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Estimates of combining ability for grain yield and other agronmic traits in yellow maize hybrids

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Abstract

Nineteen yellow maize (*zea mays* L.) inbred lines were top crossed with two inbred lines testers; GZ 658 and SD 3120 in season 2015. In 2016 summer season, these 38 crosses were evaluated in a randomized complete blocks designs experiment with four replications at two locations; Sakha and Sids, Agriculture Research Center, Egypt. Locations mean square were highly significant for all traits. Mean squares of crosses and their partitions (lines, testers and lines x testers) showed highly significant for all traits under this study except, testers mean square for ear height and ear diameter and lines x testers for ear height and ear length. The additive and additive x additive gene actions played more important in the inheritance traits; days to 50% silking, ear length, ear diameter and grain yield, while, the non- additive gene actions in the inheritance traits pant and ear height. The inbred lines (L_1, L_7 and L_{14}) and the tester GZ 658 had desirable positive and significant ($\hat{g}_i$) for grain yield (ard/ fad) (ardab (ard) =140 kg, faddan (fad) = 4200 m^2). Five crosses: L_1 x Gz 658 (35.86 ard/ fad), L_2 x Gz 658(34.86 ard/ fad), L_7 x Sd 3120 (35.66 ard/ fad), L_{14} x Gz 658 (35.20 ard/ fad) and L_{15} x Gz 658 (34.79 ard/ fad) had highly significant for grain yield (ard/ fad) more than the highest check Sc 168 (30.13 ard/ fad).

Keywords: *Zea mays*, top cross, combining ability, genotype x environment, yellow maize.

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1. Introduction

The success of hybrid maize development depends on the ability of the breeding program to rapidly isolate lines that combine well in hybrid combinations and to identify appropriate heterotic combinations to maximize the vigour of the hybrid (Kim and Ajala, 1996). The general process to develop maize hybrids starts with the creation of a source segregating breeding population that is used to develop inbred lines through inbreeding and selection (Betran *et al*., 2004). Selected inbred lines are then evaluated in hybrid combinations across locations to select superior hybrids and to estimate their combining ability. Combining ability of experimental breeding materials is imperative to a breeding program aiming to develop high yielding hybrids and composite varieties. Such information can show the type of gene action involved in controlling quantitative characters, thereby assisting breeders in selecting suitable parent materials (Hallauer and Miranda, 1988). Significant values for general combing ability (GCA) and specific combining ability (SCA) may be interpreted as indicating the performance of additive and non-additive gene action, respectively (Sprague and Tatum, 1942). Significant values for general combing ability (GCA) enabled breeders to exploit the existing variability in the breeding materials, to identify individual genotypes conferring desirable attributes and to distinguish relatedness among genotypes (Vacaro *et al.*, 2002). While, SCA is serving to determine heterotic patterns among populations or inbred lines, to identify promising single crosses and to assign inbred lines into heterotic groups (Hede *et al.*, 1999; Revilia *et al.*, 2002; Vasal *et al.*, 1992). Line × tester mating design was developed by Kempthorne (1957), which provides reliable information on the general and specific combining ability effects of parents and their hybrid combinations in applied breeding programs. The design has been widely used in maize breeding by several workers and continues to be applied in quantitative genetic studies in maize due to its significance (Sharma *et al.*, 2004). The objectives of this work were to estimate combining abilities, heterosis, and type of gene action of nineteen yellow maize inbred lines and to evaluate the test cross performance of developed hybrids for grain yield and yield related traits.

