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COMBINING ABILITY OF NEW WHITE MAIZE INBRED LINES BY USING TEST CROSSES TECHNIQUE

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ABSTRACT

Nine new white maize inbred lines were topcrossed with four line testers, i.e., Sd.1185, Sd.1194, Sd.1264 and Sd.1313 during 2020 summer season. All inbred lines were developed at Sids Agricultural Research Station. The 36 testcrosses and the two check hybrids SC10 and SC2031 were evaluated at Sakha, Gemmeiza and Sids Agric. Res. Stns. during 2021 summer season. General (GCA) and specific (SCA) combining ability effects were estimated for days to 50% silking, plant height, ear height, ear position (%) and grain yield (ardab/feddan). Combined analysis across the three locations showed significant differences between the three locations for all studied traits. Mean squares due to crosses, lines and testers were significant for all studied traits. Mean squares due to lines × testers were significant for days to 50% silking, plant height, ear height and grain yield. Mean squares due to lines × locations were significant for all studied traits. Mean squares due to testers × locations were significant for all studied traits, except for grain yield. Mean squares due to lines × testers × locations interaction were highly significant for days to 50% silking. The magnitude of δ^2 GCA (average) was larger than that of δ^2 SCA for all studied traits except, for plant height and grain yield. The inbred lines L.2 and L.4 possessed the highest GCA effects for grain yield and may be considered promising lines for improving grain yield. Also the crosses L.4×Sd.1185, L.13×Sd.1264 and L.20×Sd.1194 may be released for commercial cultivation after further testing and evaluation. The inbred lines, based on grain yield and heterotic group using specific and general combining ability (HSGCA) method, were classified into four heterotic groupings as follows: group-1 (Sd.1185) included L.14 and L.22 while, group-2 (Sd.1194) included L.22. Group-3 (Sd.1264) included L.4, L.9 and L.20 while, group-4 (tester Sd-1313) included L.12 and L13. These groups could be used in breeding programs for selecting the best parents in developing new crosses.

Key words: ***Zea mays, line × tester, GCA, SCA, heterotic group***.

INTRODUCTION

Testcross method using narrow testers is used to evaluate new improved inbred lines for combining ability. The choice of tester to test the developed inbred lines is an important decision. Line × tester analysis is an extension of this method, in which several testers are used (Kempthorne 1957). Many investigations were conducted on type of tester and evaluation of inbred lines (Davis, 1927). Darrah *et al* (1972) found that inbred testers have advantage of no sampling errors of genetic variability within are testers and greater genetic variation among top crosses. Al-Naggar *et al* (1997) suggested that inbred line testers can be effectively used for evaluation of both general and specific combining abilities. Abd El-Mottalb (2014), Gamea (2015) and Abd El-Mottalb (2015) estimated general and specific combining ability and their role in the inheritance of grain yield. Rojas and Sprague (1952) compared estimates of the variances of GCA and

SCA for yield and their interaction with location and years. Jayakumar and Sundaram (2007) reported that the specific combining ability variances were higher than the general combining ability variances for days to 50% silking and grain yield. El sherbieny *et al* (2006) found that genotype × environment (G × E) interaction were significant for grain yield. El-Zeir *et al* (2000) and El-Morshidy *et al* (2003) obtained significant GCA × Environment interaction for both lines and testers for grain yield. Variance components due to specific combining ability (SCA) for grain yield and other agronomic traits were larger than variance components due to general combining ability (GCA), indicating the importance of non-additive gene action in inheritance of these traits (El-Morshidy *et al* 2003 and Abd El-Azeem and Abd El-Moula 2009).

Heterotic groups and patterns are extremely important in hybrid breeding programs (Melchinger and Gumber 1998). Classifying maize inbred lines into heterotic groups is the initial step in maize breeding programs which would provide maximum exploitation of heterosis via determination of the relationship existing among the different inbred lines. Numerous studies on classifying inbred lines into heterotic groups have been reported by Vasal *et al* (1992), Melchinger (1999), Menkir *et al* (2004), Fan *et al* (2009), Legesse *et al* (2009), Ibrahim *et al* (2021) and Abd El-Latif *et al* (2023).

