Volume 17(2), 192- 196, 2013
JOURNAL of Horticulture, Forestry and Biotechnology
www.journal-hfb.usab-tm.ro

Analysis of genotype x environment interaction for yield in some maize hybrids

Grada F[*1]., Ciulca S.[2]

[1] Agrozooservice Curtici, [2]USAMVB Timisoara, Faculty of Horticulture and Forestry

*Corresponding author. Email: floringrada@yahoo.com

Abstract The considerable variation in soil and climate has resulted in large variation in yield performance of maize hybrids annually, thus GE interaction is an important circumstance for plant breeders and agronomists. The large GE interaction variation usually impairs the accuracy of yield estimation and reduces the relationship between genotypic and phenotypic values. The requirement for stable genotypes that perform well over a wide range of environments becomes increasingly important as farmers need reliable production quantity. The AMMI model is considered to be a better model for analysis of G×E interaction. It not only gives estimate of total G×E interaction effect of each genotype but further partitions it into interaction effects due to individual environments. The objectives of this study therefore were to determine the relative magnitude of *G*xE interaction effects on maize grain yield for a set of 32 hybrids. The weather conditions from the experimental period had the highest contribution (44.87 %) over the yield variability, whereas the genotypes had a lower influence (23.09 %), and genotype x environment interaction contributed only with 10.56% to the total variation. The hybrids: PR36V74, PR36K67, PR36D79, DKC5276, DKC4490, PR36V52, registered an upper yield to the general mean, and are specifically adapted to the higher yielding environments, achieved higher yield in favorable climatic conditions for this crop. The hybrid DKC4685, DKC5143, DKC5276 with lower GSI value are considered the most desirable of both stability and high yield.

Key words

maize, grain yield, genotype x environment interaction, AMMI

The climate conditions in the last decade, especially the rainfall are unpredictable, and cause a high stress.of maize growth and large genotype × environment (GE) interaction. It is necessary to understand the effects of various stresses on the genetic makeup of maize before we can tackle the issues relative to GE interactions.

The considerable variation in soil and climate has resulted in large variation in yield performance of maize hybrids annually, thus GE interaction is an important circumstance for plant breeders and agronomists [5]. The large GE interaction variation usually impairs the accuracy of yield estimation and reduces the relationship between genotypic and phenotypic values [8].

Numerous methods for multienvironment trials data have been developed to expose patterns of GE interaction. Among these, Muir et al. (1992) proposed an algorithm for partitioning GE sum of squares into components assignable to individual genotypes or environments. GE interaction can be expressed as imperfect genotypic or environmental correlation (crossover interaction), or as heterogeneity of variance across environments (non-crossover interaction).

AMMI analysis combines ANOVA and principal component analysis (PCA) where the sources of variability in the genotype by environment interaction are partitioned by PCA. The interpretation of results obtained from AMMI analysis is performed with a biplot that relates genotypic means to the first or some of the principal interaction components [3].

The AMMI method is used for three main purposes. The first is model diagnoses, AMMI is more appropriate in the initial statistical analysis of yield trials, because it provides an analytical tool of diagnosing other models as sub cases when these are better for particular data sets [2]. Secondly, AMMI clarifies the G x E interaction and it summarizes patterns and relationships of genotypes and environments [10; 1]. The third use is to improve the accuracy of yield estimates. Gains have been obtained in the accuracy of yield estimates that are equivalent to increasing the number of replicates by a factor of two to five [10; 1].

The objectives of this study therefore were to determine the relative magnitude of *G*xE interaction effects on maize grain yield for a set of 32 hybrids.

Material and Method

The biological material was represented by 32 commercial maize hybrids studied during 2009-2011, at Agrozooservice Curtici. The experiment was organized in a randomized block design with three replications. A plot was made up of six rows, 10 m long and a spacing of 0.7 m between rows and 0.25 m within row. NP fertilizer was applied at the total rate of 170 kg N, 80 kg P. From each repetition-plot four rows were harvested, weighed, and an average grain yield was calculated. Grain yield was adjusted at 15 % moisture, for each hybrid.

The AMMI analysis was made using the statistical model according to Gauch and Zobel (1996):

$$Y_{ij} = \mu + g_i + e_j + \sum_{K=n}^{n} \lambda_k \alpha_{ik} y_{jk} + r_{ij} + \varepsilon_{ij},$$

where Y_{ij} is the mean response of genotype i in the environment j; μ is the overall mean; g_i is the fixed effect of genotype i (i = 1, 2, ... g); e_j is the random effect of environment j (j = 1, 2, ... e); ε_{ij} is the average experimental error; the G × E interaction is represented by the factors; λ_k is a unique value of the kth interaction principal component analysis (IPCA), (k = 1, 2, ... p, where p is the maximum number of estimable main components), α_{ik} is a singular value for the ith genotype in the kth IPCA, y_{jk} is a unique value of the jth environment in the kth IPCA; r_{ij} is the error for the G × E interaction or AMMI residue (noise present in the data); and k is the characteristic non-zero roots, k = [1, 2, ... min (G - 1, E - 1)].

