ISSN 2319-3670

Journal of Rice Research

Volume 9, No.1

June 2016

Society for Advancement of Rice Research

Society For Advancement of Rice Research

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Published by :

Dr. V. Ravindra Babu, 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

ISSN 2319-3670

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Volume 9, No. 1 June 2016

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ORIGINAL RESEARCH ARTICLE OPEN ACCESS

Inheritance Studies in Panicle Characters of Rice (*Oryza sativa* L.)

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Received: 1st March, 2016 Accepted: 20th June, 2016

Abstract

The present study was to investigate the genetic basis of three panicle characters *viz.*, double grain, clustered spikelet and dense panicle and their utilization in plant breeding. The experimental material consisted of five segregating F_2 populations for different characters. The segregating ratio revealed that the double grain trait was governed by single recessive gene in both the indigenous varieties Ram-laxman and Dodana. Likewise single recessive gene was responsible for the dense panicle in the variety Keraghul. However, clustered spikelets character in both the varieties Kaudidhul and Amaruthi governed by trigenically involving two dominant genes either of them complement with one other dominant gene.

Keywords: Inheritance, rice, germplasm, panicle characters

Introduction

Rice (*Oryza sativa* L.) is the world's most important food crop and a primary source of food for more than half of the world's population and account for more than 50% of their daily calorie intake. During the course of organic evolution, rice originated much earlier than most of the other cereal crops. As a result, vast genetic variability, not only in quantitative but also in qualitative traits has been created and accumulated in this crop leading evolution of over hundred thousand genotypes possessing wide array of variation in almost all the traits. This variability has always fascinated every one including farmers, traders, evolutionists and geneticists. In order to safeguard genetic variability of rice, over 20,000 indigenous accessions of rice germplasm are being maintained at IGKV, Raipur. Of these, some accessions have unique type of morphological characters such as double grain (Multiple pistil), clustered spikelet and dense panicle (compact panicle). Normally only one grain is set in each of the spikelet. However, a tendency is seen in some of the cultivars to set two or more grains per spikelet because of more than one pistil within the spikelet. Likewise, rare forms of cultivars have 2-7 spikelets in cluster. It appears to result mainly from reduction in pedicle length. Dense panicle also has advantage over lax type panicle in offering resistance to infection (Futsuhara *et al.*, 1979). Grain number per unit length is higher in the compact panicle cultivar than the loosed panicle cultivar (Panda *et al.*, 2009). Therefore compact panicle trait may be useful for the enhancement of grain number for higher exploitation of yield potential of the cultivars. Understanding the genetic basis of panicle architecture will contribute to not only elucidating the crop evolutionary mechanism but also improving crop grain yield (Zhu *et al.*, 2013). These traits directly or indirectly affect the yield. Further, such traits provide for uniqueness to the genotype identification, which is much needed in the present era of plant variety protection (Roy *et al.*, 2004). Considering the above view, an attempt has been made to study the inheritance of these unique characters (double grain, clustered spikelets and dense panicle) using a set of cultivars.

Materials and Methods

The materials used in the present study are mainly five crosses in rice involving eight parents studied up to F_2 generation for inheritance of double grain, clustered spikelet and dense panicle. Parents were collected from different places of Chhattisgarh (India). The list of parents with their attributing traits is given in Table 1. The present investigation was carried out at the Rice Research Farm, in the Department of Genetics and Plant Breeding, IGKV, Raipur. The observations on the parents and F_1's were recorded on the row basis, while F_2 population on individual plant basis. The data were analyzed independently for each trait to determine the mode of inheritance by χ^2 (Chi-square) test as suggested by Fisher (1936).

Results and Discussion

a) Inheritance of double grain (multiple pistil)

Mode of inheritance of multiple pistil trait was studied in the crosses of R 710-4-37-1-1-1-1 (single grain) x Ram-laxaman (double grain) and R710-4-37-1-1-1-1(single grain) x Dodana (double grain). This is a special trait present in the indigenous rice germplasm. Occasionally rice varieties are found with multiple pistils ranging from 2-7 pistils in each spikelet. The F_1s of the crosses Ram-laxman and Dodana with R710-4-37-1-1-1-1 were found to have only single grained spikelets, indicating dominance of single grain over double grain character (Table 2 and Fig. 1a). The proportion of plants possessing tendency to have double grains to those having single grains plants in the F_2 populations of these crosses were closely fitted in the ratio of 1 double grain: 3 single grained types, indicated that single recessive gene was responsible for expression of the double grain trait. Multiple pistils have been found to be simple recessive to single pistil by Parthasarthy (1935) in a number of crosses. Tomar *et al.* (2000) also reported that unipistillate ovary was dominant over the multipistillate ovary.

b) Inheritance of clustered spikelets

Mode of inheritance of Clustered spikelet trait was studied in the crosses of R714-3-103-1-3-2 (Solitary spikelets) x Kaudidhul (clustered spikelets) and R714-3-103-1-3-2 (Solitary spikelets) x Amaruthi (clustered spikelets). Segregation analysis of this character was done using two crosses representing solitary spikelet × clustered spikelet parent. In both the crosses F_1 plants have clustered spikelets, indicating clustered spikelets traits to be dominant over normal spikelets. The F_2 population in both crosses were closely fitted to be in the ratio of 45:19 (clustered to solitary spikelets), indicating trigenically involving two dominant genes either of them capable of complementing with one another dominant gene, being responsible for expression of this character in both varieties Kaudidhul and Amaruthi (Table 2, Fig.1b)

c) Inheritance of Dense panicle

Mode of inheritance of dense panicle trait was studied in the cross of Keraghul (compact panicle) with Dokara-dokari (lax panicle). The F_1 plants possessed lax panicle, indicating that dense spikelet was due to recessive gene (Table 2, Fig. 1c). The proportion of plants with compact and lax panicles in the F_2 population of this cross closely fitted in to the ratio of 1: 3, suggesting that dense panicle trait was governed by single recessive gene in the variety Keraghul. Similar results were reported by Dhulappanavar, (1977) and Futsuhara *et al.*, (1979). Mitra and Ganguli (1935) reported that lax panicle was controlled by two dominant complementary genes. On the other hand Chakravorty (1948) reported dense panicle being governed by two complementary genes. Pavithran *et al.* (1995) reported duplicate recessive gene responsible for expression of compact panicle.

The results revealed that the double grain trait was governed by single recessive gene in both the indigenous varieties Ram-laxman and Dodana. Likewise single recessive gene was responsible for the compact panicle in the variety Keraghul. However, clustered spikelet character in both the varieties Kaudidhul and Amaruthi governed by trigenically involving two dominant genes either of them complement with one other dominant gene. These characteristics of indigenous rice may increase grain-yield potential of cultivated varieties through crop improvement programme.

Table 1: Details of genotypes undertaken in the present study

S. No.	Name of the genotypes/ Acc. Nos.	Panicle character	Place of origin	Place of collection Dist. / Block
1	Ram-laxaman (R:358)	Double grain	India	Raigarh/ Gharghoda
2	Dodana (D:612)	Double grain	India	Bilaspur/Bilaspur
3	Kaudidhul (K:1849)	Clustered spikelets	India	Raigarh/ Dharamjaigarh
4	Amaruthi (A:643)	Clustered spikelets	India	Bastar/Antagarh
5	Dokra-dokri (D:520)	Lax panicle	India	Raipur/Fingeshwar
6	Keraghul (K:2034)	compact panicle	India	Raigarh/Gharghoda
7	R 710-4-37-1-1-1-1 (semi dwarf)	Single grain	India	IGKV, Raipur
8	R 714-3-103-1-3-2 (semi dwarf)	Solitary spikelets	India	IGKV, Raipur

Table 2: Segregation for three qualitative characters in F_2 population in rice

S. No	Cross combination	Panicle trait	F_1 Phenotype	F_2 observations		χ^2 ratio	χ^2 Value	P value
1.	**Double grain (multiple pistil)**			Double grain	Single grain			
	R710-4-37-1-1-1-1/ Ram-laxaman	Single grain / double grain	Single grain	139	473	1:3	1.70	0.20-0.10
	R710-4-37-1-1-1-1/ Dodana	Single grain / double grain	Single grain	177	515	1:3	0.12	0.80-0.70

2.	**Clustered spikelet**			Clustered	Solitary			
	R714-3-103-1-3-2/ Kaudidhul	Solitary spikelets / clustered spikelets	clustered spikelets	535	243	45:19	0.886	0.50-0.30
	R714-3-103-1-3-2/ Amaruthi	Solitary spikelets / clustered spikelets	clustered spikelets	536	220	45:19	0.125	0.80-0.70
3.	**Dense panicle**			Compact	Lax			
	Dokra-dokari / Keraghul	Lax panicle / compact panicle	Lax panicle	228	597	1:3	3.05	0.10-0.05

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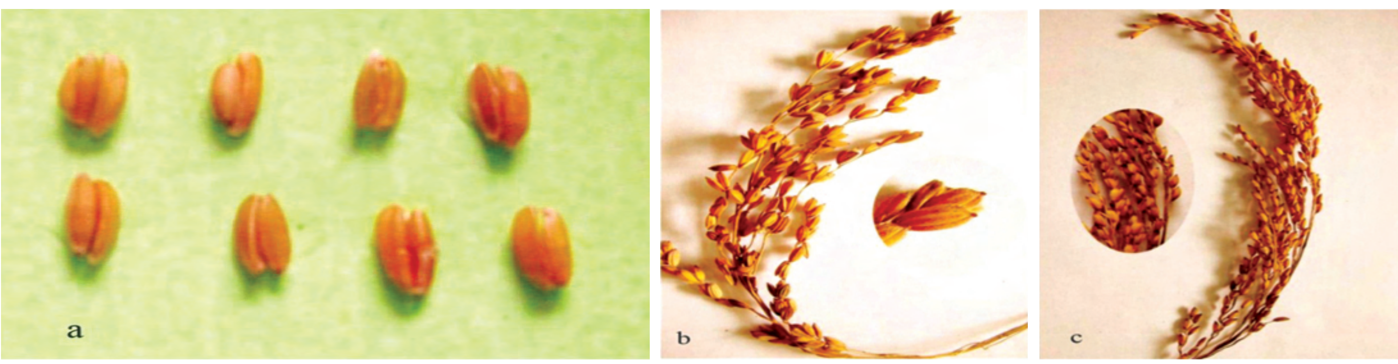

Fig. 1. Photograph of rice cultivars showing different panicle characters:
(a) double grain in Ram-Laxman; (b) clustered spikelets in Amaruthi and (c) dense panicle in Keraghul

ORIGINAL RESEARCH ARTICLE OPEN ACCESS

Screening of Rice F_5 Families for Sheath Blight and Bacterial Leaf Blight

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Received: 20th February, 2016, Accepted: 28th June, 2016

Abstract

Forty three F_5 families of rice obtained from the two crosses MTU 7029/ PAU 3116-25-5-1 and MTU 7029/ PAU 3140-126-1were screened against sheath blight by adopting typha leaf bit method of artificial inoculation followed by field screening using 0-9 scale of SES, 2014. Same families were also screened against bacterial leaf blight using leaf clipping method of artificial multiplication and observed that no family was found immune or resistant to both the diseases. 21 families reported moderate resistance to sheath blight whereas only six families showed moderate resistance to bacterial leaf blight. Three families MTU 2468-25-2-1, MTU 2469-6-1-2 and MTU 2469-6-5-1 recorded moderate resistance to both the diseases and hence can be selected.

Keywords: Kresek, typha leaf bit method, leaf clipping, screening

Introduction

Rice is the staple food crop for two thirds of the world population with varied consumer preference. Paddy cultivation suffers from several biotic and abiotic stresses that seriously affect its production among which Sheath blight, caused by *Rhizoctonia solani* (teleomorph: *Thanatephorus cucumeris*) and Bacterial leaf blight, caused by *Xanthomonas oryzae pv. oryzae* were the two major devastating diseases in many countries affecting more than 50% of global rice production (Singh *et al.*, 1977; Khush and Ogawa, 1989; Groth *et al.*, 1991 and Marchetti and Bollich, 1991). Rice sheath blight spreads through sclerotia present in the soil which develops primary mycelium with the onset of favourable conditions that forms initial lesions on sheath which later develops into runner hyphae that grow on the surface of rice plant tissues, and develop infection structures that generate new lesions. Disease intensification and spread are also favoured by long duration of tissue wetness, crop canopy and canopy microclimate. The fungus affects the crop from tillering to heading stage. Initial symptoms are noticed on leaf sheaths near water level. On the leaf sheath oval or elliptical or irregular greenish grey spots are formed. As the spots enlarge, the centre becomes greyish white with an irregular blackish brown or purple brown border. Lesions on the upper parts of plants extend rapidly coalescing with each other to cover entire tillers from the water line to the flag leaf. The presence of several large lesions on a leaf sheath usually causes death of the whole leaf, and in severe cases all the leaves of a plant may be blighted in this way. The infection extends to the inner sheaths resulting in death of the entire plant. Older plants are highly susceptible. Five to six week old leaf sheaths are highly susceptible. Plants heavily infected in the early heading and grain filling growth stages produce poorly filled grain, especially in the lower part of the panicle. Many rice cultivars have been identified as moderately resistant to sheath blight, however no resistant cultivar has been found so far (Prasad and Eizenga, 2008).

Bacterial leaf blight affects the rice crop in all major rice growing countries of Asia. in India, it is a serious problem during south west monsoon. The bacterium induces either wilting of plants or leaf blight. Wilt syndrome known as Kresek is seen in seedlings within 3-4 weeks after transplanting of the crop. Kresek results either in the death of whole plant or wilting of only a few leaves. The bacterium enters through the hydathodes and cut wounds in the leaf tips, becomes systemic and cause death of entire seedling. The disease is usually noticed at the time of heading but in severe cases occur earlier also. In grown up plants water soaked, translucent lesions appear usually near the leaf margin. The lesions enlarge both in length and width with a **wavy margin** and turn straw yellow within a few days, covering the entire leaf. As the disease progresses, the lesions cover the entire leaf blade which may turn white or straw coloured. Lesions may also be seen on leaf sheaths in susceptible varieties. Milky or opaque dew drops containing bacterial masses are formed on young lesions in the early morning.

They dry up on the surface leaving a white encrustation. The affected grains have discoloured spots surrounded by water soaked areas. If the cut end of leaf is dipped in water, bacterial ooze makes the water turbid.The most effective approach to control these two diseases is using resistant varieties. Development of disease resistant rice is one of the most important achievements rice breeders attempt to accomplish .The genetic diversity of rice may incorporate genes that directly contribute to physiological host plant resistance to sheath blight (Srinivasachary *et al.,* 2011), genes that determine the architecture of plants, and thus contribute to the structure of crop canopies, as well as genes from these different groups that collectively confer resistance through interactions which can be identified by field screening by standardized methods. Hence, the objective of the present study therefore was to screen forty three F_5 families of rice against sheath blight and bacterial leaf blight which will enable us to identify rice varieties resistant to these diseases.

Materials and Methods

In the present study, during *kharif* 2015, all the forty three F_5 families obtained from two crosses MTU 7029/ PAU 3116-25-5-1 and MTU 7029/ PAU 3140-126-1 along with their susceptible check (MTU 7029) were sown in two rows each with a spacing of 20 x 15 cm at Andhra Pradesh Rice Research Institute and Regional Agricultural Research Station, Maruteru, West Godavari District, Andhra Pradesh and were screened against sheath blight by adopting typha leaf bit method of artificial inoculation done at 69 DAS followed by field screening at maximum tillering stage and panicle initiation stage when 95% of check variety was affected using 0-9 scale of Standard Evaluation System give by IRRI, 2014 (Table 1). These families were also screened separately for bacterial leaf blight by following leaf clipping method for artificial multiplication of bacteria at 80 DAS followed by field screening at maximum tillering stage and later at panicle initiation stage when 95% of check variety TN-1 was affected using 0-9 scale of Standard Evaluation System (SES) of IRRI, 2014 (Table 2). Fertilizer management and plant protection measures for other pests and diseases were followed as per recommendations. Screening for disease resistance based on natural infection may not always be conclusive due to environmental variation and the absence of adequate inoculum that initiates the disease. Artificial inoculation minimizes such problems. Hence, for proper infestation and to get good reaction of test seedlings, artificial inoculation by typha leaf bit method for sheath blight and leaf clipping method for bacterial leaf blight were practiced in the present study.

Table 1: Standard Evaluation System, IRRI (2014) scale for sheath blight

Scale	Rating	Disease symptoms
0	Highly Resistant	No Infection (Immune reaction)
1	Resistant	Lesions limited to lower 20% of the plant height
3	Moderately Resistant	20-30
5	Susceptible	31-45
7	Highly Susceptible	46-65
9	Highly Resistant	>65

Table 2: Standard Evaluation System, IRRI (2014) scale for bacterial leaf blight

Scale	Rating	% Leaf area diseased
1	Highly Resistant	1-5
3	Resistant	6-12
5	Moderately Resistant	13-25
7	Susceptible	26-50
9	Highly Susceptible	51-100

Typha leaf bit method

This method was first used by Bhaktavatsalam *et al.* (1978) for mass multiplication of Sheath blight causing fungus. In this method, uniform sized typha bits were cut and sterilized in autoclave and inoculated with *Rhizoctonia solani*. The material is kept under wet condition for multiplication of the fungus. After complete coverage of the typha bits with fungal mat, the bits were used for artificial inoculation. Two bits per hill were used for artificial inoculation. The bits were inserted in between the tillers at the base of the plant and tied with thread so as to come in contact with the neighbouring tillers. Inoculated hills were observed for the appearance of the symptoms twice, initially at maximum tillering stage and later at panicle initiation stage and scores were recorded as per 0-9 scale of SES, IRRI, 2014. Highest score among the two was considered as final one.

Leaf clipping method

Kauffman *et al*. (1973) reported the leaf clipping method of artificial inoculation for bacterial leaf blight disease. In this method, sterilized surgical scissors dipped in bacterial suspension were used for inoculation. Leaves of all the three plants in a pot were grasped in one hand and the top 1-3 inches of three leaves were clipped off simultaneously. The inoculum should be used within two hours after preparation as *Xanthomonas oryzae* pv. *oryzae* quickly losses its viability. A control of each variety was also maintained, by using scissors dipped in sterile water for clipping off the leaves. This method is very efficient for inoculating large amount of breeding materials in the field and is currently being used at IRRI, Phillippines. One should note that in both seedling and field tests, folded young leaves and old leaves or leaves with symptoms of nutrient deficiency or other diseases should be avoided for inoculation.

Results and Discussion

Screening was conducted at Andhra Pradesh Rice Research Institute and Regional Agricultural Research Station, Maruteru during *kharif*, 2015 based on SES, IRRI, 2014. All the forty three F_5 families were grouped into five classes based on their susceptibility to that disease *viz.*, immune or highly resistant with score 1, resistant with score 3, moderately resistant with score 5, susceptible with score 7 and highly susceptible with score 9.

Immunity refers to the inability of the pathogen to cause disease symptoms on host plant. No yield loss will be observed in this case where as Resistance refers to the ability of a plant to overcome completely or in some degree the effect of a pathogen or damaging factor. Yield loss is very low or neglible when seen in economic terms. Moderately reistant plants can tolerate disease to some extent giving moderate to high yield when disease intensity is low where as suscetibility refers to inability of a plant to resist the effect of a pathogen or other damaging factor. Yield loss will be high in this case. Highly susceptible plants cannot withstand lower intensity of disease and complete yield loss will be observed under such circumstances. Practically it is very difficult to develop immune varieties. Hence plant breeders mostly concentrate on developing resistant and moderately resistant varieties.

In the present study, among the forty three F_5 families screened against sheath blight and bacterial leaf blight, no family was found to be immune or resistant. In the F_5 population obtained from the cross MTU 7029/ PAU 3116-25-5-1, among the fifteen F_5 families, six recorded moderate resistance (score 5) while nine were susceptible to sheath blight (score 7) where as two families recorded moderate resistance (score 5) while thirteen were susceptible (score 7) to bacterial leaf blight (Table 3).

Table 3: Screening of F_5 families for sheath blight and bacterial leaf blight resistance

Sl. No.	Cross	Number of families screened	Number of families with score		
			5	7	9
	Sheath blight resistance				
1	MTU 7029/ PAU 3116-25-5-1	15	6	9	-
2	MTU 7029/ PAU 3140-126-1	28	15	13	-
	Total	43	21	22	-
	Bacterial leaf blight resistance				
1	MTU 7029/ PAU 3116-25-5-1	15	2	13	-
2	MTU 7029/ PAU 3140-126-1	28	4	22	2
	Total	43	6	35	2

Out of twenty eight F_5 families obtained from the cross MTU 7029/ PAU 3140-126-1, fifteen families recorded moderate resistance (score 5) while thirteen families showed susceptibility (score 7) for sheath blight where as for bacterial leaf blight, four families recorded moderate resistance (score 5) while twenty two families showed susceptibility (score 7) in addition to two highly susceptible families which reported 9 score (Table 3).

In total, out of 43 F_5 families, 21 families reported moderate resistance to sheath blight while 22 families were susceptible. Regarding bacterial leaf blight, only six families showed moderate resistance while 35 families were susceptible and two families were found to be highly susceptible. Diseases resistance scores for all the 43 F_5 families were provided in table 4. Graphical representation for number of families under each cross was represented in Fig. 1. Similar results were reported by Channamallikarjuna *et al.* (2010), Ling *et al.* (2011), Shamim *et al.* (2014) and Yadav *et al.* (2015) for sheath blight and Ahmed Khan *et al.* (2009) and Thimmegowda *et al.* (2011) for bacterial leaf blight.

Three families MTU 2468-25-2-1, MTU 2469-6-1-2 and MTU 2469-6-5-1 recorded moderate resistance to both the diseases and hence can be selected (Table 4).

Table 4: Screening scores of 43 F_5 families

S. No.	Code	Entry	Cross Combination	Scores		Remarks
				ShB	Blb	
1	TSM-118	MTU 2468-1-1-1	MTU 7029/ PAU 3116-25-5-1	5	7	Moderately resistant to sheath blight but susceptible to bacterial leaf blight
2	TSM-120	MTU 2468-2-1-1	MTU 7029/ PAU 3116-25-5-1	7	5	Moderately resistant to bacterial leaf blight but susceptible to sheath blight
3	TSM-128	MTU 2468-8-2-1	MTU 7029/ PAU 3116-25-5-1	7	7	Susceptible to both the diseases
4	TSM-132	MTU 2468-18-1-1	MTU 7029/ PAU 3116-25-5-1	7	7	Susceptible to both the diseases
5	TSM-133	MTU 2468-18-1-2	MTU 7029/ PAU 3116-25-5-1	5	7	Moderately resistant to sheath blight but susceptible to bacterial leaf blight
6	TSM-134	MTU 2468-20-1-1	MTU 7029/ PAU 3116-25-5-1	7	7	Susceptible to both the diseases

S. No.	Code	Entry	Cross Combination	Scores		Remarks
				ShB	Blb	
7	TSM-138	MTU 2468-21-4-1	MTU 7029/ PAU 3116-25-5-1	7	7	Susceptible to both the diseases
8	TSM-141	MTU 2468-25-2-1	MTU 7029/ PAU 3116-25-5-1	5	5	Moderately resistant to both the diseases, hence can be selected
9	TSM-146	MTU 2468-27-2-1	MTU 7029/ PAU 3116-25-5-1	7	7	Susceptible to both the diseases
10	TSM-147	MTU 2468-28-1-1	MTU 7029/ PAU 3116-25-5-1	7	7	Susceptible to both the diseases
11	TSM-148	MTU 2468-29-2-1	MTU 7029/ PAU 3116-25-5-1	5	7	Moderately resistant to sheath blight but susceptible to bacterial leaf blight
12	TSM-149	MTU 2468-29-3-1	MTU 7029/ PAU 3116-25-5-1	5	7	Moderately resistant to sheath blight but susceptible to bacterial leaf blight
13	TSM-150	MTU 2468-29-4-1	MTU 7029/ PAU 3116-25-5-1	7	7	Susceptible to both the diseases
14	TSM-152	MTU 2468-30-2-2	MTU 7029/ PAU 3116-25-5-1	5	7	Moderately resistant to sheath blight but susceptible to bacterial leaf blight
15	TSM-153	MTU-31-1-1	MTU 7029/ PAU 3116-25-5-1	7	7	Susceptible to both the diseases
16	TSM-164	MTU 2469-6-1-2	MTU 7029/ PAU 3140-126-1	5	5	Moderately resistant to both the diseases, hence can be selected
17	TSM-165	MTU 2469-6-2-1	MTU 7029/ PAU 3140-126-1	7	7	Susceptible to both the diseases
18	TSM-166	MTU 2469-6-3-1	MTU 7029/ PAU 3140-126-1	7	5	Moderately resistant to bacterial leaf blight but susceptible to sheath blight
19	TSM-167	MTU 2469-6-3-2	MTU 7029/ PAU 3140-126-1	5	7	Moderately resistant to sheath blight but susceptible to bacterial leaf blight
20	TSM-168	MTU 2469-6-5-1	MTU 7029/ PAU 3140-126-1	5	5	Moderately resistant to both the diseases, hence can be selected
21	TSM-169	MTU 2469-7-1-1	MTU 7029/ PAU 3140-126-1	5	7	Moderately resistant to sheath blight but susceptible to bacterial leaf blight
22	TSM-171	MTU 2469-8-1-1	MTU 7029/ PAU 3140-126-1	5	7	Moderately resistant to sheath blight but susceptible to bacterial leaf blight
23	TSM-174	MTU 2469-10-2-1	MTU 7029/ PAU 3140-126-1	7	5	Moderately resistant to bacterial leaf blight but susceptible to sheath blight
24	TSM-175	MTU 2469-11-1-1	MTU 7029/ PAU 3140-126-1	5	7	Moderately resistant to sheath blight but susceptible to bacterial leaf blight
25	TSM-178	MTU 2469-14-1-1	MTU 7029/ PAU 3140-126-1	7	7	Susceptible to both the diseases
26	TSM-183	MTU 2469-23-2-1	MTU 7029/ PAU 3140-126-1	5	9	Moderately resistant to sheath blight but highly susceptible to bacterial leaf blight
27	TSM-184	MTU 2469-23-2-2	MTU 7029/ PAU 3140-126-1	5	7	Moderately resistant to sheath blight but susceptible to bacterial leaf blight
28	TSM-190	MTU 2469-32-1-1	MTU 7029/ PAU 3140-126-1	5	7	Moderately resistant to sheath blight but susceptible to bacterial leaf blight
29	TSM-191	MTU 2469-32-2-1	MTU 7029/ PAU 3140-126-1	7	7	Susceptible to both the diseases
30	TSM-200	MTU 2469-36-1-1	MTU 7029/ PAU 3140-126-1	5	7	Moderately resistant to sheath blight but susceptible to bacterial leaf blight

