Yield stability of some promising maize (*Zea mays* L.) hybrids under varying locations

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ABSTRACT

Grain yield stability for the new maize hybrids is an important target in breeding programs. The main objective of this study was to identify the stable superior hybrids for grain yield under varying locations. Five promising white single crosses, i.e. Gz 505, Sk 101, Sk 103, Sk 105 and Sk 106 as well as four yellow three way crosses, i.e. Gz 51, Sd 47, Sd 49 and Sd 52 in addition to three cheek hybrids, i.e. SC 10, SC 129 and TWC 352 were evaluated in on-farm trials at eleven locations across Egypt in 2009 growing season.

Highly significant differences among hybrids for grain yield were detected at each location and in the combined analysis across locations.Variances due to locations and hybrids x locations interaction were highly significant for grain yield. Linear and non linear components were highly significant. Behera location had the highest environmental index and therefore it was considered as the most favorable environment for realizing the genotypes grain yield potential, while Minia was considered the poorest grain yielding location.

The promising single crosses, i.e. Gz 505, Sk101, Sk 105 and Sk 106 did not significantly differ from SC10 and SC 129 for grain yield , while SC 103 was significantly higher than SC 10 and insignificantly higher than SC129 for grain yield . Also, TWC Sd 47, TWC Sd 49 and TWC Sd 52 did not significantly differ from the check TWC 352, while TWC Gz 51 was significantly higher than TWC 352 for grain yield. These nine new hybrids, according to maize hybrid registration rules in Egypt, might be recommended for release as new commercial hybrids. However, this study prefer SC Sk 101, SC Sk 105 and SC Sk 106 to be released as new commercial single crosses, due to their high stability for grain yield under varying locations.

Key words: *Maize, Stability, Genotype x environment interaction.*

INTRODUCTION

Hybrid adaptability across diverse environments is usually tested by its interaction with different environments. Hybrid or genotype is considered to be more adaptive or stable if it has a high mean yield but low degree of fluctuations in yielding ability when grown across diverse environments. There are two possible strategies for developing cultivars with low G x E interaction. The first is subdivision or stratification of a heterogeneous area into smaller, more homogenous sub-regions, with breeding programs aimed at developing cultivars for specific sub-regions. However, even with this refinement, the level of interaction can remain high because breeding area does not reduce the interaction of cultivars with locations on years. The second strategy for reducing G x E interaction involves selecting cultivars with better stability across a wide range of environments in order to better predict behavior (Eberthart and

Ressell 1966, Tai 1971).The variety with a high mean, regression coefficient close to unity ($b_i = 1$) and the deviations from regression as small as possible ($S^2d_i = 0$) was stable (Eberhart and Russell 1966). Yield stability is influenced in part by the genetic structure of the variety. More heterozygous and more heterogeneous varieties are less affected by environmental differences (Lewontin 1957 and Allard and Bradshaw 1964). For example, maize double- cross hybrids that have smaller G x E interactions are more stable than maize single cross hybrids (Sprague and Federer 1951). More homogeneous generations, inbred lines and F_1 have larger G x E interactions than more heterogeneous generations, F_2 and BC_1 and more homozygous generations, inbred lines, have a larger G x E interaction than more heterozygous ones (Valdivia – Bernal and Hallauer 1991). Jensen and Cavalieri (1983) found that the correlation between yield and b value of the regression over the environmental index was negative but the correlation was relatively low. Carvalho *et al* (2000) found that the hybrids showed better environment adaptation than open pollinated cultivars. The hybrids had good production stability in all environments. Tollenaar and Lee (2002) showed that high yielding maize hybrids can differ in yield stability, but results do not support the contention that yield stability and high grain yield are mutually exclusive. Badu-Apraku *et al* (2003) found that the differences among environments accounted for 85% of total variation in grain yield. Lee *et al* (2003) stated that grain yield stability can be improved through recurrent selection by selecting solely for mean performance across multiple environments. Shehata *et al* (2005) constructed an index which combined the mean yield and two parameters of stability,i.e. b_i and $S^2_{y.x}$ of the regression of variety mean on environmental index and it was designated as a superiority index. They reported that a superiority index could be used in estimating the degree of desirability for the different hybrids. El Sherbieny *et al* (2008) found that genotype x environment (G x E) interaction and their partition, E (linear), G x E (linear) and pooled deviations (non- linear) were significant for grain yield. They added that the coefficient of determination (R^2) values ranged from 0.68 to 0.96for grain yield, suggesting that large portion of variation for this trait could be attributed to linear regression on environmental index.

