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ASSESSMENT OF GENOTYPE-BY-ENVIRONMENT INTERACTIONS OF WHITE QUALITY PROTEIN MAIZE HYBRIDS IN BANGLADESH

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Abstract

Present study assessed genotypes and their interactions with environments (GEI) for plant height, days to maturity and grain yield of 40 maize hybrids including two local checks across five different locations of Bangladesh. Thirty eight white QPM (Quality Protein Maize) hybrids were collected from CIMMYT, Mexico. The AMMI (additive main effect and multiplicative interactions) and GGE (genotype + genotype × environment) model were used to assess the additive and multiplicative effects of the interactions. Significant variations were found for genotypes (G), environments (E) and GEI for all the studied characters. The environment of Gazipur is poor while those of Ishurdi and Rangpur are rich for QPM hybrids production. Considering three parameters viz., mean, bi and S^2di, it was evident that all the genotypes showed different responses of adaptability under different environmental conditions. Among the hybrids E21, E23, E30 and E22 exhibited bi~1 and S^2di~0 for all the characters under study, which clearly indicated that the hybrids are stable across the environments. The hybrids E11, E25, E37 and E4 had bi value significantly different from the unity with non significant S^2di value for one or more characters studied, indicating high responsiveness of the hybrid but suitable for favorable environments only. E5 was a good yielder and stable over environments. Considering the yield potentiality and stability parameters five hybrids were found promising over the locations.

Keywords: QPM, AMMI, stability, hybrids, GEI, adaptability.

Introduction

Maize (*Zea mays* L.) plays a significant role in human and livestock nutrition worldwide. In Bangladesh, it is an important cereal crop that ranks third and first position in terms of acreage and production, respectively. Due to high yield potentiality coupled with versatile uses, almost year round grow ability and higher yield compared to other cereals, area and production of maize is increasing every year. Its production has also increased significantly in the country because of the fast growing poultry and poultry feed industry and price hike of food materials. During 2011-12, 4,87,000 acres of hybrid maize were

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cultivated in Bangladesh and 12,98,000 tons of hybrid maize were produced (BBS, 2014)

Commonly, the yellow and yellow orange kernel maize is being cultivated in Bangladesh. BARI has only one variety (BARI Hybrid Maize-5) with increased protein percentage which is yellow colored. Now-a-days people are interested to uptake white colored flour either mixing with wheat or solely from maize. Considering this concern, white maize with quality protein can be a good player amongst the human consumption food material, because general people prefer white flour compared to yellow flour.

Customarily we know that cereals grain are lacking in essential amino acids particularly lysine and tryptophan. But CIMMYT evolved QPM hybrid maize certainly contain elevated percentage of lysine and tryptophan compared to normal maize. Under UN charter of "Sustainable Development Goals (SDG)" more emphasis has been laid down for nutritional replenishment of food grains. Hence, HYV as well as QPM white floured hybrid maize unquestionably would be able to fulfill those demands in near future.

The most used methods to interpret genotype stability are based on regression analyses (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966; Silva and Baretto, 1985; Cruz *et a*l., 1989). Agronomic zoning is used to stratify environments in sub-regions within which the interactions are not significant (Duarte and Zimmermann, 1999). These methods are dependent on the genotypes and environments under study and may not be much informative if linearity fails (Crossa, 1990). The additive nature of the common analysis of variance (ANOVA) allows for an adequate description of the main effects (genotypic and environmental effects). The multi-location testing, however, usually results in genotype-by-environment (G×E) interactions that often complicate the interpretation of results obtained and thereby reduce efficiency in selecting the best genotypes (Annicchiarico and Perenzin, 1994).

Plant breeders and geneticists, as well as statisticians, have a long-standing interest in investigating and integrating G and GE in selecting superior genotypes in crop performance trials. Many statistical methods have purposefully been developed for GEI analyses, including AMMI analysis and GGE biplot analysis (Yan and Kang, 2003). In the initial assessment, maize hybrids were tested in relatively few environments, and interaction can interfere in 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. The objective of this study was to test the performance of CIMMYT developed white QPM hybrids, under different agro-ecological zones of Bangladesh and select better one(s).

