Journal of Experimental Biology and Agricultural Sciences, June - 2018; Volume – 6(3) page xxx – xxx

Journal of Experimental Biology and Agricultural Sciences

http://www.jebas.org

ISSN No. 2320 – 8694

STABILITY ANALYSIS UTILIZING AMMI MODEL AND REGRESSION ANALYSIS FOR GRAIN YIELD OF BASMATI RICE (*Oryza sativa* L.) GENOTYPES

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Received – xxx; Revision – xxx; Accepted – xxx
Available Online – xxx, 2018

DOI: http://dx.doi.org/10.18006/2018.6(3).xxx.xxx

KEYWORDS

Rice

Genotypes

G × E

TPR

SRI

DSR

AMMI biplot analysis

ABSTRACT

A field experiment comprising of released varieties, elite lines and hybrid under four production systems viz. Transplanted rice (TPR), Dry direct seeded rice (Dry DSR), Wet direct seeded rice (Wet DSR) and System of rice intensification (SRI) was conducted at Research farm of RRS, Kaul, CCS HAU, Hisar, Haryana during *Kharif* of 2014-15 and 2015-16. Present study tested and identified the basmati rice genotypes for yield and its components under System of rice intensification, Direct seeded rice (both Dry and Wet) and regular Transplanted rice system. Four characters namely, grain yield, plant height, tiller/ plant panicle length and panicle weight were recorded.

Estimates of genotype x environment interaction and additive main effect were significant for all the mentioned traits. The traits viz. tiller/ plant and plant height were found proportional to grain yield. Based on AMMI biplot analysis genotypes Pusa RH 10 has been identified for SRI, while genotypes i.e. Imp Pusa Basmati-1, CSR-30, Haryana Basmati-1 and Haryana Mehak-1 were identified for Wet DSR and two genotypes Super Basmati and HKR 06-487 for Dry DSR conditions.

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Peer review under responsibility of Journal of Experimental Biology and Agricultural Sciences.

Production and Hosting by Horizon Publisher India [HPI]
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1 Introduction

Rice (*Oryza sativa* L.) is such a wonder crop as it can be grown under diversified edaphic conditions like aerobic and anaerobic (Submerged Conditions)(Miro & Ismail, 2013). In the present era of energy crisis and the inadequacy of water, it is not possible to proceed for transplanted rice (Nguyen & Ferrero, 2006). Due to pressure exerted by input crisis, rice production systems are experiencing great changes like wet direct seeded rice, dry direct seeded rice, drum seeding and system of rice intensification (Dawe, 2010; Prasetyo & Anindita, 2016). For the success of alternate non-conventional resources, the saving techniques and optimization of input requirement are mandatory (Rao et al., 2017). To date, the researchers have been focused on optimum input requirement for transplanted rice, however, the new production systems are governed by the inputs fixed for transplanted rice or a slight change in a previous recommendation. Thus, it is not possible to exploit the complete potential of genotypes under non-conventional methods, which is one of the major hurdles for low adoption rate of these methods among rice growers. Evaluation of different genotypes performance under different production systems is required for the optimization of the genetic potential of different genotypes under diverse edaphic conditions. Since conventional transplanting system during puddling creates a hard pan below the plough-zone, reduces soil permeability and increases water loss through surface evaporation and percolation. Because of high water requirement and labor cost profits are reduced (Surendra, 2010). Therefore, in recent years, the farmers have shifted from a conventional to a non-conventional method of paddy cultivation, namely the system of rice intensification and direct seeded rice in several countries of Southeast Asia (Takashima et al., 2013). Hence, to promote diversification and enable farmers to choose a crop alternative for increased productivity and income, the technology innovation involving non-conventional production methods such as the system of rice intensification and direct seeded rice in basmati rice cultivation could be explored to enhance the productivity and sustainability in agriculture (Vaughan et al., 2008; Fuller et al., 2016). Uphoff (2003), Satyanarayana et al. (2007) and Grihtlahre et al. (2012) have advocated the adaptation of system of rice intensification and obtained on an average 12-24% higher grain yield by a system of rice intensification over the normal transplanted system. Therefore, the present experiment was performed to understand the genetics of interaction of rice genotypes with the environment and to identify the stable genotype to sustain new production systems applied to rice these days to conserve resources.