S. No.	Code	Entry	Cross Combination	Scores		Remarks
				ShB	Blb	
31	TSM-204	MTU 2469-38-4-1	MTU 7029/ PAU 3140-126-1	5	7	Moderately resistant to sheath blight but susceptible to bacterial leaf blight
32	TSM-211	MTU 2469-41-2-2	MTU 7029/ PAU 3140-126-1	7	7	Susceptible to both the diseases
33	TSM-213	MTU 2469-42-1-1	MTU 7029/ PAU 3140-126-1	5	7	Moderately resistant to sheath blight but susceptible to bacterial leaf blight
34	TSM-215	MTU 2469-42-3-1	MTU 7029/ PAU 3140-126-1	7	7	Susceptible to both the diseases
35	TSM-216	MTU 2469-42-4-1	MTU 7029/ PAU 3140-126-1	7	7	Susceptible to both the diseases
36	TSM-219	MTU 2469-55-1-1	MTU 7029/ PAU 3140-126-1	7	7	Susceptible to both the diseases
37	TSM-220	MTU 2469-55-2-1	MTU 7029/ PAU 3140-126-1	7	7	Susceptible to both the diseases
38	TSM-221	MTU 2469-55-2-2	MTU 7029/ PAU 3140-126-1	5	7	Moderately resistant to sheath blight but susceptible to bacterial leaf blight
39	TSM-223	MTU 2469-57-1-2	MTU 7029/ PAU 3140-126-1	7	7	Susceptible to both the diseases
40	TSM-228	MTU 2469-68-1-1	MTU 7029/ PAU 3140-126-1	5	7	Moderately resistant to sheath blight but susceptible to bacterial leaf blight
41	TSM-229	MTU 2469-68-1-2	MTU 7029/ PAU 3140-126-1	5	7	Moderately resistant to sheath blight but susceptible to bacterial leaf blight
42	TSM-230	MTU 2469-68-2-1	MTU 7029/ PAU 3140-126-1	7	9	Susceptible to sheath blight and highly susceptible to bacterial leaf blight
43	TSM-235	MTU 2469-74-2-1	MTU 7029/ PAU 3140-126-1	7	7	Susceptible to both the diseases
44		MTU 7029		9	-	Highly susceptible check for sheath blight
45		TN-1		-	9	Highly susceptible check for bacterial leaf blight

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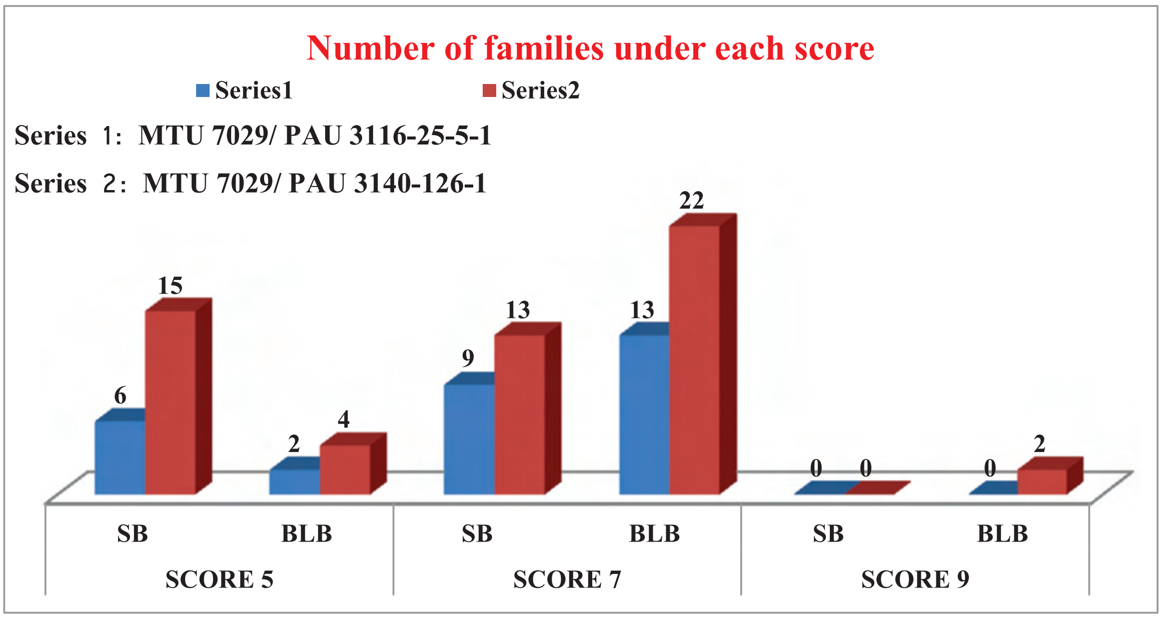

Fig. 1. Graphical representation of number of families of each cross under each score

ORIGINAL RESEARCH ARTICLE OPEN ACCESS

Evaluation of Rice (*O. sativa* L.) Genotypes Carrying the Drought QTL Under Moisture Stress and Non-Stress Condition

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Received: 14th April, 2016; Accepted 30th June, 2016

Abstract

A field screening of thirty six rice genotypes carrying the drought QTLs comprising advanced breeding lines and current high yielding varieties was carried out under moisture stress and non-stress natural field condition with the objective to study the effect of drought stress on yield and yield attributes performance. Results revealed a significant reduction in grain yield under water stress condition in most of the genotypes as compared to non-stress condition. Out of these thirty six rice genotypes, IR 92523-35-1-1-1, IR 94314-20-2-1-B and IR 92546-33-4-2-3 were found to be superior in terms of grain yield. These genotypes may further be used in drought breeding programme as well as adoption in rainfed lowland ecosystem and fulfill the gap of availability of drought tolerant varieties for the less rainfall areas of Bihar.

Keywords: Drought, grain yield, rain fed lowland, rice

Introduction

Drought is the most serious abiotic stress reducing rice production and cause yield instability even in rain fed lowland ecosystem of eastern India. In Asia, at least 23 million ha (about 20% of the total area) under rain fed rice is drought prone (Pandey *et al.,* 2000). Economic losses can be minimized with availability of drought tolerant cultivars with improved yield. Some traditional rice varieties are still grown, partly due to their greater drought tolerance and yield stability, but these have low yield potential (Mackill *et al.,* 1996). Breeding of drought tolerant rice with improved yield suitable for rain fed areas is an efficient way to overcome this natural disaster.

Being a semi aquatic crop, rice gets severely affected by even moderate intensities of drought and varying levels of yield decline can be seen depending on the variety. Conventional and molecular breeding approaches targeting these traits have been used in the past to develop drought tolerant rice varieties. It has been reported that the progress in breeding for drought tolerance has been slow. One of the reasons for this is the complexity of genetic control of grain yield under drought. The traits related to yield potential such as number of tillers, panicles, and fertile grains can play a role in determining the yield under drought. Low yield potential under non stress conditions has also been known as another setback for several drought breeding programs and leads to difficulty in release and/or adaptation of the lines. While selection for all the drought attributing traits becomes difficult simultaneously, hence using grain yield *per se* as a selection criterion in a large population can be an efficient alternative. Despite availability of a large number of traits affecting drought related traits and some of these QTLs being able to explain a large proportion of phenotypic variance for the traits, very few reports of their utilization for marker assisted selection (MAS) exist. The possible reasons for this could be the inconsistency of QTLs across varying environments and the lack of high effect on grain yield (Ashraf, 2010). MAS programs targeting multiple QTLs related drought tolerance as well as that targeting grain yield *per se* seem to be more effective in enhancing the yield under drought (Dixit *et al*., 2014).

Most improved cultivars grown in drought prone rain fed lowlands were originally bred for irrigated conditions and were never selected for drought tolerance (Kumar *et al.*, 2015). Traditional as well as high yielding varieties of the eastern region are also highly susceptible to drought, particularly at reproductive stage. Degree and duration of drought stress during the reproductive stage in rain fed lowland rice is in need of development of drought tolerant rice cultivars (Kamoshita *et al*., 2008) which must survive under water deficit stress at reproductive stage, quickly recover, and grow rapidly upon renewed availability of soil moisture (De Datta *et al*., 1988).

Materials and Methods

Two separate experiments were conducted with of thirty six medium maturity duration rice genotypes carrying QTLs for drought tolerance including three checks namely MTU 1010, IR 64 and Lalat under normal and reproductive stage drought condition at rice research farm of Bihar Agricultural University, Sabour, (Bihar), India during *Kharif*, 2014. The drought QTLs in all the entries under study has been reported by (Kumar *et al.*, 2014). The genotypes (Table 1) used in these experiments were obtained from International Rice Research Institute (IRRI), Philippines under STRASA (Stress-Tolerant Rice for Africa and South Asia) (STRASA) project.

Table 1: Details of the entries and their parentage used in the present study

Sl. No.	Entry	Parentage
1.	CRR 719-1-B (IR 88903-34)	IR 77298-5-6-18/IR05N359
2.	CRR 724-1-B (IR 88889-44)	IR 77298-14-1-2-10/IR05A260
3.	RP 1-27-7-6-1-2-1	TAICHUNG NATIVE 1/ T 141
4.	IR 94313:18-4-1-4-1-B	IR 81896-B-B-195/2*IR05F102
5.	IR 88287-383-1-B-B-1-1-B	IR 81896-B-B-182/2*SWARNA
6.	IR 94391-587-1-2-B	IR 81896-B-B-195/3*IR05F102
7.	IR 94314-20-2-1-B	IR 94312:1/SWARNA
8.	IR 93339:40-B-18-13-B-B-1	IR 77298-14-1-2-10/SANHUANGZHAN NO 2//IR 45427-2B-2-2B-1-1/ NSIC RC 158///IRRI 123/IR 4630-22-2-5-1-3//FEDEARROZ 50/IR07F287
9.	IR 92521-5-3-1-2	IR08L217/IR08L183
10.	IR 92521-7-5-1-1	IR08L217/IR08L183
11.	IR 92521-23-6-1-3	IR08L217/IR08L183
12.	IR 92521-24-5-1-3	IR08L217/IR08L183
13.	IR 92522-47-2-1-1	IR08L183/MTU 1010
14.	IR 92522-47-2-1-4	IR08L183/MTU 1010
15.	IR 92522-61-3-1-4	IR08L183/MTU 1010
16.	IR 92523-35-1-1-1	IR09L347/CNA 10657
17.	IR 92523-37-1-1-2	IR09L347/CNA 10657
18.	IR 92527-6-2-1-2	IR08L119/IR09N516
19.	IR 92527-6-2-1-4	IR08L119/IR09N516
20.	IR 92545-53-4-1-3	THADOKKHAM 1/IR 77298-14-1-2-10
21	CRR 719-1-B (IR 88903-34)	THADOKKHAM 1/IR 77298-14-1-2-10
22.	IR 92546-7-1-1-3	THADOKKHAM 1/IR08L119
23.	IR 92546-17-6-4-3	THADOKKHAM 1/IR08L119
24.	IR 92546-17-6-4-4	THADOKKHAM 1/IR08L119
25.	IR 92546-33-3-1-1	THADOKKHAM 1/IR08L119
26.	IR 92517-1-3-1-1	IRRI 154/IR08L118
27.	IR 92522-45-3-1-4	IR08L183/MTU 1010
28.	IR 92545-23-2-1-1	THADOKKHAM 1/IR 77298-14-1-2-10
29.	IR 92545-24-3-1-1	THADOKKHAM 1/IR 77298-14-1-2-10
30.	IR 92545-40-2-2-3	THADOKKHAM 1/IR 77298-14-1-2-10
31.	IR 92545-51-1-1-4	THADOKKHAM 1/IR 77298-14-1-2-10
32.	IR 92546-33-4-2-3	THADOKKHAM 1/IR08L119
33.	IR 92516-8-3-3-4	IRRI 154/IR08L119
34.	MTU 1010	MTU 2077 (KRISHNAVENI)/IR 64
35.	IR 64	IR 5657-33-2-1/IR 2061-465-1-5-5
36.	LALAT	OBS 677/IR 2071//VIKRAM/W 1263

Table 2: Soil moisture status at reproductive stage

S. No.	Date	Soil Moisture % at 15 cm depth	Soil Moisture % at 30 cm depth
1	14.9.14	43.26	42.34
2	15.9.14	35.39	34.43
3	16.9.14	31.51	29.24
4	17.9.14	24.61	20.51
5	18.9.14	23.90	22.28
6	19.9.14	21.26	20.45
7	20.9.14	20.66	19.41
8	21.9.14	19.23	18.54
9	22.9.14	27.07	20.22
10	23.9.14	24.74	22.78
11	24.9.14	21.84	20.87
12	25.9.14	18.41	17.28
13	26.9.14	17.74	16.12
14	27.9.14	44.10	31.28
15	28.9.14	32.56	26.81
16	29.9.14	24.41	17.61
17	30.9.14	22.12	14.86

On 11th June, 2015 the genotypes were sown in nursery and 21 days old seedlings were transplanted in puddle field under the normal growing conditions in an 8.0 m^2 plot. The single rice seedlings were transplanted manually in puddle field spaced 20 cm apart. Row to row space was maintained at 20 cm. After 7 days, missing hills were again re-transplanted fresh. Two experiments, each for normal and reproductive drought conditions were laid out with the same set of genotypes in alpha lattice design with three replications Field was thoroughly prepared and well leveled before transplanting so that if rainfall occurred at reproductive stage, water should not be stagnant in drought stress field. In each plot, a uniform plant stand was maintained and standard agronomic practices were followed for raising and maintenance of plants. Non-stress irrigated experimental field was kept continuously flooded with 5 cm water after transplanting until 25 days before harvest. Under drought stress experimental field, the crop was grown under normal irrigation for four weeks after transplanting and then irrigation was withdrawn for next one month and beyond, till the susceptible checks showed permanent wilting. During the reproductive stage stress period soil moisture status (Table 2) was monitored through periodical soil sampling at 15 and 30 cm soil depth. Observations of yield and yield contributing traits *i.e.* days to 50% flowering (DFF), plant height (PH) and grain yield (GY) in kg/ha were recorded on plot basis.

Results and Discussion

The results related to performance of yield and yield attributes in rice genotypes under drought stress at reproductive stage and irrigated condition are presented in (Table 3). The analysis of variance revealed significant differences among the genotypes for yield and yield attributing characters. Under control condition, yield varied from 3417kg/ha (CRR 724-1-B (IR 88889-44) to 5708 kg/ha (RP 1-27-7- 6-1-2-1) and under stress condition it varied from 3102 kg/ha (CRR 724-1-B (IR 88889-44) to 5139 kg/ha (IR 92523-35-1-1-1). Among checks, Lalat recorded highest grain yield of 5000 kg/ha and 4491 kg/ha under control and reproductive drought condition, respectively. None of the genotypes under testing found to be significantly superior over the best check Lalat. However, under reproductive stress conditions, entry IR 92523-35-1-1-1 (5139 kg/ha) followed by IR 94314-20-2-1-B (4954 kg/ha) and IR 92546-33-4-2-3 (4908 kg/ha) were found to be superior to the best check Lalat for grain yield. Yield reduction under drought condition was recorded ranging from 0-23 percent. One of the reasons for this is the complexity of genetic control of grain yield under drought. One or more of the traits mentioned above along with traits related to yield potential such as number of tillers, panicles and fertile grains can play a role in determining the yield under drought. Lowest yield reduction *i.e.* almost zero % was recorded for entry CRR 719-1-B (IR 88903-34) which was lowest yielder under both the situations. Seven entries recorded only one percent yield reduction under stress condition, of which, IR 94314-20-2-1-B recorded highest yield, *i.e.* 5000 kg/ha and 4954 kg/ha, under control and stress condition, respectively. Among checks, MTU 1010 recorded lowest yield reduction under stress (6%) followed by Lalat (10%) and IR 64 (13%).

Rice genotypes grown under water stress condition produced significantly lower grain yield than irrigated condition. Yield decline was observed almost in all the rice genotypes grown under stress condition. The range of yield varied from 3102 kg/ha (CRR 724-1-B (IR 88889-44) to 5139 kg/ha (IR 92523-35-1-1-1) under water stress condition as compared to non-stress (control) where yield varied from 3417 Kg/ha (CRR 724-1-B (IR 88889-44) to 5708 kg/ha (RP 1-27-7- 6-1-2-1). Under drought stress condition, the highest grain yields was observed in IR 92523-35-1-1-1 (5139 kg/ha) followed by

Table 3: Yield and yield attributes response of rice genotypes and check varieties to drought stress and non-stress condition

Sl. No.	Entry	Days to 50% flowering		Plant height (cm)		Grain yield (Kg/ Ha)		% reduction in yield under stress
		Control	**Stress**	**Control**	**Stress**	**Control**	**Stress**	
1.	CRR 719-1-B (IR 88903-34)	76	78	114	98	4083	4074	0.23
2.	CRR 724-1-B (IR 88889-44)	74	75	118	106	3417	3102	9.21
3.	RP 1-27-7-6-1-2-1	79	80	113	98	5708	4722	17.27
4.	IR 94313:18-4-1-4-1-B	76	79	103	105	4708	4213	10.52
5.	IR 88287-383-1-B-B-1-1-B	85	83	102	103	4708	4676	0.69
6.	IR 94391-587-1-2-B	79	77	106	107	4792	4074	14.98
7.	IR 94314-20-2-1-B	83	84	106	101	5000	4954	0.93
8.	IR 93339:40-B-18-13-B-B-1	85	83	108	108	4833	4769	1.34
9.	IR 92521-5-3-1-2	78	80	119	105	4625	4074	11.91
10.	IR 92521-7-5-1-1	81	78	112	109	4583	3884	15.25
11.	IR 92521-23-6-1-3	78	84	114	103	4833	4023	16.76
12.	IR 92521-24-5-1-3	77	80	111	102	4417	4352	1.47
13.	IR 92522-47-2-1-1	81	82	104	110	4875	4398	9.78
14.	IR 92522-47-2-1-4	80	80	110	102	4375	3704	15.34
15.	IR 92522-61-3-1-4	78	78	108	106	4417	4356	1.36
16.	IR 92523-35-1-1-1	80	81	108	106	5250	5139	2.12
17.	IR 92523-37-1-1-2	81	86	106	109	4917	4630	5.84
18.	IR 92527-6-2-1-2	82	82	105	94	5500	4755	13.55
19.	IR 92527-6-2-1-4	81	82	96	96	5417	4704	13.16
20.	IR 92545-53-4-1-3	76	78	108	103	4167	3889	6.67
21	CRR 719-1-B (IR 88903-34)	78	81	111	99	3958	3935	0.58
22.	IR 92546-7-1-1-3	54	82	113	100	4792	4120	14.01
23.	IR 92546-17-6-4-3	80	80	102	102	5708	4653	18.49
24.	IR 92546-17-6-4-4	78	79	100	102	4833	4722	2.30
25.	IR 92546-33-3-1-1	78	79	111	106	4917	4352	11.49
26.	IR 92517-1-3-1-1	80	81	104	103	4875	4213	13.58
27.	IR 92522-45-3-1-4	82	81	100	100	4667	4444	4.76
28.	IR 92545-23-2-1-1	80	86	113	101	4125	4074	1.23
29.	IR 92545-24-3-1-1	77	80	103	114	4333	3889	10.26
30.	IR 92545-40-2-2-3	81	82	109	118	4708	3889	17.40
31.	IR 92545-51-1-1-4	82	84	113	107	4792	4306	10.14
32.	IR 92546-33-4-2-3	83	82	103	101	5083	4907	3.46
33.	IR 92516-8-3-3-4	88	85	107	101	5208	3986	23.47
34.	MTU 1010	76	77	111	110	4750	4537	4.48
35.	IR 64	77	77	109	95	4958	4306	13.17
36.	LALAT	85	82	110	102	4583	4491	2.02
Mean		**79**	**81**	**108**	**104**	**4748**	**4314**	
CV (%)		**0.98**	**0.72**	**5.54**	**5.62**	**10.88**	**10.55**	
LSD (5%)		**1**	**1.0**	**10**	**10**	**841**	**741**	

IR 94314-20-2-1-B (4954 kg/ha) and IR 92546-33-4-2-3 (4908 kg/ha). The difference in grain yield between drought stress and non-stress rice was 2.12 % in IR 92523-35-1-1-1. Yield reduction under drought condition ranged from 0.23 to 23.48% percent. These findings were in accordance with the result of (Kumar *et al*., 2015). Under irrigated condition, maximum grain yield was observed in 5708 kg/ha (RP 1-27-7- 6-1-2-1), IR 92527-6-2-1-4, followed by IR 92516-8-3-3-4 and IR 92527-6-2-1-2. Significant decrease in plant height was also observed in rice genotypes grown under drought stress condition. Singh (2000) also reported significant reduction in plant height due to drought in rice cultivars. Variations were observed among genotypes for drought tolerance parameters leaf rolling, leaf drying and stress recovery. Drought tolerance genotypes *viz*., IR 92523-35-1-1-1 followed by IR 94314-20-2-1-B and IR 92546-33-4-2-3 had lesser leaf rolling, leaf drying and better stress recovery. They showed delayed leaf rolling and drying. According to (Hsiao, 1982) leaf rolling was induced by the loss of turgor and poor osmotic adjustment in rice and delayed leaf rolling is an indication of turgor maintenance and dehydration avoidance (Blum *et al.*, 1999).

The yield reduction difference between drought stress and non-stress rice ranged between 0.23 to 23.48% (Fig.1). The minimum yield reduction was observed in CRR 719-1-B (IR 88903-34) (0.23%) followed by IR 92545-54-6-1-4 (34.70.58%) whereas maximum yield reduction recorded in IR 92516-8-3-3-4 (23.48 %). A similar result of yield reduction under drought stress condition was reported by (Ouk *et al*. 2006). They reported 12 to 46% reduction in grain yield under drought affect condition. In other studies in Cambodia, (Basnayake *et al*. 2004) estimated yield reduction due to drought from 9 to 51% in rice genotypes in multi-locational trial conducted in three year in the target environment.

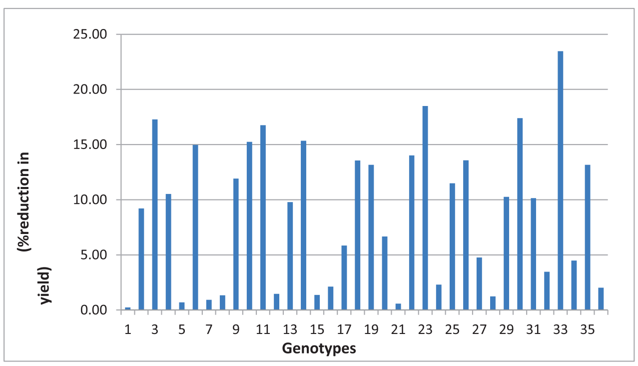

Fig. 1: Percentage yield reduction in promising rice genotypes and check varieties under reproductive stage drought stress condition compared to control

Conclusion

The present study suggested the existence of variation among the genotypes for grain yield and yield contributing morpho-physiological traits which showed differential response to drought stress environment at reproductive stage. Drought stress at reproductive stage caused significant reduction in plant height, grain yield, plant biomass in rice genotypes; however, the responses varied among the genotypes. Further yield improvements in drought situation can also be achieved by identifying physiological and biochemical traits contributing for tolerance against water stress by selection of promising drought tolerant rice genotypes on the basis of yield and yield attributing traits. The genotypes namely IR 92523-35-1-1-1 showed significant yield advantage over check varieties which was followed by IR 94314-20-2-1-B and IR 92546-33-4-2-3 under drought stress condition. The QTLs present in the identified superior lines are *qDTY3.1, qDTY6.1* and *qDTY6.2* introgressed from IR55419-04 in IR 92523-35-1-1-1, *qDTY1.1* from N22 in IR94314-20-2-1-B and *qDTY3.1* and *qDTY2.1* from IR55423-01 in IR 92546-33-4-2-3 (Kumar *et al.*, 2014).

These genotypes carrying QTLs for drought tolerance can be adopted in large area in rainfed lowland ecosystem of Bihar where drought is regular phenomena, particularly at reproductive stage. These promising genotypes may fulfill the gap of availability of drought tolerant varieties for the less rainfall areas of Bihar.

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ORIGINAL RESEARCH ARTICLE OPEN ACCESS

Stability of TGMS Lines under Different Temperature Regimes for Pollen Sterility

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Received: 8th January, 2016, Accepted: 20th May, 2016

Abstract

The new TGMS lines developed at TNAU *viz*., TNAU 45S, TNAU 60S, TNAU 95 S, TNAU 19S and TNAU 39S were evaluated for their stability of pollen sterility under different temperature regimes. A multi location experiments were conducted at Coimbatore, Sathiyamangalam and Hybrid Rice Evaluation Centre, Gudalur during the *rabi and kharif* seasons in 2013 & 2014. During the flowering stage all these lines showed 100% pollen sterility at both the locations and was test verified for next year also. The sterile stubbles of these lines were planted at HREC, Gudalur during May to induce fertility for their seed multiplication and were exposed at critical stages to fertility inducing temperature. At the time of flowering pollen fertility was observed and found that there was reversion in pollen fertility (more than 90%). The above TGMS lines with wider pollen sterility period under plains can be very well exploited for developing two line rice hybrids during the period of December to April. The same lines can be easily seed multiplied at Gudalur during April to November.

Keywords: Stability, TGMS, pollen sterility, rice

Introduction

Globally, rice is now being cultivated in 160 Mha with an annual production of around 650 million tonnes of rough rice and average productivity of 4.18 tons/ha. More than 90% of the rice is produced and consumed in Asian countries. In India, rice is cultivated in an area of 44.0 million hectare with a production of 103.41 million tons of paddy and an average productivity of 2.35 t/ha milled rice or 3.52 t/ha rough rice (India stat, 2012). The current Indian population of 1.22 billion is expected to reach 1.3 billion by 2020 and 1.53 billion by 2030 AD. So, to support such a huge population, rice production has to be increased by at least 70 per cent over next three decades to meet growing demand (Balkunde *et al*., 2013). A 70% increase in food production is required over the next four decades to feed an ever-increasing population. With the dwindling or stagnant agricultural land and water resources, the sought-after increases will therefore be attained mainly through the enhancement of crop productivity under eco-efficient crop production systems. Hybrid rice technology is one of the best options to increase the productivity. A new vista in hybrid rice breeding has been opened by successful development of two line hybrids using

Thermo Sensitive Genetic Male Sterile (TGMS) lines which further enhances the scope of exploiting the additional heterotic potential by 20–30 per cent. The main advantages of two-line heterosis breeding include the ability to use a wide range of genotypes as male parents, absence of negative effects associated with sterility-inducing cytoplasm and no need for maintainer lines. Male sterility in temperature sensitive genic male sterile (TGMS) lines is heritable. Higher temperature (>30^{o}C) results in sterility while lower temperature (<23^{o}C) results in fertility. These characteristic features of TGMS ease out the hybrid seed production and subsequently it was demonstrated that the TGMS was more effective in increasing grain yield and seed production efficiency (Yuan, 1990). Hence, the present study was undertaken with the specific objective of studying a set of promising TGMS lines for their fertility behaviour at different locations so as to use them in two-line heterosis breeding.