The main objectives of this investigation were to evaluate 36 testcrosses for grain yield and other agronomic traits, estimate GCA effects for both lines and testers, estimate SCA effects for crosses, estimate variances due to GCA and SCA (δ^2 GCA and δ^2 SCA) and their interaction with location and classify the new inbred lines into different heterotic groups for future use in breeding programs.

MATERIALS AND METHODS

Nine white maize inbred lines in the S_5 generation were selected in the disease nursery field at Sids Agric. Res. Stn. In 2020 growing season, the 9 lines were topcrossed with each of four narrow base inbred lines, *i.e.,* Sd.1185, Sd.1194, Sd.1264, and Sd.1313 at Sids Agric. Res. Stn. In 2021 growing season, the 36 resultant testcrosses along with two commercial check hybrids, *i.e.,* SC10 and SC2031 were evaluated in replicated yield trials conducted at Sakha, Gemmiza and Sids Agric. Res. Stn. The experimental design was Randomized Complete Block Design with three replications. Plot size was one row, 6 m long and 0.80 m apart. Sowing was in hills spaced at 0.25 m along the row, at the rate of two kernels per hill and later thinned to one plant per hill. All cultural practices for maize production were applied as recommended. Data were recorded for number of days to 50% silking, plant height (cm), ear height (cm), ear position (%) and grain yield (ardab/feddan) adjusted to 15.5 % moisture content. Statistical analysis of the combined data across three locations was performed according to Snedecor and Cochran (1989). Combining ability analysis was computed according to Kempthorne (1957). Calculation of analysis of variance and line × tester analysis were carried out using computer application of Statistical Analysis System (SAS, 2008). Heterotic groups using specific and general combining ability (HSGCA) were identified according to Fan *et al* (2009).

RESULTS AND DISCUSSION

Mean squares of the combined analysis of variance across the three locations for five studied traits are given in Table (1). Mean squares due to locations were highly significant for all traits, indicating that the three locations differed from each other in their environmental conditions. These results are in agreement with those reported by Sadek *et al* (2000), El-Shenawy *et al* (2003), Mahmoud, and Abd El-Azeem *et al* (2004), Abd El-Azeem and Abd El-Moula (2009), Abd El-Azeem (2011) and Abd El-Azeem *et al* (2022). Mean squares due to crosses were highly significant for all studied traits. These results are in agreement with those reported by Abd El-Azeem *el al* (2004), Soliman *et al* (2007), Ibrahim *et al* (2010), Abd El-Mottalb (2014), Gamea (2015), Moshera *et al* (2016), Abd El-Mottalb (2017), Abd El-Mottalb (2019), and Abd El-Azeem *et al* (2022). Mean squares due to lines and testers were significant or highly significant for all the studied traits, indicating the presence of genetic variation among lines and testers. Mean squares due to lines × testers were highly significant for all the studied traits, except for ear position, indicating that lines differed in their order of performance in crosses with each of testers. Results are in agreement with those reported by Soliman and Sadek (1999), Amer *et al*

(2003), Ibrahim *et al* (2012), and Abd El-Azeem *et al* (2022). Mean squares due to crosses × location interaction were significant or highly significant. Mean squares due to lines × location interaction were highly significant for all studied traits, except for plant height, indicating that the behavior of crosses and lines were markedly different from location to another. Mean squares due to testers × location interaction were highly significant for all studied traits, except for grain yield, indicating that the behavior of testers differed from location to another. Mean squares due to line × tester × location interaction were highly significant for number of days to 50% silking. These results are in agreement with those obtained by Moshera *et al* (2016), Abd El-Mottalb (2017) and Abd El-Azeem *et al* (2022). The magnitude of mean squares due to lines was higher than those due to testers for all studied traits, except for number of days to 50% silking, indicating that lines contributed much more than testers to the total variation of the studied traits. Also the mean squares due to testers × location were higher than those due to lines × location for all the studied traits, except for grain yield, indicating that the testers were more affected by the environmental conditions than lines. These results are in agreement with those reported by Gado *et al* (2000), El-Morshidy *et al* (2003), Ibrahim *et al* (2010), Abd El-Mottalb (2015), Abd El-Mottalb (2017) and Dar *et al* (2017).