2 Materials and Methods

2.1 Experimental site and design

A field experiment was laid out during the *Kharif* season of 2014-2015 and 2015-2016 at the Regional Research Station Kaul, CCSHAU, Haryana, Hisar India. Geographically it is located at 29.8498° and 76.6615°E longitudes which fall under the subtropical region. The experiments were carried out in a Randomized Complete Block Design (RCBD) with three replications in total seven environments (four production systems in 2014-15 and three production systems in 2015-2016) created agronomically termed production systems of rice as shown in Table 1. Plot size consisted of 5 rows of 2mtr long and 0.20 mtr row spacing each. The accessions used in the present study were consisted of twenty two popular genotypes grown in the state Haryana (Table 2).

2.2 Statistical Analysis

The analysis of variance of the present investigation was carried out as per the standard procedures of Panse & Sukhatme (1985) for Grain Yield per plant, Plant height, Panicle Length, Panicle Weight, Number of Tillers per Plant in all the seven environments (E1-E7) (Table 1). Standard package of practices was followed for the rice production. Border rows were not included in the data to avoid the border effect. The data for grain yield were taken at the 14 % moisture while all the other remaining characters were measured as demarcated in the manual (Yoshida et al., 1976). Analysis of variance was computed for the individual environment. The significance of all effects was tested against the mean square of error. Data were subjected to statistical analysis using Windostat Version 9.2 (Indostat services, Hyderabad,

Table 1 Environmental conditions used during study

Environment	2014-2015				2015-2016		
	E1	E2	E3	E4	E5	E6	E7
Description	Transplanted Rice (TPR)	System of Rice Intensification (SRI)	Direct Seeded Rice (DSR) (Wet)	Direct Seeded Rice (DSR) (Dry)	Transplanted Rice (TPR)	Direct Seeded Rice (DSR) (Wet)	Direct Seeded Rice (DSR) (Dry)

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Table 2 List of Genotypes Used in Study Table is Adapted from Jain et al. (2018).

Code	Genotypes	Pedigree
1	Pusa Basmati 1121	P614-1-2/P614 2-4-3
2	Pusa Basmati 1509	PUSA 1301/PB1121
3	Pusa Sugandh 2	PUSA 1238-1/PUSA 1238-81-6
4	Pusa Sugandh 3	PUSA 1238-1/PUSA 1238-81-6
5	Pusa Sugandh 5	PUSA 3A/ HARAYANA BASMATI
6	Pusa Basmati 6	PUSA BASMATI-1/PUSA 1121-92-8-2-7-1
7	Pusa Basmati 1	PUSA 150/ KARNAL LOCAL
8	Improved Pusa Basmati 1	PB 1//PB 1/ IRBB55
9	HKR 98-476	Collected from RRS, Kaul, Haryana
10	HKR 03-408	Collected from RRS, Kaul, Haryana
11	HKR 06-434	Collected from RRS, Kaul, Haryana
12	HKR 06-443	Collected from RRS, Kaul, Haryana
13	HKR 06-487	Collected from RRS, Kaul, Haryana
14	HKR 08-417	Collected from RRS, Kaul, Haryana
15	HKR 08-425	Collected from RRS, Kaul, Haryana
16	Haryana Mahek-1	Collected from RRS, Kaul, Haryana
17	Haryana Basmati-1	SONA/BASMATI 370
18	Traori Basmati	SELECTION BASMATI 370
19	Super Basamati	BASMATI 320/IR661
20	CSR-30	BR4-10/BASMATI-370
21	Basmati-370	OLD SELECTION
22	Pusa RH-10	PUSA 6A/PRR 78

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India). The performance of twenty-two genotypes was tested over four production system for two year and analyses using stability models *viz*, (1) Eberhart & Russel (1966), (2) Additive Main effects and Multiplicative Interaction (AMMI) (Gauch & Zobel, 1989).