2. Materials and methods

The experimental work of this study was carried out in 2015 and 2016 summer seasons at Sids and Sakha stations of the Agriculture Research Center, Egypt. In 2015 growing summer were made crosses at nineteen yellow maize inbred lines (Table 1) and two genotypes namely Gz 658 and SD 3120 were used as testers (males). In 2016 summer season, the 38 test crosses and two check hybrids Sc.162 and Sc.168 were evaluated at two locations; Sakha, and Sids. A randomized complete blocks design with four replications was used at both locations. The experimental plot was one row 6.0 m long, and 80 cm apart, with hills spaced at 25 cm along the row and one plant was left per hill. Data were recorded for days to 50% silking, plant and ear height, ear length , ear diameter and grain yield (ard/fed) (ardab (ard) =140 kg, faddan (fad) = 4200 m^2) adjusted to 15.5% grain moisture content. Statistical analysis of the combined data over two locations was performed according to Steel and Torrie (1980) after testing homogeneity of error mean squares. Combining ability analysis was computed according to Kempthorne (1957).

Table (1): The name and origin of the nineteen yellow inbred lines.

No.	Name	Origen
L_1	Line 24	Bank -70-s6
L_2	Line 25	Bank -70-s6
L_3	Line 45	Bank -96-s6
L_4	Line 83	Bank -206-s6
L_5	Line 86	Bank -206-s6
L_6	Line 88	Bank -214-s6
L_7	Line 89	Bank -214-s6
L_8	Line 90	Bank -227-s6
L_9	Line 93	Bank -284-s6
L_{10}	Line 94	Bank -284-s6
L_{11}	Line 97	Bank -284-s6
L_{12}	Line 98	Bank -290-s6
L_{13}	Line 101	Bank -290-s6
L_{14}	Line 102	Bank -294-s6
L_{15}	Line 104	Bank -295-s6
L_{16}	Line 105	Bank -295-s6
L_{17}	Line 106	Bank -295-s6
L_{18}	Line 108	Bank -296-s6
L_{19}	Line 110	Bank -314-s6

3. Results and Discussion

3.1 Analysis of variance

Mean squares for six traits (days to 50% silking, plant height, ear height, ear length, ear diameter and grain yield) under combined data at two locations were in Table (2). Locations mean square were highly significant for all traits, indicated that, different environmental conditions between two locations. These results were agreement with Ibrahim *et al*. (2007) and Darwich *et al*. (2016). Mean squares of crosses and their partitions (lines, testers and lines x testers) showed highly significant for all traits under this study except, testers mean square for ear height and ear diameter and lines x testers for ear height and ear length, indicating that a large amount of variability in crosses and their partitions. The similar results were obtained by Sadek *et al*. (2001), Gamea (2015) and Aboyousef *et al*. (2016). On the other hand, highly significant differences were detected between crosses x locations interaction for grain yield. Line x location was significant for eat height and ear diameter, while, tester x location exhibited significant for plant height.

3.2 Mean performance

Data in Table (3) cleared that, mean performance of 38 crosses and two checks (Sc 162 and Sc 168) for six traits under combined data. For days to 50% silking, 16 crosses were highly significant for earliness compared to earliest check Sc 168. 7 crosses (L_2 x Sd 3120, L_6 x Gz 658, L_7 x Gz 658, L_8 x Sd 3120, L_9 x Gz 658, L_{10} x Gz 658 and L_{11} x Gz 658) and 5 crosses (L_2 x Sd 3120, L_7 x Gz 658, L_8 x Sd 3120, L_9 x Gz 658 and L_{11} x Gz 658) showed highly significant negative for plant and ear height, respectively comparing with the best check Sc 168. On the other hand two crosses; L_1 x Gz 658 and L_2 x Sd 3120 expressed significant for ear diameter than the better check Sc 168. For grain yield (ard/ fad) five crosses: L_1 x Gz 658

(35.86 ard/ fad), L_2 x Gz 658(34.86 ard/ fad), L_7 x Sd 3120 (35.66 ard/ fad), L_{14} x Gz 658 (35.20 ard/ fad) and L_{15} x Gz 658 (34.79 ard/ fad) had highly significant more than grain yield (ard/ fad) than the highest check Sc 168 (30.13 ard/ fad).

Table (2): Mean squares for grain yield and other studied traits at the combined across two locations (2016 season).

