G X E interaction and AMMI Biplot Analysis of Harvest Index and Test Grain Weight in Direct Seeded Basmati Rice

B.T. Jain[1] and A.K. Sarial[2]

[1]*Dept of Genetics and Plant Breeding, CCS HAU, Hisar*
[2]*College of Agriculture, CCS Haryana Agricultural University Campus Kaul, District Kaithal-136021 (Haryana)*
E-mail: [2]aksarial@yahoo.com

Abstract—*Harvest index (HI) is directly proportional to grain yield and inversely to total biological yield. The HI of direct-seeded rice is often lower than that of transplanted crops [15]. Cultivars able to maintain a high HI are preferred for direct seeding. Aimed so, 22 basmati rice genotypes comprising released varieties and elite lines including an hybrid were evaluated under direct and indirect seeding conditions . In direct seeding (DSR-wet) and (DSR-dry) and under indirect seeding transplanted rice (TPR) and system of rice intensification (SRI) made the four environments of experiment. The experiment was conducted during Kharif 2014 season in RBD with three replications at experimental farm of CCSHAU, College of Agriculture, Kaul. Plot size consisted of 5 row of 2m length and 0.20m breadth. Standard agronomic practices of different production systems were followed. Data were recorded for HI and test grain weight. Estimates of G x E interaction following Eberhart and Russell (1966) and AMMI biplot analysis as per Gauch and Zobel, (1989) model were computed. Stability parameter and AMMI biplot identified genotypes Pusa Basmati-1, HKR 08-425 and Haryana Basmati-1 with high HI adaptable to better environment SRI and DSR. Genotype Pusa Basmati 1509, Pusa Sugandh 5, HKR 06- 443, CSR-30 and Pusa RH 10 were identified to be stable for test grain weight. Environment wise genotype Traori Basmati and Pusa Sugandh 5 were adapted to DSR (dry) while HKR 06-487 and Pusa RH 10 were adapted to DSR (wet) for HI.*

Indexwords*: G x E interaction, AMMI biplot, harvest index, basmati rice, Oryza sativa L.*

1. INTRODUCTION

Harvest index is directly proportional to the grain yield and inversely proportional to biological weight. Due to high biological weight of genotypes in SRI, all genotypes have low harvest index. The harvest index of direct-seeded rice is often lower than that of transplanted crops [15] perhaps because of higher plant density. Thus, cultivars required for direct seeding are those that are able to maintain a high harvest index. Test grain weight is directly proportional to grain yield. Generally, plants having better partitioning of dry matter lead to increase in the number of filled spikelet's and higher test grain weight. Rice is primarily grown by transplanting of seedling in puddled field which is very cumbersome and labour intensive as it requires 30 man days ha^{-1} [18]. Due to conventional transplanting method, it has been causing a sharp decline in water table. It is imperative to shift from conventional namely Transplanting method (TPR) to non-conventional cultivation techniques such as direct seeded rice (DSR). The direct seeding technique offers an useful option to reduce the limitations of transplanted paddy. Direct-seeded rice offers the advantage of faster and easier planting, ensure proper plant population, reduce labour, 10-12 days earlier crop maturity, more efficient water use, higher tolerance to water-deficit and often high profit in areas with assured water supply [5].

In Haryana whole area of 12.2 lakh ha. is transplanted giving an average productivity of 3.2 t/ha. The state ranks 1st in Basmati cultivation covering 70% of the total area. Its internationally recognized for export of basmati rice. The world's longest grain basmati rice Pusa 1121 is exported from Haryana and Punjab together constitute 70% of the total basmati turn over of Rs 29299 crores as per report APEDA, 2014.

However, to date, no specific varieties have been developed for the non-conventional direct seeding technologies. Released varieties for TPR do not perform well under such techniques. Varieties differed in their genetic potential and all varieties are not promising for direct seeding. The varietal response to different production systems is wide [9]. To overcome such challenges estimate of G x E interaction and adaptability is imperative. The Additive Main effects and Multiplicative Interaction (AMMI) model is a hybrid model involving both additive and multiplicative components. Using AMMI analysis and biplot facility, the data on HI and TGW were analysed to determine G x E interaction effects and identify stable as well as genotypes adaptable to specific environments.