Materials and Method

The experiment was conducted at five locations viz., Barisal, Jamalpur, Gazipur, Ishurdi and Rangpur during *rabi* 2011-12. Thirty eight CIMMYT developed white-QPM hybrids and two local checks, viz. BARI Hybrid Maize-5 (BHM 5) and BARI Hybrid Maize-9 (BHM-9) were evaluated in this trial. Seeds were sown on November to December, 2011 at 5 locations following Alpha lattice design with 3 replications. The unit plot size was 5.0 X 1.5 m. Spacing adopted was 75 cm × 20 cm between rows and hill, respectively. One healthy seedling per hill was kept after proper thinning. Fertilizers were applied @ 250, 120, 120, 40 and 5 kg ha^{-1} of N, P_20_5, K_20, S and Zn, respectively. Standard agronomic practices were followed (Quayyum, 1993) and plant protection measures were taken as required. Two border rows were used to minimize the border effect. Data on days to tasseling and days to silking were recorded on whole plot basis. Ten randomly selected plants were used for recording observations on plant and ear height. All the plants in two rows were considered for plot yield. The grain yield (t ha^{-1}) data was assessed and corrected to 12% moisture. The CIMMYT hybrids are: CLWN210/CML494, CLWN224/CML494, CLWN208/CML494, CML494/CML495, CML491/CML503, CLWN221/CML494, CLWN216/CML494, CLQRCWQ124/CML491, CLWN211/CML494, CLWQ222/CML503, CL04368/ CLSPLW04, CLWN205/CML494, CLWN209/CML494, CLWQ238/CML491, CLWN228/CML495, CLWN212/CML494, CLWN219/CML494, CLWN217/ CML494, CLWQ223/CML503, CLWN227/CML495, CLRCW104/CML494, CLWN218/CML494, CLRCW105/CML494, CLWN215/CML494, CLQRCWQ123/ CML491, CLWN204/CML494, CLWN222/CML494, CLWN207/CML494, CLWN206/CML494, (CLQ-6203xCL-04321)-B-7-1-2-4-B/CL-FAWW11)-B-6-1-2-B-B-B-B/CML491, CLWN220/CML494, CLWQ221/CML503, CLWN213/ CML494, CLWN214/CML494, CLRCW107/CML494, CLWN223/CML494, CLWN201/CML495, CLRCW109/CML494. All the materials were marked as E and considered as individual entry.

Statistical Analysis

The analysis of variance (ANOVA) was used and the GE interaction was estimated by the AMMI model (Duarte and Vencovsky, 1999). Thus, the mean response of the genotype i in environment j (Yij) is modeled by: $Yij = \mu + gi + aj + \Sigma\lambda k\gamma ik\alpha jk + \rho ij + eij$; where μ is a common constant to the responses (normally the general mean); gi is the fixed effect of genotype i (i = 1, 2, ..., g); aj is the fixed effects of environment j (j = 1, 2, ..., a); $\Sigma\lambda k\gamma ik\alpha jk$ is the fixed significant effect or pattern of the specific interaction of the genotype i with environment j ($gaij$), where, λk is the k-th singular value (scalar), γik and αjk are the correspondent elements, associated to λk, of the singular vectors (rows vector and column vector) of the matrix of interaction estimated by ANOVA. For the same matrix, ρij is the non-significant effect or noise of $(ga)ij$, which is an additional residue, and eij is the pooled experimental error, assumed independent and *eij* ~ N(0, σ2). In this procedure, the contribution of each genotype and each environment to the GE interaction is assessed by the biplot graph display in which yield means are plotted against the scores of the first principal component of the interaction (IPCA1). The stability parameters, regression coefficient (bi) and deviation from regression (S^2di) were estimated according to Eberhart and Russell (1966). Significance of differences among bi value and unity was tested by t-test, between S^2di and zero by F-test. All the data were subjected to analysis using statistical analysis package software Cropstat7.2 version (AMMI, SSA and BANOVA models).

Results and Discussion

Results pertaining to various statistical analyses can be depicted below: There were highly significant (P<0.01) mean squares (MS) for plant height, days to maturity and yield for all sources of variations (Table 1). AMMI analysis in five environments (Table 2) shows that AMMI has partitioned main effects into genotypes, environments and G×E with all the components showing highly significant effects (P<0.01). The highly significant effects of environment indicate high differential genotypic responses across the different environments. 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 genotype effect, suggesting that genotype performance is influenced more by environmental factors.

Table 1. Mean squares from combined analysis of variance (ANOVA) for maize yield and yield components analyzed over 5 locations during 2011-2012

Source of variation	df	Mean sum of square		
		PH (cm)	DM	Y (ton ha^{-1})
Loc	4	27663.2**	1299.96**	183.80**
Entry	39	1020.88**	6.074	5.86**
Loc*entry	156	152858	3.858	1.08
Loc*rep*entry	400	117.187	6.30	1.02
Error	599	369.26	14.29	2.57

* P<0.05, ** P < 0.01; PH, Plant Height; DM, Days to maturity; Y, Yield.