Mean performances for all crosses along with the two hybrid checks SC10 and SC2031 for all studied traits in the combined analysis are presented in Table (2). Results indicated that for days to 50% silking the earliest cross was L.14×Sd.1194 (57.00 days) while latest cross was L.13×Sd.1185 and L.21×Sd.1313 (62.22 days). All crosses except L.13×Sd.1185 and L.21×Sd.1313 were significantly earlier than the early check hybrid SC10. Plant height ranged from 250.11 cm for the cross L.22×Sd.1264 to 277.0 cm for the cross L.20×Sd.1185. Twenty-six crosses had significantly shorter plants than the check hybrid SC2031. Ear height ranged from 129.89 cm for the cross L.22×Sd.1194 to 170.33 cm for the cross L.20×Sd.1185. Ten crosses possessed significantly lower ear placement than the check hybrid SC2031. Mean ear position ranged from 51.39% to 61.39% for the cross L.22×Sd.1194 and L.20×Sd.1185, respectively. For grain yield, the results showed that the three crosses

L.2×Sd.1264 (39.58 ard/fed), L.2×Sd.1313 (38.29 ard/fed) and L.4×Sd.1185 (36.93 ard/fed) were significantly superior to the check hybrid SC10 (34.01 ard/fed), while the two crosses L.2×Sd.1185 (34.91 ard/fed) and L.2×Sd.1194 (35.52 ard/fed) did not differ significantly than the highest check SC10 (34.01 ard/fed), these high yielding testcrosses are recommended for further evaluation to accurately identify the promising ones for further commercial cultivation.

Table 1. Mean squares of the genotypes and their interaction with location for five studied traits across three locations.

SOV	df	Number of days to 50% silking	Plant height (cm)	Ear height (cm)	Ear position%	Grain yield (ard/fed)
Locations (Loc.)	2	426.15**	32480.21**	19133.43**	454.90**	699.79**
Reps/Loc.	6	2.38	640.99	526.83	24.62	12.83
Crosses (C)	35	10.56**	474.43**	540.40**	36.54**	137.95**
Lines (L)	8	23.75**	988.81**	1677.56**	106.38**	442.10**
Testers (T)	3	29.39**	760.35**	882.77**	84.06**	28.72*
Lines × Testers	24	3.82**	267.23**	118.54**	7.32	50.22**
C × Loc.	70	3.05**	107.76**	105.50**	10.60**	14.27*
L × Loc.	16	5.17**	108.64	183.40**	19.15**	25.23**
T × Loc.	6	7.11**	290.76**	269.40**	29.45**	12.16
L × T × Loc	48	1.83**	84.59	59.04	5.39	10.87
Pooled error	210	0.94	69.23	57.45	5.14	9.30

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

Table 2. Mean performances of 36 crosses and two check hybrids for five studied traits across three locations.

Cross	Number of days to 50% silking	Plant height (cm)	Ear height (cm)	Ear position%	Grain yield (ard/fed)
L.2 × Sd.1185	59.78	273.89	156.78	57.14	34.91
L.2 × Sd.1194	59.00	271.89	149.89	55.24	35.52
L.2 × Sd.1264	59.67	265.89	150.78	56.71	39.58
L.2 × Sd.1313	59.67	266.56	152.33	57.16	38.29
L.4 × Sd.1185	60.11	262.00	150.22	57.21	36.93
L.4 × Sd.1194	58.56	260.00	145.22	55.80	33.22
L.4 × Sd.1264	58.89	269.33	152.56	56.73	28.35
L.4 × Sd.1313	59.11	256.11	150.00	58.46	31.89
L.9 × Sd.1185	60.22	271.89	156.33	57.46	27.73
L.9 × Sd.1194	58.56	263.00	144.56	54.94	27.63
L.9 × Sd.1264	58.89	274.67	152.56	55.49	27.11
L.9 × Sd.1313	59.22	261.33	154.78	59.22	28.76
L.12 × Sd.1185	59.89	265.56	152.00	57.15	26.54
L.12 × Sd.1194	58.44	268.33	147.44	55.00	30.01
L.12 × Sd.1264	60.22	250.89	142.44	56.70	28.47
L.12 × Sd.1313	60.00	252.11	138.67	54.97	26.69

Table 2. Cont.

