

GENOTYPE x ENVIRONMENT INTERACTION OF SOME PROMISING YELLOW MAIZE SINGLE CROSSES

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ABSTRACT

Four field experiments were conducted at Sakha, Gemmeiza, Sids and Mallawi Research Stations, Egypt in 2005, to evaluate the performance and the GxE interaction of thirteen promising yellow single crosses in addition to three commercial single crosses (SC155, SC3080 and SC3084) using RCBD with four replications.. Highly significant additive genotypic (i.e., in the positive and/or negative directions) and environmental effects were found for grain yield. G x E interaction was significant after partitioning to IPCA significant axis, leaving the non-significant part in the residual. Single crosses, G2, G4 and G9 differ in the additive effects but do not differ much in the interaction effect and hence, they are considered as stable hybrids. Besides, differences in their performance depend mainly on differences in their additive genotypic effects. G2 had the highest additive genotypic effect followed by G5, G6, G8, G15 and G10. In contrast, G14, G9, G12 and G16 are in the negative genotypic side. Sakha followed by Mallawi had the highest positive additive effects among all environments, while Sids and Gemmeiza had negative additive effects. Sakha and Gemmeiza had the highest interaction scores. G14 followed by G15, G10 and G8 in the negative side and G11, G3 and G5 in the positive side, had the highest interaction scores. The interactions of G11, G3 and G5 at Sakha, in the positive side and G14, G15, G10 and G8, at Gemmeiza, in the negative side, are positive as well. These interactions represent the highest interactions among all genotype-environment combinations.

Key words: *Maize, Zea mays, GxE, interaction, single crosses, AMMI model, IPCA analysis, Additive Effects.*

INTRODUCTION

Performance of a maize hybrid depends on the genotype (G), environment (E) and genotype x environment (G x E) interaction. Genotypes are considered to be stable as long as the G x E interaction is not significant. Powerful statistical models would provide plant breeders with more precise estimation to the G x E interaction and consequently more accurate information about the performance of maize genotypes over different environments. One of the powerful statistical models which can provide an accurate estimation of the genotype x environment interaction is the additive main effect and multiplicative interaction (AMMI) statistical model. The AMMI model incorporates multivariate techniques, such as principal components analysis (PCA) and the additive effects of the analysis

of variance, where the additive main effects and multiplicative components are estimated according to Mandel (1971); Bradu and Gabriel (1978) and Gauch and Zobel (1990). The analysis of variance (ANOVA) is an additive model and therefore describes only the main effects effectively (Snedecor and Cochran, 1980). ANOVA can test the significance of the G x E interaction, but this test may prove to be misleading and provide no insight into the particular patterns of genotypes or environments that give rise to the interaction (Zobel *et al* 1988, Mahgoub and Sadek 1995, Sadek *et al* 1995, Vargas *et al* 1999 and Gabour 2003). Gauch (1992) reported that the first PCA axis is placed in that direction for which the sum of squared perpendicular projections of the points off the PCA axis is minimized, and the second PCA axis may then be defined perpendicular (uncorrelated) to the first, accounting for as much of the remaining interaction sum of squares as possible. Mandel (1969) describes the ANOVA as a subcase of the AMMI model and concludes that it can be diagnosed from the AMMI model. Zobel *et al* (1988) reported that experimental design (randomized complete block, completely randomized design, Latin square, etc.) is not a significant consideration in the selection of an appropriate model(s).

The objective of this study was to estimate the additive and interaction effects of some newly maize single crosses at different environments and hence their stability using the AMMI model.

MATERIALS AND METHODS

Thirteen promising yellow single crosses (G1 through G13) were resulted from crossing new thirteen yellow maize inbred lines, i.e. GZ-18, GZ-19, GZ-25, GZ-79, improved GZ-614 (1), (10), (12), (18), (27), (30), (36), (37), and (38) with the high general combining ability (GCA) inbred line GZ-639 were developed at Giza Res. St., Field Crops Res. Inst., Agric. Res. Center during 2004 growing season. These crosses in addition to three commercial single crosses, viz. SC155 (G14), SC3080 (G15) and SC3084 (G16) were evaluated during 2005 season.

The field experiments were conducted at Sakha (SK), Gemmeiza (GM), Sids (SD) and Mallawi (ML) Research Stations, Egypt.

