081	BPT 5204/MTU 1075	32.2	18.8	15.9	10.3	8.4	49.1	23.9	24.9	8.8	22.2	32.6	7.6	23.9	3
BPT 3034	BPT 5204/MTU 1075	20.2	29.3	16.2	14.0	13.0	48.1	29.3	23.2	5.5	23.9	19.6	6.5	32.1	3
BPT 3029	BPT 5204/IR 50	31.4	14.5	12.8	6.0	9.8	49.9	24.7	28.8	5.8	27.3	28.5	9.8	31.5	3
BPT 2824	MTU 2077/NLR 34449	33.5	13.1	14.7	6.5	8.5	45.4	27.4	26.3	3.9	26.0	18.6	13.3	30.3	3
BPT 3032	BPT 5204/IR 50	29.4	12.5	17.5	11.5	12.7	34.2	24.9	23.5	3.0	25.5	26.4	9.6	33.4	2
BPT 3059	MTU 1061/IR 78585-64-24-2-4-3-1	30.1	20.0	17.9	11.5	8.0	51.2	22.7	23.4	9.7	21.3	24.9	5.9	30.0	2
BPT 2935	MTU 1010/IR 50	23.8	19.9	12.5	11.3	12.0	52.0	24.7	25.5	5.9	21.4	45.0	7.9	30.3	2
BPT 2699	BPT 5204/RP 4677-16-6-1-12-1	22.7	20.1	13.5	11.1	8.4	47.7	29.6	25.4	5.7	22.5	23.9	8.4	29.4	2
BPT 2953	BPT 5204/IR 50	62.9	28.0	13.9	6.7	8.7	49.9	26.5	22.4	6.3	26.2	30.9	10.7	31.1	2
BPT 3050	BPT 5204/BPT 3291	32.3	14.4	13.3	6.5	9.3	52.7	34.5	24.5	8.0	22.3	34.2	10.1	28.2	2
BPT 3157	MTU 7029/IRGC 18195/MTU 1081	28.6	14.6	21.6	9.2	8.9	43.6	22.6	25.3	15.2	32.1	24.6	10.1	33.8	1
BPT 3115	BPT 2270/NLR 145	31.3	20.9	19.7	14.4	10.0	44.9	25.5	25.8	12.4	23.3	25.1	5.5	30.5	1
W 1263	Resistant check	4.9	7.7	9.6	5.6	2.4	4.4	19.4	19.5	0.7	18.3	19.9	7.7	27.3	12
TN1	Susceptible check	33.4	19.4	14.5	10.3	14.5	40.9	25.5	38.2	29.1	48.3	30.4	18.5	39.9	
Minimum damage		4.9	7.7	9.6	5.4	2.4	4.4	19.4	19.5	0.7	18.3	18.6	4.7	21.6	
Maximum damage		62.9	29.3	21.6	14.4	14.5	52.7	34.5	38.2	29.1	48.3	45.0	18.5	39.9	
Average damage in trial		29.9	17.2	14.9	9.1	9.3	44.2	26.5	25.3	7.9	25.0	26.9	8.7	29.8	
Promising level		15	10	10	10	5	15	20	20	10	20	20	10	25	
No. Promising		11	1	1	24	4	1	2	5	24	5	6	26	10	

ADT = Aduthurai, BPT = Bapatla, CHT = Chatha, CHN = Chinsurah, JDP = Jagdalpur, KRK = Karaikal, LDN = Ludhiana, MLN = Malan, NVS = Navsari, NWG = Nawagam, PTB = Pattambi, RNR = Rajendranagar, KUL = Kaul, NPT = Number of Promising tests

Table 2. Performance of nominations from Bapatla against leaf folder in LFST, *Kharif* 2021