Furthermore, AMMI's stability value (ASV) was calculated in order to rank genotypes in terms of stability using the formula suggested by Purchase (1997).

Based on the rank of mean yield of genotypes and rank of ASV a genotype selection index (GSI) was calculated for each genotype which incorporate both indices in a single criterion [4].

Results and Discussions

The combined analyses of variance for the 32 maize hybrids evaluated during 2009-2011 according to the AMMI 2 model (Table 1) indicated highly significant differences (P < 0.01) for environments, genotypes and genotypes x environment interaction.

Table 1

Combined analysis of variance according to the AMMI 2 model for studied genotypes during 2009-2011

Source of variation	SS	DF	MS	F Test
Total	550467763	287		
Years	246982367	2	123491183	12.03**
Reps. within years	61609536	6	10268256	33.71**
Genotypes	127083973	31	4099483	13.46**
Genotypes x Years	58138692	62	937721	3.08**
IPCA 1	38459533	32	1201860	3.95**
IPCA 2	19679158	30	655972	2.15**
Residual IPCA	0	0	-	
Error	56653195	186	304587	

V_G	V_{GxY}	V_P	h^2_{bs} (%)
351306.90	211044.59	455498.11	77.13

The weather conditions from the experimental period had the highest contribution (44.87 %) over the yield variability, whereas the genotypes had a lower influence (23.09 %), and genotype x environment interaction contributed only with 10.56% to the total variation. The genetic components of the studied hybrids had an influence about 77% over their yield during the experimental period. The high percentage of the environment from total variation is an indication that the variability of climate conditions is one of the major factors that influence yield performance of these maize hybrids.

The analysis genotype x environment interaction (Table 2.), shows that the lowest values of hybrid x year interactions, are presented by: DKC4685, PR37F73, DK440, PR37Y12, DK315, where the yield performance are affected in a lesser extent by the climate condition variability. A large genotype x environment interaction associated with a higher instability of this trait has been observed at hybrids.

In the case of this trait 50.40% of the genotype x environment interaction is due to variances heterogeneity, and 49.60% to imperfect correlations. Therefore in the assessment of yield stability for different hybrids, the results of both crossover and non-crossover interactions can be effectively used.

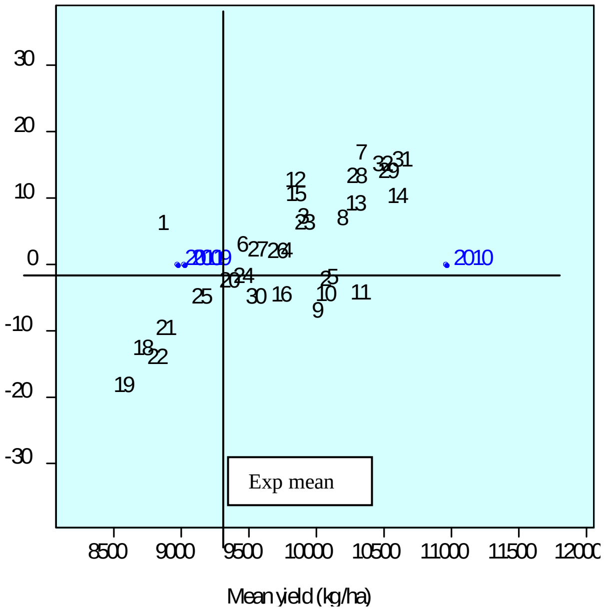
Considering the imperfect correlation it is noted that the lowest crossover interaction were recorded by hybrids: PR38R92, PR37D25, DKC4964, DKC4685, which showed a high constancy of ranks related to yields achieved in the climatic conditions of the three experimental years. High values of deviations between ranks for this trait throughout the experimental period presented the hybrids: DKC4795, PR39D81 and DKC4082.

