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Evaluation of Some Inbred Lines of Maize in a Diallel Cross Under Two Sowing Dates

Hossam M. Abd-Elmonem[1], Amal Z.A. Mohamed[1], Samir H. Saleh[1], Yasser A. El-Gabry[1] and Mahmoud S. Abd-Ellatif[2]

[1]Agronomy Dept., Fac. of Agric., Ain Shams Univ., Cairo, Egypt.
[2]Field Crops Research Institute, Agricultural Research Center, Giza, Egypt

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ABSTRACT

A half diallel set of crosses were made among seven inbred lines of white maize during 2021 growing season to estimate combining ability for days to 50% tasseling, days to 50% silking, plant height, ear height, ear leaf area, chlorophyll content, number of rows per ear, number of kernels per row, ear length, ear diameter, 100-kernels weight and grain yield per plant under two sowing dates (14^{th} of May "recommended date" and 14^{th} of June "late sowing date") in two separate field experiments. Each experiment included 21 F_1 hybrids and the check variety SC 128 in a randomized complete block design with three replications during 2022 season. Results indicated that mean squares due to genotypes, sowing dates and the interactions between them were significant / or highly significant for all the studied traits. Mean squares due to GCA, SCA and their interactions with sowing dates were highly significant for all the studied traits. The ratios of GCA/SCA variances were less than the unity for all the studied traits indicating that the non-additive genetic effects had the main role of the expression of these traits. The parental inbred lines P_3, P_4 and P_7 seemed to be good general combiners for grain yield and most studied traits under the two sowing dates. The crosses P_1xP_4, P_2xP_6, P_3xP_5, P_3xP_7 and P_6xP_7 were the best cross-combinations for grain yield and most of the studied traits under two sowing dates.

***Keywords**:* White maize, diallel, combining ability, sowing dates.

Introduction

Maize *(Zea mays* L.*)* is a major cereal crop essential for human consumption and poultry and livestock feeding. Constraints in increasing total production of maize come from the limited cultivated land in Egypt where miscellaneous crops compete with each other on the one hand and the explosive population on the other. The area cultivated with maize amounted to 2.26 million faddan in 2023 season gave a total production of about 22.61 ardab fed^{-1} of grain yield (USDA-FAS 2023), constituting about 46.9% of the self-sufficiency of maize. Therefore, Maize breeder can play a major role in narrowing the gap between the production and the consumption through utilization of high-yielding maize hybrids.

Maize breeding is effective in developing improved hybrids to meet the rapidly changing cultural conditions. Successful development of the inbred lines-hybrid concept of maize to a useful form is still considered one of plant breeding greatest achievements.

Knowledge about variance of general and specific combining abilities and their interactions with different environments is useful in formulating maize breeding procedures. General combining ability (GCA) is assumed to be the main source for additive gene action however specific combining ability (SCA) may be of limited value and with less accuracy at other environments especially, when epistasis predominates. Therefore, estimation of genetic effects at different environments may supply the breeder with valuable information to identify the best conditions for evaluating parents for GCA effects and in hybrids for SCA effects. Diallel analysis is an attempt to partition phenotypic variation into genotypic variation and environmental component and to further subdivide genotypic variation into its additive and non-additive components. These estimates can then be used to draw inferences about the genetic systems involved for yield and its components and the best breeding strategy to improve them. In this

Corresponding Author: Hossam M. Abd-Elmonem, Agronomy Dept., Fac. of Agric., Ain Shams Univ., Cairo, Egypt.

respect, the additive gene effects have been reported to be important in the genetic expression of maize grain yield (Wattoo *et al.,* 2014; Sultan *et al.,* 2016; Keimeso *et al*., 2020 and Onejeme *et al.,* 2020), however, other researchers reported that the non-additive genetic effects represented the major role in the inheritance of maize grain yield and most of its components (Azad *et al.* 2014; Abdel-Moneam *et al.,* 2015; EL-Hosary and EL-Fiki 2015; Turkey *et al.,* 2018; Imam *et al*., 2020 and Patel 2022). These differences generally arise due to differences in the genetic materials and the environments under which the experiments were performed.

Therefore, the main objectives of the present investigation were to evaluate the mean performance of 21 maize hybrids and the check variety 128 under two different sowing dates and to estimate the effect of general and specific combining abilities and their interactions with different environments on grain yield and its contributing traits in a half seven parental diallel cross of maize.

2. Materials and Methods

The experimental field work was carried out at the experimental farm of the Faculty of Agriculture, Ain Shams University, Shoubra El-Kheima, Kalubia Governorate and at the Agriculture Research Stat. of the Faculty of Agriculture, Ain Shams University, Shalakan, Kalubia Governorate, during the two growing summer seasons of 2021 and 2022. Seven white inbred lines of maize were used as parents. These inbred lines namely; Inb-51 (P_1), Inb-59 (P_2), Inb-81 (P_3), Inb-87 (P_4), Inb-172 (P_5), Inb-208 (P_6) and Inb-24 (P_7) were kindly provided by the Maize Research Department, Field Crops Res. Inst. (FCRI), Agricultural Research Center (ARC), Giza, Egypt. In a half-diallel mating, seven inbred lines were crossed to produce a total of 21 F_1 crosses during the 2022 growing season. The 21 F_1 crosses along with commercial check hybrid SC.128 were evaluated in two separate experiments under two sowing dates (favorable, 14th May and late sowing, 14th June). Each experiment was designed in a randomized complete block design with three replications. The experimental plot consisted of one ridge of five meters long and 70 cm apart. Hills were spaced at 25 cm with two kernels hill^{-1} on one side of the ridge. The seedlings were thinned to one plant hill^{-1}. The other cultural practices were followed as usual for ordinary maize field in the area.

Days to 50% tasseling, days to 50% silking were evaluated and data were recorded on ten guarded plants chosen at random from each plot for F_1 crosses, and check variety for plant height (cm), ear height (cm), ear leaf area (cm2), chlorophyll content (SPAD), number of rows per ear, number of kernels per row, ear length (cm), ear diameter (cm), 100-kernel weight (g) and grain yield per plant (g). All statistical analyses were performed according to Gomez and Gomez (1984) with GENES software (Cruz, 2013). The ordinary statistical analysis for RCB design was separately carried out for each sowing date. Then, the homogeneity of error variances was tested as outlined by Snedecor and Cochran (1981) before applying the combined analysis on the two sowing dates. L.S.D. was computed to compare the differences among means of sowing dates, hybrids and their interactions at 5% level of probability. All factors used in this study were considered as fixed factors. The combining ability effects were calculated using the procedure of Griffing's (1956) method 4 and model I (fixed effect). According to this method, only the data set of F_1 excluding parents and reciprocals were used. The GCA/SCA ratio was used to reveal the nature of genetic variance involved, i.e. additive vs. non-additive effects according to Singh and Chaudhary (1995).

3. Results and Discussion

3.1. Analysis of variance

Mean squares of all studied traits of maize genotypes under the two sowing dates are illustrated in Table (1). The results showed that mean squares of sowing dates were highly significant for all studied traits indicating that these characteristics were influenced by sowing dates. Similar results were detected by El-Hosary and El-Fiki (2015), Hassaan (2018), Turkey *et al*. (2018) and Turk *et al*. (2020). Meantime, the variance due to genotypes were highly significant for all the studied traits suggesting the presence of wide genetic variability among the studied maize crosses which could be used in maize breeding programs for improving grain yield and the related characters. These results are in agreement with finding of Mohamed (2011); Estakhr and Heidari (2012); Turkey *et al*., (2018); El-Hosary (2020) and Altaweel and Yousif (2020). The interaction mean squares between genotypes and sowing dates were significant/ or highly significant for all the studied traits indicating that the rank of the studied maize crosses is greatly affected by sowing dates and consequently emphasized the importance of

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testing these crosses under several environments for better judgment of its performance. These results were supported by Mohamed (2011) and Turkey *et al*. (2018).

Table (1): Mean squares of variance for the studied traits of maize crosses under favorable (D_1), late (D_2) sowing dates and their combined data.