2. MATERIALS AND METHODS

The experimental materials consisted of twenty two released basmati varieties including elite lines. The experiment was conducted in a randomized block design with three replications in four environments created agronomically [11] termed production systems of rice during (kharif) rainy season of 2014 at CCS Haryana Agricultural University, Rice Research Station, Kaul farm (District, Kaithal). They are conventional transplanted rice (TPR) and non-conventional viz; system of rice intensification (SRI), direct seeded dry (DSR, dry) and direct seeded wet (DSR, wet). Plot size consisted of 5 row of 2m length and 0.20m breadth. The production systems have been described in Table 1. The data were recorded on five randomly selected plants per genotype per replication for harvest index and test grain weight. The G x E interaction was analyzed following Eberhart and Russell (1966) [6] model and AMMI biplot [8].

Table 1: Description of Environment

Environment	E1	E2	E3	E4
Description	TPR	SRI	DSR(wet)	DSR(dry)
Seed rate (Kg/ha)	20	5	20	20
Seedling age (Days)	25	15	Direct sowing at 5 cm depth	Direct sowing at 5 cm depth
Spacing (cm^2)	15x15	25x25	20 (R-R)	20 (R-R)
Seedling /Hill	2	1	2	2
No. of Irrigation	30-33	18-20	18-20	16-18
Weeding	spray	Spray	Hand 30-35 (DAS)	Hand 30-35(DAS)

Source: Jain and Sarial, 2015.

3. RESULTS AND DISCUSSION

Pooled analysis of variance computed as per Eberhart and Russell (1966) model for harvest index and test grain weight (Table 2) showed that the variance due to genotypes were significant ($p < 0.05$) for both the characters. This revealed the presence of considerable genotypic variability among the genotypes for traits under study. The mean sum of squares due to genotype x environment interaction when tested against pooled error was significant for both the traits. Further partitioning of combined environment and genotype x environment variance into linear and non-linear components showed that environment linear was highly significant, G x E (linear) was non significant while, pooled deviation (non linear component) when tested against pooled error was significant for both the characters.

Table 2: Pooled Analysis of variance over 4 production systems for harvest index and test grain weight in rice. (Eberhart and Russell, 1966 model)

Source	Harvest index (%)	Test grain weight(g)
Genotype	121.48*	36.42*
Environment	493.74*	50.55*
Gen X Env	37.83*	4.56*
Env+Gen X Env	58.56*	6.65*
Env (Linear)	1,481.24	151.67
Env X Gen (Lin)	36.69	3.18
Pooled Deviation	36.66*	5.02*
Pooled Error	19.6	2.24

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

The Eberhart and Russell (1966) model used two parameters (bi and S^{-2}di) to define stability. S^{-2}d; is largely used to rank the relative stability of cultivars. For harvest index (Table 3) Stability analysis revealed Pusa Basmati-1, HKR 08-425 and Haryana Basmati-1 having regression coefficient significantly greater than one, non significant deviation from regression and mean greater than population mean were found suitable for better environment. Under intensive agriculture, when inputs are not limitations, such varieties can yield maximum, whereas in poor conditions they fail miserably. Hence, these varieties can be recommended for rich environments [2]. None of the genotypes was found to be stable as well as suitable for poor environments (DSR).

With regards to test grain weight ten genotypes had significant regression coefficient (bi) and three significant deviation from regression (S^{-2}di). Thus, the later three were unpredictable. Many workers revealed significant regression and deviation from regression for 1000-grain weight [13], [9] and [17]. Genotype Pusa Basmati 1509, Pusa Sugandh 5, HKR 06- 443, CSR-30 and Pusa RH 10 with test grain weight more than grand mean, unit regression coefficient and zero deviation from regression were identified to be stable. Genotype Pusa Basmati 1121, Pusa Sugandh 3, and Haryana Mehak-1 with regression coefficient significantly greater than one, non-significant deviation from regression and test grain weight more than population mean were found suitable for better environment (TPR and SRI) While genotype Pusa Sugandh 2 with regression coefficient significantly less than one, non-significant deviation from regression and test grain weight greater than population mean was found suitable for unfavourable environment (DSR)

Table 3: Stability parameters for harvest index and test grain weight of rice genotypes tested over 4 production systems

Genotypes	Mean	HI(%)		Mean	T G W	
		b_i	S^{-2}_{di}		b_i	S^{-2}_{di}
Pusa Basmati 1121	27.88	1.25	33.65*	26.64	1.43*	1.31
Pusa Basmati 1509	35.28	1.03	71.05*	31	0.74	4.35
Pusa Sugandh 2	30.93	1.12	56.09*	27.45	0.95*	-0.73

