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Identification of Stable Maize Hybrids Over Environments

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The objective of the present study was to analyse the pattern of genotype x environment interaction for grain yield in experimental maize hybrids. The Additive Main Effects and Multiplicative Interaction(AMMI) model was applied to yield data obtained from a zonal trial conducted over five locations, involving fourteen experimental and three commercial hybrid checks. AMMI analysis indicated genotype, environment and the genotype x environment interaction were significant. The first two principal components were significant and jointly accounted for 74.5% of total interaction. Based on PCA values, genotypes with general and specific adaptability and preferable locations for different genotypes were suggested.

Key words: Maize hybrids, grain yield, AMMI, G x E interaction, biplot.

Maize (*Zea mays* L.) is the second most important cereal crop after rice in peninsular India, comprising the states of Andhra Pradesh, Karnataka and Tamilnadu. The average productivity of maize in this zone is 32 q/ha as against the national average of 19 q/ha. The major factor responsible for higher yield of maize in the zone is large scale cultivation of hybrids, especially the single cross hybrids in recent past. The single cross hybrids are more uniform and high yielding compared to double and three way cross hybrids but they are less adaptable to environmental fluctuations. Guillen -Portal *et.al* (2003) reported that maize single cross hybrids were superior to double crosses in mean grain yield, however ,the double crosses were more stable than single crosses. Numerous researchers have reported that GxE variance for double crosses is less than for single crosses. The cause of this greater stability of the double crosses probably was their greater heterogeneity(Eberhart and Russel,1969).

Hence, it is essential to study adaptability of the single cross hybrids to different environments before recommending for large scale cultivation . Varietal adaptability can be judged by Genotype x Environment Interaction (GEI) studies by conducting yield trials over locations or years or location and year combinations. The total sum of square for the yield data can be partitioned into three general sources, the genotype main effect, the environment main effect and the genotype x environment (GE) interaction. Snedcor and Cochron (1980) described main effects as additive and interaction (residual from the additive model) as non additive. Zobel *et al* (1988), reported that the customary statistical analyses applied to yield trials, (a) analysis of variance (ANOVA), (b) Principal component analysis (PCA) and (c) linear regression are often inadequate in effectively treating such a complex data structure, as these models describe either of additive or multiplicative effects. On the other hand the Additive Main Effects and Multiplicative Interaction (AMMI) model which incorporates both additive and multiplicative components into an integrated, powerful, least square analysis ,offers a more appropriate statistical analysis of yield trials that may have a genotype x environment interaction (Crossa *et al* 1990, Castanon *et al.* 2000, Reddy *et al* 2004). Hence, the present study was undertaken to determine the GEI effects on grain yield of experimental maize hybrids developed at Maize Research Centre, Acharya N G Ranga Agricultural University, Hyderabad, India and to identity hybrids that are broadly adapted across maize growing states of peninsular India.

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Materials and Methods

The data pertains to a zonal trial of maize hybrids conducted during *kharif* , 2009 under rainfed conditions. Fourteen experimental hybrids along with three check hybrids (900 M, 30V 92 and Pinnacle) were evaluated at five locations. The locations were Nagenhalli, Karimnagar, Mandya, Coimbatore and Hyderabad representing the three major maize growing states of peninsular India, i.e. Andhra Pradesh, Karnataka and Tamilnadu. At each location, the experimental plot size was $6m_2$. The grain yield per plot was extrapolated to yield per hectare and was used for statistical analysis in this study.

The AMMI model is depicted as $Y_{ij}=m+g_i+e_j+S\ddot{e}_k a_{ik} \tilde{a}_{jk}+R_{ij}$ where Y_{ij} is the yield of i^{th} genotype in the j_{th} environment, g_i is the mean of the i_{th} genotype as a deviation from the grand mean m; e_j is the mean of the j_{th} environment minus grand mean (m),$\ddot{e}_k$ is the eigen value of the PCA axis k, a_{ik}

and ã $_{jk}$ are the principal component scores for PCA axis k of i_{th} genotype and j_{th} environment respectively and R_{ij} is the residual. The GE interaction sum of squares can be subdivided into PCA axes, where axis k is regarded as having t+s-1-2k degrees of freedom and t and s are the number of genotypes and environments respectively (Zobel *et al*.1988). The data were analysed by GENSTAT statistical package developed at International Crops Research Institute for Semi Arid Tropics (ICRISAT).