Source of variation	d.f.		Days to 50% tasseling (day)			Days to 50% silking (day)			Plant height (cm)		
	Single	Combined	D_1	D_2	Combined	D_1	D_2	Combined	D_1	D_2	Combined
Sowing dates (D)		1			232.01**			184.36**			67641.98**
Reps/D	2	4	3.47*	0.11	1.79	2.92*	0.29	1.61*	19	62.35	40.67
Genotypes (G)	21	21	3.64**	3.91**	5.33**	3.86**	6.02**	7.38**	971.49**	1573.24**	2344.93**
G x D		21			2.21**			2.51**			199.79**
Error	42	84	0.87	0.68	0.77	0.65	0.61	0.63	16.06	29.69	22.87
Crosses (C)	20	20	3.76**	4.09**	5.54**	4.02**	6.32**	7.74**	1019.81**	1648.96**	2459.77**
GCA	6	6	4.68**	8.44**	11.04**	3.85**	12.52**	12.61**	1824.85**	3285.05**	4869.63**
SCA	14	14	3.37**	2.22**	3.18**	4.09**	3.66**	5.65**	674.79**	947.78**	1426.97**
C x D		20			2.31**			2.60**			209.01**
GCA x D		6			2.09**			3.75**			240.27**
SCA x D		14			2.41**			2.11**			195.61**
Error	40	80	0.29	0.22	0.25	0.22	0.20	0.21	4.18	10.05	7.12
σ^2GCA/σ^2SCA			0.28	0.82	0.78	0.19	0.71	0.47	0.54	0.70	0.69

Source of variation	d.f.		Ear height (cm)			Ear leaf area (cm^2)			Chlorophyll content (SPAD)		
	Single	Combined	D_1	D_2	Combined	D_1	D_2	Combined	D_1	D_2	Combined
Sowing dates (D)		1			31387.41**			274813.07**			124443.68**
Reps/D	2	4	19.82	33.24	26.53	103.19	64.37	83.78	9.07	3.25	6.16
Genotypes (G)	21	21	955.60**	484.68**	1240.71**	26732.51**	22489.56**	48864.99**	9571.29**	5239.23**	12622.78**
G x D		21			199.57**			357.08**			2187.73**
Error	42	84	20.26	17.29	18.78	32.86	66.52	49.69	34.04	104.62	69.33
Crosses (C)	20	20	998.03**	507.41**	1302.05**	22401.93**	17338.46**	39373.15**	8691.27**	5120.75**	11665.65**
GCA	6	6	895.34**	743.89**	1425.11**	32976.04**	25073.62**	57680.61**	7074.71**	8184.10**	12390.95**
SCA	14	14	1042.05**	406.06**	1249.32**	17870.17**	14023.39**	31527.09**	9384.08**	3807.89**	11354.81**
C x D		20			203.39**			367.24**			2146.37**
GCA x D		6			214.12**			369.05**			2867.86**
SCA x D		14			198.79**			366.47**			1837.16**
Error	40	80	7.03	5.94	6.49	10.65	23.02	16.84	11.43	35.25	23.34
σ^2GCA/σ^2SCA			0.17	0.37	0.23	0.37	0.36	0.37	0.15	0.43	0.22

Table (1): Cont.

Source of variation	d.f. Single	d.f. Combined	Ear length (cm) D_1	D_2	Combined	Ear diameter (cm) D_1	D_2	Combined	No. of rows/ear D_1	D_2	Combined
Sowing dates (D)		1			50.20**			4.15**			2031.19**
Reps/D	2	4	0.18	0.15	0.17	0.02	0.04	0.03	2.26	2.94	2.6
Genotypes (G)	21	21	8.63**	7.90**	14.69**	0.15**	0.15**	0.25**	25.82**	35.13**	52.97**
G x D		21			1.83**			0.05*			7.98*
Error	42	84	0.72	0.84	0.78	0.02	0.03	0.03	4.67	4.24	4.46
Crosses (C)	20	20	8.80**	6.80**	13.92**	0.13**	0.11**	0.19**	26.33**	34.43**	52.61**
GCA	6	6	10.41**	5.69**	14.39**	0.21**	0.16**	0.31**	46.21**	23.97**	60.27**
SCA	14	14	8.11**	7.27**	13.72**	0.09**	0.09**	0.14**	17.81**	38.92**	49.32**
C x D		20			1.67**			0.05**			8.16**
GCA x D		6			1.70**			0.06**			9.92**
SCA x D		14			1.65**			0.04**			7.40**
Error	40	80	0.25	0.29	0.27	0.01	0.01	0.01	1.62	1.44	1.53
σ^2GCA/σ^2SCA			0.26	0.15	0.21	0.33	0.33	0.50	0.55	0.12	0.25

Source of variation	d.f. Single	d.f. Combined	No. of kernels/row D_1	D_2	Combined	100-kernel weight (g) D_1	D_2	Combined	Grain yield/plant (g) D_1	D_2	Combined
Sowing dates (D)		1			123.35**			3635.21**			67550.56**
Reps/D	2	4	0.11	0.99	0.55	9.58	13.42	11.5	10.53	145.52	78.03
Genotypes (G)	21	21	4.53**	3.15**	6.38**	35.71**	56.36**	80.93**	840.38**	1347.49**	1955.90**
G x D		21			1.31**			11.13			231.97**
Error	42	84	0.67	0.43	0.55	8.75	6.07	7.41	47.85	69.19	58.52
Crosses (C)	20	20	4.63**	3.31**	6.65**	30.58**	41.54**	61.66**	690.90**	1106.37**	1560.59**
GCA	6	6	5.22**	4.66**	8.41**	22.30**	24.50**	40.09**	966.97**	1143.55**	2074.94**
SCA	14	14	4.38**	2.73**	5.89**	34.13**	48.85**	70.91**	572.58**	1090.43**	1340.15**
C x D		20			1.30**			10.46**			236.68**
GCA x D		6			1.47**			6.70**			35.59
SCA x D		14			1.23**			12.07**			322.87**
Error	40	80	0.22	0.13	0.17	2.90	2.05	2.47	16.67	24.19	20.43
σ^2GCA/σ^2SCA			0.24	0.35	0.29	0.12	0.10	0.11	0.34	0.21	0.31

D_1 and D_2 denote 14th May and 14th June, respectively.

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

3.2. Mean performance

The mean performances of the 21 maize hybrids and the check variety (SC 128) for all the studied traits under recommended and late sowing dates are presented in Tables (2).

For days to 50% tasseling, mean values ranged from 57.33 days for the cross P_1xP_4 to 61 days for the crosses P_2xP_3 and P_6xP_7 compared to a value of 60 days for the check variety SC128 with an average of 59.39 days at the recommended sowing date. Meantime, the days to tasseling ranged from 55 days for the two crosses P_1xP_5 and P_4xP_5 to 58.33 days for the cross P_1xP_2 compared to 57 days for the check variety SC128 with an average of 56.74 days at the late sowing date. The earliest crosses were P_1xP_3, P_1xP_4, P_4xP_5 and P_5xP_7 at the two sowing dates, P_1xP_6, P_1xP_7 and P_2xP_5 at the recommended sowing date and P_1xP_5, P_2xP_6, P_3xP_4, P_3xP_5, P_4xP_6 and P_5xP_6 at the late sowing date. Furthermore, late sowing date caused significant reduction percentage in days to tasseling reached 4.46%. Similar results were reported by Mohamed (2011); Abdrabbo *et al.* (2013); Khalil *et al.* (2013); Turkey *et al.* (2018) and Turk *et al.,* (2020).

For days to 50% silking, mean values ranged from 59.67 days for the cross P_5xP_7 to 63.33 days for the crosses P_1xP_2, P_1xP_6 and P_3xP_6 with an average of 61.51 days compared to a values of 62 days for the check variety SC128 at the recommended sowing date. Whereas, values of days to 50% silking at the late sowing date ranged from 56 days for the cross P_4xP_5 to 62.33 days for the cross P_2xP_7 with a mean value reached 59.15 days compared to a value of 59 days for the check variety. The earliest crosses were P_4xP_5 at the two sowing dates and P_1xP_3, P_1xP_4, P_1xP_6, P_1xP_7, P_2xP_5, P_2xP_7, P_4xP_5, P_5xP_6 and P_5xP_7 at the recommended sowing date. Delaying the sowing date caused a significant reduction percent of

3.84% comparing to the optimum sowing date. The reduction of days to tasseling and days to silking was due to the effect of high temperatures during the flowering stage. These results are confirmed by Mohamed (2011); Sultan *et al.* (2012); Abdrabbo *et al.* (2013); Khalil *et al.* (2013); Turkey *et al.* (2018) and Turk *et al*. (2020).

