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Evaluation of new maize single and three way crosses for earliness and grain yield over three locations

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Abstract

New 17 yellow inbred lines of maize were mated to the two early testers; inbred line SK11 and SC173 at Sakha Agricultural Research Station in 2012 growing season. The resulting 17 single crosses, 17 three way crosses and two commercial hybrids SC162 and TWC352 were evaluated at three locations i.e. Sakha, Nubaria and Sids stations in 2013 growing season. Data were collected for days to 50% silking, plant height and grain yield. Analysis of variance revealed the mean squares due to locations (Loc.), crosses (Cr.) and Cr x Loc. interaction were highly significant for all of studied traits. Mean square due to lines (L) , tester (T), L x T and their interaction with locations were significant or highly significant for all traits. The additive gene effects were most responsible for controlling the inheritance of all traits except for grain yield. The best parental inbred lines which showed desirable GCA effects were SK5056/52 for earliness, SK5062/55 for plant height and SK5038/41 for grain yield. Tester SC173 was the best combiner for all traits except grain yield, SCSK5038/41 x SK11, TWCSK5066/58 x SC173 which were stable for grain yield, outyield and earliness than checks. These two crosses were selected for advanced testing in maize breeding program as early maturing crosses and of high yielding ability.

Key words: combining ability – earliness – yellow maize – genotype x location interaction

Introduction

The national maize breeding program in Egypt is adopting the policy of producing high yielding single and three way crosses and could to be early of maturity. However the earlier hybrids were desirable for specific cropping sequence, intercropping and reduce using water compared to late maturity hybrids. Days to 50% silking is a highly heritable trait and responds to selection for earliness (Troyer and Brown 1976). When selection for a trait, the expected response depends on the amount of additive genetic variance. The additive genetic variance is the fixable portion of genetic variability (Hallauer and Miranda, 1988) for days to 50% silking, it is attributed to additive gene effects, therefore, we can depend on silking date as a good and simple index for earliness in maize, a positive correlation has been reported between silking date and grain yield and plant height by Troyer and Brown (1972). The new maize inbred lines could be tested by Line x Tester Methods to classify them and estimates their general combining ability effects. Hallauer and Miranda (1981), and Menz *et al*. (1999) reported that the suitable tester should be based on simple of using, ability to classify of lines and maximizing genetic gain. Russell and Eberhart (1975), Darrah (1985)and Horner *et al*. (1989) suggested that the inbred lines can be used as a tester. Also, El-Ghawas (1963), Castellanos *et al*. (1998) and Mosa (2010) used single cross as a tester in their investigations.

The objectives of this study were to estimate combining ability effects, determine single and three way crosses for high yielding and earliness and determine stable superior hybrids for grain yield.

Materials and methods

New seventeen yellow maize inbred lines developed at Sakha Agricultural Research Station (Table 1) were crossed to two early testers i.e. inbred line SK11 and SC173 in 2012 growing season at Sakha station.

The resulting 17 single crosses and 17 three way crosses and two commercial hybrids (SC162, TWC352) were evaluated at Sakha, Nubaria and Sids Experimental Stations. The experimental design was randomized complete block design with four replications.

Plot size was one row of 6 m long and 80 cm apart. Planting was in hills at25 cm apart. All of the required cultural practices were applied as recommended at the proper time. Data were taken on silking date (number of days from planting to 50% emergence silking), plant height (cm), and grain yield (ardab/fed.) adjusted based on shelling percent at 15.5% moisture content.

The combined analysis was done after test of homogeneity of error mean squares for the three locations, according to **Steel and Torrie (1980).** When differences among top crosses were found significant, line x tester analysis as outline by **Singh and Chaudary (1999)** was done.

Stability parameters for grain yield were worked out as suggested by **Eberhart and Russel (1996).** The coefficient of determination (R^2) was computed according to **Pinthus (1973).**

Table 1. Pedigree and source of the seventeen yellow maize inbred lines and two testers.

