Combining Ability for Grain Yield and Some Other Traits and Classification of New Yellow Maize Inbred Lines into Heterotic Groups Using Line × Tester

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Abstract: Seven new yellow maize inbred lines developed from different sources were top-crossed with three testers, i.e.; SC-180, SC-173 and SC-168 during 2023 summer season at Ismailia Agricultural Research Station. The 21 testcrosses and the two yellow check hybrids (TWC-368 and TWC-377) were evaluated at Ismailia, Sakha and Mallawei Agricultural Research Stations for 2024 summer season. Results revealed that the mean squares of locations, genotypes and their interaction with locations were significant for all studied traits. Variances of crosses, lines, testers, line x testers and their interaction with locations were also significant for most of the studied traits. The results showed that five crosses, L_4 x T_3, L_5 x T_3, L_6 x T_3, L_2 x T_1 and L_3 x T_2 recorded significant and good mean performance toward earliness, short plants, lower ear placement and high yield ability. The inbred line L_3 and the tester T_1 were the best general combiner for high yielding ability. L_4 and L_6 showed significant and negative combining ability for silking date toward earliness and T_2 as a tester was the best general combiner toward earliness, short plants and ear height, and lower ear placement. Three crosses; L_2 x T_1, L_3 x T_2 and L_5 x T_3 possessed positive and significant SCA effects toward high yielding. Results based on HSGCA method, helps the plant breeders to make a good combination between different lines from different heterotic groups to produce superior hybrids having high yield, earliness and plant characteristics.

Keywords: Maize, combining ability, correlation, HSGCA method, grain yield and attributes

INTRODUCTION

Maize (*Zea mays* L.) is an important and strategic crop grown in different agroecological conditions throughout the world (Job *et al.*, 2024). It is the third important cereal crops in Egypt after wheat and rice. The area cultivated by maize is estimated to be about 2.040 million feddan yielding 7.314 million tons of grains, with an average yield of about 22.11 ardeb feddan^{-1} (Economic Affairs Sector, 2024). The performance of a hybrid is related to the two types of combining abilities: general combining ability (GCA) and specific combining ability (SCA) of the inbred lines involved in the cross formation. GCA is a measure of the additive gene effects and SCA is related to the non-additive gene effects (Sprague and Tatum, 1942; Rojas and Sprague, 1952). Combining ability analyses are commonly employed in maize breeding programs to provide GCA and SCA information of maize populations for genetic diversity evaluation, inbred line selection, heterotic pattern classification, heterosis calculation and hybrid production (Barata and Carena, 2006 and Fan *et al.*, 2009). Combining ability estimates of lines in their hybrid combinations is very important for maize hybrid improvement (Murtadha *et al.*, 2018 and Oluwaseun *et al.*, 2022). This method used to estimate the combining ability, heritability, and gene action that influenced traits (Singh and Chaudhary 1985). Superior maize hybrids depend on the availability of good plant materials, which should possess high genetic variability necessary to produce new superior lines. Also, genetic parameters can be estimated using line × tester mating design. Classification of inbred lines into heterotic groups in maize is of prime importance owing to its application in exploitation of heterosis. Heterotic groups are the initial step in maize program, would provide the breeders maximum utilization of heterotic effects (Melchinger, 1999). The heterotic group classification methods used by researchers have great influence on how a maize line is assigned to maize heterotic group; Fan *et al.*, 2009, proposed a method of heterotic grouping based on specific and general combining ability effects (HSGCA) while, inbred lines were divided into groups as follows: Step-1 placed all tested inbred lines in the same heterotic group as their tester. Step-2 kept the inbred lines with heterotic group where its HSGCA effects had the smallest value (or largest negative value) and removed it from another heterotic group. Step-3, if the line had positive HSGCA effects with all representative testers, it will be cautious to assign that inbred to any heterotic group because the inbred line might belong to a heterotic group different from the testers used in the investigation. The objectives of this investigation were to, i) define the superior crosses possess high yielding ability and earliness using Line x Tester mating design, ii) classify the new yellow maize inbred lines into heterotic groups using specific and general combining abilities (HSGCA) and iii) estimate the correlation coefficient between grain yield and its attributes.

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MATERIALS AND METHODS

Plant material and their sources:

Seven new yellow maize inbred lines were used as plant materials and developed from different geographical regions of maize breeding program at Ismailia, Giza and Gemmeiza Agricultural Research Stations, Field Crops Research institute (FCRI), Agricultural Research Center (ARC). The plant materials are shown in Table (1).

Locations and growing season:

In 2023 growing season, the seven yellow maize inbred lines were crossed with the three testers: SC-180 (T_1), SC173 (T_2) and SC-168 (T_3) in a line × tester mating design at Ismailia Agricultural Research Station to obtain 21 crosses. For 2024 summer season, the resulted 21 crosses along with two yellow check hybrids; TWC-368 and TWC-377 were evaluated in a yield trial at three locations; Ismailia, Sakha, and Mallawei Agricultural Research Stations, Egypt.