Materials and Methods

The new TGMS lines developed through various breeding methods at TNAU *viz*., TNAU 45S, TNAU 60S, TNAU 95S, TNAU 19S and TNAU 39S were selected for studying their sterility behavior across the environments. These TGMS lines were developed by pedigree breeding, mutation breeding and identification of spontaneous mutant in the breeding material. These TGMS lines are having medium duration with better agronomic characters and very good floral traits *viz*., high stigma exertion, wider glume opening and acceptable grain quality characters like medium slender grain type *etc*. Multi location experiments were conducted at Paddy Breeding Station, Coimbatore, Farmers field at Sathiyamangalam and Hybrid Rice Evaluation Centre, Gudalur during the *rabi and kharif* seasons in 2013 & 2014 to assess the pollen fertility expression under different temperature regimes in new generation temperature sensitive genic male sterile lines of TNAU. Weather parameters at Coimbatore and Gudalur during the past fifteen years were analyzed for fixing the sowing season (Fig. 1 & 2). *Tgms* lines were evaluated under two sterility inducing environments Coimbatore and Sathiyamangalam during the month of December 2013 & 2014 (*Rabi* 2013 & 2014). The same lines were stubble planted and evaluated for pollen sterility under pollen fertility inducing environment during the month of July *Kharif* 2013 & 2014 at high altitude (1500 MSL) with cool climate at Hybrid Rice Evaluation Centre, Gudalur. At the time of flowering pollen sterility was determined by staining the pollen grains with 1% Iodine Potassium Iodide solution (IKI) in all locations.

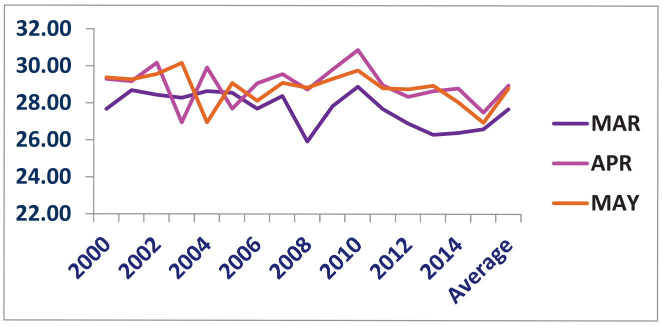

Fig. 1. Mean Weather data at Coimbatore Location

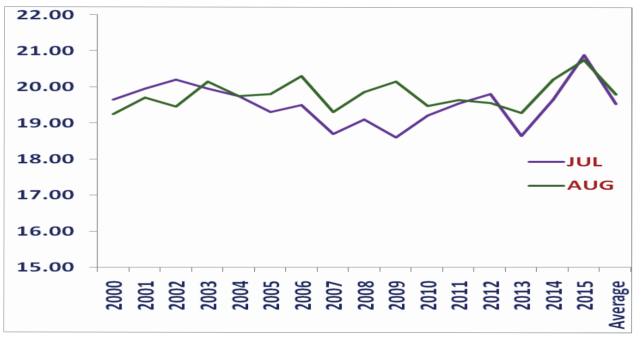

Fig. 2. Mean Weather data at Gudalur Location

Results and Discussion

The new TGMS lines developed at TNAU *viz*., TNAU 45S, TNAU 60S, TNAU 95 S, TNAU 19S and TNAU 39S were evaluated for their stability of pollen sterility under different temperature regimes were given in the Table 1. At sterility inducing environments, the lines showed 100 % pollen sterility. These lines were seeded during December at Coimbatore and Sathiyamangalam to expose them to a sterility inducing temperature (>29^{o}C /< 23^{o}C day night) during panicle initiation to flowering stage to test their sterility behavior so that their critical stage of flowering coincides with more than 29^{o}C. Both the locations weather data is provided in fig. 1 & 3 and it showed that both the places temperature recorded was >25^{0}C during the month of March, April and May. During the flowering stage, all these lines showed 100% pollen sterility at both the locations for more than 60 days and were test verified for next year also. (Latha *et al*., 2012) characterized a set of six promising TGMS lines for their fertility behaviour under field conditions. The pollen and spikelet fertility recorded on the plants raised at fortnightly interval revealed that all lines had stable sterile phase with 100 per cent pollen sterility for more than 50 consecutive days during high temperature condition (30/20°C maximum/minimum temperature) and they reverted to fertile during low temperature condition (less than 30/20°C) with more than 60 per cent pollen and spikelet fertility. The daily mean temperature of 24 to 26°C was found to be the critical temperature for fertility alteration. The sterile stubbles of these lines were planted at HREC, Gudalur during May to induce fertility for their seed multiplication and were exposed at critical stages to fertility inducing temperature (24^{o}C / 18^{o}C day / night). Maximum, minimum and mean temperature significantly influenced the pollen and spikelet fertility in all five TGMS lines at high altitude. Seed production potential in the TGMS lines during fertility reversion phase can be enhanced by growing them under medium hill regions of Gudalur (1500m MSL) in Nilgiris district (Kesary *et al*., 2015). At the time of flowering pollen fertility was observed and found that there was reversion in pollen fertility (more than 90%). The lines with complete pollen sterility under high temperature condition and more than 30 per cent self seed set under low temperature condition are considered as promising TGMS lines for commercial exploitation (Lu *et al*., 1994). Sanchez and Virmani, (2005) and Ramakrishna *et al*. (2006) also reported that the maximum, mean and minimum temperature played a significant role in the fertility of TGMS lines. The eight TGMS lines DDR 1S, DDR 18S, DDR 19S, DDR 20S, DDR 23S, DDR 27S, DRR 28S and DDR 29 which showed satisfactory seed-set percentage at high altitude (Bhaderwah) were completely sterile at low altitude (Chatha). (Sagotra *et al*., 2012). Evaluation of TGMS lines under Coimbatore and Gudalur increase the breeding efficiency of TGMS line development. Wide range of temperature differences prevailing in Tamil Nadu favour both hybrid seed production and the maintenance of TGMS in different locations (Siddiq and Ali, 1999). Jiang *et al.* (2015) reported that analysis of pollen sterility data in relation to temperature weather charts showed that when the DMT during 13 to 16 of September declined to below 22°C, the pollen grains of developed TGMS lines and C815S had shown reversal to partial fertility around 26 September and indicated that the sensitive stage to temperature located at 13 days before heading. At Gudalur the temperature range during the month of July and August was less than 20^{0}C. The appropriate sowing date of TGMS lines was fixed during June-July in such a way that the critical stages of panicle development would be exposed to the required temperature. The individual lines were maintained under isolation and genetically pure seeds were produced at Gudalur.

Table 1: Pollen sterility of different TGMS lines in Rice

TGMS lines	*Rabi* 2013		*Rabi* 2014		*Kharif* 2013	*Kharif* 2014
	COIMBATORE	BSR	CBE	BSR	GDR	GDR
TNAU 45S	100	100	100	100	5	4
TNAU 60S	100	100	100	100	3	5
TNAU 95S	100	100	100	100	6	5
TNAU 19S	100	100	100	100	7	9
TNAU 39S	100	100	100	100	4	6

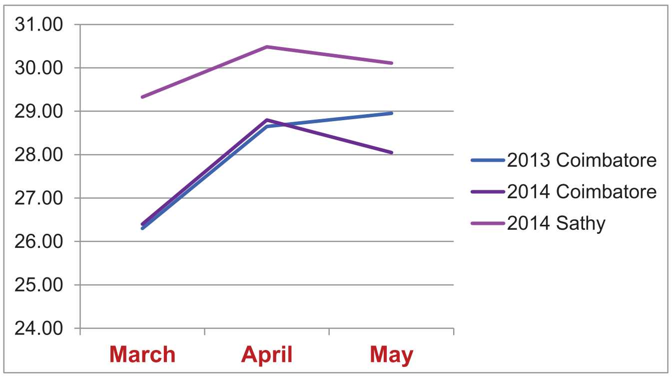

Fig. 3. Mean Weather data at Coimbatore and Sathyamangalam

Conclusion

The above TGMS lines with wider pollen sterility period under plains can be very well exploited for developing two line rice hybrids during the period of December to April. Seed production of the same lines can be easily done at Gudalur between July to November. These TGMS lines will not only reduce the cost of seed production but also increase the heterosis in rice hybrids as evidenced in our research. These TGMS lines with stable sterility can be exploited commercially for the development of two line rice hybrids in India.

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ORIGINAL RESEARCH ARTICLE OPEN ACCESS

Sulphur Application in Rice Blackgram Cropping System – Changes in Yield, Economics and Post Harvest Quality

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Received: 20th December, 2015; Accepted 14th March, 2016

Abstract

Field experiment was conducted during *kharif* 2006 and *rabi* 2006-07 in Sulphur (S) deficient clay soil of the Research Farm of Directorate of Rice Research, Rajendranagar, Hyderabad with the objective of applied, residual and cumulative effect of Sulphur on rice-blackgram cropping system. The experiment was conducted in split plot design with three replications. The main plot treatments included 2 fertilizer schedules and subplot treatments were 4 S schedules. The results revealed that in rice, recommended fertilizer dose (RFD) has given significantly higher grain yield of (5.20 t/ha) over half the RFD (4.70 t/ha). Among the sulphur schedules, Sulphur application in *kharif* has given maximum grain yield (5.56 t/ha) followed by Sulphur application in both *kharif* and *rabi* seasons (5.23 t/ha). Straw yield showed similar trend as that of grain yield at fertilizer levels and S schedules. Blackgram has given maximum seed yield (1.8 t/ha) with RFD applied in *kharif*. Among the S schedules, application in *kharif* or *rabi* or both *kharif* and *rabi* resulted in significantly higher seed yield. Stalk yield was significantly high with S application in both *kharif* and *rabi* at both fertilizer levels. Rice equivalent yield was maximum with RFD (10.14 t/ha). S application in *kharif* (10.31 t/ha) followed by S application in both *kharif* and *rabi* (10.14 t/ha) recorded higher yields. Economics have shown that, gross returns obtained were high with RFD+S application in both *kharif* and *rabi*. Net returns were high with RFD + S application during *kharif* season. In S deficient clay soil, S application significantly increased the productivity of rice-blackgram cropping system.

Key words: Sulphur, cropping system, rice, blackgram, rice equivalent yield, economic return

Introduction

Sulphur is considered as the fourth major nutrient for crops (Platou and Jones, 1982). It is a critical nutrient for crop growth, and it's deficiency is accentuated in soils of the tropics by intensive agricultural practices, less use of organic manures, removal of crop residues and leaching of Sulphur by heavy rains (Yadvinder Singh *et al.*, 2005). Deficiency is also caused by absence of Sulphate containing fertilizers, low Sulphur content in irrigation water, rain water and soil condition. As a result of leaching and lack of replenishment of the nutrients lost, soils of the tropical region are either inherently deficient in Sulphur or are likely to become more deficient due to continuous cropping. Sulphur deficiency in soil adversely affects not only the crop yields but also the nutritional quality of the crop. Sulphur deficiency is common in crop rotations including pulses and oil seeds.Sulphur contributes to an increase in crop yields in three different ways as it provides a direct nutritive value; it provides indirect nutritive value as soil amendment; it improves use efficiency of other essential plant nutrients, particularly nitrogen and phosphorus. To augment the production of legume crops, S may be identified as a key element and fertilizer S must form part of the integrated management program. Hence present study was conducted with the objective of applied, residual and cumulative effect of Sulphur on rice-blackgram cropping system.

Materials and Methods

Field experiment on rice pulse system was conducted during *kharif* and *rabi* seasons of 2008-09 in the research farm of Directorate of Rice Research. The soil is clayey in texture with a pH of 8.28 and EC of 0.665 dsm-1. The organic carbon content was 0.56 %.The available N, P_20_5 and K_2O status of the soil were 314, 109 kg/ ha respectively. The soil was deficient in available Sulphur (8.32 ppm). The main plot treatments included 2 fertilizer schedules (F1-RFD (Recommended Fertilizer Schedule-100:50:50 NPK); F2 -Half the RFD); 4 S Schedules as subplot treatments (S1 No sulphur; S2 Sulphur during *kharif* ; S3 Sulphur during *rabi*; S4 Sulphur during *kharif* and *rabi*). The experiment was laid out in split plot design with three replications. The fertilizer levels of N, P_2O_5 and K_2O were as per the general recommendation (120:60:40). Sulphur was applied as per the treatments @ 30 kg/ha as Ammonium Sulphate. Half the dose of Nitrogen as Ammonium Sulphate and full dose of P_2O_5 and K_2O as diammonium phosphate, and K_2O as muriate of Potash, was applied basically. The balance N was applied in two equal splits at maximum tillering and panicle initiation stage in the form of urea. During *rabi* season blackgram was sown by using residual moisture and nutrients except S treatments. All the other cultural operations were followed as per the package of practices to rice and blackgram crops then and there.

The available Sulphur was estimated colorimetrically using soil extraction with 0.15% $CaCl_2$ solution (Williams and Steinbergs, 1959). The grain yields were recorded and analysed statistically. Economics including cost and returns were calculated.

Results and Discussion

Yield

Recommended Fertilizer Schedule of 120:60:40 has given significantly higher grain yield of (5.20 t/ha) over half the recommended dose (4.70 t/ha) Table 1. Among the sulphur schedules, Sulphur application in *kharif* has given maximum grain yield (5.56 t/ha) followed by Sulphur application in both *kharif* and *rabi* seasons (5.23 t/ha). The interaction of fertilizer levels and sulphur treatments were significant. Straw yield showed similar trend as that of grain yield at fertilizer levels and S schedules except that interactions were not significant. Though the visual deficiency symptoms were not appeared due to hidden hunger, there is apparent increase in growth and yield. The influence of Sulphur application on the rice yield was well explained by (Clarson and Ramaswami, 1992). Nambiar and Ghosh (1984) reported similar results in S deficient soils of Barrackpore where S application increased paddy yield by (1.2 t/ha).

Blackgram has given maximum seed yield of (1.8 t/ha) with RFD applied in *kharif*. Among the S schedules, application in *kharif* or *rabi* or both *kharif* and *rabi* resulted in significantly higher seed yield than no Sulphur plot. Interactions were found to be significant. Stalk yield was significantly high with S application in both *kharif* and *rabi* at both fertilizer levels and interactions were not significant. Table 1. Aulakh and Pasricha (1986) also demonstrated that application of Sulphur containing phosphrous fertilizer gave an extra yield over S free nitrogen and phosphorus fertilized plots.

Rice equivalent yield was maximum with RFD (10.14 t/ha). S application in *kharif* (10.31 t/ha) followed by S application in both *kharif* and *rabi* (10.14 t/ha) recorded higher yields. Interactions were significant (Table 1).

Economics

The cost of cultivation was high (Rs. 28,612/-) in the treatment with RFD + S application in both *kharif* and *rabi* seasons and low in treatment with half the recommended dose +No S application (Rs. 176,00/-). Gross returns obtained were high with RFD + S application in both *kharif* and *rabi*. Net returns were high with RFD+ S application during *kharif* season (Table 1). Tandon (1986) reported that such high levels of profitability have been obtained on fields which were deficient in S and in the absence of optimum levels of other nutrients.

Post harvest quality of Paddy

Head rice recovery (%) and polished rice (%) were significantly influenced by S schedules. Maximum % were observed in treatments with S application during *kharif* season, S application during both seasons. The hulling % was not influenced by S application. Whereas milling % was significantly influenced by S application during *kharif* and during both seasons. Interaction of fertilizer levels and S schedules also showed the similar trend. The brokens % was more in S control treatments than S applied during paddy season and applied during both seasons (Table 2).

Nutrient composition

In paddy seed the nitrogen content was influenced by fertilizer levels and S schedules. S schedules except control have influenced similarly. The N content ranged from 0.86 to 0.93% and Protein content 5.14 to 5.52%. Phosphorus content was influenced by S application during *rabi*. Sulphur schedules altered K content significantly with highest being observed in *rabi* season plot. S schedules have significant influence on S content of grain. Except control, S applied in any season or both seasons increased S content considerably (0.44 to 0.46%). Zinc content of paddy grain was not altered by any of the treatments (Table-3).

In black-gram seed, N content was significantly influenced by fertilizer levels, S schedules. Recommended dose has resulted in maximum N content of 3.57%. Among S schedules, S application in both seasons resulted in significantly high N content. Protein content followed similar trend as that N content with highest of 22.82% with recommended dose+S application during both seasons. Phosphorus content was also significantly high with S application during both seasons & during *rabi* season. Potassium content of seed was not influenced significantly by any of the treatments. Sulphur content was altered significantly by S schedules. Application of S during both seasons and during current *rabi* season only. Were on par (0.31 and 0.30%). Fertilizer levels or interactions were not significant enough to alter S content. Zinc content was influenced significantly by S schedules and S application in both the seasons and during *rabi* season recorded significantly high content of 77.67 – 76.67 ppm (Table 3).

Conclusion

In S deficient clay soil, S application during *kharif* season significantly increased the productivity of rice-blackgram cropping system.

Table 1: Yield and economics of Rice-Blackgram System as influenced by Sulphur nutrition

Rice (t/ha) Grain	Sub-plot treatments (S1,S2,S3,S4)			Blackgram		Rice equivalent yield	Cost of cultivation	Gross returns	Net returns	C : B Ratio
			Straw	Seed	Stalk	(t/ha)	(Rs./ha)	(Rs./ha)	(Rs./ha)	
Half RFD	Control	3.71	5.01	0.87	2.50	6.07	17600	39152	21552	2.22
	S in *kharif*	5.47	5.66	1.59	3.80	9.76	22406	62952	40546	2.81
	S in *rabi*	4.38	5.45	1.70	3.40	8.97	22406	57857	35451	2.58
	S in *kharif* and *rabi*	5.21	5.91	1.73	4.57	9.87	27212	63662	36450	2.34
RFD	Control	4.88	3.49	1.46	3.20	8.81	19000	56825	37825	2.99
	S in *kharif*	5.64	4.80	1.94	3.97	10.86	23806	70047	46241	2.94
	S in *rabi*	5.04	4.50	1.98	3.53	10.38	23806	66951	43145	2.81
	S in *kharif* and *rabi*	5.24	4.71	1.92	5.63	10.41	28612	67145	38533	2.35
C.D.(0.05)	M x S	0.24	NS	0.12	NS					
	S x M	0.25	NS	0.13	NS					
Main										
	Half RFD	4.70	4.34	1.47	3.57	8.67	22406	55941	33535	2.50
	RFD	5.20	5.51	1.82	4.08	10.11	23806	65235	41429	2.74
C.D.(0.05)		0.26	0.23	0.15	NS					
C.V. (%)		2.97	2.59	5.30						
Sub										
	Control	4.30	4.25	1.16	2.85	7.44	18300	47982	29682	2.62
	S in *kharif*	5.56	5.23	1.76	3.88	10.31	23106	66512	43406	2.88
	S in *rabi*	4.71	5.00	1.84	3.47	9.68	23106	62404	39298	2.70
	S in *kharif* and *rabi*	5.23	5.31	1.82	5.10	10.14	27912	65429	37517	2.34
C.D.(0.05)		0.17	0.36	0.08	0.59					
C.V. (%)		2.77	5.80	3.99	12.35					
Exp. Mean		4.95		1.65	3.83					

Table 2: Post Harvest quality of paddy

Treatments		Hulling %	Milling %	Polished Rice %	HRR%	Brokens %
Main	**F1**	81.1	74.8	81.3	68.3	37.6
	F2	75.0	75.5	89.4	72.1	41.6
CD(0.05)		NS	NS	NS	NS	NS
Sub	**S1**	76.5	58.2	72.2	67.0	41.5
	S2	70.5	84.8	82.4	71.5	37.9
	S3	86.4	70.0	81.7	69.9	40.3
	S4	78.8	83.7	85.1	78.4	38.7
CD (0.05)		NS	10.7	6.3	5.1	NS
F at same S		NS	15.2	8.9	7.3	22.9
S at same F			21.2	14.6	9.1	23.6

Table 3: Nutrient composition of paddy and Black-gram seed in rice-Blackgram system

Treat-ment	Sulphur content %		N content %		Protein content %		P content %		K content %		Zn content ppm	
	Paddy	Black gram	Paddy	Black gram	Paddy	Black gram	Paddy	Black gram	Paddy	Black gram	Paddy	Black gram
120-60-40 NPK	0.43	0.28	0.83	3.48	4.91	20.95	0.31	0.65	0.16	1.03	10.83	72.50
60-30-20 NPK	0.44	0.30	0.89	3.57	5.30	21.84	0.37	0.71	0.17	1.02	14.58	73.50
CD(0.05)	*NS*	NS	*0.06*	0.03	*0.38*	0.63	*NS*	NS	*NS*	NS	*NS*	NS
Control	0.39	0.27	0.75	3.36	4.44	20.61	0.35	0.60	0.16	1.03	10.50	66.67
S-*kharif*	0.44	0.29	0.86	3.54	5.14	20.99	0.30	0.65	0.15	1.06	13.50	71.00
S-*rabi*	0.46	0.30	0.89	3.54	5.32	21.69	0.41	0.71	0.21	0.95	12.50	76.67
S-*kharif &rabi*	0.45	0.31	0.93	3.67	5.52	22.29	0.29	0.75	0.13	1.05	14.33	77.67
CD (0.05)	0.02	0.03	0.07	0.09	0.41	0.14	0.07	0.07	0.03	NS	NS	5.06
NPK at same S	0.05	NS	NS	0.12	NS	0.20	NS	0.10	0.05	NS	NS	7.16
S at same NPK	0.04	NS		0.11		0.36		0.11	0.04	NS		6.60

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ORIGINAL RESEARCH ARTICLE OPEN ACCESS

Response of Rice Genotypes for Heat Stress during Summer Season in the Northern Parts of Karnataka

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Received: 20th December, 2015; Accepted 14th April, 2016

Abstract

Global warming results in high temperature-induced floret sterility in rice. The anticipated high temperature will induce floret sterility and increase the instability of rice yield even in temperate regions. In the Tungabhadra command area of Karnataka, India, the rice is being grown to an extent of 3.5 lacks ha during summer season, the temperature in the months of April and May rise upto 40^{o}C, during which the crop suffer from terminal heat stress and leads to more spikelet sterility resulting the chaffyness of grains. Hence in the present investigation, as the part of development of rice varieties for high temperature tolerance, forty rice accessions were screened for heat tolerance. The experiment was carried out at the Agriculture Research Station Gangavathi, University of Agricultural Sciences, Raichur during *summer* season 2014 to screen the forty rice accessions received from the IRRI, India office, ICRISAT Hyderabad, with Gangavati sona, IR-64, MTU 1010 and N-22 as checks. Transplanting was taken up with a row spacing of 20 cm between rows and 15 cm between plants. Among the forty accessions screened for heat tolerance, the check N-22 (66.00 days) was the earliest to days to 50 per cent flowering followed by the accessions EC792177 and EC792206. Number of tillers per plant at maturity was significantly highest (22.50) in the accession EC792195 followed by the accessions EC792203 and EC792178 (17.30) which were on par with each other. Significantly highest thousand grain weight was recorded in the accessions EC792200 and EC792286 (25.00g). The significantly minimum per cent of chaffyness (0.40%) was recorded in the accession EC792183 followed by the accessions EC792179 (0.80%) and EC792216 (1.20%). The highest grain yield of 6167 kg/ha was recorded by accession EC792239 followed by EC792285 (5777 kg/ha) and EC792185 (5333 kg/ha), as against the checks MTU-1010(2520 kg/ha), N-22 (2400 kg/ha), IR-64 (2283 kg/ha) and Local check Gangavati sona (1490 kg/ha).

Keywords: Heat tolerance, rice, genotypes, summer

Introduction

Rice has been cultivated under a wide range of climatic conditions. Almost 90% of the World's rice is grown and consumed in Asia, where 50% of the population depends on rice for food. However, the rice crop during the sensitive flowering and early grain-filling stages is currently exposed top temperatures higher than the critical threshold of 33^{o}C in South Asia (Bangladesh, India) and South east Asia (Myanmar, Thailand) (Wassmann *et al*., 2009). Since the 1980s, the increase in the atmospheric concentration of greenhouse gases, such as carbon dioxide, is believed to cause the increase in air temperature (Hansen *et al.*, 1984). Global warming results in high temperature- induced floret sterility in rice. Jagadish *et al.* (2012) reported that high temperature stress negatively affects rice production, especially in vulnerable regions in South and Southeast Asia. High temperature stress is a major constraint in rice production in tropical and subtropical regions. Crop scientists have attempted to assess the effects of increasing temperature and high carbon dioxide concentration in the atmosphere on the growth and yield of rice using simulation models (Boote *et al.*, 1994; Horie *et al.*, 1996, 1997; Matthews *et al.*, 1997). Many reports confirmed that high temperature affects all rice growth stages, from emergence to ripening. However, the flowering stage and, to a lesser extent, the booting stage are the most sensitive to temperature (Imaki *et al.*, 1982; Shah *et al.*, 2011). Horie *et al.* (1996) suggested that the anticipated high temperature will induce floretsterility and increase the instability of rice yield even in temperate regions. The main cause of floret sterility, which is induced by high temperature at the flowering stage, is anther indehiscence (Satake and Yoshida, 1978; Mackill *et al.*, 1982; Matsui *et al.*, 1997, 2001). Anthers of heat tolerant cultivars dehisce more easily than those of heat-susceptible cultivars and contribute to pollination under high temperature conditions

(Satake and Yoshida, 1978; Mackill *et al.*, 1982; Matsui *et al*, 2000, 2001). Rice yields are estimated to be reduced by 41% due to high temperatures by the end of the 21st century (Ceccareli *et al.*, 2010). Increasing severity of the problem in rice-growing areas in Asia is due to rising temperatures (Catherine *et al.*, 2012). Global temperatures are estimated to rise by 1.1°C to 6.4°C during the next century (IPCC, 2012), thereby threatening rice production. The development of rice varieties for high temperature tolerance has received little attention in the past. With climate change, breeding for heat tolerance is one of the key research areas that may address problems related to temperature increase (Manigbas and Sebastian, 2007; Redona *et al.*, 2009). Hence in the present investigation, as the part of development of rice varieties for high temperature tolerance, forty rice accessions were screened for heat tolerance during summer season.

Materials and Methods

The experiment was carried out in the Agriculture Research Station Gangavathi, University of Agricultural Sciences, Raichur during *summer* seaso n 2014 to screen the forty rice accessions received from the IRRI, India office, ICRISAT Hyderabad, with GGV-05-01 (Gangavati sona), IR-64, MTU 1010 and N-22 as checks. Nursery sowing was taken up on 26/01/2014 and transplanted on 22/02/2014 in 4 rows of three meters length with a row spacing of 20 cm between rows and 15 cm between plants in a randomized block design with three replications (Fig. 1(a) Agronomic practices followed as per the recommendations. The flowering stage of the crop was coincided with hottest month (April & May), recorded weather data of the testing location (Fig. 1 (b). The mean data was statistically analysed by adopting the appropriate methods outlined by Panse and Sukhatme (1978) and Sundarajan *et al.* (1972). The critical differences were calculated at five per cent level of probability, wherever 'F' test was significant.