The objectives of our study were to determine the superior hybrids for grain yield under each environment and to identify the stable superior hybrids for grain yield under different environments.

MATERIALS AND METHODS

Five promising white single crosses, i.e. Gz505, Sk101, Sk103, Sk105 and Sk106 and four promising yellow three way crosses, i.e. Gz51, Sd47, Sd49 and Sd52 were produced in the Maize Breeding Program at Giza (Gz), Sakha (Sk) and Sids (Sd) Agricultural Research

Stations in 2008 growing season. These nine promising hybrids, in addition to three commercial hybrids, i.e. SC10, SC129 and TWC 352 were evaluated in on-farm variety testing trials in farmers fields in the last stage of maize hybrid registration in Egypt at eleven governorates across Egypt, i.e. Behera, Kafr El-Sheikh, Dakahlia, Gharbia, Menufia, Sharkia, Kalubia, Beni-Suef, Minia, Assiut and Sohag in 2009 growing summer season. A randomized complete block design with six replications was used at each location. Plot size was four rows, 6m long, 0.7m apart and 0.25m between hills. Two kernels were planted per hill and the plants were thinned to one plant/hill before the first irrigation, giving a plant density of 24000 plants/feddan. Nitrogen fertilizer, at the rate of 120 kg N/fed was splited into two equal doses and was applied before the first and second irrigation in Urea form. Phosphorus and Potassium fertilizers were added at the rate of 30 kg P_2O_5 and 24 kg K_2O /fed for all plots before planting irrigation. All recommended agricultural practices were followed through the growing season. The inner two rows of each plot were harvested and weight of the harvested ears/plot (kg/plot), shelling percentage and grain moisture were recorded; these data were used to calculate grain yield in ardab/feddan (ard/fed),where one ardab = 140 kg adjusted at 15.5% grain moisture and one feddan = 4200 m^2.

Statistical analysis at each location for grain yield was done according to Steel and Torrie (1980). Bartlett (1937) test was used to test the homogeneity of error mean squares. In case of homogeneity, combined analysis of variance across locations was done. Hybrid effect was assumed to be fixed, while the location effect was considered random. Stability analysis across eleven locations was performed according to Eberhart and Russell (1966).

RESULTS AND DISCUSSION

Mean grain yield (ard/fed) of the nine promising hybrids and the three check hybrids at eleven environments are presented in Table (1). Highly significant differences among hybrids were detected at each location for grain yield. The promising single crosses, which revealed significant superior yield than the highest check, were SC Sk 101 at Kafr El-Sheikh, Dakahlia and Menofia; SC 103 at Dakahlia, Menofia and Minia; SC Sk 105 at Menofia and SC Gz 505 at Minia. Compared with the check TWC 352, the promising TWC Gz 51 was significantly higher for grain yield at Gharbia, Minia, Assiut and Sohag, hybrid TWC Sd 47 at Kafr El-Sheikh, Sharkia, Assiout and Sohag, TWC Sd 49 at Garbia and Kalubia and TWC Sd 52 at Sharkia. This study suggests using the above mentioned promising hybrids for these locations.

Analysis of variance of grain yield for the 12 hybrids across the eleven locations is presented in Table (2) . Differences among the locations were found to be highly significant for grain yield, indicating that the eleven locations were different in their environmental conditions. Highly significant differences among hybrids were detected for grain yield.

Mean values ($\overline{X}$) of five promising single crosses for grain yield (ard/fed) and their percentage of yield superiority over checks SC 10 and SC 129 as well as four promising yellow three way crosses relative to the yellow check TWC 352 are presented in Table (3). The promising single hybrids Gz 505, Sk 101, Sk 105 and Sk 106 did not significantly differ from SC 10 and SC 129 for grain yield , while SC 103 was significantly higher than SC 10 but did not differ from SC 129 for grain yield . Also, TWC Sd 47, TWC Sd 49 and TWC Sd 52 did not significantly differ from the check TWC 352, while TWC Gz 51 was significantly higher than

Table 1: Mean grain yield (ard/fed) of the nine promising hybrids and the three check hybrids evaluated at eleven environments in 2009 season.

