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STABILITY ANALYSIS OF MAIZE HYBRIDS UNDER DIFFERENT AGRO-ECOLOGICAL ZONES OF ODISHA, INDIA

Devraj Lenka, Sindhusnata Das, Digbijaya Swain[1], Devidutta Lenka and Swapan K Tripathy[2]*

Department of Plant Breeding & Genetics, College of Agriculture, OUAT Bhubaneswar-751 003, India

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Abstract

Thirty maize hybrids were evaluated for stability of yield performance across six locations of Odisha using the additive main effect and multiplicative interaction (AMMI) model. The analysis of variance revealed significant difference among genotypes, environments, G x E interactions, IPCA I, IPCA II and IPCA III scores. Among the high yielding genotypes, ZH17210, ZH159, ZH17223, P3502 and ZH161418 recorded low interaction, 28(ZH159) and 2(ZH161418) exhibited positive interactions (both IPCA 1 and IPCA II had same sign) and 6(ZH17223) revealed negative interaction. Koraput location(E6) was found to be most favorable environment while Banjanagar (E2) indicated as a poor environmental condition for grain yield. Bhubaneswar location with IPCA I and IPCA II scores close to zero seems to have minimum environmental interaction for grain yield. Among the hybrids; ZH17229), VH151139 and ZH161418 showed higher grain yield and minimum interaction (IPCA I) and hence, may be considered most stable. In contrast, the highest yielding hybrid ZH17210 demonstrated differential yield performance over environment and appreciably higher magnitude of G x E interaction (IPCA I) indicating adaptation to specific environment.

Introduction

Maize (*Zea mays* L.) is the third most important cereal crop in India next to rice and wheat (Give Ref.). Recently, the demand for maize cultivation is increasing gradually among the farmers mainly due to high yield potential, more economic return and versatile uses including its high nutritional value. Globally, it is cultivated in an area of 183.24 million hectares with a total net production 1,036.07 million metric tonnes and an average yield of 5.65 metric tonnes per hectare during 2017-18 (USDA 2018). United States is the world's largest producer of maize followed by China and Brazil which dominate world maize trade. Production of heterotic hybrids is required to increase grain yield in maize. However, the crop is reported to have high Genotype x Environment (G x E) interaction (Guloria *et al.* 2010) and it continues to be a challenging issue to develop high yielding maize hybrids. Stability is the ability of a genotype to have sustainable production without significant variation in yield regardless of environmental effects (Becker 1981). For this, large numbers of locations are necessary for reliable screening to select widely stable hybrids (Jensen and Cavalieri 1983). Adaptability and grain yield are most complex traits (Gama and Hallauer 1980). Adjustment to environment is conditioned by a set of genes and therefore, a genotype adaptable across environments is rarely achieved in any crop. However, it seems to be a reality in oat that resulted in a significant increase in mean grain yield over diverse target environments (Helms 1993).

Most of the researchers use Eberhart and Russel (1966) model, but the additive main effect and multiplicative interaction (AMMI) approach could be a model of choice to make the selection

*Author for correspondence: <swapankumartripathy@yahoo.co.in>. [1]AICRP on Maize, Directorate of Research, OUAT, Bhubaneswar-751 003, India. [2]Department of Agricultural Biotechnology, College of Agriculture, OUAT Bhubaneswar-751 003, India.

components attributable to contribution of each genotypes and determines the merit of genotypes by their main effect(mean yield performance) and G x E interaction in the same platform using bi-plot analysis. Therefore, an attempt has been made in the present investigation to evaluate different maize hybrids for their stability performance (using AMMI model) under varied agro-climatic conditions in Odisha where maize is traditionally grown under rainfed situations.