With respect to plant height, results revealed that mean values of plant height ranged from 244.31 cm for the two crosses P_1xP_2 and P_3xP_5 to 300.55 cm for the cross P_3xP_7 with an average of 268.42 cm compared to a mean value of 268.6 cm for the check variety SC 128 at the recommended sowing date. Considering the late sowing date, means values of plant height ranged from 194.76 cm for the cross P_1xP_2 to 266.30 cm for the cross P_4xP_7 with an average of 222.15 cm compared to a mean value of 226.47 cm for the check variety SC 128. The tallest crosses were P_3xP_7 at the two sowing dates, P_3xP_4 at the recommended sowing date and P_4xP_7 at the late sowing date.

The delay in the sowing date caused significant reduction of plant height reached 17.24% compared to the recommended sowing date. These result are in accordance with findings of Mohamed (2011), Sultan *et al.* (2012); Khalil *et al.* (2013); Buriro *et al.* (2015); El-Hosary and El-Fiki (2015); Turkey *et al.* (2018); Hegab *et al.* (2019); El-Hosary (2020) and Omar *et al.* (2022).

Regarding ear height, results revealed that mean values of ear height ranged from 125.32 cm for the cross P_2xP_4 to 196.35 cm for the cross P_5xP_7 with an average of 152.41 cm compared to a mean values of 146.57 cm for the check variety SC 128 at the optimum sowing date, Furthermore, at the late sowing date, values of ear height ranged from 101.58 cm for the cross P_5xP_6 to 144.63 cm for the cross P_2xP_7 with a mean value of 121.57 cm compared to a mean value of 124.56cm for the check variety SC128. The late sowing date caused significant reduction in ear height by 20.23% compared to the recommended sowing date. The crosses which had lower ear placement were P_1xP_3 at the two sowing dates, P_3xP_5 and P_3xP_6 at the recommended sowing date and P_1xP_7, P_2xP_5 as well as P_5xP_7 at the late sowing date. Maize plants with low ear position on the stalk are more favourable because of its resistance to lodging compared to high ear position therefore the breeders select plants with low ear positions. These results are in coincidence with finding of Mohamed (2011); Estakhr and Heidari (2012); Turkey *et al.* (2018); El-Hosary (2020) and Turk *et al*. (2020).

For ear leaf area, mean values at the recommended sowing date ranged from 662.19 cm^2 for the cross P_2xP_7 to 975.12 cm^2 for the cross P_6xP_7 with an average of 809.9 cm^2 compared to a mean value of 999.81 cm^2 for the check variety SC128. At the late sowing date ear leaf area values ranged from 579.32 cm^2 for the cross P_2xP_7 to 866.19 cm^2 for the cross P_6xP_7 with an average of 718.64 cm^2 compared to a mean value of 918.48 cm^2 for the check variety SC128.The highest cross in ear leaf area was P_6xP_7 only at the two sowing dates. The lateness of sowing date caused significant reduction by 11.27% in ear leaf area compared to the optimum sowing date, because of the reduction in growth period which resulted in reducing all the photosynthetic area in maize plants. These results were corresponded with those obtained by Turkey *et al*. (2018).

With respect to chlorophyll content, the mean values of chlorophyll contents ranged from 476.46 spad for the cross P_2xP_4 to 651.88 spad for the cross P_3xP_7 with an average of 578.76 spad compared to a value of 671.74 spad for the check variety SC128 at the recommended sowing date. While, means of chlorophyll content ranged from 432.25 spad for the cross P_2xP_5 to 566.88 spad for the cross P_6xP_7 with an average of 517.35 spad compared to a mean value of 566.54 spad for the check variety SC128. The highest chlorophyll content were recorded in crosses P_2xP_6 and P_3xP_7 at the recommended sowing date as well as the cross P_6xP_7 at the late sowing date. The delaying in sowing date caused a significant reduction of chlorophyll content by 10.61% compared to the optimum sowing date. These finding supported by those mentioned by Muhammad *et al.,* (2019), Szulc *et al.,* (2021) and Guo *et al.,* (2022).

Regarding ear length, at the optimum sowing date mean values of ear length ranged from 18.07 cm for the cross P_4xP_5 to 23.87 cm for the cross P_3xP_4 with an average of 21.45 cm compared to a mean value of 22.73 cm for the check variety SC128. Besides the ear length mean values ranged from 17.7 cm for the cross P_4xP_5 to 23.07 cm for the cross P_3xP_7 with an average of 20.22 cm compared to a mean value of 23.30 cm for the check variety SC128.

Table 2: Mean performance of 21 F_1 maize crosses and the check cv. SC 128 for the studied traits under favorable (D_1) and late (D_2) sowing dates and their combined data.

Genotypes (G)	Days to 50% tasseling			Days to 50% silking			Plant height (cm)		
	D_1	D_2	Combined	D_1	D_2	Combined	D_1	D_2	Combined
$P_1 \times P_2$	61.00	58.33	59.67	63.33	61.33	62.33	244.31	194.76	219.54
$\times P_3$	58.00	55.33	56.67	60.00	59.00	59.50	245.87	207.06	226.46
$\times P_4$	57.33	55.33	56.33	60.00	58.33	59.17	272.87	224.30	248.58
$\times P_5$	60.00	55.00	57.50	62.00	58.33	60.17	251.07	202.71	226.89
$\times P_6$	58.67	57.33	58.00	60.33	59.67	60.00	246.88	202.05	224.46
$\times P_7$	58.67	57.67	58.17	61.00	60.00	60.50	254.00	203.20	228.60
$P_2 \times P_3$	61.00	57.00	59.00	62.00	57.67	59.83	283.36	246.02	264.69
$\times P_4$	59.67	57.00	58.33	61.67	59.67	60.67	243.80	206.64	225.22
$\times P_5$	58.67	57.67	58.17	61.00	59.67	60.33	265.82	226.01	245.92
$\times P_6$	60.33	56.00	58.17	62.33	59.33	60.83	265.77	207.95	236.86
$\times P_7$	59.00	59.33	59.17	61.33	62.33	61.83	286.32	249.77	268.05
$P_3 \times P_4$	60.00	56.33	58.17	62.00	58.33	60.17	295.92	243.37	269.64
$\times P_5$	59.00	56.00	57.50	62.00	58.00	60.00	244.31	199.19	221.75
$\times P_6$	60.67	57.67	59.17	63.33	60.67	62.00	269.13	240.03	254.58
$\times P_7$	59.33	57.67	58.50	62.00	59.33	60.67	300.55	265.38	282.96
$P_4 \times P_5$	58.00	55.00	56.50	60.00	56.00	58.00	249.49	198.08	223.78
$\times P_6$	59.33	56.00	57.67	61.00	58.33	59.67	277.52	241.00	259.26
$\times P_7$	60.33	57.00	58.67	63.00	61.00	62.00	292.63	266.30	279.46
$P_5 \times P_6$	59.00	56.33	57.67	60.33	57.67	59.00	273.67	195.47	234.57
$\times P_7$	57.67	55.67	56.67	59.67	58.00	58.83	280.43	233.29	256.86
$P_6 \times P_7$	61.00	57.67	59.33	63.00	59.67	61.33	270.97	208.19	239.58
Check SC128	60.00	57.00	58.50	62.00	59.00	60.50	268.60	226.47	247.54
Genotypes mean	59.39	56.74	58.07	61.51	59.15	60.33	268.42	222.15	244.78
Reduction (%)			4.46			3.84			17.24
L.S.D. 0.05 (D)			0.30			0.27			1.66
(G)	1.53	1.36	1.01	1.33	1.28	0.91	6.60	8.98	5.49
(G×D)			1.43			1.29			7.77

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Table 2: Cont.