Pusa Sugandh 3	33.07	1.88*	26.59*	23.65	1.43*	3.79
Pusa Sugandh 5	36.91	0.53	75.10*	24.01	1.01	6.17
Pusa Basmati 6	29.52	2.00*	24.52*	22.15	1.44	16.90*
Pusa Basmati 1	31.91	1.24*	3.49	19.91	2.19*	0.71
Imp Pusa Basmati 1	33.03	1.24	55.24*	20.65	1.81*	0.8
HKR 98-476	19.62	0.71*	-3.84	20.36	-0.38	3.2
HKR 3-408	22.47	0.19	-1.18	20.36	0.79*	-0.24
HKR 06-434	25.14	1.16*	-2.78	22.77	2.11	15.10*
HKR 06-443	24.97	1.23*	-3.07	25.41	0.38	2.33
HKR 06-487	25.19	1.65*	8.5	18.16	0.75	1.32
HKR 08-417	37.03	-0.16	15.95*	20.48	0.92*	-0.32
HKR 08-425	31.25	1.57*	7.86	20	0.77*	0.34
Haryana Mahek-1	20.39	0.55	16.10*	22.63	1.38*	1.27
Haryana Basmati-1	29.94	1.30*	1.2	20.86	2.06*	6.25
Traoari Basmati	30.95	-0.6	185.5*	22.18	0.78	1.62
Super Basmati	24.74	1.12*	8.99*	20.85	0.24	23.48*
CSR-30	20.93	2.23*	18.02*	22.85	0.62	0.33
BASMATI-370	26.5	1.06*	7.97	19.48	0.41	1.58
PUSA RH-10	37.7	-0.38	57.73*	23.9	0.064	4.39
Mean	28.88			22.53		
Standard error		0.73			0.85	

4. AMMI ANALYSIS

On the other hand, biplot analysis is possibly the most powerful interpretive tool for AMMI models. There are two basic AMMI biplots, the AMMI 1 biplot where the main effects (genotype mean and environment mean) and IPCA 1 scores for both genotypes and environments are plotted against each other. In the second AMMI 2 biplot scores for IPCA 1 and IPCA 2 are plotted. The biplot technique was used to identify appropriate genotype adapted to specific locations/ environments [7]. For harvest index presence of GEI was clearly demonstrated by the AMMI model (Table 4) when the interaction was partitioned among the first two interaction principal component axis (IPCA) they cumulatively captured 80.40% of total GEI. This implied that the interaction of the 22 rice genotypes with four environments was predicted by the first two components of PCAI and PCAII. The findings were in agreement with those of [10], [4] and [19] analyzed G x E interaction in rice by AMMI model. They found significant G x E interaction stated the usefulness of AMMI analysis for selection of genotypes for specific location/environment. Trait wise for harvest index, the total mean sum of square was attributed to environmental effects 23.08%, genotypic 39.76% and G x E interaction effects 37.15%. The environments were diverse but genotypic effect caused the greatest variation. The genotype effect higher than GEI, which suggests the possible existence of different genotype groups [16].

Table 5: AMMI analysis of harvest index and test grain weight in rice across 4 production systems

Source	Harvest Index %		Test grain weight(g)	
	MSS	% explained	MSS	% explained
Trials	73.74		13.84	
Genotypes	121.48*	39.76	36.42*	63.51
Environments	493.74*	23.08	50.55*	12.59
G*E Interaction	37.83*	37.15	4.56*	23.88
PCA I	49.50**	47.67	7.03**	56.22
PCA II	37.22**	32.73	3.49**	25.51
PCA III	24.38**	19.4	2.76**	18.27
Error	6.59		0.79	