3 Results and Discussion

3.1 Genotypic performance of Yield and Yield Related Traits

In four different production systems-wide genotypic variation was observed and average pooled data ranged for Plant Height (75.00-116.00); Tiller per Plant (10.21-14.51); Panicle Length (22.66-25.33); Panicle Weight (1.08-2.45); Grain Yield Per Plant (8.74-15.25) among the twenty-two genotypes under study as shown in Table 5**.** Considering the four-different production system among twenty-two genotypes, Pusa RH 10 scored high Grain yield per plant (15.25 g), Panicle Length (24.93 cm) and Panicle Weight (22.30 g). CSR-30 recorded the minimum Grain Yield per plant in all production systems except System of Rice Intensification in which it performed better while HKR 06-434 had the maximum (17.11 g) Grain yield per plant in Transplanted Rice, Pusa Basmati 6 (28.41 g) followed by Pusa Basmati 1121 (27.16 g) in System of Rice Intensification, Pusa RH 10 in Direct Seeded Rice (wet) (18.04 g) and Direct Seeded Rice (dry)(14.22). Pusa RH 10 consistently yielded better in all production systems. In DSR (dry) only three genotypes Pusa Sugandh 5, Traori Basmati and Pusa RH 10 performed better. Genotypic performance of rice in realtion to different environments has been estimated by worker like Mohammadi et al. (2012), Rakshit et al. (2012) and Amiri et al.(2015) all of them identified verities suitable for a defined production system.

3.2 Pooled analysis of variance

The ANOVA showed that mean squares due to genotypes were highly significant for grain yield in all environments. The significance of genotypes mean squares indicated that genotypes differed among themselves and there existed a considerable variability irrespective of the effect of environments on the characters under study. Inconsistent performance of a given cultivar in different environments is termed as G × E interaction. Pooled analysis of variance combined with joint regression analysis proposed by Yates & Cochran (1938), modified by Finlay &Wilkinson (1963) and made popular by Eberhart &Russell (1966) has been and still is a popular technique for studying G × E effects and stability. Additive main effects and multiplicative interaction (AMMI), GGE Biplot analysis is extensively used for Genotype-environment interaction investigation.

The pooled analysis (Table 3) was highly significant ($p < 0.01$) for genotypes and environments for five characters except for Panicle length which it was non-significant for genotype. This revealed that there was considerable variability among genotypes and production systems. The mean squares due to G × E interaction when tested against pooled error were significant for all the characters viz; Grain yield per plant, Tiller per plant, Panicle Weight, Panicle Length, Panicle Height indicating that genotypes interacted with environments and performed inconsistently over different production systems. Sinha & Biswas (1987) also reported significant G × E interaction for Grain Yield per plant, but not for tiller /plant.

3.3 Stability Estimates

Both the parameters i.e. bi and S- 2dimentioned in the model of Eberhart & Russel (1966) were used to define stability of our genotypes. The stability analysis revealed one genotype in case of Plant height, Panicle length three genotypes in Panicle weight, two genotypes in Grain yield per plant and Tiller per plant had significant regression coefficient (bi) and non-significant deviation from the regression (S^{-2}di) in Table 5. Genotype Pusa Basmati-6 in Grain yield per plant, Pusa Sugandh 2 in Panicle Weight, Haryana Basmati-1 in Panicle Length, Pusa Basmati 1121 in Tiller Per Plant, HKR 98-476 in Plant Height exhibited non-significant S^{-2}di, regression coefficient significantly greater than one, and mean greater than the population mean was found suitable for a better environment. The better environment here refers to Transplanted Rice and System of Rice Intensification. Genotype Pusa RH 10 in Panicle Weight with regression coefficient significantly less than one and non-significant deviation from regression and mean greater than the population mean was identified suitable for unfavorable environments Direct Seeded rice (dry & wet). None of the genotypes was found stable. Moreover in the previous studies it is well demonstrated that the yield from DSR was low than puddled rice overall stability of DSR was not as much of other systems like SRI when it comes to

Table 3 Pooled Analysis of variance over 7 environments (production systems) for yield related traits in rice (Eberhart & Russell, 1966 model)

Source of Variations	DF	Grain Yield	Plant Height	Tiller/Plant	Panicle Length	Panicle weight
Rep within Env.	14	0.3	7.37	0.43	0.34	0.01
Varieties	21	16.58**	831.44**	8.96**	3.1779	0.76**
Env.+ (Var.* Env.)	132	23.44**	170.03**	10.26**	3.46*	0.23**
Environments	6	326.74**	2779.87**	139.28**	27.65**	3.29**
Var.* Env.	126	9.005**	45.75**	4.12**	2.3149	0.087*
Environments (Lin.)	1	1960.49**	16679.26**	835.68**	165.93**	19.78**
Var.* Env.(Lin.)	21	18.15**	42.0537	6.48*	1.9105	0.173**
Pooled Deviation	110	6.84**	44.38**	3.48**	2.28**	0.066**
Pooled Error	294	0.7831	7.4935	0.7892	0.4354	0.0197
Total	153	22.5065	260.814	10.0855	3.4271	0.3064

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

Indo-Gangetic Plains with alluvial soils compared to other parts of country (Pandey &Velasco, 2002; Raman et al., 2011).