Experimental design and its management:

A randomized complete blocks design (RCBD) with three replications was used. Plot size was one row, 6 m long and 0.8 m a part. Seeds were planted in hills evenly spaced at 0.25 m within a row at the rate of two kernels hill^{-1}, which was thinned to one plant hill^{-1} after three weeks from planting to get a total plant population about of 21875 plants feddan^{-1}. The field trials were kept clean of weeds throughout the growing season, and the recommended cultural practices for maize production were applied at the optimum time.

Data recorded and Statistical analysis:

The data collected on number of days to 50% silking emergency (day), plant height (cm), ear height (cm), ear position %, ear length (cm) and grain yield (ardeb. feddan.$^{-1}$) adjusted to 15.5% moisture content, (one ardeb = 140 kg and one feddan = 4200 m^2). Before data analysis, homogeneity test was performed, then combined analysis was executed across three locations following the procedure of Snedecor and Cochran (1989). Calculation of variances analysis was carried out by using computer application of general linear model (GLM) procedures, in Statistical Analysis System (SAS, 2008). When the differences between crosses were significant, hence line × tester analysis was done according to Kempthorne (1957). Also combining ability analysis was performed for traits that showed statistical differences among crosses. Kempthorne (1957) method was employed to determine general and specific combining abilities and their interaction effects with the three locations. The least significant differences (LSD) were calculated to compare treatment means. Simple correlation coefficients among all studied traits were calculated. The inbred lines were classified into heterotic groups based on HSGCA method proposed by Fan *et al*., (2009) as follows:

HSGCA = Cross mean X_{ij} – Tester means X_i = GCA + SCA

Where, Xij = mean yield of the cross between ith tester and jth line

and Xi = mean yield of the ith tester

Table (1): Name, line symbol and origin of the seven investigated yellow maize inbred lines and the three testers

No	***Inbred lines***	**Line symbol**	**origin**
1	CML-594	L_1	CIMMYT resources
2	Gz-078(33)	L_2	Giza Agric. Res. Station
3	SC-176 S7 (6)	L_3	Ism. Agric. Res. Station
4	SC-176 S7 (10)	L_4	
5	Hungarian x Spanish (8)	L_5	
6	Hungarian x Spanish (11)	L_6	
7	Gm-1002	L_7	Gemmeiza Agric. Res. Station
	Testers		
1	SC-180	T_1	National Maize Breeding Programs, FCRI, ARC.
2	SC-173	T_2	
3	SC-168	T_3	

RESULTS AND DISCUSSION

Analysis of variances of the tested maize genotypes for six studies traits combined across three locations are presented in Table 2. The results revealed highly significant differences among the three locations for all studied traits, indicating that the three locations differed from each to other in the environmental conditions. These findings are agreement with those obtained by Mousa *et al*., (2021); Mosa *et al*., (2024) and Bhatla *et al*., (2025). Mean squares of the maize genotypes and their interactions with locations were significant or highly significant for all studied traits. These results confirmed different responses among genotypes at different locations for the investigated traits and that genotypes performed differently from location to other. Several researchers *viz*, Subba *et al*., (2021); Abd El-Azeem *et al*., (2023); Aly *et al*., (2023); Matongera *et al*., (2023) and Hamada *et al*., (2024) were reach to the same results, which detected in this current work.

Table (2): Mean squares of 23 crosses for six studied traits combined across three locations

sov	df	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear position %	Ear length (cm)	Grain yield (ard. fed.$^{-1}$)
Locations (Loc.)	2	394.05**	207812.63**	77894.20**	676.29**	45.95**	4063.45**
Reps/Loc.	6	16.97	128.88	147.06	47.32	0.55	6.41
Genotypes (Geno)	22	29.96**	2787.24**	1264.77**	42.49**	5.28**	55.58**
Geno x Loc	44	6.15**	626.80**	274.06**	23.04*	2.90**	23.96**
Pooled error	132	1.356	156.332	91.261	16.159	1.038	7.422