Pedigree	Sources
SK5038/41	Pop. (DMY5001/218-1-1-2-1-1 x Com21
SK5043/43	Pop (Sku-10 x Comp21)
SK5044/44	Pop (SK6241 x Comp21)
SK5045/46	Pop (SK7070/9-2-2-1-1-9 x Comp21)
SK5046/47	Pop (SK7070/9-2-2-1-1-9 x Comp21)
SK5046/48	Pop (SK7070/9-2-2-1-1-9 x Comp21)
SK5046/49	Pop (SK7070/9-2-2-1-1-9 x Comp21)
SK5054/50	I.Y.309
SK5056/51	I.Y.398
SK5056/52	I.Y.398
SK5056/53	I.Y.398
SK5061/54	SC162
SK5062/55	SC166
SK5064/56	Pop. (Exp.B.9/2005-102)
SK5066/57	Pop. (Exp. B. 9/2005-108)
SK5066/58	Pop. (Exp. B. 9/2005-108)
SK5067/59	Pop. (Exp. B. 9/2005-109)
SK11	Gm1021 x Sd318
SC173	GZ666 x GZ647

Results and discussion

Combined analyses of variance of 36 entries for the three traits across in three locations are shown in Table 2. Results in revealed that the differences between three locations (Loc) were highly significant for all studied traits. Also, the entries mean squares were highly significant for all traits. The mean squares and the variance due to the interaction of entries with the locations were highly significant for all traits. Meaning that the tested entries varied from each to other and showed differential performance in the testing locations.

Table 2. Analysis of variance of 36 entries for three traits across three locations.

S.O.V.	d.f	Days to 50% silking	Plant height (cm)	Grain yield (ard. /fed.)
Locations (Loc)	2	2969.05**	157851.2**	1889.805**
Rep/Loc	9	15.357	554.826	34.564
Entries	35	46.628**	1921.27**	83.342**
E x Loc	70	5.641**	244.220**	41.515**
Error	315	2.320	141.811	9.547

** significant at 0.01 level of probability

The grand mean of locations for the three traits are presented in Table (3). Sakha location gave the highest mean for all of studied traits except for days to 50% silking. Meanwhile, Sids location had the lowest values for all traits except for days to 50% silking which Nubaria location gave the lowest mean for days to 50% silking. **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 traits does not mean stress for all traits under study.

Table 3. Grand means of locations for the three traits.

Trait Location	Days to 50% silking	Plant height (cm)	Grain yield (ardab/fed.)
Sakha	56.796 b	281.276	32.776 a
Sids	60.033 a	224.375 b	25.830 c
Nubaria	51.270 c	226.612 b	28.244 b
C.V.%	2.72	4.88	10.67

Mean performance of the 36 entries (17 single cross, 17 three way crosses) and 2 check hybrids for three traits across three locations are presented in Table (4).

For days to 50% silking 17 single crosses were earlier than SC162, the best crosses from them were SK5054/50 x SK11, SK5056/52 x SK11 and SK5062/55 x SK11, while 11 three way crosses were earlier than check TWC 352. The best crosses from them were SK5054/50 x SC173, SK5056/52 x SC173 and SK5062/55 x SC173. These results exhibited that the inbred lines SK5054/50, SK5056/52 and SK5062/55 gave the best single and three way crosses for earliness. Hence these inbred lines and their single and three way crosses could be utilized for the breeding programs as early maturing crosses where their harvesting ranged from 95 to 100 days from planting. The 16 single crosses were shorter than SC162. The best crosses from them were SK5044/44 x SK11 and SK5062/55 x SK11. The three crosses of TWC were shortly for plant height than TWC352, the best crosses from them SK5044/44 x SC173 and SK5062/55 x SC173. Results showed that inbred lines SK5044/44 and SK5062/55 gave shortest single and three way crosses for plant height.

For grain yield, single cross SK5038/41 x SK11 was significantly outyielded than SC162, while three way cross SK5054/50 x SC173 was higher than TWC 352. Also, three way crosses SK5038/41 x SC173, SK5061/54 x SC173 and SK5066/58 x SC173 were not significantly outyielded than TWC352. The above results exhibited that TWCSK5054/50 x SC173 (53.07 days and 32.75 ard/fed.), SK5066/58 x SC173 (55.83 days and 31.72 ard/fed.) and SCSK5038/41 x SK11 (58.38 days and 34.97 ard/fed.) could be used in maize breeding program as early maturing crosses and high yielding ability.