Table 2

Partitioning of G x E interactions through heterogeneous variances (HV) and imperfect correlations (IC) for studied maize hybrids during 2009-2010

Hybrids	SS		SS		SS		Hybrids	SS		SS		SS	
	(HV)	(%)	(IC)	(%)	(GxE)	(%)		(HV)	(%)	(IC)	(%)	(GxE)	(%)
DK315	177225	1.79	180247	1.85	357472	1.82	PR39D81	1026701	10.38	1017308	10.45	2044009	10.41
DKC4082	155982	1.58	691944	7.11	847926	4.32	PR39F58	517454	5.23	201575	2.07	719029	3.66
DKC3511	190313	1.92	180995	1.86	371308	1.89	PR38R92	923728	9.34	63128	0.65	986856	5.03
DK440	154854	1.56	177318	1.82	332172	1.69	PR38A79	189917	1.92	221902	2.28	411819	2.10
DKC4685	191829	1.94	135290	1.39	327119	1.67	PR38A24	312295	3.16	410996	4.22	723291	3.68
DKC4626	157193	1.59	239890	2.46	397083	2.02	PR37D25	632789	6.40	96600	0.99	729389	3.72
DKC4490	508715	5.14	233295	2.40	742010	3.78	PR37N01	177694	1.80	188636	1.94	366330	1.87
DKC4889	189167	1.91	199937	2.05	389104	1.98	PR37Y12	189387	1.91	147188	1.51	336575	1.71
DKC4795	154816	1.56	1084591	11.14	1239407	6.31	PR37N54	210986	2.13	341246	3.50	552232	2.81
DKC4964	245763	2.48	124766	1.28	370529	1.89	PR37F73	155068	1.57	172029	1.77	327097	1.67
DKC5143	160520	1.62	319510	3.28	480030	2.45	PR37M34	159642	1.61	407514	4.19	567156	2.89
DKC4995	332620	3.36	210983	2.17	543603	2.77	PR36V52	365207	3.69	253813	2.61	619020	3.15
DKC5170	229847	2.32	193610	1.99	423457	2.16	PR36D79	387678	3.92	233777	2.40	621455	3.17
DKC5276	257462	2.60	202497	2.08	459959	2.34	PR36R10	199630	2.02	400764	4.12	600394	3.06
DKC5190	276036	2.79	225884	2.32	501920	2.56	PR36V74	458514	4.63	228015	2.34	686529	3.50
DKC5783	158689	1.60	672981	6.91	831670	4.24	PR36K67	447244	4.52	278037	2.86	725281	3.69

Based on variances heterogeneity it is found that the lowest values of non-crossover interaction were recorded at hybrids: DK440, DKC4626, DKC4795 and PR37F73, which showed lower deviations to the average of each year. The highest non-crossover interaction associated with large deviations from the yearly average of the other hybrids was presented by PR39D81.



1-DK315; 2-DKC4082; 3-DKC3511; 4-DK440; 5-DKC4685; 6-DKC4626; 7-DKC4490; 8-DKC4889; 9-DKC4795; 10-DKC4964; 11-DKC5143; 12-DKC4995; 13-DKC5170; 14-DKC5276; 15-DKC5190; 16-DKC5783; 17-PR39D81; 18-PR39F58; 19-PR38R92; 20-PR38A79; 21-PR38A24; 22-PR37D25; 23-PR37N01; 24-PR37Y12; 25-PR37N54,; 26-PR37F73; 27-PR37M34; 28-PR36V52; 29-PR36D79; 30-PR36R10; 31-PR36V74; 32-PR36K67

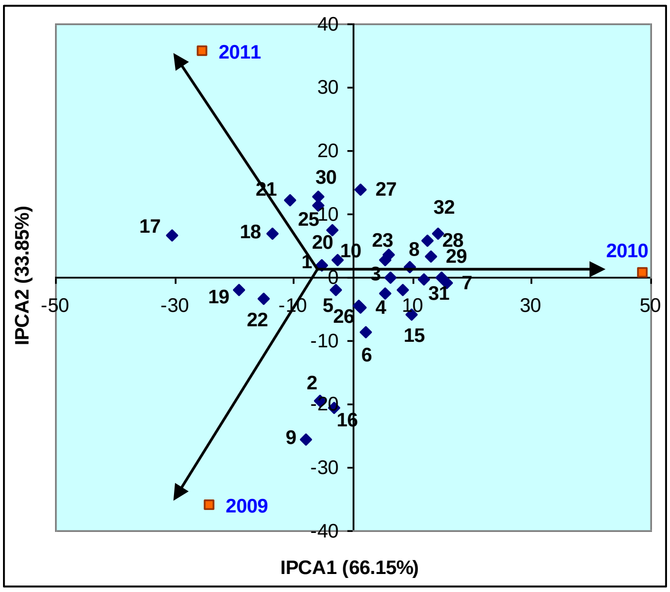
Fig. 1. AMMI I biplot for mean yield and IPCA 1 of studied maize hybrids during 2009-2011

By plotting both the hybrids and years on the same graph (Fig 1.), the associations between the hybrids and years 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, either negative or positive, 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. Genotypes that are close to each other tend to have similar performance and those that are close to one year indicates their better adaptation to that particular climate conditions.