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

Analysis of line x tester of 21 crosses for studied traits across three locations are illustrated in Table 3. Analysis of variance revealed that mean squares due to crosses and their interaction with locations wre significant for all studied traits. Also, mean squares due to lines (L), testers (T) and interaction of lines x testers (L x T) were significantly or highly significant for all studied traits, except of ear position% and ear length for L and T, respectively. These findings indicating that the presence of genetic variation among lines and testers and lines performances differed from tester to the other for these traits. These results are in general agreement with those of Panwar *et al*., (2013); Rajesh *et al*., (2018); Subba *et al.,* (2021); Abd El-Azeem *et al*., (2023) and Mosa *et al*., (2024). The results revealed that, the interactions of locations with lines and testers were significantly or highly significant for all studied traits except for ear position% and grain yield for L x Loc and ear position% and ear length for T x Loc, indicating that the inbred lines performed differently from location to other. Furthermore, L x T x Loc interaction was significant for days to 50% silking and ear length. These results are in harmony with those obtained by Abd El-latif *et al*., (2023); Matongera *et al*., (2023) and Hamada *et al*., (2024). Mean performance of the 21 maize crosses and the two check hybrids; TWC-368 and TWC-377 measured on studied traits and combined across three locations are presented in Table 4. For days to 50% silking date, the crosses were ranged from 55.33 days for cross L2 x T2 to 61.22 days for cross L2 x T3 whereas 11 out 21 crosses were scored significantly earlier than the two checks TWC-368 and TWC-377 (60.00 ± 1.08 days). The best values toward earliness was observed for L2 x T2 (55.33) followed by L6 x T2 (55.44) and L1 x T2 (56.00). For plant height, the values ranged from 174.67 cm for cross L4 x T3 to 304.22 cm for cross L7 x T2. 9 out 21 crosses were significantly shorter than the two check hybrids TWC-368 (279.11 ± 11.55 cm) and TWC-377 (275.67 ± 11.55 cm). The crosses L4 x T3 (174.67) followed by L5 x T3 (175.22) and L6 x T3 (183.78 cm) showed best values toward short plants. Regarding ear height, values ranged from 103.22 cm for cross L5 x T2 to 142.78 cm for cross L7 x T1. 14 out 21 crosses were significantly less than two check hybrids TWC-368 (147.89 ± 8.83 cm) and TWC-377 (138.33 ± 8.83 cm) toward shorter ear height. The best crosses had values toward short ear height was L5 x T2 (103.22) followed by L2 x T2 (107.44) and L6 x T2 (110.22 cm). For ear position%, the crosses ranged from 45.67% for cross L1 x T1 and 56.56% for cross L2 x T2. 3 out 21 crosses were significantly compared with the two checks TWC-368 (52.33 ± 3.71) and TWC-377 (50.11 ± 3.71) toward lower ear placement.

Table (3): Line × Tester analysis of variance for six studied traits combined across three locations

sov	df	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear position %	Ear length (cm)	Grain yield (ard. fed.$^{-1}$)
Crosses (C)	20	30.62**	2361.96**	1086.00**	44.05**	5.71**	54.91**
Lines (L)	6	16.68**	652.70**	209.89*	28.64	6.05**	26.87**
Testers (T)	2	180.54**	19651.00**	8739.37**	120.58**	0.67	282.39**
Lines x Testers	12	12.60**	335.09**	248.49**	39.00**	6.38**	31.01**
C x Loc.	40	5.95**	602.63**	277.84**	24.27*	2.78**	22.61**
Lines x Loc.	12	4.81**	764.89**	354.54**	22.92	2.73**	12.27
Testers x Loc.	4	24.18**	2179.92**	863.93**	31.64	1.34	120.75**
L x T x Loc	24	3.49*	258.63	141.81	23.72	3.05**	11.42
Pooled error	120	1.418	163.350	90.341	16.945	1.121	7.923

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

The best crosses for this trait were L_1 x T_1 (45.67) followed by L_3 x T_3 (45.89) and L_5 x T_1 (46.11%). For ear length, 4 out 21 crosses recorded significantly longer ear compared with the check TWC-377 (19.13 ± 0.94 cm). On the other hand, 14 out 21 crosses did not differ significant compared with the check with longest ear; TWC-368 (19.53 ± 0.94). Grain yield ranged from 20.86 ardeb fed^{-1} for cross L_2 x T_2 to 29.38 ardeb fed.$^{-1}$ for cross L_2 x T_1. The crosses had the highest values toward high yielding were L_2 x T_1 (29.38), L_6 x T_1 (28.96), L_5 x T_3 (27.84) and L_4 x T_1 (26.63 ardeb fed^{-1}). 7 out of 21 crosses; L_2 x T_1, L_3 x T_1, L_3 x T_2, L_4 x T_1, L_5 x T_1, L_5 x T_3 and L_6 x T_1 did not differed significantly compared with the highest yielding check hybrid TWC-368 (28.09 ardeb fed.$^{-1}$ ± 2.52). On the other hand, two crosses; L_2 x T_1 (29.38 ardeb fed.$^{-1}$) and L_6 x T_1 (28.96) out yield significantly compared with the check TWC-377 (25.76 ± 2.52 ardeb fed.$^{-1}$). The previous results showed that, two crosses; L_4 x T_3 and L_6 x T_3 were significantly for silking date, plant height and ear height toward earliness, short plant and lower ear placement. In addition, that, two crosses; L_2 x T_1 and L_3 x T_2 and L_4 x T_1 had the good mean performance values toward earliness and high yield ability. These crosses could be recommended to use in maize breeding programs to produce a promising hybrid with high yielding ability. General combining ability effects (g_i) of seven new yellow maize inbred lines and three testers were recorded for all studied traits combined across three locations are illustrated in Table 5. Two maize inbred lines, L_4 and L_6 recorded negative and significant desirable effect for silking date toward earliness. For plant height and ear height, each of L_2 and L_5 were good combiner toward short plant and ear height, respectively. Two inbred lines, L_6 and L_7 had positive and highly significant values for ear length toward longest ear. For grain yield, L_3 was the best general combiner toward high yielding ability. On the other hand, T_2 as a tester was the best general combiner for silking date, plant height, ear height and ear position% toward earliness, short plant, short ear height and lower ear placement. While T_1 as a tester displayed good general combiner toward high yielding. Based on the preceding results appeared, the inbred lines and testers showed differences in general combining ability effects for the studied traits. In this constant, many researchers *viz*, Yadav and Gangwar (2021), Aly *et al*., (2023 & 2025) and Abd EL-Azeem *et al*., (2023) were reached to the same results with other plant materials.

