Assiut Journal of Agricultural Sciences 55 (2) 2024 (15-28)
ISSN: 1110-0486 / EISSN: 2356-9840
Website: http://ajas.journals.ekb.eg/
E-mail: ajas@aun.edu.eg

(Original Article)

Superiority and Combining Ability for Grain Yield and Agronomic Traits of Maize (*Zea mays* L.)

Mohamed E.M. Abd El-Azeem; Rezk S.H. Aly; Ashraf K. Mostafa* and Hany A.A. Mohamed

Maize Department, Field Crops Research Institute, Agriculture Research Center, Giza, Egypt.

*Correspondence: ashraf_kamal_1976@yahoo.com
DOI: 10.21608/AJAS.2024.277977.1348

Abstract

The investigation was conducted to calculate the superiority % for of the F_1's over commercial check hybrids, combining ability and genetic variability of eleven white maize inbred lines using a half-diallel design at Sids Agricultural Research Station in the 2022 growing season. The 55 crosses along with two commercial hybrids as checks; SC-10 and Hytech SC-2031 were evaluated in field trials at Sids, Sakha, and Gemmeiza Agricultural Research Stations using randomized complete block design with three replications in the growing season 2023. The results showed highly significant differences between three locations for all studied traits except GY and DTS traits. Mean squares for crosses and their interaction with locations were significant for all studied traits except for EHT. Also, variances of GCA and SCA were significant for all studied traits except EHT, indicating that additive and non-additive gene effects were important in the inheritance of most studied traits. However additive gene effects were more important than non-additive gene effects in the inheritance of all studied traits except for GY. Two inbred lines; Sd-4/2013 and Sk-12 had good general combining effects for GY. The best cross for SCA effects was Sd-63 × Gz-613 for GY; and Sd-1185 × Gz-613 for DTS. The cross Sd-2/2013 × Sk-9 was superior for grain yield and earliness than two checks. Also, four crosses; (Sd-2/2013 × Gz-613), (Sd-41/2015 × Sk-13), (Sd-63 × Gz-613) and (Sd-1185 × Sk-9), were significantly superiority% relative to the two checks. These crosses will be further evaluated in the maize breeding program.

Keywords: *Genetic variability, Combining ability, Superiority%, Additive*

Introduction

Maize (*Zea mays* L.) is the world's leading crop and is widely cultivated as cereal grain and it is also known as the queen of cereals, because of its highest genetic yield potential (Shree *et al*., 2018). The best way to increase maize yield per unit through cultivating the hybrid, and there are different methods to procedure hybrid (Aisyah, *et al*., 2016). The success of development of high yielding and widely adapted maize crosses will depend on the combining ability of parent of crosses. Hence, a combining ability study is imperative in order to

Received: 19 March 2024/ Accepted: 4 April 2024/ Published online: 17 April 2024

determine parents and crosses for advancement in the character under consideration; and provides information on the nature of genetic variability present in the germplasm under investigation. Diallel crosses approach is commonly used to gain information on the genetic action controlling traits of interest, and the combining ability effects of the inbred lines and crosses (Griffing, 1956). Two parameters of diallel analysis; general (GCA) and specific (SCA) combining abilities are essential in developing breeding programs. Breeding for high yielding crops require the information on the nature and magnitude of variation in the available germplasm, relationship between yield and some other agronomic traits and the degree of genetic variability influence in the expression of these attributes' traits. The good information of heritability enables the breeders decide the course of selection procedure to be followed under a given situation (Li and Yang, 1985). Genotypic coefficient of variability (GCV) and phenotypic coefficient of variability (PCV) values were characterized as low when less than 10%, moderate 10–20% and high more than 20% (Deshmukh and Reddy (1986). While heritability was low when value less than 40%, medium 40–59%, moderately high 60–79% and very high heritability 80% and above (Singh 2001).

The main objectives of this investigation were to: (1) estimate the combining ability effects for inbred lines and its crosses for the studied traits. (2) determine types of gene action controlling in inheritance of these traits and (3) identify the superior hybrids over the check hybrids for gain yield and earliness.

Material and Methods

Plant materials and its sources

Eleven new white maize inbred lines, developed from different geographical regions and divergent in isolation sources (Sids Sd, Sakha Sk and Giza Gz) namely, Sd-2/2013, Sd-41/2013, Sd-4/2015, Sd-2/2016, Sd-4/2017, Sd-63, Sd-1185, Gz-613, Sk-9, Sk-12 and Sk-13 were chosen and used in this investigation.

Locations and growing seasons

All possible combinations without reciprocal crosses among them were done in a half diallel mating design to obtain 55 crosses at Sids Agriculture Research Station during 2022 summer season. The 55 new single crosses along with two commercial hybrids as checks; SC-10 and Hytech SC-2031 were evaluated in field trails at three locations; Sids, Sakha and Gemmeiza Agriculture Research Stations.

Experimental design and its management

A randomized complete block design (RCBD) with three replications was used at each location. The experimental plot size was one row, 6 ml on g and 0.8 m apart. Kernels were sown in hills evenly spaced at 0.25 m along the row at the rate of two kernels hill^{-1}, then thinned to one plant hill^{-1} after three weeks from planting. All agricultural practices for maize production were applied as recommended at the proper time.

Data recorded

Data were recorded for number of days to 50% silking emergency date (DTS days), plant height (PHT cm), ear height (EHT cm), ear position (Epos%) and grain yield (GY ard fed^{-1}) adjustedat15.5% grain moisture, (one ard = 140 Kg and one fed = 4200 m^2).

Statistical analysis

Data collected were analyzed using General Linear Model (GLM) procedure in SAS Statistical Package (SAS institute, version 9.3, 2014). After performance homogeneity test, the combined analysis was done across three locations according to Snedecor and Cochran (1989). Combining ability analysis was performed for traits that showed statistical differences among crosses. Griffing' s Method-4, model-1 (Griffing, 1956) was utilized to determine general and specific combining abilities and their interaction effects with locations. Superiority % of 55 single crosses was determined according to Singh *et al.,* (2004).