Table 4. Mean performance of 36 entries (17 single crosses (SC), 17 three way crosses (TWC) and 2 checks) for three traits across three locations

Trait	Days to 50% silking		Plant height (cm)		Grain yield (ardab/fed)	
Inbreeding line	SK11	SC173	SK11	SC173	SK11	SC173
SK5038/41	58.58**	57.50	251.66**	255.83	34.97*	31.76
SK5043/43	57.16**	56.16	242.58**	240.91	28.54	27.02
SK5044/44	55.41**	54.41**	226.25**	230.41**	26.29	28.26
SK5045/46	54.83**	54.41**	249.50**	238.83	28.62	28.82
SK5046/47	55.66**	53.58**	246.00**	236.16	26.23	26.24
SK5046/48	55.58**	53.08**	240.66**	231.50**	26.21	27.48
SK5046/49	59.25*	54.91*	240.91**	242.16	30.59	28.69
SK5054/50	54.25**	53.08**	249.33**	239.50	28.57	32.75*
SK5056/51	55.75**	54.08**	242.33**	241.08	26.85	29.73
SK5056/52	53.00**	53.00**	251.41**	240.66	28.75	27.60
SK5056/53	58.75**	57.50	274.41	259.00	32.12	24.41
SK5061/54	57.66**	56.08	244.41**	250.83	31.22	30.32
SK5062/55	54.50**	53.58**	211.41**	209.91**	31.15	28.30
SK5064/56	55.91**	56.83	246.41**	251.00	29.11	29.49
SK5066/57	58.83**	56.58	253.33**	247.75	28.32	20.69
SK5066/58	57.83**	55.83*	255.33**	255.33	27.34	31.72
SK5067/59	56.50**	55.00**	230.33**	237.58	30.46	27.23
Check SC162	60.83	-	267.75	-	32.50	-
TWC352	-	57.08	-	245.08	-	30.18
LSD 0.05	1.22	1.22	9.52	9.52	2.47	2.47
0.01	1.66	1.66	12.54	12.54	3.26	3.26

*, ** significant or highly significant than the check.

Mean squares of line x tester analysis for the 34 new crosses for three traits across three locations are presented in Table 5. Significant or highly significant differences were detected among lines (L), tester (T) and L x T interaction and their interaction with locations (L x Loc, T x Loc and L x T x Loc) for all of the studied traits meaning that the both inbred lines and tester behaved differently in their crosses over three locations and were differently in location to another. The obtained results are in harmony with those conclusions reached by **Nawar and El-Hosary (1984), El-Shenawy (2005), Mosa *et al*. (2008) and Mosa (2010).**

Table 5. Mean squares due to liens (L), testers (T) and L x T and their interaction with location (Loc) for studied three traits.

S.O.V.	d.f	Days to 50% silking	Plant height (cm)	Grain yield (ardab/fed.)
Line (L)	16	61.823**	3528.438**	88.589**
Tester T	1	196.297**	807.539*	74.62**
L x T	16	7.896**	299.487**	69.47**
L x Loc	32	15.311**	337.06**	71.74**
T x Loc	2	34.659**	1907.429**	170.521**
L x T x Loc	32	6.398**	402.35**	39.169**
Error	297	2.316	140.87	9.63

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

Estimates of the variance due to general combining ability (GCA), specific combining ability SCA and their interaction with locations for three traits are shown in Table 6.

Table 6. Estimates of the additive gene effects (K^2GCA) and the non-additive gene effect (K^2SCA) and their interactions with locations for three traits.