Table (4): Mean performances of the 21 crosses and the 2 check hybrids for six studied traits combined across three locations

Crosses	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear position %	Ear length (cm)	Grain yield (ard. fed.$^{-1}$)
L1 x T1	59.11	257.78	129.78	45.67	18.03	24.43
L1 x T2	56.00	303.11	115.56	53.11	19.52	22.01
L1 x T3	59.22	190.22	126.00	48.56	17.54	22.10
L2 x T1	58.89	242.22	133.22	48.00	18.29	29.38
L2 x T2	55.33	290.56	107.44	56.56	20.88	20.86
L2 x T3	61.22	187.67	128.89	47.44	17.58	22.27
L3x T1	60.78	265.00	130.78	47.56	19.32	26.21
L3x T2	56.56	301.56	121.44	54.89	19.30	26.06
L3x T3	59.00	188.78	125.89	45.89	18.87	25.09
L4x T1	58.00	278.33	138.11	49.56	18.64	26.63
L4 x T2	56.56	285.11	115.89	53.56	19.76	22.89
L4 x T3	56.89	174.67	124.44	51.67	17.96	23.49
L5 x T1	60.67	271.11	139.11	46.11	18.81	25.90
L5 x T2	56.33	288.11	103.22	52.22	19.73	22.07
L5 x T3	59.11	175.22	116.89	47.11	18.13	27.84
L6 x T1	60.00	265.00	139.89	47.33	20.20	28.96
L6 x T2	55.44	298.56	110.22	52.00	20.32	22.01
L6 x T3	57.11	183.78	122.00	49.44	18.57	24.37
L7 x T1	59.33	270.00	142.78	49.33	19.26	25.51
L7 x T2	58.44	304.22	115.00	52.89	20.31	21.69
L7 x T3	60.56	190.67	127.89	47.67	19.32	24.20
TWC368	60.00	279.11	147.89	52.33	19.53	28.09
TWC377	60.00	275.67	138.33	50.11	19.13	25.76
LSD 0.05	1.08	11.55	8.83	3.71	0.94	2.52
0.01	1.41	15.18	11.60	4.88	1.24	3.31

Specific combining ability effects (S_{ij}) of 21 crosses for all investigated traits combined across three locations are illustrated in Table 6. Results showed that, five crosses; L_2 x T_1, L_2 x T_2, L_4 x T_3, L_6 x T_3 and L_7 x T_1 had negative and significant SCA effects for silking date toward earliness. One cross for each plant and ear heights; (L_6 x T_2) and (L_3 x T_1) had negative and significant specific combining ability toward short plant and short ear height, respectively. For ear length, five crosses, L_2 x T_2, L_3 x T_2, L_4 x T_3, L_5 x T_1 and L_7 x T_3 were marked as positive and significant combiners for longest ears. Three crosses; L_2 x T_1, L_3 x T_2 and L_5 x T_3 were possessed positive and significant SCA effects toward high yielding. These maize crosses were scored values 2.97**, 2.23* and 2.85**, respectively. Estimates of genetic parameters and contribution of line, tester and line x tester for all studied traits combined across three locations are presented in Table 7. Results showed that the K^2GCA more than the K^2SCA for silking date, plant height and ear height traits, indicating that the important role of additive gene action in the inheritance of these traits. Meanwhile, K^2SCA more than K^2GCA for ear position%, ear length and grain yield, indicating that the non-additive gene action played an important role in the inheritance of these traits under these conditions. Similar results were reported by Yosra (2020), Abd El-Azeem *et al*., (2023) and Aly *et al*., (2025) for silking date, plant height and ear height; Mousa *et al*., (2021) for silking date and El-Ghonemy *et al*., (2023) for plant height. The magnitudes of the interaction variances of σ^2GCA x Loc. were greater than those of σ^2SCA × Loc. for silking date, plant height and ear height, indicating that the additive gene action interacted more affected by the environmental conditions than the non-additive components of gene action for these investigated traits. While σ^2SCA × Loc. was more affected by environmental conditions for ear position%, ear length and grain yield. These findings results are in agreement with those detected by Mosa *et al.*, (2016) and Aly *et al.*, (2025) for grain yield; Mousa *et al.*, (2021) for ear length and grain yield ; Abd El-Azeem *et al.*, (2023) for silking date, plant height and ear height and Aly *et al.*, (2023) for ear position% and grain yield. Based on the results on contribution of line, tester and their interactions to the total variances of crosses, the tester components largely contribution for all studied traits except ear position% and ear length traits. These results confirming the possibility selection of testers for manipulating these traits need to consider than the selection of line parent.

