African Crop Science Journal, Vol. 31, No. 4, pp. 417 - 425
pISSN 1021-9730/2023
eISSN 2072-6589/2023

DOI: https://dx.doi.org/10.4314/acsj.v31i4.4

DIALLEL ANALYSIS OF MAIZE INBRED LINES FOR ESTIMATING SUPERIORITY AND COMBINING ABILITY

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(*Received 28 September 2023; accepted 31 October 2023*)

ABSTRACT

The phenomenon of heterosis has provided the most important genetic tools for crop yield improvement. Identification of specific parental combinations capable of producing the highest level of heterotic effects in F_1 has immense value for commercial exploitation of heterosis. The objective of this study was to assess the combining ability variances and superiority in twenty one combinations developed by crossing seven maize (*Zea mays* L.) inbred lines in half diallel fashion design. The resulting 21 hybrids, along with two check hybrids, were evaluated in Randomised Complete Block Design, in three locations during 2022 season in Egypt. The results showed that both additive and non-additive gene actions were important in controlling all the measured traits. The General Combining Ability (GCA) variance was found to be greater than Specific Combining Ability (SCA) variance, indicating predominance of additive and additive by additive gene effects in the inheritance for all studied traits. Cross $P_2 \times P_3$ significantly out yielded the best check (SC. 168) for the grain yield trait. The parental inbred lines, P_1, P_2 and P_3, possessed significant desirable (GCA) effects for the grain yield trait. The cross combinations $(P_1 \times P_5)$, $(P_2 \times P_7)$, $(P_3 \times P_7)$, $(P_4 \times P_5)$, $(P_4 \times P_6)$ and $(P_6 \times P_7)$ showed significant positive *sca* effects for grain yield. Cross $P_2 \times P_3$ (10.32**) obtained superiority (%) relative to the check hybrid SC.168 for grain yield. On the other hand, five crosses *viz*. $(P_1 \times P_3)$, $(P_1 \times P_5)$, $(P_2 \times P_3)$, $(P_2 \times P_5)$ and $(P_3 \times P_5)$ expressed positive superiority (%) over the check hybrid SC.3444 for same trait. Thus, these crosses could be recommended to be released as commercial hybrids by Maize Research Programme after further evaluation and testing in multi-locations in Egypt.

Key Words: Additive effects, heterosis, single cross, *Zea mays*

RÉSUMÉ

Le phénomène d'hétérosis a fourni les outils génétiques les plus importants pour l'amélioration du rendement des cultures. L'identification de combinaisons parentales spécifiques capables de produire le plus haut niveau d'effets hétérotiques en F1 présente une immense valeur pour l'exploitation commerciale de l'hétérosis. L'objectif de cette étude était d'évaluer les variations de capacité de combinaison et la supériorité dans vingt et une combinaisons développées en croisant sept lignées consanguines de maïs (*Zea mays* L.) dans un modèle demi-diallèle. Les 21 hybrides résultants, ainsi que deux hybrides témoins, ont été évalués dans le cadre d'une conception en blocs complets randomisés, dans trois endroits au cours de la saison 2022 en Égypte. Les résultats ont montré que les actions génétiques additives et non additives étaient importantes dans le contrôle de tous les caractères mesurés. La variance de la capacité de combinaison générale (CCG) s'est avérée supérieure à la variance de la capacité de combinaison spécifique (CCS), indiquant la prédominance des effets de gènes additifs et additifs par additifs dans l'héritage pour tous les caractères étudiés. Le croisement $P_2 \times P_3$ a donné le meilleur contrôle (CS. 168) pour le caractère de rendement en grains. Les lignées parentales consanguines, P_1, P_2 et P_3, possédaient des effets souhaitables (CCG) significatifs pour le caractère de rendement en grains. Les combinaisons croisées ($P_1 \times P_5$), ($P_2 \times P_7$), ($P_3 \times P_7$), ($P_4 \times P_5$), ($P_4 \times P_6$) et ($P_6 \times P_7$) ont montré des effets CCS positifs significatifs sur le rendement en grains. Le croisement $P_2 \times P_3$ (10,32**) a obtenu une supériorité (%) par rapport à l'hybride témoin SC.168 pour le rendement en grains. D'autre part, cinq croix à savoir. ($P_1 \times P_3$), ($P_1 \times P_5$), ($P_2 \times P_3$), ($P_2 \times P_5$) et ($P_3 \times P_5$) ont exprimé une supériorité positive (%) sur l'hybride témoin CS.3444 pour le même caractère. Ainsi, il pourrait être recommandé que ces croisements soient commercialisés en tant qu'hybrides commerciaux par le programme de recherche sur le maïs après une évaluation et des tests plus approfondis dans plusieurs sites en Égypte.