S.O.V.	df	Mean Squares					
		Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Grain yield (ard fad^{-1})
Location (E)	1	5131.58**	63887.00**	23415.21**	833.59**	1.24**	709.61**
Rep/Loc	6	17.45	333.85	258.35	1.70	0.07	27.44
Crosses (C)	37	21.91**	841.52**	400.85**	10.49**	0.08**	60.96**
Lines (L)	18	19.97**	1426.72**	682.57**	15.04**	0.13**	70.96**
Testers (T)	1	351.74**	892.90**	0.08	59.95**	0.003	273.11**
L x T	18	5.518**	253.46**	141.35	3.20	0.04*	40.05**
C x Loc	37	2.23	108.29	99.32	2.05	0.03	17.52*
L x Loc	18	2.42	126.33	168.18**	2.56	0.04*	17.02
T x Loc	1	0.40	452.77*	29.07	2.84	0.05	6.97
L x T x Loc	18	2.15	71.11	34.36	1.49	0.02	18.62
Pooled error	222	1.73	111.29	72.01	1.70	0.02	11.97
C V%		1.98	4.36	6.22	6.57	3.26	11.04

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

Table (3): Mean performance of top crosses for the studied traits combined across two locations (2016 growing season).

Lines	Days to 50% silking		Plant height (cm)		Ear height (cm)		Ear length (cm)		Ear diameter (cm)		Grain yield (ard fed^{-1})	
	Gz.658	SD.3120	Gz.658	SD.3120	Gz.658	SD.3120	Gz.658	SD.3120	Gz.658	SD.3120	Gz.658	SD.3120
L_1	69	67	247	246	143	139	19.3	18.0	5.0	4.9	35.86	31.67
L_2	68	65	241	232	135	127	19.7	18.2	4.9	5.0	34.86	30.55
L_3	68	67	253	250	151	142	21.3	20.7	4.8	4.9	32.21	31.23
L_4	69	69	247	252	144	145	22.0	21.8	4.6	4.9	33.79	27.72
L_5	67	67	244	244	145	140	19.6	19.8	4.7	4.6	32.44	31.46
L_6	69	66	228	239	129	135	20.5	20.7	4.8	4.8	31.92	31.88
L_7	68	64	226	236	125	132	20.3	21.1	4.8	4.7	33.21	35.66
L_8	65	63	240	233	134	126	20.7	19.2	4.7	4.7	32.77	26.55
L_9	67	64	228	242	128	134	19.0	18.1	4.7	4.8	27.57	30.24
L_{10}	68	64	229	236	131	130	19.9	18.1	4.6	4.7	27.61	29.19
L_{11}	67	63	222	237	125	129	17.9	18.2	4.7	4.9	25.61	29.98
L_{12}	68	66	237	238	130	131	20.1	18.4	4.7	4.7	30.06	25.25
L_{13}	68	66	248	251	140	139	20.2	19.4	4.8	4.8	33.33	30.14
L_{14}	69	67	260	279	143	155	21.6	20.4	4.7	4.7	35.20	33.75
L_{15}	68	65	242	250	141	139	20.6	19.3	4.8	4.7	34.79	31.33
L_{16}	65	65	243	243	136	142	21.2	18.7	4.7	4.7	33.74	29.83
L_{17}	68	65	248	242	142	137	21.4	19.5	4.8	4.6	32.42	27.99
L_{18}	68	66	244	247	136	134	20.7	19.7	4.7	4.6	34.09	30.02
L_{19}	68	65	243	238	137	135	19.9	19.8	4.7	4.7	32.20	33.25
Cheeks												
SC.162	71		272		152		22.4		4.7		25.97	
SC.168	68		247		139		22.4		4.8		30.13	
LSD 0.01	2		14		11		1.7		o.2		4.46	