Table (5): General combining ability effects of seven new yellow maize inbred lines and three testers for six studied traits combined across three locations

Lines Testers	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear position %	Ear length (cm)	Grain yield (ard. fed.$^{-1}$)
L1	-0.201	2.196	-0.720	-0.725	-0.697**	-1.626**
L2	0.169	-8.026**	-1.312	0.831	-0.149	-0.307
L3	0.466*	3.603	1.540	-0.392	0.099	1.311*
L4	-1.164**	-2.138	1.651	1.757*	-0.279	-0.137
L5	0.392	-3.360	-4.757*	-1.354	-0.171	0.796
L6	-0.794**	0.937	-0.460	-0.243	0.632**	0.637
L7	1.132**	6.788**	4.058*	0.127	0.566**	-0.674
SE gi (L)	0.229	2.460	1.829	0.792	0.204	0.542
LSD 0.05	0.454	4.870	3.622	1.569	0.403	1.073
0.01	0.600	6.438	4.788	2.074	0.533	1.418
T1	1.228**	18.476**	11.741**	1.275*	-0.039	2.243**
T2	-1.931**	-16.714**	-11.815**	-1.471**	-0.078	-1.963**
T3	0.704**	-1.762	0.074	0.196	0.117	-0.280
S.E. gi (T)	0.150	1.610	1.197	0.519	0.133	0.355
LSD 0.05	0.297	3.188	2.371	1.027	0.264	0.702
0.01	0.393	4.215	3.134	1.357	0.349	0.928

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

Simple correlation coefficient between all studied traits combined across three locations are summarized in Table 8. Results confirmed that, while grain yield recorded positive and significant correlation with silking date and ear height, negative and significant correlation with ear position% existed. Correlation coefficient between silking date was negative and significant with ear position% and ear length traits, and positively significant with ear height. Plant height scored values positive and significant correlation with ear position% and ear length. The correlation coefficient was positive and significant between ear position% with ear length. These results are in harmony with those obtained by Pandey *et al.*, (2017); Abd El-Latif *et al.*, (2023) and Aly *et al.*, (2025). Heterotic groups estimate using specific and general combining ability methods (HSGCA) for grain yield across three locations are illustrated in Table 9. HSGCA integrates SCA and GCA effects providing a more complete understanding of the genetic potential of parental lines and helps in the identification of the best parental combinations, leading to the development of high-yielding and resilient hybrids (Fan *et al.*, 2009). Results revealed that the seven new yellow maize inbred lines were placed into three heterotic groups. Group1 (T_1 SC180) consisted of four lines; L_1, L_3, L_5 and L_7. While group2 (T_2 SC173) included one only inbred line (L_6). Group3 (T_3 SC168) included two inbred lines; L_2 and L_4. According to these results, this method was able to classify all inbred lines under this investigation. These results could be recommended in selecting good parents for making hybrids and give the breeder chances for developing a high yielding maize cross through crossing of these inbred lines belonging to other inbred lines from different heterotic groups (Fan *et al*,. 2009 and Legesse *et al*., 2014).

