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GENOTYPE × ENVIRONMENT INTERACTION AND STABILITY OF GRAIN YIELD AND LATE WILT RESISTANCE IN SOME PROMISING MAIZE HYBRIDS

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ABSTRACT

Stability analysis helps in understanding the genotypes adaptability over different environmental conditions and identification of adaptable genotypes. The objective of this study was to estimate the stable superior corn hybrids for grain yield and late wilt resistance. Ten promising white maize hybrids along with four commercial white hybrids were evaluated in 2007 growing season at five research stations i.e Sakha, Gemmeiza, Sids, Nubaria and to Mallawy evaluate: days to 50% silking, plant height, ear height and grain yield. The best seven promising hybrids for grain yield which were selected from 2007 experiments (SC Sk 99, SC Sk 100, SC Sk 101, SC Sk 103, SC Sk 105, SC Sk 106 and TWC Sk 107) along with three checks (SC10, SC122 and TWC 321) were planted in late wilt disease nurseries under artificial inoculation conditions at Sakha, Gemmeiza, Sids and Mallawy locations in 2008 growing season for evaluating: grain yield and late wilt resistance. The results of 2007 summer season showed that mean squares due to the environments, hybrids and their interaction were significant for all studied traits. SC Sk103 was significantly higher in yield, earlier and of shorter plants than the best check (SC 129). Also, SC Sk99, SC Sk100, SC Sk101, SC Sk105 and SC Sk106 did not significantly differ from SC129 for grain yield and other studied traits. On the other hand, the TWC Sk107 gave desirable estimates for grain yield, earliness and plant and ear heights compared to the check TWC 321. Evaluation results of 2008 season showed significant mean squares due to the interaction between hybrids and environments for the studied traits. The linear interaction was highly significant for late wilt resistance, while the non linear interaction was significant for grain yield. The single crosses SC Sk101, SC Sk103, SC Sk105 and SC Sk106 showed stable performance for grain yield under different environments and produced grain yield that surpassed the two checks SC 10 and SC 122. Moreover they were more resistant to late wilt disease. More extensive experiments will be needed before their release as stable high yielding varieties of resistance to late wilt disease.

Key words: ***Maize, Stability, Genotype X Environment interaction, Late wilt.***

INTRODUCTION

In a plant breeding program, the existence of genotype - environment (GE) interaction necessitates extensive yield testing in order to identify genotypes that are high in yield and stable across environments. Comstock and Moll (1963) have outlined the concept of environments. The environment of a single plant, as opposed to that of another one grown at the same time and almost the same place, can be termed the micro-environment, as compared to the environment associated with a general location or a

period of time, which can be termed the macro environment. Eberhart and Russell (1966) and Scott (1967) demonstrated genetic differences among maize hybrids in yield stability. Several other methods have been proposed to characterize such stability (Freeman 1973). All methods, however, require employing a large number of testing environments. Elto and Hallauer (1980) found that the simple correlations between mean yield and regression coefficient and mean yield and deviation from regression were highly significant. It seems that selection of hybrids for high mean yield across environments should be emphasized first and then the relative stability of the elite hybrids across environments should be determined. Hallauer and Miranda (1981) and Gauch and Zobel (1996) reported that if the number of new genotypes to be evaluated were large, five different environments would be adequate to determine different stability parameters and/or optimize the amount of GE interactions. Lin *et al* (1986) reported that a particular genotype may be considered to be stable if its variance among environments is small, response to environments is parallel to the mean response of all genotypes in the trial and the residual mean squares from regression model is small. Vargas *et al* (1999) reported that, multi-environments trials play an important role in selecting the best cultivars to be used in future years at different locations and in assessing cultivars stability across environments before its commercial release. Pixley and Bjarnason (2002) used variances of deviation from regression (S^2d) and genotype x environment interaction approach to define the most desirable and stable maize genotypes. They indicated that the previous estimates were large for single cross hybrids followed by three way, double - cross and open pollinated cultivars, respectively. Tollenaar and Lee (2002) found that high yielding maize hybrids can differ in yield stability. Soliman (2006) found that, the genotype x environment interaction was highly significant for days to 50% silking and grain yield. A large portion of this interaction was accounted for the linear regression on the environmental means. The magnitude of non linear components was considerably small.

The objective of this investigation was to identify the stable superior hybrids for grain yield and late wilt resistance.

