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EVALUATION OF MAIZE HYBRIDS SUITABLE FOR DIFFERENT AGRO-ECOLOGICAL REGIONS OF BANGLADESH BY USING GGE –BIPLOT AND AMMI MODEL ANALYSIS

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ABSTRACT

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Evaluation of the productivity and performance of maize hybrid in variable environment is a basic demand for releasing verities. The present study assessed genotype × environment interaction and stability for grain yield, plant height and ear height of 15 maize hybrids in 5 different agro ecological regions of Bangladesh during 2016-17. The GGE Biplot and AMMI model (additive main effects and multiplicative interaction) analysis were used to assess the genotype-environment interactions over five locations to select the hybrid having higher yield and other potential attributes. A significant variation for genotypes (G), environment (E) and GEI were observed for the yield and its related characters. Among these tested environments, Gazipur, Ishurdi and Jamalpur were found not suitable to get desirable yields for all tested genotypes; but Rangpur and Barisal were found suitable for the production of maize hybrid. Among the suited two locations, Rangpur was found highly suitable for hybrid maize cultivation followed by Barisal. Considering the mean, bi and S^2di, all the hybrids showed different responses of adaptability under different environmental conditions. Among the hybrids, A-9×B-19, BARI hybrid maize-9, 981, 7074/S_5-15×M-10, and 7074/S_5-15×M-15 exhibited the higher grain yield, bi~1 and S^2di~0 indicated that the hybrids are stable across the environment.

Key words: *AMMI Model, Evaluation, GGE-biplot, maize stability*

INTRODUCTION

Maize is gaining popularity among farmers mainly due to its high yield, more economic return and versatile uses. The area and production of maize is increasing day by day in Bangladesh and it continues to expand rapidly at an average rate of 20% year^{-1} (CIMMYT 2008). To meet the demand for seed, several seed companies import hybrid maize seed and about 70% of seed demand is met up through imported seeds. One of the greatest challenges to maize breeders is the obtainment of a hybrid with a high mean yield and the widest possible adaptation to the various environments so that the maize hybrids can be produced on a large scale, lowering the production costs of the basic material and making it more accessible to producers. In the initial assessment, maize hybrids are tested in relatively few environments, and interaction can interfere with the performance results leading to errors in selection where promising materials are discarded because of the lack of a more careful analysis of the data obtained. The relative performance of the genotypes can be altered with changes in the environments and these different responses are due to the genotype-environment interactions (GE) because there are environments that are either more or less favorable to certain genotypes. Several statistical analysis procedures have been used to better interpret these interactions, that is, to analyze the performance of the various environments and ascertain the genotype stability. The most used methods to interpret genotype stability are based on regression analyses (such as Finlay and Wilkinson, 1963; Eberhart and Russell, 1966; Cruz *et al.* 1989; Agronomic Zoning is used to stratify environment in sub regions within which the interactions are not significant (Duarte and Zimmermann, 1991). Used to assess Genotype × Environment interaction (Yan and Tinker, 2006). GEI for field experiments, for yield, usually determined by AMMI model. In the case of genotype evaluation for macro environment analysis and genotype evaluation, AMMI graph is comparatively lees effective than GGE biplot as it provides poor information about G+GE (Yan *et al*. 2007). GGE biplot can effectively calculate the target location by analyzing the status of discriminating vs representativeness. Better graphical illustration is possible by using multiple environments the GGE biplot model method as it multi-location data (Yan and Holland, 2010). There are several research findings revealed that this model has been perfectly applied for different crop experiment (Chen *et al.* 2009). However, the GE interaction (residue after fitting an additive model for these effects) may not be additive and other techniques are required to identify the existing relationships.

The principal components analysis is a statistical procedure that gives a multiplicative model that can be used to diagnose and analyze the interaction, although it is also faulty in the identification of the main significant effects (Shafii and Price, 1998). In this sense, the AMMI model (Crossa 1990) is a method that combines, in a single WW model, the estimation of the main effects and multiplicative components for the effects of the GE interaction. More precise genotype x environment interaction estimates can be obtained with the AMMI model which makes it easier to interpret the results obtained (Duarte and Vencovsky, 1999). Bangladesh Agricultural Research Institute (BARI) has released few maize hybrids, those are now cultivated in farmers' fields along with some commercial varieties but there is a high demand to develop more hybrids to fulfill sustainable development goal, Farmer's interest and to fit for variable environments.