Results and Discussion

Analysis of variances

The mean squares of locations, crosses, and their interaction for grain yield along with agronomic traits are presented in Table 1. Results showed that there were highly significant differences among locations for all studied traits except for GY and DTS traits, indicating that the three locations differed in the environmental conditions. These results are similar to those obtained by Haddadi *et al.,* (2012), Aly (2013), Abd EL-Azeem *et al.,* (2021), Apraku *et al.,* (2021) and Aly *et al.,* (2022). Mean squares for crosses (C) and their interaction with locations (C × Loc) were significant and highly significant for all studied traits except for C × Loc of EHT. These results match those obtained by; Bisen *et al.,* (2020) for DTS and PHT, Abd El-Azeem *et al.,* (2021) for DTS, PHT, EHT, Epos% and GY, Hussain *et al.,* (2021) for DTS, PHT and EHT, Tulu *et al.,* (2021) for DTS and GY and Ramadan *et al.,* (2022) for DTS, PHT and GY.

Table 1. Mean squares of location and 57 crosses and their interaction for grain yield and some agronomic traits

sov	df	GY (ard fed^{-1})	DTS (days)	PHT (cm)	EHT (cm)	Epos %
Loc	2	77.43	139.92	9652.42**	11631.07**	695.60**
Rep/Loc	6	48.99	33.66	1154.85	880.25	24.53
Crosses (C)	56	79.52**	15.99**	447.04**	268.69*	19.85**
C × Loc	112	59.75**	7.34**	335.97**	174.27	18.36**
Error	336	11.55	3.23	223.40	175.81	11.86

*, ** significant at 0.05 and 0.01 levels of probability, respectively. GY = grain yield ard. fed^{-1}, DTS = days to 50% silking (days), PHT = plant height, cm, EHT = ear height, cm, Epos% = ear position %

General (GCA) and Specific (SCA) combining ability variances

General (GCA) and Specific (SCA) combining ability variances and their interaction with locations (GCA × Loc and SCA × Loc) are shown in Table 2.

Results showed that variances of GCA and SCA were significant and highly significant for all studied traits except for SCA of EHT, indicating that additive and non-additive gene effects were important in the inheritance of most studied traits. Our results are relevant to those obtained by Bisen *et al.,* (2020) and Abd EL-Zaher *et al.,* (2021) for DTS and PHT, Onejeme *et al.,* (2020) and Ramadan *et al.,* (2022) for DTS, PHT and GY, Abd EL-Azeem *et al.,* (2021) for DTS, PHT, Epos% and GY, Patil *et al.,* (2021) for DTS and GY and Abdulla *et al.,* (2022) for DTS and PHT. The ratio of GCA/SCA was more than unity for all studied traits except GY trait, indicating that the additive gene effects were more important and played major role in the inheritance of all studied traits except for GY trait. Therefore, the non-additive gene effects were more important for the inheritance of GY. Similar results were obtained by El-Hosary (2020) for DTS, Onejeme *et al.,* (2020) for DTS and PHT, and Abd El-Azeem *et al.,* (2021) for DTS, PHT, EHT and Epos%. Mean squares due to GCA × Loc and SCA × Loc interactions were significant for all studied traits except for GCA × Loc and SCA × Loc of EHT and for GCA × Loc of Epos%, indicating that additive and non-additive gene effects were affected by environmental conditions in most traits. GCA × Loc was larger than SCA × Loc for all studied traits except Epos% trait, indicating that additive gene effects are more influenced by environmental than non-additive components; Abd EL- Azeem *et al.,* (2021) for DTS and GY, Aboyousef *et al.,* (2022) and Aly *et al.,* (2022) for DTS, PHT, EHT and GY traits.

Table 2. Diallel analysis for five traits across three locations

sov	df	GY (ard fed^{-1})	DTS (days)	PHT (cm)	EHT (cm)	Epos %
GCA	10	62.02**	54.78**	838.31**	454.30**	28.02**
SCA	44	86.32**	7.42**	370.41*	229.46	19.13*
GCA × Loc	20	69.48**	12.71**	493.74**	212.99	9.92
SCA × Loc	88	58.65**	6.14**	306.92*	170.02	19.98**
Error	324	11.52	3.24	228.95	177.03	11.94
GCA/SCA		0.72	7.38	2.26	1.98	1.47
GCA × Loc /SCA × loc		1.19	2.07	1.61	1.25	0.50

*, ** significant at 0.05 and 0.01 levels of probability, respectively. GY = grain yield ard. fed^{-1}, DTS = days to 50% silking (days), PHT = plant height, cm, EHT = ear height, cm, Epos% = ear position %.

Mean performances of the 55 single crosses and the two check hybrids for grain yield and some agronomic traits across three locations are illustrated in Table 3. Results showed that, for GY ard fed^{-1}, the crosses ranged from 21.55 for cross Sd-2/2013 × Sd-1185 to 35.00 ard fed^{-1} for cross Sd-41/2015 × Sk-13. Five crosses; Sd-2/2013 × Sk-9 (34.65 ard fed^{-1}), Sd-41/2015 × Sk-13 (35.00 ard fed^{-1}), Sd-63 × Gz-613 (34.26 ard fed^{-1}), Sd-2/2013 × Gz-613 (34.25 ard fed^{-1}) and Sd-1185 × Sk-9 (34.60 ard fed^{-1}) were significantly superior than the two check hybrids; SC-10 (29.32 ±3.14) and SC-2031 (31.10±3.14). In addition, six crosses; Sd-41/2015 × Sd-4/2015 (31.55 ard fed^{-1}), Sd-41/2015 × Sd-2/2016 (33.57 ard fed^{-1}), Sd-41/2015 × Sk-9 (32.13 ard fed^{-1}), Sd-41/2015 × Sk12 (33.67 ard fed^{-1}), Sd-4/2015 × Sk-12 (32.63 ard fed^{-1}) and Sd-1185 × Sk-12 31.16 ard fed^{-1}were not significant out yielded more than the highest check hybrid SC-2031 (31.10 ard fed^{-1}). For DTS day, the crosses ranged from 60.88 for cross Sd-2/2013 × Sk-9 to 66.33