Results and Discussion

The AMMI analysis of variance indicated that the mean sum of squares for genotypes, environments and genotype x environment interactions were significant (Table 1). This suggested existence of broad range of diversion among genotypes and among environments. Out of the total treatment variation (trial SS) the proportion of variance due to differences in environments was large (73.4%), followed by the variance due to G x E interaction (16.4%) and variance due to genotypes (10.2%) .The GEI was further partitioned into three PCA axes. The first (PCA I) and the second (PCA II) were significant and jointly accounted for 74.5% total interaction.

Table 1. AMMI Analysis of Variance for grain yield of maize hybrids tested at five locations in peninsular India

Source	d.f	Mean squares
Trials	84	317.88**
Genotypes	16	170.62**
Environments	4	4902.78**
GE interaction	64	68.15*
PCAI	19	107.84**
PCA II	17	70.44*
PCA III	15	46.49
Residual	13	32.15

*=Significant at 5% level;**= Significant at 1% level

The mean yield data, along with the first principal component of fourteen experimental hybrids and three checks evaluated across five locations is presented in table 2. The check hybrid 30 V 92 was the top yielding entry (95.17 q/ha) with a PCA I score -0.43.The top yielding experimental hybrid BH 40717 (86.88 q/ha) recorded the second highest PCA I score (2.44) .The experimental hybrid BH 407106 with a mean grain yield of 80.65 q/ha recorded the least PCA I score (-0.08).

The results of the AMMI analysis can also be easily comprehended with the help of AMMI biplot as represented in Fig 1. Generally in an AMMI biplot with means of main effects on the abscissa and PCA values as the ordinates, genotypes or the environments that appear almost on a perpendicular line have a similar means and those that fall on a horizontal line have similar interaction patterns. Genotypes or environments with large PCA scores (either positive or negative) have high interaction effects, whereas combinations of PCA scores of opposite signs have negative specific effects (Crossa *et.al.,* 1990). According to AMMI analysis, the genotypes which are having mean greater than the grand mean and the PCA scores nearly zero are considered to be generally adaptable to all the environments. However, the genotypes with high mean performance and large value of PCA scores are considered to be having specific adaptability to the environments. Accordingly, BH 407106, BH 408010, BH 40701 and BH 40615 were found to be

Table 2. Mean grain yield (q/ha) of maize hybrids and first PCA scores for the GE interaction effect as derived from AMMI analysis

Hybrid No.	Name of the hybrid	Naganhalli	Karimnagar	Mandya	Coimbatore	Hyderabad	Genotype Mean	PCAI
1	BH 40701	83.70	66.32	89.51	113.92	63.89	83.47	0.31
2	BH 40630	75.80	84.03	101.94	117.75	54.22	86.75	-1.59
3	BH 407109	82.50	61.82	92.25	90.49	30.93	71.60	-3.04
4	BH 406126	88.40	59.52	87.63	95.26	34.04	72.97	-2.67
5	BH 40896	81.30	78.02	92.42	102.80	46.75	80.26	-1.44
6	BH 407106	80.70	73.86	94.51	96.95	57.24	80.65	-0.08
7	BH 408010	89.60	74.40	82.97	107.30	55.00	81.85	-0.14
8	BH 407123	86.20	81.31	79.54	89.20	72.39	81.73	3.06
9	BH 407132	84.73	64.20	86.81	106.18	70.85	82.55	1.62
10	BH 40717	90.30	83.84	89.57	95.19	75.50	86.88	2.44
11	BH 407107	87.90	83.41	86.48	100.66	61.76	84.04	0.80
12	BH 40615	79.50	79.93	88.38	102.11	57.24	81.43	0.22
13	BH 407122	78.80	74.22	99.61	93.26	61.23	81.42	0.25
14	BH 407119	74.70	68.66	82.29	92.49	36.79	70.99	-1.48
15	900 M	77.50	73.69	83.04	109.32	68.39	82.39	1.69
16	30V92	85.70	94.33	100.81	127.70	67.29	95.17	-0.43
17	Pinnacle	76.20	78.07	91.55	111.48	63.55	84.17	0.47
	Location mean	82.56	75.27	89.96	103.06	57.47	81.7*	
	PCAI	-1.02	0.32	-3.16	-1.73	5.58		