The studied hybrids achieved the highest yield values in the conditions from 2010, while the average yields for 2009 and 2011 were very close, and below the general mean of the experience.

The hybrids: PR36V74, PR36K67, PR36D79, DKC5276, DKC4490, PR36V52, registered an upper yield to the mean associated with high IPCA1 values, and are specifically adapted to the higher yielding environments, achieved higher yield in favorable climatic conditions for this crop, respectively.

Hybrids adapted to the lower yielding environments are: PR39F58; PR38R92; PR38A79; PR38A24; PR37D25, who due to unfavorable weather conditions show high values of the genotype x environment interaction.



1-DK315; 2-DKC4082; 3-DKC3511; 4-DK440; 5-DKC4685; 6-DKC4626; 7-DKC4490; 8-DKC4889;
9-DKC4795; 10-DKC4964; 11-DKC5143; 12-DKC4995; 13-DKC5170; 14-DKC5276; 15-DKC5190; 16-DKC5783;
17-PR39D81; 18-PR39F58; 19-PR38R92; 20-PR38A79; 21-PR38A24; 22-PR37D25; 23-PR37N01; 24-PR37Y12;
25-PR37N54,; 26-PR37F73; 27-PR37M34; 28-PR36V52; 29-PR36D79; 30-PR36R10; 31-PR36V74; 32-PR36K67

Fig. 2. AMMI 2 interaction biplot for yield of studied maize hybrids during 2009-2011

Since IPCA 2 scores also play a significant contribution (33.85%) in explaining the genotype x environment interaction, the IPCA 1 scores were plotted against the IPCA 2 scores to further explore adaptation (Fig 2). With respect to environments 2010 was most discriminating as indicated by the longest distance between its marker and the origin, the genotypic differences in this year should be highly consistent with those averaged yield over years, because it had less IPCA 2 scores compared to other two years. Generally hybrids with a smaller vector angle in between and have similar projection, designate their proximity in the grain yield performance.

According the vectors length for different hybrids it is noted that the highest genotype x environment interaction for yield was presented by the hybrids: PR39D81, DKC4795, PR38R92, PR37D25 and DKC4490. In case of the DK315, DK440;, DKC4685, DKC4626, PR37F73, the position of these close to the origin, correlated with low genotype x environment interaction, shows a high stability during experimentation period.

Stability per se should however not be only parameter for selection, because the most stable genotypes would not necessarily give the best yield performance [6], hence there is a need for approaches that incorporate both mean grain yield and stability in a single criteria [4]. In this regard, as ASV takes into account both IPCA1 and IPCA2 that justify most of the variation for genotype x environment interaction, therefore the rank of ASV and mean yield are incorporated in a single selection index namely genotype selection index (GSI). The hybrid DKC4685, DKC5143, DKC5276 with lower GSI value are considered the most desirable of both stability and high yield. Low mean yield associated with high genotype x environment interaction were observed for PR39D81, PR38R92, PR37D25. For hybrids: PR36V74, PR36D79, PR36K67, DKC4490, the high mean yield are strongly controlled by the genotype x environment interaction.

Table 3

AMMI stability values (ASV) and genotype selection index (GSI) for maize hybrids during 2009-2011