3.3 Gene action

Estimation of genetic parameters for the six traits under combined data in Table (4). Results in this Table cleared that, δ^2 $_{GCA-L}$ was more than δ^2 $_{GCA-T}$ for all studies traits except, for days to 50% silking, meaning that most of additive gene action due to lines. These results in harmony with those reported by Aly *et al.* (2011), Mousa and Aly (2012), and Aly (2013). The additive and additive x additive gene actions played more important in the inheritance traits; days to 50% silking, ear length, ear diameter and grain yield, while, the non- additive gene actions in the inheritance traits pant and ear height. Singh and Roy (2007) and Aboyousef *et al.* (2016) reported the same conclusion. The ratio $\delta^2_{GCA\ x\ Loc}$ / $\delta^2_{SCA\ x\ Loc}$ less than unity for days to 50% silking, plant height and grain yield, indicating the non- additive gene effects with changing the environments for these traits. On the other side the same ratio more than unity for traits ear height, ear length and ear diameter, meaning that additive genes more important than non-additive with changing the locations for this traits. Barakat *et al*. (2003) found that the non additive gene effects were more interacted with locations for grain yield and days to 50% silking. Motawei (2006) indicated that mean squares due to GCA x location were higher than those due to SCA x location for all traits, indicating that additive gene effects was more affected by the environmental conditions than non-additive gene action and Aly (2013) found that The interaction of $\delta^2_{SCA\ x}$ location was higher than those $\delta^2_{GCA\ x}$ location for days to 50% silking, plant height, ear length and grain yield.

Table (4): Estimates of the variance due to general combining ability (GCA), specific combining ability (SCA) and their interaction with locations for six traits, in the combined across two locations.

Parameter	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Grain yield (ard fed^{-1})
$\delta^2_{GCA\text{-}L}$	0.89	69.88	25.463	0.67	0.004	2.032
$\delta^2_{GCA\text{-}T}$	2.29	1.70	-0.895	0.36	0.000	1.610
$\delta^2_{GCA(average)}$	3.52	10.09	5.862	3.50	3.438	3.631
δ^2_{SCA}	0.42	22.79	13.373	0.21	0.003	2.679
$\delta^2_{GCAL\ x\ Loc}$	0.03	6.90	16.727	0.13	0.002	-0.200
$\delta^2_{GCAT\ x\ Loc}$	-0.02	5.02	-0.070	0.02	0.000	-0.153
$\delta^2_{GCA\ x\ Loc}$	0.03	6.90	16.727	0.13	0.002	-0.200
$\delta^2_{SCA\ x\ Loc}$	0.10	-10.05	-9.412	-0.05	0.001	1.661

All negative estimates of variance were considered zero.

3.4 General combining ability effects

Estimation of General combining ability effects (g^i) effects for the nineteen yellow maize inbred lines and the two testers in Table (5).

3.4.1 Lines

For days to 50% silking, 5 inbred lines (L_8, L_9, L_{10}, L_{11} and L_{16}) had desirable negative and significant values for (g^i) towards earliness. 7 and 8 inbred lines exhibited highly significant (g^i) towards shortness and low ear placement, respectively. For ear length and ear diameter, five inbred line (L_3, L_4, L_6, L_7

and L_{14}) for ear length and three inbred line (L_1, L_2 and L_3) for ear diameter showed positive desirable and highly significant of g^i for these traits. Regarding to data in Table (5), the results dictated for grain yield three inbred lines (L_1, L_7 and L_{14}) had desirable positive and significant (g^i) for this trait.

Table (5): General combining ability effects (g^i) for all tested lines and testers combined cross two locations.

