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GENOTYPE–ENVIRONMENT INTERACTION AND STABILITY ANALYSIS OF CHILLI (*Capsicum frutescens* L.)

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ABSTRACT

An investigation was performed for assessment of genotype-environment interaction and stability of the 10 promising genotypes of Chilli on plant height, root length, individual fruit weight, fresh weight of shoot, oven dry weight of shoot and fruit yield per plant with ten promising chilli (*Capsicum frutescens* L.) genotypes. The experiment was laid out in randomized complete block design with three replications and four environments. The combined analysis of variance showed that the mean sum of square due to Genotype (G), Environment (E) and G × E interaction were significant for all the characters studied here suggesting presence of significant variation among the genotypes and environments. The additive main effects and multiplicative interaction (AMMI) biplot for yield clearly indicated that Env-3 (Urea + TSP + MOP + Boric Acid) and Env-4 (only Cow dung) were poor and Env-1 (Urea + TSP + MOP + Gypsum+ ZnO) and Env-2 (Urea + TSP + MOP + Cow dung) were found to be rich and favourable due to high inputs for chilli production. Where, Env-2 (Urea + TSP + MOP + Cow dung) was found highly favourable for chilli production. The stable genotypes found were BD-2059 and Bogura Jatt, exhibited moderate mean yield and could be adopted for general cultivation. Kalo Dhawna morich, Bogurar Lomba Morich and Bullet exhibited comparatively higher mean yield but were unstable across the environments and can be recommended to cultivate in rich environments.

Key words: genotype, environment, interaction, stability, *Capsicum frutescens*, AMMI

INTRODUCTION

Chilli is an important spices crop in Bangladesh. It is a cash crop of the country too (Ahmed and Haque, 1980). Chilli has its unique place in Asian diet as spice as well as vegetable. Phenotypic expressions of genotypes are variable under different environmental conditions. It is observed that G × E interaction is widely present and continues to the non-realization of expected gain from the selection (Comstock and Moll, 1963). Stable genotypes are particularly of great importance in the country like Bangladesh, where the crops are grown in varied environmental conditions. Approximate yield of chilli in Bangladesh during 2008, 2011, 2012 and 2013 was 109, 176, 126 and 95 thousand tons, respectively (BBS, 2013). So, we can see that, there is a decreasing trend in chilli production. That is mostly due to lacking of suitable varieties and increasing production cost. Stability is a genetic character (Perkins and Jinks, 1968) and stability of varieties can be measured by determining interaction of varieties with locations, seasons (Luthra *et al.*, 1974) and different cultural practices (Gonsalves *et al.*, 2009; Tembhurne and Rao, 2013). To recommend a new variety to the farmers, the varieties must be evaluated in trials testing the value of cultivation and use where fertilizer rate recommended is important (Gonsalves *et al.*, 2009).

The AMMI model (Gauch, 1993) is more efficient in determining the most stable and high yielding genotypes in multi-environment trials compared to earlier procedures (Finlay and Wilkinson, 1963, Eberhart and Russel, 1966). Biplot analysis is possibly the most powerful interpretive tool for AMMI models. Biplots are graphs where aspects of both genotypes and environments are plotted on the same axes so that interrelationships can be visualized. The AMMI biplot where the main effects (genotype mean and environment mean) are plotted in X axis and IPCA1 (Interaction principal component axix) scores for both genotypes and environments are plotted in Y axis. The effectiveness of AMMI

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procedure has been clearly demonstrated (Das *et al.* 2009). Considering these facts the present study was undertaken to identify high yielding stable genotypes and to determine the most suitable fertilizer environment for chilli to be adapted for producing economically competitive yields.

MATERIALS AND METHODS

The research work was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, with ten promising chilli lines from different sources. The experiment was laid out in Randomized Complete Block Design (RCBD) with 3 replications. The field plot (20.5 m × 8 m) was divided into 12 blocks (4×3) sized 4.25 m × 1.6 m, where treatments were randomly assigned. Then in each block the genotypes were assigned randomly in 10 lines maintaining spacing 50 cm × 45 cm. Environments were created by different fertilizers, whose are Urea + TSP + MOP + Gypsum+ ZnO (Env-1), Urea + TSP + MOP + Cow dung (Env-2), Urea + TSP + MOP + Boric Acid (Env-3) and only Cow dung (Env-4). Standard agronomic practices were followed as per soil test and plant protection measures were taken as required. Data were collected as per standard procedure.

The data on growth parameters and other plant characters were statistically analyzed following standard procedure followed by Kulsum *et al.* (2013). ANOVA was used and the genotype environment interaction was estimated by the AMMI model (Zobel *et al.*, 1988). In this model the contribution of each genotype and each environment to the GEI is assessed by use of the biplot graph display in which yield means are plotted against the scores of the IPCA1 (Zobel *et al.*,1988). 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 (Eberhart and Russell, 1966). All the data were subjected to analysis using statistical analysis package software Cropstat version 7.2 (AMMI, SSA and ANOVA models) after Zobel *et al.* (1988).