Genotypes (G)	Ear height (cm)			Ear leaf area (cm^2)			Chlorophyll content (SPAD)		
	D_1	D_2	Combined	D_1	D_2	Combined	D_1	D_2	Combined
$P_1 \times P_2$	147.93	115.02	131.48	721.82	630.19	676.01	592.21	509.03	550.62
$\times P_3$	126.44	103.27	114.85	875.19	778.98	827.09	547.93	539.76	543.84
$\times P_4$	150.99	124.95	137.97	826.12	708.06	767.09	566.89	544.44	555.67
$\times P_5$	155.27	111.00	133.13	693.30	619.16	656.23	519.25	525.34	522.30
$\times P_6$	162.30	128.21	145.26	841.37	743.70	792.53	547.31	519.34	533.32
$\times P_7$	144.60	103.63	124.11	917.43	817.05	867.24	551.78	513.81	532.80
$P_2 \times P_3$	169.80	131.00	150.40	679.79	591.43	635.61	629.85	538.78	584.32
$\times P_4$	125.32	110.62	117.97	705.83	630.49	668.16	476.46	445.21	460.83
$\times P_5$	133.40	104.06	118.73	777.47	715.08	746.27	536.40	432.25	484.32
$\times P_6$	157.47	121.89	139.68	779.02	697.33	738.17	649.26	535.09	592.17
$\times P_7$	172.23	144.63	158.43	662.19	579.32	620.75	487.03	426.37	456.70
$P_3 \times P_4$	164.72	133.63	149.18	730.22	654.88	692.55	621.42	540.67	581.04
$\times P_5$	132.13	114.24	123.19	824.48	720.46	772.47	596.29	542.01	569.15
$\times P_6$	131.18	122.03	126.61	834.44	734.34	784.39	544.41	531.01	537.71
$\times P_7$	171.16	133.86	152.51	887.73	774.41	831.07	651.88	556.62	604.25
$P_4 \times P_5$	140.35	117.90	129.12	927.30	807.00	867.15	621.10	528.39	574.74
$\times P_6$	154.47	125.26	139.87	799.45	721.66	760.55	624.91	517.21	571.06
$\times P_7$	173.72	141.13	157.43	786.62	703.12	744.87	617.66	537.35	577.51
$P_5 \times P_6$	152.94	101.58	127.26	736.51	655.35	695.93	520.86	443.25	482.05
$\times P_7$	196.35	139.10	167.73	836.55	743.46	790.01	523.64	522.27	522.95
$P_6 \times P_7$	143.71	122.98	133.35	975.12	866.19	920.65	634.34	566.88	600.61
Check SC128	146.57	124.56	135.56	999.81	918.48	959.14	671.74	566.54	619.14
Genotypes mean	152.41	121.57	136.99	809.90	718.64	764.27	578.76	517.35	548.05
Reduction (%)			20.23			11.27			10.61
L.S.D. 0.05 (D)			1.50			2.44			2.88
(G)	7.42	6.85	4.98	9.44	13.44	8.09	9.61	16.85	9.56
(G×D)			7.04			11.45			13.52

Table 2: Cont.

Genotypes (G)	Ear length (cm)			Ear diameter (cm)			Number of rows ear^{-1}		
	D1	D2	Combined	D1	D2	Combined	D1	D2	Combined
P1× P2	23.23	21.80	22.52	4.03	3.83	3.93	11.80	12.00	11.9
× P3	22.47	20.03	21.25	3.90	3.37	3.63	12.80	10.73	11.77
× P4	21.40	18.73	20.07	3.93	3.67	3.80	12.53	11.93	12.23
× P5	22.30	21.30	21.80	4.10	3.53	3.82	15.67	13.60	14.63
× P6	19.73	19.23	19.48	4.50	3.83	4.17	15.40	13.40	14.40
× P7	22.13	19.27	20.70	4.17	3.67	3.92	14.80	13.00	13.90
P2× P3	22.23	21.53	21.88	3.97	3.83	3.90	13.87	11.27	12.57
× P4	19.10	17.77	18.43	4.03	3.73	3.88	13.73	11.33	12.53
× P5	20.20	17.90	19.05	4.03	4.03	4.03	13.93	10.67	12.30
× P6	23.53	20.53	22.03	4.30	3.80	4.05	13.27	11.07	12.17
× P7	19.33	19.33	19.33	4.13	3.83	3.98	12.60	11.93	12.27
P3× P4	23.87	21.43	22.65	4.17	4.03	4.10	15.73	12.00	13.87
× P5	20.43	18.97	19.70	4.60	4.07	4.33	15.00	12.80	13.90
× P6	22.53	19.77	21.15	4.03	3.80	3.92	12.07	10.60	11.33
× P7	23.50	23.07	23.28	4.37	4.03	4.20	13.67	12.87	13.27
P4× P5	18.07	17.70	17.88	4.03	3.73	3.88	13.73	10.73	12.23
× P6	23.37	22.30	22.83	4.00	3.77	3.88	12.73	10.53	11.63
× P7	19.40	19.17	19.28	4.13	3.57	3.85	12.87	11.13	12.00
P5× P6	20.07	19.93	20.00	4.40	3.87	4.13	15.67	13.87	14.77
× P7	21.40	20.77	21.08	4.40	4.03	4.22	14.87	12.40	13.63
P6× P7	20.83	20.90	20.87	4.47	4.13	4.30	14.67	12.00	13.33
CheckSC128	22.73	23.30	23.02	4.60	4.33	4.47	12.93	11.93	12.43
Genotypes mean	21.45	20.22	20.83	4.20	3.84	4.02	13.83	11.89	12.87
Reduction (%)			5.73			8.57			14.03
L.S.D. 0.05 (D)			0.31			0.06			0.26
(G)	1.39	1.51	1.01	0.25	0.27	0.18	1.34	1.08	0.85
(G×D)			1.43			0.26			1.20

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Table 2: Cont.

Genotypes (G)	Number of kernels row^{-1}			100-kernel weight (g)			Grain yield plant^{-1} (g)			
	D_1	D_2	Combined	D_1	D_2	Combined	D_1	D_2	Combined	Reduction (%)
$P_1\times P_2$	38.20	35.00	36.60	37.01	22.68	29.85	163.83	127.35	145.59	22.27
$\times P_3$	42.33	34.73	38.53	39.71	26.62	33.17	195.66	146.16	170.91	25.30
$\times P_4$	39.40	35.20	37.30	39.73	31.40	35.56	198.79	174.71	186.75	12.11
$\times P_5$	36.33	28.53	32.43	35.16	24.03	29.60	174.15	131.98	153.06	24.21
$\times P_6$	36.60	28.47	32.53	38.87	29.38	34.13	177.02	126.67	151.85	28.44
$\times P_7$	33.93	28.53	31.23	36.11	23.28	29.70	180.22	117.61	148.91	34.74
$P_2\times P_3$	41.67	31.00	36.33	40.68	27.93	34.31	192.34	139.95	166.15	27.24
$\times P_4$	36.47	27.47	31.97	38.60	24.02	31.31	166.74	121.30	144.02	27.25
$\times P_5$	39.00	30.80	34.90	34.05	22.70	28.38	175.17	121.37	148.27	30.71
$\times P_6$	42.87	32.80	37.83	40.16	31.65	35.90	192.29	154.93	173.61	19.43
$\times P_7$	42.67	31.73	37.20	32.16	22.11	27.14	151.90	109.52	130.71	27.90
$P_3\times P_4$	44.27	36.33	40.30	34.75	28.94	31.84	190.85	161.67	176.26	15.29
$\times P_5$	45.73	37.87	41.80	36.85	26.02	31.43	196.46	151.11	173.79	23.08
$\times P_6$	40.60	29.60	35.10	30.52	21.48	26.00	176.24	138.31	157.27	21.52
$\times P_7$	41.33	37.40	39.37	40.24	29.17	34.71	217.13	169.71	193.42	21.84
$P_4\times P_5$	42.07	32.47	37.27	37.64	27.77	32.70	182.60	128.58	155.59	29.58
$\times P_6$	43.27	37.80	40.53	39.89	23.44	31.66	198.67	114.51	156.59	42.36
$\times P_7$	37.87	28.13	33.00	36.75	27.11	31.93	186.78	147.71	167.25	20.92
$P_5\times P_6$	39.87	29.53	34.70	33.11	24.28	28.70	168.55	122.14	145.35	27.53
$\times P_7$	39.60	32.07	35.83	32.50	22.51	27.50	177.94	132.04	154.99	25.80
$P_6\times P_7$	41.20	33.33	37.27	41.63	35.19	38.41	200.72	167.21	183.96	16.69
Check SC128	42.60	36.47	39.53	43.90	37.38	40.64	220.58	184.72	202.65	16.26
Genotypes mean	40.36	32.51	36.43	37.27	26.78	32.03	185.67	140.42	163.04	
Reduction (%)			19.45			28.15				24.37
L.S.D. 0.05 (D)			0.73			0.94			2.65	
(G)	3.56	3.39	2.42	4.87	4.06	3.12	11.40	13.71	8.78	
(G×D)			3.43			4.42			12.24	

D_1 and D_2 denote 14th May and 14th June, respectively.
P_1,P_2,P_3,P_4,P_5,P_6, and P_7: denote P-51,P-59,P-81,P87,P-172,P-208, and P-24, respectively.

