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Research Article

Study of specificity in adaptability of rice (*Oryza sativa* L.) genotypes to specific environment

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Abstract
A field experiment was conducted in Randomized Block Design with three replications at three locations *viz.,* Educational and Research Farm, Department of Agricultural Botany, College of Agriculture, Dapoli, Agricultural Research Station, Shirgoan Dist. Ratnagiri and Agricultural Research Station, Phondaghat during *Kharif* 2016. The AMMI model, which combines the standard analysis of variance with IPC analysis was used to investigate G × E interaction. In AMMI model, the contribution of each genotype and each environment to the GEI is assessed by the use of biplot graph display in which yield means are plotted against the scores of the IPCA 1. In interaction principle axis of AMMI biplot, first interaction principle axis (IPCA I) were favorable for all the characters but the second interaction principle axis (IPCA II) were favorable for characters such as spikelets fertility, grain yield plot^{-1} (kg), the number of panicles square meter^{-1}, protein content (%), iron content (ppm), amylose content (%), grain yield plant^{-1}(g) and total number of spikelets panicle^{-1}. The genotype *viz.,* RTN-1201-13-2-2-1-32 was found most favourable for all the characters in the entire three environments with high yield, maximum plant height and more content of micronutrients. The genotype *viz.*, RTN-1211-4-2-1-1 was found stable for grain yield plot^{-1}, grain yield plant^{-1} and protein content. The genotypes RTN-1201-51-2-1-5-48, RTN-1211-5-1-3-5 and RTN-1201-5-1-3-14 were found to be stable for Dapoli and Shirgaon locations for the traits *viz.*, grain yield plant^{-1}, grain yield plot^{-1} and micronutrients. The genotypes *viz.,* RTN-1201-51-2-1-5-48 and RTN-1211-6-1-3-1-8 were found stable for Shirgaon location for traits *viz.,* spikelet fertility, test weight, plant height, panicle length and micronutrients.

Keywords
Stability, AMMI Model, G x E interaction, IPCA, Biplot.

INTRODUCTION

In Maharashtra, rice is the second most important food grain crop of the people, which is grown over an area of 15.57 lakh hectares with an annual rough rice and milled rice production of 52.95 lakh tons and 26.54 lakh tons, respectively. The average productivity of rough rice and milled rice of the state is 3.4 t/ha and 2.35 t/ha and it is stable, which is low as compared to other rice producing states like Punjab (3.84 t/ha), Tamil Nadu (3.19 t/ha), Telangana (3.14 t/ha), Haryana (3.11 t/ha) andhra Pradesh (3.02 t/ha), West Bengal (2.73 t/ha), Karnataka (2.67 t/ha), Gujarat (2.33 t/ha) and national productivity (2.39 t/ha) (Anonymous, 2016-17). Konkan region is a major rice producing area of Maharashtra. Nearly 3.69 lakh ha area of Konkan is under rice crop with rough rice production of 15.70 lakh tones. The average rough rice productivity of the Konkan region is 4.25 t/ha. Konkan region contributes 23.70% in area under rice crop and produces 29.65% rough rice at state level (Anonymous, 2016-17).

In some areas of India, red rice is considered as highly nutritive and medicinal. The rice is eaten as whole grain. Red gunja is preferred for making bread and chapati (Rani and Krishnaiah, 2001). Glutinous rice is used for making puttu in South India. In Himachal Pradesh, Jatu red rice is prized for its aroma and taste. Matali and Laldhan of Himachal Pradesh are used for curing blood pressure and fever. Kafalya, from the hills of Himachal Pradesh and Uttar Pradesh, is used for treating leucorrhea and abortion complications. Karikagga and Atikaya of Karnataka are used for coolness and as a tonic, while Neelamsamba is used for lactating mothers in Tamil Nadu (Arumugasamy *et al.,* 2001).

Rice with a red bran layer is called red rice. Though the colour is confined to the bran layer, a red tinge remains even after a high degree of milling. The colour of the bran ranges from light to dark red. The bran layer contains polyphenols and anthocyanin and possesses antioxidant properties. The zinc and iron content of red rice is 2–3 times higher than that of white rice (Ramaiah and Rao, 1953).