Hybrid	Behera	Kafr El-Sheikh	Dakahlia	Gharbia	Menufia	Sharkia	Kalubia	Beni-Seuf	Minia	Assiut	Sohag
SC Gz 505	34.44	28.16	23.67	28.98	30.26	29.17	31.67	29.48	28.75	33.58	26.77
SC Sk 101	34.73	30.45	26.84	31.98	32.28	27.96	32.50	24.29	26.58	32.58	24.79
SC Sk 103	37.68	24.96	27.45	36.40	35.46	28.48	30.56	26.55	28.63	32.86	29.76
SC Sk 105	35.15	24.63	24.22	34.60	31.34	29.67	29.88	26.12	22.32	33.19	22.07
SC Sk 106	35.39	27.31	24.58	29.15	29.30	28.95	27.56	25.27	24.22	31.44	21.03
TWC Gz 51	31.72	26.58	26.34	29.56	26.87	29.59	25.49	23.80	24.02	32.90	25.23
TWC Sd 47	35.26	26.52	22.63	26.44	30.35	30.02	25.44	22.00	17.13	27.34	22.50
TWC Sd 49	32.91	25.66	20.86	28.36	32.33	29.21	29.82	22.56	19.46	24.41	16.21
TWC Sd 52	31.91	25.77	22.78	24.65	28.12	30.50	26.83	21.71	13.16	24.41	15.83
SC10	36.24	26.63	22.89	32.05	28.49	29.57	30.43	24.95	24.63	31.33	24.45
SC 129	37.07	26.12	23.35	33.26	26.98	30.24	30.78	26.82	24.54	35.77	29.26
TWC 352	33.46	24.21	21.20	23.22	29.89	28.87	24.45	20.61	16.98	24.45	18.85
F test	2.64**	5.01**	4.25**	10.03**	7.42**	3.29**	8.27**	4.06**	20.36**	20.10**	29.19**
Mean	34.66	26.42	23.90	29.89	30.14	29.35	28.78	24.51	22.54	30.35	23.06
LSD 0.05	3.30	2.14	2.89	3.55	2.58	1.14	2.67	3.58	3.07	2.57	2.39

** Significant at 0.01 level of probability.

Table2: Analysis of variance of grain yield for 12 hybrids across eleven locations

SOV	d.f	S.S	M.S
Locations (L)	10	10403.78	1040.37**
Rep/L	55	3100.9	56.38
Hybrids (H)	11	3473.41	315.76**
H x L	110	3671.53	33.37**
Error	605	3529.06	5.83

** Significant at 0.01 level of probability.

Table 3: Mean ($\bar{X}$) of five promising single crosses for grain yield (ard/fed) and their percentage of yield superiority over the checks SC10 and SC129 as well as of four promising yellow three way crosses relative to TWC 352 across eleven locations.

Hybrid	$\bar{X}$	% Grain yield (ard /fed)		
		SC 10	SC 129	TWC 352
SC Gz 505	29.54	4.27	0.23	---
SC Sk 101	29.54	4.27	0.23	---
SC Sk 103	30.80	8.71*	4.51	---
SC Sk 105	28.47	0.49	-3.39	---
SC Sk 106	27.65	-2.40	-6.17	---
TWC Gz 51	27.46	---	---	14.25*
TWC Sd 47	25.97	---	---	7.31
TWC Sd 49	25.62	---	---	5.86
TWC Sd 52	24.15	---	---	-0.20
SC 10	28.33			
SC 129	29.47			
TWC 352	24.20			
L S D 0.05	1.97			

* Significant at 0.05 level of probability.

TWC 352 for grain yield. These nine hybrids, according to maize hybrid registration rules in Egypt, might be recommended to be released as new commercial hybrids.

The mean squares due to hybrids × locations interaction (Table 2) were highly significant, indicating that the grain yield of hybrids was different from one location to another. Also presence of significant genotype × environment interaction showed the consistency of performance of maize genotypes across the testing environments and advocating the adequacy of stability analysis. Kang and Gorman (1989) stated, where G x E interaction is significant, its cause, nature and implications must be carefully considered in breeding programs. Basford and Cooper (1998) reported that statistically, G xE interactions are detected as significantly different patterns of response among the genotypes across environments and biologically, this will occur when the contributions (or level of expression) of the genes regulating the trait differ among environments. Badu- Apraku *et al* (2003), Habliza and Khalifa (2006), El-Sherbieny *et al* (2008) and Mosa *et al* (2009) found that G x E interaction was significant for grain yield.