Nitrogen fertilizer of 120 kg N/fed in Urea form was splitted into two equal doses and was applied before the first and second irrigation's. Moreover 30 kg P₂O₅ and 24 kg K₂O/fed were applied for all plots. Plots consisted of two rows. Rows were 6 m long x 70 cm wide. Two to three kernels were planted per hill, 30 cm between hills then thinned to one plant/hill before the first irrigation, giving a plant density of 21,000 plants/fed. The experimental design was a randomized complete block with

four replications. Ears were harvested at maturity, weighed, shelled and sample of about 5 kg/plot were taken for measuring moisture percent. Grain yield was adjusted to 15.5 % grain moisture content. Analysis of variance was done for grain yield data according to Snedecor and Cochran (1980). Statistical analysis for the additive main effect and multiplicative interaction model (AMMI) was performed by MATMODEL (Gauch 1986), where the non-significant axes were pooled in the residual. The AMMI model is:

$$Y_{ge} = \mu + \alpha_g + \beta_e + \sum_n \lambda_n \zeta_{gn} \eta_{en} + \Theta_{ge} + \varepsilon_{ger}$$

Where, Y_{ge} is the yield of the i^{th} genotypes in the j^{th} environments; μ is the grand mean, α_g is the genotype mean deviation, β_e is the environment mean deviation, λ_n is the eigen value of the PCA axes, n , ζ_{gn} and η_{en} are the genotype and environment PCA scores for the PCA axes, Θ_{ge} is the residual and ε_{ger} is the error for the deviation between the Y_{ge} treatment mean and the single observation for the replicate r .

RESULTS AND DISCUSSION

Highly significant additive (positive) genotypic and environmental effects were found for grain yield (Table 1). G x E interaction was not significant according to the ordinary analysis of variance (ANOVA). However, this interaction was partitioned to a significant IPCA I, leaving the non-significant part in the residual (the non significant IPCAII and III). The additive main effect of the genotypic variance and multiplicative interaction model (AMMI) was therefore effective to detect the significant part of the G x E interaction after its partitioning. The IPCA I axis for grain yield was able to capture 62 % of the total G x E interaction sum of squares, resulting in a highly significant result. This indicated that the AMMI model was more powerful than the ordinary ANOVA in detecting real differences among the genotypes in terms of their interaction with different environments. These results are in agreement with Zobel *et al* (1988), Gauch (1992), Mahgoub and Sadek (1995), El-Sherbieny *et al* (1996), Vargas *et al* (1999), Ghabour (2003) and Mahmoud and Atia (2005).

Partitioning of the data revealed the superiority for the AMMI statistical model, since it can further analyze the interaction data beyond that possible with ANOVA. Moreover, the AMMI model should be used to detect the significant interaction which might not be observed by the ordinary ANOVA.

Table 1. Analysis of variance according to the AMMI model for grain yield, where GxE interaction was partitioned into IPCA1 and the residual.

Source of variation	df	SS	MS
Replications	3	32.60	10.87
Genotypes (G)	15	460.50	30.70**
Environments (E)	3	8396.02	2798.67**
G x E	45	780.13	17.34
IPCA 1	17	487.49	28.68**
Residual	28	292.64	10.45
Error	189	2011.02	10.64
Total	255	11680.28	---

1- Genotypes

Figure 1 represents the biplot of the AMMI results. A total of 16 yellow single crosses G1 through G16 are shown. The abscissa represents the additive effects of the genotypes (the deviation of the genotype means from the grand mean), and the environments (the deviation of the environment means from the grand mean), and the ordinate shows the first IPCA axis. In the biplot, when a genotype and an environment have the same sign on the IPCA axis, their interaction is positive (the interaction is mainly the product of the multiplication of the genotype score and the environment score). Therefore, the G x E interaction is negative if the genotype and the environment have different signs. In general, genotypes fit better to environments on their side (positive or negative) resulting in a positive interaction, and do not fit to environment on the other side, which results in a negative interaction. If a genotype or an environment has an IPCA score of nearly zero it has small interaction effects.

For example, G2, G4 and G9 differ in the additive effects but do not differ much in the interaction effect (IPCA 1 scores). These hybrids are considered to be stable in terms of their interactions with different environments. Furthermore, the performance of hybrids depends mainly on their additive effects. Hybrid G2 had the highest additive effect, followed by G5, G6, G4, G8, G15 and G10 whereas G14, G9, G12 and G16 in the negative side and G7 in the positive side had the lowest additive effects. This indicated that the additive effect controls to a large extent the overall performance of the hybrids, especially those hybrids that do not interact much with different environments, (Zobel *et al* 1988, Gauch, 1992, Mahgoub and sadek 1995, Sadek *et al* 1995, El-Sherbieny *et al* 1996, Vargas *et al* 1999 and Mahmoud and Atia 2005).