Lines	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Grain yield (ard fad^{-1})
L_1	1.145**	4.026	4.684**	-1.216**	0.206**	2.410**
L_2	-0.480	-5.786**	-5.566**	-0.903**	0.206**	1.353
L_3	1.332**	9.589	9.934**	1.134**	0.093	0.370
L_4	2.082**	7.276**	7.747**	2.034**	0.006	-0.600
L_5	0.332	1.401	6.059	-0.178	-0.094**	0.600
L_6	0.957**	-8.974**	-4.628*	0.709*	0.043	0.545
L_7	-0.480	-10.911**	-8.191**	0.834*	0.031	3.083**
L_8	-2.418**	-6.099**	-6.191**	0.072	-0.032	-1.692
L_9	-0.855**	-7.286**	-5.566**	-1.278**	-0.019	-2.444**
L_{10}	-0.668*	-9.349**	-6.003**	-0.866**	-0.069	-2.950**
L_{11}	-1.355**	-12.411**	-9.378**	-1.841**	0.031	-3.558**
L_{12}	0.707*	-4.786	-6.128**	-0.641	-0.044	-3.694**
L_{13}	0.457	7.401**	3.309	-0.078	0.018	0.382
L_{14}	1.269**	27.651**	12.684**	1.134**	-0.069	3.127**
L_{15}	-0.355	3.339	3.372	0.072	-0.007	1.707
L_{16}	-1.480**	0.651	2.559	0.047	-0.057	0.430
L_{17}	-0.043	2.526	2.934	0.584	-0.057	-1.144
L_{18}	0.082	3.651	-1.316	0.372	-0.132*	0.703
L_{19}	-0.230	-1.911	-0.316	0.009	-0.057	1.372
LSD_{gi} 5%	0.655	5.248	4.221	0.649	0.070	1.721
LSD_{gi} 1%	0.849	6.803	5.472	0.841	0.090	2.232
Tester						
Gz.658	1.075**	- 1.714*	0.053	0.444*	-0.003	0.948**
SD.3120	-1.075**	1.714*	-0.053	-0.444*	0.003	-0.948**
LSD_{gi} 5%	0.213	1.703	1.371	0.211	0.229	0.559
LSD_{gi} 1%	0.276	2.208	1.778	0.273	0.297	0.725

*, ** indicating significance at 0.05 and 0.01 levels of probability, respectively.

Table (6): Specific combining ability effects of top crosses for days to 50% silking, plant height, ear height, ear length, ear diameter and grain yield in the combined across two locations (2016 growing season).

Lines	Days to 50% silking		Plant height (cm)		Ear height (cm)		Ear length (cm)		Ear diameter (cm)		Grain yield (ard fed^{-1})	
	Gz.658	SD.3120	Gz.658	SD.3120	Gz.658	SD.3120	Gz.658	SD.3120	Gz.658	SD.3120	Gz.658	SD.3120
L_1	-0.013	0.013	2.276	-2.276	1.947	-1.947	0.243	-0.243	0.028	-0.028	1.148	-1.148
L_2	0.467	-0.467	6.339	-6.339	3.947	-3.947	0.281	-0.281	-0.047	0.047	1.205	-1.205
L_3	-0.576	0.576	3.214	-3.214	4.322	-4.322	-0.132	0.132	-0.059	0.059	-0.457	0.457
L_4	-1.076*	1.076*	-0.474	0.474	-0.615	0.615	-0.357	0.357	-0.122	0.122*	2.090	-2.090
L_5	-0.826	0.826	1.651	-1.651	2.447	-2.447	-0.569	0.569	0.028	-0.028	-0.455	0.455
L_6	0.049	-0.049	-3.849	3.849	-3.240	3.240	-0.557	0.557	-0.009	0.009	-0.928	0.928
L_7	0.862	-0.862	-3.286	3.286	-3.428	3.428	-0.832	0.832	0.053	-0.053	-2.172	2.172
L_8	-0.326	0.326	5.276	-5.276	4.072	-4.072	0.331	-0.331	0.016	-0.016	2.163	-2.163
L_9	0.362	-0.362	-5.661	5.661	-3.428	3.428	0.006	-0.006	-0.022	0.022	-2.285	2.285
L_{10}	0.924	-0.924	-1.724	1.724	0.010	-0.010	0.468	-0.468	-0.047	0.047	-1.736	1.736
L_{11}	0.737	-0.737	-5.661	5.661	-1.740	1.740	-0.607	0.607	-0.097	0.097	-3.134*	3.134*
L_{12}	0.049	-0.049	1.089	-1.089	-0.865	0.865	0.418	-0.418	0.028	-0.028	1.459	-1.459
L_{13}	-0.326	0.326	0.401	-0.401	0.447	-0.447	-0.044	0.044	0.016	-0.016	0.649	-0.649
L_{14}	-0.388	0.388	-7.724*	7.724*	-6.303*	6.303*	0.143	-0.143	0.028	-0.028	-0.222	0.222
L_{15}	0.237	-0.237	-2.286	2.286	1.010	-1.010	0.231	-0.231	0.016	-0.016	0.783	-0.783
L_{16}	-0.888	0.888	1.526	-1.526	-3.178	3.178	0.806	-0.806	0.016	-0.016	1.010	-1.010
L_{17}	0.424	-0.424	4.651	-4.651	2.697	-2.697	0.493	-0.493	0.066	-0.066	1.268	-1.268
L_{18}	-0.076	0.076	0.276	-0.276	0.697	-0.697	0.056	-0.056	0.066	-0.066	1.087	-1.087
L_{19}	0.362	-0.362	3.964	-3.964	1.197	-1.197	-0.382	0.382	0.041	-0.041	-1.473	1.473
LSD_{Sij} 5%	0.925		7.423		5.970		0.917		0.100		2.434	
LSD_{Sij} 1%	1.200		9.623		7.740		1.189		0.129		3.155	