RESULTS AND DISCUSSION

The combined analysis of variance showed that mean sum of square due to genotypes and environment was significant for plant height excluding root length (cm), root length (cm), fresh weight of shoot (g), oven dry weight of shoot (g), individual fruit weight (g) and fruit yield per plant (g) indicating the presence of variability among the genotypes and environments (Table 1).

Table 1. Analysis of variance including the partitioning of G x E interaction of ten genotypes of chilli

Source of variations	df	Mean sum of squares					
		Plant height	Root length	Fresh weight of shoot	Oven dry weight of shoot	Individual fruit weight	Fruit yield per plant
Genotype (G)	9	754.40**	15.62**	17335.9**	1267.55**	0.691**	14940.4**
Environment (E)	3	1317.72**	20.11**	30582.4**	2275.12**	0.722**	41462.4**
Interaction (G×E)	27	107.16*	7.89*	4184.02*	245.35*	0.063*	6627.60*
AMMI component 1	11	168.516*	10.94*	8502.94**	415.43*	0.067**	6455.09*
AMMI component 2	9	93.02	7.79*	1446.74	183.18	0.012	2528.68
AMMI component 3	7	28.95	3.21	916.51	58.03	0.006	597.28
G x E (Linear)	9	59.68	7.76*	9868.15**	468.84**	0.068**	7226.45**
Pool deviation	18	130.91*	7.95*	1341.95	133.61	0.015	1828.17
Polled error	105	83.54	6.33	3239.38	191.79	0.025	2999.63

* and ** indicates significant at 0.05% and 0.01% level, respectively.

These results are in agreement with Desai *et al.*(1991) and Dahiya *et al.*(1993). It wasshowed the G×E interaction was significant, it was possible to proceed further and calculate phenotypic stability (Farshadfar and Sutka, 2003). ANOVA based on AMMI model for grain yield is presented in Table 1.

The effects of genotype × environment interaction could be divided into 3 AMMI components, i.e. IPCA1, IPCA2 and IPCA3 where IPCA1 was significantly different for all while IPCA2 was significantly different for root length (cm). IPCA3 was not significantly different in all traits (Table 1). Positive phenotypic index represents the higher plant height and negative represents the lower, where in case of plant height lower stature is expected to protect lodging. In case of plant height most of the genotype showed low stature, only Kalo Dhawna morich, DBP 14 5G (China), BD-2059 showed higher plant height (Table 2). Bogurar Jhal Morich, Suryamukhi and Bullet showed negative

Table 2. Stability analysis for six characters in Chilli

Code	Genotype Name	Plant height (cm)				Root length (cm)				Fresh weight of shoot (g)			
		Mean	Pi	bi	S^2di	Mean	Pi	bi	S^2di	Mean	Pi	Bi	S^2di
G1	Kalo Dhawna morich	76.87	28.64	1.141	198.67	14.19	2.17	2.92	13.47	208.2	111.2	2.56*	944.13
G2	Bogurar Jhal Morich	34.67	-13.56	0.622	16.16	10.32	-1.69	1.04	6.98	29.11	-67.93	0.18*	5.54
G3	Balojhuri	38.66	-9.564	1.022	108.80	11.06	-0.95	0.60	10.56	43.80	-53.24	0.42*	161.31
G4	*DBP 14 5G (China)*	*63.05*	*14.83*	*1.795*	*205.17*	*14.81*	2.79	2.59	19.69	208.0	110.9	3.17	3440.98
G5	Suryamukhi	40.92	-7.303	0.920	26.40	9.34	-2.67	-0.42	6.91	65.53	-31.51	0.87	834.96
G6	Bogurar lomba Morich	37.05	-11.18	0.910	89.79	11.61	-0.41	1.01	5.45	73.06	-23.98	0.81	526.65
G7	BD-2059	59.81	11.58	0.954	112.70	13.56	1.54	1.16	2.58	141.8	44.79	0.99	1372.75
G8	BD-2122	44.59	-3.636	0.524	349.52	13.32	1.30	0.82	4.96	60.97	-36.06	0.08	4277.59
G9	Bogura Jatt	41.33	-6.897	1.452	47.90	9.34	-2.67	1.02	0.23	53.36	-43.68	0.53	402.72
G10	Bullet	45.31	-2.920	0.660	23.05	12.60	0.58	-0.76*	0.74	86.53	-10.51	0.36*	110.94
	Grand mean	**48.23**				**12.01**				**97.04**			

Table 2. continued...