3.4 AMMI analysis

AMMI models are well used to study the stability statistics and helped at several instances to indentify genotypes for a broad environments.

3.4.1 1st year (2014-2015) and 2nd year (2015-2016)

ANOVA based on AMMI as shown in Table 4. This has shown

Table 4 AMMI analysis of Rice genotypes over different production system for 2014-15 and 2015-16 Analyses of Variance for AMMI model

`	2014-2015			2015-2016		
Source of Variations	D.F.	M.S.S.	Variance %	D.F.	M.S.S	Variance %
Trials	87	26.306*		153	22.50**	
Genotypes	21	21.158*		21	16.58*	
Environments	3	399.06*		6	326.76**	
G*E Interaction	63	10.27*		126	9.005**	
PCA I	23	17.34*	61.64	26	17.83**	40.87%
PCA II	21	7.1*	23.06	24	9.85**	20.85%
PCA III	19	5.2*	15.28	22	7.70**	14.94%

*, ** Significant at 5% & 1% level of significance, respectively

Table 5 Stability parameters for Yield related trait of rice genotypes tested over 7 environments (production systems) (Eberhart &Russell, 1966 model)

Genotypes	Parameters	Grain Yield	Plant Height	Tiller/ Plant	Panicle Length	Panicle Weight
Pusa Basmati 1121	Mean	13.552	88.721	14.514	24.224	1.469
	bi	1.523	0.938	1.79*	0.497	0.717
	$S^{-2}di$	6.80**	20.82**	0.95	0.345	0.01
Pusa Basmati 1509	Mean	12.471	84.571	12.23	25.293	1.833
	bi	0.721	0.959	1.334	1.098	0.779
	$S^{-2}di$	1.71**	15.16*	0.523	0.277	0.049**
Pusa Sugandh 2	Mean	12.827	87.019	11.14	24.79	2.457
	bi	0.855	1.019	1.348	1.447	1.83
	$S^{-2}di$	4.44**	13.67*	3.18**	2.02**	0.049**
Pusa Sugandh 3	Mean	12.279	91.636	10.71	24.078	1.884
	bi	1.037	0.261	0.889	0.759	1.269
	$S^{-2}di$	7.84**	125.77*	9.05**	0.237	0.14**
Pusa Sugandh 5	Mean	12.514	86.074	10.4	24.247	2.116
	bi	0.648	0.829	0.99	1.528	1.319
	$S^{-2}di$	6.89**	1.829	1.15*	0.357	0.098**
Pusa Basmati 6	Mean	13.507	76.2	12.419	24.181	1.691
	bi	2.19*	1.175	1.316	1.278	0.353
	$S^{-2}di$	0.242	1.53	0.307	0.59*	0.043**
Pusa Basmati 1	Mean	12.159	81.063	10.219	25.328	1.86
	bi	1.194	1.238	0.39*	1.188	1.419
	$S^{-2}di$	1.58**	2.508	0.262	3.99**	0.039*