Mots Clés : effets additifs, hétérosis, croisement unique, *Zea mays*

INTRODUCTION

Maize (*Zea mays* L.) is considered the second widely cultivated crop in the world after wheat (FAOStat, 2021). Global maize production has surged in the past decades, propelled by rising demand and a combination of yield increases and cultivated area expansion. Global maize use is set for continued growth; and is set to become the internationally traded cereal, reflecting the marked spatial disparity between supply and demand (Erenstein *et al*., 2022).

In Egypt, maize is consumed by both human and livestock, apart from serving as an industrial raw material for making starch and cooking oil. Nearly 60% of Egypt focus on maize needs met by imports; yet the country struggles to bridge up the gap between production and consumption. However, the expansion of maize production is greatly challenged by limited availability of arable land and water resources. Therefore, increasing productivity appears to be solely by genetic improvement.

The success of development of high yielding and widely adapted maize hybrid will depend on the combining ability of parental crosses. Hence, a combining ability study is imperative in order to determine parents and crosses for advancement in the character under consideration; and also provides information on the nature of genetic variation present in the material under study. Diallel cross analysis was suggested by Griffing (1956) to estimate the combing ability of parents in hybrids; since then it remains widely advocated by plant breeders (Shaaban *et al*., 2022; Kamal *et al*., 2023; Nadeem *et al*., 2023). Increased maize yield can be obtained, through exploiting heterosis.

The expression of heterosis is allied to Specific Combining Ability (SCA) characterised by non-additive genetic effect and General Combing Ability (GCA) related to the additive genetic effects. For developing hybrids with desirable traits, information about combining ability of parents and crosses is crucial (Kage *et al*., 2013). Both GCA and SCA are important in determining the improvement or decline in hybrid traits (Vieira *et al*., 2009); and subsequently, for the development of maize hybrids with high yield and desired traits. It is imperative that we screen inbred lines for their genetic potential for the required traits, and combining ability of parents and their cross combinations. The objective of this study was to assess the combining ability and superiority in twenty one combinations developed by crossing seven maize (*Zea mays* L.) inbred lines in half diallel fashion design.

MATERIALS AND METHODS

Plant materials. The genetic materials used included seven yellow inbred lines, developed by the Maize Research Programme of the Agricultural Research Centre in Egypt. These inbred lines were chosen based on genetic diversity and flowering synchronisation (Table 1). A half diallel system was adopted to form all the crosses between the seven inbred lines, by hand pollination at the Ismailia Research Station in the 2021summer season.

Experimental procedure. The resulting 21 F1s along with two commercial checks (SC.168 & SC.3444), were evaluated in the field, in a randomised complete block design (RCBD), with three replications; and at three locations, *viz*. Gemmiza, Sids and Sakha Research stations. Each entry was planted in two rows of 6 m long. Plant spacing between and within rows was 80 cm by 25 cm, respectively. One plant per hill was maintained after thinning. All recommended agronomic practices were followed to maintain a healthy crop for all entries. Data collected included number of days to silk emergence (DTS), plant height (PH), ear height (EH) and grain yield (GY). Plant height was determined at 10% flowering on 10 competitive plants plot$^-$ from ground to the point of flag leaf insertion; while ear height was determined after flowering on 10 competitive plants per plot as distance from the ground surface to the ear leaf. Grain yield was estimated at physiological maturity, and adjusted to 15.5% grain moisture and finally converted to (ardab/feddan) ardab = 140 kg and Feddan = 4200 m^2.

Data analysis. The data collected were subjected to analysis of variance (ANOVA) according to Steel and Torrie (1980). Bartlett test was used to test the homogeneity of error variance among locations, for all studied traits. Analysis of GCA and SCA were carried out following the method of Griffing (1956) Method 2, model I. Superiority percentage was calculated using formula:

Superiority % = $[F_1 - CH)/CH]X100$

Where:

F_1 and CH represented the mean performance of the exotic and check hybrids.

The significance test for superiority was done using standard error of the value of the check hybrid.

RESULTS AND DISCUSSION

Analysis of variance. Results showed that mean squares due to location were highly significant for all the measured traits (Table

TABLE 1. Names and origins of yellow maize inbred lines used in the study

SN	Identification	Inbred Line	Origin
1	P_1	Sk-2	Sakha
2	P_2	Gz.639	Giza
3	P_3	Gz.074(213)	Giza
4	P_4	Nub.679	Nubaria
5	P_5	Mall.5030A	Mallawy
6	P_6	Sd.10/2015	Sids
7	P_7	Sd.3118	Sids

2), suggesting that locations diverge possibly due to differences in climate and soil properties. Crosses mean squares were also highly significant for the measured traits, reflecting the divergence between parental inbred lines used in this study for all the measured traits. This result is consistent with the works of Karim *et al.* (2022) and Kamal *et al.* (2023).