Genetic components	Days to 50% silking	Plant height (cm)	Grain yield (ardab/fed.)
K^2GCA	1.450	14.288	0.629
K^2SCA	0.465	13.218	4.980
K^2GCA x Loc	0.596	18.94	15.460
K^2SCA x Loc	1.020	65.37	7.380

The additive gene effects (K^2GCA) played an important role more than non-additive gene effects (K^2SCA) in the expression of all of studied traits except for grain yield, where non-additive gene effects K^2SCA were extremely high. These results are in agreement with those obtained by **El-Shenawy (2005)** for days to 50% silking, **El-Shenawy and Mosa (2005)** for grain yield and **Mosa (2010)** for plant height.

Estimates of K^2GCA x Loc were higher than those of K^2SCA x Loc for grain yield meaning that the additive components of the genetic variation were more affected by location for grain yield while for days to 50% silking and plant height showed that, the non-additive gene effects were more interacted with locations. Similar results were obtained by **Silva and Hallauer (1975) and Mosa (2010).**

Estimates of general combining ability effects of 17 inbred lines for three studied traits across three locations are presented in Table (7). Results showed that eight inbred lines showed significant desirable GCA effects for earliness. The best inbred lines from them were SK5056/52, SK5054/50 and SK5062/55. For plant height four inbred lines exhibited desirable negative GCA effects, the best inbreds from them SK5044/44 and SK5062/55. While the desirable inbred lines for GCA effects for grain yield were SK5038/41, SK5054/50 and SK5061/54.

On the other hand, the heterozygous tester SC173 was the best combiner for days to 50% silking and plant height, while, the homozygous tester inbred line SK11 was the best for grain yield. **El-Ghawas (1963); Sokolov and Kostyuchence (1978), Mosa (2001) and Mosa (2004)** found that the cross was the best as tester, while **Al-Naggar *et al*. (1997), Mosa *et al*. (2004)** noticed that inbred lines was good combiner as tester.

Table 7. Estimates of general combining ability effects for the 17 inbred lines and two testers over three locations

Inbred lines	Days to 50% silking	Plant height (cm)	Grain yield (ardab/fed.)
SK5038/41	2.3088**	10.6667**	4.434**
SK5043/43	0.9338**	-1.3333	-0.903
SK5044/44	-0.8162**	-14.750**	-1.411*
SK5045/46	-1.2328**	1.0833	0.042
SK5046/47	-1.1078**	-2.000	-2.237**
SK5046/48	-1.3995**	-7.000**	-1.821**
SK5046/49	1.3505**	-1.5417	0.957
SK5054/50	-2.0662**	1.3333	1.668*
SK5056/51	-0.8162**	-1.3750	-0.391
SK5056/52	-2.7328**	2.9583	-0.509
SK5056/53	2.3922**	23.6250**	-0.413
SK5061/54	1.1422**	4.5417	2.085**
SK5062/55	-1.6912**	-32.4167**	1.040
SK5064/56	0.6422*	5.6250*	0.619
SK5066/57	1.9755**	7.4583**	-4.172**
SK5066/58	1.1005**	12.250**	0.849
SK5067/59	0.0172	-9.125**	0.163
LSD g_i 0.05	0.608	4.748	1.241
0.01	0.829	6.468	1.691
Tester Sk-11	0.693**	1.50*	0.427*
Tester SC-173	-0.693**	-1.50*	-0.427*
LSD g_i 0.05	0.20	1.50	0.425
0.01	0.23	1.97	0.580

Estimates of specific combining ability effects of the 34 crosses across the three grown locations are presented in Table (8). The crosses SK5046/49 x SC173 and SK5064/56 x SK11 showed significant desirable SCA for days to 50% silking, while the crosses SK5054/50 x SC173,SK5056/51 x SC173, SK5061/53 x SK11, SK5064/56 x SK11 and SK5066/58 x SC173 exhibited significant positive SCA for grain yield. These results suggest use of these crosses in maize breeding program to produce high yielding hybrids.