Results of stability and response of the genotypes under different environments according to Eberhart and Russell (1966) model are discussed character-wise as follows where stability parameters i.e. regression coefficient (bi) and deviation from regression (S^2di) for plant height, days to maturity and yield of the individual genotypes are presented in Tables 3, 4, and 5, respectively.

Table 2. Full joint analysis of variance including the partitioning of the G × E interaction of maize

Source of variation	df	Mean sum of squares			
		DT	PH (cm)	DM	Y (ton ha^{-1})
Gen (G)	39	7.20	340.29*	2.02	1.95*
Env (E)	4	1419.94**	9221.05**	433.31**	61.26**
Inter (GEI)	156	0.94	50.95	1.28	0.36
AMMI Comp 1	42	1.29**	72.23**	1.68**	0.59***
AMMI Comp 2	40	1.24**	57.20**	1.66**	0.43
AMMI Comp 3	38	0.89**	51.62	1.05	0.21
AMMI Comp 4	36	0.27	18.47	0.64	0.15
G×E (Linear)	39	1.12	48.70	0.95	0.36
Pool dev	117	0.89	51.70	1.39	0.35
Pooled error	199	30.69	291.98	10.11	1.89

* P<0.05, ** P < 0.01; DT, Days to tasseling, PH, Plant Height; DM, Days to maturity; Y, Yield.

The plant height along with the value of phenotypic indices (Pi), environmental indices (Ei), regression coefficient (bi) and stability (S^2di) are presented in Table 3. The environmental mean and genotypic mean ranged from 187.9 cm to 228.2 cm and 120.6 cm 227.4 cm, respectively. Twenty two hybrids showed positive phenotypic index while the other genotypes had negative phenotypic index for plant height. Thus, positive phenotypic index represents the taller plant and negative represents the shorter plant height among the genotypes. Again, positive and negative environmental index (Ij) reflects the rich or favorable and poor or unfavorable environments for this character, respectively. The environmental index (Ij) directly reflects the poor or rich environment in terms of negative and positive Ij, respectively. Thus the environment Gazipur was poor and Ishurdi was rich environments for higher plant height.

The regression coefficient (bi) values of these genotypes ranged from 0.51 to 1.50. These differences in bi values indicated that all the genotypes responded differently to different environments. Considering the three parameters mean, bi and S^2di, it was revealed that all the genotypes showed different response of adaptability under different environmental conditions. Among the hybrids E6, E8, E15, E18, E24, exhibited short plant height, bi~1 and S^2di~0 indicated that the hybrids are stable across the environment. The hybrids E10, E12 and E31 had bi value significantly different from the unity with non significant S^2di value for one or more characters studied indicating a high responsiveness of the hybrid but suitable for favorable environments. So these hybrids are expected for short stature character.

Table 3. Stability analysis for Plant height (cm) of 40 white hybrids of maize over 5 environments