day for cross Sd-41/2015 × Gz-613. Generally, almost new single crosses were significantly earlier than the two checks: SC-10 (63.33 day) and SC-2031 (64.77 day). Six crosses; Sd-2/2013 × Sk-9 (60.88 day), sd-4/2015 × Sd-4/2017 (61.22 day), Sd-4/2015 × Sk-12 (61.22 day), Sd-4/2017 × Sd-1185 (61.44 day), Sd-4/2017 × Sk-9 (61.11 day) and Sd-1185 × Gz-613 61.66 day were significantly earlier than the earliest check SC-10 (63.33 day). For PHT cm, 32 out 55 crosses were did not differ significantly than the shorter check hybrid SC-2031 (247.67 cm). On the other hand, seven crosses were significantly less than the check hybrid SC-10 (252.78 cm toward short plant height). Regarding EHT cm trait, 36 out 55 crosses were did not differ significantly from the check shortest ear height SC-2031 (141.66 cm). Furthermore, 10 crosses were significantly less than the check hybrid SC-10 (146.66 cm) toward shorter ear height. For Epos%, cross Sk-9 × Sk-12 (52.04%) was significantly less than the best lower ear placement of check SC-2031 (57.11%). Set of 33 crosses did not differ significantly from the lower ear placement SC-2031. Four crosses; Sd-4/2015 × Sd-4/2017 (54.33%), Sd-4/2017 × Gz-613 (54.03%), Sd-4/2017 × Sk-9 (54.62%) and Sk-9 × Sk-12 (52.04%) were significantly lower than the check hybrid SC-10 (58.10%). The previous results revealed that, seven crosses; Sd-2/2013 × Gz-613, Sd-2/2013 × Sk-9, Sd-41/2015 × Sk-12, Sd-41/2015 × Sk-13, Sd-4/2015 × Sk-12, Sd-1185 × Sk-9 and Sd-1185 × Sk-12 had the good mean performances values which were significantly or did not differ significantly than the check hybrid for GY and one or more of other agronomic trait under this investigation.

Table 3. Mean performances of the 55 single crosses and the two check hybrids across three locations for grain yield and some agronomic traits

Crosses	GY (ard fed^{-1})	DTS (days)	PHT (cm)	EHT (cm)	Epos %
Sd-2/2013 × Sd-41/2013	28.00	63.66	250.89	149.11	59.04
Sd-2/2013 × Sd-4/2015	30.85	62.00	243.11	139.88	57.50
Sd-2/2013 × Sd-2/2016	28.36	63.77	247.44	140.33	56.61
Sd-2/2013 × Sd-4/2017	28.77	62.55	240.67	143.11	59.48
Sd-2/2013 × Sd-63	29.61	62.55	241.33	137.11	56.79
Sd-2/2013 × Sd-1185	21.55	64.55	238.00	134.00	56.33
Sd-2/2013 × Gz-613	34.25	65.44	249.44	138.55	55.62
Sd-2/2013 × Sk-9	34.65	60.88	255.00	148.88	58.26
Sd-2/2013 × Sk-12	26.14	62.66	240.67	140.33	58.22
Sd-2/2013 × Sk-13	28.36	62.33	239.56	134.77	56.22
Sd-41/2015 × Sd-4/2015	31.55	62.77	242.22	145.77	60.17
Sd-41/2015 × Sd-2/2016	33.57	65.33	260.89	147.33	56.42
Sd-41/2015 × Sd-4/2017	26.81	61.77	255.78	144.22	56.46
Sd-41/2015 × Sd-63	27.68	63.55	248.00	137.66	55.52
Sd-41/2015 × Sd-1185	28.77	63.88	243.89	137.11	56.24
Sd-41/2015 × Gz-613	27.11	66.33	256.89	150.11	58.41
Sd-41/2015 × Sk-9	32.13	63.44	263.78	153.00	57.82
Sd-41/2015 × Sk-12	33.67	64.44	242.56	138.77	57.24
Sd-41/2015 × Sk-13	35.00	64.00	247.11	140.22	56.78
Sd-4/2015 × Sd-2/2016	29.52	65.88	259.67	143.22	55.16
Sd-4/2z15 × Sd-4/2017	26.63	61.22	242.00	131.77	54.33
Sd-4/2015 × Sd-63	25.01	63.22	241.22	133.88	55.53
Sd-4/2015 × Sd-1185	30.07	62.44	252.11	146.33	58.08

Table 3. Continue

Crosses	GY (ard fed^{-1})	DTS (days)	PHT (cm)	EHT (cm)	Epos %
Sd-4/2015 × Gz-613	29.14	63.11	249.00	138.22	55.48
Sd-4/2015 × Sk-9	28.73	61.77	248.56	137.66	55.41
Sd-4/2015 × Sk-12	32.63	61.22	239.00	132.44	55.22
Sd-4/2015 × Sk-13	30.92	63.55	241.22	137.77	56.97
Sd-2/2016 × Sd-4/2017	28.95	62.00	237.89	131.33	55.16
Sd-4/2016 × Sd-63	22.53	65.22	248.78	145.11	58.11
Sd-4/2016 × Sd-1185	30.01	63.44	242.89	139.33	57.37
Sd-4/2016 × Gz-613	25.37	65.88	257.67	149.33	57.84
Sd-4/2016 × Sk-9	30.18	63.33	245.89	137.33	55.74
Sd-4/2016 × Sk-12	28.45	64.55	242.11	139.00	57.39
Sd-4/2016 × Sk-13	28.93	64.11	236.78	131.00	55.13
Sd-4/2017 × Sd-63	26.00	61.88	237.11	135.88	57.32
Sd-4/2017 × Sd-1185	29.74	61.44	246.00	139.88	56.88
Sd-4/2017 × Gz-613	28.64	63.11	250.56	136.00	54.03
Sd-4/2017 × Sk-9	22.16	61.11	241.67	132.66	54.62
Sd-4/2017 × Sk-12	31.09	61.88	243.00	136.77	55.99
Sd-4/2017 × Sk-13	29.76	62.44	244.22	137.11	55.90
Sd-63 × Sd-1185	29.82	63.88	237.89	141.22	59.29
Sd-63 × Gz-613	34.26	64.66	265.11	149.33	56.47
Sd-63 × SK-9	29.22	63.33	247.89	139.77	56.29
Sd-63 × Sk-12	29.93	62.66	245.44	140.11	56.96
Sd-63 × Sk-13	28.09	64.11	254.00	146.22	57.47
Sd-1185 × Gz-613	27.35	61.66	241.67	142.55	58.96
Sd-1185 × Sk-9	34.60	61.77	250.00	141.77	56.64
Sd-1185 × Sk-12	31.16	63.11	243.44	137.88	56.60
Sd-1185 × Sk-13	28.62	64.22	247.22	144.00	58.12
Gz-613 × Sk-9	26.65	64.55	253.56	148.44	58.57
Gz-613 × Sk-12	28.88	65.00	242.89	134.11	55.24
Sd-1185 × Sk-13	24.21	62.66	237.44	134.55	56.82
Sk-9 × Sk-12	30.28	62.11	255.22	132.66	52.04
Sk-9 × Sk-13	28.69	62.11	236.44	134.88	57.02
Sk-12 × Sk-13	28.83	63.00	246.67	142.66	58.00
SC.10	29.32	63.33	252.78	146.66	58.10
SC.2031	31.10	64.77	247.67	141.66	57.11
LSD 0.05	3.140	1.660	13.810	12.251	3.182
0.01	4.127	2.182	18.150	16.101	4.183

