Egypt. J. Plant Breed. 24(1):55– 63(2020)

STABILITY FOR GRAIN YIELD OF SOME PROMISING MAIZE HYBRIDS

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ABSTRACT

Grain yield stability for the new maize hybrids is an important target in breeding programs. This study was carried out to identify the stable superior hybrids for grain yield across different environments in Egypt. Nine crosses along with the two commercial yellow single crosses, SC 162 and SC 168 were evaluated in 2018 season in on-farm trails at eleven locations (environments) across Egypt. These trails were the last stage evaluation of new maize hybrids registration in Egypt. A randomized complete block design with 6 replications was used. Plot size was 4 rows, 6 m long, 0.70 m apart and 0.24 m between hills. Results showed that mean squares due to environments (E), hybrids (H) and their interaction (HEI) were highly significant for grain yield. Environments (E) explained 73.07% of the total (E + H + HEI) variation, whereas (H) and (HEI) accounted for 5.68 and 21.25%, respectively. The promising hybrids H-1, H-3, H-5, H-6, H-7, H-8 and H-9 were significantly or not significantly superior to the better check for grain yield. According to maize registration rules in Egypt, these hybrids might be recommended to be released as new hybrids. However, this study suggests hybrids H-1, H-3, H-5 and H-7 because these hybrids had both high grain yield and stability performance under different environments.

Key words: ***Maize, Yield, Stability parameters, Single crosses, G x E interaction***

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important crops in Egypt and in the world agriculture economy. Developing high yielding maize hybrids and well adapted to a wide range of environments is the most important goal of the National Maize Research Program. The hybrid is considered to be more adaptive or stable if it shows a high mean yield and low degree of fluctuation in yielding ability when grown across diverse environments. There are many statistical methods to measure stability, no single method can adequately explain genotype performance across environments. Flores *et al* (1998) used twenty-two different methods (parametric, nonparametric and multivariate) for analysis of genotype x environment interaction. They reported that all methods of stability are valid although it's very different concepts of stability. Simultaneous selection for yield and stability has been proposed by many investigators. Frey (1983) found that the stability of yield depends on the ability of a given cultivar to react to changes in the environment. Zivanovic *et al* (2004) reported that a strategy that provides a maximal genetic improvement in maize yield must include simultaneous breeding for yield and stability, starting from initial segregating generations.

Tollenaar and Lee (2002) and Delic *et al* (2009) reported that the high grain yield and yield stability are not mutually exclusive. Flores *et al* (1998) and Sabaghnia *et al* (2006) revealed that usually the low mean yielding genotypes are the most stable. Bachireddy *et al* (1992) used three selection methods to compare 30 sweet corn hybrids over 5 years and they found that a significant genotype x environment interaction and mentioned that selection of hybrids on the basis of mean yield alone would not be appropriate but combining both yield and stability performance are useful. Sabaghnia *et al* (2014) and Sabaghnia (2016) reported that nonparametric statistical methods are independent of any assumption about the distribution of observations and thus can be useful alternatives to routine classical statistical methods. Delic *et al* (2009) found that the nonparametric methods are simple and easy for stability analysis.

The objective of this study was to estimate grain yield stability for nine hybrids using 6 stability parameters; coefficient of variation (CV%), coefficient of determination (R^2), ecovalence (W_i^2), stability variance (σ_i^2), the genotype absolute rank difference mean as tested across n environments ($S_i^{(1)}$) and the variance between the ranks across n environments ($S_i^{(2)}$).

MATERIALS AND METHODS

Nine promising yellow maize single crosses along with two check hybrids (SC 162 and SC 168) were evaluated in farmer fields in the last stage of maize hybrid registration in Egypt at eleven diverse locations (environments) across Egypt, *i.e.*, Behera, Kafr El Sheikh, Dakahlia, Gharbia, Menufiya, Sharkia, Giza, Beni-Suef, Minia, Assiut, and Sohag in 2018 season.