Analysis of variance for grain yield stability parameters for the 12 hybrids across locations is presented in Table (4). Hybrids significantly differ for grain yield. Hybrids x locations interaction component was further partitioned into linear (hybrids x locations) and non linear (pooled deviation) components. Mean squares for both of these components were tested against pooled error mean square. The linear and non linear components were highly significant, indicating that the linear (predictable) and non linear (unpredictable) components shared with hybrids x locations interaction. Also significant linear component means that the tested hybrids did not similarly respond to the varied locations, while significant pooled deviation, means that the deviation of all hybrids from linearity was significant. These results are in agreement with conclusions reached by Worku *et al* (2001), Lee *et al* (2003) , Rasul *et al* (2005), El- Sherbieny *et al* (2008) and Mosa *et al* (2009).

Linear component was not significant when tested against non linear, indicating the equal importance of both linear and non- linear interaction for grain yield in these hybrids. This result supports the findings of Worku *et al* (2001) and El-Sherbieny *et al* (2008).

Table 4. Analysis of variance for stability parameters of grain yield for 12 Hybrids planted at eleven locations.

SOV	d.f	S.S	M.S
Hybrids (H)	11	578.9025	52.6275**
Locations(L)+(HxL)	120	2345.892	19.5491**
L (Linear)	1	1733.965	1733.965**
C x L (Linear)	11	65.5699	5.9609**
Pooled deviation	108	546.3828	5.0591**
SC Gz 505	9	36.6912	4.0768*
SC Sk 101	9	28.29	3.14
SC Sk 103	9	75.0699	8.3411**
SC Sk 105	9	26.181	2.909
SC Sk 106	9	13.3263	1.4807
TWC Gz 51	9	32.247	3.583*
TWC Sd 47	9	35.6049	3.9561*
TWC Sd 49	9	63.0126	7.0014**
TWC Sd 52	9	86.9463	9.6607**
SC 10	9	15.3603	1.7067
SC 129	9	70.6383	7.8487**
TWC 352	9	44.3223	4.9247*
Pooled error	660	4430.052	1.67

*,** significant at 0.05 and 0.01 levels of probability, respectively

Estimates of environmental index for grain yield at eleven locations are presented in Table (5). Results showed that Behera location had the highest yield potential of the genotypes, while Minia was the lowest yielding location, indicating that the mean of the tested genotypes varied from one location to another .

Table 5: Estimates of environmental index for grain yield at eleven locations.

Environment	Environmental index
Behera	7.064
Kafr El-Sheikh	-1.185
Dakahlia	-3.70
Gharbia	2.286
Menufia	2.538
Sharkia	1.751
Kalubia	1.183
Beni- Seuf	-3.087
Minia	-5.065
Assiut	2.754
Sohag	-4.539

Estimates of stability parameters for grain yield (ard/fed) of 12 hybrids evaluated across eleven locations are presented in Table (6). Genotype with high grain yield mean ($\bar{x}$) larger than the over all genotypes mean ($\bar{\bar{x}}$) combined with a regression coefficient equal to the unity (b_i =1) and small deviation from regression (S^2d_i =0) is stable (Eberhart and Russel 1966). Therefore the three promising single crosses, i.e. SC Sk101(b_i = 0.83 was not significantly different from unity, S^2d_i = 1.47 was not significant and $\bar{x}$ = 107.02 % of $\bar{\bar{x}}$), SC Sk105 (b_i = 1.18, S^2d_i = 1.23 and $\bar{x}$ = 103.15% of $\bar{\bar{x}}$) and SC Sk106 (b_i = 0.98, S^2d_i =- 0.19 and $\bar{x}$ = 100.18% of $\bar{\bar{x}}$) and the check SC10 (b_i = 1.01, S^2d_i = 0.03 and $\bar{x}$ = 102.64% of $\bar{\bar{x}}$)were the most stable for grain yield. Moreover their coefficient of determination (R^2) were high (0.79, 0.88, 0.91 and 0.90%, respectively), confirming their stability . Vargas *et al* (1999) reported that, multi-environment trials play an important role in selecting the best cultivars to be used in future years at different locations and in assessing cultivar

Table 6. Estimates of stability parameters of grain yield (ard/fed) for 12 crosses evaluated at 11 locations.