Entry	Environment						Pi	bi	S^2d
	Gaz	Jam	Bur	Isr	Bari	Overall mean			
E1	183.3	214.3	200.6	238.1	215.9	210.5	1.5	1.14	19.02
E2	181.7	203.0	212.4	230.2	219.9	209.4	0.4	1.19	34.85
E3	190.7	205.7	203.5	232.1	210.5	208.5	-0.5	0.90	7.61
E4	174.0	204.0	212.4	234.4	228.7	210.7	1.7	1.50	230.27
E5	186.7	202.7	223.7	232.4	215.0	212.1	3.1	1.15	23.01
E6	167.7	169.7	190.1	208.4	203.6	187.9	-21.1	1.14	18.52
E7	179.7	181.7	218.7	226.0	202.3	201.7	-7.3	1.26	66.18
E8	168.3	198.7	209.3	222.3	192.6	198.2	-10.8	1.20	39.07
E9	177.3	191.7	210.6	227.3	214.3	204.3	-4.7	1.29*	78.08
E10	171.0	190.0	208.9	218.5	210.5	199.8	-9.2	1.23	51.58
E11	206.7	213.0	221.8	243.8	226.3	222.3	13.3	0.90	8.80
E12	174.7	197.0	216.1	224.6	214.1	205.3	-3.7	1.27	70.16
E13	203.3	201.7	217.1	229.1	210.2	212.3	3.3	0.65	108.49
E14	197.7	209.0	217.5	232.8	221.1	215.6	6.6	0.86	16.82
E15	167.7	176.3	206.2	208.9	208.4	193.5	-15.5	1.20	38.56
E16	196.0	201.0	223.6	228.6	210.5	211.9	2.9	0.85	19.45
E17	185.7	202.3	194.1	223.3	216.7	204.4	-4.6	0.85	19.06
E18	162.7	197.3	203.6	215.3	208.4	197.5	-11.5	1.26	63.01
E19	191.0	198.0	201.9	231.0	211.5	206.7	-2.3	0.94	3.26
E20	201.0	201.3	219.8	233.2	216.0	214.3	5.3	0.84	22.17
E21	195.7	213.7	216.5	234.8	220.7	216.3	7.3	0.90	8.25
E22	198.0	208.0	215.7	245.7	235.8	120.6	11.6	1.20	39.04
E23	213.7	215.0	233.9	250.0	224.3	227.4	18.4	0.90	8.43
E24	186.0	198.7	214.9	218.9	211.2	205.9	-3.1	0.86	17.43
E25	193.7	200.3	205.1	232.0	219.7	210.2	1.2	0.94	3.06
E26	185.3	202.3	214.4	223.0	224.4	209.9	0.9	1.00	0.01
E27	190.0	204.3	218.5	227.9	201.6	208.5	-0.5	0.87	14.49
E28	189.3	220.3	226.7	234.6	205.6	215.3	6.3	0.95	1.70
E29	194.7	203.0	218.9	223.2	216.0	211.2	2.2	0.76	51.97
E30	207.3	211.3	215.6	235.0	212.1	216.3	7.3	0.60	141.29
E31	187.7	182.7	210.5	215.1	206.4	200.5	-8.5	0.83	25.94
E32	193.0	195.7	225.7	228.3	228.5	214.2	5.2	1.07	4.99
E33	187.7	210.0	225.1	230.7	212.2	213.1	4.1	1.02	0.79
E34	190.0	192.7	212.4	222.5	213.5	206.2	-2.8	0.89	10.07
E35	207.7	210.0	223.5	227.2	215.7	216.8	7.8	0.51*	121.59
E36	181.7	199.3	225.4	235.7	217.3	211.9	2.9	1.39	141.77

Entry	Environment						Pi	bi	S^2d
	Gaz	Jam	Bur	Isr	Bari	Overall mean			
E37	165.7	198.0	209.9	215.9	211.7	200.3	-8.7	1.25	57.65
E38	207.3	221.7	221.3	243.7	223.1	223.4	14.4	0.79	40.32
E39(L.C.1)	173.3	199.7	198.7	213.4	204.9	198.0	-11.0	0.91	6.90
E40(L.C.2)	210.7	203.3	202.5	228.7	206.	208.5	-0.5	0.57	165.92
Mean	187.9	201.2	213.7	228.2	214.2	209.0			
Ei (Ij)	-21.1	-7.8	4.7	19.2	5.2				
LSD (0.05)	20.56	18.5	5.07	9.39	21.48				

Gaz= Gazipur, Jam= Jamalpur, Bur= Burirhat, Isr= Ishurdi, Bar= Barisal.

E1=CLWN210/CML494, E2=CLWN224/CML494, E3=CLWN208/CML494, E4=CML494/CML495, E5=CML491/CML503, E6=CLWN221/CML494, E7=CLWN216/CML494, E8=CLQRCWQ124/CML491, E9=CLWN211/CML494, E10=CLWQ222/CML503, E11= CL04368/CLSPLW04, E12=CLWN205/CML494, E13=CLWN209/CML494, E14= CLWQ238/CML491, E15=CLWN228/CML495, E16=CLWN212/CML494, E17= CLWN219/CML494, E19=CLWN217/CML494, E1=CLWQ223/CML503, E20= CLWN227/CML495, E21=CLRCW104/CML494, E22=CLWN218/CML494, E23= CLRCW105/CML494, E24=CLWN215/CML494, E25=CLQRCWQ123/CML491, E26= CLWN204/CML494, E27=CLWN222/CML494, E28=CLWN207/CML494, E29= CLWN206/CML494, E30= ((CLQ-6203xCL-04321)-B-7-1-2-4-B/CL-FAWW11)-B-6-1-2-B-B-B-B/CML491, E31=CLWN220/CML494, E32=CLWQ221/CML503, E33= CLWN213/CML494, E34=CLWN214/CML494, E35=CLRCW107/CML494, E36=CLWN223/CML494, E37=CLWN201/CML495, E38=CLRCW109/CML494, E39= BARI Hybrid Maize 5, E40= BARI Hybrid Maize 9.