MATERIALS AND METHODS

Nine promising white single crosses i.e. SC Sk 99, SC Sk100, SC Sk 101, SC Sk 102, SC Sk103, SC Sk104, SC Sk105, SC Sk106, SC Gz120 and one promising white three way cross TWC Sk107 were developed at Sakha and Giza Research Stations and were produced in 2006 growing season. These ten hybrids along with four commercial white checks, i.e SC10, SC125 SC129 and TWC 321 were evaluated in 2007 growing season at five locations, i.e Sakha, Gemmeiza, Sids, Nubaria and Mallawy. The best seven promising hybrids for grain yield which were selected from 2007

evaluation trails, i.e SC Sk 99, SC Sk100, SC Sk101, SC Sk103, SC Sk105, SC Sk106, TWC Sk107 along with three checks SC 10, SC 122 and TWC 321 were evaluated in late wilt disease nurseries under artificial soil inoculation by the pathogen *Cephalosporium maydis* at Sakha, Gemmeiza, Sids and Mallawy locations in 2008 growing season. Randomized complete block design with four replications was used at each environment in 2007 growing season and six replications at each environment in 2008 growing season. Plot size was four rows, 6 m long, 0.8 m apart and 0.25 m between hills. Three kernels were planted per seedlings hill and plants were thinned to one plant/hill before the first 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 the grain yield in tons/hectare (t/ha) adjusted at 15.5% grain moisture content. Data were recorded for grain yield (t/ha), number of days to 50% silking, plant and ear height (cm) for experiments 2007 season. While grain yield (t/ha) and late wilt resistance % (after transforming the data by using arcsine scale), were recorded for experiments of 2008 season. Statistical analysis at each location for the studied traits was done according to Steel and Torrie (1960). Bartlett (1937) test was used to test the homogeneity of error mean squares. In case of homogeneity, combined analysis of variance over locations was done. The hybrid effect was assumed to be fixed while the location effect was considered random. Stability analysis across four locations was performed for 2008 experiments according to the following model of Eberhart and Russell (1966).

$Yij = Ui + B_i Ij + Sij$

Yij = The mean of the i^{th} variety at the j^{th} environment

Ui = Mean of all the varieties over all the environments

Bi = the regression coefficient of the i^{th} variety on the environmental index which measures the response of this variety to varying environments

Ij = The environmental index which is defined as the deviation of the mean of all the varieties at a given location from the over all mean.

Sij = The deviation from regression of the i^{th} variety at the j^{th} environment.

Also, they defined the desired variety with a high mean performance ($\overline{X}$), unit regression coefficient (b_i=1.0) and the deviations from regression as small as possible (S^2d_i= 0)

RESULTS AND DISCUSSION

The combined analysis and of variance for four studied traits across five environments in 2007 season are shown in Table (1). Differences among the five environments were found to be highly significant for all studied traits, suggesting marked differences between the five environments in their climatic and soil conditions.

Table 1. Combined analysis of variance for four traits across five environments in 2007 season.

S.O.V	d.f	Days to 50% silking	Plant height	Ear height	Grain yield
Environment (E)	4	957.61**	54184.31**	18089.72**	418.83**
Rep/E	15	10.72	300.98	185.47	1.36
Hybrids (H)	13	100.06**	3058.76**	2208.63**	4.70**
E x H	52	3.63**	511.28**	382.62**	1.28**
Error	195	1.22	161.61	106.22	0.69

** Significant at 0.01 level of probability.

Mean performance of four traits at the five environments in 2007 season is presented in Table (2). The results exhibited that, Sakha location produced high mean for all studied traits except for days to 50% silking, while reverse result was obtained for Sids location where it produced the lowest mean for all traits except for days to 50% silking, indicating that the environmental conditions at Sakha location were non stress, while Sids location was a stressed environment. Frey (1964) and Frey and Maldonado (1967) defined the stressed environment as the one in which mean performance for a certain attribute is low and that stress for one trait does not mean stress for all traits under study.

Table 2. Means of four traits at five environments in 2007 season.