* Overall mean

stable genotypes across the locations. The check hybrid 30 V 92 with the highest mean yield of 95.17 q/ha was found less adaptable compared to the above experimental hybrids which recorded PCA value – 0.43. On the other hand experimental hybrids BH 40630, BH 407123, BH 40717and BH 407107

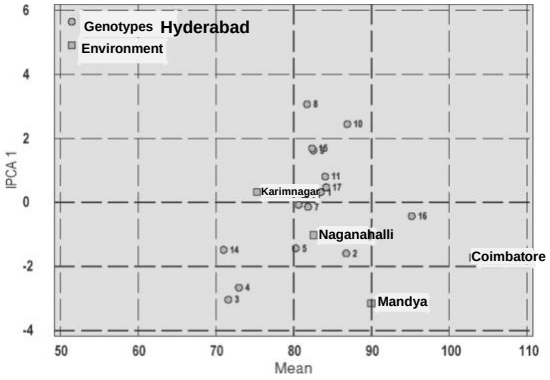

Fig.1. Biplot of locations and interaction component-I for grain yield of maize hybrids

recorded high general mean than grand mean but PCA values were high, implies that these hybrids are specifically adapted specific environments (Table2).

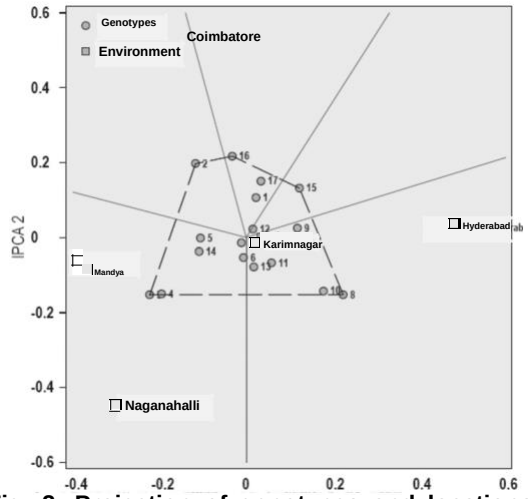

Fig. 2. Projection of genotypes and locations on the first to principal component for grain yield of maize hybrids

The AMMI biplot with PCA I score as abscissa and PCA II scores as ordinates, the genotypes or environments falling at the centre of the biplot near the origin have less interactions and are stable(Fig.2). When environment mean and PCA were compared, it is clear the location Nagenhalli had good conditions for all the hybrids as it recorded high mean yield and PCA-I scores near to zero. Another location with almost zero score on PCA-I axis was Karimnagar but it recorded the below average yield potential. The mean grain yield of Mandya centre was above the grand mean but it recorded high PCA value, therefore it is most suitable for specifically adapted genotypes.. Accordingly, the hybrids BH 407106, BH 408010, BH 40701 and BH 40615 and the locations Nagenhalli and Coimbatore can be considered as more stable (Table 2).Reddy *et al* (2004) carried out AMMI analysis to maize yield trials with 45 hybrids over four locations and identified stable locations and hybrids. The usefulness of this model to have greater insight into the magnitude and nature of genotype x environment interaction was also reported by Vijayakumar *et al*.(2001).

The adaptability of these maize hybrids can be further studied over the seasons/years before recommending for general cultivation.

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