Cross	Number of days to 50% silking	Plant height (cm)	Ear height (cm)	Ear position%	Grain yield (ard/fed)
L.13 × Sd.1185	62.22	263.89	151.22	57.27	23.64
L.13 × Sd.1194	60.11	264.78	147.78	55.82	24.16
L.13 × Sd.1264	59.78	270.00	154.78	57.25	31.44
L.13 × Sd.1313	60.11	266.11	152.33	57.11	23.33
L.14 × Sd.1185	59.56	258.44	152.00	58.58	26.42
L.14 × Sd.1194	57.00	263.56	144.44	54.78	29.12
L.14 × Sd.1264	59.00	251.44	141.11	56.05	27.98
L.14 × Sd.1313	57.89	257.56	148.11	57.47	28.33
L.20 × Sd.1185	59.22	277.00	170.33	61.39	28.73
L.20 × Sd.1194	58.33	269.33	157.44	58.38	32.13
L.20 × Sd.1264	58.67	262.22	158.44	60.39	27.53
L.20 × Sd.1313	59.22	262.56	154.78	58.92	28.35
L.21 × Sd.1185	60.44	266.89	150.56	56.32	26.69
L.21 × Sd.1194	59.11	261.11	143.44	54.90	30.55
L.21 × Sd.1264	59.33	273.22	153.89	56.29	29.73
L.21 × Sd.1313	62.22	256.56	149.11	58.07	27.23
L.22 × Sd.1185	58.33	260.33	142.11	54.59	26.36
L.22 × Sd.1194	57.67	252.44	129.89	51.39	24.50
L.22 × Sd.1264	58.44	250.11	134.11	53.57	28.83
L.22 × Sd.1313	57.89	254.11	133.78	52.54	26.89
SC10	62.33	287.22	163.00	56.69	34.01
SC2031	62.67	276.89	151.67	54.88	33.82
LSD 0.05	0.91	7.64	6.95	2.07	2.84
LSD 0.01	1.19	10.07	9.16	2.73	3.75

General combining ability effects of inbred lines and testers for all studied traits are presented in Table (3). For days to 50% silking, the three inbred lines L.14, L.20 and L.22 exhibited negative desirable and significant GCA effects. These inbred lines are considered the best for earliness.

Table 3. General combining ability effects of the nine inbred lines and the four testers for all studied traits across three locations.

Line	Number of days to 50% silking	Plant height (cm)	Ear height (cm)	Ear position%	Grain yield (ard/fed)
L.2	0.228	6.358**	3.383**	-0.005	7.811**
L.4	-0.133	-1.336	0.438	0.483	3.332**
L.9	-0.077	4.525**	2.994*	0.211	-1.457**
L.12	0.340*	-3.975**	-3.923**	-0.613	-1.337**
L.13	1.256**	2.997*	2.466*	0.293	-3.623**
L.14	-0.938**	-5.448**	-2.645*	0.151	-1.305*
L.20	-0.438**	4.580**	11.188**	3.203**	-0.081
L.21	0.978**	1.247	0.188	-0.174	-0.717
L.22	-1.216**	-8.948**	-14.090**	-3.548**	-2.622**
LSD g_i 0.05	0.318	2.734	2.490	0.745	1.002
0.01	0.419	3.605	3.284	0.982	1.322
LSD g_i-g_j 0.05	0.455	3.911	3.563	1.066	1.434
0.01	0.604	5.193	4.731	1.415	1.904
Sd.1185	0.676**	3.457**	4.444**	0.888**	-0.603
Sd.1194	-0.769**	0.630	-3.494**	-1.428**	0.383
Sd.1264	-0.090	-0.111	-0.099	0.006	0.624
Sd.1313	0.182	-3.975**	-0.852	0.534*	-0.404
LSD g_i 0.05	0.214	1.844	1.680	0.502	0.676
0.01	0.285	2.448	2.230	0.667	0.897
LSD g_i-g_j 0.05	0.303	2.608	2.375	0.710	0.956
0.01	0.402	3.462	3.154	0.943	1.269