*, ** significant at 0.05 and 0.01 levels of probability, respectively. GY = grain yield ard. fed^{-1}, DTS = days to 50% silking (days), PHT = plant height, cm, EHT = ear height, cm, Epos% = ear position %.

Combining ability effects

General combining ability (GCA) effects of the eleven white maize inbred lines for grain yield and some agronomic traits across three locations are shown in Table 4. Results showed that the two inbred lines; Sd-4/2013 and Sk-12 had a good general combiner effect for GY. For DTS, three inbred lines; Sd-4/2015, Sd-4/2017 and Sk-9 had negative and significantly GCA effects (desirable values) toward earliness. Inbred line Sk-13 exhibited desirable value of GCA effects for PHT cm toward shorter plant. In the same direction, two inbred lines; Sd-4/2017 and Sk-12 had negative and significant GCA effects (desirable values) for EHT cm toward shorter ear heights. Inbred line Sd-4/2017 showed negative and significant GCA effects for Epos% toward lower ear placement. The differences between inbred lines for GCA effects of different traits obtained by many researchers; Gamea *et al*., (2018), Anees *et al*., (2019), Saeid *et al*., (2019) and Abd EL-Azeem *et al*., (2021).

Table 4. General combining ability (GCA) effects of the eleven inbred lines for grain yield and some agronomic traits as combined across three locations

Inbred lines	GY (ard fed^{-1})	DTS (days)	PHT (cm)	EHT (cm)	Epos%
Sd-2/2013	-0.080	-0.208	-2.138	0.625	0.760*
Sd-4/2013	1.448**	0.766**	5.182**	4.760**	0.738*
Sd-4/2015	0.422	-0.566**	-0.804	-1.498	-0.344
Sd-2/2016	-0.597	1.248**	1.627	0.316	-0.325
Sd-4/2017	-1.410**	-1.430**	-2.940	-3.523*	-0.846*
Sd-63	-1.009**	0.309	0.158	0.649	0.257
Sd-1185	0.050	-0.208	-2.471	0.402	0.814*
Gz-613	-0.603	1.124**	4.318**	2.306	0.019
Sk-9	0.671	-0.875**	3.627*	0.736	-0.606
Sk-12	1.091**	-0.184	-2.705	-2.856*	-0.542
Sk-13	0.016	0.025	-3.854*	-1.918	0.074
S.E. g_i	0.359	0.191	1.603	1.410	0.366
LSD g_i 0.05	0.705	0.373	3.142	2.763	0.718
0.01	0.926	0.491	4.129	3.631	0.943
LSD g_i-g_j 0.05	2.60	1.38	11.63	10.22	2.65
0.01	3.42	1.81	15.28	13.44	3.49

*, ** significant at 0.05 and 0.01 levels of probability, respectively, GY = grain yield ard. fed^{-1}, DTS = days to 50% silking (days), PHT = plant height, cm, EHT = ear height, cm, Epos% = ear position %.

Specific combining ability effects (SCA) of 55 single crosses for grain yield and some agronomic traits as combined across three locations are presented in Table 5. Results showed that the 11 crosses; Sd-2/2013 × Gz-613 (5.776**), Sd-2/2013 × Sk-9 (4.938**), Sd-41/2015 × Sd-2/2016 (3.591**), Sd-41/2015 × Sk-12 (2.006*), Sd-41/2015 × Sk-13 (4.406**), Sd-4/2015 × Sk-12 (1.995*), Sd-4/2017 × Sd-1185 (1.980*), Sd-4/2017 × Sk-12 (2.280*), Sd-4/2017 × Sk-13 (2.025*), Sd-63 × Gz-613 (6.747**) and Sd-1185 × Sk-9 (4.752**) had positive and significant SCA effects for GY ard fed-1.These aforementioned crosses are potentially high yielding. These finding showed that, the crosses that show high SCA effects were not always include parents with high GCA effects. Five crosses; Sd-2/2013 × Sk-9, Sd-4/2015 × Sk-12, Sd-2/2016 × Sd-4/2017, Sd-1185 × Gz-613 and Sd-1185 × Sk-13 had negative and significant SCA effects for DTS trait toward earliness. For PHT cm, EHT cm and Epos% traits, two crosses for each trait; (Sd-1185 × Sk-13 and Sk-9 × Sk-13), (Sd-41/2015 × Sd-63 and sd-41/2015 × Sd-1185) and (Sd-41/2015 × Sd-63 and Sk-9 × Sk-12) had negative and significantly SCA effects toward shorter both plant and ear heights and lower ear placement, respectively. From the above results, two crosses; Sd-2/2013 × Sk-9 and Sd-4/2015 × Sk-12 had positive and significant SCA effects for GY toward high yielding and in the same time had negative and significant SCA effects toward earliness. All these crosses might be vital in maize breeding programs for production to release promising hybrids.