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Genotypes	Parameters	Grain Yield	Plant Height	Tiller/ Plant	Panicle Length	Panicle Weight
Imp Pusa Bas 1	Mean	12.186	75.002	10.429	24.982	1.88
	bi	1.301	0.803	0.539	2.202	1.42
	S^{-2}di	3.13**	15.13*	1.97**	3.48**	0.073**
HKR 98-476	Mean	9.842	104.67	13.286	24.094	1.274
	bi	0.34*	1.45	1.898	1.385	0.793
	S^{-2}di	0.542	3.416	6.23**	0.406	0.042**
HKR 3-408	Mean	10.636	101.91	11.743	24.295	1.39
	bi	0.691	0.921	0.393	0.462	0.13*
	S^{-2}di	2.35**	35.77**	2.96**	0.75*	0.013
HKR 06-434	Mean	12.136	106.071	10.933	23.714	1.508
	bi	1.649	1.124	0.587	0.742	1.342
	S^{-2}di	5.27**	15.62**	2.10**	0.266	0.008
HKR 06-443	Mean	11.24	91.748	12.576	24.473	1.362
	bi	0.666	0.92	1.309	0.91	0.679
	S^{-2}di	3.92**	22.32**	0.239	0.025	0.001
HKR 06-487	Mean	11.31	108.87	10.686	24.783	1.562
	bi	0.851	0.777	1.28	0.423	0.551
	S^{-2}di	3.74**	15.33*	8.22**	4.60**	0.19**
HKR 08-417	Mean	14.888	91.381	12.629	24.386	1.825
	bi	1.161	0.874	0.976	1.097	1.09
	S^{-2}di	18.60**	11.45*	2.47**	0.63*	0.03*
HKR 08-425	Mean	14.249	89.886	12.79	23.87	1.558
	bi	1.50*	1.205	0.89	0.277	0.986
	S^{-2}di	2.57*	24.81**	0.842	2.58**	0.019
Haryana Mahek-1	Mean	10.596	96.501	10.314	24.348	1.844
	bi	0.69	1.039	0.51	1.004	0.941
	S^{-2}di	1.57*	56.90**	7.65**	6.07**	0.033*
Haryana Basmati-1	Mean	12.139	95.314	12.029	25.877	1.925
	bi	1.259	1.084	1.151	1.74*	1.67*
	S^{-2}di	3.36**	70.17**	4.47**	0.183	0.041**
Travari Basmati	Mean	12.974	109.695	12.452	24.263	1.508
	bi	0.917	1.146	0.803	1.344	0.476
	S^{-2}di	11.89**	66.11**	0.109	1.35**	0.053
Super Basmati	Mean	11.883	98.748	12.01	24.508	1.511
	bi	0.846	1.053	0.796	0.502	1.195
	S^{-2}di	7.04**	10.96*	1.02*	2.72**	0.118
CSR-30	Mean	8.740	97.952	12.257	22.658	1.008
	bi	1.096	1.064	0.649	0.4	0.74*
	S^{-2}di	7.76**	69.22**	1.55*	3.85**	0.013
BASMATI-370	Mean	12.101	116.067	10.552	25.29	1.734
	bi	0.44*	1.242	0.998	1.209	1.001
	S^{-2}di	2.95**	174.32**	1.85**	6.28**	0.003
PUSA RH-10	Mean	15.250	86.005	12.1	24.926	2.234
	bi	0.405	0.872	1.157	0.499	0.28**
	S^{-2}di	29.65**	38.75**	2.41**	0.294	0.004

*, ** Significant at 5% and 1% respectively; bi: Regression coefficient; S^{-2}di.: Deviation from regression

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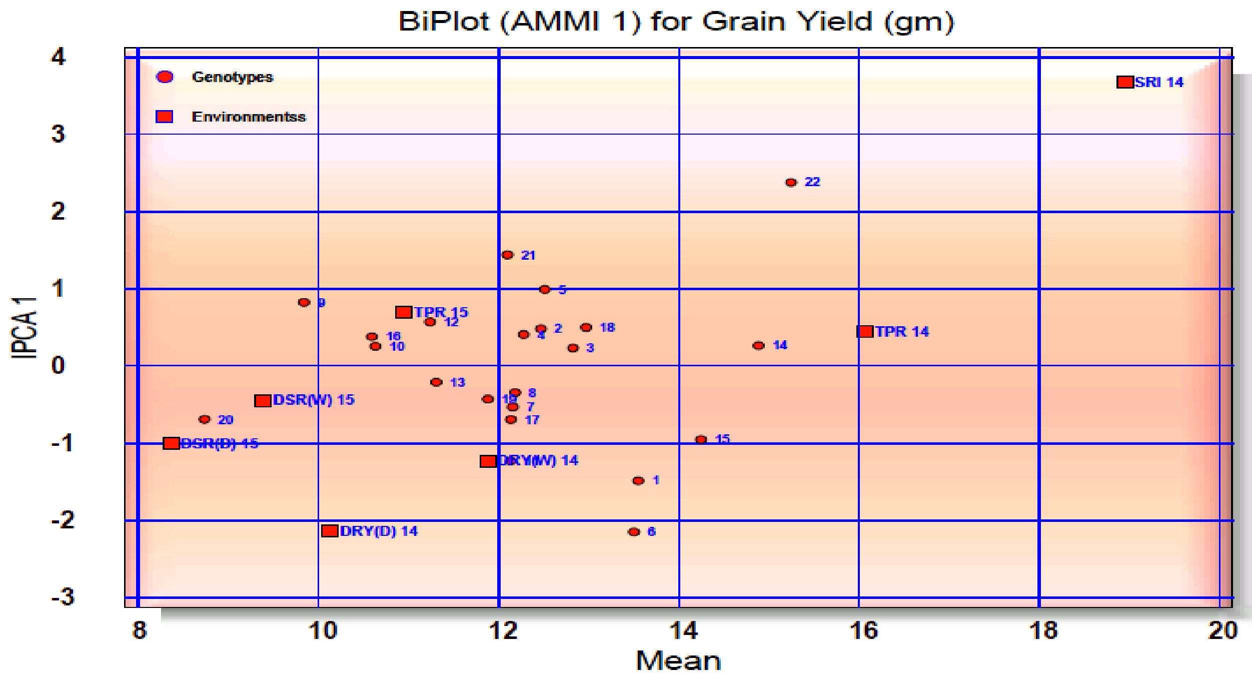