Designation	Parentage	ADT	KRK	CHT	CTC	KUL	LDN	MLN	MSD	NLR	NVS	NWG	PTB	NPT
BPT 2699	BPT 5204/RP 4677-16-6-1-12-1	3.0	15.4	19.4	5.4	23.6	44.6	20.8	8.2	12.6	7.0	8.9	41.0	8
BPT 3034	BPT 5204/MTU 1075	3.5	13.3	19.8	6.5	26.3	43.8	21.6	7.5	20.0	6.8	9.4	63.6	6
BPT 3059	MTU 1061/IR 78585-64-24-2-4-3-1	47.1	19.9	18.6	9.4	23.9	44.3	20.9	6.4	21.1	2.6	9.1	73.5	6
BPT 2677	MTU 2077/Ajay/MTU 2077	14.3	16.7	18.6	9.2	27.3	47.4	20.3	6.3	14.7	10.1	9.6	36.5	5
BPT 2954	NLR 34449/Annada/NLR 34449	27.4	10.3	21.1	2.7	31.5	40.3	21.1	9.5	13.4	2.5	9.9	61.4	5
BPT 3081	BPT 5204/MTU 1075	28.5	14.8	19.7	9.5	23.8	42.4	21.6	6.5	25.8	3.9	11.9	54.0	5
BPT 2935	MTU 1010/IR 50	14.9	17.8	19.4	5.9	23.6	42.2	21.3	11.4	17.6	6.0	9.7	49.7	5
BPT 3049	MTU 1010/IR 50	19.2	15.5	20.3	7.2	32.1	51.1	21.3	8.0	20.2	7.3	8.8	58.7	4
BPT 3032	BPT 5204/IR 50	29.9	17.6	20.1	10.0	27.3	39.4	19.6	7.3	20.5	5.5	8.9	75.4	4
BPT 2953	BPT 5204/IR 50	30.9	16.5	20.4	10.4	23.2	53.1	21.3	5.9	22.8	9.4	8.8	68.1	4
BPT 3157	MTU 7029/IRGC 18195/MTU 1081	51.0	12.3	21.5	8.0	31.7	48.7	19.8	7.9	22.0	4.3	10.2	68.4	4
BPT 3115	BPT 2270/NLR 145	35.5	17.0	21.0	4.6	27.4	38.3	20.3	9.8	22.9	6.7	9.3	64.9	4
BPT 2932	BPT 5204/MTU 1075	20.5	18.1	20.1	5.0	22.9	47.1	20.5	7.7	24.1	11.7	10.9	75.8	3
BPT 3029	BPT 5204/IR 50	30.0	16.9	19.8	11.7	23.5	52.0	20.4	8.4	21.3	10.7	10.1	67.6	3
BPT 3050	BPT 5204/BPT 3291	36.3	15.5	21.0	6.4	25.1	48.1	21.8	5.4	22.1	5.9	10.4	58.2	3
BPT 2824	MTU 2077/NLR 34449	30.4	19.4	20.4	10.7	31.4	58.8	21.3	8.1	20.4	7.8	11.4	62.7	2
W1263	Resistant check	5.8	1.6	20.4	1.2	20.4	24.8	21.5	6.4	14.9	2.3	8.6	21.5	10
TN1	Susceptible check	72.0	24.1	20.6	28.7	34.3	55.1	21.9	14.7	50.3	18.0	12.8	75.7	
Minimum damage		3.0	1.6	18.6	1.2	20.4	24.8	19.6	5.4	12.6	2.3	8.6	21.5	
Maximum damage		72.0	24.1	21.5	28.7	34.3	58.8	21.9	14.7	50.3	18.0	12.8	75.8	
Average damage in trial		28.8	15.2	20.2	8.0	26.6	44.7	21.0	7.9	22.0	7.7	10.0	58.2	
Promising level		10	10	20	10	25	30	20	10	15	10	10	25	
Number Promising		3	1	7	16	9	0	2	19	3	15	12	0	

ADT = Aduthurai, KRK = Karaikal, CHT = Chatha, CTC = Cuttack, KUL = Kaul, LDN = Ludhiana, MLN = Malan, MSD = Masodha, NLR = Nellore, NVS = Navsari, NWG = Nawagam, PTB = Pattambi, NPT = Number of Promising tests promising in 3- 5 locations. Most of these entries consistently performed better during both years across several locations tested and proved promising over the check variety (TN 1) for leaf folder resistance and can be used as donors in future breeding programmes.

References

Chitra N, Soundarajan RP, Gunasekaran k, Anbalagan G and Kumar K. 1998. Role of Silica in rice cultivars against insect pests. In: Abstract, ICPPMSA, 11-13, Dec., CSAUA &T, Kanpur (India). pp. 60.

Heinrichs EA, Camang E and Romena A. 1985. Evaluation of rice cultivars for resistance to *Cnaphalocrocis medinalis* Guen. (Lepidoptera: Pyralidae). *Journal of Economic Entomology*, 78: 274-278.

Heinrichs EA. 1986. Perspectives and directions for the continued development of insect-resistant rice varieties. *Agriculture Ecosystems and Environment*, 18: 9-36.

Khan ZR and Joshi RC. 1990. Varietal resistance to *Cnaphalocrocis medinalis* (G) in rice - A review. *Crop Protection*, 9: 243-251.

Singh J and Dhaliwal GS. 1985. Varietal reaction to rice leaf folder, *Cnaphalocrocis medinalis*. *Oryza*, 20: 233-234.

JRR Best Paper Award

Guidelines

Purpose

The purpose of the Best Paper Award is to recognize and promote quality contributions to the Journal of Rice Research (JRR) and encourage young scientists, scholars and students who publish papers.

Eligibility

All the authors of one Research article or Review article or Short Communication published in the JRR during June and December of every year (as a regular or special issue submission) are eligible for this award. There are no limits in the number of authors involved.

Criteria

The best paper will be selected by a committee (Outside experts & Editorial Board members). Special attention will be given to the originality and novelty of the paper content, and to its utility. Additional criteria will be fixed by the committee. Award will start from June 2022 issue onwards.

How to Apply

All the published papers are automatically included in the list of papers for evaluation. No action is required.