Fig. 1a: Field view of heat tolerant experiment at Agriculture Research Station, Gangavathi

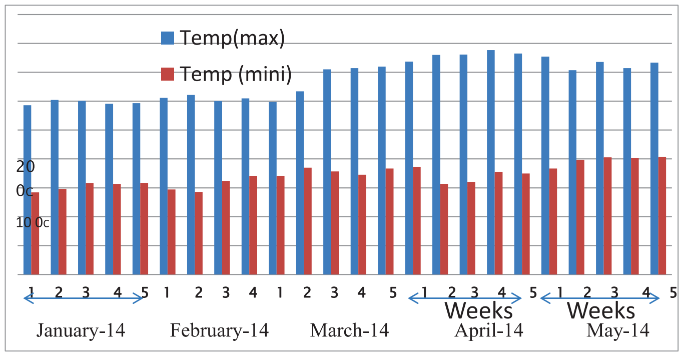

Fig. 1b: Temperature pattern during summer season 2014, Agriculture Research Station, Gangavathi

Results and Discussion

Among the forty accessions screened for heat tolerance, the check N-22 (66.00 days) was the earliest to days to 50 percent flowering followed by the accessions EC792177, EC792206, EC792239, EC792193 and EC792235 (80.00 days). The local check gangavathi sona (105.00 days) was late to days to 50 per cent flowering. The results obtained on plant height are presented in Table 01. Among the forty accessions screened for heat tolerance, the check N-22 recorded significantly highest plant height (102.97cm) followed by the accessions EC792310 (102.30), EC792239 (101.60 cm) and the significantly lowest plant height (77.60 cm) was in the accessions EC792216 and EC792238.

Number of tillers per plant at maturity was significantly highest (22.50) in the accession EC792195 followed by the accessions EC792203 and EC792178 (17.30) which were on par with each other. The accession EC792233 recorded significantly lowest (9.30) number of tillers per plant among the accessions screened for heat tolerance which was on par with the accessions EC792270, EC792230 and EC792204 (10.00). The data on average weight of five panicles of forty accessions screened for heat tolerance are presented in the Table 1. The accession EC792284 recorded significantly maximum (35.40g) average weight of five panicles among the accessions which was on par with the accessions EC792286 (27.50g) and EC792237 (26.40g). The accession EC792178 recorded significantly minimum (12.50g) average weight of five panicles followed by EC792183 (14.70g) and EC792231 (15.10g).

Significant differences on grain yield per plot were recorded among the forty accessions screened for heat tolerance Table 1. The grain yield per hectare recorded in screening of the forty accessions showed significant differences. The accession EC792239 recorded significantly higher grain yield per hectare (6166.67kg) followed by the accessions EC792285 (5776.67kg) and EC792185 (5333.33kg) which were on par with each other. The check gangavathi sona recorded significantly lowest grain yield per hectare (1490.00kg) followed by the check IR-64 (2283.00kg) which were on par with each other.Significantly highest thousand grain weight was recorded in the accessions EC792200 and EC792286 (25.00g) among the accessions screened followed by the accessions EC792310, EC792186, EC792316 and EC792222 (24.00g) which were on par with each other (Table 1). The check gangavathi sona recorded significantly minimum (12.80g) thousand grain weight followed by the accession EC792193 (15.00g) which were on par with each other (Figure 01). The observations recorded on per cent of chaffyness are presented in Table 01. The per cent of chaffyness was recorded significant differences among the accessions screened for heat tolerance. The significantly minimum per cent of chaffyness (0.40%) was recorded in the accession EC792183 followed by the accessions EC792179 (0.80%) and EC792216 (1.20%). The accessions EC792286, EC792192 and EC792284 recorded significantly maximum (14.40%) per cent of chaffyness followed by the accessions EC792288 and EC792193 (12.00%). Among the forty accessions screened along with the four checks for heat tolerance, sixteen accessions showed the long bold grain size, eleven accessions showed the short bold grain size, sixteen accessions showed the long slender grain size and only one genotype showed the medium slender grain size (Table 01). Popular varieties in Asia, particularly in the India, have high yields, good grain quality, and resistance to pests and diseases. However, they lack heat tolerance. Due to the advent of climate change caused by global warming, breeding for heat-tolerant varieties has become important. New rice varieties should possess adaptability to rising temperatures in addition to the desirable traits that a variety should have. The breeding populations created through a regional collaboration project need to adapt to increasing temperatures in specific locations.

Genetic variability in any crop is pre-requisite for selection of superior genotypes over the existing cultivars. Variation was observed for all the characters among the genotypes studied, indicating the existence of sufficient amount of variability. These results were in conformity with the findings of Dhanwani *et al.* (2013), Dhurai *et al.* (2014) and Kavitha *et al.* (2015).Yield data were obtained from screening of the rice accessions showed the genotypic difference. The highest yield was produced by the accessions EC792239, EC792285 and EC792185 which had heat tolerance. An increase in panicle length, number of panicles, number of tillers per plant, average weight of five panicles and minimum per cent of chaffyness observed and this increase resulted in high yields even with high temperature compared with other accessions.

Tolerance is a combined reaction of the plant ability to survive the stress conditions and to complete its developmental stages before, during or later the stress period (Levitt, 1980). This was clear that the few lines having passed through the period of high temperature are tolerant to high temperature stress. The present results support Liu *et al.* (1981), Chen *et al.* (1982) and Mohammad Sarwar and Ghulam Mustafa Avesi (1985). Factors responsible for the induction of sterility by high temperature during anthesis were not studied during the present study but it is likely that the tolerant lines were able to shed sufficient amount of viable pollen for self-pollination (Mackill *et al*., 1982). During heading the average atmospheric temperature was ranged from 35^{o}C to 38^{o}C which was high enough to induce spikelet sterility.

Conclusion

Breeding heat-tolerant rice is one of the strategies used to mitigate the effects of climate change, particularly in high temperature regions where the majority of rice is grown. The screening and selection strategies that we developed for breeding under heat prone conditions could differentiate the germplasm accessions according to heat tolerance traits. In view of the same, in the present study forty rice accessions along with the four checks were screened and few promising heat tolerant accessions were selected based on their grain yield performance

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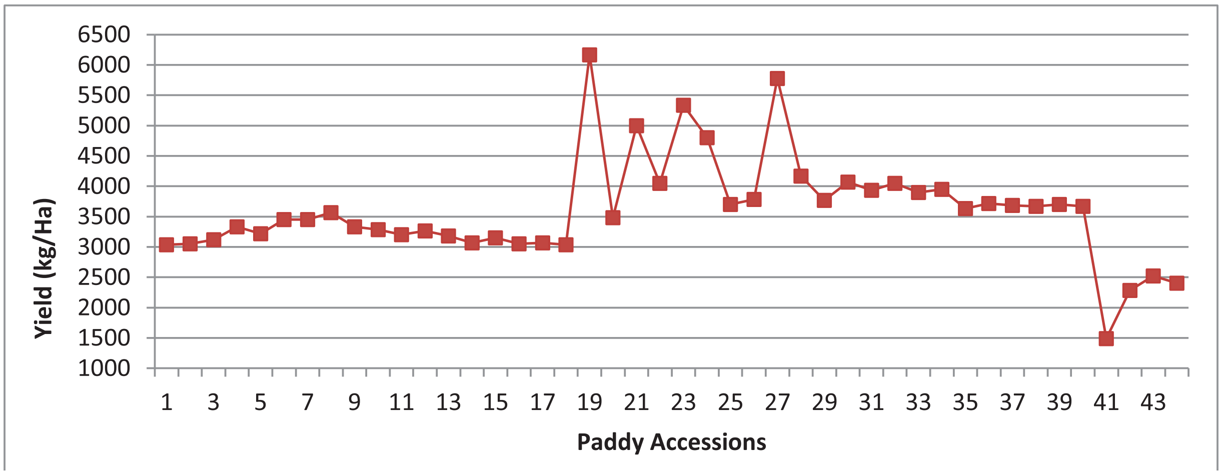

Figure 2: Grain yield (kg/ha) of forty four genotypes evaluated for heat tolerance

Sl. No	Accession	Days to 50% flowering	Plant height (cm)	Panicle length (cm)	Total number of tillers	Av. Wt. of five panicles (g)	Yield (kg/ha)	1000 grain wt.	Per cent choffyness	Grain type
1	EC792270	84.00	93.60	23.30	10.00	20.50	3033.33	22.00	2.80	SB
2	EC792199	84.00	82.60	22.30	11.60	23.60	3050.00	20.00	1.60	LS
3	EC792231	81.00	83.60	21.00	10.60	15.10	3116.67	18.00	2.80	SB
4	EC792310	87.00	102.30	23.00	15.60	25.80	3333.33	24.00	4.40	LB
5	EC792200	84.00	86.60	20.00	15.00	22.00	3216.67	25.00	6.40	LB
6	EC792227	83.00	94.60	25.00	10.30	17.90	3450.00	21.10	4.00	LB
7	EC792183	85.00	86.30	20.00	14.60	14.70	3450.00	20.00	0.40	SB
8	EC792286	90.00	94.30	24.00	12.30	27.50	3566.67	25.00	14.40	LS
9	EC792186	90.00	80.30	19.60	16.00	21.00	3333.33	24.00	4.40	LB
10	EC792216	85.00	77.60	22.00	15.60	21.00	3283.33	22.00	1.20	LB
11	EC792230	85.00	85.60	21.30	1.00	21.50	3200.00	18.50	3.90	LS
12	EC792177	80.00	85.30	21.60	11.00	19.90	3266.67	19.00	2.80	SB
13	EC792237	81.00	84.00	23.60	13.00	26.40	3183.33	23.00	3.20	LS
14	EC792210	85.00	85.00	21.60	15.00	18.70	3066.67	22.00	2.80	LB
15	EC792288	83.00	81.30	23.00	11.30	22.50	3150.00	23.00	12.00	LB
16	EC792198	83.00	94.30	23.00	12.00	25.60	3050.00	21.00	5.00	LS
17	EC792206	80.00	84.00	21.00	12.30	20.30	3066.67	19.00	2.80	SB
18	EC792187	81.00	91.30	22.60	12.30	20.90	3033.33	19.00	1.60	LB
19	EC792239	80.00	101.60	22.30	11.60	21.80	6166.67	20.00	2.00	SB
20	EC792192	81.00	86.30	22.60	15.60	22.30	3483.33	22.00	14.40	LS
21	EC792179	81.00	88.60	23.60	12.30	20.90	5000.00	19.00	0.80	LS
22	EC792236	90.00	91.00	24.00	13.00	20.00	4050.00	21.00	8.40	SB
23	EC792185	84.00	86.60	22.00	12.60	18.30	5333.33	19.00	1.60	LB
24	EC792240	84.00	81.30	22.00	10.30	24.20	4800.00	20.00	3.20	LB
25	EC792225	81.00	88.60	23.00	11.30	19.90	3700.00	19.00	3.20	LS
26	EC792193	80.00	92.00	22.00	14.60	17.50	3783.33	15.00	12.00	LS
27	EC792285	92.00	80.00	19.00	11.00	16.00	5776.67	22.00	4.80	LS
28	EC792316	84.00	92.00	24.00	12.00	23.60	4166.67	24.00	7.60	LS
29	EC792203	83.00	91.60	23.00	17.30	23.30	3766.67	21.00	2.00	SB

30	EC792222	85.00	90.00	21.00	13.00	18.60	4066.67	24.00	2.40	LB
31	EC792178	84.00	89.00	22.60	17.30	12.50	3933.33	21.00	2.40	LB
32	EC792235	80.00	87.60	21.00	12.00	20.30	4050.00	22.00	2.00	LB
33	EC792195	83.00	92.00	22.00	20.00	16.50	3900.00	20.00	2.40	LS
34	EC792238	81.00	77.60	20.00	13.30	18.40	3950.00	19.00	5.60	SB
35	EC792233	81.00	88.60	23.00	9.30	21.90	3633.33	19.00	2.80	LS
36	EC792217	85.00	85.30	21.00	11.00	19.30	3716.67	22.00	10.40	LS
37	EC792224	84.00	86.60	23.30	14.60	19.40	3683.33	17.00	2.40	LB
38	EC792284	91.00	91.60	23.00	14.60	35.40	3666.67	21.00	14.40	SB
39	EC792208	84.00	91.00	23.00	15.60	17.90	3700.00	19.30	3.30	LS
40	EC792204	83.00	88.60	22.60	10.00	19.90	3666.67	22.00	2.00	LS
41	G sona	105.00	97.08	24.27	11.45	18.43	1490.00	12.80	11.80	MS
42	IR-64	87.83	101.58	24.83	10.87	20.93	2283.00	23.80	8.20	LB
43	MUT-1010	87.00	96.13	24.32	11.47	22.72	2520.00	21.40	6.36	LB
44	N-22	66.00	102.97	24.25	10.18	21.90	2400.00	21.70	6.00	SB
	Mean	84.04	89.04	22.40	12.63	20.84	3603.10	20.76	4.98	
	S.Em±	1.88	2.42	1.99	1.49	3.01	329.80	1.09	0.61	
	CD (5%)	5.29	6.81	3.37	4.21	9.28	927.19	3.09	1.72	

ORIGINAL RESEARCH ARTICLE OPEN ACCESS

Adoption Status of Direct Seeding Rice using Drum Seeder

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Received: 8th March, 2016 Accepted: 20th June, 2016

Abstract

The study was conducted in Vizianagaram district, Andhra pradesh during 2010-11 to study the adoption status of direct sowing paddy using drum seeder in puddle fields by District Agricultural Advisory and Transfer of Technology Centre in five villages consists of 10 Frontline demonstrations and non FLD farmers for enhanced resource use efficiency and reducing the cost of paddy cultivation. DAATT Centre promoted direct sowing paddy technology through 34 on-farm trials, 36 frontline demonstrations, 18 farmers training programmes, 6 field days and 18 exposure visits during the period from 2007 to 2010. Majority of FLD farmers (54%) had high extension contact and medium farm holding (40%), where as majority of non FLD farmers had (50%) medium extension contact and small farm holding (44%). Forty percent of FLD farmers had high adoption level followed by medium (36%) and low (24%) level adoption. Comprehensive and holistic efforts of DAATT Centre and its technical support to the department of agriculture in promoting direct sowing paddy through large scale demonstrations has created significant change at farmers level in paddy cultivation.

Keywords: Paddy, direct sowing, puddle condition, drum seeder

Introduction

Conventional paddy cultivation involves transplanting of seedlings in puddle fields performed by labours predominantly by women labours. Transplanting method involves seedbed preparation, nursery growing, care of seedlings in nursery, uprooting of seedlings, hauling and transplanting operations. The preparation of seedbed and sowing are done 30 days before planting. The rice farmers practicing transplanting are facing problems like shortage of labour during peak time, hike in labour charges, small and fragmented land holdings etc. In Vizianagaram district, Andhra pradesh, the major area of rice cultivation depends on rainfall and seedlings are used for planting due to delayed monsoon. The rice farmers practicing transplanting are facing problems like over aged seedlings, delayed planting, lack of water and shortage of labour during the season. In this contest, DAATT Centre, vizianagaram endeavoured to develop direct seeding of rice using drum seeder. The present study was conducted in farmers fields to findout the sustainability of the direct seeding rice in puddled conditions using drum seeder in comparision with traditional methods of paddy cultivation.

Materials and Methods

The study was conducted in vizianagaram district of Andhra Pradesh to evaluate the adoption of direct seeding rice using drum seeder by the paddy farmers. Thirty six frontline demonstrations and 34 on-farm trials were conducted during 2007 to 2010 through farmer's participatory approach in farmer's fields for large scale implementation of direct seeding rice. The study was conducted during 2010-11 in five villages consists of ten FLD and 10 non FLD farmers selected randomly to serve as respondents for the study.

Results and Discussion

The data on knowledge and adoption of direct sowing paddy using drum seeder was presented in table 1 & 2. The results revealed that majority of FLD farmers have high knowledge on field preparation (60%); seed germination (56%); sowing method (58%); water management (52%); increased tillering and yield in direct seeding (52%). Majority of FLD farmers are interested in replacement of conventional transplanting into direct seeding rice using drum seeder in future (60%). Majority farmers (54%) knew about direct sowing technology through the awareness created by DAATT centre scientists along with department of agriculture and NGO. Forty six per cent farmers expressed that they opted direct sowing paddy due to saving of 2-3 irrigations compared to conventional transplanting followed by forty per cent farmers expected higher yields and net profit and another sixteen per cent farmers opted due to labour scarcity. Majority of farmers (84%) expressed ease in operating drum seeder. It is clear that sixty eight per cent farmers told that direct seeding rice using drum seeder saves costly seed than conventional transplanting.

These knowledge levels reveal that the FLD's, on farm trials, training programmes, field days and exposure visits organised by DAATT centre has created impact in terms of knowledge levels of FLD farmers compared to non FLD farmers.

Majority of FLD farmers were adopting water management (38%); use of drum seeder by one person (40%); saving irrigations (46%). Majority of FLD farmers are interested in adopting direct sowing paddy due to increased yield (40%); higher net profit (40%); and adopting replacement of conventional transplanting into direct seeding using drum seeder (42%). This might be due to the fact that majority of FLD farmers belonged to middle age group having high farming experience with medium farm holding and high extension contact for technical advice.

Most of the non-FLD farmers were moderately (38-40%) interested in using drum seeder in paddy cultivation. This might be due to the reason that it is easy, convenient to use involves less cost on seed, less labour requirement, water saving, higher yield and more net profit in direct sowing paddy using drum seeder than conventional transplanting.

Majority of non-FLD farmers were partially adopting field puddling, levelling and draining standing water before sowing; settling of puddled soil before sowing; seed soaking and incubation for germination; use of weedicide; keeping thin layer of irrigation water after sowing for seed germination (32-36%). This might be due to medium contact of farmers with DAATT centre scientists and also medium farming experience.

It was clearly evident from the study that 32 per cent farmers did not adopt proper puddling and levelling operations which is otherwise an important operation in direct sowing paddy that avoids water logging condition. The present finding shows that lot of awareness is to be created on the importance of levelling.

Similarly, majority of farmers (58%) did not operate power weeders for weeding because the existing conoweeder creates drudgery in operation ; did not follow timely application of weedicides due to lack of knowledge on weedicides. Hence, there is a need to modify conoweeder for easy operation.

From the study it was very interesting to find that 82 per cent FLD farmers are interested to continue direct sowing paddy in the coming seasons. This may be due to less dependence on labour, less cost of cultivation and higher yields.

Table 1: Profile characteristics of respondents

S. No.	Profile characteristics	FLD farmers (50)	Non-FLD farmers (50)
1	Age:		
	Young : 25-36	12(24)	10(20)
	Middle : 37-46	30(60)	19(38)
	Old : 47-60	8(16)	21(42)
2	Farming experience :		
	Low : 0-10	15(30)	8(16)
	Medium : 11-22	11(22)	22(44)
	High : 23-34	16(32)	20(40)
3	Farm holding :		
	Marginal : upto 2.5 acre	10(20)	14(28)
	Small : 2.6-5.0	14(28)	22(44)
	Medium : 5.1-10	20(40)	10(20)
	Large : >10	6(12)	4(8)
4	Extension contact :		
	Low : 0-10	4(8)	16(32)
	Medium : 11-22	19(38)	25(50)
	High : 23-34	27(54)	9(18)
5	Knowledge :		
	Low : 0-6	7(14)	10(20)
	Medium : 7-13	16(32)	22(44)
	High : 14-20	27(54)	20(40)
6	Adoption :		
	Low : 0-6	12(24)	14(28)
	Medium : 7-13	18(36)	20(40)
	High : 14-20	20(40)	16(32)

Table 2: Knowledge and adoption of Direct sowing technology practices by paddy farmers

S. No.	Direct sowing technology practices	Knowledge				Adoption			
		FLD farmers (50)		Non-FLD farmers (50)		FLD farmers (50)		Non-FLD farmers (50)	
		Frequency	Percentage	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
1	Direct sowing paddy using drum seeder require fields in well puddled and levelled condition	30	60%	24	48%	18	36%	16	32%
2	Pre germinated paddy seed are sown with drum seeder after draining standing water	29	58%	21	42%	18	36%	16	32%
3	If there is more standing water in the field, leave the field for 1-2 days for settling of puddled soil	26	52%	20	40%	18	36%	17	34%
4	Seeds are soaked in water for 24 hours and incubation in gunny bags for 24-48 hours	21	42%	18	36%	19	38%	16	32%
5	Germination length of seeds should not be more than 1-2mm to avoid mechanical injury of pregerminated seeds and to ensure flow of seeds with the drum seeder	28	56%	24	48%	15	30%	13	26%
6	Sowing of sprouted seed using drum seeder in 8 rows with row to row spacing of 20 cm facilitates good tillering	26	52%	20	40%	19	38%	18	36%
7	Weedicide is a must in direct sowing using drum seeder in puddle fields	23	46%	20	40%	18	36%	16	32%
8	Thin layer of irrigation water is to be maintained till the seeds germinate	26	52%	19	38%	19	38%	18	36%
9	Operating conoweeder between the rows in direct seeding incorporates weeds and improves tillering.	22	44%	18	36%	15	30%	14	28%
1	Intermittant irrigation at every 2-3 days upto panicle initiation stage enhances good tillering	26	52%	18	36%	14	28%	12	24%
11	Use of drum seeder is easy to operate and 3-4 acres sowing can be done in one day by one man labour	21	42%	13	26%	18	36%	17	34%
12	Drum seeder is a drudgery reducing tool. Use of drum seeder is easy, convenient by one person resulted in shift of work of women to men	21	42%	21	42%	20	40%	20	40%
13	Sowing by drum seeder saves costly seeds	20	40%	14	28%	14	28%	13	26%
14	Drum seeder reduces labour requirement in paddy cultivation	9	18%	7	14%	8	16%	7	14%
15	Direct sowing in puddle fields using drum seeder, saving 2-3 irrigations compared to transplanting	26	52%	20	40%	23	46%	20	40%
16	Use of drum seeder helps in timely sowing of crop resulting in more yields	7	14%	6	12%	6	12%	6	12%
17	Crop matures one week early in direct sowing compared to transplanting	24	48%	18	36%	21	42%	20	40%
18	Use of direct sowing increased paddy yield compared to transplanting	26	52%	20	40%	20	40%	19	38%
19	Net profit is more in direct sowing using drum seeder than transplanting	26	52%	22	44%	20	40%	20	40%
20	Farmers are interested in replacement of transplanting into direct sowing paddy using drum seeder in future.	30	60%	26	52%	21	42%	20	40%

The data in Table 3 depicts the comparison on various parameters for conventional method of transplanting paddy and seeding of pregerminated seeds using drum seeder. The seed requirement in direct sowing paddy (30-37.5 kg/ ha) is reduced by 60% as compared to conventional transplanting (75 kg/ha). The labour requirement in sowing by drum seeder (5 /ha) is reduced by 90% as compared to manual transplanting (50 /ha). The transplanting of rice seedlings which is a highly labour-intensive and expensive operation can be replaced by direct seeding that can reduce labour needs by more than 20 per cent in terms of working hours required (Pradhan, 1969; Santhi *et al*., 1998.). Days to transplant elucidates that nursery has to be sown about one month in advance than direct sowing.

The Table 4 delineates that the cost cultivation by direct sowing paddy using drum seeder was Rs. 16,500/- per ha as compared to Rs.21,167/- per ha in conventional method. The cost of paddy cultivation is reduced by 22% as compared to conventional transplanting. Grain yield was 7.58 t/ha for direct sowing paddy and 5.23 t/ha for transplanted paddy. The benefit cost ratio of paddy is 3.59 in direct sowing paddy as compared to 1.88 in conventional transplanting. Shekar and Singh (1991) have stated that direct seeding of sprouted seeds under puddled condition results in significant improvement in yield attributes like number of effective tillers and grain yield. The higher benefit cost ratio achieved among majority of farmers in direct sowing paddy may be due to not only higher yields obtained but also due to less cost involved in cultivation, reduced crop duration and water saving.

With regard to yield 78 per cent farmers realized higher yield over normal, thus expressed satisfaction with direct sowing technology. Higher yield, less cost of cultivation, net profit, higher benefit cost ratio and reduced crop duration was realized by 80 per cent farmers. Majority of farmers observed water saving (86 %) in direct sowing paddy over conventional transplanting. The reduced crop duration and water saving has got advantage in present situation of severe water scarcity and poor power supply which adds to the advantages of direct sowing paddy using drum seeder. Similar trend of reduction in crop duration and water saving was also reported by Wang and Sun (1990). Direct sowing paddy using drum seeder helps to reduce water requirement and facilitates to avoid water stress specially for rice grown in tail end areas, under wells and tube wells.

Adoption of direct sowing paddy using drum seeder resulted in increase in the rice yield from 5.23 to 7.58 tonnes/ha in Vizianagaram district during *kharif*, 2007, 2008 and 2009. The cost of paddy cultivation is reduced by 22% as compared to conventional transplanting. The benefit - cost ratio of rice is 3.59 in direct sowing paddy as compared to1.88 in conventional transplanting. The higher benefit cost ratio achieved among majority of farmers in direct sowing paddy may be due to not only higher yields obtained but also due to less cost involved in cultivation, reduced crop duration and water saving.

The findings indicated that majority (60%) of the FLD farmers belonged to middle age while majority (42%) of the non-FLD farmers belonged to old age. The middle and young aged farmers are motivated towards adoption of innovations and able to adopt the direct sowing paddy in puddle field using drum seeder. Majority of the FLD farmers had high farming experience (42%) while majority of the non-FLD farmers had high level of farming experience (44%). Farming experience correlated with the age of the farmers as old farmers had more years of farming experience than the young farmers. Majority of FLD farmers (54%) had high extension contact and majority of non-FLD farmers had (50%) medium extension contact. Majority of FLD farmers (40%) having medium farm holding and majority of non-FLD (44%) were small farmers. Fifty four per cent of the FLD farmers possessed high knowledge level and remaining farmers possessed medium (32%) and low (16%) level knowledge regarding direct sowing paddy. This might be due to the fact that majority of the farmers were educated and frequently contacted different extension functionaries on technical matters. It is evident from the findings that the improvement in these characters would positively enhance knowledge and adoption levels and was supported by the findings of Raji *et al*., (1996), Parthasarathi (1997) and Ramesh and Govind (2008).

Whereas forty four percent of non-FLD farmers possessed medium level of knowledge followed by high (40%) and low (20%) level of knowledge on direct sowing paddy. Forty percent of FLD farmers had high adoption level followed by medium (36%) and low (24%) level adoption. Forty per cent of non-FLD farmers had medium adoption level of direct sowing paddy practices followed by high (32%) and low (28%) adoption.

Table 3: Comparison on various parameters for conventional method of transplanting paddy and direct sowing using drum seeder

S. No.	Particulars	Direct sowing paddy	Conventional transplanting
1.	Seed rate	30-37.5 kg/ ha	75 kg/ha
2.	Days to transplant	0 days	30-40 days
3.	Seed placement	Seed on the surface	Seedling under the soil
4.	Cost of nursery raising	Rs.0/-	Rs. 3000/-
5.	Labour required for transplanting/seed operation	5 / ha	50 /ha

Table 4: Comparision on economic parameters for conventional method of transplanting paddy and direct sowing using drum seeder

S. No.	Particulars	Direct sowing paddy	Conventional transplanting
1.	Cost of sowing /transplanting (Rs./ha)	800	3000
2.	Cost of weeding (Rs./ha)	700	1500
3.	Cost of irrigation (Rs./ha)	5600	4800
4.	Average cost of cultivation (Rs./ha)	16500	21167
5.	Grain yield (t/ha)	7.58	5.33
6.	Gross returns (Rs./ha)	53197	37428
7.	Net profit (Rs./ha)	36697	16261
8.	Benefit cost ratio	3.59	1.88

Conclusion

Comprehensive and holistic efforts of DAATT Centre and its technical support to the department of agriculture in promoting direct sowing paddy through front line demonstrations has created significant change at farmers level in paddy cultivation. The present study had clearly indicated the superiority of direct sowing paddy using drum seeder as a sustainable method of rice cultivation.