Materials and Methods

Thirty single cross maize hybrids were tested at six diverse agro-ecological zones (Table 1) of Odisha (Bhubaneswar, Bhanjanagar, Rayagada, Jashipur, Umarkote and Koraput), India during Rabi 2019-20 following randomized block design (RBD) with two replications at normal spacing (60 cm x 25 cm). Fertilizers were applied at the rate of 120-kg N, 60-kg P_2O_5,60 kg K_2O per hectare in the form of urea, single super phosphate(SSP) and MOP muriate of potash (MOP), respectively along with FYM 12cart loads/ha and zinc sulphate 25kg/ha. In order to ensure uniform plant stand two seeds were dibbled per hill and later thinned to one seedling per hill. Normal agronomic practices and plant protection measures were followed to raise a successful crop. At the time of harvest, fresh ear weight was recorded in grams per plant. Moisture determinations were made from shelled samples of five random ears of each plot with the help of electronic moisture meter. The fresh weight of cob data was used to work out the dry weight grain yield per plant at respective per cent moisture level. Grain yield per plot was computed by using the formula given below:

Shelled weight = (Fresh weight of cobs x Shelling %) /100

Moisture corrected yield = Shelled weight x (100-Moisture %) /85

Grain yield (q/ha) =(Moisture corrected yield/area of plot)/10000

G x E interaction was estimated by the Additive Main effects and AMMI model (Zobel *et al*. 1988). Besides, biplot analysis (Gabriel 1971) was used to assess contribution of each genotype and environment to the G X E interaction.

Results and Discussion

Using ANOVA, the G x E interaction was partitioned into three Interaction Principal Components e.g., IPCA I, IPCA II and IPCA III. Genotypes, environments, G x E interactions, IPCA I, IPCA II and IPCA III were highly significant at even 1 % level of significance (Table 2). The significant effects of G x E interaction indicated differential response of genotypes in various environments. Further, 69.09 % of sum of squares attributable to genotypes and environment effects signify validity of the experiment to study stability of performance of maize hybrids across diverse environments. IPCA I accounted maximum variation (39.84 %) than IPCA II (24.71 %) and IPCA III (19.51%).

The mean grain yield (pooled over environments) along with ranks and AMMI scores of genotypes for IPCA I, IPCA II and IPCA III are presented in Table 3. Mean yield performance along with rank of genotypes across environments indicated high variability among the genotypes around the average grain yield (82.40 q/ha) (Table 3). The mean grain yield ranged from 73.12 q/ha (ZH17215) to 103.76 q/ha (ZH17210). ZH17210, ZH159, ZH17223, P3502 and ZH161418 produced significantly higher grain yield across environments.

The nature (positive or negative) and magnitude of G x E interactions of a genotype *in vogue* determined by the sign and magnitude of its corresponding IPCA scores. Interactions are positive if IPCA scores have the same sign and negative if the two scores have different sign. Interaction may be positive in one principal component (PC) axis and negative in another. Same type of result had been observed by Bhakta (2005) and Suthamathi and Nallathambi (2016). The IPCA I scores of hybrids ranged from -3.91 (P3502) to 2.90 (ZH17206) and IPCA II scores ranged from -2.52 (ZH17210) to 3.29 (ZH17225). IPCA -1 score of maize hybrids Sl. 2 (ZH161418), 13(ZH17229), 19 (VH131376), 21 (VH151139) and 27 (VH113014) revealed lowest value (around zero) indicating higher stability of these genotypes across the environments. Among these, hybrid Sl. 6 (ZH17223), 28 (ZH159) and 2 (ZH161418) had higher grain yield across environments. The latter two hybrids 28 (ZH159) and 2(ZH161418) exhibited similar interactions (both IPCA 1 and IPCA II had same sign), while 6 (ZH17223) revealed negative interaction.

Table 1. Details of soil type, nutrient status and pH of soil for different locations.

Properties of soil	Quantity					
	Bhuba-neswar	Jashipur	Rayagada	Bhanja-nagar	Umarkote	Koraput
Soil type	Sandy loam	Sandy loam	Red sandy	Red soil	Sandy loam	Red sandy
Available nitrogen (kg/ha)	175.00	190	287.00	266.6	130.00	396.00
Phosphorus (kg/ha)	55.20	16.4	40.49	45.38	5.10	14.00
Potash(kg/ha)	276.80	80	162.38	235.4	158.00	46.47
Organic carbon (%)	0.50	0.30	0.48	0.42	0.29	0.61
Soil pH	5.82	5.6	5.23	5.02	4.90	4.90

Table 2. AMMI ANOVA for yield performance (q/ha) of a set of 30 maize hybrids over six locations.