Cross	$\bar{X}$	b_i	S^2d_i	R_i^2
SC Gz 505	29.54	0.61*	2.40*	0.59
SC Sk 101	29.54	0.83	1.47	0.79
SC Sk 103	30.80	0.85	6.66**	0.58
SC Sk 105	28.47	1.18	1.23	0.88
SC Sk 106	27.65	0.98	-0.19	0.91
TWC Gz 51	27.46	0.65*	1.90*	0.65
TWC Sd 47	25.97	1.19*	2.28*	0.85
TWC Sd 49	25.62	1.27*	5.32**	0.78
TWC Sd 52	24.15	1.28*	7.98**	0.73
SC 10	28.33	1.01	0.03	0.90
SC 129	29.47	0.95	6.17**	0.64
TWC 352	24.20	1.17	3.25*	0.81
Mean ($\bar{\bar{X}}$)	27.6	1.00± 0.19		

$\bar{X}$: mean cross for grain yield (ard/ fed) , b_i : regression coefficient, S^2d_i : deviation from regression

$\bar{\bar{X}}$: mean over all crosses for grain yield (ard/ fed) , R_i^2: coefficient of determination (Phinthus 1973)

stability across environments before its commercial release. Carvalho *et al* (2000) stated that the hybrids that gave coefficient of determination (R^2) more than 80% had good production stability in all of the environments .Tollenaar and Lee (2002) found that stability analysis showed that high yielding maize hybrid can differ in yield stability, but results did not support the contention that yield stability and high grain yield are mutually exclusive.

Although results from this study showed that the nine promising hybrids according to maize hybrid registration rules in Egypt might be recommended to be released as new commercial hybrids, however this study prefer SC Sk101, SC Sk105 and SC Sk106 to be released as new commercial single crosses, because they showed stable grain yield under varying environments.

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الملخص العربى

الثبات المحصولي لبعض هجن الذرة الشامية المبشرة تحت مواقع مختلفة

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ثبات صفة محصول الحبوب للهجن الجديدة من الأهداف المهمة في برنامج التربية. ويهدف هذا البحث التعرف على الهجن المتفوقة و الثابتة فى صفة محصول الحبوب تحت المواقع المختلفة .حيث تم تقييم خمس هجن فردية بيضاء مبشرة (هـ.ف جيزة ٥٠٥، هـ.ف سخا١٠١، هـ.ف سخا ١٠٣، هـ.ف سخا١٠٥و هـ.ف سخا١٠٦) واربع هجن ثلاثية صفراء مبشرة (هـ.ث جيزة ٥١، هـ.ث سدس٤٧، هـ.ث سدس٤٩و هـ.ث سدس ٥٢) مع ثلاث من الهجن التجارية (هـ.ف ١٠، هـ.ف ١٢٩و هـ.ث ٣٥٢) فـي التجـارب التأكيدية فـى حقـول المزارعين فى ١١ موقع مختلفة فى مصر فى موسم ٢٠٠٩.

كانت الاختلافات بين الهجن فى محصول الحبوب عالية المعنوية عند كل موقع والتحليل المجمع عبر المواقع كذلك كان التباين بين المواقع والتفاعل بين المواقع والهجن عالي المعنوية لمحصول الحبوب .اظهر التفاعل الخطى وغير الخطى للهجن معنوية عالية. أعلى دليل بيئي تحصل عليه فى موقع البحيرة مما يدل على أنة أفضل المواقع محصولا

وعلى العكس موقع المنيا اظهر اقل دليل بيئى. الهجن الفردية (جيزة ٥٠٥ ، سخا١٠١، سخا١٠٥ و سخا ١٠٦) كانت غير مختلفة معنوياً عن هجن المقارنة هـ.ف ١٠، و هـ.ف١٢٩ بينما زاد محصول الهجين سخا ١٠٣ معنويا عن هجين فردى ١٠ وغير معنوى عن هـ.ف١٢٩ .كذلك الهجن الثلاثية سدس٤٧ و سدس٤٩ وسدس ٥٢ كانت غير مختلفة معنوياً عن هجين المقارنة هـ.ث ٣٥٢ بينما هجين ثلاثى جيزة٥١ يزيد معنويا فى المحصول عن هـ.ث٣٥٢. هذه الهجن التسعة طبقا للنظام المصرى لتسجيل الاصناف يمكن التوصية بتسجيلها كهجن جديدة ومع ذلك هذه الدراسة تفضل هـ.ف سخا١٠١ وهـ.ف سخا ١٠٥ و هـ.ف ١٠٦ للتسجيل كهجن تجارية حيث أنها أظهرت ثباتاً لصفة المحصول تحت المواقع المختلفة.