Table (6): Specific combining ability effects of 21 top crosses of maize for seven studied traits combined across three locations

Crosses	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear position %	Ear length (cm)	Grain yield (ard. fed.$^{-1}$)
L1 x T1	-0.23	-3.51	-5.74	-1.72	0.55	-0.66
L1 x T2	-0.18	4.34	3.59	0.69	0.22	1.13
L1 x T3	0.41	-0.83	2.15	1.03	-0.77*	-0.47
L2 x T1	-0.82*	2.04	-1.70	-1.39	-0.04	2.97**
L2 x T2	-1.22*	1.68	-3.93	-1.97	0.74*	-1.35
L2 x T3	2.04**	-3.72	5.63	3.36*	-0.70	-1.62
L3x T1	0.78*	-5.70	-7.00*	-1.94	-0.81*	-1.82*
L3x T2	-0.29	7.05	7.22*	2.03	0.72*	2.23*
L3x T3	-0.48	-1.35	-0.22	-0.08	0.10	-0.42
L4x T1	-0.38	-3.18	0.22	2.13	0.31	0.05
L4 x T2	1.34**	6.12	1.56	-1.46	-1.01**	0.51
L4 x T3	-0.96*	-2.94	-1.78	-0.68	0.71*	-0.57
L5 x T1	0.74	2.60	7.63*	2.35	0.86*	-1.61
L5 x T2	-0.44	-6.54	-4.70	-0.68	0.06	-1.24
L5 x T3	-0.30	3.95	-2.93	-1.68	-0.92*	2.85**
L6 x T1	1.25**	6.97	4.11	-0.09	-0.19	1.60
L6 x T2	-0.14	-10.95*	-2.00	1.77	-0.36	-1.14
L6 x T3	-1.11**	3.97	-2.11	-1.68	0.55	-0.46
L7 x T1	-1.35**	0.78	2.48	0.65	-0.67	-0.53
L7 x T2	0.93*	-1.69	-1.74	-0.38	-0.39	-0.15
L7 x T3	0.41	0.91	-0.74	-0.27	1.04**	0.68
SE Sij	0.39	4.28	3.18	1.37	0.36	0.94
LSD 0.05	0.78	8.48	6.29	2.72	0.71	1.86
0.01	1.03	11.21	8.31	3.60	0.93	2.45

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

Table (7): Genetic parameters and contribution of line, tester and line x tester for six studied traits combined across three locations

Genetic parameters	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear position %	Ear length (cm)	Grain yield (ard. fed.$^{-1}$)
K^2 GCA	1.87	192.88	85.90	1.05	0.03	1.96
K^2SCA	1.01	8.49	11.85	1.70	0.37	2.18
σ^2 GCA x Loc	0.88	87.74	34.53	0.74	0.07	1.33
σ^2SCA x Loc	0.71	34.10	16.85	2.52	0.67	3.94
Contribution of Lines	16.34	8.29	5.80	19.50	31.81	14.68
Contribution of Tester	58.97	83.20	80.47	27.37	1.18	51.43
Contribution of L x T	24.69	8.51	13.73	53.12	67.01	33.89

Table (8): Simple correlation coefficient between all the studied traits across three locations

	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear position %	Ear length (cm)	Grain yield (ard. fed.$^{-1}$)
Days to 50% silking	---	-0.423	0.723**	-0.831**	-0.449*	0.458*
Plant height (cm)		---	-0.205	0.551**	0.715**	-0.149
Ear height (cm)			---	-0.668**	-0.407	0.660**
Ear position%				---	0.590**	-0.543*
Ear length (cm)					---	-0.239
Grain yield (ard. fed.$^{-1}$)						---

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

Table (9): Heterotic groups estimate using specific and general combining ability method (HSGCA) for grain yield combined across locations

Lines	Testers		
	SC-180 (T1)	**SC-173 (T2)**	**SC-168 (T3)**
L1	-2.28#	-0.50	-2.09
L2	2.75	-1.53	-1.93#
L3	-0.42#	3.67	0.90
L4	0.00	0.50	-0.70#
L5	-0.73#	-0.32	3.65
L6	2.33	-0.38#	0.17
L7	-1.12#	-0.70	0.01

≠ means that this inbred line belongs to tester group.

REFFERENCES

Abd El-Azeem, M.E.M.; Aly, R.S.H.; Abd El-Latif, M.S.; Abd-Elaziz, M.A.A. and W.M. El-Sayed (2023). Combining ability of new white maize inbred lines by using test crosses technique. Egypt. J. Plant Breed. 27(3):309– 326.

Abd El-Latif, M.S.; Yosra A. Galal and M.S. Kotp (2023). Combining ability, heterotic grouping, correlation and path coefficient in maize. Egypt. J. Plant Breed. 27(2):203– 223.

Aly, R. S. H.; Abd El-Azeem, M.E.M. and El-Sayed, W.M. (2023). Combining ability and classification of new thirteen yellow maize inbred lines (*Zea mays* L.) using line x tester mating design across three locations. Journal of Plant Production Sciences; Suez Canal University, 12(1): 21-30.

Aly, R.S.H.; Abd El-Azeem, M.E.M. and A.K. Mostafa (2025). Line × tester analysis using three-way crosses of yellow maize in a multi-location trial. Assiut Journal of Agricultural Sciences 56 (1):21-32.

Barata, C. and M. Carena (2006). Classification of North Dakota maize inbred lines into heterotic groups based on molecular and testcross data. Euphytica, 151: 339-349.