Table 5. Specific combining ability effects (SCA) of 55 single crosses for grain yield and some agronomic traits as combined across three locations

Cross	GY (ard fed^{-1})	DTS (days)	PHT (cm)	EHT (cm)	Epos %
Sd-2/2013 × Sd-41/2013	-2.496*	-0.123	1.308	3.677	0.718
Sd-2/2013 × Sd-4/2015	1.379	-0.456	-0.481	0.714	0.455
Sd-2/2013 × Sd-2/2016	-0.082	-0.493	1.419	-0.657	-0.555
Sd-2/2013 × Sd-4/2017	1.138	0.962	-0.790	5.960	2.746**
Sd-2/2013 × Sd-63	1.578	-0.777	-3.222	-4.212	-1.059
Sd-2/2013 × Sd-1185	-7.54**	1.740**	-3.925	-7.077	-1.939
Sd-2/2013 × Gz-613	5.776**	1.296*	0.728	-4.422	-1.844
Sd-2/2013 × Sk-9	4.938**	-1.259*	6.975	7.479	1.364
Sd-2/2013 × Sk-12	-3.989**	-0.172	-1.024	2.516	1.347
Sd-2/2013 × Sk-13	-0.702	-0.716	-0.987	-3.978	-1.233
Sd-41/2015 × Sd-4/2015	0.554	-0.654	-8.691	2.466	3.022**
Sd-41/2015 × Sd-2/2016	3.591**	0.086	7.543	2.207	-0.736
Sd-41/2015 × Sd-4/2017	-2.356*	-0.790	7.000	2.935	-0.192
Sd-41/2015 × Sd-63	-1.879	-0.753	-3.877	-7.792*	-2.276*
Sd-41/2015 × Sd-1185	-1.849	0.098	-5.358	-8.101*	-1.950
Sd-41/2015 × Gz-613	-2.864**	1.209*	0.852	2.997	1.010
Sd-41/2015 × Sk-9	0.886	0.32	8.432	7.454	0.940
Sd-41/2015 × Sk-12	2.006*	0.629	-6.457	-3.175	0.362
Sd-41/2015 × Sk-13	4.406**	-0.024	-0.753	-2.669	-0.897
Sd-4/2015 × Sd-2/2016	0.566	1.975**	12.308**	4.355	-0.949
Sd-4/2015 × Sd-4/2017	-1.502	-0.012	-0.790	-3.249	-1.205
Sd-4/2015 × Sd-63	-3.523**	0.246	-4.666	-5.311	-1.050
Sd-4/2015 × Sd-1185	0.473	-0.012	8.851*	7.380	1.079
Sd-4/2015 × Gz-613	0.194	-0.679	-1.049	-2.632	-0.877
Sd-4/2015 × Sk-9	-1.489	-0.012	-0.802	-1.619	-0.377
Sd-4/2015 × Sk-12	1.995*	-1.259*	-4.024	-3.249	-0.549
Sd-4/2015 × Sk-13	1.351	0.864	-0.654	1.145	0.453
Sd-2/2016 × Sd-4/2017	1.833	-1.049*	-7.333	-5.509	-0.539
Sd-4/2016 × Sd-63	-4.985**	0.432	0.456	4.096	1.546
Sd-4/2016 × Sd-1185	1.432	-0.827	-2.802	-1.435	0.160
Sd-4/2016 × Gz-613	-2.556*	0.283	5.185	6.664	1.386
Sd-4/2016 × Sk-9	0.980	-0.271	-5.901	-3.768	-0.211
Sd-4/2016 × Sk-12	-1.167	0.259	-3.345	1.491	1.342
Sd-4/2016 × Sk-13	0.387	-0.395	-7.530	-7.447	-1.443
Sd-4/2017 × Sd-63	-0.702	-0.222	-6.641	-1.286	1.255
Sd-4/2017 × Sd-1185	1.980*	-0.148	4.876	2.960	0.198
Sd-4/2017 × Gz-613	1.530	0.185	2.641	-2.829	-1.939
Sd-4/2017 × Sk-9	-6.227**	0.185	-5.555	-4.595	-0.720
Sd-4/2017 × Sk-12	2.280*	0.271	2.111	3.108	0.563
Sd-4/2017 × Sk-13	2.025*	0.617	4.481	2.503	-0.166
Sd-63 × Sd-1185	1.652	0.555	-6.333	0.120	1.391
Sd-63 × Gz-613	6.747**	0.000	14.098**	6.330	-0.474
Sd-63 × SK-9	0.430	0.666	-2.432	-1.656	-0.182
Sd-63 × Sk-12	0.724	-0.691	1.456	2.269	0.455
Sd-63 × Sk-13	-0.042	0.543	11.160**	7.441	0.395
Sd-1185 × Gz-613	-1.220	-2.481**	-6.716	-0.200	1.339
Sd-1185 × Sk-9	4.752**	-0.370	2.308	0.590	-0.317
Sd-1185 × Sk-12	0.891	0.272	2.086	0.294	-0.473
Sd-1185 × Sk-13	-0.572	1.173*	7.012	5.467	0.510
Gz-613 × Sk-9	-2.544*	1.074*	-0.926	5.355	2.474*
Gz-613 × Sk-12	-0.732	0.8271	-5.259	-5.385	-1.056
Sd-1185 × Sk-13	-4.331	-1.716**	-9.556*	-5.879	-0.017
Sk-9 × Sk-12	-0.606	-0.061	7.765	-5.261	-3.682**
Sk-9 × Sk-13	-1.119	-0.271	-9.864*	-3.977	0.711
Sk-12 × Sk-13	-1.402	-0.074	6.691	7.393	1.689
SE sij	1.012	0.535	4.511	3.967	1.030
LSD_{Sij} 0.05	1.983	1.049	8.842	7.775	2.019
0.01	2.606	1.381	11.621	10.219	2.654

*, ** significant at 0.05 and 0.01 levels of probability, respectively. GY = grain yield ard. fed^{-1}, DTS = days to 50% silking (days), PHT = plant height, cm, EHT = ear height, cm, Epos% = ear position %.