The days to maturity along with the value of phenotypic indices (Pi), environmental indices (Ei), regression coefficient (bi) and stability (S^2di) are presented in Table 4. The environmental mean and genotypic mean ranged from 150.3 days to 158.2 days and 152.5 days to 155.0 days, respectively. Twenty one hybrids showed positive phenotypic index while the other genotypes had negative phenotypic index for days to maturity. Thus, positive phenotypic index represents the long duration hybrids and negative represents short duration among the genotypes. Again, positive and negative environmental index (Ij) reflects the rich or favorable and poor or unfavorable environments for this character, respectively. The environmental index (Ij) directly reflects the poor or rich environment in terms of negative and positive Ij, respectively. Thus, the environment Ishurdi was poor and Barisal was rich environments for high plant duration.

The regression coefficient (bi) values of these genotypes ranged from 0.72 to 1.40. These differences in bi values indicated that all the genotypes responded differently to different environments. Considering the three parameters mean, bi and S^2di, it was evident that all the genotypes showed different response of adaptability under different environmental conditions. Among the hybrids E8, E18, E33, E39, exhibited the short duration hybrids, bi~1 and S^2di~0 indicated that the hybrids are stable across the environment. The hybrids E3, E10 and E15 had bi value significantly different from the unity with non significant S^2di value for one or more characters studied indicating high responsiveness of the hybrid but suitable for favorable environments. So these hybrids are expected for short duration character.

Table 4. Stability analysis for days to maturity of 40 white hybrids of maize over 5 environments

Entry	Environment						Pi	bi	S^2d
	Gaz	Jam	Bur	Isr	Bari	Overall mean			
E1	156.0	152.0	154.0	152.7	158.3	154.6	0.6	0.76	2.49
E2	156.0	154.3	154.7	150.3	157.7	154.7	0.7	0.77	2.13
E3	156.0	152.7	153.0	151.0	157.0	153.9	-0.1	0.72	3.18
E4	156.3	152.7	155.3	151.0	158.0	154.7	0.7	0.84	1.06
E5	157.7	152.0	154.0	150.3	157.0	154.2	0.2	0.91	0.33
E6	157.0	149.3	154.3	150.3	159.3	154.1	0.1	1.27	3.25
E7	157.7	153.0	152.0	151.3	158.7	154.5	0.5	0.92	0.24
E8	154.0	150.0	154.3	149.0	157.3	152.9	-1.1	0.99	0.00
E9	156.0	153.3	154.3	149.3	158.3	154.3	0.3	0.95	0.08
E10	155.3	150.0	155.7	147.3	159.3	153.5	-0.5	1.40	6.92
E11	158.3	151.3	155.3	152.7	160.0	155.5	1.5	1.08	0.30
E12	155.3	150.0	155.7	150.0	158.7	153.9	-0.1	1.11	0.53
E13	157.7	153.3	155.0	148.7	158	154.5	0.5	1.06	0.19
E14	157.7	153.3	153.0	152.3	157.7	154.8	0.8	0.72	3.30
E15	156.7	150.0	154.7	148.7	157.0	153.4	-0.6	1.12	0.73
E16	156.7	151.3	154.7	152.7	159.7	155.0	1.00	0.96	0.05
E17	156.0	152.0	153.7	150.3	159.0	154.2	0.2	1.02	0.02
E18	154.3	150.3	152.3	150.0	158.0	153.0	-1.0	0.97	0.03
E19	157.0	150.0	155.3	149.3	157.3	153.8	-0.2	1.12	0.65
E20	156.3	150.3	154.0	149.0	157.0	153.3	-0.7	1.06	0.17
E21	157.0	151.0	151.7	151.3	160.0	154.2	0.2	1.14	0.95
E22	157.0	150.7	153.7	150.0	158.3	153.9	-0.1	1.12	0.63
E23	157.3	151.0	154.0	150.3	158.0	154.1	0.1	1.05	0.14
E24	154.3	149.3	154.3	151.7	159.3	153.8	-0.2	1.02	0.03
E25	156.3	150.3	155.3	150.7	158.7	154.3	0.3	1.08	0.31
E26	156.3	151.3	154.7	152.3	158.7	154.7	0.7	0.88	0.62
E27	157.0	152.0	155.3	149.7	159.0	154.6	0.6	1.12	0.72
E28	156.3	151.3	154.3	150.3	159.0	154.3	0.3	1.08	0.28
E29	156.7	150.7	155.0	150.3	157.3	154.0	0.00	0.97	0.02