Environments (Locations)	Days to 50% silking	Plant height (cm)	Ear height (cm)	Grain yield (t/ha)
Sakha	65.19	297.85	163.3	12.13
Gemmeiza	61.94	264.08	146.39	6.82
Sids	68.69	221.16	120.26	5.14
Nubaria	58.23	226.69	121.73	6.91
Mallawy	60.28	246.25	139.64	9.47
$L.S.D_{0.05}$	1.2	6.6	5.1	0.4

Mean squares due hybrids were found to be highly significant for all traits, indicating wide differences existing among them for all studied traits. The interaction G x E was found to be highly significant for all traits, meaning that the behavior of these hybrids differed markedly from one location to another. Comstock and Moll (1963) defined the genotypes x

environment interaction as the differential response of phenotypes to the change in environments.

Mean performance for the studied traits of the ten promising hybrids and four checks across the five environments is presented in Table (3). The results exhibited that the promising cross SC Sk103 was significantly higher in yield, earlier and, shorter in plant and ear height compared to the best check SC 129. Meanwhile there were no significant differences between single crosses Sk 99, Sk 100, Sk 101, Sk 104, Sk 105, Sk 106 and SC GZ 120 and SC 129 for grain yield and other studied traits.

Table 3. Mean performance of ten promising and four check hybrids for four traits as an average across five environments in 2007 season.

Hybrids	Days to 50% silking	Plant height (cm)	Ear height (cm)	Grain yield (t/ha)
SC Sk 99	64.2	242.2	137.1	8.4
SC Sk100	65.6	258.6	147.2	8.1
SC Sk101	63.7	244.5	136.7	8.5
SC Sk102	64.8	270.6	157.7	7.6
SC Sk103	60.1	239.3	127.1	9.1
SC Sk104	60.8	248.1	126.4	8.0
SC Sk105	59.8	239.1	130.1	8.1
SC Sk106	64.1	261.2	150.7	8.6
SC Gz120	63.9	260.6	148.8	8.0
TWC Sk107	58.4	224.5	119.5	7.7
Check SC10	65.1	265.1	140.4	7.4
Check SC125	63.8	256.2	141.2	8.0
Check SC129	61.9	252.1	135.5	8.2
Check TWC321	64.1	254.5	137.2	7.2
C.V%	1.75	5.06	7.45	10.31
LSD 0.05	1.2	14.30	12.37	0.71

Percentage of grain yield superiority for the ten promising single crosses relative to commercial hybrid SC 10, SC 125 and SC 129 across the five environments in 2007 season is shown in Table (4). The promising hybrids SC Sk99, SC Sk101, SC Sk103 and SC Sk106 were better for grain yield than all checks. While, SC Sk100 and SC Sk105 were higher in grain yield than the two checks SC 10 and SC 125. These six promising single crosses were selected for an advanced level of testing.

On the other hand, TWC Sk107 was better than the check TWC 321 for grain yield, earliness, plant and ear heights. This hybrid was recommended for further levels of testing. Elto and Hallauer (1980) stated that the selection of hybrids for mean yield across environments should be emphasized first and then the relative stability of the elite hybrids across environments should be determined.

Table 4. Percentage of grain yield superiority for ten promising single crosses over the commercial hybrids SC10, SC125 and SC129, data are combined across five environments in 2007 season.

Hybrids	%		
	SC10	SC125	SC129
SC Sk 99	12,31*	4.09	1.57
SC Sk 100	9.10	1.11	-1.33
SC Sk 101	13.78*	5.45	2.90
SC Sk 102	2.54	-4.96	-7.26
SC Sk 103	22.08*	13.15*	10.41*
SC Sk 104	7.49	-0.37	-2.78
SC Sk 105	9.23	1.24	-1.21
SC Sk 106	15.12*	6.69	4.11
SC Gz 120	7.36	-0.49	-2.90

*, Significant at 0.05 level of probability.

Stability analysis of variance for grain yield and late wilt resistance for the ten hybrids which was evaluated at four environments in 2008 season is presented in Table (5). Results showed that the differences among locations were highly significant for all studied traits, indicating that the four environments differed in their conditions. Highly significant differences among hybrids were also exhibited for all the studied traits.

Table 5. Stability analysis of variance for grain yield and late wilt resistance for ten hybrids evaluated at four environments in 2008 season.