Superiority %

Superiority % of crosses relative the two checks; SC-10 and SC-2031 for grain yield (GY ard fed^{-1}) and days to 50% silking (DTS day) traits are presented in Table 6. Superiority% of crosses ranged from -26.50% for Sd-2/2013 × Sd-1185 to 19.35% for Sd-41/2015 × Sk-12 relative check SC-10. Meanwhile, ranged from -30.69% to 10.03% for the same crosses relative to check SC-2031. Five crosses positive and significantly superiority% heterosis relative to the two checks SC-10 and SC-2031; Sd-2/2013 × Gz-613 (16.68%** and 10.03%*), Sd-2/2013 × Sk-9 (18.18%** and 11.44%*), Sd-41/2015 × Sk-13 (19.35%** and 12.54%*), Sd-63 × Gz-613 (16.83%** and 10.17%*) and Sd-1185 × Sk-9 (17.98%** and 11.25%*), respectively. In addition, 3 crosses; Sd-41/2015 × Sd-2/2016 (14.47%**), Sd-41/2015 × Sk-12 (14.82%*) and Sd-4/2015 × Sk-12 (11.28%*) had positive and significant superiority% for GY ard fed^{-1} relative to check hybrid SC-10. Similar results obtained by Onejeme *et al.,* (2020) and Abd El-Azeem *et al*., (2021). For DTS day, six crosses showed negative and significant superiority% (desirable values) toward earliness than the check SC-10 and SC-2031; Sd-2/2013 × Sk-9, Sd-4/2015 × Sd-4/2017, Sd-4/2015 × Sk-12), Sd-4/2017 × Sd-1185, Sd-4/2017 × Sk-9 and Sd-1185 × Gz-613;in addition to 21 crosses were earliness than SC-2031.In addition to, the aforementioned results showed that the cross Sd-2/2013 × Sk-9 had high grain yield and early maturity. These crosses can be recommended to be used in maize breeding programs to produce promising high yielding and early maturity hybrids. These results were confirmed with results by Aly and Mousa (2011), Onejeme *at al*., (2020) and Abd EL- Azeem *et al*., (2021).

Conclusion

Two inbred lines; Sd-4/2013 and Sk-12 had good general combiner effect for grain yield for high yielding ability. While, for number of days to 50% silking date, three inbred lines; Sd-4/2015, Sd-4/2017 and Sk-9 had negative and significant GCA effects for earliness. Results of SCA effects revealed that, the crosses that show high SCA effects did not always involve parent with high GCA effects, suggesting the importance of inter allelic interactions for the concerned studied traits. Five crosses positive and significantly superiority% heterosis relative to the two checks SC-10 and SC-2031; Sd-2/2013 × Gz-613, Sd-2/2013 × Sk-9, Sd-41/2015 × Sk-13, Sd-63 × Gz-613 and Sd-1185 × Sk-9. Thus, these crosses could be recommended to be released as new crosses by Maize Research Program after further evaluation and passes the advanced evaluation stages in a large scale in different environmental conditions in Egypt.

Table 6. Superiority% of crosses relative the two checks; SC-10 and SC-2031 for grain yield (GY ard fed^{-1}) and Silking date (DTS day) traits across three locations

Crosses	GY (ard fed^{-1})		DTS (days)	
	SC 10	SC 2031	SC 10	SC 2031
Sd-2/2013 × Sd-41/2013	-4.53	-9.97*	0.53	-1.70
Sd-2/2013 × Sd-4/2015	5.19	-0.81	-2.10	-4.28**
Sd-2/2013 × Sd-2/2016	-3.28	-8.79	0.71	-1.53
Sd-2/2013 × Sd-4/2017	-1.88	-7.48	-1.22	-3.42**
Sd-2/2013 × Sd-63	0.98	-4.78	-1.22	-3.42**
Sd-2/2013 × Sd-1185	-26.50**	-30.69**	1.94	-0.33
Sd-2/2013 × Gz-613	16.81**	10.12*	3.34**	1.04
Sd-2/2013 × Sk-9	18.18**	11.44*	-3.85**	-5.99**
Sd-2/2013 × Sk-12	-10.84*	-15.93**	-1.05	-3.25**
Sd-2/2013 × Sk-13	-3.29	-8.81	-1.57	-3.76**
Sd-41/2015 × Sd-4/2015	7.59	1.46	-0.87	-3.08*
Sd-41/2015 × Sd-2/2016	14.47**	7.94	3.16*	0.87
Sd-41/2015 × Sd-4/2017	-8.59	-13.80**	-2.45	-4.62**
Sd-41/2015 × Sd-63	-5.59	-10.98*	0.36	-1.88
Sd-41/2015 × Sd-1185	-1.88	-7.47	0.88	-1.36
Sd-41/2015 × Gz-613	-7.57	-12.84*	4.74	2.41
Sd-41/2015 × Sk-9	9.57	3.32	0.18	-2.05
Sd-41/2015 × Sk-12	14.82**	8.27	1.76	-0.50
Sd-41/2015 × Sk-13	19.35**	12.54*	1.06	-1.19
Sd-4/2015 × Sd-2/2016	0.65	-5.09	4.04**	1.73
Sd-4/2015 × Sd-4/2017	-9.18	-14.36**	-3.33**	-5.48**
Sd-4/2015 × Sd-63	-14.70**	-19.56**	-0.17	-2.39
Sd-4/2015 × Sd-1185	2.54	-3.30	-1.40	-3.59**
Sd-4/2015 × Gz-613	-0.64	-6.30	-0.35	-2.56*
Sd-4/2015 × Sk-9	-2.04	-7.62	-2.45	-4.62**
Sd-4/2015 × Sk-12	11.28*	4.94	-3.33**	-5.48**
Sd-4/2015 × Sk-13	5.42	-0.59	0.36	-1.88
Sd-2/2016 × Sd-4/2017	-1.29	-6.92	-2.10	-4.28**
Sd-4/2016 × Sd-63	-23.16**	-27.54**	2.99*	0.70
Sd-4/2016 × Sd-1185	2.33	-3.50	0.18	-2.05
Sd-4/2016 × Gz-613	-13.49*	-18.42**	4.04**	1.73
Sd-4/2016 × Sk-9	2.91	-2.96	0.01	-2.22
Sd-4/2016 × Sk-12	-2.98	-8.52	1.94	-0.33
Sd-4/2016 × Sk-13	-1.35	-6.98	1.23	-1.02
Sd-4/2017 × Sd-63	-11.33*	-16.39**	-2.28	-4.45**
Sd-4/2017 × Sd-1185	1.44	-4.35	-2.98*	-5.13**
Sd-4/2017 × Gz-613	-2.33	-7.90	-0.35	-2.56*
Sd-4/2017 × Sk-9	-24.43**	-28.74**	-3.50**	-5.65**
Sd-4/2017 × Sk-12	6.01	-0.04	-2.28	-4.45**
Sd-4/2017 × Sk-13	1.48	-4.31	-1.40	-3.59**
Sd-63 × Sd-1185	1.68	-4.12	0.88	-1.36
Sd-63 × Gz-613	16.83**	10.17*	2.11	-0.16
Sd-63 × SK-9	-0.37	-6.05	0.01	-2.22
Sd-63 × Sk-12	2.07	-3.75	-1.05	-3.25**
Sd-63 × Sk-13	-4.21	-9.68	1.23	-1.02
Sd-1185 × Gz-613	-6.74	-12.05*	-2.63*	-4.79**
Sd-1185 × Sk-9	17.98**	11.25*	-2.45	-4.62**
Sd-1185 × Sk-12	6.25	0.19	-0.35	-2.56*
Sd-1185 × Sk-13	-2.41	-7.97	1.41	-0.85
Gz-613 × Sk-9	-9.13	-14.31**	1.94	-0.33
Gz-613 × Sk-12	-1.52	-7.14	2.64*	0.36
Sd-1185 × Sk-13	-17.45**	-22.16**	-1.05	-3.25**
Sk-9 × Sk-12	3.26	-2.63	-1.92	-4.11**
Sk-9 × Sk-13	-2.16	-7.74	-1.92	-4.11**
Sk-12 × Sk-13	-1.69	-7.30	-0.52	-2.73*
LSD_{Sij} 0.05	3.14		1.66	
0.01	4.13		2.18	