A randomized complete block design (RCBD) with six replications was used at each environment. Plot size consisted of 4 rows, 6 m long and 0.7 m apart. The inner two rows were harvested (plot size = 1/500 feddan (fed), one feddan = 4200 m^2). Planting was done in hills (2-3 kernels/hill) equally spaced 24 cm along the ridge. Thinning to one plant/hill was done 21 days after planting to secure 25000 plants/feddan. All cultural practices were carried out as recommended. At harvest, 110-120 days after planting, weight of harvested ears/plot, shelling percentage, and grain moisture were recorded. These data were used to calculate grain yield in ardab/feddan (ard/fed) adjusted at 15.5 % moisture.

Grain yield are statistically analyzed at each environment and across all environments. Combined analysis were computed after test homogeneity of variances according to Snedecor and Cochran (1967). Once ANOVA revealed that genotypes (G) and locations or environments (E) and GxE interaction (GEI) were statistically significant, four parametric and two nonparametric stability approaches were used. Parametric methods were, coefficient of variation (CV%) according to Francis and Kannenberg (1978), coefficient of determination (R^2) by Pinthus (1973), stability variance (σ_i^2) proposed by Shukla (1972), ecovalence (W_i^2) according to Wricke (1962), while nonparametric methods were the genotype absolute rank difference mean as tested across n environments ($S_i^{(1)}$) and the variance between the ranks across n environments ($S_i^{(2)}$) proposed by Huehn (1990).

RESULTS AND DISCUSSION

Combined analysis of variance for grain yield of 11 hybrids is presented in Table (1). Results revealed that highly significant mean squares were observed due to environments (E) for grain yield, meaning that these environments represented a wide range of differences in their climatic and soil conditions. Mean squares due to hybrids (H) were highly significant, indicating wide differences existed among them for grain yield. Mean squares due to hybrid x environment interaction (HEI) were highly significant, indicating that hybrids behaved differently under different environments. That encourages maize breeders to develop high yielding and more uniform hybrids under varied environmental conditions. Similar results were reported by Sowmya *et al* (2018) and Mosa *et al* (2019). Of the total (H + E + HEI) variance the largest portion of variation was caused by the environment effect 73.07%, whereas H and HEI accounted for 5.68 and 21.25%, respectively. Mosa *et al* (2012) found that environment explained most of variation, while (H) and (H x E) were small.

Table 1. Mean squares for grain yield combined over 11 environments in Egypt, 2018.

SOV	df	Grain yield		Explained%
		S.S	M.S	
Environments (E)	10	16938.57	1693.86**	73.07
Rep/E	55	2079.81	37.82	
Hybrids (H)	10	1316.02	131.60**	5.68
H × E	100	4925.84	49.26**	21.25
Error	550	5953.37	10.82	

** Significant at 0.01 level of probability.

Environmental index for grain yield (Table 2) was calculated as the difference between the environment mean and the mean over all environments. Results showed that Kafr El-Sheikh, Sohag, Dakahlia, Menia and Assiut were the most favorable environments, which expressed the highest mean grain yield, while Beni-Suif, Gharbya, Giza, Menufia, Behera and Sharkia were the poorest yielding environments. This illustrate that the performance of the studied hybrids varied from one environment to another.

Table 2. Environmental index for grain yield at 11 locations.

Location	Mean (ard fed^{-1})	Environmental index
Behera	**24.68**	**-3.474**
Kafr El-Sheikh	**36.26**	**8.104**
Dakahlia	**32.18**	**4.020**
Gharbia	**23.16**	**-4.994**
Menufiya	**24.47**	**-3.683**
Sharkia	**26.13**	**-2.030**
Giza	**23.73**	**-4.426**
Beni-Suef	**22.09**	**-6.071**
Minia	**32.97**	**4.812**
Assiut	**29.68**	**1.526**
Sohag	**34.37**	**6.216**
Average	**28.15**	