The present finding shows that lot of awareness is to be created on the advantages of ploughing, levelling, seed germination, sowing, water and weed management in direct seeding rice using drum seeder in puddle field.

Future thrust to upscale adoption of direct seedng rice is : large scale supply of drum seeders, conoweeders, organising training programmes involving department of agriculture and NGO's in promotional activities.

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ORIGINAL RESEARCH ARTICLE OPEN ACCESS

Study of Adoption of Mechanical Rice Transplanters through Custom Hiring in Tamil Nadu-a Case Study

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Received: 8th February, 2016; Accepted: 20th May, 2016

Abstract

A case study was carried out in selected districts of Tamil Nadu to study the impact of rice transplanter. It was observed that there is a paradigm shift from manual rice transplanting to mechanical rice transplanting, basically due to increased farm power availability, reduction in working manpower, import of mechanical rice transplanter and constant government support through various schemes. It is observed that for the 8 row Yanji rice transplanter, the break even hours of usage is 100 per annum. The total cost of operation of the machine works out to Rs. 200 /h, where in Yanmar rice transplanter, it was found that the break even hours of usage is 550 per annum. The total cost of operation of the machine works out to Rs. 400 /h. Case study clearly depicts that custom hiring services will help both farmers and entrepreneur in rice cultivation.

Keywords: Mechanical rice transplanter, custom hiring, power availability, break even analysis

Introduction

Rice is cultivated in 113 countries and it is the staple food of more than 50 percent population of the world. About 90 per cent rice area exists in Asia (Das, 2012). India is one of the world's largest producers of rice, accounting for 21% of total world's rice production with the annual production of 102.5 MT in 2015 (Anon., 2015). The average rice yield in India is 3.72 t/ha, as compared to world average of 4.55 t/ha (Anon., 2014). Rice is cultivated in almost all the states of India but most of its cultivation is concentrated in the river valleys, deltas of rivers and coastal plains. The main rice producing states are Tamil Nadu, West Bengal, Andhra Pradesh, Bihar, Punjab, Orissa, Uttar Pradesh, Karnataka, Assam and Maharashtra. During various rice cultivation operations agriculture workers undergo high physical strain and fatigue. In overall rice cultivation process manual rice transplanting operation is one of the drudgery prone and back- breaking activity. Due to severe weed problem, farmers often prefer transplanting than direct sowing of seeds. Manual rice transplanting is a labour intensive operation which requires 200-250 man-h/ha. During peak season labourers are not available (Das, 2012). Therefore modern agricultural machineries play a vital role in developing countries. Mechanization increases land productivity by timely completion of farm operations. It increases labour productivity and reduce drudgery of human and animals. It increases production by precision and efficient placement of inputs such as seed, fertilizer, chemicals and irrigation water. Mechanization decreases cost of production by reducing labour needed for particular operation and economy of power and other inputs (Das, 2012).

Though manual transplanting gives uniform crop stand it is quite expensive and requires lot of labour besides involving lot of drudgery. Singh *et al.* (1985) reported that transplanting takes about 250-300 man hours/ha which is roughly 25 per cent of the total labour requirement of the crop. Further, due to rapid industrialization and migration to urban areas, the availability of labour became very scarce and with hike in the wages of labour, manual transplanting is found to be costly leading to reduced profits to farmers. Under such circumstances a less expensive and labour-saving method of rice transplanting without yield loss is the urgent need of the hour (Tripathi *et al.*, 2004). The mechanical transplanting of rice has been considered the most promising option, as it saves labour, ensures timely transplanting and attains optimum plant density that contributes to high productivity. It also Generates an alternate source of income for rural youth through custom services on nursery raising and mechanical transplanting.

Studies were conducted at Agricultural Research Station, Gangavathi, Karnataka state during 2002 to 2004 on the feasibility of mechanizing transplanting operations in rice crop with a view to reduce the cost of cultivation.

An eight row self-propelled rice transplanter was used for the purpose. The performance of the mechanical transplanter was quite satisfactory. The field capacity, field efficiency and fuel consumption of the transplanter were 0.19 ha/h, 78 per cent and 6.25 l/ha, respectively. Cost of mechanical transplanting was Rs.789/ha as compared to Rs.1625/ha in case of manual transplanting provided the machines are used for their maximum usage of 90 hectares in a year. As the usage of the machine in terms of number of hectares/year decreases, the cost of operation increases. To breakeven with the cost of manual operation, the mechanical transplanter should be used at least in an area of 28 hectares per year. Hence, the mechanical transplanting would be economical provided an area of 28 ha and above is covered every year. Grain yield in both manual and mechanical transplanting was on par with mean grain yield of 5.38 and 5.4. t/ha, respectively (Manjunatha *et al*., 2009).

Nagaraj *et al*. (2013) conducted a study to know the knowledge and adoption level of rice growers of Raichur district about farm mechanization practices. The study was conducted in Sindhanur and Manvi taluks of Raichur district of Karnataka comprising 120 respondents from six villages. Majority of the respondents had complete knowledge *i.e.*, mode of operation, frequency of use and specification of the implements such as mouldboard plough, harrow, cultivator, power tiller, cage wheel, puddler, sprayer, combine harvester and thresher. Further, less than half of the respondents (42.50%) belonged to medium level of adoption category. As in case of knowledge level, large majority of farmers used the implements *viz,* Mouldboard plough, harrow, puddler, cultivator, cage wheel, power tiller, sprayer, combine harvester and thresher. However, only (15.00%) of the rice growers possessed skill in the use of rice transplanter.

The area under rice crop is decreasing year by year due to various factors such as increased cost of inputs, labour shortage and less profitability. Transplanting of rice seedlings in the traditional way is a labourious, time consuming and causes drudgery. Non-availability of labourers for transplanting at appropriate time leads to late planting, which results in poor yields. In rice, planting methods have an impact on the growth, yield attributes and yield besides cost of cultivation and labour requirement. Rice transplanting if done manually and requires about 306 man-h/ha, which is roughly 42 per cent of the total labor requirement of rice production. At transplanting time, acute labor shortage results in increased labor wages and delay in the transplanting operation. Manual transplanting also results in non-uniform and inadequate seedling populations. These problems necessitated the introduction of mechanized rice transplanting to achieve timely planting and better crop stands (Sangeetha and Baskar, 2015). The SRI (System of Rice Intensification) transplanting method encourages the planting of one seedling per hill and spaced in 25×25 cm for better usage of water, nutrient and pest management (Ibrahim and Ismail 2014).

Agricultural workers, draught animals, tractors, power tillers, diesel engines and electric motors are used as sources of farm power in Indian agriculture. The availability of draught animals power has come down from 0.133 kW/ha in 1971-72 to 0.094 kW/ha in 2012-13, whereas the share of tractors, power tillers, diesel engines and electric motors has increased from 0.020 to 0.844, 0.001 to 0.015, 0.053 to 0.300 and 0.041 to 0.494 kW/ha, respectively during the same period. The total power availability on Indian farms has increased at a CAGR of 4.58% from 0.293 to 1.841 kW/ha during the last four to five decades.

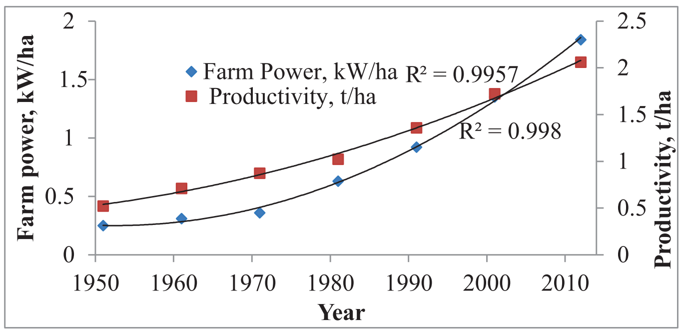

Fig.1 Trend of farm power and agricultural productivity

Farm power availability and productivity in India

Fig.1 shows the relationship between farm power availability and agricultural productivity for the past six decades in Indian agriculture. It is seen from Fig. 1 that the farm power availability and productivity increased from 0.25 to 1.84 kW/ha and from 0.52 t/ha to 1.92 t/ha, respectively over the years from 1951 to 2012. It has been observed that farm power availability and food grain productivity have a direct relationship (r^2= 0.986) during the last six decades *(*Mehta *et al., 2014).*

Status of rice transplanter market in India

Table 1 presents the market overview of the major Rice based machinery used in India.

Table 1: Market overview of the major farm machinery used in India

Name of machinery	Market size annually	Approximate cost, US $
Tractor	600000	7000-12000
Power tiller	56000	2100
Combine harvester	4000-5000	22000 – 35000
Thresher	100000	1600 – 2500
Rotavator	60000-80000	1300-2000
Rice transplanter	1500-1600	
Walking type		2500-4200
Riding type		3300-16600
Self-propelled vertical conveyor reaper	4000-5000	1300-2000
Zero till seed drill	25000-30000	750-850
Multi -crop planter	1000-2000	850-1000
Laser land leveller	3000-4000	5800-6500
Power weeder	25000	8500

Source: Mehta et al., 2014

From the table it is found that the market for self-propelled (walking and riding type) rice transplanters in India was almost nil about 5-6 years back as the rice transplantation was done manually with the use of labour. Presently, many companies in India are importing rice transplanters from China, Japan and Korea and marketing them in all regions of country. The rice transplanters market in India has grown from about 550 in 2008-09 to 1,500-1,600 units in 2013-14. The industry is expected to grow by more than 50% in coming years with Chhattisgarh, Odisha, Bihar and southern states showing positive sign of adoption of mechanized technology.

Role of Government of India in promoting rice transplanters through schemes

Realizing the need to enhance farm mechanisation domestically, the central government under its flagship ministry *i.e.* Ministry of Agriculture has undertaken various steps to promote the usage of machinery by domestic farmers. The central government's efforts towards farm mechanisation have been aggregated under a formal programme *viz.* Sub-Mission on Agricultural Mechanisation (SMAM). It came into existence during the current five year plan (2012-17) at an estimated outlay of Rs. 2000 crore over the five year term. The details of the mission components and government assistance is given in Table 2 and financial assistance for promotion of farm machinery and equipment is given in Table 3.

Table 2: SMAM – Mission components, government's assistance (www. agricoop.nic.in or www.vistar.nic.in)

S. No.	Mission Components	Share of Assistance		Implementing Agency
		Centre	State	
1	Promotion and Strengthening of Agricultural Mechanization through Training, Testing and Demonstration	100	0	State identified institutions, ICAR institutions, PSUs of GOI, State Governments
2	Demonstration, Training and Distribution of Post Harvest Technology and Management (PHTM):	100	0	State identified institutions, ICAR institutions, PSUs of GOI,State Governments
3	Financial Assistance for Procurement of Agriculture Machinery and Equipment	50	50	State Governments
4	Establish Farm Machinery Banks for Custom Hiring	50	50	State Governments
5	Establish Hi-Tech, High Productive Equipment Hub for Custom Hiring	50	50	State Governments
6	Promotion of Farm Mechanization in Selected Villages	50	50	State Governments
	Financial Assistance for Promotion of Mechanized Operations/ hectare Carried out			
7	Through Custom Hiring Centers	50	50	State Governments
8	Promotion of Farm Machinery and Equipment in North-Eastern Region	50	50	State Governments of 8 North eastern States

Table 3: Financial assistance for procurement of farm machinery & equipment (www. agricoop.nic.in or www.vistar.nic.in)

Agriculture Machinery	For General Farmers: Pattern of Assistance (%)	For General Farmers: Max permissible subsidy per machine/equipment per beneficiary (Rs)	For SC, ST, Small & Marginal farmers, Women and NE States beneficiary: Pattern of Assistance (%)	For SC, ST, Small & Marginal farmers, Women and NE States beneficiary: Max permissible subsidy per machine/equipment per beneficiary (|Rs)
Tractors				
1) 05-15 Hp	25	0.75 lakh	35	1.0 lakh
2) 15-20 Hp	25	0.75 lakh	35	1.0 lakh
3) 20-40 Hp	25	1.0 lakh	35	1.25 lakh
4) 40-70 Hp	25	1.0 lakh	35	1.25 lakh
Power Tillers				
1) <8 Hp	40	0.4 lakh	50	0.5 lakh
2) >8 Hp	40	0.6 lakh	50	0.75 lakh
Self Propelled Rice Transplanter				
4 rows	40	0.75 lakh	50	0.94 lakh
8 rows	40	2.0 lakh	40	2.0 lakh
16 rows	40	2.0 lakh	40	2.0 lakh
Self Propelled Machinery				
Reaper cum Binder	40	1.0 lakh	50	1.25 lakh
Paddy Thresher		0.2 lakh		0.25 lakh

Sub-Mission on Agricultural Mechanisation lays emphasis on custom hiring services through the rural entrepreneurship model, thereby making an effort to reach out to small and marginal farmers.

Status of rice transplanter in Tamil Nadu

Tamil Nadu is rapidly transforming to a high level of agricultural mechanization. In the recent years 50-60 crores were allotted for distribution of machinery under supply of subsidized machines under National Agricultural Development Programme (NADP). Due to the sudden change in labour scenario, many farmers adopted mechanization in rice. Different custom hire operators have emerged according to the economic necessity especially for rice harvesting and transplanting in addition to the traditional services of plowing and transport. However the small and medium farmers find it extremely difficult to carry out day to day work. Due to the fragmented holding the farmers are not able to engage private hire operators. Realizing this scenario the Tamil Nadu Government has stepped in to set up custom hire centers under primary agricultural cooperatives. In the past two years about 225 custom hiring centers has been set up in TN. Now the Tamil Nadu Government has planned to expand in a massive scale and to set up 2000 agro service centers in Tamil Nadu. Hand holding support and technical guidance is given to these centres.

Three types of rice transplanter introduced in Tamil Nadu by State Government are Self-propelled single wheel riding type transplanter, Self-propelled walk behind type rice transplanter and Self-propelled 4 wheel type rice transplanter. These transplanters are being custom hired directly or through other agencies.

Self propelled single wheel type rice transplanter was introduced in 8 row models (Fig. 2). Machine was operated by diesel engine with power ranging from 2.94 to 3.68 kW. The machine consisted of power transmission system, handle for operation, main frame and rice transplanting tray, float and transplanting unit. It had a lugged wheel and the weight of the machine rests on the lugged wheel and float at the time of transplanting. The same lugged wheel was replaced by a pneumatic wheel for transportation. Power from the engine is transmitted to front traction wheels through gear train and to the transmission housing of transplanting unit through universal shaft. Six row machine had row spacing of 30 cm and eight row machine had row spacing of 23.8 cm. Plant to plant spacing is adjustable (12-14 and 14-17 cm). Setting is provided for adjusting the number of hills transplanted/sq. meter. Transplanting depth is also adjustable. Brief specifications of machine are given in Table 4.

Self-propelled walk behind type rice transplanter is a 4 row walk behind type machine operated by a 3.2 kW petrol engine (Fig. 3). The machine consisted of power transmission system; handle for steering the machine, main frame and rice transplanting tray, float and two pairs of transplanting units.

Fig. 2. Single wheel riding type transplanter

Fig. 3. Self propelled walk behind type transplanter

It had only two lugged wheels and the weight of the machine rests on the lugged wheel and float at the time of transplanting. The same lugged wheels were used for transportation. Power from the engine is transmitted to front traction wheels through gear train and to the transmission housing of transplanting unit through universal shaft. The machine had 1 forward gear 1 reverse gear. Row to row spacing is 30.0 cm and four settings are provided for plant to plant spacing *i.e.* 12, 14, 18 and 21 cm. Four settings are provided for adjusting the number of hills transplanted/ sq. meter. Transplanting depth is also adjustable. Brief specifications of machine are given in Table 4.

Self-propelled 4 wheel type rice transplanter is a 6 row riding type machine operated by a 12.5 kW petrol engine (Fig. 4). The machine consisted of power transmission system, handle for steering the machine, main frame and rice transplanting tray, float and two pairs of transplanting units. It had four lugged wheels and the weight of the machine rests on the lugged wheel. The position of rice transplanting tray is adjusted by hydraulic system. The same lugged wheels were used for transportation. The machine had hydrostatic transmission with 5 forward and 5 reverse speeds. Row to row spacing is 30.0 cm and five settings are provided for plant to plant spacing *i.e.* 12, 14, 16, 18 and 21 cm. Five settings are provided for adjusting the number of hills transplanted/sq. meter. Transplanting depth is also adjustable.

Fig. 4. Self propelled riding type transplanter

The following advantages were observed with the use of mechanical transplanter in rice cultivation

1. Efficient utilization of resources by saving labour and cost of overall production.
2. Timely transplanting of seedlings of optimal age.
3. Ensures uniform spacing and optimum plant density.
4. Higher productivity compared to traditional methods.
5. Less incidence of disease in seedlings due to less root injury generated due to shock while transplanting.
6. Improving soil health through reduced puddling.

Table 4: Typical specifications of different types of rice transplanters

S. No.	Specification	Observations		
1	Machine	Self propelled single wheel riding type	Self propelled walk behind	Self propelled 4 wheel type
2	Type of nursery used	Mat type	Mat type	Mat type
3	Power Source	Diesel Engine, 2.94 to 3.68 kW	Petrol Engine, 3.20 kW	Petrol Engine, 12.5 kW
4	Type of Steering	Mechanical	Handle type	Hydraulic
5	No. of gear	Forward - 3 (2 for Field and 1 for Road) Reverse – Not Provided	Forward – 1 Reverse – 1	5 Forward and 5 Reverse Speeds
6	Number of rows	6 and 8	4	6
7	Row to row spacing, cm	23.8 and 30	30	30
8	Plant to plant spacing, cm	12-14, 14-17	12, 14, 18, 21	12, 14, 16, 18, 21
9	Number of hills transplanted/m^2	Two settings	Four settings	Five settings
10	Transplanting depth	Adjustable	Adjustable	Adjustable
11	Type of planting finger	Needle type	Plate bar with Notch	Plate bar with notch
12	Material of tray	Galvanized iron sheet	Plastic	Plastic
13	Type and material of traction wheel	Iron wheel with iron lugs	Iron wheel with rubber lugs	Two front non-puncture rubber wheels and two rear iron wheels with rubber lugs
14	Transport wheel type	Pneumatic	-do-	-do-
15	Float type and material	Single piece, fiber	Split bars, plastic	Split bars, plastic

Overall custom hiring scenario in study area

The study was taken up in the rice bowl of Tami Nadu *viz.*, Tanjore, Sivaganga, Kumbakonam, Kancheepuram, Chengalpet and Tiruvannamalai. The following observation was noted during the survey.

1. Rapid growth of custom hiring in transplanting with coverage of about10 % of transplanted area.

1. Emergence of centralized nursery for supply of seedlings at Sivaganga, Kumbakonam and Vaipoor. Emergence of transplanter service providers were seen in these areas.

2. Subsidy provided by government is a great driver for adoption of mechanization.

3. Mechanized transplanting has spread in delta districts and slowly increasing in other districts in south.

4. High demand for mechanized transplanting was noticed in Northern districts of Kancheepuram, Chengalpet Thiruvannamalai.

The details of population of transplanters available in Tamil Nadu is furnished in Table 5.

Table 5: Population of transplanters in Tamil Nadu

Sl. No.	Transplanter-Make	Numbers (aproximate)
	4 WD Transplanters	
1	Yanmar 8 row	60
2	Kubota 6 row	70
3	Deodang 6 Row	35
4	Kukje 6 Row	25
	Walk behind	
1	Kukje 4 row	50
2	Southern agro Chennai	500
3	Kubota 4 row	200
4	Deodang 4 row	6
	Single wheel riding type	
1	Yanchi 8 row	200
	Total	1146

A total of 1146 rice transplanters were available in the 2014 in Tamil Nadu, 17.45% were single wheel riding type rice transplanters, 65.96 % were walk behind type rice transplanters and only 16.57% were 4 wheel type rice transplanters.

Break even analysis

The break even analysis was carried out based on interaction effect between total cost incurred (Rs/year), annual Usage of the machine (hour) and total return obtained (Rs/year).

a. Yanji rice transplanter

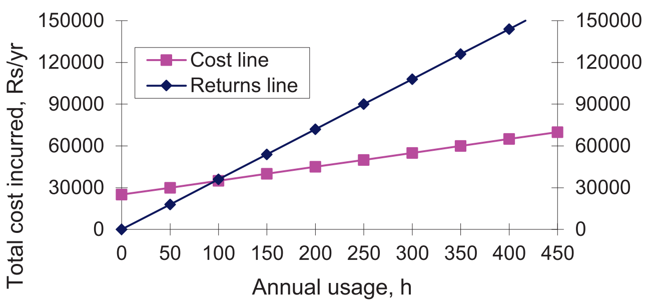

Fig. 5 Breakeven analysis on hiring of 8 row Yanji rice transplanter

On plotting the cost and returns lines for the 8 row Yanji rice transplanter (Fig.5), it was found that the breakeven hours of usage is 100 per annum. The total cost of operation of the machine works out to Rs. 200 /h. Annual machine usage under hire exceeded 1000 h and the machine break-evened the cost in approximately 100 h of operation. On plotting the cost and returns lines for the Yanmar rice transplanter (Fig. 6), it was found that the breakeven hours of usage is 550 per annum. The total cost of operation of the machine works out to Rs. 400 /h. Annual machine usage under hire exceeded 2000 h and the machine break-evened the cost in approximately 550 h of operation.

b. Yanmar rice transplanter

Economics of transplanting

A study was conducted with existing custom hiring operator in Tamil Nadu. The average of the operating cost from various custom hiring service operators operating eight row Yanmar rice transplanter is detailed Table 6. The custom hiring rate and profit details are given in Table 7.

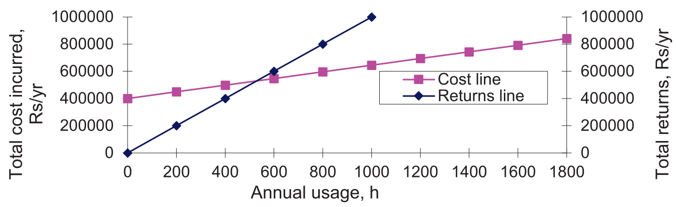

Fig. 6 Breakeven analysis on hiring of 8 row Yanmar rice transplanter

Table 6: Operating cost of riding type six row transplanter

Sl. No.	Cost classification	Average Cost (Rs/ha)
1	Cost of Machine	2500
2	Fuel	625
3	Operator	170
4	Helper	100
5	Maintenance	250
6	Transport of machine	250
	Total	3895

Table 7: Custom hiring rate and profit

Sl. No.	Cost classification	Average Cost (Rs/ha)
1	Operating Cost	3900
2	Seed	1100
3	Sowing labour	250
4	Polyethylene sheet	60
5	Total cost	5300 ~5500
6	Custom rate for transplanting with nursery	7500
7	Profit to service provider	2000
8	Management-overhead	Nursery maintenance-one supervisor and one Manager for overall management

From the table 7, it was inferred that the entrepreneur is getting Rs.2000 per ha and covers about 1000 ha covered per year, the entrepreneur will get profit of Rs. 8,00,000 from the custom hiring of transplanters. Thus custom hiring services will help both the farmers and the entrepreneur in rice cultivation.

Conclusion

Three types of rice transplanter introduced in Tamil Nadu by State Government were Self- propelled single wheel riding type transplanter, Self-propelled walk behind type rice transplanter and Self-propelled 4 wheel type rice transplanter. Out of total transplanters 17.45% were single wheel riding type rice transplanters, 65.96 % were walk behind type rice transplanters and only 16.57% were 4 wheel type rice transplanters. Rapid growth of custom hiring in transplanting with coverage of 10 % of transplanted area at present. The rice mechanization can be further increased by following the steps are listed below

a) Subsidized transplanting machinery.

b) Subsidized nursery sowing machine and nursery centers.

c) Providing incentive to farmer for mechanized transplanting.

d) Training women SHGs to use transplanting machinery in order to ensure alternative employment.

e) Setting up separate training center to train operators or initiating apprentice training under government subsidy.

f) Ensuring only proven machinery that are reliable, serviceable and having adequate service facility.

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ORIGINAL RESEARCH ARTICLE OPEN ACCESS

Studies on Mechanized Rice Transplanting and SRI Method of Rice Cultivation

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Received: 18th March, 2016; Accepted 25th May, 2016

Abstract

SRI has reached certain level of acceptance among the research and scientific community in major rice producing countries. The SRI method of rice cultivation involves planting single seedling in wider row spacing ie, 25x 25 cm, which involves more labour intensive and laborious process. Hence, the present study was conducted with an objective to compare the mechanized rice transplanting method with SRI method of cultivation. The study was conducted with four treatments *viz.*, T_1- Planting with transplanter + SRI principles, T_2- Planting with manual labour (25 cm x 25 cm) + SRI principles, T_3- Conventional transplanting (20 cm x 10 cm), T_4- Farmers practices. The study indicated that mechanized transplanting with rice transplanter adopting 30 x 14 cm row spacing recorded more 10.00 per cent more yield when compared to SRI method of planting (25 x 25 cm spacing) with the high cost benefit ratio of 2.72.

Key words: Mechanical rice transplanter, SRI, panicle weight, benefit cost ratio

Introduction

Rice is one of the most important cereals that holds the key for food security. In India, rice is presently grown in an area of 43.42 m. ha. with a production of about 98.95 m.t (Anonymous, 2014). At the current rate of population growth, the country has to produce about 120 m. t. of rice by 2030 to feed the ever growing population (Anonymous, 2011). Meeting the targeted demands of rice is a challenging task for the policy makers, researcher and all other stakeholders.

The problem is still confounded as the targeted increase has to be met in the background of declining resource base especially the land, water and labour and increasing environmental concerns. Increasing water scarcity is becoming a real threat for rice cultivation. About 80 percent of fresh water is being used for agriculture and out of this more than 50 percent is consumed by the rice crop alone. It is now evident that rice crop cannot have the luxury of water that it had in the past due to acute water shortages. There are some options such as zero tillage, direct seeding, aerobic rice and the System of Rice Intensification (SRI) which can help to save water and enhance water productivity irice cultivation. However, the former methods lead to yield reduction, while SRI has the potential to enhance yield and economize the water use. SRI has reached certain level of acceptance among the research and scientific community in major rice producing countries. The SRI method of rice cultivation involves planting single seedling in wider row spacing *i.e.* 25x 25 cm, which involves more labour intensive and laborious process. Reliance on human and animal power for day to day management of farm operations is showing a continuous decline over the last few years leading to considerable progress in agriculture mechanization. Mechanical equipments for various farm operations are generally being used by the farming community. Even small farmers are adopting and utilising selected farm equipments for efficient farm management through custom hiring. Transplanting, weeding and harvesting are the major operations that consume most of the labour requirement in rice cultivation. Mechanization with SRI methods leads to maintain plant-to-plant spacing and reducing seedling age, reducing the seed requirements by 50%, labor requirements reduction by 60%, and the time required for all of the main rice-farming activities by 70%. High labour demand during peak periods adversely affects timeliness of operation, thereby reducing the crop yield. Usage of tools, implements and machineries for puddling, transplanting, weeding and harvesting will lead to reduction in drudgery, cost and time. Hence, the present study was conducted with an objective to compare the mechanized rice transplanting method with SRI method of cultivation.