Figure 1 AMMI biplot of grain yield per plant main effects and GxE interaction of 22 rice genotypes under seven environments for grain yield per plant.

that the interaction of the twenty-two rice genotypes with seven environments was clearly predicted by the first two components of PCAI and PCAII. Genotypes HKR 3-408, Haryana Mehak-1, Pusa Sugandh-2, HKR 08-417 differed only in main (additive) effect. Conversely, many the genotypes differed only in interaction effects. While the genotype CSR-30 and Pusa RH-10 differed both in main effect and interaction effect. The interactions of environments were highly varied, while the normal TPR (E1) and TPR (E5) production system had low interaction, SRI (E2) high positive, DSR (wet) (E3), DSR (dry) (E4), DSR (wet) (E6), DSR (dry) (E7) had negative interaction. Production system (TPR and SRI) i.e. environments SRI, TPR had been always on the right-hand side of the midpoint of the main effect axis, seemed to be favorable environments, while DSR (wet) and DSR (dry) were generally less favorable environments. The genotypes having high interaction with environments were adapted to specific environments. Genotypes Pusa RH-10, Travori Basmati, HKR 08-417 with high mean and positive interaction was adapted to the favourable environment. Conversely, the genotype CSR-30 with low mean and negative interaction adapted to unfavourable environments. Pusa RH-10 had a higher mean grain yield and large IPCA1 scores indicated that they were unstable genotypes. Genotypes HKR 06-487, HKR 3-408, Haryana Mehak-1, Pusa Sugandh-2, HKR 08-417 had an IPAC1 score near zero. Hence, had small interaction effects indicating that these varieties were less influenced by the environment thus, stable. HKR 08-417 was found to be well acclimatized to the environments studied in this study. Using Figure the genotype and environment combination can be predicated as defined by Zobel et al. (1988).

The environments of the normal production system (E1) and DSR (Wet) (E7) had short spokes and they did not exert strong interactive force while environment SRI (E2), DSR (W) (E3), DSR (D) (E4), DSR (D) (E6), TPR (E5) having long spoke exert strong interaction. AMMI biplot for grain yield per plant of 22 rice genotypes studied under seven environments is shown in the Figure 1. Genotypes Pusa RH-10, Imp Pusa Basmati 1, HKR 98-476 were away from thus, most responsive. In this case, the best-adapted genotypes with respect to sites SRI were Pusa RH-10 but unsuitable for DSR (dry), DSR (wet). Genotype Imp Pusa Basmati1, Haryana Mehak-1 were adapted to DSR (wet) (E3) and CSR-30, Haryana Basmati-1 to DSR (wet) (E7) while Super Basmati, HKR 06-487 to DSR (dry) (E6). Genotypes HKR 98-476, Haryana Mehak-1, HKR 06--443, HKR 3-408 adapted to TPR(E5) and Pusa Sugandh 3 to TPR (E1). In Figure 2 the environment effects are joined to the origin, the sites with strong interaction are those with long spoke while week interactive force were present in the sites with short spokes. For effective breeding and adaption in different environmental conditions required stable