Source	DF	SS	MS	F	SS (%)
Genotype (G)	29	9515.04	328.10	7.42**	14.70
Environment (E)	5	35190.01	7038.00	159.29**	54.39
G X E	145	19989.34	137.86	3.122**	30.89
IPCA I	33	7964.02	241.33	5.46**	39.84
IPCA II	31	4940.01	159.36	3.61**	24.71
IPCA III	29	3900.58	134.50	3.04**	19.51
Residuals	52	3184.74	61.24	1.39	15.93
Error	174		44.182		

** significance at 1 % level.

The highest magnitude of IPCA I score was recorded in hybrid Sl. 30 (P3502) followed by hybrid Sl. 11 (VH12180), 3 (ZH17206), 10 (ZH17227), 17 (ZH17236) and 18 (ZH17238) in decreasing order. Therefore, these genotypes are specifically adapted to specific environments. As per IPCA II scores; the maize hybrid Sl. 1 (ZH161330), 2 (ZH161418), 5 (ZH17215), 12 (ZH17228), 20 (VH13729) and 28 (ZH159) are also stable over environments and among these hybrid 2 (ZH161418) and hybrid 28 (ZH159) are high yielder. However, considering all IPCA scores (including IPCA III) and grain yield, the hybrid 2 (ZH161418) seems to have merit for stability of performance across all environments.

The environmental mean grain yield pooled over 30 hybrids ranged from 59.62q/ha at Bhanjanagar (E_2) to 98.20q/ha at Koraput (E_6) (Table 4). The IPCA I scores of environments ranged from -4.91 at Rayagada (E_3) to 6.79 at Umerkote (E_5) and IPCA II scores ranged from -5.29 at Koraput (E_6) to 4.34 at Bhanjanagar (E_2). ICPA III score was lowest at Rayagada (E_3) and maximum at Koraput (E_6). On the basis of grain yield, Koraput (E_6) was shown to be favourable environment for overall productivity of hybrid maize, while Banjanagar (E_2) indicated as a poor environment. However, Bhubaneswar location with IPCA I and IPCA II scores close to zero seems to have minimum environmental interaction for grain yield in maize hybrids.

In the present investigation, stability of grain yield of individual maize hybrids over six locations could be accurately decided using AMMI I and AMMI II biplot analysis. In AMMI I (Fig. 1), the main effect (i.e.. the genotype and environment additive effect which is reflected by mean grain yield) and IPCA I are plotted against each other, while in AMMI II biplot analysis, both interaction principal components i.e., IPCA I and IPCA II scores are plotted against each other. AMMI II biplot does not include main effects and hence, cannot show extent of yield performance, but give a better picture of interaction captured by the two principal component axes.

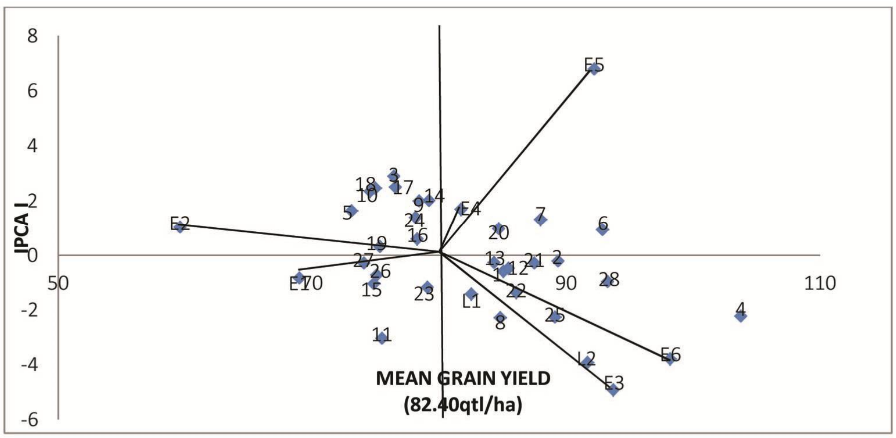

Fig. 1. AMMI I biplot graph of main effects (grain yield) and environmental interaction (IPCA I) of 30 maize hybrids under six environments.