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In this experiment fifteen maize hybrids including two check verities were tested for their yield potentiality as well as the stability in different five location of Bangladesh to select the hybrid having higher yield and other potential attributes.

MATERIALS AND METHODS

Experimental Details

The experiment was conducted at five locations (*viz.*, Gazipur, Jessore, Barishal, Rangpur and Ishurdi during Rabi 2016-17. The materials consisted of Fifteen single cross hybrids with Tow check like BARI Hybrid maize-9 and very much popular hybrid 981) were evaluated in this trial. Gazipur, Jessore, Barishal, Rangpur and Ishurdi during rabi 2016-17. The experiment was laid out in alpha lattice design with 3 replications. Seeds of each entry were sown in 2 rows, 5m long plot at 60 cm and 20 cm spacing. Seeds were sown on mid-November-2016. One healthy seedling per hill was kept after thinning. Fertilizers were applied @ 250, 55, 110, 40, 5 and 1.5 kg/ha of N, P, K, S, Zn, and B, respectively. Standard agronomic practices were followed and plant protection measures were taken as required. Two extra row were used at the end of each replication to avoid the border effect Weed control was done manually as and when needed. Mature cobs were harvested from the field manually and dried under the sun and seeds were separated. Plant height (PH), Ear height (EH), thousand grain weight (TGW), and grain yield (ton/ha). All data were processed and analyzed using the Crops stat 6.1 program.

Statistical Analysis

The analysis of variance (ANOVA) was used and the GE interaction was estimated by the AMMI model (Zobel *et at.* 1988). Thus, the mean response of the genotype i in environment j (Yij) is modeled by: $Yij = \mu + gi + aj + \sum \lambda k\gamma ik\alpha jk + \rho ij + eij$. According to Eberhart and Russel (1966), regression coefficient (bi), deviation from regression (S^2di) and the stability parameters were also estimated through the AMMI model. In this procedure, the contribution of each genotype and each environment to the GE interaction is assessed by use of the biplot graph display in which yield means are plotted against the scores of the first principal component of the interaction (IPCA1). The computational program for AMMI analyses is supplied by Duarte and Vencovsky (1999). The stability parameters, regression coefficient (bi) and deviation from regression (S^2di) were estimated according to Eberhart and Russel (1966). The significance of differences among bi value and unity was tested by t-test, between S^2di and zero by F-test.

RESULTS AND DISCUSSION

Results of the combined analysis of variance for three characters of fifteen hybrids at five environments are presented in Table 1. The mean sum of squares for the genotypes was highly significant for all the traits which revealed the presence of genetic variability in the material under investigation for all the characters studied. Environments mean sum of squares were highly significant for days to tasseling, silking, plant height, ear height and yield. The highly significant effects of environment indicate high differential genotypic response across the different environments. Interaction G×E mean sum of squares were highly significant for yield. The variation in soil structure and moisture across the different environments were considered as a major underlying causal factor for the G×E interaction. Environment relative magnitude was much higher than the genotypic effect, suggesting that performance of each genotype is influenced more by environmental factors.

Table 1. Full joint analysis of variance including the partitioning of the G×E interaction of maize hybrids

Source of variation	Df	Mean sum of squares		
		Plant height (cm)	**Ear height (cm)**	**(Yield) (t/ha)**
Genotypes (G)	14	3593.43**	1889.17**	15.75**
Environment (E)	4	11646.29**	5932.11**	18.14**
Interaction G×E	56	137.66**	58.86**	1.30**
G×E (Linear)	14	221.42**	112.65**	1.67**
Pool deviation	42	109.76**	40.93**	1.18**
Pooled error	140	120.01	50.42	1.44

*P<0.05, **P<0.01

Results of stability and response of the genotypes for yield under different environments according to Eberhart and Russell (1966) are discussed character-wise as follows; Stability parameter i.e. regression coefficient (bi) and deviation from regression (S^2di) for plant height, ear height and yield of the individual genotypes are presented in Tables 2, 3 & 4.

Plant heights along with the value of phenotypic index (Pi,) Regression coefficient (bi), and deviation from regression (S^2di) are presented in Table 4. The genotypic mean ranged for plant height from 102cm (CML-498×CML-511) to 257cm (A-9×B-19). Six hybrids showed a positive Pi index while rest nine showed a negative Pi index in plant height. The hybrids which showed a positive Pi index these hybrids represent taller plants and the negative Pi index showing genotypes represent dwarf plants. The bi and S^2di values range for plant height were 0.72 (7074/S_5-8×BML-36 and7074/S_5-15×M-15) to 1.48 (BHM-9) and 18.07(981) to 342.687074/S_5-15×M-10) respectively.