S.O.V.	d.f	Mean squares	
		Grain yield	Late wilt resistance
Hybrids (H)	9	1.772**	14.445**
Environments (E)	3	57.18**	57.962**
H x E	27	0.217*	5.703**
E+H x E	30	5.913**	10.929**
E (Linear)	1	171.54**	173.88**
H x E (Linear)	9	0.109	14.890**
Poold deviation	20	0.244*	0.997
SC Sk 99	2	0.432*	0.0038
SC Sk100	2	0.508*	1.011
SC Sk101	2	0.162	0.058
SC Sk103	2	0.305	0.015
SC Sk105	2	0.293	2.059
SC Sk106	2	0.185	0.727
TWCSK 107	2	0.276	4.538**
SC 10	2	0.027	0.09
SC 122	2	0.032	1.413
TWC 321	2	0.224	0.063
Pooled error	200	0.13	0.922

*,** Significant at 0.05 and 0.01 levels of probability, respectively.

Means of ten hybrids for grain yield and percentage of late wilt resistance over four environments in 2008 season are presented in Table (6). For grain yield, SC Sk101, SC Sk103, SC Sk105 and SC Sk106 were significantly higher than the check SC10 by 5.92%, 21.6%, 12.54 and 10.80% and than the check SC122 by 5.31%, 20.9%, 11.89% and 10.16%, respectively. Also, these four single crosses were highly resistant to late wilt disease with 99.81%, 97.52%, 98.37% and 99.37%, respectively. On the other hand, the check TWC 321 was insignificantly better than TWC Sk107 for grain yield and late wilt resistance.

Significant differences were observed for hybrid x environment interaction for the studied traits Table (5), indicating that the hybrid performance significantly differed from location to another, which encourage maize breeders to develop high yielding and more stable hybrids under wide environmental conditions. In this respect, Eberhart and Russell (1966), Lin *et al* (1986), Ragheb *et al* (1993), Soliman (2006) and El Sherbieny *et al* (2008) mentioned that the high yielding potential and average stability are mainly due to the attributes involved in determining the wide adaptation of new genotypes.

Table 6. Means ($\bar{X}$) of ten hybrids for grain yield (t/ha) and late wilt resistance and percentage of yield superiority for six promising single crosses over the commercial hybrids SC10 and SC 122, data are combined across four environments in 2008 season.

Hybrids	Grain yield (t/ha)			Late wilt resistance %
	$\bar{X}$	%		$\bar{X}$
		SC10	SC122	
SC Sk 99	8.9	3.48	2.88	99.62
SC Sk 100	8.3	-3.01	-3.57	98.71
SC Sk 101	9.1	5.92*	5.31*	99.81
SC Sk 103	10.4	21.60*	20.90*	97.52
SC Sk 105	9.6	12.54*	11.89*	98.37
SC Sk 106	9.5	10.80*	10.16*	99.37
TWC Sk107	8.4	-	-	94.58
SC 10	8.6	-	-	99.68
SC 122	8.6	-	-	98.47
TWC 321	8.7	-	-	99.02

*** significant at 0.05 level of probability.**

Partitioning of H x E interaction into H x E (linear) and pooled deviations (non linear) exhibited that G x E (linear) was highly significant for late wilt resistance, while pooled deviation (non linear) was significant for grain yield. This means that a large portion of hybrid x environment

interaction was accounted by the linear regression on the environmental means for late wilt disease and non linear for grain yield. Also, it means that the tested hybrids did not similarly respond within the varied locations for late wilt resistance while, significant pooled deviation for grain yield means that the deviation of all hybrids from linearity was significant and more obvious.

Considering the three criteria of the promising hybrid recognized by Eberhart and Russell (1966), the SC Sk101, SC Sk103, SC Sk105 and SC Sk106 would be the most stable hybrids with respect to grain yield because they exhibited higher yield performance than mean grain yield of all hybrids, have values of b_i around unity (0.933, 0.989, 0.799 and 1.041 respectively), with small and insignificant deviations from regression (0.032, 0.175, 0.163 and 0.055, respectively). While for late wilt resistance, the results exhibited that the hybrids SC Sk100 and TW C321 could be considered to be stable hybrids for late wilt resistance (Table 7).

Table 7. Stability parameters for grain yield (t/ha) and late wilt resistance % of ten hybrids under different environmental conditions.