***, ** indicate significant at 0.05 and 0.01 level of probability, respectively.**

General combining ability effects for plant height were negative and significant for the inbred lines L.12, L.14 and L.22. The same parental inbred lines (L.12, L.14 and L.22) exhibited significant and negative GCA effects for ear height. With respect to ear position, the most desirable GCA effects toward low ear placement was obtained for the parental line L.22 which produced significantly negative GCA effects while the parental line L.20 exhibited significantly positive GCA effects toward high ear position.

Regarding grain yield, the highest general combiners were L.2 and L.4 which produced positive and highly significant GCA effects. The comparison between the four testers for GCA effects (Table 3) revealed that the inbred line tester Sd.1194 exhibited the desirable GCA effects for days to 50% silking, ear height, and ear position, while the inbred line tester Sd.1313 exhibited the most desirable GCA effects for plant height.

Specific combining ability effects of the test crosses for all traits are presented in Table (4).

Table 4. Specific combining ability effects of 36 crosses for five studied traits across three locations.

Cross	Number of days to 50% silking	Plant height (cm)	Ear height (cm)	Ear position %	Grain yield (ard/fed)
L.2 × Sd.1185	**-0.426**	**0.877**	**-0.111**	**-0.312**	**-1.558**
L.2 × Sd.1194	**0.241**	**1.704**	**0.938**	**0.108**	**-1.941**
L.2 × Sd.1264	**0.228**	**-3.556**	**-1.568**	**0.142**	**1.885**
L.2 × Sd.1313	**-0.043**	**0.975**	**0.741**	**0.061**	**1.614**
L.4 × Sd.1185	**0.269**	**-3.318**	**-3.722**	**-0.730**	**4.940****
L.4 × Sd.1194	**0.157**	**-2.491**	**-0.784**	**0.181**	**0.238**
L.4 × Sd.1264	**-0.188**	**7.583****	**3.154**	**-0.326**	**-4.870****
L.4 × Sd.1313	**-0.238**	**-1.775**	**1.352**	**0.876**	**-0.308**
L.9 × Sd.1185	**0.324**	**0.710**	**-0.167**	**-0.203**	**0.525**
L.9 × Sd.1194	**0.102**	**-5.352***	**-4.006**	**-0.413**	**-0.562**
L.9 × Sd.1264	**-0.244**	**7.056***	**0.599**	**-1.293**	**-1.322**
L.9 × Sd.1313	**-0.182**	**-2.414**	**3.574**	**1.910***	**1.359**
L.12 × Sd.1185	**-0.426**	**2.877**	**2.417**	**0.307**	**-0.785**
L.12 × Sd.1194	**-0.426**	**8.481****	**5.799***	**0.476**	**1.701**
L.12 × Sd.1264	**0.673***	**-8.222****	**-2.596**	**0.736**	**-0.084**
L.12 × Sd.1313	**0.179**	**-3.136**	**-5.620***	**-1.520***	**-0.832**
L.13 × Sd.1185	**0.991****	**-5.762***	**-4.750**	**-0.479**	**-1.398**
L.13 × Sd.1194	**0.324**	**-2.046**	**-0.256**	**0.387**	**-1.867**
L.13 × Sd.1264	**-0.688***	**3.917**	**3.349**	**0.381**	**5.169****
L.13 × Sd.1313	**-0.627**	**3.892**	**1.657**	**-0.289**	**-1.905**

Table 4. Cont.