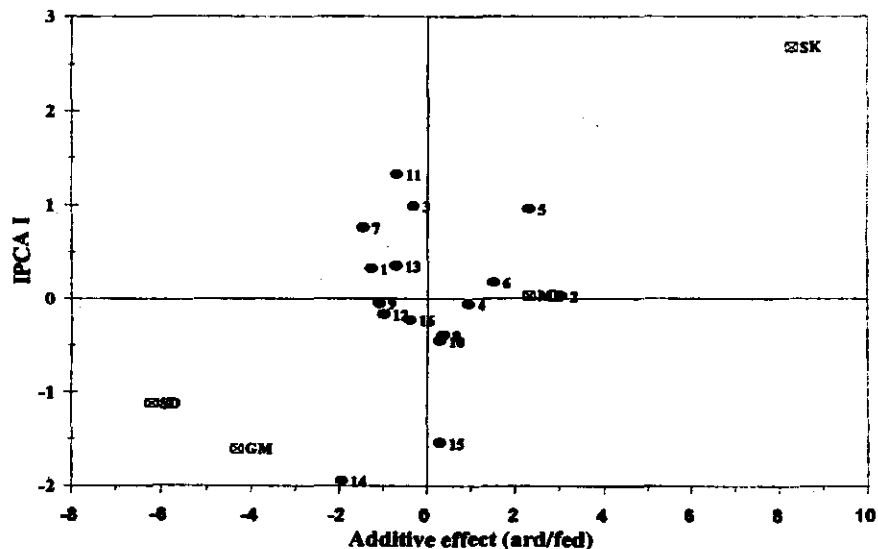


Fig.1. Additive effects (ard/fed.) and the IPCA 1 scores according to the AMMI model.

2- Environments

SK followed by ML-site had the highest and positive additive effect among all environments (Fig.1). While, SD and GM sites had negative additive effects. GM-site had the lowest additive effect indicating that the contribution of SD and GM to the overall performance of maize hybrids was inferior to SK and ML-site. This may be due to the better climatical and experimental conditions of the sites of SK and ML than GM and SD. Similar results were obtained by Sadek *et al* (1995) and El-Sherbieny *et al* (1996).

3- Interaction effect

In the negative side, G14 followed by G15, G10 and G8 had the highest interaction scores, while, G11, G3 and G5, in the positive side, showed the highest scores (Fig.1.). On the other hand, SK-site had the highest interaction score (regardless of sign) among all environments. However, GM-site had the highest interaction score in the negative side followed by SD-site. Single crosses that possess the highest positive scores fit well to environments with the highest positive scores and *vice versa* as indicated above. Consequently, the interactions between G11, G3 and G5 with SK-site, in the positive side, and G14, G15, G10 and G8 with GM and SD sites, in the negative side, are positive as well. These interactions represent the highest interactions among all genotype-environment combinations.

In Table 2, additive genotypic and interaction effects of the single crosses at the four environments are shown where the means were ranked in a descending order. The additive effects represent the additive effect of the single cross plus the additive effect of the corresponding environment. Whereas, the interaction effects represent the cross product of the genotype x environment scores. For simplicity, the highest 30 genotype- environment combinations and the lowest 10 ones (ranked from 55 to 64) are shown to reveal the role of the positive or negative additive as well as interaction effects in the overall performance of the hybrids. The highest yielding hybrid possesses positive additive as well as interaction effects, i.e. G5, G11 and G3 at SK environment. G15 and G3 at GM- environment, G4 at SD environment, and G2 and G5 at ML- environment. Similarly, G6 had high and almost similar additive effect to G11 but it ranked 5th as a result of its low interaction with SK-environment.

Table 2. Descending rankings, additive (A) and interaction (I) effects of the highest 30 and the lowest 10 (genotype-environment) combinations based on predicted grain yield means.