The new nine hybrids yield ranged from 26.33(ard fed^{-1}) for H-4 to 30.88 (ard fed^{-1}) for H-5 (Table 3). The yellow promising single cross H-5 significantly outyielded the two yellow checks, SC 162 and SC 168, with a superiority percentage of 8.20% relative to the superior check SC.168. Crosses H-1, H-3, H-6, H-7, H-8 and H-9 didn't differ significantly from the superior check. According to maize registration rules in Egypt, the promising hybrids could be recommended to be released as new commercial hybrids when they did not significantly (±) or significantly outyield the best commercial hybrid across eleven locations. Hence the promising hybrids H-1, H-3, H-5, H-6, H-7, H-8 and H-9 might be recommended to be released as new hybrids. 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 3. Mean performance of the nine promising yellow hybrids, two check hybrids and superiority percentage relative to the superior check hybrid across eleven environments.

Hybrid	Grain yield (ard fed^{-1})	
	Mean	Superiority% relative to the superior check
H-1	29.10	1.96
H-2	27.04	-5.26
H-3	28.42	-0.42
H-4	26.33	-7.74
H-5	30.88*	8.20*
H-6	27.66	-3.08
H-7	28.94	1.40
H-8	27.57	-3.40
H-9	29.19	2.28
SC 162	26.02	-
SC 168	28.54	-
Mean	28.15	
LSD 0.05	1.12	

***Indicates significant ($P \leq 0.05$)**

Stability parameters of the 11 studied hybrids for grain yield are given in Table (4). Francis and Kannenberg (1978) stated that the stable genotype has low CV% (<20%). Therefore, the hybrids H-1, H-3, H-4, H-5, H-9 and SC.168 were stable. On the contrary, H-2, H-6, H-7, H-8 and SC 162 were unstable. Based on Pinthus (1973) coefficient of determination R^2 values for grain yield, the hybrids H-6, H-7 and H-8 were stable because they had R^2 values close to 1. Carvalho *et al* (2000) stated that the hybrids that give R^2 >80% had good production stability in all environments. The ecovalence W_i^2 according to Wricke (1962) is the stability parameter. The genotypes with the smallest W_i^2 values are considered stable.

Table 4. Estimates of parametric and nonparametric stability statistics of 11 hybrids for grain yield across 11 environments.

Hybrids	Mean	CV%	R^2	W_i^2	σ_i^2	$S_i^{(1)}$	$S_i^{(2)}$
H-1	29.10	18.32	0.80	59.15	13.77	0.51	8.40
H-2	27.04	22.30	0.67	120.09	5.71	0.65	11.90
H-3	28.42	17.72	0.80	54.19	6.82	0.56	7.30
H-4	26.33	17.47	0.76	63.30	13.63	0.78	9.10
H-5	30.88*	19.27	0.79	73.93	7.29	0.67	9.80
H-6	27.66	21.90	0.88	48.06	8.12	0.64	10.10
H-7	28.94	25.90	0.93	86.44	4.96	0.62	11.40
H-8	27.57	20.74	0.85	49.10	9.65	0.60	8.60
H-9	29.19	17.01	0.71	80.60	5.09	0.73	10.70
SC 162	26.02	24.02	0.70	119.01	8.94	0.47	6.40
SC 168	28.54	18.68	0.77	67.11	6.32	0.71	9.80
Mean	28.21	20.30	0.79	74.63	8.21	0.63	9.41
LSD 0.05	1.12						

*** Significantly different from the superior check hybrid at 0.05 level of probability.**

The lowest W_i^2 values were shown by H-6 followed by H-8, H-3, H-1, H-4, SC 168 and H-5, respectively. These hybrids were therefore considered as stable, While H-2, H-7, H-9 and SC 162 were considered unstable based on W_i^2. A hybrid with small value of σ_i^2 is the most stable one (Shukla 1972), hence H-7, H-9, H-2, SC 168, H-3, H-5 and H-6 were considered stable, while H-1, H-4, H-8 and SC 162 were unstable.