The late sowing caused a significant reduction percentage of 5.73%, compared to sowing at the favorable time. The best ear length were noticed at the crosses P_1xP_2, P_3xP_7 and P_4xP_6 at the two sowing dates, P_2xP_6 and P_3xP_4 at the recommended sowing date. Sowing at the favorable time caused taller ears because of heat units and metabolites stored to which caused vigorous growth and taller ears. Similar results were detected by Abdel-Moneam *et al*. (2015); Hassan *et al*. (2018) and Altaweel and Yousif (2020).

For ear diameter, results revealed that ear diameter ranged from 3.9 cm for the cross P_1xP_3 to 4.6 cm for the cross P_3xP_5 with an average value reached 4.20 cm compared to a mean value of 4.60 cm for the check variety SC 128 at the recommended sowing date. Considering the late sowing date, means of ear diameter ranged from 3.37 cm for the cross P_1xP_3 to 4.13 cm for the cross P_6xP_7 with an average of 3.84 cm compared to a mean value of 4.33 cm for the check variety SC 128. Results illustrated that the late sowing caused a significant reduction percentage of 8.57%. The best crosses for ear diameter were P_3xP_5, P_3xP_7, P_5xP_6, P_5xP_7 and P_6xP_7 at the two sowing dates, P_1xP_6 at the recommended sowing date as well as P_2xP_5 and P_3xP_4 at the late sowing date. The delayed sowing date led to a shorter growth period, which in turn decreased the overall ear diameter. These results were corresponded with those obtained by Mohamed (2011); Estakhr and Heidari (2012); Abdel-Moneam *et al*. (2015) and Tian *et al.* (2015).

For number of rows per ear, mean values ranged from 11.8 rows for the cross P_1xP_2 to 15.73 rows for the cross P_3xP_4 with an average of 13.83 rows compared to a mean value of 12.93 rows for the check variety SC128 at the recommended sowing date. Furthermore, mean values of number of rows/ear at the late sowing date ranged from 10.53 rows for the cross P_4xP_6 to 13.87 rows for the cross P_4xP_6 with an average of 11.89 rows compared to a value of 11.93 rows for the check variety SC128. The highest crosses in number of rows per ear were P_1xP_5, P_1xP_6, P_1xP_7, P_3xP_5 and P_5xP_6 at the two sowing dates, P_3xP_4, P_3xP_7 and P_6xP_7 at the recommended sowing date. Results indicated that the late sowing date caused a significant reduction in number of rows per ear by 14.03% than those at the recommended sowing date. Such results agreed with those obtained by Abdel-Moneam *et al*. (2015) and Omar *et al*. (2022).

With respect to number of kernels per row, data showed that the mean values ranged from 33.93 kernels for the cross P_1xP_7 to 45.73 kernels for the cross P_3xP_5 with an average of 40.36 kernel compared to a value of 42.60 kernels for the check variety SC128 at the recommended sowing date. In addition, results at the late sowing date indicated that mean values of number of kernels/row ranged from 27.47 kernels for the cross P_2xP_4 to 37.87 kernels for the cross P3xP5 with an average of 32.51 kernels compared to a mean value of 36.47 kernels for the check variety SC128. The best crosses in number of kernels per row were P_1xP_3, P_3xP_4, P_3xP_5 and P_4xP_6 at the two sowing dates, P_1xP_7, P_2xP_6 and P_2xP_7 at the recommended sowing date as well as P_1xP_4 at the late sowing date. Delaying the sowing date caused significant reduction by 19.45% compared to the optimum sowing date. Number of kennels per row was influenced by late sowing date due to prevailing high temperature during the ear development phase. These results are in the same trend with findings of Abdel-Moneam *et al*. (2015); El-Hosary (2020), Turk *et al*. (2020) and Omar *et al*., (2022).

Regarding 100-kernels weight mean values ranged from 30.52g for the cross P_3xP_6 to 41.63g for the cross P_6xP_7 with an average of 37.27g compared to a mean value of 43.90g for the check variety SC128 at the recommended sowing date. Concerning the late sowing date, mean values of 100-kernel weight ranged from 21.48g for the cross P_3xP_6 to 35.19g for the cross P_6xP_7 with an average reached 26.78g compared to a mean value of 37.38g for the check variety SC128, the mean performance of genotypes were decreased by delaying sowing date with reduction percentage reached 28.15% for 100-kernels weight compared to the recommended sowing. The best crosses in 100-kernels weight were P_1xP_4, P_2xP_4 and P_6xP_7 at the two sowing dates and P_1xP_2, P_1xP_3, P_1xP_6, P_2xP_3, P_2xP_4, P_3xP_5, P_3xP_7, P_4xP_5 as well as P_4xP_6 at the recommended sowing date. The reduction in 100-kernel weight was due to the rise in temperature accompanied with late sowing date which resulted in decreasing vegetative growth period and consequently reducing the photosynthetic area and decreased dry matter accumulation and translocation to kernels. These results were corresponded with finding of Abdel-Moneam *et al*. (2015); Turkey *et al*. (2018); Hegab *et al*. (2019); El-Hosary (2020); Turk *et al*. (2020) and Omar *et al*. (2022).

With respect to the grain yield per plant mean values ranged from 151.90g for the cross P_2xP_7 to 200.72g for the cross P6xP7 with an average of 185.67g compared to a mean value of 220.58g for the check variety SC128 at the optimum sowing date. Meanwhile, at the late sowing date mean values of grain yield ranged from 109.52g for the cross P_2xP_7 to 174.71g for the cross P_1xP_4 with an average of 140.42g compared to a mean value of 184.72 g for the check variety SC 128. The percentages of decrease in grain yield/plant, ranged from 12.11% for the cross P_1xP_4 to 42.36% for the cross P_4xP_6 with an average of 24.37%. Results showed that delaying the sowing date caused significant reduction by 24.37% compared to the optimum sowing date. The best crosses in grain yield per plant were P_1xP_4, P_3xP_4 and P_6xP_7 at the two sowing dates, P_1xP_3, P_2xP_3, P_2xP_7, P_3xP_5 and P_4xP_6 at the recommended sowing date as well as P_3xP_7 at the late sowing date. The reduction of grain yield associated with postponement of sowing date may be due to the changes in weather conditions especially rise in temperature at the reproductive stage and also the short period of growth and consequently adequate time for photosynthesis which resulted in the reduction of all yield contributors. Similar results were obtained by Abdel-Moneam *et al*. (2015), Buriro *et al*. (2015); El-Hosary and El-Fiki (2015); Hegab *et al*. (2019); Turk *et al*. (2020) and Omar *et al*. (2022).

3.3 Combining ability analysis

Mean squares of GCA and SCA for all studied traits of maize genotypes under two sowing dates are illustrated in (Table 1). The results indicated that mean squares due to GCA and SCA were highly significant for all studied traits at both sowing dates and their combined analysis, suggesting that both additive and non-additive genetic effects were important in the inheritance of these traits. The ratios of GCA/SCA variances were less than the unity for all the studied traits indicating that the non-additive genetic effects had the main role of the expression of these traits. Similar results were obtained by Sultan *et al*. (2012); Azad *et al*., (2014); El-Hosary (2014); Abdel-Moneam *et al*. (2014 and 2015); Turk *et al.* (2020); Imam *et al*. (2020) and Patel (2022). The interactions of GCA and SCA with sowing dates were highly significant for all the studied traits which led to the conclusion that sowing dates are considered an effective factor for declaring GCA and SCA variances and the magnitude for types of gene action were fluctuated from sowing date to another. These results were supported with those mentioned by Sultan *et al*. (2012); Abdel-Moneam *et al*. (2015); Al-Falahy (2015); El-Hosary (2020) and Turk *et al*. (2020).

3.3.1 General combining ability effects

Estimates of GCA effects for each parental inbred line of maize for all studied traits under the two sowing dates are given in Table (3). High positive GCA effects would be of interest in all studied traits except days to 50% tasseling, days to 50% silking and ear height where high negative GCA effects is desired for these traits.

For 50% days to tasseling, significant negative GCA effects were detected for P_1, P_4 and P_5 which considered as the best general combiners at the two sowing dates for earliness.