*, ** significant at 0.05 and 0.01 levels of probability, respectively. GY = grain yield ard. fed^{-1}, DTS = days to 50% silking (days)

References

Abd El-Azeem, M.E.M.; Aly, R.S.H.; El Sayed, W.M. and Hassan, N.A. (2021). Combining ability and gene action using 10 × 10 diallel crosses of ten maize inbred lines (*Zea mays* L.). J. of Plant Production, Mansoura Univ. 12(11): 1205-1211.

Abd El-Zaher, L.N. (2021). Determination of combining ability and type of gene action using half-diallel cross among seven S_6 white maize inbred lines. J. of plant Production, Mansoura Univ. 12(11): 1157-1163.

Abdulla, S. M.; Abdulkhaliq, D. A. and Towfiq, Sh. I. (2022). Partial diallel analysis of maize inbred lines for kernel yield and its components in Sulaimani-Iraq. Iraqi Journal of Agricultural Sciences,53(5): 1190- 1202.

Aboyousef, H.A.; Abu Shosha, A.M.; El- Shahed, H.M., and Darwich, M.M.B. (2022). Diallel analysis among yellow maize inbred lines for grain yield and other agronomic traits. African Crop Science Journal, 30(2): 133 – 146.

Aisyah, S.I.; Wahyuni, S.; Syukur, M. and Witono, J.R. (2016). The estimation of combining ability and heterosis effect for yield and yield components in Tomato (*Solanum lycopersicum* Mill.) at Lowland. Ekin. J. Crop Breed. Gen. 2(1): 23-29.

Aly, R.S.H. (2013). Relationship between combining ability of grain yield and yield components for some newly yellow maize inbred lines via line × tester analysis. Alex. J. Agric. Res. 58(2): 115-124.

Aly, R.S.H. and Mousa, S.Th.M. (2011). Combining ability for grain yield and other yield component traits using half diallel crosses of maize inbred lines. J. Agric. Chem. and Biotech., Mansoura Univ., 2(12): 317-329.

Aly, R.S.H.; Abd El-Azeem, M. E. M.; Abd El-Mottalb, A.A. and El Sayed, W. M. (2022). Genetic variability, combining Ability, gene action and superiority for new white maize inbred lines (*Zea mays* L.). Journal of Plant Production Sciences; Suez Canal University, 11 (1): 1-10.

Anees, A.; Al-Zubaidy, K.; Al-Rawi, W., and Al Dawody, S. (2019). Study of genetic behavior for some productivity and morphology traits in half diallel cross of maize. Syrian Journal of Agricultural research, 6(1): 134-150.

Apraku, B. B.; Obisesan, O.; Olumide, O. B. and Toyinbo, J. (2021). Gene action, heterotic patterns, and inter-trait relationships of early maturing pro-Vitamin. A-maize inbred lines and performance of testcrosses under contrasting environments. Agronomy 11(7): 2-24; https://doi.org/10.3390/agronomy 11071371.

Bisen, V.; Yadav, M.; Verma, V.; Gathiya, G. and Ketwe, D. (2020). Heterosis and combining ability through diallel method in maize (*Zea mays* L.). J. of Pharmacognosy and Photochemistry, 9(1): 1986- 1994.

Deshmukh, S.N.N.; Basu, M.S. and Reddy, P.S. (1986) Genetic variability, character association and path coefficients of quantitative traits in Virginia Bunch varieties of Groundnut. Indian J Agric Sci 56:816–821.

El Hosary, A.A.A. (2020). Diallel analysis of some quantitative traits in eight inbred lines of maize and GGE biplot analysis for elite hybrids. J. of Plant Prod., Mansoura Univ., 11(3): 275-283.

Gamea, H.; Darwich, M. and Aboyousef, H.A. (2018). Combining ability for some inbred lines in half diallel crosses of maize under two different locations conditions. Archives of Agriculture Sciences Journal, 1(3): 14-25.

Griffing, B. (1956). Concept of general and specific combining ability in relation to diallel crossing systems. Australian Journal of Biological Science, 9: 463-493.

Haddadi, M. H.; Esmaeilo, M.; Choukan, R. and Rameeh, V. (2012). Combining ability analysis of days to silking, plant height, yield components and kernel yield in maize breeding lines. African J. of Agric. Res. 7(33): 4685-4691.