Small values of the $S_i^{(1)}$ statistic measuring the mean absolute rank difference of genotypes across environments, indicate stability according to Huehn (1990). Hence, the hybrid SC 162 followed by H-1, H-3, H-8 and H-7 were stable, while the rest of hybrids were unstable. Also, Huehn (1990) suggested using the variance between the ranks across environments $S_i^{(2)}$ as a stability parameter, where genotypes with the smallest $S_i^{(2)}$ values are considered stable. Then the hybrids, SC 162 followed by H-3, H-1, H-8 and H-4 were stable.

In conclusion, both yield and stability of performance should be considered simultaneously to exploit the useful effect of hybrid x environment interaction (HEI) and to make hybrid selection more refined and precise. So from above results the yellow promising single cross H-5 had an average grain yield of 30.88 ard/fed which exceeded significantly the superior check SC 168 (28.54 ard/fed) and showed stable by three parametric stability statistics, *i.e.* CV%, W_i^2, and σ_i^2. Also hybrids H-1, H-3 and H-7 were not significantly higher for grain yield than the superior check (SC 168) and exhibited stable for (CV%, W_i^2, $S_i^{(1)}$ and $S_i^{(2)}$), (CV%, W_i^2, σ_i^2, $S_i^{(1)}$ and $S_i^{(2)}$) and (R^2, σ_i^2 and $S_i^{(1)}$). This study prefers these (H-5, H-1, H-3 and H-7) hybrids to be released as new commercial hybrids in Egypt, because the genotype that combines both high mean grain yield and stability performance together is favorable and so is suitable across variable environmental conditions (Allard and Bradshaw 1964, Kang and Pham 1991 and Mosa *et al* 2019).

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الثبات لمحصول الحبوب لبعض هجن الذرة الشامية المبشرة

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ثبات أداء الهجين تحت البيئات المختلفة من أهم أهداف برنامج التربية. لذلك تهدف هذه الدراسة لإنتخاب الهجن التى تمتلك كلا من المحصول العالى والثبات تحت البيئات المختلفة فى مصر. تم تقييم تسعة هجن فردية مبشرة صفراء بالإضافة إلى اثنين من الهجن التجارية للمقارنة فى ١١ موقع أو محافظة فى مصر موسم ٢٠١٨ . هذه التجارب تكون أخر مرحلة من مراحل التقييم لتسجيل الهجن الجديدة فى مصر. استخدم تصميم القطاعات الكاملة العشوائية فى ٦ مكرارات. القطعة التجريبية عبارة عن ٤ خطوط طول الخط ٦ متر والمسافة بين الخطين ٧٠ سم والمسافة بين الجور ٢٤ سم. أظهر التباين الراجع إلى البيئات والهجن والتفاعل بينها معنوية عاليه لصفة المحصول. تمثل الإختلافات بين البيئات ٧٣,٠٧% من إجمالى الاختلافات الراجعة لكل من (البيئات والهجن والتفاعل بينهما) بينما تمثل الاختلافات الراجعة للهجن حوالى ٥,٦٨% والإختلافات الراجعة للتفاعل بين الهجن والبيئات حوالى ٢١,٢٥%. أظهرت الهجن الفردية المبشرة الصفراء (H-1, H-3, H-5, H-6, H-7, H-8, H-9) زيادة معنوية أو غير معنوية فى محصولها عن أفضل هجين مقارنة ولذلك يمكن تسجيلها كهجن جديدة طبقا للقواعد المصرية لتسجيل الهجن. ولكن الدراسة تقترح تسجيل فقط الهجن (H-1, H-3, H-5, H-7) وذلك لانها تجمع بين المحصول العالى والثبات المحصولى تحت البيئات المختلفة.

المجلة المصرية لتربية النبات ٢٤(١): ٥٥-٦٣ (٢٠٢٠)