Entry	Environment						Pi	bi	S^2d
	Gaz	Jam	Bur	Isr	Bari	Overall mean			
E30	157.3	150.0	155.3	150.3	157.7	154.1	0.1	1.08	0.33
E31	156.0	151.7	154.3	150.3	160.0	154.5	0.5	1.13	0.84
E32	155.0	151.3	154.0	150.3	157.7	153.7	-0.3	0.88	0.58
E33	155.7	149.3	153.3	150.7	156.3	153.1	-0.9	0.88	0.55
E34	155.3	151.0	151.7	152.0	158.0	153.6	-0.4	0.81	1.51
E35	158.0	150.0	153.7	150.3	157.0	153.8	-0.2	1.05	0.14
E36	156.3	150.0	152.0	151.0	158.0	153.5	-0.5	1.01	0.01
E37	154.0	154.7	153.7	149.3	158.0	153.9	-0.1	0.73	2.98
E38	155.0	150.3	151.7	150.3	158.3	153.1	-0.9	1.01	0.01
E39(L.C.1)	153.0	150.7	153.7	148.3	156.7	152.5	-1.5	0.91	0.33
E40(L.C.2)	155.0	151.7	153.0	147.7	158.0	153.1	-0.9	1.11	0.62
Mean	156.2	151.2	154.0	150.3	158.2	154.0			
Ei (Ij)	2.2	-2.8	0.00	-3.7	4.2				
LSD (0.05)	2.91	3.09	3.83	2.71	1.31				

Gaz= Gazipur, Jam= Jamalpur, Bur= Burirhat, Isr= Ishurdi, Bar= Barisal.

E1=CLWN210/CML494, E2=CLWN224/CML494, E3=CLWN208/CML494, E4=CML494/CML495, E5=CML491/CML503, E6=CLWN221/CML494, E7=CLWN216/CML494, E8=CLQRCWQ124/CML491, E9=CLWN211/CML494, E10=CLWQ222/CML503, E11= CL04368/CLSPLW04, E12=CLWN205/CML494, E13=CLWN209/CML494, E14= CLWQ238/CML491, E15=CLWN228/CML495, E16=CLWN212/CML494, E17= CLWN219/CML494, E19=CLWN217/CML494, E1=CLWQ223/CML503, E20= CLWN227/CML495, E21=CLRCW104/CML494, E22=CLWN218/CML494, E23= CLRCW105/CML494, E24=CLWN215/CML494, E25=CLQRCWQ123/CML491, E26= CLWN204/CML494, E27=CLWN222/CML494, E28=CLWN207/CML494, E29= CLWN206/CML494, E30= ((CLQ-6203xCL-04321)-B-7-1-2-4-B/CL-FAWW11)-B-6-1-2-B-B-B-B/CML491, E31=CLWN220/CML494, E32=CLWQ221/CML503, E33=CLWN213/CML494, E34=CLWN214/CML494, E35=CLRCW107/CML494, E36=CLWN223/CML494, E37=CLWN201/CML495, E38=CLRCW109/CML494, E39= BARI Hybrid Maize 5, E40= BARI Hybrid Maize 9.

The grain yield along with the value of phenotypic indices (Pi), regression coefficient (bi) stability (S^2di), and are presented in Table 5. The environmental mean and genotypic mean ranged from 7.93 t/ha to 10.95 t/ha and 8.96 to 11.47 t/ha, respectively. Twenty two hybrids showed positive phenotypic index while the other genotypes had negative phenotypic index for yield. Thus, positive phenotypic index represents the higher yield and negative represents the lower yield among the genotypes. Again, positive and negative environmental index (Ij) reflects the rich or favorable and poor or unfavorable environments for this character, respectively. The environmental index (Ij) directly reflects the poor or rich environment in terms of negative and positive Ij, respectively. Thus the environment Gazipur was poor and Rangpur and Ishurdi were rich environments for QPM hybrids production.

The regression coefficient (bi) values of these genotypes ranged from 0.43 to 1.68. These differences in bi values indicated that all the genotypes responded differently to different environments. Considering the mean, bi and S^2di it was evident that all the genotypes showed different response of adaptability under different environmental conditions. Among the hybrids E21, E23, E30 and E22 exhibited the higher grain yield, bi~1 and S^2di~0 indicated that the hybrids are stable across the environments. The hybrids E11, E25, E37 and E4 had bi value significantly different from the unity with non significant S^2di value for one or more characters studied indicating high responsiveness of the hybrid but suitable for favorable environments.