Hussain, M.A.; Dawod, K.M. and Khether, A.A. (2021). Gene action, heterosis and combining ability in maize hybrids. A- Using half diallel analysis. Kufa Journal for Agricultural Sciences, 13(2): 18 – 29.

Li, C.M. and Yang, K.C. (1985). Studies on inheritance of quantitative characters for plant type in some inbred lines of maize. Scientia Agriculture Sinical, 9: 28-36.

Magar, B.T.; Acharya, S., Gyawali, B., Timilsena, K., Upadhayaya, J. and Shrestha, J. (2021). Genetic variability and trait association in maize (*Zea mays* L.) varieties for growth and yield traits. Heliyon 7(10): E08144.

Nzuve, F.; Githiri, S., Mukunya, D.M. and Gethi, J. (2014). Genetic varability and correlation studies of grain yield and related agronomic traits in maize. J. Agric. Sci. 6(9): 166-167.

Onejeme, F.C.; Okporie, E.O. and Eze, C.E. (2020). Combining ability and heterosis in diallel analysis of maize (*Zea mays* L.) lines. International annals of science 9(1): 188-200

Patil, N.L.; Kachapur, R.M. and Nair, S.K. (2021). Genetic evaluation for understanding combining ability effects and Heterotic grouping in Maize (*Zea mays* L.). Maydica electronic publication, 66 - M 10: 1-13.

Ramadan, A.S.A.; Mukhlif, F.H. and Najm, B.F. (2022). Evaluation of performance, combining ability and gene action of inbred lines and its single hybrids in maize (*Zea mays* L.). Int. J. Agricult. Stat. Sci., 18(1): 1117-1125.

Saeid, H.A.S.; Majeed, A.H. and Shallal, A.S. (2019). Estimation of heterosis and combing ability for the yield components in single crosses of corn (*Zea mays* L.). Syrian Journal of Agricultural Research, 6(4): 210-220.

SAS Institute (2014). Statistical Analysis System Version 9.3, SAS Institute, Inc., Cary, NC, USA.

Shazia, G.; Dar, Z.A., Lone A.A., Khan, M.A., Bhat, M.A., Ali, G., Yousuf, N. and Lone, R.A. (2017). Genetic diversity in maize (*Zea mays* L.) inbred lines from Kashmir. International Journal Pure Applied Biosciences 5(1): 229–235.

Shree, B.; Chakraborty, M., Madhuparna, B., Krishna, P., Rana, M. and Tudu, V.K. (2018). Tissue culture dependent regeneration of maize (*Zea mays* L.). Photochemistry, (E-ISSN: {2278-4136} P-ISSN {2349-2468-2466} 8234.

Singh, A.; Shahi, J. and Singh, J. (2004). Heterosis in maize. Journal of Applied Biology, 14(1), 1-5

Singh, B.D. (2001). Plant Breeding: Principles and Methods. Kalyani Publish- pres, New Delhi, India.

Sivasubramanian, S. and Menon, M. (1973). Heterosis and inbreeding depression in rice. Madras Agric. J. 60, 1139.

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

Tulu, D.; Abakemal, D., Keimeso, Z., Kumsa, T., Terefe, W., Wolde, L. and Abebe, A. (2021). Standard heterosis and heterotic grouping of highland adapted maize (*Zea mays* L.) inbred lines in Ethiopia. African Journal of Plant Science, 15(7): 185-192.

التفوق والقدرة على التآلف لمحصول الحبوب والصفات المحصولية في الذرة الشامية

محمد المهدى محمد عبد العظيم، رزق صلاح حسانين علي، أشرف كمال مصطفى، هاني عبد الله عبد المجيد محمد

قسم بحوث الذرة الشامية، معهد بحوث المحاصيل الحقلية، مركز البحوث الزراعية، الجيزة، مصر.

الملخص

تم إجراء البحث بغرض حساب النسبة المئوية لتفوق الهجن تحت الدراسة مقارنة بالهجن التجارية، وتقدير قدرة التآلف والتباين الوراثي لإحدى عشرة سلالة بيضاء من الذرة الشامية تم التهجين فيها بمحطة البحوث الزراعية بسدس باستخدام تصميم التزاوج الدياليل النصف دائري في الموسم الزراعي 2022. تم تقييم الــ 55 هجين الناتجة بالإضافة إلى إثنين من الهجن التجارية (هجين فردى-10، هجين فردى هاى تك2031) كهجن للمقارنة وذلك في ثلاث محطات بحثية (سدس، سخا، الجميزة) وتم استخدام تصميم القطاعات الكاملة العشوائية فيثلاث مكررات بكل موقع. أظهرت النتائج إلى وجود اختلافات عالية المعنوية بين المواقع الثلاثة لكافة الصفات المدروسة فيما عدا صفة محصول الحبوب وميعاد ظهور 50% من حراير النورات المؤنثة. أظهرالتباين الراجع للهجن وكذلك تفاعلاتها مع المواقع معنوية لجميع الصفات المدروسة فيما عدا صفة ارتفاع الكوز. كانت تباينات كلاً من القدرة العامة والخاصة على التآلف معنوية لكل الصفات المدروسة فيما عدا صفة ارتفاع الكوز مشيراً إلى أهمية كلاً من الفعل الجيني المضيف وغير المضيف في وراثة معظم هذه الصفات تحت تلك الدراسة ومع ذلك كان تباين الفعل الوراثي المضيف أكثر أهمية في وراثة جميع الصفات تحت الدراسة ما عدا صفة المحصول. أفضل هجن لتأثيرات القدرة الخاصة على التآلف لصفة المحصول كان سدس-63 × جيزة-613 ولصفة التبكير سدس-1185 × جيزة-613. أظهر الهجين سدس-2013/2 × سدس-1185 تفوقاً معنوياً في المحصول والتبكير مقارنة بهجيني المقارنة. أظهرت الأربعة هجن سدس-2013/2 × جيزة-613، سدس-2015/41 × سخا-13، سدس-63 × جيزة-613، وسدس-1185 × سخا-9 تفوقاً معنوياً لصفة المحصول عن هجيني المقارنة وهذه الهجن سوف يتم تقييمها في اختبار على نطاق أوسع من خلال برنامج تربية الذرة الشامية.