Hybrids	Grain yield (t / ha)			Late wilt resistance%		
	$\overline{X}$	b_i	S^2d_i	$\overline{X}$	b_i	S^2d_i
SC Sk 99	8.91	0.998	0.302*	99.62	0.297	-0.918
SC Sk 100	8.35	1.152	0.378*	98.71	1.074	0.089
SC Sk 101	9.12	0.933	0.032	99.81	0.235	-0.864
SC Sk 103	10.47	0.989	0.175	97.52	1.982	-0.907
SC Sk 105	9.69	0.799	0.163	98.37	0.811	1.137
SC Sk 106	9.54	1.041	0.055	99.37	0.136	-0.195
TWC Sk107	8.47	0.941	0.146	94.58	2.968	3.616**
SC 10	8.61	1.084	-0.103	99.68	0.297	-0.832
SC 122	8.66	1.036	-0.098	98.47	1.591	0.491
TWC 321	8.70	1.026	0.094	99.02	0.609	-0.859
Mean	9.05			98.51		

*,** Significant at 0.05 and 0.01 levels of probability, respectively.

In general, the four single crosses Sk 101, Sk 103, Sk 105 and Sk 106 showed stability performance for grain yield under different environments, giving high average, have values of b_i around unity with small and insignificant deviations from regression. In addition they produced grain yield that surpassed the two check crosses (SC 10 and SC 122). Moreover, they had high resistance to late wilt disease. These four hybrids might be recommended to be released as new commercial white single crosses of maize.

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التفاعل البيئي الوراثي وتقديرات الثبات لمحصول الحبوب ومقاومة الذبول المتأخر لبعض هجن الذرة الشامية المبشرة

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يساعد تحليل الثبات فى تحديد كفاءة التراكيب الوراثية المختلفة على التأقلم تحت الظروف البيئية المختلفة. ويهدف هذا البحث الى تقدير الثبات لهجن الذرة الشامية الواعدة فى محصول الحبوب ومقاومة مرض الذبول المتأخر. قيمت ١٠ هجن بيضاء مبشرة مع أربع هجن تجارية من الذرة الشامية في خمسة محطات بحوث هى سخا والجميزة وسدس والنوبارية وملوى فى موسم ٢٠٠٧. اخذت البيانات لصفات عدد الايام حتى ظهور حرائر ٥٠% من النورات المؤنثة وارتفاعي النبات والكوز ومحصول الحبوب . تم انتخاب افضل الهجن للمحصول العالي وقيمت مع ثلاث من الهجن التجاريه فى حقول العدوى الصناعية بمرض الذبول المتأخر بسخا والجميزة وسدس وملوى موسم ٢٠٠٨ لتقدير صفة محصول الحبوب والمقاومة للذبول المتأخر.

أظهرت النتائج معنوية التباينات الراجعة لكل من البيئات المختلفة والهجن والتفاعل بينهما لكل الصفات المدروسة. اظهر الهجين الفردى سخا ١٠٣ زيادة معنويه فى المحصول وتبكيراً فى النضج وقصر فى ارتفاع النبات والكوز عن ه.ف١٢٩ أفضل الهجن التجارية في التجربة لهذه الصفات. كذلك كانت الهجن الفردية سخا ٩٩وسخا ١٠٠ وسخا ١٠١ وسخا ١٠٥و سخا١٠٦ لا تختلف معنويا عن هجين المقارنة الفردى ١٢٩ فى المحصول والصفات الأخرى. بينما تفوق الهجين الثلاثى سخا ١٠٧ فى المحصول والتبكير وقصر ارتفاع النبات والكوز عن الهجين الثلاثى التجارى ٣٢١. تم انتخاب هذه الهجن السبعه و تصعيدها الى مستوى متقدم من التقييم التجريبى.

أوضح التقييم موسم ٢٠٠٨ معنوية التباينات الراجعة للتفاعل بين الهجن والبيئات لكل الصفات المدروسة . كان التفاعل الخطى معنوي لصفه المقاومة لمرض الذبول المتأخر بينما كان التفاعل الغير خطى معنوي لصفة المحصول. أظهرت الهجن الفردية سخا ١٠١وسخا١٠٣وسخا١٠٥و سخا١٠٦ ثبات لصفه المحصول مع متوسطات عالية تتفوق على هجن المقارنة ه.ف ١٠ و ه.ف١٢٢ كذلك اظهرت مقاومة عاليه لمرض الذبول المتأخر. هذه الهجن الأربعة يمكن التوصية باستكمال خطوات تسجيلها للإطلاق التجاري لمن تثبت كفاءته منها بعد إجراء مزيد من التجارب المكبرة.

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