Cross	Number of days to 50% silking	Plant height (cm)	Ear height (cm)	Ear position%	Grain yield (ard/fed)
L.14 × Sd.1185	0.519	-2.762	1.139	0.971	-0.940
L.14 × Sd.1194	-0.593	5.176	1.522	-0.512	0.776
L.14 × Sd.1264	0.728*	-6.194*	-5.207*	-0.680	-0.610
L.14 × Sd.1313	-0.654*	3.781	2.546	0.220	0.774
L.20 × Sd.1185	-0.315	5.765*	5.639*	0.731	0.150
L.20 × Sd.1194	0.241	0.926	0.688	0.041	2.563*
L.20 × Sd.1264	-0.105	-5.444	-1.707	0.614	-2.282*
L.20 × Sd.1313	0.179	-1.247	-4.620	-1.385	-0.431
L.21 × Sd.1185	-0.509	-1.012	-3.139	-0.965	-1.252
L.21 × Sd.1194	-0.398	-3.963	-2.312	-0.067	1.617
L.21 × Sd.1264	-0.855**	8.889**	4.738	-0.113	0.553
L.21 × Sd.1313	1.762**	-3.914	0.713	1.145	-0.919
L.22 × Sd.1185	-0.426	2.627	2.694	0.680	0.318
L.22 × Sd.1194	0.352	-2.435	-1.590	-0.202	-2.526*
L.22 × Sd.1264	0.451	-4.028	-0.762	0.539	1.561
L.22 × Sd.1313	-0.377	3.836	-0.343	-1.018	0.646
LSD S_{ij} 0.05	0.643	5.532	5.039	1.507	2.028
0.01	0.854	7.344	6.690	2.001	2.692
LSD S_{ij}-S_{ik} 0.05	0.909	7.823	7.126	2.131	2.868
0.01	1.207	10.386	9.461	2.830	3.808

***, ** indicate significant at 0.05 and 0.01 level of probability, respectively**

For days to 50% silking, the testcrosses L.13×Sd.1264, L.14×Sd.1313 and L.21×Sd.1264 exhibited significant and negative SCA effects. The testcrosses L.9×Sd.1194, L.12×Sd.1264 and L.14×Sd.1264 exhibited significant and negative SCA effects for plant height. The testcrosses L.12×Sd.1313 and L.14×Sd.1264 exhibited significant and negative SCA effects for ear height. The testcross L.12×Sd.1313 exhibited significant and negative SCA effects for ear position. The testcrosses L.4×Sd.1185, L.13×Sd.1264 and L.20×Sd.1194 exhibited significant and positive SCA effects for grain yield.

Estimates of δ^2 GCA for lines and testers and δ^2 SCA for lines × tester crosses along with their interaction with location are presented in Table (5). The results revealed that values of δ^2 GCA for lines were higher than those of δ^2 GCA for testers for all traits. These results indicate that the most of the total variance was due to GCA variance of lines for those traits. Values of δ^2 GCA were higher than those of the δ^2 SCA for all traits, except for plants height and grain yield, indicating that the additive gene effects were more important than the non-additive in inheritance of all traits, except for plant height and grain yield where the non-additive effects were more important.

Table 5. Genetic parameters and their interaction with locations for five studied traits of maize across three locations.

Genetic Parameters	Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear positio%	Grain yield (ard/fed)
δ^2 GCA (Lines)	0.634	25.544	45.003	2.812	12.022
δ^2 GCA (Testers)	0.351	8.532	10.189	0.974	0.240
δ^2 GCA (aver.)	0.438	13.767	20.901	1.540	3.865
δ^2 SCA (aver.)	0.320	22.000	6.788	0.242	4.546
δ^2 L × Loc = δ^2 GCA (L) × Loc	0.353	3.284	10.496	1.168	1.327
δ^2 T × Loc = δ^2 GCA (T) × Loc	0.229	8.205	7.850	0.900	0.106
δ^2 GCA × Loc = δ^2 GCA average × Loc	0.240	6.438	7.857	0.893	0.379
δ^2 L × T × Loc = δ^2 SCA average × Loc	0.298	5.119	0.530	0.084	0.523