No.	Hybrids	Mean (kg/ha)	Yield ranks	ASV	ASV ranks	GSI	GSI ranks	No.	Hybrids	Mean (kg/ha)	Yield ranks	ASV	ASV ranks	GSI	GSI ranks
1	DK315	8822	*27*	10.50	*8*	35	*21.5*	17	PR39D81	7707	*32*	59.55	*32*	64	*32*
2	DKC4082	10024	*11*	21.52	*19*	30	*16*	18	PR39F58	8639	*30*	27.46	*25*	55	*29*
3	DKC3511	9859	*14*	12.11	*11*	25	*10*	19	PR38R92	8499	*31*	37.53	*31*	62	*31*
4	DK440	9737	*18*	5.21	*2*	20	*4*	20	PR38A79	9278	*25*	10.11	*6*	31	*18*
5	DKC4685	10075	*10*	5.98	*3*	13	*1.5*	21	PR38A24	8810	*28*	24.02	*22*	50	*28*
6	DKC4626	9409	*23*	9.40	*5*	28	*13*	22	PR37D25	8745	*29*	29.34	*28*	57	*30*
7	DKC4490	10290	*5*	30.83	*30*	35	*21.5*	23	PR37N01	9836	*15*	10.67	*9*	24	*9*
8	DKC4889	10151	*9*	12.31	*12*	21	*5.5*	24	PR37Y12	9384	*24*	6.10	*4*	28	*13*
9	DKC4795	9966	*13*	29.95	*29*	42	*27*	25	PR37N54	9075	*26*	16.15	*15*	41	*26*
10	DKC4964	9993	*12*	10.74	*10*	22	*7*	26	PR37F73	9636	*20*	4.72	*1*	21	*5.5*
11	DKC5143	9916	*6*	10.35	*7*	13	*1.5*	27	PR37M34	9489	*21*	13.97	*13*	34	*20*
12	DKC4995	9765	*17*	22.85	*21*	38	*23.5*	28	PR36V52	10221	*7*	24.72	*23*	30	*16*
13	DKC5170	10213	*8*	16.10	*14*	22	*8*	29	PR36D79	10458	*3*	25.71	*24*	27	*11*
14	DKC5276	10523	*2*	18.24	*17*	19	*3*	30	PR36R10	9477	*22*	17.21	*16*	38	*23.5*
15	DKC5190	9771	*16*	19.65	*18*	34	*19*	31	PR36V74	10560	*1*	28.83	*27*	28	*13*
16	DKC5783	9664	*19*	22.28	*20*	39	*25*	32	PR36K67	10413	*4*	28.44	*26*	30	*16*

Conclusions

1. The weather conditions from the experimental period had the highest contribution (44.87 %) over the yield variability, whereas the genotypes had a lower influence (23.09 %), and genotype x environment interaction contributed only with 10.56% to the total variation.

2. Taking into account that 50.40 % of the genotype x environment interaction is due to variances heterogeneity, and 49.60% to imperfect correlations, in the assessment of yield stability for different hybrids, the results of both crossover and non-crossover interactions can be effectively used.

3. The highest genotype x environment interaction for yield was presented by the hybrids: PR39D81, DKC4795, PR38R92, PR37D25 and DKC4490. In case of the DK315, DK440;, DKC4685, DKC4626, PR37F73, the position of these close to the origin, correlated with low genotype x environment interaction, shows a high stability during experimentation period.

4. The hybrids: PR36V74, PR36K67, PR36D79, DKC5276, DKC4490, PR36V52, registered an upper yield to the general mean, and are specifically adapted to the higher yielding environments, achieved higher yield in favorable climatic conditions for this crop.

5. The hybrid DKC4685, DKC5143, DKC5276 with lower GSI value are considered the most desirable of both stability and high yield.

References

1. Crossa, J., 1990. Statistical analysis of multilocation trials. *Advances in Agronomy* 44:55-85.

2. Gauch, H.G., 1988. Model selection and validation for yield trials with interaction. *Biometrics* 44: 705-715.

3. Gauch, H.G. and Zobel, R.W., 1996. AMMI analysis of yield trials. In: Kang, M.S. and Gauch, Jr. H.G. (eds.). Genotype by environment interaction. 85-122.

4. Farshadfar E (2008) Incorporation of AMMI stability value and grain yield in a single non-parametric index (GSI) in bread wheat. Pak J Biol Sci 11(14): 1791-1796

5. Ilker, E., Aykut Tonk, F., Caylak, O., Tosun M., Ozmen, I., 2009. Assessment of genotype x environment interactions for grain yield in maize hybrids using AMMI and GGE biplot analyses. Turkish J. of Field Crops 14(2): 123-135

6. Mohammadi R, Abdulahi A, Haghparast R and Armion M (2007) Interpreting genotype- environment interactions for durum wheat grain yields using non-parametric methods. Euphytica 157: 239–251

7. Muir W, Nyquist WE, and Xu S, 1992. Alternative partitioning of the genotype-by-environment interaction. Theor Appl Genet 84:193–200.

8. Nachit, M.N., M.E. Sorrells, R.W. Zobel, H.G. Gauch, R.A. Fischer and W.R. Coffman, 1992. Association of environmental variables with sites mean grain yield and components of genotype-environment interaction in durum wheat. J. Genet. Breed., 46: 369-372.

9. Purchase, J.L., 1997. Parametric analysis to describe Genotype x Environment interaction and yield stability in winter wheat. Ph.D. Thesis, University of the Free State, Bloemfontein, South Africa.

10. Zobel, R.W., Wright, M.J. and Gauch, Jr. H.G., 1988. Statistical analysis of a yield trial. *Agronomy Journal* 80: 388-393.