Table 2. Stability analysis for Plant height of maize hybrids over five environments

Sl. No.	Entry	Location					Overall mean	P. Index (Pi)	bi	S^2di
		Gazipur	Jashore	Barisal	Rangpur	Ishurdi				
1	7074/S_5-11×BML-36	130	181	171	170	129	156.33	-22.01	0.87	34.07
2	7074/S_5-1×BML-36	143	198	195	168	156	171.93	-6.41	0.80	103.73
3	7074/S_5-5×CML-425	137	195	188	149	151	164.00	-14.35	0.76	297.89
4	7074/S_5-8×BML-36	110	156	151	157	128	140.13	-38.21	0.72	28.32
5	7074/S_5-8×CML-425	133	180	176	184	141	162.73	-15.61	0.83	48.91
6	7074/S_5-15×M-10	155	206	186	185	126	171.60	-6.75	0.96	342.68
7	7074/S_5-15×M-15	150	201	184	189	163	177.40	-0.95	0.72	20.26
8	A-17×M-4	154	225	209	239	168	199.13	*20.79	1.22	241.50
9	A-9×B-19	173	257	227	240	195	218.47	*40.12	1.20	77.76
10	A-10×B-19	152	243	233	242	185	211.00	*32.65	1.44	76.66
11	M-2×BIL-106	134	211	212	186	159	180.33	*1.99	1.18	85.89
12	M-9×BIL-110	138	198	196	181	166	175.80	-2.55	0.86	60.41
13	CML-498×CML-511	102	143	151	132	112	128.07	-50.28	0.71	55.20
14	BHM-9	153	247	241	240	186	213.47	*35.12	1.48	45.21
15	981	155	238	225	223	184	204.80	*26.45	1.23	18.07
	Mean	141.16	205.31	196.36	192.36	156.56	178.35			
	Env. Index(Ij)	-37.19	26.96	18.01	14.01	-21.79				
	LSD (0.05)									

Table 3. Stability analysis for Ear height of maize hybrids over 5 environments

Sl. No.	Entry	Location					Overall mean	P. Index (Pi)	bi	S^2di
		Gazipur	Jashore	Barisal	Rangpur	Ishurdi				
1	7074/S_5-11×BML-36	51	98	87	89	58	77	-5.74	1.03	7.03
2	7074/S_5-1×BML-36	47	92	88	83	64	75	-7.51	0.93	19.36
3	7074/S_5-5×CML-425	59	98	89	65	68	76	-6.42	0.61	182.89
4	7074/S_5-8×BML-36	33	60	69	80	46	58	-24.74	0.83	97.78
5	7074/S_5-8×CML-425	50	80	80	79	59	70	-12.58	0.70	6.96
6	7074/S_5-15×M-10	53	91	80	80	67	74	-8.02	0.70	17.84
7	7074/S_5-15×M-15	54	100	93	101	71	84	1.31	1.02	9.34
8	A-17×M-4	66	118	105	134	77	100	17.69	1.34	119.76
9	A-9×B-19	80	142	123	137	90	114	31.98	1.40	18.81
10	A-10×B-19	71	137	125	132	89	111	28.54	1.46	0.62
11	M-2×BIL-106	67	118	114	105	76	96	13.64	1.14	38.62
12	M-9×BIL-110	44	83	76	81	58	69	-13.78	0.85	3.29
13	CML-498×CML-511	28	58	52	60	27	45	-37.64	0.79	23.36
14	BHM-9	69	124	109	124	81	101	19.02	1.25	15.88
15	981	62	108	94	97	72	87	4.26	0.94	11.51
	Mean	55.47	100.29	92.33	96.44	66.89	82.28			
	Env. Index(Ij)	-26.82	18.00	10.05	14.16	-15.40				
	LSD (0.05)									

Table 4. Stability analysis for yield (t/ha) of maize hybrids over 5 environments