It is now known that flavonoid and anthocyanin compounds are closely related to the anti-oxidation properties of black rice (Zhang *et al*., 2005). Oki *et al*. (2005) found that the DPPH (1-1-diphenyl-2-picrylhydrazyl) radical scavenging activity is higher in red rice than in black and white rice and this activity is correlated with polyphenols and proanthocyanidin content.

In Maharashtra, particularly in Sindhudurg, Ratnagiri, Raigad and Thane districts, local red kernel types are grown since ancient years. These varieties are Patni, Munga, Bela, Valai, Halga Red, Kala Rata, Bura Rata, Jaddu, Varangal *etc*. These local red rices are mainly having bold grain type, tall and grassy stature, seed dormancy, sparse plant type, lodging and low yields. However, these varieties are having low amylose, high zinc, iron, riboflavin and antioxidant properties. Their nutritional and physico-chemical properties are used for making soup; locally known as *Pej* and served to children, women and patients for their daily breakfast. Considering these attributes, red rice could once again find favour with health conscious consumers. It is high time that people in India took a fresh look at similar properties in the vast pool of indigenous red rice.

MATERIAL AND METHODS

Eighteen biofortified red kernel lines (higher zinc and iron) along with two red kernel checks were taken as experimental material. The experiment was conducted in the Randomized Block Design (RBD) with three replications at three locations *viz.,* Educational and Research Farm Department of Agricultural Botany, College of Agriculture, Dapoli, Agricultural Research Station, Shirgoan, Dist. Ratnagiri, Agricultural Research Station, Phondaghat during *Kharif,* 2016. The plot size was 3 m x 2 m along with 20 cm x 15 cm spacing and two seedlings hill^{-1}. Line to line distance was 20 cm and plant to plant was 15 cm. There were 10 lines plot^{-1} and 20 hills line^{-1} with 200 hills in each plot were transplanted.

AMMI model was used to quantify the effect of different factors (genotype, location and year) of the experiment. The AMMI Model helps for preparing the standard ANOVA for separation the additive variance from multiplicative variance (genotype and environment interaction). Thereafter, it uses a multiplicative procedure PCA to extract the pattern from the G x E portion of the ANOVA (Zobel *et al*., 1988). The member of the AMMI family with IPCA I axis denoted AMMI 1; while AMMI 2 retains IPCA II axis and so on. In general, AMMI N denotes the AMMI model with PCA axis 1 to N. AMMI 0 has no IPCA axes and is identically ANOVA**.** Experimental material was obtained from ARS, Shirgaon. Developed and maintained at ARS, Shirgaon (Ratnagiri).

Table 1. Promising bio-fortified red kernel lines

Sl. No.	Designation of cultures	Cross combination	Source
1	RTN-1201-13-2-2-1-32	KJT-4/ Patani-6	ARS, Shirgaon
2	RTN-1201-23-2-2-1-43	KJT-4/ Patani-6	ARS, Shirgaon
3	RTN-1201-51-2-1-5-48	KJT-4/ Patani-6	ARS, Shirgaon
4	RTN-1209-10-1-2-1-9	RTN-13A/ MO-17	ARS, Shirgaon
5	RTN-1211-6-1-3-1-8	RTN-1A/ MO-9	ARS, Shirgaon
6	RTN-1211-6-1-4-1-11	RTN-1A/ MO-9	ARS, Shirgaon
7	RTN-1211-6-1-4-3-13	RTN-1A/ MO-9	ARS, Shirgaon
8	RTN-1211-6-1-5-1-14	RTN-1A/ MO-9	ARS, Shirgaon
9	RTN-1211-15-1-4-2-23	RTN-1A/ MO-9	ARS, Shirgaon
10	RTN-1212-4-1-2-4	RTN-13A/ MO-17	ARS, Shirgaon
11	RTN-1211-4-2-2-2	RTN-1A/ MO-9	ARS, Shirgaon
12	RTN-1210-3-1-4-5	RTN-1A/ MO-13	ARS, Shirgaon
13	RTN-1211-5-1-3-5	RTN-1A/ MO-9	ARS, Shirgaon
14	RTN-1211-6-1-2-7	RTN-1A/ MO-9	ARS, Shirgaon
15	RTN-1212-4-3-5-5	RTN-13A/ MO-17	ARS, Shirgaon
16	RTN-1201-5-1-3-14	KJT-4/ Patani-6	ARS, Shirgaon
17	RTN-1211-4-2-1-1	RTN-1A/ MO-9	ARS, Shirgaon
18	RTN-1211-9-1-2-12	RTN-1A/ MO-9	ARS, Shirgaon
19	Red kernel check -1	Bela	ARS, Shirgaon
20	Red kernel check -2	Patni-6	ARS, Shirgaon