Data were collected from a representative sample of growers using Self-propelled Paddy Transplanter and manual transplanting of paddy in different villages of Trishur, Palakkad and Mallappuram districts of Kerala during the year 2009-10. The average net returns were Rs. 19,798 per ha and Rs. 27,462 per ha in traditional and self-propelled paddy transplanting methods of paddy cultivation, respectively. The yield realised in traditional method was 4.83 tha^{-1} and it was 5.70 t ha^{-1} in self-propelled paddy transplanting method. The cost of cultivation in both the methods was more or less the same (Rs. 30,387 ha^{-1} in traditional method and Rs. 31,750 in self-propelled paddy transplanting). The benefit cost ratio was 1.87 in self-propelled paddy transplanting technology as compared to 1.65 in manual transplanting (Singh and Rao, 2012).

Mohanty *et al*. (2010) conducted a study at farmer's field by Krishi Vigyan Kendra, Deogarh, Odisha state during 2009 on the feasibility of mechanizing transplanting operations of paddy crop with a view to reduce the cost of cultivation. A plant population of 34-36 hills m^{-2} was achieved by the transplanter. Number of plants per hill was observed to be with in 3 to 5. An eight row self-propelled paddy transplanter was used for the purpose. The performance of the mechanical transplanter was quite satisfactory. The field capacity, field efficiency and fuel consumption of the transplanter were 0.123 ha h^{-1}, 78 per cent and 6.5 l ha^{-1}, respectively. Cost of mechanical transplanting was Rs.1554 ha^{-1} as compared to Rs. 2675 ha^{-1} in case of manual transplanting. Grain yield in both manual and mechanical transplanting remained on par with mean grain yield of 41.4 and 34.8 q ha^{-1}, respectively. The missing hill percentage was less than 10 per cent.

The impacts of the system of rice intensification (SRI) and conventional management (CM) on grain yield, yield components and tillering capacity were examined under 4 rice establishment methods transplanting (TP), seedling casting (SC), mechanical transplanting (MT) and direct seeding (DS) (Song Chen *et al*., 2013). SRI produced significantly higher grain yield than CM under TP and MT but not under DS or SC. DS and SC produced much higher seedling quality than TP or MT, suggesting that robust seedlings with vigorous roots weaken the positive effect of SRI on rice yield. SRI produced a higher tillering rate than CM, but did not affect ear-bearing tiller rate significantly. Moreover, the net photosynthetic rate of the recent fully expanded leaf at mid-tillering stage was significantly higher in SRI than in CM under MT and TP.

A field experiment was conducted during March -June 2008 at wet land in Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu to optimize the spacing and depth of transplanting in rice cultivation using self propelled rice transplanter (Yanmar 6 row) (Duraisamy *et al*., 2011). Higher DMP (24231 kg ha-[1]), root length (16.63 cm), number of panicle m^{-2} (862 Nos.m^{-2}) and grain yield (7167 kg ha-[1]) was produced when transplanting was done at 30 x 22 cm spacing (15 hills m^{-2}). Among the depth of planting, increased plant dry matter production (17498 kg ha-[1]), root length (17.28 cm), number of panicle m^{-2} (812 Nos.m^{-2}), filled grains panicle[1] (113 Nos.) panicle length (22 cm) and grain yield (7667 kg ha-[1]) was produced in 4 cm depth. Veeramani *et al*. (2012) reported that tiller production could be optimized by transplanting seedlings at younger ages compared to modified rice mat nursery. The maximum number of tillers produced by the rice plant is inversely proportional to the length of the phyllochron.

Materials and Methods

A trial was conducted during *Rabi* 2012, at Department of rice fields, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu by comparing four treatments detailed below with the variety CO (R) 50.

T_1- Planting with transplanter (30 x 14 cm) + SRI principles

T_2- Planting with manual labour (25 cm x 25 cm) + SRI principles

T_3- Conventional transplanting (20 cm x 10 cm)

T_4- Farmers practices (Random planting)

Nursery for machine planting was raised in trays. The trays were filled with media consisted of mixture of decomposed coir pith, farmyard manure and well sieved field soil. A seed rate of 75 g/tray was used. Fourteen days old seedlings were planted at a spacing of 30 x 14 cm using four row walk behind self propelled rice transplanter (Kukje). Other management practices like weeding, fertilization and irrigation was done as per the standard procedure followed for SRI techniques.

In SRI method the nursery was raised in raised bed and fourteen days old seedlings were planted at a spacing of 25 x 25 cm. In conventional method the nursery was raised and 22 days old seedlings were planted at a spacing of 20 x 10 cm. In farmers method nursery was raised and 22 days old seedlings were planted randomly with manual labours. The recommended package of practices was followed as per the treatments. The operational view of rice transplanter is shown in Fig.1 and the transplanted field is shown in Fig. 2.

Fig. 2. Mechanical rice transplanted field

Cost of cultivation for each treatments were calculated by taking considerations of all inputs and labour cost based on the requirements of the each treatment and cost benefit ratio was calculated. The data recorded were statistically analysed.

Fig. 1. Self propelled walk behind rice transplanter (kukje) in operation

Results and Discussion

Grain yields were significantly higher under all the treatment when compared to the farmers practice, with average yields that were 44.56 per cent higher for Mechanical transplanting with SRI principles , 31.83 per cent higher for SRI planting with manual labour and 18.35 per cent higher for manual transplanting by recommended spacing of 20 x 10 cm. The greatest yield of 7.72 t ha^{-1} was found in Mechanical transplanting with SRI principles (Table 1). There was about 10.00 per cent increase in grain yield of mechanized transplanting over SRI practice. There was no significant difference in panicle number per m^2 between mechanical transplanting with SRI principles and SRI planting with manual labour. Significant increase in panicle number per m^2 was found in between farmers practice to Mechanical transplanting with SRI principles and SRI planting with manual labour. The positive effect of SRI system has been well documented by Song Chen *et al*. (2013). In the current study, similar results were found in the Mechanical transplanting with SRI principles. The response of yield components to SRI also indicated that the increased grain yield using the SRI system with mechanical transplanting methods might be attributed to the improved number of panicle and panicle weight. Our results indicate that SRI might play an important role in single panicle development in mechanical transplanting, which provided evidence for the importance of a strong individual tiller. It also found that promoting early tiller emergence as a response to transplanting young seedlings increased grain yield. This might partly explain the yield increase in SRI treatment in the mechanical transplanting and manual transplanting systems.

The results revealed that the higher yield under mechanized planting was attributed to adoption of required plant population with wider spacing resulted in more number of productive tillers and panicle weight. The cost of cultivation under mechanized planting was also considerably less (Rs. 28600 ha^{-1}) as compared to SRI practice (Rs. 29357 ha^{-1}). The Benefit cost ratio was higher with machine transplanting (2.72) as compared to SRI practice (2.40) conventional method (2.05) farmers method of random planting (1.59).

Conclusion

The study indicated that mechanized transplanting with rice transplanter adopting 30 x 14 cm row spacing with SRI principles recorded 10.00 per cent more yield when compared to SRI method of manual planting (25 x 25 cm spacing) and 44.56 per cent higher yield than farmers practice with the high cost benefit ratio of 2.7

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Table 1: Comparative performance of Machine planting, SRI method, conventional and farmers practice on yield parameters, grain yield of rice and B:C ratio

Treatments	Panicle no./m^2	Panicle weight (g)	Grain yield (t ha^{-1})	Percent increase in grain yield over farmers practice	Cost of Cultivation (Rs ha^{-1})	B:C ratio
Transplanter + SRI principles	447^{c}	2.97^{c}	7.72^{d}	44.56	28600	2.72
Planting with manual labour (25 cm x 25 cm) + SRI principles	436^{c}	2.87^{c}	7.04^{c}	31.83	29357	2.40
Conventional transplanting (20 cm x 10 cm)	416^{b}	2.72^{b}	6.32^{b}	18.35	30783	2.05
Farmers practice	362^{a}	2.32^{a}	5.34^{a}		32530	1.59
CD (0.05)	20	0.14	0.36			

ORIGINAL RESEARCH ARTICLE OPEN ACCESS

Biology and Predatory Potential of Rhynocoris fuscipes (Fabricius) (Hemiptera: Reduviidae) on the Rice Leaffolder Cnaphalocrocis medinalis (Guenee)

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Received: 28th April 2016; Accepted: 21st June 2016

Abstract

Biology and feeding potential of the reduviid predator, *Rhynocoris fuscipes* (Fabricius) studied on the leaffolder *Cnaphalocrocis medinalis* Guenee. Approximately 117.7±18.16 *C. medinalis* larvae were required for development of one nymph throughout its developmental period of about 72.37±6.78 days (1.01 to 2.06 larvae per day). The mean nymphal survival was 74.77 to 94.45 % from I to V instar with a total survival rate of 86.21%. The per day predation rate of I, II, III, IV and V instar nymphs were 1.24±0.36, 1.01±0.30, 2.06±0.38, 1.66±0.61, and 1.25±0.38 larvae respectively. Adult females had a greater feeding potential and higher longevity (70.30±19.06 days) in comparison to males (57.20±16.16days). The results indicated that *R. fuscipes* had great biocontrol potential for leaffolder management in rice.

Keywords: Reduviid, harpactorine, biocontrol, prey

Introduction

The Reduviidae is the largest family of predaceous land Heteroptera and many of its members are potential predators of a number of insect pests. *Rhynocoris fuscipes* (Fab.) (Reduviidae: Heteroptera) is common generalist predator in rice fields. *R. fuscipes* was reported to predate upon more than 42 insect pests (Sahayaraj and Selvaraj, 2003) and is a potential biocontrol agent for pests of pigeonpea, cotton, groundnut and other crops. It has also been observed predating on many insect pests in the rice ecosystem. The rice leaffolder, *Cnaphalocrocis medinalis* Guenée (Lepidoptera: Pyralidae), is the most widely distributed foliage feeder in all the rice growing tracts of Southeast Asia. The large scale cultivation of high yielding varieties, application of fertilizers, and continuous use of insecticides have caused an increase in leaffolder population in several countries, including India. (Gurr *et al*., 2012). *C. medinalis* damages the rice plant through-out the crop growth period resulting in increased insecticide use. At flowering stage, damage of above 25 per cent of the flag leaf area could cause 50 per cent unfilled grains (Padmavathi *et al*., 2013). The knowledge on biology and pest suppression efficacy is a prerequisite for its utilization as a biological control agent. Though biological control potential of *R. fuscipes* has been studied on many agricultural pests, less information is available on rice pests. In order to reduce use of insecticides against this pest and to assess an indigenous predator for its potential to control it, an attempt was made to assess the predatory potential and developmental biology of the reduviid *R. fuscipes* on rice leaffolder in the laboratory.

Materials and Methods

The adult males and females of the reduviid, *R. fuscipes* were collected from rice fields and maintained in plastic containers (4 cm diameter) on the larvae of *Corcyra cephalonica* (Stainton) under laboratory conditions (28±2^{0}C and ambient RH). The eggs laid in the laboratory were allowed to hatch in petri dishes (9.2 x 2.0 cm) with wet cotton swabs for maintaining optimum humidity. The cotton swabs were changed periodically in order to prevent fungal attack. Freshly hatched first instar nymphs of the predator were introduced into individual plastic containers and offered leaffolder larvae. Observations on the biological parameters such as number of eggs laid/female, developmental period, prey consumed by predator, nymphal mortality, adult emergence, sex ratio, longevity of adults that emerged in the laboratory was recorded daily. From the quantity of prey consumed per predator and stadial period data, quantity of prey consumed per predator per stadium was calculated.

Results and Discussion

Biology

The adult laid deep brown coloured eggs in small clusters of 6 to 12. Observations on continuous rearing of *R. fuscipes* on leaffolder larvae for three generations revealed that there were no significant differences in the nymphal duration and total development period (Table 1) except in the second and fifth instar stages. All stages fed well on *C. medinalis* larvae and completed their life cycle. *R. fuscipes* female laid a mean of 60.4±20.23 eggs during its lifetime. The egg period ranged from 7-12 days and total nymphal developmental period ranged from 67.80±2.04 to 76.80±11.21 days (Table 1). The developmental period varies based on prey. The developmental period of *R. fuscipes* was observed to be 42.5±0.3, 45.6±0.4 and 49.5±0.5 days on *C. cephalonica*, *Dysdercus cingulatus* Fab and *Phenacoccus solenopsis* Tinsley (Majesh, 2015) which was lower than that observed in the present study. On the other hand, some studies have indicated higher duration when reared on hopper pests (Sunil *et al.*, 2013). The growth, development and reproduction of the reduviid predators vary in relation to hosts and rearing environment (Sahayaraj *et al*., 2004). The developmental rate of individual predator was significantly affected by predator density and prey. Ambrose *et al.* (1990) reported that the total nymphal period of *Rhynocoris marginatus* (Fab.) was higher when it was reared in solitary condition on *Odontotermes obesus* Rambur while it was shorter when it was reared on *Spodoptera litura* (Fab.) in isolation. Rearing in groups on the other hand decreased the total nymphal period (Sahayaraj, 2002). Many reports indicate that lepidopteran larvae increase survival, shorten development in generalist predators but such predators may also feed on inferior prey based abundance and availability (Eubanks and Denno, 2000). Maximum longevity of male and female was 113 and 121 days. Maximum female fecundity was 169 eggs/ female with an average of 60.4±20.23 eggs per female (Table 2). The male-female sex ratio was slightly female biased being 0.83: 1.0. Female biased ratios have been reported in reduviids especially of the genus *Rhynocoris*. However, in some cases it is clearly biased to female with a sex ratio of 1:3 (male to female) observed in *R. fuscipes* when reared on *S. litura* (Ambrose and Claver, 1997). The average nymphal survival ranged from 74.77 to 94.45 % from I to V instar with a total survival rate of 86.21% (Table 3). The adult male longevity was shorter than females. Adult male lived for 57.20±16.16 and female 70.30±19.06 days. Earlier studies confirm that female reduviids usually lived longer than the males (Ambrose *et al*., 1990). The pre-oviposition period was quite long in *R. fuscipes* in the laboratory (53.20±10.06 days) and was comparable to that observed in a related species *R. marginatus* reared on *C. cephalonica* which ranged from 62.7 ± 15 days to 73.3 ± 1.6 days (Sahayaraj and Sathiamoorthi, 2002). The same study indicated that the pre-oviposition period of *R. marginatus* was found to vary with prey and also with prey rearing media.

Table 1. Nymphal development of *R. fuscipes* on *C. medinalis*

Life stages/ parameter in days	I generation	II generation	III generation	Mean duration	CD
1st instar	15.10±1.55	16.70±1.42	17.90±1,85	15.57 ±1.57	1.72 NS
2nd instar	15.20±1.14	14.80±1.32	17.00±1.76	15.70 ±1.60	1.41*
3rd instar	15.60±4.14	14.60±3.53	12.30±1.77	14.40 ±3.43	3.51 NS
4th instar	14.70±3.47	13.80±2.66	12.60±0.84	13.70 ±2.50	2.80 NS
5th instar	16.20±2.25	12.60±2.84	11.00±0.47	13.27 ±2.10	2.13**
Total developmental period (days)	76.80±11.21	72.50±7.08	67.80±2.04	72.37±6.78	8.34 NS

*Significant at 0.05%; ** Significant at 0.01%; NS: Not significant

Table 2. Biological parameters of *R. fuscipes* on *C. medinalis*

Parameter	Mean	Range
Fecundity/female(No.)	60.4±20.23	48-169
Hatchability (%)	94.3	92-100
Per cent Survival	86.21	60-100
Sex ratio (male: female)	0.83:1	
Pre-oviposition period (days)	53.20±10.06	38-74
Male longevity (days)	57.20±16.16	54-113
Female longevity (days)	70.30±19.06	51-121

Table 3. Predatory potential of various stages of R. *fuscipes* on *C. medinalis*

Stadia	No. Observed	% survival	Developmental period (days)	Prey consumed (No.)/ instar	Mean prey (No.)/day
1st instar	45	74.77	13-20	21.72±14.54	1.24±0.36
2nd instar	45	84.85	13-18	16.41±10.15	1.01±0.30
3rd instar	45	94.45	08-21	32.34±26.73	2.06±0.38
4th instar	45	83.64	11-18	26.21±20.73	1.66±0.61
5th instar	45	93.33	09-21	21.03±18.67	1.25±0.38
Mean	45	86.21	54-98*	117.71±18.16*	1.44±0.40

* Total developmental period and Total prey consumed (No.)/instar

Predatory efficiency of *R. fuscipes* on *C. medinalis*

During its nymphal development, *R. fuscipes* predated upon 117.7±18.16 larvae. The predation rate of the five nymphal stages ranged from 16.41±10.15 to 32.34±26.73 with maximum predation being observed in the third instar predator at a mean of 2.06 leaffolder larvae in one day (Table 3). Predatory rate was reported to gradually increase from the first instar to the fourth instar and decreased in fifth instar in *R. fuscipes* (Lakkuundi, 1989). Though reduviids are reported to feed on different species of prey, lepidopteran pests were observed to be the most suitable for its growth (George, 2000). The results signify that *R. fuscipes* being indigenously present in the rice eco-system, is a likely candidate for biocontrol of rice leaffolder. It is also highly amenable for mass rearing on the factitious laboratory host, *C. cephalonica*. Conservation and augmentation of this important predator offers an eco-friendly option for rice pest management.

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ORIGINAL RESEARCH ARTICLE OPEN ACCESS

Metominostrobin, a Novel Strobilurin Fungicide for Managing Rice Blast

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Received: 13th June, 2016 Accepted: 29th June, 2016

Abstract

The new fungicides *viz.*, metominostrobin 20 SC, tricyclazole 75 WP, isoprothiolane 40 EC and propiconazole 25 EC were tested against blast of rice. The lowest incidence (55.93%) and intensity (14.19%) of leaf blast and incidence of neck blast (39.64%) were noticed in the treatment with metominostrobin 20 SC (0.20 %) and thus it showed highest leaf and neck blast reduction of 77.80 and 45.68 per cent, respectively. This was followed by propiconazole 25 EC (0.10 %) and isoprothiolane 40 EC (0.15%) that recorded 76.38 and 64.49 per cent leaf and 42.31 and 24.36 per cent neck blast control, respectively.The highest grain yield (28.84 q/ha) was obtained in treatment with metominostrobin (0.2 %) that recorded maximum increase of 75.32 per cent in yield of paddy. It was followed by propiconazole (0.1 %) and isoprothiolane 40 EC (0.15%), which recorded yield of 28.47 and 26.57 q/ha with 73.07 and 61.52 per cent increase in yield, correspondingly.

Key words: Management, blast, rice, novel fungicides.

Introduction

Rice (*Oryza sativa* L.) is the most widely cultivated food crop in the world. It is the most important staple food grain for the people living in the rural and urban areas of humid and sub-humid Asia. The productivity of rice is less (1.8 t/ha) in Maharashtra and the major constraints for low productivity are diseases occurring on this crop. More than 70 diseases are caused by fungi, bacteria, viruses and nematodes on rice. Among the several diseases infecting rice, the severe disease infecting rice in Maharashtra is blast caused by *Pyricularia grisea* (*Magnaporthe oryzae*), which causes about 10-80 per cent loss in paddy yield depending upon the location, and variety infected.

Among the several methods of rice blast management, the use of fungicides is proved to be the most effective method. The fungicides recommended earlier for management of disease are sometimes not showing expected results. Looking to the severity of disease, its economic importance and need of the rice growers, it was very necessary to manage the disease by use of modern fungicides. Hence, the trials were conducted with new molecules of fungicides for testing their bio-efficacy against blast disease.

Materials and Methods

The field experiments were conducted during *kharif* seasons of 2009 and 2010 on EK – 70, a highly susceptible variety of paddy in randomized block design with four replications at blast disease hot spot location, Agricultural Research Station, Lonavala. The fungicides tested were metominostrobin 20 SC ((*E*)-2-methoxyimino-*N*-methyl-2-(2-phenoxyphenyl) acetamide)), tricyclazole 75 WP *i.e.* Beam (5-methyl-1,2,4-triazole [3,4,-b][1,3] benzothiazole), isoprothiolane 40 EC *i.e.* Fuji-One (Dilsopropyl 1,3-dithiolam-2-y liden malonate) and propiconazole 25 EC *i.e.* Tilt (1-[2-(2,4-dichlorophenyl)-4-porpyl-1,3-dioxolan-2-yl-methyl]-1H-1,2,4-trizole). Three sprays were taken at 15 days interval, starting first spray at first appearance of disease.

The gross plot size for each treatment was 5.60 × 2.60 m with 17 rows in each plot and plant to plant and row to row distance was 15 cm. Fertilizer was applied @ 100, 50 and 0 kg of NPK. The observations on leaf and neck blast were recorded by following 0 - 9 SES scale as per IRRI, Philippines (Anonymous, 2002) and then converting into per cent disease intensity by using the formulas.

$$\text{\% disease intensity} = \frac{\text{Sum of the scores X 100}}{\text{No. of observation X Highest rating } i.e. 9}$$

The data on the yield were recorded by marking 5 × 2 m section within each plot using a wire frame as described by (Seebold *et al.*, 2004) and tillers within the frame were cut and harvested in order to determine the yield.

Results and Discussion

Management of blast

The year wise and pooled disease data presented in Table 1 indicate that the treatment differences due to all parameters under study were statistically significant. The lowest incidence (55.93%) and intensity (14.19%) of leaf blast and neck blast incidence (39.64%) were noticed in the treatment with metominostrobin 20 SC (0.20%) and thus showed highest leaf and neck blast reduction of 77.80 and 45.68 per cent, respectively. However, it was at par with propiconazole 25 EC (0.10%) that recorded 58.24, 15.10 and 42.11 per cent incidence and intensity of leaf blast and incidence of neck blast, respectively with 76.38 per cent leaf and 42.31 per cent neck blast control. These findings are in agreement with the reports of earlier workers (Mizutani *et al*., 1995; Mizutani *et al*., 1996; Furuta, 1999; Bartlett *et al*., 2001and Anonymous, 2014) who noticed the excellent control of rice blast with metominostrobin.

Table 1: Influence of new fungicides on incidence and intensity of leaf blast in rice

Tr. No.	Name of Treatment	Conc. (%)	Per cent leaf blast Incidence 2009	Incidence 2010	Incidence Mean	Intensity 2009	Intensity 2010	Intensity Mean	Reduction (%)
T_1	Metominostrobin 20 SC	0.05	77.50	85.10	81.30	24.86	34.28	29.57	53.74
			61.86	**67.45**	**64.45**	**29.85**	**35.82**	**32.90**	
T_2	Metominostrobin 20 SC	0.10	71.25	78.03	74.64	19.31	28.49	23.90	62.61
			57.75	**62.12**	**59.80**	**26.02**	**32.23**	**29.20**	
T_3	Metominostrobin 20 SC	0.20	52.50	59.35	55.93	10.14	18.24	14.19	77.80
			46.46	**50.41**	**48.41**	**18.46**	**25.20**	**21.99**	
T_4	Tricyclazole 75 WP (Beam)	0.06	73.75	79.17	76.46	19.59	29.65	24.62	61.48
			59.43	**62.93**	**61.00**	**26.25**	**32.93**	**29.67**	
T_5	Isoprothiolane 40 EC (Fuji-One)	0.15	67.50	72.94	70.22	18.61	26.78	22.70	64.49
			55.32	**58.69**	**56.94**	**25.54**	**31.12**	**28.39**	
T_6	Propiconazole 25 EC (Bumper)	0.10	55.00	61.47	58.24	10.83	19.36	15.10	76.38
			47.91	**51.65**	**49.75**	**19.18**	**26.03**	**22.73**	
T_7	Check (Untreated)	-	92.50	100.00	96.25	57.92	69.91	63.92	0.00
			76.46	**85.95**	**79.63**	**49.58**	**56.80**	**53.12**	
	S.E. ±		2.97	1.65	1.88	1.05	1.85	1.17	
	C.D. at 5%		8.84	5.09	5.70	3.11	5.71	5.10	
	C.V.		10.28	4.55	12.53	7.53	9.35	9.2	

The next treatments in order of superiority were isoprothiolane 40 EC (0.15%) metominostrobin 20 SC (0.10%) and tricyclazole 75 WP (0.06%) those were at par with each other and had leaf blast severity of 22.70, 23.90 and 24.62 per cent with disease reduction of 64.49, 62.61 and 61.48 per cent, respectively. Similar trend was noticed in respect of neck blast, wherein the incidence was 53.01, 55.59 and 57.96 per cent with disease decrease of 27.36, 23.83 and 20.58 per cent in isoprothiolane 40 EC (0.15%) metominostrobin 20 SC (0.10%) and tricyclazole 75 WP (0.06%), respectively. On the contrary, the untreated control had significantly highest incidence of leaf (96.25%) and neck blast (72.98 %) as well as blast severity on leaves (63.92 %). Ghazanfar *et al.* (2009) and Hajime (2001) also observed effectiveness of all tested fungicides like metominostrobin, propiconazole, tricyclazole, isoprothiolane, etc. in management of rice blast.

Grain yield

The highest grain yield (28.84 q/ha) was obtained in treatment with metominostrobin (0.20%) that recorded maximum increase of 75.32 per cent in yield of paddy Table 2. Whereas, it was at par with propiconazole (0.10%), isoprothiolane 40 EC (0.15%) and metominostrobin (0.10%), which recorded yields of 28.47, 26.57 and 24.99 q/ha with 73.07, 61.52 and 51.91 per cent increase in yield, in that order. The next treatments in order of superiority were tricyclazole 75 WP (0.06%) and metominostrobin 20 SC (0.05%), where the grain yields were 23.59 and 22.52 q/ha with yield increase of 43.40 and 36.87 per cent, correspondingly. The untreated control yielded just 16.45 q/ha. Bhat *et al.* (2012) found that tricyclazole (0.06%) was more effective thanmetominostrobin (0.20%) for control of leaf and neck blasts and increasing yields in paddy that is not in consonance with present findings wherein tricyclazole was less effective than metominostrobin and propiconazole.