Sl. No.	Entry	Location					Overall mean	P. Index (Pi)	bi	S^2di
		Gazipur	Jashore	Barisal	Rangpur	Ishurdi				
1	7074/S_5-11×BML-36	8.43	7.43	7.68	8.56	6.41	7.70	-1.08	0.35	0.81
2	7074/S_5-1×BML-36	9.25	8.35	9.51	11.48	6.57	9.03	0.24	1.27	1.68
3	7074/S_5-5×CML-425	7.52	7.85	9.55	10.2	7.77	8.58	-0.21	1.09	0.03
4	7074/S_5-8×BML-36	5.71	5.14	6.89	7.47	4.91	6.03	-2.76	0.92	0.27
5	7074/S_5-8×CML-425	7.04	7.24	7.48	7.86	7.03	7.33	-1.46	0.31	0.01
6	7074/S_5-15×M-10	8.67	9.05	10.12	9.55	8.09	9.10	0.31	0.58	0.28
7	7074/S_5-15×M-15	8.33	10.17	9.51	9.04	10.18	9.45	0.66	-0.06	0.81
8	A-17×M-4	7.47	10.15	9.73	10.68	10.17	9.64	0.85	0.68	1.38
9	A-9×B-19	10.44	12.11	12.71	14.02	10.91	12.04	3.25	1.26	0.19
10	A-10×B-19	8.04	9.2	10.95	12.25	8.98	9.88	1.09	1.52	0.07
11	M-2×BIL-106	8.35	7.93	9.36	9.6	7.24	8.50	-0.29	0.78	0.32
12	M-9×BIL-110	4.23	9.78	9.89	12.64	9.77	9.26	0.48	2.11	5.37
13	CML-498×CML-511	4.25	3.29	7.87	5.01	3.76	4.84	-3.95	1.00	2.74
14	BHM-9	9.27	10.17	10.11	13.14	8.71	10.28	1.49	1.35	0.96
15	981	9.04	7.62	12.56	12.67	8.96	10.17	1.38	1.85	1.59
	Mean	7.74	8.37	9.59	10.28	7.96	8.79			
	Env. Index(Ij)	-1.05	-0.42	0.81	1.49	-0.82				
	LSD (0.05)									

Ear heights along with the value of phenotypic index (Pi,) Regression coefficient (bi), and deviation from regression (S^2di) are presented in Table 3. The genotypic mean ranged from ear height 28 cm (CML-498×CML-511) to 142 cm (A-9×B-19). Six hybrids showed a positive Pi index while the rest nine showed a negative Pi index in ear height. The hybrids which showed a positive Pi index these hybrids represent taller plants and the negative Pi index showing genotypes represent dwarf plants. The bi and S^2di values range for plant height were 0.61 (7074/S_5-5×CML-425) to 1.48 (A-9×B-19) and 0.62(A-10×B-19) to 182.89(7074/S_5-5×CML-425) respectively.

Yield along with the value of the phenotypic index (Pi,) Regression coefficient (bi), and deviation from regression (S^2di) are presented in Table 4. The environmental mean and genotypic mean ranged from 7.74 to 10.28 t/ha and 4.84 to 12.04 t/ha. Among the hybrids, A-9×B-19 produced the highest yield (12.04 t/ha) followed by 981 (10.28 t/ha); whereas CML-498×CML-511 produced lowest yield (4.84 t/ha) followed by 7074/S_5-8×BML-36 (6.03 t/ha).

Nine genotypes showed a positive phenotypic index while the other genotypes had a negative phenotypic index for yield. Thus, the positive phenotypic index represents the higher yield and the negative represents the lower yield among the genotypes. Again, the positive and negative environmental index (Ij) reflects the rich or favorable and poor or unfavorable environments for this character, respectively. Thus the environment of Gazipur, Ishurdi and Jashore were poor whereas Rangpur and Barisal were positive environments for hybrid maize production. Rangpur was highly suitable for hybrid maize cultivation followed by Barisal.

The regression coefficient (bi) values of these genotypes ranged from 0.06 to 2.11. These differences in bi values indicated that all the genotypes responded differently to different environments. Considering the mean, bi and S^2di three stability parameters, it was evident that all the genotypes showed different responses of adaptability under different environmental conditions. The regression coefficient should be better considered as an indicator for genotypic responses to varying environments said by Alberts (2004) and Solomon *et al.* (2008). Among the hybrids A-9×B-19, BHM-9, 981, 7074/S_5-15×M-10, and 7074/S_5-15×M-15 exhibited the higher grain yield. bi~1 and S^2di~0 indicated that the hybrids are stable across the environment.