Code	Genotype Name	Oven dry weight of shoot (g)				Individual fruit weight (g)				Fruit yield per plant (g)			
		Mean	Pi	bi	S^2di	Mean	Pi	Bi	S^2di	Mean	Pi	bi	S^2di
G1	Kalo Dhawna morich	67.65	31.22	2.336	110.83	0.700	-0.53	1.08	0.02	196.5	83.94	2.385	3325.26
G2	Bogurar Jhal Morich	15.18	-21.25	0.415*	4.61	1.214	-0.06	0.94	0.00	64.29	-48.24	0.231	869.68
G3	Balojhuri	22.72	-13.71	0.453	19.97	0.850	-0.41	0.42	0.01	89.33	-23.21	0.504	1195.25
G4	DBP 14 5G (China)	63.97	27.54	2.645	342.17	1.108	-0.17	0.97	0.00	58.93	-53.61	0.798	29.69
G5	Suryamukhi	29.30	-7.129	0.990	147.21	1.68	0.40	1.16	0.03	64.22	-48.32	0.317*	108.92
G6	Bogurar lomba Morich	31.54	-4.887	0.852	71.55	1.42	0.14	1.22	0.00	223.5	111.0	1.937	2770.02
G7	BD-2059	48.56	12.13	0.886	57.69	1.19	-0.08	0.76	0.00	93.73	18.81	1.121	168.57
G8	BD-2122	25.58	-10.85	0.333	354.77	0.94	-0.34	0.56*	0.00	53.82	-58.72	0.256	682.30
G9	Bogura Jatt	24.67	-11.76	0.825	86.10	1.50	0.22	0.48*	0.00	120.4	7.833	1.065	165.37
G10	Bullet	35.12	-1.304	0.266*	7.57	2.128	0.84	2.38	0.07	160.7	48.17	1.487	6103.44
	Grand mean	**36.43**				**1.283**				**112.5**			

Pi = Phenotypic index, bi = Regression coefficient, S^2di = Deviation from regression * indicates slopes significantly different from the slope for the overall regression which is 1.0

phenotypic index (Pi), non significant regression coefficient (bi) and deviation from regression (S^2di) indicating stable genotype over all environments with low plant stature. highly responsive genotypes couldn't be found to any rich environment. Tembhurne and Rao. (2013) found similar results on plant height in chilli. The genotypes BD-2059, Bogura Jatt and Bullet showed positive phenotypic index (Pi) with insignificant regression coefficient (bi) and deviation from regression (S^2di) which indicated that these genotypes were stable over the environments for root length (cm). Most of the Bogurar Jhal Morich, Balojhuri, Suryamukhi, Bogurar lomba Morich, BD-2059, BD-2122, Bogura Jatt and Bullet genotypes showed low fresh weight of shoot (g), only Kalo Dhawna morich, DBP 14 5G (China), BD-2059 showed higher fresh weight. The genotype BD-2059 showed positive phenotypic index (Pi), non significant bi and S^2di indicating stable genotype over all environments. Positive phenotypic index represents the higher fresh weight of shoot and negative represents the lower. Kalo Dhawna morich showed positive Pi, significant bi and non significant S^2di indicating the highly responsive to the rich environments. Bogurar Jhal Morich, Balojhuri and Bullet showed negative Pi, significant bi and non significant S^2di indicating their suitability to the poor environments. These results are in agreement with Kulsum *et al.* (2013).

(Pi), non significant bi and S^2di indicating stable genotype over all environments. Five genotypes showed positive phenotypic index where others showed negative. Env-2 was found rich for higher fruit yield. Suryamukhi showed negative Pi, significant bi and non significant S^2di indicating the suitability to the poor environments. These results are in agreement with Kulsum *et al.* (2013), Silveira and Vencovsky (1983) in rice grain yield. The estimates of environmental indices (Ij) indicate that, Env-2 was highly favourable for chilli production (Table 3). Positive and negative environmental index (Ij) reflects the rich or favourable and poor or unfavourable environments for a character, respectively. For plant height positive and negative environmental index (Ij) reflects the poor or unfavourable and rich or favourable environments for shorter plant stature, respectively. Thus the Env-3 and Env-4 were found rich for plant height. Env-1 and Env-2 were found rich for higher root length, fresh weight of shoot and higher dry matter weight. Between November, 2013 to April, 2014, the temperature fluctuated rapidly (average 20.6^{0}C) with an average 14 cm rainfall slowed the growth and caused early maturity and reduced yield, though Kalo Dhawna morich and Bogurar lomba Morich were showed good yielder.