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

The AMMI-1 biplot for harvest index of 22 genotypes at four environmental conditions is presented in Fig. 1. Genotypes Traori Basmati and Pusa RH 10 differed from CSR-30 in both the main effect and interaction effect. The interaction amongst environments was high. Environments SRI, TPR and DSR (wet) had low negative interaction while DSR (dry) had high positive interaction. TPR and SRI 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. Genotypes HKR 08-425, Haryana Basmati- 1 and Pusa Basmati 1509 had high mean and negative interaction, hence were adapted to favourable environment. Conversely, the genotypes CSR-30 with low mean and negative interaction was suited to unfavourable environments. Genotypes HKR 98-476, Haryana Mahek-1, Super Basmati, HKR 06-434, Basmati-370, Pusa Basmati 1121, Haryana Basmati-1, Pusa Sugandh 3, HKR 08-417, HKR 06-443 and HKR 06-487 had IPAC1 score near zero, hence had small interaction effects indicating that these varieties were less influenced by the environment were considered as stable. Among them, the genotype HKR 08-417 had high means values could be recommended for all the environments. Genotypes with IPCA1 scores near zero had little interaction across environments and vice versa for environments [3].

In AMMI 2 biplot (Fig 2), environments of normal production system had short spokes and they did not exert strong interaction force while environment SRI, DSR (wet) and DSR (dry) having long spoke exert strong interaction. Genotypes Traoari Basmati and Pusa RH 10 had highest PCA score were rated the most responsive genotype. Environment wise genotype HKR 08-417, Haryana Mehak-1 and Pusa Basmati 1 were adapted to SRI. Imp Pusa Basmati 1, HKR 08-425, Pusa Basmati 6 and Basmati 370 to TPR and DSR (wet) while genotype Traori Basmati and Pusa Sugandh 5 were adapted to DSR (dry).

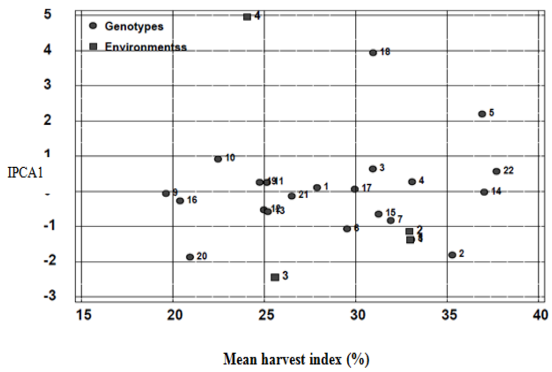

Fig. 1: AMMI biplot of harvest index main effects and G x E interaction of rice genotypes in four environments

Legend: 1:Pusa Basmati 1121, 2:Pusa Basmati 1509, 3:Pusa Sugandh 2, 4:Pusa Sugandh 3, 5:Pusa Sugandh 5, 6:Pusa Basmati 6, 7:Pusa Basmati 1, 8: Improved 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:Normal production system, E2:SRI, E3:DSR (wet), E4:DSR (dry)

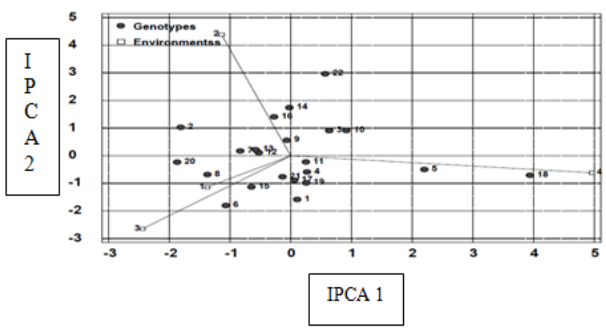

Fig. 2: AMMI 2 biplot of harvest index showing IPCA scores of rice genotype (G) ploted across environments (E).

AMMI1 biplot (Fig. 3) for test grain weight revealed that interactions of environments were high and varied. DSR (wet) had positive interaction while DSR (dry), TPR and SRI had negative. Environments TPR, SRI and DSR (wet) being on the right hand side of the midpoint of the main effect axis, seemed to be favorable environments for test grain weight, while DSR (dry) away from midpoint were generally less favorable environments. Genotypes Pusa RH 10 and Pusa Basmati 6 had high mean and positive interaction were adapted to DSR (wet). Conversely, the genotypes HKR 08-425, Basmati-370 and HKR 98-476 with low mean and negative interaction were adapted to DSR (dry). The genotype HKR 06-434, Pusa Sugandh 3, and Pusa Sugandh 5 with low mean but high interaction was adapted to TPR and SRI. Genotypes that grouped together have similar adaptation while environments which grouped together influences the genotypes in the same way (Kempton, 1984). Genotypes HKR 06-487, HKR 3-408, HKR 08-417, Haryana Mehak-1, Pusa Sugandh 2, Pusa Basmati 1509, Pusa Basmari 1, Imp Pusa Basmati 1, CSR-30, and HKR 06-443 had IPAC1 score near zero, hence had small interaction effects indicating that these varieties were less influenced by the environment. Among them Pusa Sugandh 2 had high mean hence, found stable and recommended for all the environments. Similar findings were also reported by [4] and [14].