The interaction variance of δ^2 GCA lines × location were larger than those of δ^2 GCA tester × location for all traits, except for plant height indicating, that the additive gene action of the inbred lines was more affected by the location change than that of the testers for all traits, except for plant height, where the opposite was the case. While the magnitudes of the interaction variances of δ^2 SCA × loc interaction was greater than those of δ^2 GCA × loc for all traits, except for plant height, ear height and ear position, indicating that the non-additive gene action interacted more with the environmental conditions than the additive components of gene action for these traits. These results are in agreement with the findings of several investigations who reported that specific combining ability variance was more sensitive to environmental changes than general combining ability variance (Sadek *et al* 2000, Mahmoud and Abd El-Azeem 2004, Mousa and Abd El-Azeem 2009. Ibrahim *et al* 2012 and Gamea 2015). On the other hand El-Itriby *et al* 1990, Soliman *et al* 2001, Abd El-Azeem and Abd El-Moula 2009, Abd El-Azeem 2011 and Abd El-Mottalb 2015) reported that the additive type of gene action was more affected by environment than non-additive one.

Estimates of heterotic groups based on specific and general combining ability effects (HSGCA) for grain yield across the three locations are presented in Table (6). Fan *et al* (2009) suggested 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 other heterotic group. Step-3, if the inbred line had positive HSGCA effects with all representative testers, it will be cautious to assign that line to any heterotic group because the line might belong to a heterotic group different from the testers used in the investigation. According to the findings, there were four heterotic groupings formed from the nine inbred lines. Group-1(tester Sd-1185) included the two inbred lines L.14 and L.21 while, group-2 (tester Sd-1194) included the inbred line L.22. Group-3 (tester Sd-1264) included the three inbred lines L.4, L.9 and L.20 while, group-4 (tester Sd-

1313) included the two inbred lines L.12 and L13. Meanwhile, the method was unable to categorize the inbred line L.2. The above results for heterotic grouping could be recommended for breeding programs to select the best parents for developing crosses of high heterosis. Mosa *et al* (2017), Ibrahim *et al* (2021) and Abd El-Latif *et al* (2023) stated that the heterotic group is a collection of closely related inbred lines which tend to result in vigorous hybrids when crossed with lines from different heterotic group, but not when crossed to other lines of the same heterotic group. Also, Vasal *et al* (1992), Melchinger (1999), Menkir *et al* (2004) and Legesse *et al* (2009) classified inbred lines into heterotic groups for grain yield and reported that the classification of inbred lines into heterotic groups facilitates the exploitation of heterosis in maize, which can contribute to hybrid performance.

Table 6. Estimates of heterotic groups using specific and general combining ability method (HSGCA) for grain yield across the three locations.

Line	Sd.1185	Sd.1194	Sd.1264	Sd.1313
L.2	6.252	5.870	9.695	9.425
L.4	8.273	3.570	-1.538 ≠	3.024
L.9	-0.933	-2.019	-2.779 ≠	-0.098
L.12	-2.122	0.363	-1.421	-2.170 ≠
L.13	-5.021	-5.489	1.546	-5.527 ≠
L.14	-2.245 ≠	-0.529	-1.915	-0.530
L.20	0.068	2.482	-2.363 ≠	-0.512
L21	-1.969 ≠	0.900	-0.164	-1.636
L.22	-2.304	-5.148 ≠	-1.061	-1.976

≠ means that this inbred line belongs to tester group.

CONCLUSION

Inbred lines L.2 and L.4 which possessed the best GCA effects for grain yield may be considered promising lines for improving grain yield. While inbred lines L.14, L.20 and L.22 possessed the best GCA effects for days to 50% silking, L.12, L.14 and L.22 possessed the best GCA effects for plant height and ear height, they are recommended for developing varieties characterized with earlier maturity, shorter plant and lower ear placement. Moreover, the crosses L.4×Sd.1185, L.13×Sd.1264, and L.20×Sd.1194 may be released for commercial cultivation after further testing and evaluation. The inbred lines for grain yield, based on heterotic group specific and general combining ability (HSGCA) method, were classified into four heterotic groupings as follows: group-1 (Sd.1185) included L.14 and L.22 while, group-2 (Sd.1194) included L.22. Group-3 (Sd.1264) included L.4, L.9 and L.20 while, group-4 (tester Sd-1313) included L.12 and L13.