With respect to 50% days to silking significant negative GCA values were detected for P_4 and P_5 at the two sowing dates, P_1 at the recommended sowing date and P_3 at the late sowing date. These results indicated that these inbreds were considered as the best general combiners for earliness and may be utilize for developing early hybrids.

Regarding plant height, the results revealed that P_3, P_4 and P_7 at the two sowing dates were considered as good general combiners for tallness due to significant positive GCA values under these conditions.

For ear height, results showed that P_1 and P_6 at the two sowing dates, P_2, P_3 and P_4 at the recommended sowing date and P_5 at the late sowing date considered to be the good combiners towards low ear placement as they had significant negative GCA effects. Since the plants which have low ear placement are required for lodging resistance.

For ear leaf area, the estimates revealed that P_1, P_6 and P_7 at the two sowing dates, and P_3 at the recommended sowing dates had positive GCA effects for ear leaf area and considered as good combiners for this trait.

Table (3): Estimates of general combining ability effects of the seven parental maize inbred lines for the studied traits under favorable (D1) and late (D2) sowing dates.

Parent	Days to 50% tasseling		Days to 50% silking		Plant height (cm)	
	D_1	D_2	D_1	D_2	D_1	D_2
P-51 (P_1)	-0.5**	-0.28**	-0.46**	0.34**	-17.84**	-19.51**
P-59 (P_2)	0.7**	0.99**	0.54**	1.01**	-2.96**	-0.10
P-81 (P_3)	0.36**	-0.08	0.48**	-0.39**	6.99**	13.88**
P-87 (P_4)	-0.31*	-0.74**	-0.26*	-0.66**	5.61**	9.61**
P-172 (P_5)	-0.77**	-0.94**	-0.79**	-1.46**	-7.88**	-15.38**
P-208 (P_6)	0.56**	0.12	0.27*	0.08	-0.05	-7.39**
P-24 (P_7)	-0.04	0.93**	0.21	1.08**	16.14**	18.9**
LSD (0.05) ĝi	0.25	0.22	0.22	0.21	0.96	1.49
(0.01) ĝi	0.33	0.29	0.29	0.27	1.26	1.96
(0.05) ĝi - ĝj	0.38	0.33	0.34	0.32	1.46	2.27
(0.01) ĝi - ĝj	0.51	0.44	0.44	0.42	1.93	2.99
	Ear height (cm)		**Ear leaf area (cm^2)**		**Chlorophyll content (SPAD)**	
Parent	D_1	D_2	D_1	D_2	D_1	D_2
P-51 (P_1)	-5.72**	-7.11**	14.02**	8.48**	-24.12**	12.34**
P-59 (P_2)	-2.00**	-1.13	-95.8**	-82.18**	-14.95**	-40.66**
P-81 (P_3)	-4.14**	-1.13	5.34**	-0.05	29.16**	31.77**
P-87 (P_4)	-1.31*	1.84**	-5.92**	-5.91**	16.49**	4.65**
P-172 (P_5)	-1.14	-4.64**	-1.90*	1.15	-25.69**	-19.3**
P-208 (P_6)	-2.81**	-2.07**	32.16**	32.76**	15.02**	4.55**
P-24 (P_7)	17.13**	14.24**	52.1**	45.76**	4.07**	6.66**
LSD (0.05) ĝi	1.24	1.14	1.53	2.25	1.58	2.78
(0.01) ĝi	1.64	1.50	2.01	2.96	2.09	3.66
(0.05) ĝi - ĝj	1.90	1.74	2.34	3.43	2.42	4.25
(0.01) ĝi - ĝj	2.50	2.30	3.07	4.52	3.19	5.59

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Table (3): Cont.

Parent	Ear length (cm)		Ear diameter (cm)		No. of rows ear^{-1}	
	D_1	D_2	D_1	D_2	D_1	D_2
P-51 (P_1)	0.59**	-0.01	-0.08**	-0.20**	-0.05	0.65**
P-59 (P_2)	-0.14	-0.31*	-0.11**	0.03	-0.81**	-0.62**
P-81 (P_3)	1.34**	0.88**	0.00	0.05*	-0.02	-0.22**
P-87 (P_4)	-0.62**	-0.66**	-0.15**	-0.08*	-0.39**	-0.75**
P-172 (P_5)	-1.17**	-0.77**	0.10**	0.07**	1.12**	0.54**
P-208 (P_6)	0.35**	0.45**	0.13**	0.06**	0.11	0.02
P-24 (P_7)	-0.35**	0.42**	0.12**	0.07**	0.04	0.39**
LSD (0.05) ĝi	0.23	0.25	0.05	0.05	0.22	0.17
(0.01) ĝi	0.31	0.33	0.07	0.06	0.29	0.22
(0.05) ĝi - ĝj	0.36	0.38	0.08	0.07	0.34	0.26
(0.01) ĝi - ĝj	0.47	0.51	0.11	0.11	0.44	0.34
Parent	No. of kernels row^{-1}		100-kernel weight (g)		Grain yield plant^{-1} (g)	
	D_1	D_2	D_1	D_2	D_1	D_2
P-51 (P_1)	-2.94**	-0.70*	0.97*	-0.05	-2.87**	-1.08
P-59 (P_2)	-0.13	-1.03**	0.18	-1.31**	-12.35**	-11.09**
P-81 (P_3)	2.88**	2.60**	0.20	0.51	12.93**	15.41**
P-87 (P_4)	0.37	0.69*	1.12**	1.01**	4.08**	3.72**
P-172 (P_5)	0.22	-0.53	-2.49**	-2.06**	-5.83**	-8.53**
P-208 (P_6)	0.58	-0.48	0.49	1.56**	1.90	-1.22
P-24 (P_7)	-0.98**	-0.55	-0.47	0.35	2.14*	2.79*
LSD (0.05) ĝi	0.60	0.56	0.80	0.67	1.91	2.30
(0.01) ĝi	0.78	0.74	1.05	0.88	2.52	3.03
(0.05) ĝi - ĝj	0.91	0.86	1.22	1.02	2.92	3.52
(0.01) ĝi - ĝj	1.20	1.13	1.60	1.35	3.85	4.63

D_1 and D_2 denote 14th May and 14th June, respectively.

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

With respect to chlorophyll content, P_3, P_4, P_6 and P_7 at the two sowing dates and P_1 at the late sowing date exhibited positive significant GCA effects and consequently could be considered as good combiners for chlorophyll content.

For ear length, the estimates of GCA effects revealed that P_3 and P_6 at the two sowing dates, P_1 at the recommend sowing date and P_7 at the late sowing date had significant positive GCA effects for ear length and consequently these parents proved to be good general combines for this trait.

Regarding ear diameter data showed that P_5, P_6 and P_7 at the two sowing dates and P_3 at the late sowing date are considered as good combiners for ear diameter due to their positive significant GCA effects.

Concerning number of rows per ear, estimates of GCA showed significant positive GCA effects for P_5 at the two sowing dates and P_1 as well as P_7 at the late sowing date and consequently considered as good combiners for this trait.

With respect to number of kernels per row, estimates of GCA effects at the two sowing dates indicated that P_3 at the two sowing dates and P_4 at the late sowing date had positive significant GCA effects and considered as good combiners for this trait.

For 100-kernels weight, positive significant GCA effects were recorded for P_4 at the two sowing dates, P_1 at the recommended sowing date and P_6 at the late sowing date and which led to conclusion that these parents seemed to be good combiners for 100-kernel weight.

Regarding grain yield per plant, positive significant GCA effects were detected for P_3, P_4 and P_7 at the two sowing dates for grain yield/plant. These results suggested that these inbred lines considered to be good general combiners for this trait.

3.3.2 Specific combining ability effects

Estimates of specific combining ability effects of 21 F_1 maize crosses for the studied traits under two sowing dates are presented in Table (4).

For 50% days to tasseling, results showed that significant negative SCA values towards earliness were recorded in crosses; P_1xP_3, and P_5xP_7 at the two sowing dates, P_1xP_4, $P_1x\ P_6$, P_2xP_5 and P_2xP_7 at the recommended sowing date and P_1xP_5, P_2xP_3 as well as P_2xP_6 at the late sowing date. Therefore, these crosses are considered as good F_1-cross combinations for this traits under the studied sowing dates.