RESULTS AND DISCUSSION

The AMMI analysis of variance for grain yield plant^{-1} illustrated that 13.83 of the total sum of square was attributable to environmental effects, only 1.81 to genotypic effects and to 0.08 GEI effects (**Table 2**). The IPCA I captured 2.17 of the interaction sum of square. Similarly, the IPCA II explained a further 0.43 of the GEI sum of square and together with IPCA I and IPCA II contributed 2.62 of the total GEI. Both AMMI 1 and AMMI 2 biplot analysis was performed for grain yield plant^{-1}since mean square for the IPCA I and IPCA II were found to be significant.

The variation of grain yield plant^{-1} in all the three environments explained by AMMI analysis. They showed that the environment interaction was higher than that for genotypic, so the major difference was due to environments effect. These findings were in conformity to those of Islam *et al.* (2014) and Gauch *et al.* (1996). The variance of GEI was partitioned among the first two interaction principle component axis of which IPCA I exhibited 2.17 sum of square of the total GEI, IPCA II was 0.43 sum of square these implied that the interaction of the 20 rice genotype with three environments was predicted by the both the IPCA I and IPCA II .

Table 2. AMMI ANOVA of twenty genotypes of bio-fortified red kernel rice for eight different characters pooled over three environments

Sources	DF	Mean Sum of Squares							
		Days to 50% flowering	Plant height (cm)	No.of tillers plant^{-1}	No.of panicles sq.m^{-1}	Panicle Length (cm)	No.of spikelets panicle^{-1}	No.of filled spiklets panicle^{-1}	Spiklet fertility (%)
Trial	59	80.28	161.34	0.93	99.97	4.54	1068.27	865.47	32.40
Genotypes	19	246.89*	500.34*	0.99*	287.09*	7.55*	1164.02*	823.49*	40.37*
Environments	2	13.74	0.03	5.98	12.64	1.86	7835.51	5421.75	161.89
GxE Interaction	38	0.48	0.32	0.64	11.00	3.18	664.23	646.66	21.60
PCA I	20	0.80	0.56	0.68	12.56	4.53	693.32	677.04	30.34
IPCA II	18	0.13	0.06	0.59	9.26	1.68	631.90	612.91	11.90
Error	120	35.19	16.65	0.29	13.24	1.91	217.60	126.04	11.38
Total	**179**	**50.06**	**64.34**	**0.50**	**41.82**	**2.78**	**497.99**	**369.76**	**18.31**

Table 2 continued …

Source	DF	Mean Sum of Squares								
		Test wt. (g)	Grain yield plant^{-1} (g)	Straw yield plant^{-1} (g)	Grain yield plot^{-1} (kg)	Straw Yield plot^{-1} (kg)	Iron content (ppm)	Zinc content (ppm)	Protein content (%)	Amylose content (%)
Trial	59	12.56	1.92	5.67	0.42	0.09	2.87	10.68	0.55	4.04
Genotypes	19	32.52*	1.81*	2.37*	0.19*	0.04*	7.81*	30.20*	1.53*	11.53*
Environments	2	27.81	13.83	62.63	4.49	0.17	7.85	8.39	0.01	3.33
GxE Interaction	38	1.78	1.35	4.32	0.31	0.11	0.14	1.01	0.08	0.33
PCA I	20	2.52	2.17	5.30	0.41	0.16	0.22	1.40	0.10	0.42
PCA II	18	0.96	0.43	3.23	0.21	0.07	0.06	0.57	0.06	0.23
Error	120	2.01	0.36	1.22	0.10	0.03	0.35	1.49	0.09	1.70
Total	**179**	**5.49**	**0.87**	**2.69**	**0.20**	**0.05**	**1.18**	**4.51**	**0.24**	**2.47**