Rank	G	E	A	I	Mean (ard/fed)	Rank	G	E	A	I	Mean (ard/fed)
1	5	SK	12.71	2.548	44.15	21	8	ML	2.86	-0.014	32.35
2	11	SK	10.96	3.542	43.65	22	11	ML	1.98	0.046	31.67
3	3	SK	10.48	2.633	42.32	23	3	ML	2.11	0.034	31.54
4	7	SK	9.46	2.026	41.41	24	4	ML	2.41	-0.002	30.88
5	6	SK	10.83	0.457	41.20	25	15	GM	-1.27	2.461	30.82
6	2	SK	10.68	0.067	39.39	26	6	ML	2.31	0.006	30.12
7	13	SK	8.71	0.938	39.17	27	13	ML	1.03	0.012	29.79
8	4	SK	9.11	-0.177	38.32	28	15	SK	-4.38	-4.135	29.51
9	2	ML	7.06	0.001	38.11	29	14	ML	0.23	-0.068	29.41
10	12	SK	7.78	-0.460	37.59	30	4	SD	-2.92	0.074	28.76
11	5	ML	6.33	0.033	37.37	55	3	SD	-6.89	-1.101	22.06
12	9	SK	7.56	-0.146	37.25	56	13	SD	-7.24	-0.392	21.76
13	1	SK	7.33	0.863	36.99	57	12	SD	-7.62	0.192	21.28
14	8	SK	7.58	-1.072	35.83	58	7	SD	-7.99	-0.847	21.00
15	16	SK	6.91	-0.618	35.25	59	11	SD	-7.94	-1.480	20.34
16	10	ML	3.98	-0.016	34.68	60	3	GM	-6.92	-1.567	20.13
17	16	ML	3.63	-0.008	34.67	61	1	SD	-8.64	-0.361	19.52
18	10	SK	5.73	-1.220	34.21	62	5	SD	-7.02	-1.064	19.19
19	1	ML	2.66	0.011	33.60	63	11	GM	-7.72	-2.107	18.90
20	15	ML	2.86	-0.054	32.43	64	16	SD	-9.02	0.258	17.89

On the other hand, the lowest additive effects were associated with the low performing hybrids if it was associated with negative or low interaction effects, i.e. G15 at SK and G11 at GM environment. These combinations ranked 28th and 63rd, respectively, due to the low and negative additive and interaction of G15 and G11 (Table 2). It should be noted that the highest interaction effects were associated with the top highest ranking hybrids, i.e. G5 at SK and ML- environments. These results suggest the best single crosses to be distributed to farmers in a particular environment depending either on the additive and/or interaction effects. This indicated that the biplot shows us by glance the best G x E interaction (Zobel *et al* 1988, Gauch 1992, Mahgoub and Sadek 1995, Sadek *et al* 1995, El-Sherbieny *et al* 1996 and Vargas *et al* 1999).

Observed and predicted grain yield (ard/fed.) calculated according to the AMMI model are shown in Table (3). Predicted means represent the actual means after removing the residual. At Sakha which had the highest additive and interaction score among all locations. The difference between observed and predicted means (ard/fed.) was higher than the differences at Mallawi for all hybrids. On the other hand, this difference was lower than three ardabs/feddan for most hybrids at Gemmeiza and Sids, which showed negative additive effects. For example, predicted means were less than the observed ones by 5.25 and 4.19 (ard/fed.) for yellow single crosses G14 and G15 at Sakha, 2.70 and 2.27 ard/fed for hybrids G11 and G3 at Gemmeiza, 3.11 and 2.41 ard/fed for hybrids G5 and G16 at Sids and 2.32 and 2.01 ard/fed for hybrids G12 and G9 at Mallawi, respectively. In the contrary, predicted means were higher than the observed ones by 3.37, 2.52 and 2.12 ard/fed for hybrids G11, G3 and G5 at Sakha, 2.82, 2.77 and 2.25 ard/fed for hybrids G14, G15 and G12 at Gemmeiza, 2.56, 2.36 and 2.11 ard/fed for hybrids G14, G4 and G9 at Sids and 1.72 and 1.72 ard/fed for hybrids G16 and G5 at Mallawi, respectively. This might indicate that the observed-predicted mean deviations are expected to be higher at low performing environment (Table 3).

The AMMI model, with the biplot display of the model, helps to visualize the overall patterns of the data available as well as the additive and interaction effects of the genotypes and the environments (Zobel *et al*. 1988).

Table 3. Observed and predicted grain yield means (ard/fed) and IPCAI scores for 16 genotypes and the four environments in 2005 season.