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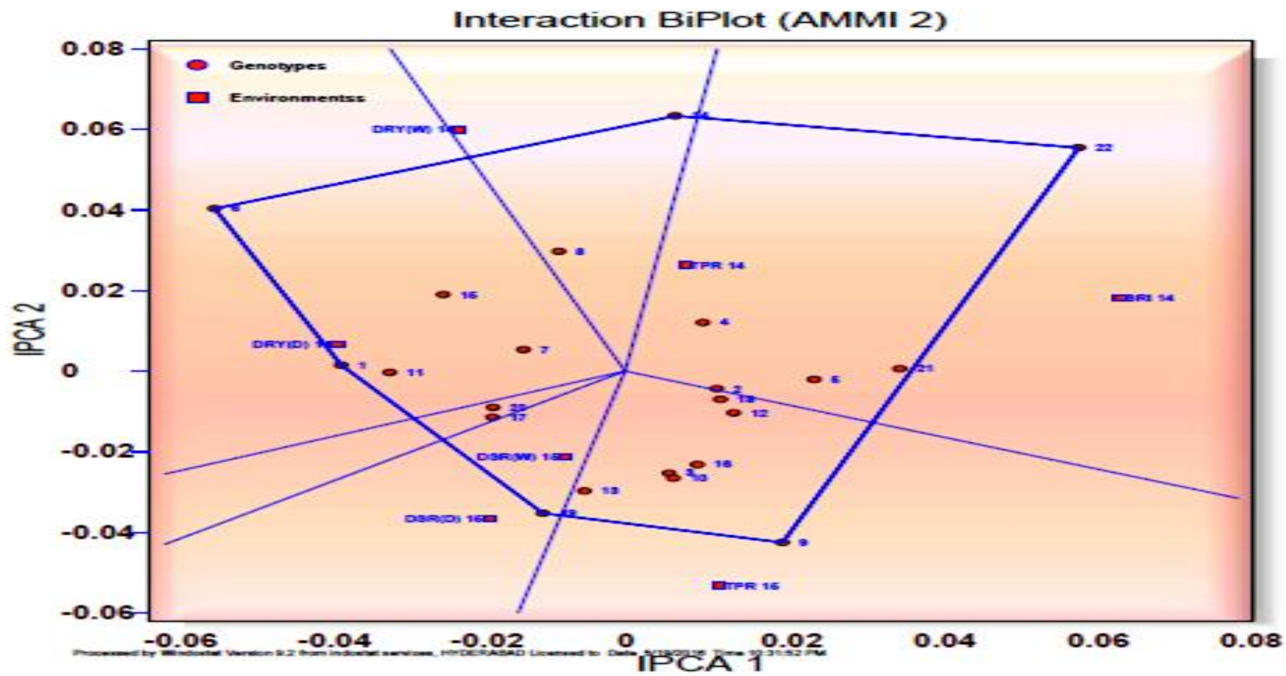

Figure 2 AMMI-2 model for grain yield per plant showing IPCA scores of rice genotype planted across environment (E).

Legend : 1: Pusa Basmati 1121, 2: Pusa Basmati 1509, 3: Pusa Sugandh 2, 4: Pusa Sugandh3, 5: Pusa Sugandh 5, 6: Pusa Basmati 6, 7: Pusa Basmati 1, 8: Imp Pusa Basmati 1, 9: HKR 98-476, 10: HKR 3-408, 11: HKR06-434, 12: HKR 06-443, 13: HKR 06-487, 14: HKR 08-417,15:HKR 08-425, 16: Haryana mehak-1, 17: Haryana Basmati-1, 18: Traori Basmati, 19: Super Basmati, 20: CSR-30, 21: Basmati 370, 22: Pusa RH 10, E1: TPR 14,E2: SRI14, E3: DSR(wet)14, E4: DSR (dry)14, E5:TPR15, E6 : DSR(D)15, E7: DSR(W)15.

and GEI study (Liang et al., 2015). GEI is analyzed by regression and multivariate methods. The benefits of methods based on multivariate analysis are naturally more accurate concept of GEI, the simplicity of interpretation of results delivered using Biplots charts (Carvalh et al. 2015). AMMI1 and AMMI2 biplot in muti-environment analysis and genotype evaluation because it clarifies more G+GE (Agyeman et al., 2015).

Acknowledgements

The author is thankful to the Regional Director RRS, Kaul, CCSHAU, Haryana for providing land, inputs and other facilities required for conducting the above experiment.

Disclosure statement

Authors declare that no conflict of interest could arise.

Conflicts of interest

All authors declare that there exist no commercial or financial relationships that could in any way lead to a potential conflict of interest.

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Accepted Article