*Significant for 5%

AMMI 1 (**Fig.1.**) biplot relieved that the interaction of environments was high and varied. The location Phondaghat had negative interaction while Shirgaon and Dapoli had positive interaction, because they present right hand side of the midpoint of the main effect axis seemed to be favourable environments for grain yield plant^{-1}. These results are in line with the studies of Padmavathi *et al*. (2013). Genotypes, RTN-1212-4-1-2-4 and RTN-1211-6-1-3-1-8 had high mean and positive interaction were adapted to Dapoli and Shirgaon environments. Genotype, Bela and RTN-1211-6-1-4-1-11 score near zero had small interaction effect indicating that these verities were less influenced by environment.

In AMMI 2 (**Fig.2.**) biplot, Shirgaon had short spokes and they did not exert strong interactive force while environment Phondaghat and Dapoli having long spokes exert strong interaction. Genotypes, RTN-1211-15-1-4-2-

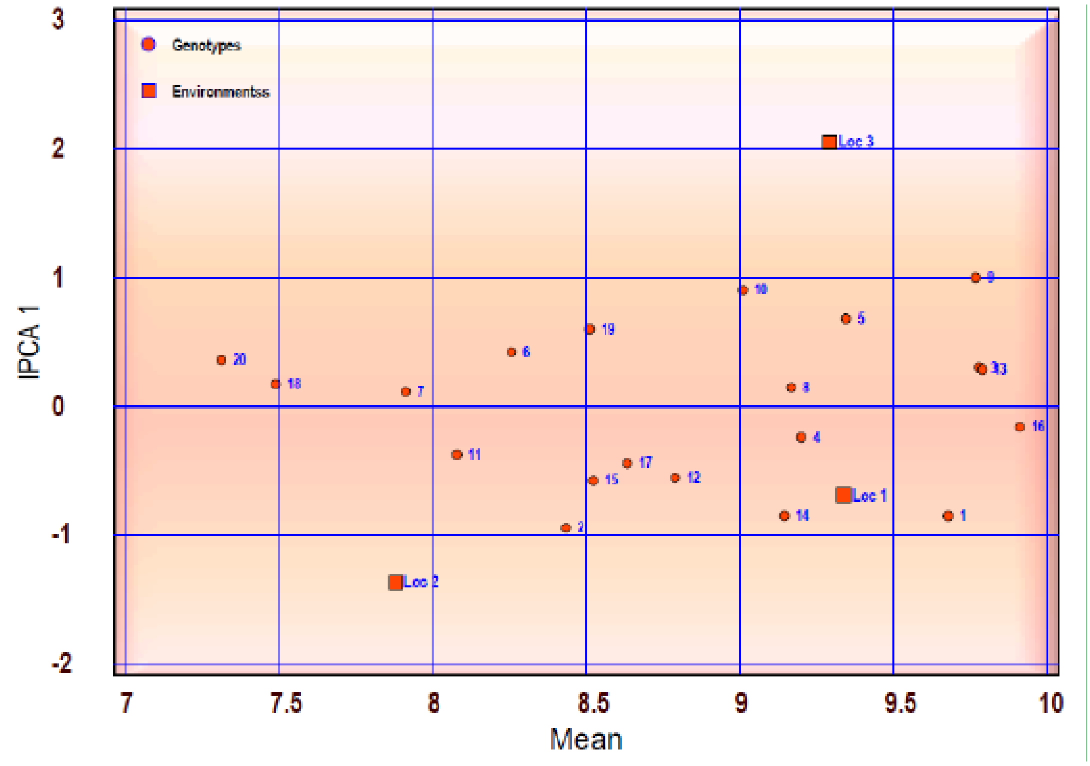

Fig 1. Biplot (AMMI 1) for grain yield plant^{-1}(g)