Table 5. Stability analysis for yield (t/ha) of 40 white hybrids of maize over 5 environments

Entry	Environment						Pi	bi	S^2d
	Gaz	Jam	Bur	Isr	Bari	Overall mean			
E1	8.00	11.43	10.79	11.14	9.19	10.11	0.06	1.00	0.00
E2	6.66	9.71	10.21	10.11	9.36	9.21	-0.84	1.17	0.19
E3	8.33	11.07	1087	10.93	9.18	10.08	0.03	0.85	0.13
E4	8.00	10.67	11.43	12.16	10.33	10.52	0.47	1.24	0.35
E5	8.36	10.67	11.47	11.19	10.79	10.50	0.45	0.99	0.00
E6	7.00	9.23	9.80	10.93	9.05	9.20	-0.85	1.09	0.06
E7	7.06	10.61	11.13	9.26	9.86	9.58	-0.47	1.09	0.05
E8	7.36	10.19	9.91	10.58	9.59	9.35	-0.7	0.97	0.00
E9	7.20	9.60	10.17	10.12	8.75	9.17	-0.88	0.96	0.01
E10	7.50	10.01	9.92	9.70	8.60	9.15	-0.9	0.78	0.29
E11	8.66	10.95	11.43	12.59	11.61	11.05	1.00	1.10	0.07
E12	7.40	9.78	11.08	10.17	9.89	9.66	-0.39	1.07	0.03
E13	8.66	10.74	10.85	10.44	10.13	10.16	0.11	0.67	0.64
E14	8.20	10.06	10.83	11.13	10.45	10.13	0.08	0.91	0.04
E15	7.50	9.86	10.04	9.99	9.35	9.35	-0.7	0.85	0.13
E16	7.76	10.13	10.31	12.02	10.17	10.08	0.03	1.11	0.08
E17	8.33	10.86	10.08	10.40	10.12	10.16	0.11	0.82	0.19
E18	6.66	9.45	10.90	9.53	9.50	9.21	-0.84	1.18	0.22
E19	6.66	8.69	9.34	11.22	9.96	9.17	-0.88	1.18	0.21
E20	8.40	9.85	10.63	11.33	9.85	10.01	-0.04	0.82	0.18
E21	8.76	11.01	11.60	12.32	12.26	11.19	1.14	1.07	0.04
E22	8.66	10.44	12.10	12.36	11.76	11.07	1.02	1.16	0.16
E23	9.66	11.45	12.57	12.20	11.45	11.47	1.42	0.88	0.08
E24	7.33	9.86	10.69	10.62	9.98	9.69	-0.36	1.10	0.07

Entry	Environment						Pi	bi	S^2d
	Gaz	Jam	Bur	Isr	Bari	Overall mean			
E25	9.33	10.64	11.49	11.84	10.67	10.79	0.74	0.74	0.39
E26	7.66	9.88	11.51	11.66	10.46	10.24	0.19	1.27	0.45
E27	8.33	9.76	11.63	10.26	10.03	10.01	-0.04	0.84	0.15
E28	8.76	10.11	10.88	11.31	9.18	10.05	0.00	0.72	0.45
E29	9.00	10.44	8.96	11.52	10.18	10.02	-0.03	0.43	1.99
E30	8.00	11.53	12.84	11.59	11.83	11.16	1.11	1.42	1.12
E31	9.00	9.84	9.62	11.76	9.66	9.97	-0.08	0.52	1.36
E32	8.00	9.46	10.62	10.55	9.45	9.61	-0.44	0.83	0.18
E33	7.00	11.08	11.60	10.99	9.81	10.10	0.05	1.44	1.22
E34	8.66	10.34	11.37	10.66	10.97	10.40	0.35	0.78	0.27
E35	7.96	10.92	11.53	10.34	10.79	10.31	0.26	1.02	0.00
E36	7.33	9.78	11.31	10.23	11.03	9.93	-0.12	1.16	0.16
E37	9.00	11.77	12.12	10.85	9.98	10.55	0.5	0.80	0.23
E38	6.73	11.30	11.72	11.80	11.40	10.39	0.34	1.68	2.84
E39(L.C.1)	6.33	8.86	10.55	8.92	10.18	8.96	-1.09	1.16	0.16
E40(L.C.2)	8.00	10.36	11.16	10.32	10.75	10.12	0.07	0.93	0.02
Mean	7.93	10.26	10.95	10.93	10.19	10.05			
Ei (Ij)	-2.12	0.21	0.90	0.88	0.14				
LSD (0.05)	1.95	1.26	1.45	1.57	1.31				

Gaz= Gazipur, Jam= Jamalpur, Bur= Burirhat, Isr= Ishurdi, Bar= Barisal.