Table 2. Incidence of neck blast and yield as influenced by use of new fungicides in rice

Tr. No.	Name of Treatment	Conc. (%)	Per cent neck blast incidence 2009	2010	Mean	Reduction (%)	Yield (q/ha) 2009	2010	Mean	Increase (%)
T_1	Metominostrobin 20 SC	0.05	62.50 **53.78**	68.67 **56.06**	65.59 **54.10**	10.13	23.49	21.54	22.52	36.87
T_2	Metominostrobin 20 SC	0.10	53.23 **46.86**	57.95 **49.59**	55.59 **48.21**	23.83	25.76	24.22	24.99	51.91
T_3	Metominostrobin 20 SC	0.20	37.50 **37.67**	41.78 **40.24**	39.64 **38.02**	45.68	29.39	28.29	28.84	75.32
T_4	Tricyclazole 75 WP (Beam)	0.06	55.73 **48.34**	60.19 **50.90**	57.96 **49.58**	20.58	24.05	23.13	23.59	43.40
T_5	Isoprothiolane 40 EC (Fuji-One)	0.15	50.00 **45.00**	56.02 **48.47**	53.01 **46.73**	27.36	27.31	25.83	26.57	61.52
T_6	Propiconazole 25 EC (Bumper)	0.10	39.65 **38.98**	44.56 **41.87**	42.11 **40.45**	42.31	28.79	28.15	28.47	73.07
T_7	Check (Untreated)	-	69.64 **56.97**	76.31 **60.97**	72.98 **58.71**	0.00	17.25	15.64	16.45	0.00
	S.E. ±		3.57	2.21	2.00		2.33	2.42	1.30	
	C.D. at 5%		10.60	6.81	6.00		6.93	7.44	4.00	
	C.V.		15.25	7.7	7.00		18.55	17.55	9.20	

Note: Figures in bold faces are arcsine values

Conclusion

While testing efficacy of new fungicides against blast of paddy, the highest control of leaf (77.80%) and neck (45.68%) blast was noticed in the treatment with three sprays of fungicide metominostrobin 20 SC (0.20%) that yielded maximum (28.84 q/ha) with 75.32 per cent increase in grain yield. This was followed by propiconazole (0.10%) and isoprothiolane 40 EC (0.15%).

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ORIGINAL RESEARCH ARTICLE OPEN ACCESS

Evaluation on the Efficacy of Modern Fungicides against Rice Diseases

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Received: 13th June, 2016; Accepted: 30th June, 2016

Abstract

The modern broad spectrum fungicides *viz.*, trifloxystrobin 25% + tebuconazole 50 %, kresoxim methyl and azoxystrobin were tested along with previously recommended fungicides like tricyclazole, carbendazim and propiconazole against rice diseases. Three sprays of fungicide combination *viz.*, trifloxystrobin 25% + tebuconazole 50 % (0.04 %) at 15 days interval starting first spray immediately after disease appearance were found to be most effective in management of leaf blast, neck blast, node blast, sheath rot, leaf scald, brown spot and seed discolouration diseases and thereby enhancing the grain yield in paddy. This was followed by tricyclazole (0.06 %), propiconazole (0.10 %) and carbendazim (0.10%).

Keywords: Rice, diseases, fungicides.

Introduction

Rice is the most important staple food grain for more than two billion people living in the rural and urban areas of humid and sub-humid Asia. It accounts for 30 to 50 per cent of agricultural production and 50–90 per cent of the calories consumed by these people (Hossain and Fischer, 1995). Rice provides household and national food security and generates employment and incomes for the low-income groups in these areas. However, the biotic causes like diseases and pests are causing huge losses to the rice crop.

In Maharashtra, the productivity of rice is 1800 kg/ha, which is less than the national level (2410 kg/ha) (Anonymous, 2014). In Maharashtra, the rice is infected by diseases *viz.*, leaf and neck blasts (*Pyricularia grisea*), leaf scald (*Rhynchosporium oryzae*), sheath rot (*Sarocladium oryzae*), brown spot (*Dreschlera oryzae*) and grain discolouration (Spp. of *Dreschlera, Sarocladium, Pyricularia*, etc.), which became the major production constraint in all rice-growing areas of the state. The average losses caused by the diseases are in between 10 to 30 per cent. However, if all these diseases appear simultaneously then huge losses ranging from 30 to 100 per cent may be caused in the susceptible varieties.

Unfortunately, varieties are not available with multiple disease resistance. Hence, there is no alternative for management of diseases by chemicals. However, the farmers failed to control the diseases by spraying the traditional chemicals having no or less broad spectrum activity. Hence, looking in to the importance of the crop as well as severity of diseases appearing on it and need of the farmers, the trials were conducted with new broad spectrum fungicides.

Materials and Methods

The field experiments were conducted at Agricultural Research Station, Lonavala, Tal. – Maval, Dist. – Pune (MS) for consecutive two years during the *kharif* seasons of 2012 and 2013 in RBD design with four replications. The modern broad spectrum fungicides *viz.*, trifloxystrobin 25% [Methyl (E) - methoxyimino - {(E) - α - [1 - (α, α, α - trifluorom-tolyl) ethylideneaminooxy] - o - tolyl} acetate] + tebuconazole 50 % [(RS) - 1 - p - chlorophenyl) - 4, 4 - dimethyl - 3 - (1H - 1, 2, 4 - triazol - 1- ylmethyl) pentan-3-ol] *i.e.* Nativo, kresoxim methyl *i.e.* Ergon [methyl (2E) - (methoxyimino) {[(2 - methylphenoxy) methyl] phenyl}acetate], and azoxystrobin *i.e.* Mirador [Methyl (E) - 2 - {2 - [6 - (2 - cyanophenoxy) pyrimidin - 4 - yloxy]phenyl}-3-methoxyacrylate] were tested along with previously recommended fungicides like tricyclazole *i.e.* Blastogan (5 - methyl - 1, 2, 4 - triazol [3, 4, - b] [1, 3] benzothiazole), carbendazim *i.e.* Benmain (2- (Methoxy-carbamoyl) benzimidazole) and propiconazole *i.e.* Bumper (1 - [2 - (2, 4 - dichlorophenyl) - 4 - porpyl - 1, 3 - dioxolan-2 - yl - methyl] - 1H - 1, 2, 4 - trizole).

The highly susceptible variety of paddy, 'EK – 70' was transplanted under rainfed lowland condition in plots of 5.30 × 2.30 m^2 for each of the treatment at 0.15 m row to row and plant to plant distance. The crop was fertilized with 50:50:50 kg NPK/ha as basal dose and top dressed with 50 kg N/ha one month after transplanting. The first spray of fungicides was taken immediately after appearance of any pathogen (*i.e. Pyricularia grisea*) and was followed by two sprays at 15 days interval thereafter. For all diseases common spray schedule was followed. The observations for incidence / severity of different diseases were recorded as per SES scale (Anonymous, 2002) and for grain yield (kg/net plot) at maturity stage.

Per cent disease incidence and intensity were calculated by the formula:

$$\text{Incidence} = \frac{\text{No. of leaves infected}}{\text{Total No. of leaves examined}} \times 100$$

$$\text{PDI} = \frac{\text{Total numerical rating}}{\text{Total No. of leaves examined} \times \text{Maximum rating } (\textit{i.e. } 7 \text{ rating})} \times 100$$

Results and Discussion

Leaf blast

The leaf blast data (Table 1) indicated that the treatment differences due to fungicides were statistically significant. The lowest incidence (33.28 %) and intensity (14.09 %) of leaf blast were noticed in the treatment with trifloxystrobin 25 % + tebuconazole 50 % (0.04 %) that showed highest disease reduction of 70.63 per cent. While, it was at par with tricyclazole (0.06 %) and propiconazole (0.10%) those recorded 62.85 and 59.70 per cent leaf blast reduction over control, respectively. The untreated control had significantly highest incidence of 75.71 per cent and severity of 47.95 per cent of the disease.

Neck and node blasts

The observations in Tables 1 and 2 divulge that the treatment differences in respect of neck and node blasts due to fungicides were statistically significant. The fungicide treatment with trifloxystrobin + tebuconazole (0.04 %) had significantly least incidence of 26.88 and 23.98 per cent of neck and node blasts and thus recorded highest disease control of 60.19 and 60.88 per cent of these diseases, respectively. This was followed by tricyclazole (0.06 %) that recorded 47.41 per cent neck blast and 50.79 per cent node blast reduction over control. The next fungicides in order of superiority were carbendazim (0.10 %) and propiconazole (0.10%), which showed 46.67 and 40.74 per cent neck blast while, 48.0 and 45.07 per cent node blast control, respectively. The control treatment showed significantly highest neck (67.50 %) and node (61.31 %) blast incidence.

Narayana Swamy *et al.* (2009) also reported the most effectiveness of trifloxystrobin + tebuconazole and tricyclazole against blast of rice. In addition, the data supports the findings of (Rohilla and Singh 1999) and corroborates the findings of (Vishwanathan and Narayanaswamy 1991). However, they did not notice the good control of blast with propiconazole.

Sheath rot

The treatment differences (Table 2) due to fungicides in respect of sheath rot were statistically significant. The treatment with trifloxystrobin + tebuconazole (0.04 %) had lowest sheath rot incidence (71.0 %) and intensity (27.56 %) and thereby recorded maximum disease reduction of 55.03 per cent. But, it was at par with most of the fungicides *viz.*, azoxystrobin (0.10 %), kresoxim methyl (0.10%), carbendazim (0.10 %) and propiconazole (0.10%), which showed 51.55, 50.32, 47.24 and 44.97 per cent reduction in the disease over control, respectively.

Leaf scald

The leaf scald observations reported in Table 3 indicate that the treatment differences due to fungicides were statistically significant. The lowest incidence of 22.52 per cent and intensity of 7.37 per cent of leaf scald was noticed in the treatment with trifloxystrobin + tebuconazole (0.04 %) that showed highest disease reduction of 81.09 per cent. While, it was at par with carbendazim (0.10 %), which recorded 73.47 per cent leaf scald reduction. The untreated control had significantly highest incidence and severity of 60.93 and 38.98 per cent, respectively.

Brown spot

The brown spot observations (Table 3) illustrated that the treatment differences due to fungicides were statistically significant. The fungicide trifloxystrobin + tebuconazole (0.04 %) showed least brown spot incidence and intensity of 62.13 and 14.38 per cent, respectively and thus highest disease reduction of 72.17 per cent. However, it was at par with azoxystrobin (0.10 %) and propiconazole (0.10 %) those recorded 65.69 and 64.18 per cent brown spot reduction, respectively. The untreated control had significantly highest incidence and severity of 96.88 and 51.65 per cent, respectively.

Seed / Glume Discolouration

The observations of seed / glume discolouration (Table 4) depicted that the treatment differences due to fungicides were statistically significant. The lowest incidence of 25.13 per cent with highest decrease of 51.80 per cent in seed discolouration was noticed in the treatment with trifloxystrobin + tebuconazole (0.04 %). Whereas, it was at par with azoxystrobin (0.10 %) that recorded 41.01 per cent reduction in disease over control. The highest seed discolouration of 52.13 per cent was noticed in untreated control.

Yield

The yield data presented in Table 4 were statistically significant. The significantly highest grain yield (35.08 q/ha) with 55.44 per cent increase was obtained in treatment with trifloxystrobin + tebuconazole (0.04 %). While, it was at par with tricyclazole (0.06 %), propiconazole (0.10 %), carbendazim (0.10%) and azoxystrobin (0.10%) wherein, 47.72, 42.16, 36.04 and 33.15 per cent increase in yield was reported, respectively. The untreated control plot yielded just 22.57 q/ha.The results are exactly matching with the findings of earlier work at DRR (IIRR), Hyderabad

(Anonymous, 2012) wherein they reported that the fungicide combination trifloxystrobin 25% + tebuconazole 50 % reduced the diseases *viz.*, leaf blast, neck blast, node blast, sheath rot, sheath blight, leaf scald, brown spot, false smut and seed discolouration and increased the yield of paddy to the greater extent. They also reported the effectiveness of tricyclazole, propiconazole and carbendazim. Further, (Kumar *et al*. 2013) also noticed the effectiveness of fungicides like carbendazim and tricyclazole in management of rice diseases and thereby increase in yield.

Conclusion

Three sprays of fungicide combination *viz.*, trifloxystrobin 25% + tebuconazole 50 % @ 0.04 per cent at 15 days interval starting first spray immediately after disease appearance were found to be most effective in management of leaf blast, neck blast, node blast, sheath rot, leaf scald, brown spot and seed discolouration diseases and thereby enhancing the grain yield in paddy. This was followed by tricyclazole (0.06 %), propiconazole (0.10 %) and carbendazim (0.10%).

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Table 1: Efficacy of new fungicides against leaf and neck blasts of paddy (Pooled results of 2012 & 2013)

Sr. No.	Name of fungicide	Dose (%)	Leaf blast (%)			Neck blast (%)	
			Incidence	PDI	Reduction over control	Incidence	Reduction over control
1	Trifloxystrobin 25 % + Tebuconazole 50 %	0.04	33.28 **35.2**	14.09 **22.02**	70.63	26.88 **31.09**	60.19
2	Kresoxim methyl	0.1	53.22 **46.86**	28.14 **31.97**	41.32	49.00 **44.42**	27.41
3	Azoxystrobin	0.1	46.02 **42.71**	24.43 **29.58**	49.05	45.85 **42.62**	32.07
4	Tricyclazole	0.06	35.90 **36.79**	17.81 **24.93**	62.85	35.50 **36.56**	47.41
5	Carbendazim	0.1	40.87 **39.73**	21.34 **27.48**	55.49	36.00 **36.87**	46.67
6	Propiconazole	0.1	38.51 **38.32**	19.32 **25.95**	59.70	40.00 **39.22**	40.74
7	Control	-	75.71 **60.50**	47.95 **43.82**	0.00	67.50 **55.31**	0.00
	SE ± CD (0.05)	-	1.36 4.05	1.25 3.81	-	1.57 4.67	-

The figures in the bold faces are arc sin values

Table 2: Efficacy of new fungicides against node blast and sheath rot of paddy (Pooled results of 2012 & 2013)

Sr. No.	Name of fungicide	Dose (%)	Node blast (%)		Sheath rot (%)		
			Incidence	Reduction over control	Incidence	PDI	Reduction over control
1	Trifloxystrobin 25 % + Tebuconazole 50 %	0.04	23.98 **21.31**	60.88	71.00 **57.47**	27.56 **31.6**	55.03
2	Kresoxim methyl	0.1	43.75 **41.4**	28.65	76.00 **60.8**	30.44 **33.38**	50.32
3	Azoxystrobin	0.1	38.94 **38.6**	36.49	74.00 **59.36**	29.44 **32.84**	51.95
4	Tricyclazole	0.06	30.17 **31.3**	50.79	81.50 **64.75**	39.00 **38.57**	36.36
5	Carbendazim	0.1	31.88 **34.35**	48.00	76.50 **61.34**	32.33 **34.65**	47.24
6	Propiconazole	0.1	33.68 **35.46**	45.07	76.50 **61.03**	33.72 **35.48**	44.97
7	Control	-	61.31 **51.54**	0.00	100.00 **85.95**	61.28 **51.53**	0.00
	SE ±		0.81		1.89	1.57	
	CD (0.05)		2.41		5.61	4.66	

The figures in the bold faces are arc sin values

Table 3: Efficacy of new fungicides against leaf scald and brown spot diseases of paddy (Pooled results of 2012 & 2013)

Sr. No.	Name of fungicide	Dose (%)	Leaf scald (%)			Brown spot (%)		
			Incidence	PDI	Reduction over control	Incidence	PDI	Reduction over control
1	Trifloxystrobin 25 % + Tebuconazole 50 %	0.04	22.52 **28.32**	7.37 **15.73**	81.09	62.13 **52.08**	14.38 **22.15**	72.17
2	Kresoxim methyl	0.1	44.64 **41.92**	24.92 **29.92**	36.08	69.00 **56.3**	18.75 **25.63**	63.70
3	Azoxystrobin	0.1	39.14 **38.72**	19.17 **25.86**	50.82	66.25 **54.5**	17.72 **24.86**	65.69
4	Tricyclazole	0.06	27.53 **31.57**	10.82 **19.15**	72.25	73.38 **59.17**	21.83 **27.83**	57.73
5	Carbendazim	0.1	24.64 **29.73**	10.34 **18.7**	73.47	86.50 **68.77**	33.49 **35.32**	35.17
6	Propiconazole	0.1	31.94 **34.39**	13.78 **21.78**	64.66	68.50 **55.87**	18.50 **25.45**	64.18
7	Control	-	60.93 **51.33**	38.98 **38.63**	0.00	96.88 **80.77**	51.65 **95.45**	0.00
	SE ±		1.06	0.87		2.16	1.12	
	CD (0.05)		3.13	2.58		6.41	3.32	

The figures in the bold faces are arc sin values

Table 4: Efficacy of new fungicides against glume discolouration and grain yield influenced by management of different diseases by these fungicides (Pooled results of 2012 & 2013)

Sr. No.	Name of fungicide	Dose (%)	Grain discolouration (%)		Grain yield	
			Incidence	Reduction over control	q/ha	Increase over control
1	Trifloxystrobin 25 % + Tebuconazole 50 %	0.04	25.13 **30.07**	51.80	35.08	55.44
2	Kresoxim methyl	0.1	31.88 **34.36**	38.85	27.30	20.95
3	Azoxystrobin	0.1	30.75 **33.64**	41.01	30.05	33.15
4	Tricyclazole	0.06	38.13 **38.05**	26.87	33.34	47.72
5	Carbendazim	0.1	32.88 **34.97**	36.94	30.71	36.04
6	Propiconazole	0.1	35.25 **36.42**	32.38	32.08	42.16
7	Control	-	52.13 **46.22**	0.00	22.57	0.00
	SE ±		1.33		1.72	
	CD (0.05)		3.95		5.11	

The figures in the bold faces are arc sin values

ORIGINAL RESEARCH ARTICLE OPEN ACCESS

Systamic and Contact Combi Fungicides for Rice Grain Discolouration Disease Control in Kuttanad

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Received: 16th March, 2016; Accepted 22nd June, 2016

Abstract

Field experiments were conducted at Rice Research Station, Kerala Agricultural University, Moncompu during *Kharif 2010, Kharif 2011* and *Rabi 2011-12* to evaluate the some systemic and contact action fungicides for management of rice grain discolouration. Anew systemic fungicide Kresoxim methyl 40% + Hexaconazole 8 % WG with different doses of 0.75 ml and 1.0 ml/lit and commercially available fungicides were tested against grain discolouration disease. Pooled analysis of three seasons showed that kresoxim methyl 40% + hexaconazole 8 % WG @ 1.0 ml/l and carbendazim 12% + mancozeb 63% @ 1.5 g/l were promising compared to standard check fungicides. The molecules were promoted for farm trials at six different farmers field of Kuttanad region during *Rabi 2012-13* and confirmed that the above two molecules performed better in restricting the appearance of both grain discoloured panicles (2.43 and 2.56 %) and spikelets (1.67 and 1.92%) compared to the standard check fungicide mancozeb 45 WP (2.49 and 1.81 %).

Keywords: Rice, grain discolouration, systemic, contact, fungicide

Introduction

Grain discoloration was considered as aminor disease in earlier days. Now it has become major problem in Kuttanad region due to increasing biotic and abiotic stresses. Grain discoloration is caused by many fungal pathogens like *Drechsleraoryzae, Curvularialunata, Helmithosporiumoryzae, Sarocladiumoryzae, Phoma sp., Microdochiumsp., Nigrosporasp. And Fusariumsp.* Its common symptom can be observed as darkening of glumes or spikelets, brown to black color in rotten glumes by one or more pathogens. The intensity ranges from sporadic discoloration to discoloration of whole glumes. The discoloration may appearexternally on the glumes or internally on the kernels or both. On the glumes, symptoms accordingly vary. The symptoms depends on type of organism involved and the degree of infection. The extent of yield loss can vary from 20 to 55 per cent depending on extent of infection (Ghose *et al.*,1960). The disease has been found to increase every year in the Kuttanad with higher damageable level. Grain discolouration not only decrease the yield but also affect the seed grain quality. The present studies were conducted to evaluate the efficacy of selected fungicides against grain discolouration.

Materials and Methods

Field experiments were conducted at Rice Research Station, Moncompu, Alappuzha, Kerala for three seasons *Kharif 2010, Kharif 2011* and *Rabi 2011-12* with the objective of evaluating some systemic action combination fungicides for grain discolouration management. The evaluated fungicides were kresoxim methyl 40% + hexaconazole 8% WG, hexaconazole 5 SC, propeiconazole 25 EC, tricyclozole 75 WP andcarbendazim 12% + mancozeb 63%. The trial was carried out in the direct sown crop of medium duration susceptible variety, Uma. The experiments were laid out in randomized block design with 3 replications in 5x2 m^2 plot size. The N,P,K fertilizers and all other cultural operations were applied as per Package of Practices recommendation (90:45:45 kg/ha) by Kerala Agricultural University. The chemicals were sprayed as prophylactic mannerat the time of panicle emergence. The details are given in Table 1. Three sampling units of 1 sq.m area were fixed in each plot at random. The percentage of panicles and spikelets affected were recorded at 15 days before harvest. The percentage of panicle affected was calculated based on the number of panicles affected from the total number of panicles present in the sampling area. The spikelet percentage was recorded by counting the infected grains from each panicle and converted in terms of percentage. Grain yield of the each plot was recorded and expressed in kg/plot at 14 % moisture. Percentages data were transformed to arcsine and analysis of variance was performed with transformed values. The confirmatory farm trials were conducted for testing the effective molecules during *Rabi 2012-13* at six locations namely Champakulam, Veeyapuram, Neelamperoor, Venattukad, E-block kayal and Thuruthy area of Kuttanad region. The four treatments were kresoxim methyl 40%

+ hexaconazole 8 % WG @ 1.0 ml/l,carbendazim 12% + mancozeb 63% @ 1.5 g/l, standard POP recommended fungicidemancozeb 45 WP @ 4.0 g/l and untreated check plot. The farm trial was laid out in a randomized complete block design (RBD), using MO 16 (Uma) as the test variety in the farmers field. Pregerminated seeds were used for direct sowing with the plot size of 20x10 m^2. Fertilizers were applied @ 90:45:45 NPK kg/ha as per Package of Practices, Kerala Agricultural University. Observations on panicles and spikelets affected were recorded 15 days before harvest. Percentage of panicles and spikelets affected was calculated on 25 plants per sampling unit, by counting the number of infected panicles/spikelets as per the SES of rice, IRRI (1996).

Results and Discussion

The results of three season station trials showed that the combination fungicides *viz.*, carbendazim 12% + mancozeb 63% and kresoxim methyl 40% + hexaconazole 8 % WG were very effective and could significantly reduce the grain discolouration disease. The analysis of pooled data of three seasons on panicle percentage affected showed that carbendazim 12% + mancozeb 63%, kresoxim methyl 40% + hexaconazole 8 % WG were highly effective than tricyclozole 75 WP, propeiconazole 25 EC and hexaconazole 5 SC. The data on spikelet affected indicated that tricyclozole 75 WP, carbendazim 12% + mancozeb 63%, and kresoxim methyl 40% + hexaconazole 8 % WG were significantly superior to all other fungicides tried (Table 1). The maximum yield was obtained from kresoxim methyl 40% + hexaconazole 8 % WG @ 1.0 ml/l (5647 kg ha^{-1}) treated plot followed by carbendazim 12% + mancozeb 63% @ 1.5 g/l (5640 kg ha^{-1}). The control plot recorded with lowest yield of 4303 kg ha^{-1}. Several workers have reported on the scope for controlling grain discolouration disease by application of fungicides like edifenphos and copper oxy chloride (Govindarajan and Kannaiyan, 1982), propiconazole (Lore *et al.*, 2007), captan 70% + hexaconazole 5% (Kumar and Kumar, 2011) and azoxystrobin and propiconazole (Hossain *et al.*, 2011). The farm trial results showed that the systemic fungicide kresoxim methyl 40 % + hexaconazole 8 % WG @ 1 g/l was effective against glume discolouration disease in restricting the incidence of disease in the panicles (2.43 %) as well as individual spikelets (1.67 %) in panicles (Table 2 and 3). It was also on par with carbendazim 12% + mancozeb 63 % @ 1.5 g/l (2.56 and 1.92%) and standard check fungicide mancozeb (dithane M 45) @ 4 g/l. There was no significant difference in the grain yield (Table 4). Dithane M 45 treated plot gave highest yield of 6015kg ha^{-1} (Fig. 1) followed by kresoxim methyl 40 % + hexaconazole 8 % WG (5937 kg ha^{-1}) and carbendazim 12% + mancozeb 63 % (5890 kg ha^{-1}).

Conclusion

It is concluded that new systemic combination product of kresoxim methyl 40 % + hexaconazole 8 % WG @ 1 g/l and commercially available carbendazim 12% + mancozeb 63 % (Saaf 75 WP) @ 1.5 g/lwere found to be equally effective and on par with standard check fungicide mancozeb (dithane M 45) against rice grain discolouration disease. The quality of grain was comparatively better in the combination fungicides treated plotsthan the standard check contact fungicide mancozeb and it can be recommended for the control of grain discolouration and improve the quality of the seed in Kuttanad region.

Acknowledgement

The authors thank the Director of Research, Kerala Agricultural University, Vellanikkara and Professor and Head, Rice Research Station, Moncompu for necessary facilities in carrying out the present investigations.