Bhatla, A.; Angidi, S.; Thomas, N.; Madankar, K. and J. P. Shahi (2025). Classification of maize inbred lines into heterotic groups based on yield and yield attributing traits. Plant Genetic Resources: Characterization and Utilization, 23, 27–39.

Economic Affairs Sector (2024). Ministry of Agricultural and land reclamation, economic affairs sector, head of the sector.

El Ghonemy, M.A.M.; Aboyousef, H.A.; Abu Shosha, A.M.; EL-Shahed, H.M. and M.S. Shalof (2023). Combining ability, main performance, and superiority percentage of maize (*Zea mays* L.) inbred lines using line x testers analysis. International Conference of Field Crops Research Institute, Egypt. J. Agric. Res., 10(3): 939-951.

Fan, X.M.; Zhang, Y.M.; Yao, W.H.; Chen, H.M.; Tan, T., Xu, C.X., Han, X.L., Luo, L.M. and M.S. Kang (2009). Classifying maize inbred lines into heterotic group using a factorial mating design. Agron. J. 101(1): 106-112.

Hamada, M.S.; Aly, R.S.H. and Manal M. Zaater (2024). Estimation of genetic parameters, combining ability and heterotic groups of new yellow maize inbred lines using line x tester model across two locations. J. of Agricultural Chemistry and Biotechnology, Mansoura Univ., 15 (3): 47 – 52.

Job, A.; Iseghohi, I.o.; Igyuve, m.t.; Olayiwola, R.; Akinwale, R.; Ojo, G.O.; Abe, A.; Obisesan, O. and E. Ogundare (2024). Performance of early-maturing topcross maize hybrids across multi-environments. Journal of Plant Breeding and Crop Science. 16(1): 15-26.

Kempthorne, O. (1957). An introduction to genetic statistics. John Wiley and Sons Inc., New York, USA.

Legesse, W.; Mosisa, W.; Berhanu, T.; Girum, A.; Wande, A.; Solomon, A.; Tolera, K.; Andualem, W. and A. Belay (2014). Genetic improvement of maize for mid-altitude and lowland sudhumid agroecologies of Ethiopia. In Worku, M., S. Twumasi-AfriyieB. M. Prasanna, (Eds.), 57: 24-34, 18-20 April 2012. Proceedings of the third National Maize Workshop of Ethiopia, Addis Ababa,

Matongera, N.; Ndhlela, T.; Biljon, A.V.; Kamutando, C.N. and M. Labuschagne (2023). Combining ability and testcross performance of multi-nutrient maize under stress and non- stress environments. Front. Plant Science. 14:1070302.

Melchinger, A.E. (1999). Genetic diversity and heterosis. In: Coors, J.G. and Pandey, S., Eds., Proceedings of the International Symposium on Genetics and Exploitation of Heterosis in Crops, CIMMYT, Mexico, 17-22 August 1997, 3-48.

Mosa, H.E.; Abd El-Moula, M.A.; Motawei, A.A.; El-Gazzar, I.A.I.; Abd El-Latif, M.S.; Rizk M.S. and T.T. El-Mouslhy (2024). Classifying new maize inbred lines into heterotic groups using three methods. Egypt. J. Plant Breed. 28(1):135–154(2024).

Mosa, H.E.; El-Gazzar, I.A.I. and M.A.A. Hassan (2016). Combining ability and type of gene action analysis of yield and yield components for some white maize inbred lines. Annals of Agric. Sci., Moshtohor, 54(2): 291–296.

Mousa, S.Th.M.; Mohamed, H.A.A.; Aly, R. S. H. and H. A. Darwish (2021). Combining ability of white maize inbred lines via line x tester analysis. J. of Plant Production, Mansoura Univ., 12(2):109 – 113.

Murtadha, M.A.; Ariyo, O.J. and S.S. Alghamdi (2018). Analysis of combining ability over environments in diallel crosses of maize (*Zea mays* L.). Journal of the Saudi Society of Agricultural Sciences 17: 69-78.

Oluwaseun, O.; Badu-Apraku, B.M. and A.M. Abubakar (2022). Combining ability and performance of extra-early maturing provitamin a maize inbreds and derived hybrids in multiple environments. Plants 11(7): 964: 1-20.

Pandey, Y., Vyas, R.P.; Kumar, J.; Singh, L.; Singh, H.C.; Yadav, P.C. and Vishwanath (2017). Heritability, correlation and path coefficient analysis for determing interrelationships among grain yield and related characters in maize (*Zea mays* L.). Int. J. Pure App. Biosci., 5(2): 595-603.

Rajesh, V.; Kumar, S.S.; Reddy, V.N. and A.S. Sankar (2018). Combining ability and genetic action studies for yield and its related traits in maize (*Zea mays* L.). Int. J. Curr. Microbiol. App .Sci, 7(6): 2645-2652.