Genotypes	Sakha		Gemmeiza		Sids		Mallawi		IPCA Genom. Score
	Observed	Predicted	Observed	Predicted	Observed	Predicted	Observed	Predicted	
GZ639 x GZ18 (G1)	36.65	36.99	22.90	22.09	20.68	19.52	31.98	33.60	0.321
GZ639 x GZ19 (G2)	40.00	39.39	26.75	25.50	26.25	26.38	36.38	38.11	0.025
GZ639 x GZ25 (G3)	39.80	42.32	22.40	20.13	22.43	22.06	31.43	31.54	0.980
GZ639 x GZ79 (G4)	38.43	38.32	24.53	23.13	26.40	28.76	31.73	30.88	-0.066
GZ639 x GZ614/1 (G5)	42.03	44.15	26.55	25.81	22.30	19.19	35.65	37.37	0.947
GZ639 x GZ614/10 (G6)	40.15	41.20	27.33	28.16	24.23	23.84	31.63	30.12	0.170
GZ639 x GZ614/12 (G7)	38.78	41.41	22.95	22.36	21.33	21.00	28.45	26.73	0.754
GZ639 x GZ614/18 (G8)	36.90	35.83	26.45	27.53	23.30	23.12	32.18	32.35	-0.399
GZ639 x GZ614/27 (G9)	36.88	37.25	23.30	22.71	24.33	26.44	28.53	26.52	-0.054
GZ639 x GZ614/30 (G10)	35.05	34.21	24.48	23.67	24.65	25.91	33.30	34.68	-0.454
GZ639 x GZ614/36 (G11)	40.28	43.65	21.60	18.90	21.38	20.34	31.30	31.67	1.318
GZ639 x GZ614/37 (G12)	37.10	37.59	26.25	28.50	21.70	21.28	28.33	26.01	-0.171
GZ639 x GZ614/38 (G13)	38.03	39.17	24.00	23.73	22.08	21.76	30.35	29.79	0.349
SC-155 (G14)	30.00	24.75	25.88	28.70	23.73	26.29	29.55	29.41	-1.949
SC-3080 (G15)	33.70	29.51	28.05	30.82	24.58	25.75	32.18	32.43	-1.539
SC-3084 (G16)	36.23	35.25	26.28	27.95	20.30	17.89	32.95	34.67	-0.230
LSD 0.05	3.921	-	2.789	-	3.988	-	4.912	-	-
IPCA Environment scores	2.687		-1.559		-1.123		0.035		--

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تفاعل التركيب الوراثي مع البيئة لبعض الهجن الفردية المباشرة من الذرة الشامية الصفراء

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برنامج بحوث الذرة الشامية-معهد بحوث المحاصيل الحقلية-مركز البحوث الزراعية-الجيزة

أجريت أربعة تجارب حقلية بمحطات البحوث الزراعية في سخا والجميزة وسدس وملوى في موسم ٢٠٠٥. حيث قيمت ثلاث عشر هجناً فردياً صفراء الحبوب من الذرة الشامية وكذلك ثلاثة هجن تجارية هي هـ ف ١٥٥، هـ ف ٣٠٨٠، هـ ف ٣٠٨٤ في تصميم القطاعات الكاملة العشوائية باستخدام أربعة مكررات من حيث سلوك هذه التراكيب الوراثية في البيئات المختلفة بتقدير تأثير الإضافة وكذلك تفاعل هذه التراكيب الوراثية مع البيئة. أظهرت النتائج ان الفروق بين التراكيب الوراثية وكذلك بين البيئات كانت عالية المعنوية لمحصول الحبوب. بينما كان التفاعل غير معنوي بين التراكيب الوراثية مع البيئات المختلفة طبقاً لتحليل التباين وأدت تجزئة التفاعل الى عدة محاور رئيسية مع ترك الجزء غير المعنوي كمتبقى الى إظهار الجانب المعنوي. اختلفت الهجن ج ٢، ج ٤، ج ٩ عن بعضها في تأثير الإضافة بينما لم يكن بينها اختلافاً في تأثير التفاعل حيث يعتمد محصولها على تأثير الإضافة (الموجبة او السالبة) في البيئات المختلفة. اظهر الهجين ج ٢ أعلى تأثير للإضافة لموجبة يليه الهجن ج ٥، ج ٦،

ج ٨، ج ١٥، ج ١٠ بينما كانت الهجن ج ١٤، ج ٩، ج ١٢، ج ٦ في الجانب السائب للإضافة. أظهرت منطقة سخا تليها منوى أعلى تأثير إضافي موجب مع جميع البيئات المختلفة الأخرى بينما كانت سدرس والجميزة ذات تأثير إضافي سائب. كما أظهرت منطقة سخا والجميزة أعلى تأثيرا للتفاعل. وقد أظهرت الهجن ج ١٤، ج ١٥، ج ١٠، ج ٨ (في الجانب السائب) والهجن ج ١١، ج ٣، ج ٥ (في الجانب الموجب) أعلى درجة للتفاعل. كان التفاعل عالياً بين الهجن ج ١١، ج ١، ج ٥ ومنطقة سخا في الجانب الموجب بينما كان للهجن ج ١٤، ج ١٥، ج ١٠، ج ٨ في تفاعلاتها بمنطقة الجميزة عالياً في الجانب السائب وهذا يشير إلى وجود تفاعل بين هذه التراكيب الوراثية مع هذه البيئات دون غيرها والذي ينعكس بدوره على محصول الحبوب لهذه الهجن.