In AMMI 2 biplot (Fig. 4) TPR and DSR (dry) had short spokes and they did not exert strong interactive force while environment SRI and DSR (wet) having long spoke exert strong interaction. Genotypes HKR 06-434, Haryana Basmati-1 and Super Basmati had high PCA score and away from origin were most responsive genotypes. Pusa Sugandh 3, Pusa Basmati 1121, Pusa Basmati 1 and HKR 06-434 were adapted to SRI. Genotypes Traori Basmati, Basmati-370, HKR 98-476 and HKR 06-443 to TPR and DSR (dry) while genotype HKR 06-487 and Pusa RH 10 were adapted to DSR (wet).

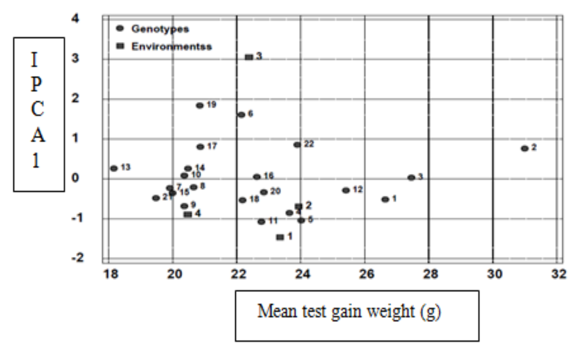

Fig 3: AMM I biplot of test grain weight showing main effects and G x E interaction of rice genotypes in four environments

Legend : 1:Pusa Basmati 1121, 2:Pusa Basmati 1509, 3:Pusa Sugandh 2, 4:Pusa Sugandh 3, 5:Pusa Sugandh 5, 6:Pusa Basmati 6, 7:Pusa Basmati 1, 8: Improved 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:Normal production system, E2:SRI, E3:DSR (wet), E4:DSR (dry)

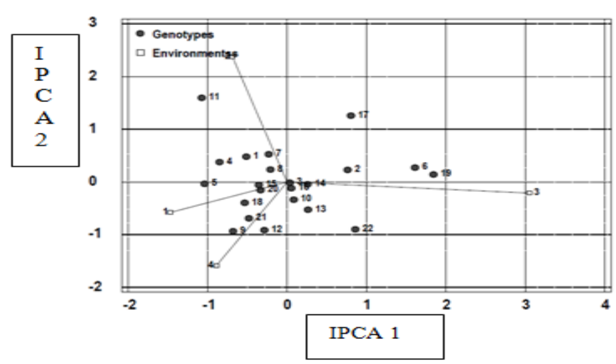

Fig 4. AMMI 2 biplot of test grain weight showing IPCA scores of rice genotype (G) ploted across environments (E).

5. SUMMARY AND CONCLUSION

The present study provided an evaluation of genotypic and environmental performance of twenty-two rice genotypes over a range of environments. According to Eberhart and Russel (1966) regarding harvest index genotypes Pusa Basmati-1, HKR 08-425 and Haryana Basmati-1 were found suitable for better environment (TPR and SRI) and for test grain weight genotype Pusa Basmati 1121, Pusa Sugandh 3 and Haryana Mehak-1 were found suitable for better environment, while Pusa Sugandh 2 was found suitable for Poor environment (DSR). Pusa Basmati 1509, Pusa Sugandh 5, HKR 06- 443, CSR-30 and Pusa RH 10 with test grain weight were identified to be stable and recommended for all the environment. AMMI statistical model could be a great tool to select the most suitable and stable genotype for specific as well as for diverse environments. In the present study, AMMI model has shown the first two interaction principal component axis (IPCA) they cumulatively captured 80.40% and 81.73% of total GEI for harvest index and test grain weight respectively. It identified HKR 08-417 for harvest index and Pusa Sugandha 2 for test grain weight as stable genotypes. Pusa Basmati 1509 was found adapted to TPR and SRI and CSR-30 to direct seeding DSR. For test grain weight genotypes HKR 06-434, Pusa Sugandh 3, and Pusa Sugandh 5 were adapted to TPR and SRI while Pusa RH 10 to DSR (wet) and Basmati-370 adapted to DSR (dry).