In AMMI I, the distance along the abscissa indicates difference in the main effect and the distance along the ordinate indicate difference in interaction effects. Hybrids that group together have similar adaptation, while environments which group together influence the genotype performance in the same way. The higher the absolute value of AMMI I, the higher is the value of G× E interaction. Genotypes with AMMI I absolute value close to zero (0) showed least interaction and are considered as most stable. This corroborates the findings of Matin *et al.* (2017), Bhakta (2005) and Haider *et al.* (2017). In this context, the hybrids, 27 (VH113014), 13 (ZH17229), 21 (VH151139) and 2 (ZH161418) showed minimum interaction (IPCA I absolute values close to 0) and hence, may be considered most stable. Among these, the hybrids 2 (ZH161418) followed by 21 (VH151139) had appreciably higher yield than the general mean (82.41 q/ha). Hence, these were considered as the most suitable hybrids with good general adaptation. In contrast, the hybrids e.g., 6 (ZH17223) and 7 (ZH17224) had higher yield but with considerable magnitude of interaction (IPCA I) indicating that these genotypes could be good for specific adaptation. The underlying causes of the interaction observed can, therefore, be based on both the differences between the genotype and the environment (Wallace *et al.* 1995).

The environment E3 (Rayagada) and E5 (Umerkote) differed greatly in interaction effect, whereas, environment E2 (Bhanjanagar) and E6 (Koraput) appreciably differed in main effect. The test hybrids revealed stable performance in E1 (Bhubaneswar) (as the AMMI-I was near to zero absolute value), but were found to be least stable under E5 (Umerkote) and E6 (Koraput). The hybrid 4 (ZH17210) which yielded highest (103.76 q/ha) over environments, demonstrated appreciably higher magnitude of G x E interaction (IPCA I) indicating adaptation to specific environment (E6).

Table 3. Means and AMMI scores of maize hybrids for grain yield.

Sl. No.	Genotypes	Overall mean (q/ha)	Rank	IPCA I	IPCA II	IPCA III
1	ZH161330	85.07	11	-0.58	0.64	-2.73
2	ZH161418	89.35	5	-0.21	-0.63	0.66
3	ZH17206	76.44	22	2.90	-0.45	-0.21
4	ZH17210	103.76	1	-2.22	-2.52	1.10
5	ZH17215	73.12	30	1.64	-0.54	0.01
6	ZH17223	92.88	3	0.95	-3.73	0.24
7	ZH17224	87.98	7	1.32	1.09	-0.33
8	ZH17225	84.80	12	-2.28	3.29	2.13
9	ZH17226	78.45	18	2.00	-0.32	0.80
10	ZH17227	74.58	28	2.36	0.92	-0.70
11	VH12180	75.49	23	-3.02	2.39	-0.15
12	ZH17228	85.48	10	-0.46	-0.51	-1.64
13	ZH17229	84.31	14	-0.27	-0.63	-3.11
14	ZH17230	79.22	16	2.02	1.23	0.37
15	ZH17231	74.87	27	-1.04	0.34	-0.04
16	ZH15571	78.29	19	0.61	1.01	-2.02
17	ZH17236	76.56	21	2.50	0.09	1.83
18	ZH17238	74.96	26	2.47	0.13	0.08
19	VH131376	75.34	24	0.33	-1.26	1.26
20	VH13729	84.70	13	0.99	-0.31	1.66
21	VH151139	87.48	8	-0.28	3.04	-0.07
22	VH16224	86.06	9	-1.35	0.62	-2.79
23	VH141618	79.07	17	-1.17	-2.09	-1.99
24	VH1252	78.15	20	1.40	1.34	0.64
25	ZH15445	89.11	6	-2.25	-1.83	-0.30
26	ZH141592	75.12	25	-0.72	1.75	0.44
27	VH113014	74.10	29	-0.28	-1.01	0.06
28	ZH159	93.29	2	-0.96	-0.83	2.99
29	900MG(Local Check-1)	82.93	15	-1.40	-0.14	1.23
30	P3502(local Check-2)	91.69	4	-3.91	-1.10	0.59
Grand mean		82.40	-	-	-	-