The SCA effects for 50% days to silking were significant and negative for the crosses; P_1xP_4, P_2xP_3, P_4xP_5 and P_5xP_7 at the two sowing dates, P_1xP_3, P_1xP_6, P_2xP_7, P_4xP_6 and P_5xP_6 at the recommended sowing date and P_1xP_7, P_2xP_6, P_3xP_7 and P_6xP_7 at the late sowing date. These crosses could be considered as good cross combinations towards earliness and may be of importance as early matured single crosses.

Effects of SCA for plant height were positive and significant for the crosses; P_1xP_4, P_1xP_5, P_2xP_3, P_2xP_5, P_2xP_7, P_3xP_7, P_4xP_6, P_4xP_7 and P_5xP_7 at the two sowing dates, P_3xP_4 and P_5xP_6 at the recommended sowing date and P_1xP_6 as well as P_3xP_6 at the late sowing date. Therefore, these crosses are considered as the best F_1-cross combinations for this trait.

Negative significant SCA effects for ear height were observed in crosses; P_1xP_3, P_1xP_7, P_2xP_4, P_2xP_5 and, P_6xP_7 at both sowing dates and P_3xP_5, P_3xP_6, P_4xP_5 at the recommended sowing date, and P_5xP_6 at the late sowing date. Therefor, these crosses could be considered as good cross combination for low ear placement.

For ear leaf area, significant positive SCA effects were detected for crosses; P_1xP_3, P_1xP_7, P_2xP_4, P_2xP_5, P_2xP_6, P_3xP_5, P_3xP_7, P_4xP_5 and P_6xP_7 at the two sowing dates as well as P_1xP_4 at the recommended sowing date. These crosses seemed to be suitable for improvement of this trait.

With respect to chlorophyll content, results showed that the crosses; P_1xP_2, P_2xP_3, P_2xP_6, P_3xP_5, P_4xP_5, P_4xP_7 and P_6xP_7 at the two sowing dates, P_3xP_7 and P_4xP_6 at the recommended sowing date as well as P_1xP_4, P_1xP_5 and P_5xP_7 at the late sowing date exhibited significant positive SCA estimates and consequently could be considered as desirable genotypes for chlorophyll improvement.

Data revealed that significant positive SCA effects for ear length were detected in crosses; P_1xP_2, P_1xP_5, P_3xP_4, P_3xP_7, P_4xP_6 and P_5xP_7 at the two sowing dates, P_1xP_7 and P_2xP_6 at the recommended sowing date and P_2xP_3 at the late sowing date. These crosses are considered as good F1-cross combinations for ear length.

Results showed that ear diameter exhibited positive significant SCA effects in crosses; P_1xP_6, P_3xP4 and P_3xP_5 at the two sowing dates, P_2xP_4 at the recommended sowing date and P_1xP_2, P_1xP_4, P_2xP_5, P_3xP_7 and P_6xP_7 at the late sowing date. Therefore, these crosses would be efficient single crosses for improving ear diameter.

Concerning number of rows per ear, data revealed that significant positive SCA effects were detected for the crosses; P_1xP_5, P_1xP_6, P_2xP_4, P_3xP_4, and P_5xP_6 at the two sowing dates, P_1xP_7, P_2xP_3 and P_6xP_7 at the recommended sowing date and P_3xP_5 as well as P_3xP= at the late sowing date and these crosses are considered to be promising crosses for number of rows per ear.

With respect to number of kernels per row, data showed that the crosses; P_1xP_4, P_2xP_6, P_3xP_5, P_4xP_6 and P_6xP_7 at the two sowing dates, P_1xP_3 and P_2xP_7 at the recommended sowing date and P_1xP_2 as well as P_3xP_7 at the late sowing date had positive significant SCA effects for number of kernels/row and considered to be the best cross combination for this trait.

Data demonstrated that significant positive SCA effects were detected for 100-kernel weight in crosses; P_2xP_3, P_2xP_6, P_4xP_5 and P_6xP_7 at the two sowing dates, P_1xP_3, P_3xP_5 and P_3xP_7 at the recommended sowing date, P_1xP_4 and P_1xP_6 at the late sowing date. Such crosses are expected to be of importance for this trait.

For grain yield per plant, positive significant SCA effects were detected for crosses; P_1xP_4, P_2xP_6, P_3xP_5, P_3xP_7 and P_6xP_7 at the two sowing dates, P_2xP_3, P_2xP_5 and P_4xP_6 at the recommended sowing date. Thus, it could be concluded that such crosses may be of practical importance as high yielding single crosses.

It is worthy to note that the crosses which have significant SCA effects for grain yield and the other grain yield contributors not necessary to develop from parents having high significant estimates of GCA effects. The crosses P_1xP_4, P_2xP_3, P_3xP_5, P_3xP_7, P_4xP_6 and P_6xP_7 contained one or two of the good parents while the crosses P_2xP_6 and P_2xP_5 involved poor parents only which exhibited insignificant GCA effects and recorded significant SCA effects which may be due to high genetic diversity among the parents. In addition, the parents having low GCA effects had a relatively high magnitude of non-additive gene effects resulted in high SCA effects when crossed. In conclusion; these hybrids could be of importance in maize breeding programs for improving the productivity of maize.

Table (4): Estimates of specific combining ability of 21 F_1 maize crosses and the check cv. SC 128 for the studie for the studied traits under favorable (D_1) and late (D_2) sowing dates.

Crosses (C)	Days to 50% tasseling		Days to 50% silking		Plant height (cm)	
	D_1	D_2	D_1	D_2	D_1	D_2
$P_1 \times P_2$	1.44**	0.89**	1.75**	0.82**	-2.25*	-7.57**
$\times P_3$	-1.22**	-1.05**	-1.51**	-0.11	-10.65**	-9.25**
$\times P_4$	-1.22**	-0.38	-0.78**	-0.51*	17.74**	12.26**
$\times P_5$	1.91**	-0.51*	1.76**	0.29	9.42**	15.66**
$\times P_6$	-0.75**	0.75**	-0.98**	0.09	-2.60**	7.01**
$\times P_7$	-0.15	0.29	-0.24	-0.58**	-11.67**	-18.12**
$P_2 \times P_3$	0.58*	-0.64**	-0.51*	-2.11**	11.97**	10.30**
$\times P_4$	-0.08	0.02	-0.11	0.16	-26.21**	-24.81**
$\times P_5$	-0.62*	0.89**	-0.24	0.96**	9.3**	19.55**
$\times P_6$	-0.29	-1.84**	0.02	-0.92**	1.42	-6.50**
$\times P_7$	-1.02*	0.68**	-0.91**	1.09**	5.78**	9.03**
$P_3 \times P_4$	0.58*	0.42	0.29	0.22	15.96**	-2.06
$\times P_5$	0.04	0.29	0.82**	0.69**	-22.16**	-21.25**
$\times P_6$	0.38	0.89**	1.09**	1.82**	-5.17**	11.60**
$\times P_7$	-0.36	0.09	-0.18	-0.51*	10.05**	10.66**
$P_4 \times P_5$	-0.29	-0.04	-0.45*	-1.04**	-15.6**	-18.09**
$\times P_6$	-0.29	-0.11	-0.51*	-0.25	4.60**	16.84**
$\times P_7$	1.31**	0.09	1.55**	1.42**	3.52**	15.85**
$P_5 \times P_6$	-0.16	0.42	-0.65**	-0.11	14.24**	-3.70*
$\times P_7$	-0.89**	-1.04**	-1.24**	-0.78**	4.8**	7.83**
$P_6 \times P_7$	1.11**	-0.11	1.02**	-0.64**	-12.49**	-25.26**
L.S.D.						
0.05 (Sij)	0.49	0.43	0.44	0.41	1.89	2.93
0.01(Sij)	0.65	0.57	0.57	0.54	2.49	3.86
0.05 (Sij – Sik)	0.77	0.67	0.67	0.63	2.93	2.93
0.01(Sij – Sik)	1.01	0.88	0.89	0.83	3.85	3.85
0.05 (Sij – Skl)	0.66	0.58	0.58	0.55	2.53	2.53
0.01(Sij – Skl)	0.87	0.76	0.72	0.72	3.34	3.34

Table (4): Cont.