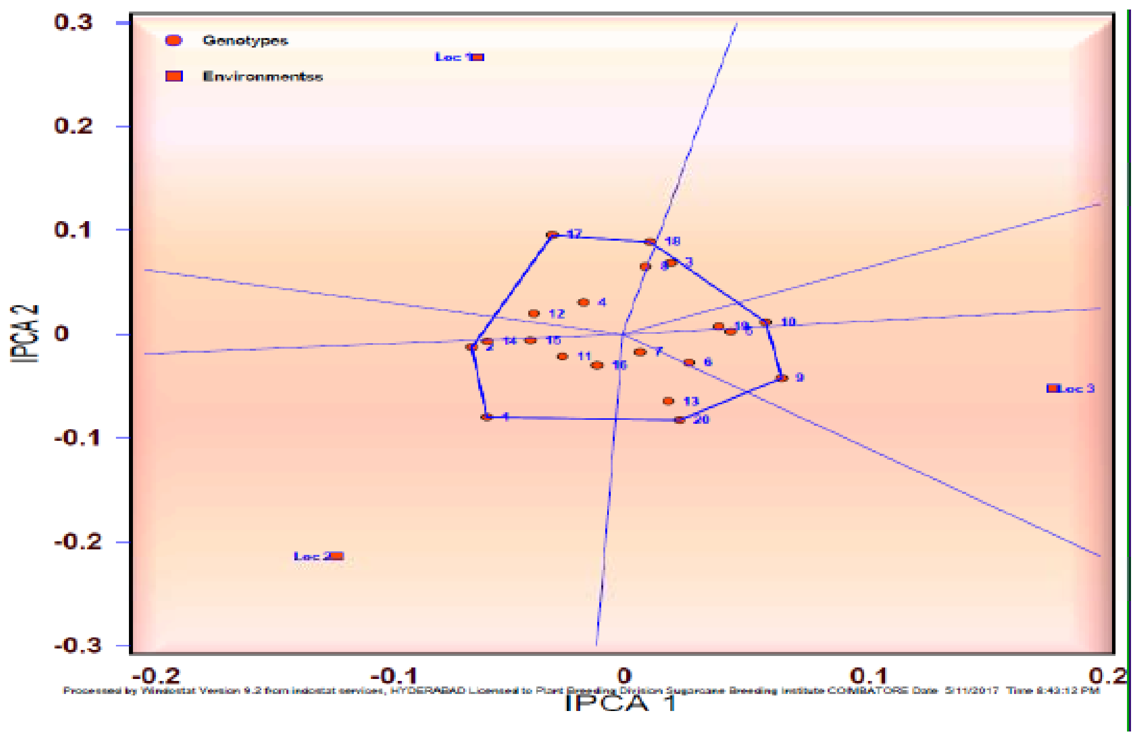

Fig 2. Intraction Biplot (AMMI 2) for grain yield plant^{-1}(g)

23 and RTN-1212-4-1-2-4 had high IPCA score and away from origin were most responsive. Genotypes, RTN-1201-13-2-2-1-32 and RTN-1201-23-2-2-1-43 were adapted to Phondaghat, genotypes, RTN-1211-9-1-2-12 and RTN-1211-4-2-1-1 to Dapoli and RTN-1211-15-1-4-2-23 and RTN-1212-4-1-2-4 to be adapted to Shirgaon.

To investigate the main effects and interactions across different environments, AMMI 1 and AMMI 2 biplots were constructed for yield and yield component traits. AMMI 1 biplot of main effects (Genotype and environments) are shown along the abscissa and the ordinate represents the first IPCA. The interpretation of a biplot assay is that if main effects have IPCA score close to zero, it indicates negligible interaction effects and when a genotype and an environment have the same sign on the IPCA axis, their interaction is positive; if different, their interaction is negative. The IPCA 1 versus IPCA 2 biplot (*i.e.*, AMMI II biplot), explain the magnitude of interaction of each Genotype and environment. The Genotypes and environments that are farthest from the origin being more responsive fit the worst. Genotypes and environments that fall into the same sector interact positively; negatively if they fall into opposite sectors.

In interaction principle axis of AMMI biplot, first interaction principle axis (IPCA I) are favourable for all characters but second interaction principle axis (IPCA II) are favourable for characters such as spikelets fertility, grain yield plot^{-1} (kg), the number of panicles square meter^{-1}, protein content (%), iron content (ppm), amylose content (%), grain yield plant^{-1} (g) and total number of spikelets panicle^{-1}.

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