Crosses and location interactions were also highly significant for all the studied traits, indicating that these crosses performed differently from one location to another.

General and specific combining ability mean squares were significant for all the studied traits; thus, both additive and non-additive gene action were important in controlling these traits. These findings agree with those of others (Kage *et al.*, 2013; Ismail *et al.,* 2019a; Aboyousef *et al.*, 2022; Karim *et. al.*, 2022) for almost all the traits.

The mean square of GCA and SCA interactions with location were also significant reflecting that both additive and non-additive gene action were influenced by locations.

The ratio of GCA/SCA exceeded unity for all the measured traits, indicating predominance of additive and additive by additive gene effects in the inheritance for all studied traits. Similar findings have been reported by Ismail *et al.* (2019 a, b), Sedhom *et al.* (2021) and Karim *et al.* (2022).

The ratio of GSA×L/SCA×L also exceeded the unity for all the studied traits, suggesting that additive gene effects were more interacted with locations than non-additive gene effects for these traits.

Performance in terms of means. The performance of the 21 studied crosses and the two check hybrids for the studied traits are illustrated in Table 3.

For days to 50% silking, seven crosses out of the 21 studied crosses were significantly earlier compared to the earlier check hybrid SC. 168. The overall earliest hybrid was recorded in cross $P_4 \times P_7$ (56.22 day), which had the lowest value for this trait, and was considered to be the earliest cross among the

TABLE 2. Analysis of variance for four traits across three locations

Traits	df	Mean squares			
SOV		DTS	PH	EH	GY
Loc. (L)	2	179.24**	69418.39**	35052.48**	712.26**
Rep/L	6	6.12	982.97	644.18	21.95
Crosses (C)	20	29.79**	2016.45**	953.43**	170.26**
CxL	40	4.48**	235.02*	139.57**	35.94**
Error	120	1.69	134.53	75.97	8.26
GCA	6	6.61**	314.72**	179.79**	41.14**
SCA	14	1.89*	185.18**	74.28**	9.39**
GCAxL	12	8.96**	397.29**	274.17**	61.18**
SCAxL	28	3.02**	261.71**	100.29**	17.92**
Error	120	0.19	14.94	8.44	0.91
GCA/SCA		3.49	1.70	2.42	4.38
GCA×L/ SCA×L		2.96	1.51	2.73	3.41
CV		2.16	4.89	6.78	9.32

DTS = Days to 50 % silking, PH = Plant height, EH= Ear height and GY = Grain yield per feddan
*,** significant at 0.05 and 0.01 level of probability , respectively

TABLE 3. Combined mean performance of 21 crosses and the two check hybrids across three locations for all the studied traits

Traits (Crosses)	DTS (Days)	PH (cm)	EH (cm)	GY ard/fed
$P_1 \times P_2$	60.88	237.89	126.56	32.64
$P_1 \times P_3$	62.44	240.33	132.44	36.82
$P_1 \times P_4$	57.22	228.67	113.89	29.20
$P_1 \times P_5$	61.44	227.22	117.56	34.99
$P_1 \times P_6$	63.00	236.22	130.89	31.69
$P_1 \times P_7$	61.33	231.00	122.11	27.45
$P_2 \times P_3$	61.44	247.22	137.89	38.45
$P_2 \times P_4$	57.22	236.44	125.78	28.23
$P_2 \times P_5$	60.89	251.00	137.78	35.83
$P_2 \times P_6$	60.67	262.33	144.89	31.85
$P_2 \times P_7$	58.78	242.78	134.00	33.43
$P_3 \times P_4$	58.89	236.67	126.56	27.65
$P_3 \times P_5$	62.11	247.78	139.89	34.83
$P_3 \times P_6$	60.44	226.78	124.67	29.07
$P_3 \times P_7$	62.11	251.67	139.78	33.87
$P_4 \times P_5$	61.89	251.22	140.33	30.55
$P_4 \times P_6$	59.78	235.89	126.11	29.54
$P_4 \times P_7$	56.22	199.00	104.67	19.99
$P_5 \times P_6$	59.56	244.78	133.67	25.64
$P_5 \times P_7$	60.44	203.22	113.67	26.12
$P_6 \times P_7$	60.44	234.22	126.67	29.21
SC. 168	61.11	238.44	137.78	34.86
SC.3444	63.88	241.11	124.67	32.11
LSD. 0.05	1.22	10.88	8.17	2.69
LSD. 0.01	1.58	14.10	10.60	3.49

DTS = Days to 50 % silking, PH = Plant height, EH = Ear height and GY = Grain yield per feddan

studied crosses. Crosses $P_1 \times P_5$, $P_3 \times P_6$, $P_4 \times P_7$, and $P_5 \times P_7$ significantly outperformed the best check, SC. 168, for plant height. On the other hand, crosses $P_1 \times P_4$, $P_4 \times P_7$ and $P_5 \times P_7$ obtained lower ear placements than the lowest check, SC. 3444. Consequently, the two hybrids $P_4 \times P_7$ and $P_5 \times P_7$ would be considered as short stature hybrids to decrease lodging and increasing plant density. The tallest hybrid overall was $P_2 \times P_6$ (262.33 cm); which could be targeted for silage hybrid production.