E1=CLWN210/CML494, E2=CLWN224/CML494, E3=CLWN208/CML494, E4= CML494/CML495, E5=CML491/CML503, E6=CLWN221/CML494, E7=CLWN216/ CML494, E8=CLQRCWQ124/CML491, E9=CLWN211/CML494, E10=CLWQ222/ CML503, E11=CL04368/CLSPLW04, E12=CLWN205/CML494, E13=CLWN209/ CML494, E14=CLWQ238/CML491, E15=CLWN228/CML495, E16=CLWN212/ CML494, E17=CLWN219/CML494, E19=CLWN217/CML494, E1=CLWQ223/CML503, E20=CLWN227/CML495, E21=CLRCW104/CML494, E22=CLWN218/CML494, E23= CLRCW105/CML494, E24=CLWN215/CML494, E25=CLQRCWQ123/CML491, E26= CLWN204/CML494, E27=CLWN222/CML494, E28=CLWN207/CML494, E29= CLWN206/CML494, E30= ((CLQ-6203xCL-04321)-B-7-1-2-4-B/CL-FAWW11)-B-6-1-2-B-B-B-B/CML491, E31=CLWN220/CML494, E32=CLWQ221/CML503, E33= CLWN213/CML494, E34=CLWN214/CML494, E35=CLRCW107/CML494, E36= CLWN223/CML494, E37=CLWN201/CML495, E38=CLRCW109/CML494, E39= BARI Hybrid Maize 5, E40= BARI Hybrid Maize 9.

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 (Figs. 1 and 2) with the biplot according for up to 78.6% of the treatment sum of squares. The first interaction principal component axis (AMMI component 1) was highly significant and explained the interaction pattern better than other interaction axis.

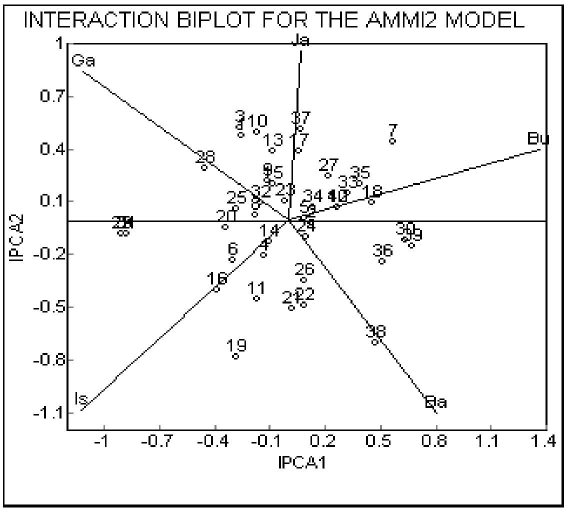

Fig. 1. AMMI model 2 biplot for 40 maize hybrids and 5 environments.

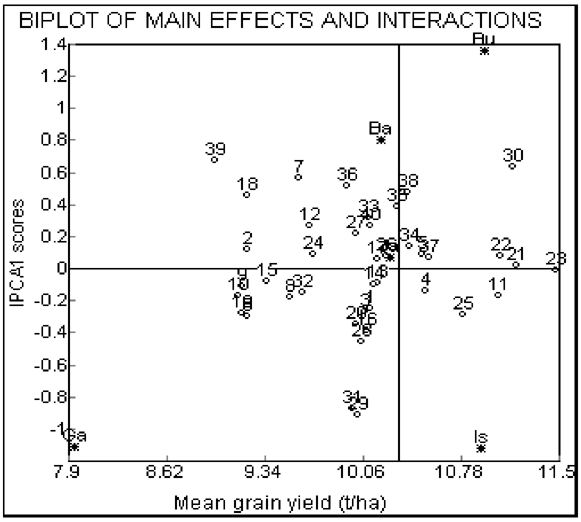

Fig. 2. Plotted IPCA1 and IPCA2 scores of maize hybrids evaluated.

In Figure 1 the IPCA 1 scores for both the hybrids (number) and the environments (upper case) were plotted against the mean yield for the hybrids and the environments, respectively. By plotting both the hybrids and the environments on the same graph, the associations between the hybrids and the 5 environments can be seen clearly. The IPCA scores of a genotype in the AMMI analysis are an indication of the stability or adaptation over environments. The greater the IPCA scores, negative or positive, (as it is a relative value), the more specific adapted is a genotype to certain environments. The more the IPCA scores approximate to zero, the more stable or adapted the genotype is over all the environments sampled.

Conclusion

Considering the yield potentiality and stability parameter five QPM hybrids (E21, E23, E30, E22 and E11) were found promising over the locations and could go for the processes of variety selection. This study also recommends for the prospect of quality maize production in Bangladesh. The AMMI statistical model has been used to diagnose the G×E interaction pattern of yield of hybrid maize. Burirhat with a relatively stable genotype performance could be regarded as a good selection site for identifying broad based and adaptable maize genotypes and other improvement work on maize.

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