As the first two IPCA components of G x E interaction were highly significant (Table 2), the status of stability of performance of 30 maize hybrids could be best predicted by AMMI II biplot analysis (Fig. 2) using IPCA I and IPCA II. Maize hybrids i.e. 4(ZH17210), 6(ZH17223), 8(ZH17225) and 11(VH12180) expressed either positively or negatively high interactive behavior and contributed more to the exhibited G x E interaction. Genotype- environment affinity was predicted as orthogonal projections of the genotypes on the environmental vectors to identify the best genotypes with respect to environments. In this regard, the best adapted genotypes with respect to environment E_6 (Korapout) were maize hybrid 4(ZH17210), 23(VH141618) and 25(ZH15445). Similarly, maize hybrids 14(ZH17230), 16(ZH15571) and 24(VH1252) adapted better to the environment E_4 (Jashipur) (Fig. 2). In contrast, the hybrids e.g., 1(ZH16133), 2(ZH161418), 12(ZH17228), 13(ZH17229) and 15(ZH17231) were non-sensitive to environmental interactive forces as they fell near the origin. This corroborates the previous reports (Matin *et al.* 2017, Nzuve *et al.* 2013 and Bhakta 2005) and confirms that AMMI model is the most accurate way to predict stability of performance by using the first two IPCs. Besides, the AMMI model of stability analysis helps in simultaneous selection of genotype(s) for grain yield and adaptability across environments (Dehghani *et al.* 2010).

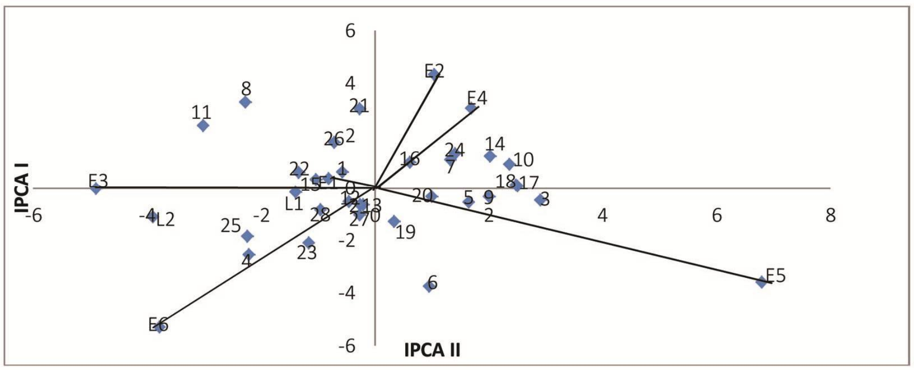

Fig 2. AMMI II biplot graph of two way environmental interaction components (IPCA I and IPCA II) of 30 maize hybrids under six environments.

Table 4. Mean and AMMI scores of different environments for grain yield.

Environments	Mean grain yield(q/ha)	Rank	IPCA I	IPCA II	IPCA III
Bhubaneswar (E_1)	68.99	5	-0.82	0.39	2.13
Bhanjanagar (E_2)	59.62	6	1.04	4.34	2.89
Rayagada (E_3)	93.70	2	-4.91	0.07	-5.72
Jashipur (E_4)	82.73	4	1.69	3.06	0.11
Umerkote (E_5)	92.21	3	6.79	-3.57	-2.58
Koraput (E_6)	98.20	1	-3.79	-5.29	3.18

The environment points were joined to the origin by straight lines. Environments with short spokes exerted weak interactive forces, whereas those with long spokes exerted strong interactions. The E_1 (Bhubaneswar) with short spokes on either of the interaction components (IPCA I and IPCA II) indicated very weak interactive force, whereas E_5 (Umerkote) and E_6 (Koraput) with long spoke exerted stronger interactive forces. This means that maize hybrids tested under Bhubaneswar (E_1) condition are less likely to vary in their inherent genotypic worth in grain yield potential compared to others locations. Sowmya *et al.* (2018) carried out stability analysis for grain yield of 20 maize hybrids in three environments using the methods of Eberhart and Russel (1966) model. They reported that hybrids, DMH 100-1, DMH 100-2 and DMH 100-14 were stable across the locations and seasons. Similarly, Ahmad *et al*. (2017) evaluated eleven maize hybrids along with one check across three locations spread over different agro-climatic zones of Jammu and Kashmir. Hybrids H1, H2, H5 and H10 were identified as most stable and among these, H2 (81.55 q/ha) surpassed the check SMH-1 (76.22) by 7 % in seed yield. Ali *et al.* (2017) reported better fitness of hybrid H 9 over four growing seasons for grain yield under water stress conditions. However, the present investigation suggests that AMMI model of stability analysis may be suitably used for reliable selection of high yielding stable maize hybrids over diverse ecological zones.

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