Stability parameters of the 36 crosses evaluated at three locations are presented in Table (9). According to the definition of **Eberhart and Russel (1966)** cross with high mean (than grand mean) combined with a regression coefficient equal to the unity (bi=1) or not significant and small deviations from regression ($S^2d=0$) or not significant is considered to be stable, also **Pinthus (1973)** reported that the hybrids may considered to be stable when coefficient of determination (R^2) is higher than 80%. Therefore, five crosses SK54038/41 x SK11, SK55038/41 x SC173, SK5064/56 x SK11, SK5064/56 x SC173 and SK5066/58 x SC173 were stable for grain yield.

Generally, single cross SK5038/41 x SK11 and three way cross SK5066/58 x SC173 were the best crosses in this study because of its stable, outyield than checks in addition significant for earliness than checks. These two crosses were selected for advanced testing in maize breeding program.

Table 8. Estimates of specific combining ability effects for the 34 new crosses across three locations.

Cross	Days to 50% silking	Plant height (cm)	Grain yield (ardab/fed.)
SK5038/41 x SK11	-0.15196	-3.490	0.926
SK5038/41 x SC173	0.15196	3.490	-0.926
SK5043/43 x SK11	-0.19363	-0.573	0.330
SK5043/43 x SC173	0.19363	0.573	-0.330
SK5044/44 x SK11	-0.19363	-3.490	-1.411
SK5044/44 x SC173	0.19363	3.490	1.411
SK5045/46 x SK11	-0.61029	3.926	-0.526
SK5045/46 x SC173	0.61029	-3.926	0.526
SK5046/47 x SK11	0.34804	3.509	-0.638
SK5046/47 x SC173	-0.34804	-3.509	0.638
SK5046/48 x SK11	0.55637	3.176	-1.049
SK5046/48 x SC173	-0.55637	-3.176	1.049
SK5046/49 x SK11	1.47304**	-2.031	0.517
SK5046/49 x SC173	-1.47304**	2.031	-0.517
SK5054/50 x SK11	-0.11029	3.509	-2.215*
SK5054/50 x SC173	0.11029	-3.509	2.215*
SK5056/51 x SK11	0.13971	-0.781	-1.870*
SK5056/51 x SC173	-0.13971	0.781	1.870*
SK5056/52 x SK11	-0.69363	3.968	0.146
SK5056/52 x SC173	0.69363	-3.968	-0.146
SK5056/53 x SK11	-0.6863	6.301	3.427**
SK5056/53 x SC173	0.06863	-6.301	-3.427**
SK5061/54 x SK11	0.09804	-4.615	0.021
SK5061/54 x SC173	-0.09804	4.615	-0.021
SK5062/55 x SK11	-0.23529	-0.656	0.995
SK5062/55 x SC173	0.23529	0.656	-0.995
SK5064/56 x SK11	-0.15196*	-3.698	-0.617
SK5064/56 x SC173	1.15196*	3.698	0.617
SK5066/57 x SK11	0.43137	1.384	3.389**
SK5066/57 x SC173	-0.43137	-1.384	-3.389**
SK5066/58 x SK11	0.30637	-1.406	-2.616**
SK5066/58 x SC173	-0.30637	1.406	2.616**
SK5067/59 x SK11	0.05637	-5.031	1.190
SK5067/59 x SC173	-0.05637	5.031	-1.190
LSD S_{ij} 0.05	0.861	6.715	1.755
0.01	1.172	9.18	2.391

Table 9. Stability parameters of grain yield for crosses evaluated at three locations