Table 3. Estimates of environmental indices (Ij) for six characters of chilli under different environments

Sl. no.	Characters	Environments Indices			
		Env-1	Env-2	Env-3	Env-4
1	Plant height	7.404	12.05	-11.47	-7.985
2	Root length	1.171	1.262	-0.983	-1.450
3	Fresh weight of shoot	11.70	73.45	-39.69	-45.47
4	Oven dry weight of shoot	5.994	18.57	-12.36	-12.21
5	Individual fruit weight	-0.05	0.285	0.078	-0.359
6	Fruit yield per plant	-2.77	84.72	-10.19	-71.76

The AMMI analysis provides a graphical representation or biplot (Fig.1) to summarize information on the main effects and the first principal component scores of the interactions (IPCA1) of both genotype and environments, simultaneously (Kempton, 1984). Displacement along the abscissa reflected differences in main effects, where as displacement along the ordinate exhibited differences in interaction effects. The AMMI expected yield for any genotype and environment combination can be calculated from Fig. 1 following standard procedures suggested by Zobel *et al.* (1988). Genotypes and environments on the same parallel line, relative to ordinate, have similar yields and a genotype or environment on the right side of the midpoint of this axis has higher yields than those on the left hand side. Consequently, the genotypes Bullet, Bogurar lomba Morich and Kalo Dhawna morich were high yielding, with BD-2059 and Bogura Jatt being the moderate yielder. In contrast, Bogurar Jhal Morich, Balojhuri, DBP 14 5G (China), Suryamukhi and BD-2122 were generally low yielding genotypes. The AMMI1 estimation had a profound effect in producing clear and stratified ranking patterns and on this basis BD-2059 and Bogura Jatt could be considered more adapted to a wide range of environments than the rest of the genotypes used in the present investigation.

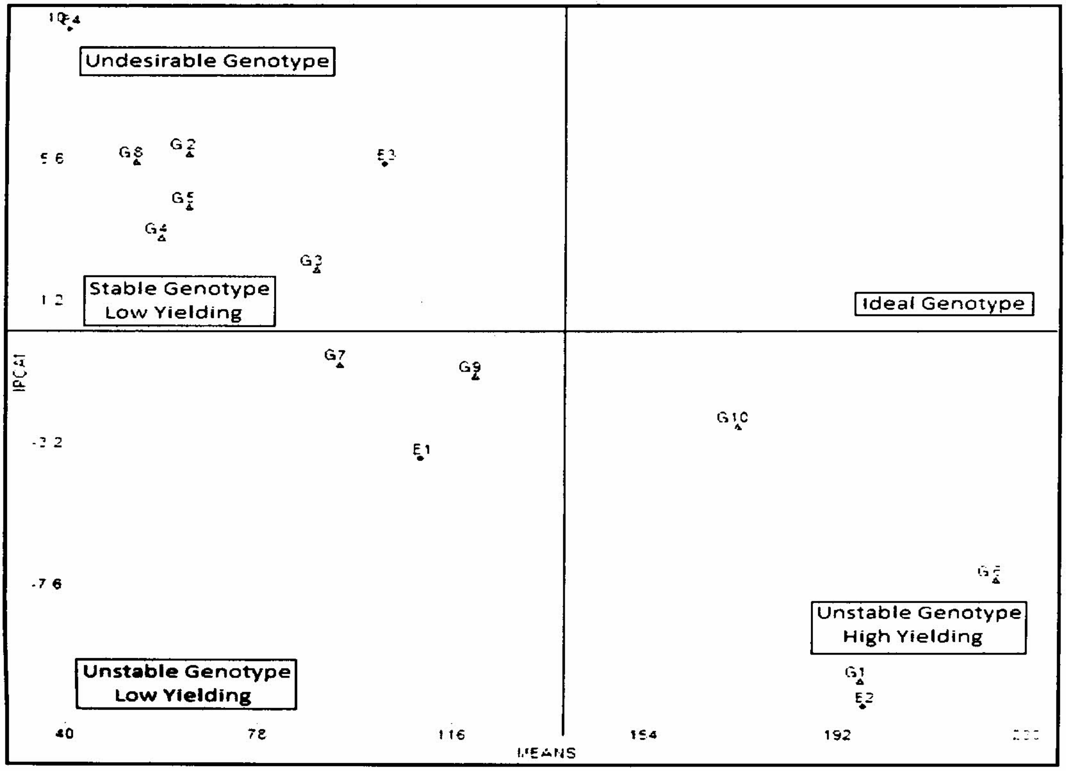

Fig. 1. Interaction biplot of of AMMI1 where IPCA1 score (Y-axis) plotted against mean yield (X-axis) for ten genotypes of chilli. Where, G1=Kalo Dhawna morich, G2 = Bogurar Jhal Morich, G3=Balojhuri, G4=DBP 14 5G (China), G5 = Suryamukhi, G6 = Bogurar lomba Morich, G7 = BD-2059, G8 = BD 2122, G9 = Bogura Jatt, G10 = Bullet and E1= Environment 1, E2= Environment 2, E3=Environment 3, E4 = Environment 4.

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