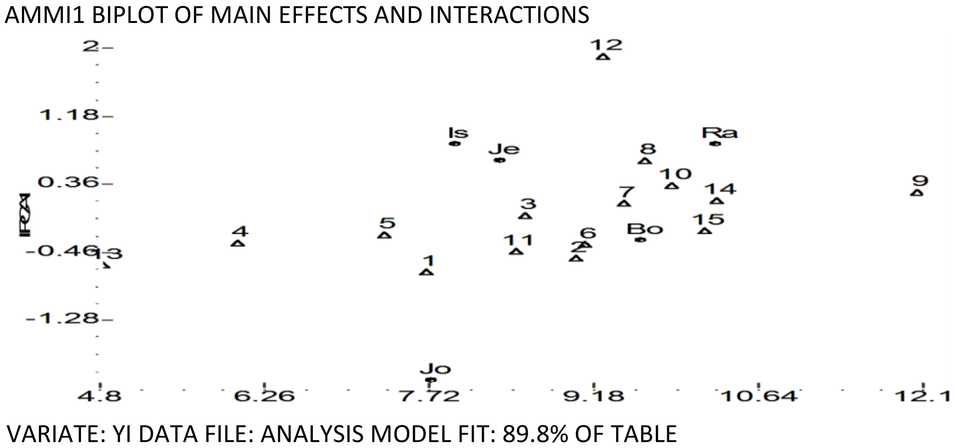

Fig. 1. Biplot of the first AMMI interaction (IPCA1) score (Y–axis) plotted against mean yield (X-Axis) of fifteen maize hybrids and five environments.

The AMMI Biplot provides a visual expression of the relationship between the first interaction principal component axis (AMMI component 1) and mean of genotypes and environment (Fig. 1) with the biplot according for up to 89.8% of the treatment sum of squares. The mean genotypes or environments in the AMMI biplot are located on the same parallel line. Relative to the ordinate, have similar yield, while those located on the left-hand side (Fig. 1). The biplot showed genotypes: A-10×B-19, was high yielding but stable; whereas 981, 7074/S_5-15×M were high yielding but unstable:

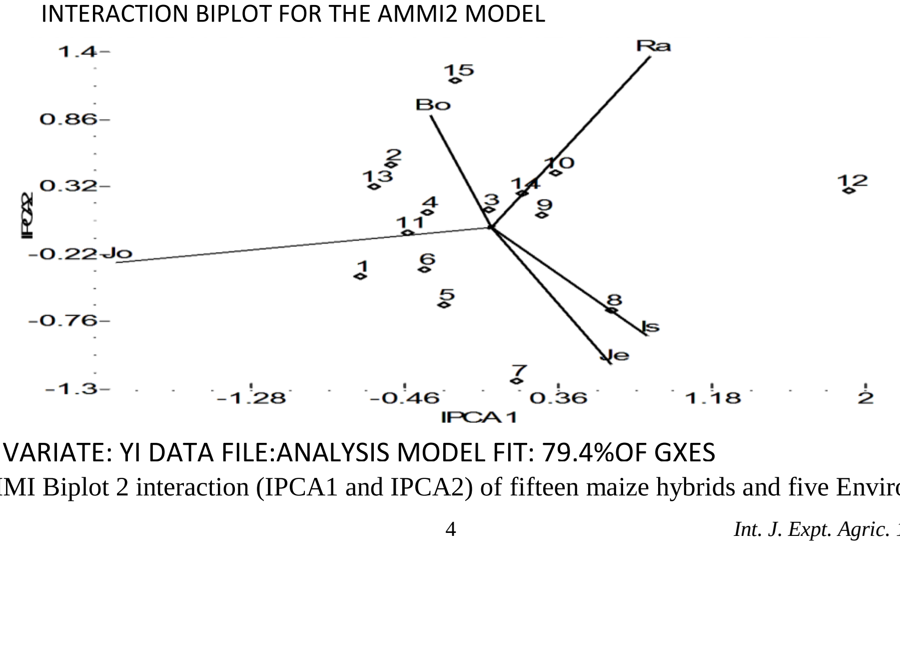

Fig. 2. AMMI Biplot 2 interaction (IPCA1 and IPCA2) of fifteen maize hybrids and five Environments.

CONCLUSION

From the results of the study, it can be said that the performance of maize yield was strongly influenced by the environment. Of the five environments, Rangpur was found suitable for hybrid maize cultivation followed by Barisal. Among the hybrids A-9×B-19produced the highest yield followed by BHM-9. Considering the yield potentiality and stability parameters.

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