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تقدير القدرة على التآلف فى سلالات جديدة من الذرة الشامية بيضاء الحبوب بإستخدام الهجن الإختبارية

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فى موسم ٢٠٢٠ هجنت تسعة سلالات من الذرة الشامية بيضاء الحبوب مرباه تربية داخلية بمحطة البحوث الزراعيه بسدس قمياً مع أربعة من السلالات الكشافة هى (Sd.1185، Sd.1194، Sd.1264، Sd.1313). وفى موسم ٢٠٢١ تم تقييم عدد ستة وثلاثون هجين قمى بالإضافه إلي هجينين المقارنة هما هجين فردى١٠ وهجين فردى ٢٠٣١ فى تجارب حقلية بمحطات البحوث الزراعية بسخا والجميزة وسدس. تم تقدير القدرة العامة والخاصة على التآلف ودراسة التفاعل البيئى لصفات عدد الأيام اللازمة حتى خروج ٥٠% من حرائر النورات المؤنثة وإرتفاع النبات والكوز وموقع الكوز ومحصول الحبوب (أردب/فدان). أظهرت نتائج التحليل المشترك عبر المواقع أن هناك فروق عالية المعنوية بين المواقع لجميع الصفات تحت الدراسة مما يدل على أن المواقع مختلفة فى الظروف البيئية. أظهرت النتائج إختلافات عالية المعنوية بين الهجن القمية والسلالات والكشافات لكل الصفات تحت الدراسة. كما أظهرت النتائج وجود تباينات معنوية لتفاعل السلالات × الكشافات لصفة عدد الأيام اللازمة حتى خروج ٥٠% من حرائر النورات المؤنثة وإرتفاع النبات وإرتفاع الكوز والمحصول. كما أظهرت النتائج وجود تباين التفاعل بين المواقع والسلالات معنوياً لكل الصفات وكان التفاعل بين المواقع

والكشافات معنوياً لكل الصفات فيما عدا صفة المحصول. كما أظهرت النتائج وجود تباين التفاعل بين السلالات × الكشافات × المواقع معنوياً لصفة عدد الأيام اللازمة حتى خروج ٥٠% من حرائر النورات المؤنثة. وقد أظهرت السلالات (L.2، L.4) أعلى قدرة عامة مرغوبة لصفة المحصول. وقد أظهرت الهجن (L.2×Sd.1264 ، L.2×Sd.1313) تفوقاً معنوياً على أعلى هجن المقارنة هجين فردى ١٠. وقد أظهرت النتائج وجود ثلاث هجن إختبارية L.20×Sd.1194 ، L.13×Sd.1264 ، L.4×Sd.1185) أحسن تأثيرات للقدرة الخاصة على التآلف لصفة المحصول. كما كان تباين القدرة العامة على التآلف عالياً لجميع الصفات فيما عدا صفة إرتفاع النبات وصفة المحصول. وكان التباين الراجع لتفاعل القدرة الخاصة على التآلف مع المواقع أعلى من تباين تفاعل القدرة العامة على التآلف مع الموقع لصفة عدد الأيام اللازمة حتى خروج ٥٠% من حرائر النورات المؤنثة وصفة المحصول مما يدل على أن الفعل الجينى غير المضيف لتلك الصفات أكثر تأثراً بالمواقع عن الفعل الجينى المضيف. تم تصنيف السلالات لمحصول الحبوب بناءً على طريقة(HSGCA) إلى أربع مجموعات هجينية على النحو التالى: تضم المجموعة الأولى (Sd.1185) السلالات L.14، L.21 وتضم المجموعة الثانية (Sd.1194) السلالة L.22 وتضم المجموعة الثالثة (Sd.1264) السلالات L.4، L.9، L.20 وتضم المجموعة الرابعة (Sd.1313) السلالات L.12، L.13 ويمكن إستخدام هذه المجموعات فى برامج التربية لإنتخاب أفضل الآباء لتكوين هجن جديدة ذات قوة هجين عالية.

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