Rojas, B.A. and G.F. Sprague (1952). A comparison of variance components in corn yield trials: III. General and specific combining ability and their interaction with locations and years. Agron. J. 44: 462-466.

SAS Institute (2008). Statistical Analysis System (SAS/STAT program, version. 9.1). SAS Inst. Cary NC

Singh R. K. and Chaudhary, B. D. (1985). Biometrical methods in quantitative genetic analysis. Kalyani publishers, Ludhiana.

Snedecor, G.W. and W.G. Cochran, (1989). Statistical methods. 7th Edition, Iowa State Univ., Press. Ames, Iowa, USA

Sprague, G. F., and Tatum, I. A. (1942). General versus specific combining ability in single crosses of corn. J. Amer. Soci. Agron. 34: 923-928.

Subba, V.; Nath, A.; Kundagrami, S.; and A. Ghosh (2021). Study of combining ability and heterosis in quality protein maize using line x tester mating design. Agricultural Science Digest - A Research Journal of Agriculture, Animal and Veterinary Sciences, D-5460, 1-7.

Yadav, M.S. and B. Gangwar (2021). Studies on heterosis and combining ability through diallel method in maize (*Zea mays* L.). Plant Archives, 21(1): 686-694.

Yosra A. Galal (2020). Line × tester analysis for estimation combining ability of some new yellow maize inbred lines for grain yield and downy mildew resistance. J. of Plant Production, Mansoura Univ., 11 12): 1209 – 1214.

القدرة الائتلافية لصفة محصول الحبوب وبعض الصفات الأخرى لسلالات صفراء جديدة من الذرة الشامية وتقسيمها لمجموعات هجينية باستخدام السلالة في الكشاف

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المستخلص: تم تهجين سبعة سلالات صفراء جديدة من الذرة الشامية من مصادر وراثية مختلفة قمياً مع ثلاثة كشافات (هجين فردى اصفر-180، هجين فردى أصفر-173 وهجين فردى أصفر-168) خلال الموسم الزراعي 2023 بمحطة البحوث الزراعية بالإسماعيلية. تم زراعة الـ 21 الهجين القمي الناتجة بالإضافة إلى هجينين من الهجن الصفراء (هجين ثلاثى-368 وهجين ثلاثى-377) كهجن مقارنة محصولية في ثلاثة محطات بحوث زراعية مختلفة (الإسماعيلية، سخا وملوى) خلال الموسم الزراعي 2024. أظهرت النتائج وجود اختلافات معنوية بالنسبة للمواقع، التراكيب الوراثية، الهجن وتفاعلهما مع المواقع لكل الصفات المدروسة. كذلك وجدت اختلافات معنوية في تباينات كلاً من السلالة، الكشاف، السلالة في الكشاف وتفاعلهم مع المواقع لمعظم الصفات تحت الدراسة. أظهرت خمسة هجن (سلالة-4 x كشاف-3)، (سلالة-5 x كشاف-3)، (سلالة-6 x كشاف-3)، (سلالة-2 x كشاف-1) و(سلالة-3 x كشاف-2) قيماً معنوية عالية في متوسط الأداء ناحية صفات التبكير في النضج، قصر النبات، أفضلية لموقع الكوز على النبات والقدرة المحصولية العالية. امتلكت كلاً من السلالة-3 والكشاف-1 أفضلية موجبة ومعنوية للقدرة العامة على الائتلاف ناحية المحصول العالي. في حين امتلكت السلالتين 4 و6 أفضلية للقدرة العامة على الائتلاف لصفة التزهير ناحية التبكير في النضج. أظهر الكشاف 2 أفضلية للقدرة العامة على الائتلاف ناحية التبكير، قصر النبات وأفضلية لموقع الكوز على النبات. أظهرت ثلاثة هجن (سلالة-2 x كشاف-1)، (سلالة-3 x كشاف-2) و (سلالة-5 x كشاف-3) أفضلية للقدرة الخاصة على الائتلاف، حيث كانت موجبة ومعنوية لصفة محصول الحبوب ناحية المحصول العالي. انطلاقا من نتائج طريقة HSGCA لتقسيم السلالات السبعة الجديدة الصفراء إلى مجموعاتهم الهجينية، أظهرت النتائج إمكانية قيام مربى النبات بعمل توليفات جيدة بين سلالات من مجموعات هجينية مختلفة لإنتاج هجن متفوقة تتميز بالقدرة المحصولية العالية والتبكير في النضج إلى جانب إمتلاكها بعض الصفات المحصولية الأخرى المرغوبة.

الكلمات المفتاحية: الذرة الشامية – السلالة في الكشاف – القدرة الإئتلافية – الإرتباط – طريقة HSGCA