*, ** indicating significance at 0.05 and 0.01 levels of probability, respectively.

3.4.2 Testers

The tester Gz 658 inbred line had desirable and significant values of (g^i) for traits; plant height, ear length and grain yield, while, the tester Sd 3120 showed negative and significant values for g^i towards earliness.

3.5 Specific combining ability effects

Estimation of specific combining ability effects ($\hat{s}_{ij}$) for the sex studied traits at combined data are presented in Table (6). Results in Table (6) cleared that, the crosses; (L_4 x Gz 658) for days to 50% silking, (L_{14} x Gz 658) for plant and ear height, (L_4 x Sd 3120) for ear diameter and (L_{11} x Sd 3120) for grain yield had desirable and significant ($\hat{s}_{ij}$) these traits.

Table (7): Superiority percentages of the thirty-eight F_1 crosses relative to two checks hybrids for grain yield under the combined data.

Lines	Sc 162		Sc 168	
	Gz 658	SD 3120	Gz 658	SD 3120
L_1	38.08**	21.95**	19.02**	5.11
L_2	34.23**	17.64**	15.70**	1.39
L_3	24.03**	20.25**	6.90	3.65
L_4	30.11**	6.74	12.15	-8.00
L_5	24.91**	21.14**	7.67	4.41
L_6	22.91**	22.76**	5.94	5.81
L_7	27.88**	37.31**	10.22	18.35**
L_8	26.18**	2.23	8.76	-11.88
L_9	6.16	16.44	-8.50	0.37
L_{10}	6.31	12.40	-8.36	-3.12
L_{11}	-1.39	15.44	-15.00	-0.50
L_{12}	15.75	-2.77	-0.23	-16.20
L_{13}	28.34**	16.06	10.62	0.03
L_{14}	35.54**	29.96**	16.83**	12.01
L_{15}	33.96**	20.64**	15.47**	3.98
L_{16}	29.92**	14.86	11.98	-1.00
L_{17}	24.84**	7.78	7.60	-7.10
L_{18}	31.27**	15.59	13.14	-0.37
L_{19}	23.99**	28.03**	6.87	10.36
LSD 1%		4.46		

3.6 Superiority percentages

For grain yield, the results indicated that the values of superiority relative to SC 162 ranged from -2.77% to 38.08 for crosses; (L_{12} x Sd 3120) and (L_1 x Gz 658), respectively. Our results indicated that 24 single crosses were the best crosses for superiority relative to SC 162 for the combined data. On the other side, superiority relative to SC 168 ranged from -16.20 for (L_{12} x Sd 3120) to 19.02% for the cross (L_1 x Gz 658) (Table 7). Also, our results indicated that five crosses; L_1 x Gz 658, L_2 x Gz 658, L_{14} x Gz 658. L_{15} x Gz 658 and L_7 x Sd 3120 had superiority relative to SC 168.

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