Award

The "JRR Best paper award" includes:

- A certificate
- A Memento and
- A Cash prize

Journal of Rice Research - Author Guidelines

Scope: Journal of Rice Research is a channel for publication of full length papers covering results of original research, invited critical reviews or interpretative articles related to all areas of rice science, rice based crop systems and rice crop management. The journal also publishes short communications, book reviews and letters to the editor.

Articles reporting experimentation or research in any field involving rice or rice based cropping systems will be accepted as original articles while critical reviews are generally invited. Short articles concerned with experimental techniques or observation of unique nature will be accepted as short communication. Letters to the editor concerning previous articles are welcome and are published subject to review and approval by the editorial board. The original authors will be invited to reply to the points raised in these letters for their response which are also published together.

General Requirement:

Submission to the journal must be reports of original research of at least two crop seasons and must not be previously published or simultaneously submitted to any other scientific or technical journal. At least one of the authors (in case of joint authorship) should be member of the Society for Advancement of Rice Research (SARR) and not in arrears of subscription. Authors of invited articles are exempted from this.

Submission of Manuscript:

Manuscripts should be sent by email to the chief editor (jrrchiefeditor@gmail.com) as an attachment. All the enclosed figures (as ppt/jpg files), graphs (as MS Excel worksheet with original data) and photographs (as jpg or ppt files with high resolution) may be submitted as separate files. Avoid using more than one font. The manuscript should be typed in double spaced times new roman font with margins of at least 2.5 cm. On the first page give the title, a byline with the names of authors, their affiliation and corresponding author's e-mail ID. Abstract should be followed by a list of key words. The usual order of sections to be included after title and abstract pages are: Introduction which includes literature review; materials and methods; results and discussion; conclusion (optional), acknowledgements and references followed by figures and tables.

Title should give a clear idea what the articles is about. It should be brief and informative (12-15 words).

Materials and Methods should include experimental design, treatment details, replications and techniques/ methods employed.

Results and Discussion should be supported by sound scientifically analysed data along with explanatory text with relevant tables and figures.

References should be quoted in author-year notation system only. All the references should be arranged alphabetically by author. All single author entries precede multiple author entries for the same first authors. Use chronological order within entries with identical authorship and add a low case letter a, b, c, etc., to year for same year entries of the same author. References should be presented in the format given below:

Research papers

1. Durvasula V. Seshu**.** 2017. Networking a Pivotal Strategy for Rice Genetic Improvement. *Journal of Rice Research*, 10: 1-8.
2. Kemparaju KB, MS Ramesha, K Sruti, AS Hari Prasad, RM Sundaram, P Senguttuvel and P Revathi**.** 2018. Breeding strategy for improvement of rice maintainer lines through composite population for short term diversity. *Journal of Rice Research*, 11: 27-30
3. Paul M and Keegstra K. 2008. Cell-wall carbohydrates and their modification as a resource for biofuels. *Plant Journal,* 54: 559-568.

Thesis

Bhuiyan MDAR. 2010. Phenotypic and genotypic evaluation of selected transgressive variants derived from *Oryza rufipogon* Griff. x *Oryza sativa* L. cv. MR219. Ph D. Thesis. University Kebaangsaan Malaysia, Malaysia, 150 p.

Book chapter

Scott JM 1984. Catabolism of folates. P. 307-327. In R.L. Blackley and S.J. Benkovic (ed.) Folates and Pterims Vol.1. John Wiley & Sons, New York

Book

Subba Rao LV, Shobha Rani N, Chiranjeevi M, Chaitanya U, Sudharshan I, Suneetha K, Jyothi Badri and Dipal R Choudhary 2013 DUS Characterization of Rice Varieties. Directorate of Rice Research, Rajendranagar, Hyderabad-500 030, AP, India. 524 pp

Figures: Photographs and drawings for graphs and charts should be prepared with good contrast of dark and light. Figure caption should be brief specifying the crop or soil, major variables presented and year. Give careful attention to the width of lines and size, and clarity of type and symbols.

Tables: Tables are used for reporting extensive numerical data in an organized manner and statistically analyzed. They should be self explanatory. Prepare tables with the word-processing tables feature and tabs or graphics boxes should not be used. Table head should be brief but complete and self contained. Define all variables and spell out all the abbreviations. An exponential expression (eg. $x\ 10^3$) in the unit's line is often needed to keep length of the data reasonably short, and referenced with an explanatory note. Unless otherwise required, two decimal place values are suggested.

Published by :

Dr. RM Sundaram, President, Society for Advancement of Rice Research, Hyderabad.

Printed at :

Balaji Scan Pvt. Ltd., Hyderabad - 500 004. Ph: 040-23303424 / 25 E-mail: bsplpress@gmail.com

Society for Advancement of Rice Research

ICAR-Indian Institute of Rice Research (ICAR-IIRR) Rajendranagar

Hyderabad – 500 030 (India), Phone No: 091 40 24591218
Fax: +91 40 24591217, www.sarr.co.in