Lines	bi	S^2di	R^2	$\dot{X}$
SK5038/41 x SK11	1.099	-1.72	97.30	34.976
SK5038/41 x SC173	1.940	1.10	96.237	31.767
SK5043/43 x SK11	0.392*	25.9**	11.833	28.540
SK5043/43 x SC173	0.605	-1.426	88.936	27.025
SK5044/44 x SK11	1.127	16.709**	62.126	26.291
SK5044/44 x SC173	0.671	-0.592	85.06	28.260
SK5045/46 x SK11	0.430*	-2.411	96.89	28.629
SK5045/46 x SC173	0.693	-2.075	96.09	28.629
SK5046/47 x SK11	0.681	-2.076	95.97	26.237
SK5046/47 x SC173	0.081*	-2.142	28.30	26.661
SK5046/48 x SK11	0.171*	-2.227	68.58	26.243
SK5046/48 x SC173	0.482*	-1.85	97.01	27.488
SK5046/49 x SK11	2.513*	-1.044	99.04	30.59
SK5046/49 x SC173	0.764	-0.647	88.35	28.699
SK5054/50 x SK11	0.635	2.489	99.29	28.571
SK5054/50 x SC173	0.079*	-2.516	77.88	32.143
SK5056/51 x SK11	1.636*	-2.308	99.62	26.853
SK5056/51 x SC173	0.884	6.784	67.53	29.738
SK5056/52 x SK11	0.499*	4.002	48.57	28.750
SK5056/52 x SC173	0.165*	1.856	13.30	27.603
SK5056/53 x SK11	2.735*	0.28	98.49	32.129
SK5056/53 x SC173	0.873	3.191	76.47	24.42
SK5061/54 x SK11	2.078*	-0.751	98.34	31.22
SK5061/54 x SC173	0.991	19.57**	52.45	30.32
SK5062/55 x SK11	0.534*	-1.378	85.72	31.152
SK5062/55 x SC173	0.419*	7.727	29.80	28.304
SK5064/56 x SK11	0.919	2.242	98.50	29.118
SK5064/56 x SC173	1.195	-2.459	99.71	29.490
SK5066/57 x SK11	1.011	2.548	99.95	28.382
SK5066/57 x SC173	0.054*	6.711	0.78	20.690
SK5066/58 x SK11	2.110*	4.878	93.7	27.340
SK5066/58 x SC173	1.312	-0.868	96.20	31.720
SK5067/59 x SK11	1.174*	0.820	90.50	30.468
SK5067/59 x SC173	0.775	-1.639	94.19	27.230
Check SC162	3.297*	30.046	89.23	32.50
Check TWC352	0.528*	4.256	50.43	30.18

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تقييم هجن ذرة شامية فردية وثلاثية جديدة للتبكير والمحصول فى ثلاث مواقع

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تم تهجين 17 سلالة صفراء جديدة من الذرة الشامية مع إثنين من الكشافات المبكرة وهى سلالة سخا 11 وهـ ف 173 فى محطة بحوث سخا الزراعية موسم 2012 وقيمت الهجن الناتجة وهى 17 هجين فردى و17 هجين ثلاثى بالإضافة إلى إثنين من الهجن التجارية للمقارنة وهى هـ ف 162 و هـ ث 352 فى ثلاث مواقع تجريبية وهى سخا وسدس والنوبارية. الصفات التى تم تقديرها هى عدد الأيام حتى ظهور 50% من حراير النورات المؤنثة وإرتفاع النبات ومحصول الحبوب وكانت النتائج كالتالى: أظهر تحليل التباين أن التباين الراجع إلى المواقع والهجن المدروسة وكذا التفاعل بينهم معنوية لكل الصفات المدروسة. أظهر التباين الراجع إلى السلالات والكشافات وتفاعل السلالات مع الكشافات وتفاعلها مع المواقع معنوية لجميع الصفات. كانت تأثيرات الفعل الجينى المضيف الأكثر تحكما فى وراثة كل الصفات ماعدا صفة محصول الحبوب.

أفضل السلالات فى القدرة العامة على الائتلاف هى سخا 52/5056 لصفة عدد الأيام حتى ظهور 50% من حرائر النورات المؤنثة وسلالة سخا 55/5062 لارتفاع النبات وسلالة 41/5038 لصفة محصول الحبوب والكشاف هـ ف 173 كان الأفضل فى قدرته على التآلف المرغوب لجميع الصفات المدروسة ماعدا صفة محصول الحبوب.

أظهر الهجين الفردى سخا 41/5038 × سخا 11 ، والهجين الثلاثى سخا 58/5066× هـ ف 173 ثبات لصفة المحصول وتفوق على هجن المقارنة فى التبكير والمحصول وبالتالى يمكن استخدامهما فى الاختبارات المتقدمة فى برنامج التربية.