REFERENCES

[1] Anonymous, "Department of Agriculture and cooperation, Ministry of Agriculture", GOI. 2013-2014.

[2] Bose, L.K., Nagaraju.M., and Singh, O.N, "Genotype x Environment interaction and stability analysis of lowland rice genotypes". *Journal of Agriculture Sci*ence, **57**(1) 2012, pp. 1-8.

[3] Crossa, J., Fox, P.N., Pfeffer, W.H., Rajaran, S. and Gauch, H.G., "AMMI adjustment for statistical analysis of an international wheat trial*"Theory of Application Genetics*, **81, 1991,** pp 27-37.

[4] Das, S., Misra, R.C. and Patnaik, M.C., "G×E interaction of mid-late rice genotypes in LR and AMMI model and evaluation of adaptability and yield stability", *Environment and Ecology*, **27**, 2009, pp 529-535.

[5] De Datta, S. K., "Technology development and the spread of direct-seeded flooded rice in South-East Asia", Experimental Agriculture, 22, 1986, pp 417-26.

[6] Eberhart, S.A. and Russel, W.A., "Stability parameters for comparing varieties" *Crop Sci*ence", **6, 1966,** pp 36-40.

[7] Gauch, H.G. and Zobel, R.W., "AMMI analysis of yield trials genotype x environment interaction", Kang, M.S. and H.G. Gauch (Eds.). CRC Press, Boca raton, FL., USA, 1996, pp 85-122.

[8] Gauch, H.G. and Zobel, R.W., "Accuracy and selection success in yield trials analysis", *Theoretical and Applied Analysis*, **77**, 1989, pp 443-481.

[9] Ghritlahre, S.K., and Sarial, A.K., "G × E Interaction and Adaptability of Rice Cultivars in SRI and Normal Production Systems", *Cereal Research Communications*, **39**(4), 2011, pp 589–597.

[10] Islam, M.R., Anisuzzaman, M., Khatun, H., Sharma, N., Islam, M.Z., Akter, A., and Biswas, P.S. (2014)., "AMMI analysis of yield performance and stability of rice genotypes across different haor areas". *Eco-friendly Agrilculture Journal*, **7**(02), 2014, pp 20-24.

[11] Jain, B.T and Sarial, A. K. (2015). G x E interaction and AMMI biplot analysis for grain yield of basmati rice genotypes in different production systems. Indian Journal of Agriculture Sciences (under process).

[12] Kempton, R.A., "The use of biplots in interpreting variety by environment interactions", *Journal of Agriculture Science*, **103**, 1984, pp 123-135.

[13] Khandhola, S.S. and Panwar, D.V.S., "Studies on genetic divergence, stability heterosis and combining ability in rice (*Oryza sativa* L.)", 1999.

[14] Kulsum, M.U., Hasan, M.J., Akter, A.K. and Biswas, H.R.P., "Genotype x Environment interaction and stability analysis in hybrid rice: an application of Additive main effects and multiplicative interaction", *Bangladesh Journal of Botony*, **42**(**1**), 2013, pp 73-81.

[15] Miyagawa, S., Konchan, S. and Kono, Y., "Yielding ability in direct seeding rice culture in northeast Thailand", *Japan Journal Tropical Agric*ulture", **42**(4), 1998, pp 248-256.

[16] Mohammadi R, Davood S E, Mohammad A and Ahmed A., "Evaluation of durum wheat experimental lines under different climate and water regime conditions of Iran", *Crop and Pasture Science*. **62**,2011, pp 37-151.

[17] Padmavathi, P.V., Satyanarayana, P.V., and Ahamed, M.L., "Stability analysis of Rice (*Oryza sativa* L.) hybrids utilizing Regression and AMMI models", *Society of Plant Research*, **26** (2), 2013, pp 148-153.

[18] Prasad R., "Recent advances in rice agronomy", Indian Farming, 54, 2014, pp 7-10.

[19] Umma K. M., Hasan M. J., Akter A, Rahman H and Biswas P., "Genotype-environment interaction and stability analysis in hybrid rice: an application of additive main effects and multiplicative interaction", Bangladesh Journal of Botany, **42**(1),2013, pp 73-81.