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Table 1: Glume discolouration on panicles and spikelets and grain yield as influenced by newer fungicides (analysis of pooled data of three seasons)

Sl. No.	Fungicides	Dose/l	Panicles affected (%)				Spikelets affected (%)				Yield (kg/ha)
			Kharif 2010	*Kharif* 2011	*Rabi* 2011-12	Mean	*Kharif* 2010	*Kharif* 2011	*Rabi* 2011-12	Mean	
1	Kresoxim methyl + Hexaconazole	1.0ml	2.23 (4.46)	2.27 (4.65)	2.21 (4.40)	2.24 (4.50)	2.50 (5.74)	2.91 (8.00)	1.31 (1.21)	2.34 (4.98)	5647
2	Kresoxim methyl + Hexaconazole	0.75ml	1.84 (2.90)	2.77 (7.19)	1.96 (3.35)	2.23 (4.48)	2.56 (6.05)	3.04 (8.75)	1.38 (1.41)	2.43 (5.40)	5289
3	Hexaconazole	2 ml	2.70 (6.80)	4.05 (15.90)	1.97 (3.37)	3.03 (8.69)	2.15 (4.14)	3.15 (9.43)	1.13 (0.78)	2.30 (4.78)	5253
4	Propiconazole	1 ml	2.92 (8.03)	2.85 (7.64)	2.09 (3.87)	2.65 (6.51)	2.54 (5.94)	2.97 (8.34)	1.25 (1.07)	2.37 (5.12)	5334
5	Tricyclazole	0.6 g	2.64 (6.45)	2.54 (5.93)	2.42 (5.36)	2.53 (5.91)	2.03 (3.52)	2.78 (7.21)	1.25 (1.07)	2.10 (3.93)	5475
6	Carbendazim +Mancozeb	1.5 g	1.32 (1.25)	1.56 (1.93)	1.89 (3.06)	1.61 (2.08)	2.27 (4.56)	2.99 (8.42)	1.45 (1.60)	2.31 (4.86)	5640
7	Check		3.27 (10.18)	4.56 (20.34)	2.70 (6.78)	3.60 (12.43)	3.18 (9.64)	3.35 (10.71)	1.89 (3.09)	2.88 (7.81)	4303
	CD (0.05)					0.89				0.29	NS

Figures in parentheses are original values. Data transformed to $(\sqrt{x+0.5})$

Table 2: Influence of kresoxim methyl + hexaconazole and saafon glume discolouration spikelets affected (%)

Fungicide	Locations						Mean
	Champakulam	Veeyapuram	Neelamperoor	Venattukad,	E-block kayal	Thuruthy	
Kresoxim methyl 40%+ Hexaconazole 8%	2.07 (3.8)	1.18 (0.9)	1.27 (1.13)	2.13 (4.05)	1.84 (2.92)	1.55 (1.91)	1.67 (2.45)
Carbendazim 12% + Mancozeb 63 % (Saaf 75 WP)	2.13 (4.06)	1.45 (1.26)	1.80 (2.76)	1.90 (3.12)	2.63 (6.4)	1.62 (2.14)	1.92 (3.29)
Mancozeb (Dithane M 45)	1.82 (2.83)	1.54 (1.88)	1.58 (2.02)	2.31(4.84)	1.88 (3.05)	1.72 (2.46)	1.81 (2.84)
Control	2.22 (4.43)	1.58 (2.01)	1.90 (3.11)	2.66 (6.61)	2.70 (6.79)	1.93 (3.23)	2.17 (4.36)
CD (0.05)				0.26			

Table 3: Influence of kresoxim methyl + hexaconazole and saafon glume discolouration panicles affected (%)

Fungicide	Locations						Mean
	Champakulam	Veeyapuram	Neelamperoor	Venattukad	E-block kayal	Thuruthy	
Kresoxim methyl 40% + Hexaconale 8%	2.80 (7.3)	2.27 (4.66)	2.07 (3.8)	2.52 (5.9)	2.54 (6.0)	2.36 (5.10)	2.43(5.46)
Carbendazim 12% + Mancozeb 63%(Saaf 75 WP)	3.03 (8.71)	2.32 (4.9)	2.42 (5.4)	2.21 (4.4)	2.84 (7.6)	2.56 (6.10)	2.56 (6.18)
Mancozeb (Dithane M 45)	2.76 (7.16)	2.25 (4.6)	2.32 (4.9)	2.56 (6.07)	2.41(5.35)	2.64(6.52)	2.49 (5.76)
Control	3.19 (9.70)	2.43 (5.44)	2.73 (7.0)	2.89 (7.9)	2.79 (7.33)	2.70 (6.8)	2.79 (7.36)

CD(0.05)	0.19

Table 4: Influence of kresoxim methyl + hexaconazole, saaf and mancozeb on grainyield

Fungicide	Locations						Mean
	Champakulam	Veeyapuram	Neelamperoor	Venattukad	E-block kayal	Thuruthy	
Kresoxim methyl 40 %+ Hexaconazole 8%	5531	7327	4730	6112	4798	5319	5937
Carbendazim 12% + Mancozeb 63 % (Saaf 75 WP)	5136	6112	6181	7327	5254	5327	5890
Mancozeb (Dithane M 45)	4639	7110	6518	7110	5327	5383	6015
Control	3719	7436	4168	7436	4429	5138	5138
CD (0.05)	NS						

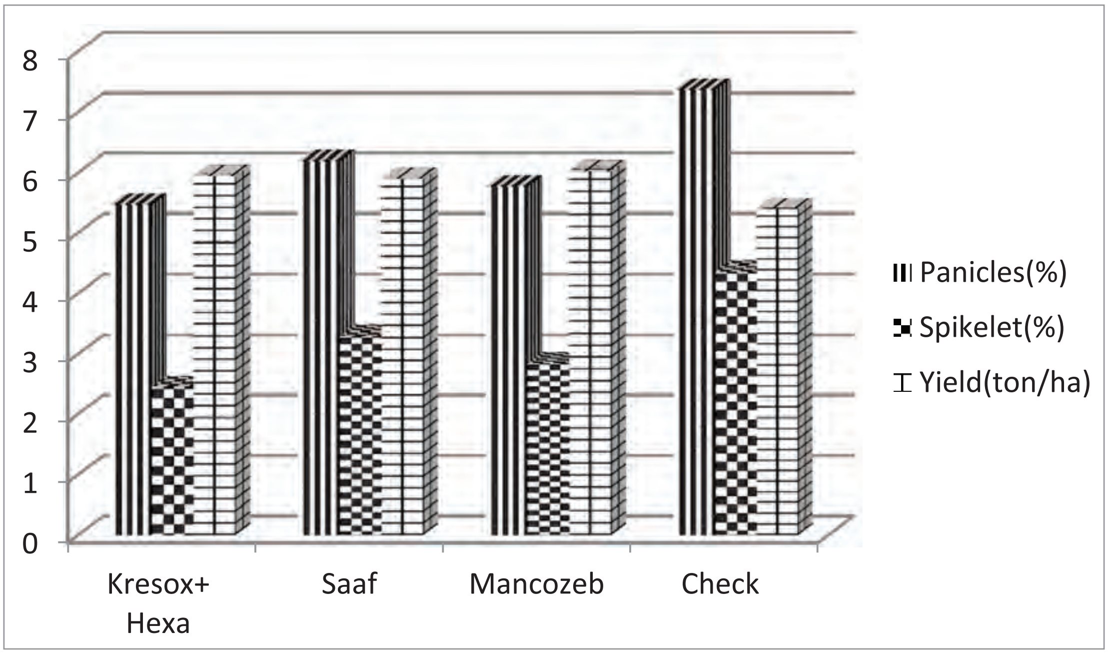

Fig. 1. Influence of kresoxim methyl + hexaconazole and saaf on glume discolouration and grain Yield

ORIGINAL RESEARCH ARTICLE OPEN ACCESS

Virulence Profile of *Xanthomonas Oryzae* pv. *Oryzae* Strains from Bihar

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Received: 20th February, 2016; Accepted 26th June, 2016

Abstract

Bacterial Leaf Blight (BLB) of rice caused by *Xanthomonas oryzae* pv. *oryzae* is a serious threat to rice production in India. Field trials were conducted at ARI, Patna during 2013 and 2014, to study the virulence profile of prevalent strain of the BLB pathogen, *Xanthomonas oryzae* pv. *oryzae* (*Xoo*) using rice differentials (IRBB NILs) possessing different bacterial blight resistant genes and their combinations. The reaction pattern on the differentials indicted the existence of moderately virulent strains of bacterial blight pathogen in this location.

Keywords: *Xanthomonas oryzae* pv *oryzae*, rice, IRBB lines.

Introduction

Bacterial leaf blight (BLB) of rice caused by *Xanthomonas oryzae* pv. *oryzae* (Ishiyama, Swings *et al*) is one of the most serious production constraints of rice, worl dwide. The disease can cause an average of 20-30% yield loss (Ou, 1985). In the tropics, depending on the severity of infection, the loss may be as high as 60-70% (Ou, 1985). Srivastava and Kapoor (1982) reported 6-37% yield loss against 1-9 infection grades in India. BLB has spread to many non-traditional areas in India, in addition to recurring incidence in the traditional areas under irrigated and rainfed shallow lands. The pathogen is highly variable in nature and continuous monitoring of the pathogen virulence profile is very important for breeding durable BLB resistant rice varieties. In the present experiment, we studied the virulence profile of the local Xoo strains on a set of rice differentials possessing different bacterial blight resistance genes and their combinations.

Methodology

Assessment of the virulence spectrum of *Xanthomonas oryzae* pv. *oryzae* was carried out at the Agricultural Research Institute, Patna (PTN) location during the rice crop season 2013 and 14 under field conditon.The trial consisted of twenty two Near Isogenic Lines (NILs/ IRBB lines) with different bacterial blight resistance genes and their combinations and different checks. The seed material for the trial was received from the ICAR-IIRR, Hyderabad. The plants at the maximum tillering stage were clip inoculated with the bacterial leaf blight pathogen (Kaufman *et al*., 1973). The pathogen was isolated in modified Wakimoto's agar medium from infected leaves collected from naturally infected rice fields. The pathogen was multiplied on same medium and the inoculum was prepared by scrapping the bacteria from culture plates and bacterial suspension was made. This bacterial suspension was used for clip inoculation.

Results and Discussion

The rice differentials used in this trial consisted of twenty two Near Isogenic Lines, possessing different BLB resistant genes singly or in various combinations of four BLB resistant genes, *viz*., *Xa4*, *xa5*, *xa13* and Xa21 in the background of rice cultivar IR24. The differentials like DV 85 Ajaya (IEI 8585) and TN1 were also included in the trial.

The reaction of different differentials to the native isolate of *Xoo* is presented in Table 1. The data revealed that the native *Xoo* isolate was not highly virulent as it did not show typical susceptible reaction in any of the NILs. The overall location severity index (LSI) during 2013 and 2014 was 3.8 and 3.7, respectively. There were no differential reactions among the different differentials. More number of *Xoo* isolates will be collected and studied in our future work to know the composition of different *Xoo* races in different rice growing regions of Bihar.

Acknowledgement

The authors are grateful to division of Rice Pathology, D.R.R., (ICAR-IIRR), Rajendranagar, Hyderabad for providing seed material for conduct of the trial at the A.R.I., Patna location. The Co-operation provided by the Regional Director, A.R.I., Patna is highly acknowledged.

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Table 1: Reaction of rice differentials to *Xanthomonas oryzae* pv. *oryzae* in rice crop season 2013 and 2014

Differentials	Gene combination	Disease reaction	
		2013	2014
IRBB-1	*Xa1*	5	7
IRBB-3	*Xa3*	4	5
IRBB-4	*Xa4*	3	5
IRBB-5	*xa5*	5	1
IRBB-7	*Xa7*	4	3
IRBB-8	*xa8*	4	5
IRBB-10	*Xa10*	4	7
IRBB-11	*Xa11*	4	1
IRBB-13	*xa13*	5	3
IRBB-14	*Xa14*	2	3
IRBB-21	*Xa21*	3	5
IRBB-50	*Xa4+ xa5*	4	1
IRBB-51	*Xa4+ xa13*	3	3
IRBB-52	*Xa4+ Xa21*	2	1
IRBB-53	*xa5+ Xa13*	4	3
IRBB-54	*xa5+ Xa21*	4	5
IRBB-55	*xa13+ Xa21*	5	3
IRBB-56	*Xa4+ xa5+ xa13*	4	5
IRBB-57	*Xa4+ xa5+ Xa21*	2	5
IRBB-58	*Xa4+ xa13+ Xa21*	3	3
IRBB-59	*xa5+ xa13+ Xa21*	3	3
IRBB-60	*Xa4+ xa5+ xa13+ Xa21*	4	3
DV-85		4	3
Ajaya		3	1
T N1		6	9
LSI		3.8	3.7
Minimum Score		2	1
Maximum Score		6	9
#entries>5		1	3
Disease reaction: Less virulent			

REVIEW ARTICLE OPEN ACCESS

Empowerment of Women Smallholder Farmers through Rice based Eco-Entrepreneurship Development-Prospects and Potential

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Received: 8th January, 2016; Accepted: 20th June, 2016

Abstract

Empowerment of the women small holder farmers is essential for development of the country. The importance of gender as an issue in developing countries was re-emphasized at the World Conference on Women in Beijing in 1995 (United Nations, 1995). Women's empowerment is defined as "the capacity of women to be economically self-sufficient and self-reliant with control over decisions affecting their life options and freedom from violence". Women suffer from different types of powerlessness in social and economic sphere of life. The lack of power or disempowerment reflects in their less education level, less income, less control over their own income, less bargaining power in selling their own produce and labour, less participation in decision making body, less access to production inputs and resources and employment opportunity than men. This vulnerable situation resulted in an overall dependency of women on their male kin through their life cycle all over the world, particularly in developing countries. Women in India in earlier days hardly participate in agricultural activities outside home. Women's economic activities were confined to homestead production and post-harvest operations. A number of studies were conducted on women's activities and their role in rice based entrepreneurship had been brought in this paper There is a need to transform the traditional roles of women in society that economic development program could automatically increase the economic status of women and thereby their overall status in community and family. The long-term comprehensive training to rural women to set up rice based entrepreneurship through Self-Help Groups will help in providing substantial income to the families thereby improving their livelihood status. The forward and backward linkages for the successful entrepreneurship development need to be provided by the technical institutions for the upliftment of women.

Key words: Women empowerment, rice based eco-entrepreneurship, small holder farmers

Introduction

Skills development is key to improving rural productivity, employability and income - earning opportunities, enhancing food security and promoting environmentally sustainable rural development and livelihoods. Women in rural areas are not only the major contributors to family income but also responsible for house hold and family maintenance. Moreover, they play an important role (60-70%) in rice cultivation especially in field preparation, transplanting, weeding, harvesting, threshing, drying and storage. Skills development is particularly important to rural women who are more likely to be contributing family workers, subsistence farmers or home-based micro-entrepreneurs in the informal sector, or performing low-paid, unskilled work as seasonal workers. (ILO, 2009). The Government of India has also introduced National Skill Development Policy and National Skill Development Mission in 2009 in order to provide skill training, vocational education and entrepreneurship development to the emerging work force. Farm women play an important role in agricultural entrepreneurship. Farm women are, in many cases, the ones who initiate and develop new onfarm business activities (Bock 2004).

Skill development of rural women in rice based entrepreneurship development

The promotion of women's entrepreneurship through the formation of women's cooperatives in the niche area of organic paddy farming can be an effective means of helping to alleviate rural poverty. Micro, small and medium-sized enterprises have been recognized as a crucial way to promote women's economic empowerment. By providing a source of income and increasing access to and control over resources such as land, women can obtain more control of their own lives. In order to transform women farmers' into entrepreneurs, it is important to provide them with access to credit, product and market information, technology, and training in management skills and enterprise development.

The following are the specific areas under which women farmers can be provided technical knowledge and skills for taking up entrepreneurship, Organic rice farming, Quality seed rice production, Mat Type Nursery Production, Vermicompost units ,Custom hiring of implements, Skilled labour force and Value added products.

Organic Rice Cultivation

The technical knowledge of eco-friendly package of technologies to grow rice organically can be imparted to farm women to set up an organic rice enterprise. The cost of cultivation of producing it is substantially reduced and the organic rice fetches a premium price in the market. No synthetic or artificial chemical pesticides and fertilizers have to be used; Soil fertility is maintained through "natural" processes such as growing cover crops and/or the application of composted manure and plant wastes and non- chemical forms of pest control are used to manage insects, diseases and weeds. Knowledge to follow the strict standards for production and processing as set by the certifying body would also be provided to the women entrepreneurs.

Employment generation through hybrid rice seed production

Hybrid rice technology is becoming popular in the country. Hybrid rice seed production is a labour intensive activity and socio-economists have estimated that additional employment of about 45-60 person days is created through this activity mostly for the rural women. Additional labour is required for specialised activities such as rouging, leaf clipping, supplementary pollination and careful harvesting. The area under hybrid rice seed production is expected to increase in the coming years which would create additional employment for women. Since the seed growers get higher profits, the wages for women working in hybrid rice seed production fields are likely to be higher. With subsequent increase in seed production area, the rural farm women have tremendous employment opportunities in the coming years.

In a village, a group of farmers/farm women can be trained in the production of quality seeds to cater to their own needs and of fellow farmers of the village and fanners of neighbouring villages in appropriate time and at affordable cost. The following advantages can be reaped along with earning a steady income through setting up this enterprise unit.

- Seed is available at the door steps of farms at an appropriate time
- Seed availability at affordable cost even lesser than market price
- Increased confidence among the farmers about the quality because of known source of production
- Producer and consumer are mutually benefited Facilitates fast spread of new cultivars of different kinds

Mat Type Nursery Production

The mass production of mat nurseries for mechanical rice transplanting can be a good business for entrepreneurial farm women. In this method seedlings are ready for planting within 15-20 days after seeding. The seedlings are raised in a layer of soil mix, arranged on a firm surface and while transplanting seedlings are uprooted like a mat. As a result, root damage is minimal while separating seedlings. The mat nursery uses less land, can be installed closer to the house than traditional field nurseries. It helps in reduction in use of labor and transportation cost.

Materials Required

- Good quality seeds
- Nursery bed for one acre seeding: 1.2 m wide x 20 m long
- Plastic sheet size: 1.2 m width and 20 m length
- Soil cleaning sieve
- Mixture of soil and Farm Yard Manure at the ratio of 4:1
- Gunny bag and water container for seed soaking
- Angle iron half inch frame

Advantages

- Production of robust seedlings in 15 days
- 18-20 cm tall seedlings with 4-5 leaves
- Mat nursery reduces the cost on fertilizer by 90%, labour by 34% and water use by 55% in nursery raising
- It reduces the cost of seedling production by about Rs.1600 per hectare which represents a saving of 50% in contrast to conventional wet bed nursery

Vermi-compost from organic wastes

Vermicompost plays important role in integrated nutrient management (INM). This will improve physical and chemical properties of soils, water and air movement in soils and provides all essential nutrients to plants.

This helps in increasing the crop productivity as well as quality of the produce. Vermicomposting refers to the use of earth worms for the production of compost. The process is faster than traditional composting.

Earth worms feed on any organic waste and any kind of waste material such as crop residues, agricultural wastes, leaf litter, house hold waste from kitchen etc. can be used. Also, partially decomposed dung/poultry manure/coir pith waste/biogas waste etc. can be used. At present, vermicompost has lot of demand and this manure will give good remuneration to the farm women.

Green manure seed production:

Green manures (GM) play major role especially if they are grown in off season utilizing either early monsoon showers or where cheap irrigation source is available. Sunnhemp, dhaincha, cluster beans, cowpea, moong, fodder legumes etc. are used as green manuring crops. Depending on the species and growth period, phytomass and N contribution vary very widely. Short duration, dual purpose grain legumes like green gram and cow pea are most promising as they offer immediate economic benefit through their grain (4-5 q/ha) in addition to 15-25 t/ha of phytomass with 35-40 kg N/ha. These can be incorporated in to the soil before taking *kharif* rice. Among the sole green manure crops, dhaincha and sunnhemp are most suitable as they put up sufficient biomass (30-40 t/ha) in a minimum required period of 55-60 days. They add nutrients and also recycle sub soil nutrients due to their deeper root system and improve soil physical condition. Green manuring is also one of the best options of INM but due to non availability of seed, most of the farmers could not adopt this practice. Hence, the green manure seed production can become a very good source of income to the farm women.

Multi variety seed mixture (Dabholkar method):

This method has been developed by a mathematician, Dabholkar who did a lot of experiments on soil fertility and organic farming. This method is similar to green manuring. But, in this method, 20-30 diverse, short duration crops involving cereals (jowar, bajra, ragi, korra etc.), pulses (black gram, green gram, Bengal gram, cowpea etc.), oil seeds (sesame, sunflower, groundnut, castor etc.), legumes (pillipesara, dhaincha, sunnhemp, subabul etc.), and spices (coriander, jeera, mustard, fenugreek etc.) will be grown *in situ* and incorporated into the soil after 30-40 days. The seed rate recommended is 50-60 kg/ha. For normal soils, this process is recommended once in between two main crops. If the soil fertility is very poor and in case of problem soils, same process has to be repeated for a period of 60 days and then the crops have to be incorporated. This process has to be repeated for the third time for a period of four months (120 days) and then the crops have to be incorporated. By this way, the degraded soil will regain its fertility and sustain the productivity of the main crop.

The seeds of cheaper cost can be taken in large quantities and costlier ones can be taken in lesser quantities. This can be considered as an income generation activity by making packets of seed mixtures and selling them directly to the farmers.

Botanicals, organic amendments/solutions

Rural women can be trained in the preparation and sale of organic solutions for use as bio-pesticides. Panchagavya and Amruthajalam are organic solutions and alternatives to chemical fertilizers and pesticides. These solutions can be bottled and sold to the farmers.

Panchagavya: The ingredients required for preparation are: 5 kg cow dung + 5 litres cow urine + 2 lit res cow milk + 2 litres cow butter milk + 500 g cow ghee + 500 g jaggery. Initially, dung and ghee are mixed and kept in a pot for 4 days and on the 5th day, the remaining ingredients are added and allowed to ferment for 15 days. The contents are stirred three times daily in the morning, afternoon and evening.

Method of application: 250 ml panchagavya mixed with 10 lt water and can be sprayed on the crop. Depending on the crop growth, 200-300 lt can be sprayed per acre.

Amruthajalam: 1 lt cow urine + 1 kg cow dung+250 g jaggery + 10 lt water are required for this. All these contents are mixed and allowed to ferment for one day.

Method of application: To 1 lt of amruthajalam, 10 lt water is mixed, filtered and the filtered solution can be sprayed on the crop.

Value added products from rice

Women play a major role in value addition to rice produce and by-products. Some of them are milling, grading, processing, parboiling etc. Rice based products (Phil Rice, 1997) like flakes, puffed rice and extruded products like sevai, idiappam, murukku (chakli) and vadagam can be prepared in bulk by rural women and sold in the urban markets where the demand for these products is high. People are willing to pay a premium price for brown rice and these products could be made from brown rice to serve the select buyers.

Custom hiring of agricultural machinery

A women's SHG Can be trained to set up a custom hiring centre utilising the benefits of the various schemes of the government. Under the Sub-Mission on Agricultural Mechanisation (SMAM 2014) proposed for the 12th Plan, financial assistance would be provided to self-help groups or farmers' co-operatives to purchase high end machinery (multi-crop thresher, power tiller, seed drills and paddy reaper) for running custom hiring centres. The custom hiring centres will provide farm machinery on rental basis to farmers who cannot afford to purchase high-end

agricultural machinery and equipment apart from servicing old machinery (Murthy *et al.*, 2004). Small farm implements like sprayers and cultivators will be supplied on 50 per cent subsidy. The high-end machinery can service an area of 500 acres in a village and regular income can be earned by hiring the machines.

Strategies for entrepreneurship development

There is a strong need to Support women's self-employment and encourage linkages between national training systems and socio-professional networks (Kiranjot and Kaur, 2006).

- Combine technical and entrepreneurship training, for example through community-based initiatives, as many rural women make a living through self-employment.
- Strengthen the capacity of entrepreneurship service providers to better address the needs and capabilities of rural female entrepreneurs.
- Provide post-training services such as access to credit or savings programmes, business development services, training in product design and marketing and linkages to new markets. New markets, especially value chains, can also provide women opportunities to adopt new technologies and production practices.
- Support rural women's networks and groups, such as cooperatives. Groups can lead to informal learning of skills and provide the collective power that may be required to reach new markets.

Conclusion

In order to develop women's entrepreneurship in rice-based enterprises they could be motivated to form Farmer's Interest Groups (FIG's) as the SHG's and FIG's have emerged as major strategies in the development of women. The collective strength will enable members of group's to source for inputs; share inputs costs and also help in marketing of produce. Therefore, providing long-term comprehensive training to rural women to set up rice based entrepreneurship through Self-Help Groups will help in providing substantial income to the families thereby improving their livelihood status. The forward and backward linkages for the successful entrepreneurship development need to be provided by the technical institutions.

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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 occasional 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 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 letter 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 and not in arrears of subscription. Authors of invited articles are exempted from this.

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Manuscripts should be sent online to the Journal office at sarr_drr@yahoo.com; surekhakuchi@gmail.com, jyothi_rishik@yahoo.com as an attachment. All the enclosed figures (as ppt 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 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, and abbreviations used in the paper. 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 and byline should give a clear idea what the articles is about. It should be brief and informative (12-15 words).

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1. Mukherjee JN. 1953. The need for delineating the basic oil and climatic regions of importance to the plant industry. *Journal of Indian Society of Soil Science* 1: 1-6
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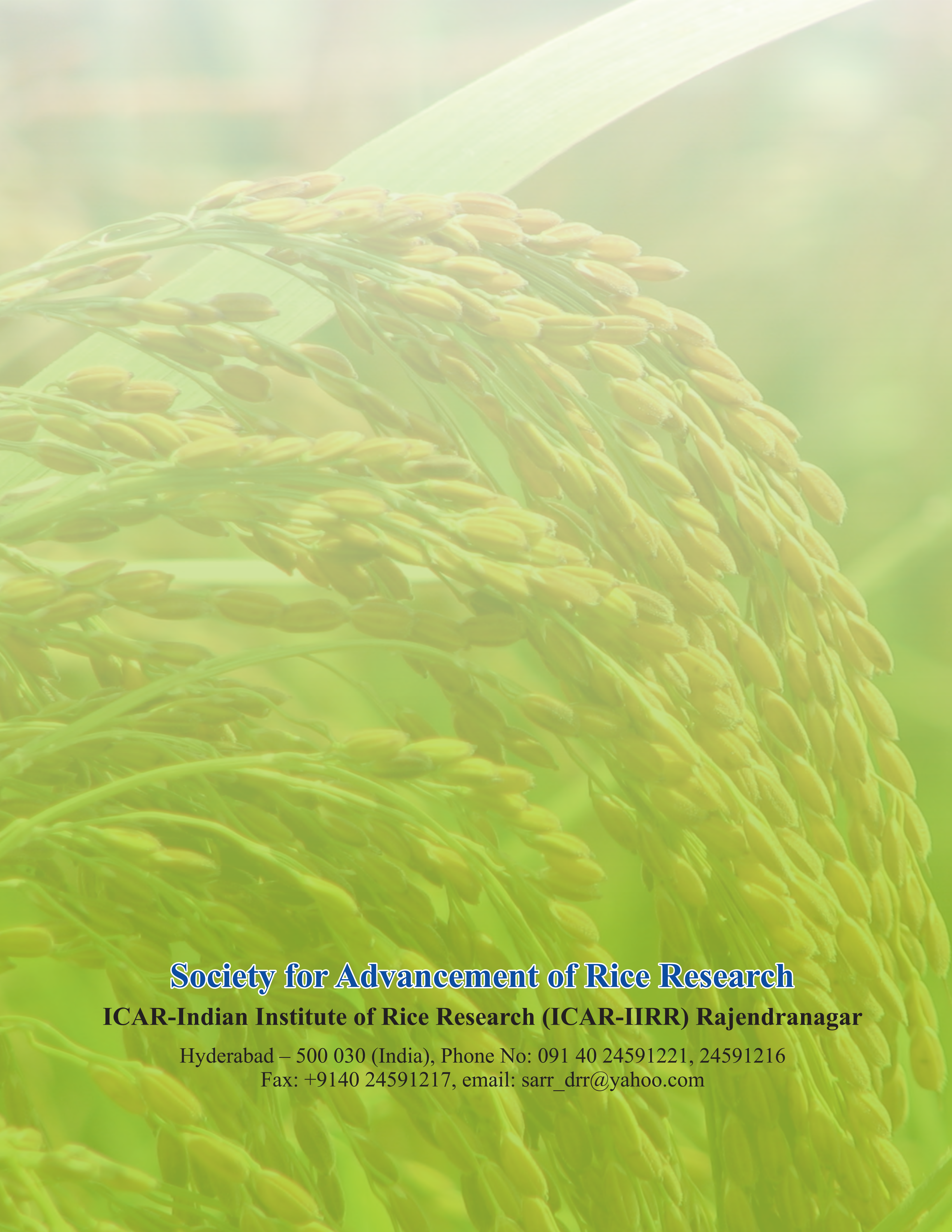
Figures: Photographs and drawings for graphs and charts should be prepared with good contract of dark and light. Figure caption should be brief specifying the crop or soil, major variables presented and lace and year. Give careful attention to the width of lines and size, and clarity of type and symbols.

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 spellout all the abbreviations. An exponenetial expression (eg. x 103) in the units 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. Follow the articles published in recent journal for table format.



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