Crosses (C)	Ear height (cm)		Ear leaf area (cm^2)		Chlorophyll content (SPAD)	
	D1	D2	D1	D2	D1	D2
$P_1 \times P_2$	2.96**	2.36*	2.75	-5.23*	56.95**	22.35**
$\times P_3$	-16.39**	-11.55**	54.97**	61.43**	-31.44**	-19.35**
$\times P_4$	5.34**	7.04**	17.16**	-3.63	0.19	12.45**
$\times P_5$	9.44**	6.21**	-119.67**	-99.59**	-5.27**	17.30**
$\times P_6$	18.15**	16.60**	-5.66**	-6.67**	-17.92**	-12.56**
$\times P_7$	-19.49**	-20.65**	50.45**	53.69**	-2.50	-20.19**
$P_2 \times P_3$	23.25**	7.95**	-30.61**	-35.46**	41.31**	32.67**
$\times P_4$	-24.06**	-15.52**	6.69**	9.46**	-99.41**	-33.79**
$\times P_5$	-16.15**	-8.96**	74.32**	86.99**	2.71	-22.79**
$\times P_6$	9.59**	2.06	41.81**	37.63**	74.86**	56.19**
$\times P_7$	4.41**	12.12**	-94.97**	-93.38**	-76.42**	-54.63**
$P_3 \times P_4$	17.49**	5.33**	-70.06**	-48.29**	1.43	-10.75**
$\times P_5$	-15.28**	-0.94	20.18**	10.24**	18.48**	14.54**
$\times P_6$	-14.55**	0.03	-3.92*	-7.50**	-74.11**	-20.31**
$\times P_7$	5.49**	-0.81	29.43**	19.58**	44.32**	3.20
$P_4 \times P_5$	-9.89**	-0.38	134.27**	102.63**	55.96**	28.04**
$\times P_6$	5.91**	0.17	-27.64**	-14.32**	19.06**	-7.00*
$\times P_7$	5.22**	3.37**	-60.42**	-45.86**	22.76**	11.04**
$P_5 \times P_6$	4.20**	-10.39**	-94.60**	-87.69**	-42.81**	-57.00**
$\times P_7$	27.67**	14.46**	-14.50**	-12.58**	-29.08**	19.91**
$P_6 \times P_7$	-23.29**	-8.48**	90.01**	78.54**	40.91**	40.67**
L.S.D.						
0.05 (Sij)	2.45	2.25	3.02	4.43	3.12	5.49
0.01(Sij)	3.23	2.96	3.97	5.84	4.11	7.22
0.05 (Sij – Sik)	3.80	3.49	4.67	6.87	4.84	8.50
0.01(Sij – Sik)	5.00	4.59	6.15	9.04	6.37	11.19
0.05 (Sij – Skl)	3.29	3.02	4.05	5.95	4.19	7.36
0.01(Sij – Skl)	4.33	3.98	5.32	7.83	5.52	9.69

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Table (4): Cont.

Crosses (C)	Ear length (cm)		Ear diameter (cm)		No. of rows ear-1	
	D_1	D_2	D_1	D_2	D_1	D_2
$P_1 \times P_2$	1.40**	2.05**	0.05	0.18**	-1.21**	0.07
$\times P_3$	-0.85**	-0.91**	-0.19**	-0.29**	-1.00**	-1.60**
$\times P_4$	0.05	-0.67**	-0.01	0.13**	-0.91**	0.13
$\times P_5$	1.50**	2.01**	-0.09	-0.16**	0.72**	0.51**
$\times P_6$	-2.59**	-1.28**	0.28**	0.15**	1.47**	0.83**
$\times P_7$	0.50*	-1.21**	-0.04	-0.02	0.93**	0.06
$P_2 \times P_3$	-0.36	0.89**	-0.09	-0.06	0.83**	0.22
$\times P_4$	-1.52**	-1.33**	0.12*	-0.04	1.05**	0.80**
$\times P_5$	0.12	-1.09**	-0.13**	0.11*	-0.26	-1.14**
$\times P_6$	1.94**	0.32	0.11	-0.11*	0.10	-0.22
$\times P_7$	-1.57**	-0.85**	-0.06	-0.09*	-0.51*	0.27
$P_3 \times P_4$	1.76**	1.15**	0.15**	0.25**	2.27**	1.07**
$\times P_5$	-1.13**	-1.21**	0.33**	0.14**	0.03	0.59**
$\times P_6$	-0.55*	-1.63**	-0.27**	-0.12**	-1.89**	-1.09**
$\times P_7$	1.12**	1.70**	0.07	0.10*	-0.23	0.81**
$P_4 \times P_5$	-1.52**	-0.94**	-0.09	-0.08	-0.88**	-0.96**
$\times P_6$	2.26**	2.44**	-0.15**	-0.03	-0.87**	-0.64**
$\times P_7$	-1.02**	-0.66**	-0.02	-0.24**	-0.66**	-0.41*
$P_5 \times P_6$	-0.49*	0.18	-0.01	-0.08	0.56*	1.42**
$\times P_7$	1.53**	1.05**	0.01	0.07	-0.17	-0.42*
$P_6 \times P_7$	-0.56*	-0.04	0.04	0.18**	0.64**	-0.30
L.S.D.						
0.05 (Sij)	0.46	0.50	0.10	0.09	0.43	0.33
0.01(Sij)	0.61	0.65	0.13	0.12	0.57	0.43
0.05 (Sij – Sik)	0.72	0.77	0.16	0.14	0.67	0.51
0.01(Sij – Sik)	0.94	1.01	0.21	0.18	0.88	0.67
0.05 (Sij – Skl)	0.62	0.66	0.14	0.12	0.58	0.44
0.01(Sij – Skl)	0.82	0.87	0.18	0.16	0.76	0.58

Table (4): Cont.

Crosses (C)	No. of kernels row-1		100-kernel weight (g)		Grain yield plant-1 (g)	
	D1	D2	D1	D2	D1	D2
$P_1 \times P_2$	1.02	4.40**	-1.10	-2.24**	-4.95**	1.21
$\times P_3$	2.14**	0.50	1.58*	-0.11	1.59	-6.48**
$\times P_4$	1.72**	2.88**	0.68	4.17**	13.57**	33.75**
$\times P_5$	-1.20*	-2.56**	-0.28	-0.13	-1.15	3.28
$\times P_6$	-1.29	-2.68**	0.46	1.60*	-6.01**	-9.34**
$\times P_7$	-2.40**	-2.55**	-1.34	-3.29**	-3.05	-22.41**
$P_2 \times P_3$	-1.34*	-2.89**	3.34**	2.46**	7.75**	-2.68
$\times P_4$	-4.02**	-4.52**	0.34	-1.95**	-9.00**	-9.64**
$\times P_5$	-1.34*	0.04	-0.60	-0.20	9.35**	2.68
$\times P_6$	2.16**	1.99**	2.53**	5.13**	18.74**	28.93**
$\times P_7$	3.53**	0.98	-4.51**	-3.20**	-21.89**	-20.49**
$P_3 \times P_4$	0.77	0.72	-3.53**	1.15	-10.17**	4.23
$\times P_5$	2.38**	3.48**	2.18**	1.31	5.35**	5.92**
$\times P_6$	-3.12**	-4.84**	-7.12**	-6.86**	-22.59**	-14.19**
$\times P_7$	-0.82	3.03**	3.55**	2.04	18.06**	13.20**
$P_4 \times P_5$	1.23*	-0.01	2.05*	2.55**	0.34	-4.92*
$\times P_6$	2.07**	5.27**	1.32	-5.40**	8.69**	-26.30**
$\times P_7$	-1.77**	-4.34**	-0.86	-0.52	-3.44	2.89
$P_5 \times P_6$	-1.18*	-1.78**	-1.85*	-1.49*	-11.52**	-6.42**
$\times P_7$	0.11	0.83	-1.50	-2.05**	-2.37	-0.53
$P_6 \times P_7$	1.35*	2.04**	4.66**	7.01**	12.69**	27.33**
L.S.D.						
0.05 (Sij)	1.18	1.11	1.57	1.32	3.77	4.54
0.01(Sij)	1.55	1.46	2.07	1.74	4.97	5.98
0.05 (Sij – Sik)	1.82	1.72	2.44	2.05	5.84	7.04
0.01(Sij – Sik)	2.40	2.26	3.21	2.70	7.70	9.27
0.05 (Sij – Skl)	1.49	1.49	2.11	1.77	5.06	6.10
0.01(Sij – Skl)	1.96	1.96	2.78	2.34	6.66	8.02

D_1 and D_2 denote 14th May and 14th June, respectively.

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

P_1,P_2,P_3,P_4,P_5,P_6, and P_7: denote P-51,P-59,P-81,P87,P-172,P-208, and P-24, respectively.

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