Cross $P_2 \times P_3$, significantly out yielded the best check, SC. 168, for grain yield. On the other hand, four crosses, *viz.* $P_1 \times P_3$, $P_1 \times P_5$, $P_2 \times P_5$ and $P_3 \times P_5$, tended (not significant) to out-yield the best check (hybrid SC.168).Therefore, these crosses could be released as commercial hybrids by the Maize Research Programme after further evaluation.

General combining ability. The estimates of GCA effects of the parents are presented in Table 4. The parental inbred lines, P_2, P_4 and P_7, showed significantly desirable ($\hat{g}_i$) effects for days to 50% silking.

The desirable ($\hat{g}_i$) effects for plant and ear heights were obtained by the parental inbred lines P_1, P_4 and P_7. Consequently, these inbred

TABLE 4. Estimates of general combining ability effects ($\hat{g}_i$) of seven inbred lines for four traits across three locations

Traits (Parents)	DTS (Days)	PH (cm)	EH (cm)	GY ard/fed
P_1	0.85**	-3.87*	-5.58**	1.59**
P_2	-0.43*	11.40**	7.10**	3.11**
P_3	1.08**	5.96**	5.97**	3.16**
P_4	-2.17**	-6.56**	-6.81**	-3.94**
P_5	0.85**	0.91	2.30	0.62
P_6	0.37*	3.91*	3.10**	-1.57**
P_7	-0.55**	-11.76**	-6.10**	-2.96**
LSD gi 5%	0.36	3.19	2.39	0.79
LSD gi 1%	0.46	4.13	3.10	1.02
LSD gi-gj 5%	0.55	4.87	3.66	1.21
LSD gi-gj 1%	0.71	6.31	4.74	1.56

DTS = Days to 50 % silking, PH = Plant height, EH = Ear height and GY = Grain yield per feddan
*, ** =significant at 0.05 and 0.01 probability levels, respectively

lines can be considered good combiners for these traits. For grain yield, the parental inbred lines P_1, P_2 and P_3 possessed significantly desirable ($\hat{g}_i$) effects. Parent P_1 seemed to be a good combiner for developing short stature hybrids, with high yielding; while, parental P_2 seemed to be a good combiner for developing early high yielding hybrids .These parents with desirable ($\hat{g}_i$) effects for particular trait could be used in future breeding programme to improve maize yield with desirable traits.

Specific combining ability. For days to 50% silking, SCA revealed that 4 among the 21 crosses exhibited significant negative *sca* effects (Table 5). The most desirable *sca* combination for this trait was obtained by $P_5 \times P_6$ (-2.01**), followed by $P_1 \times P_4$ (-1.81**).

Six and four crosses showed significant negative *sca* effects for plant and ear heights, respectively. Crosses $P_1 \times P_5$, $P_3 \times P_6$, $P_4 \times P_7$ and $P_5 \times P_7$ had the shortest stature promising hybrids. They also had the best significant negative *sca* effects for both plant and ear height. Regarding grain yield, six crosses, *viz.* ($P_1 \times P_5$), ($P_2 \times P_7$), ($P_3 \times P_7$), ($P_4 \times P_5$), ($P_4 \times P_6$) and ($P_6 \times P_7$), showed significant and positive *sca* effects. It is worthy noting that the cross ($P_1 \times P_5$) accompanied by top ranking per se performance, showed a predominant role of non-additive gene effects in expression of grain yield. Thus, for grain yield improvement, heterosis breeding may be more rewarding.

Superiority percentages. Superiority percentages related to the two checks, i.e. SC.168 and SC. 3444, for the 21 F1s crosses, under combined data are presented in Table 6. All crosses, except $P_1 \times P_6$, expressed superiority % over the check hybrid, SC. 3444, for earliness. On the other hand, seven crosses out of 21 crosses showed superiority % over the check hybrid (SC.168) for the same trait. The best crosses for earliness over the two checks were $P_4 \times P_7$ and $P_1 \times P_4$; while the best hybrids for short stature relative to the two check hybrids were $P_1 \times P_5$, $P_3 \times P_6$, $P_4 \times P_7$ and $P_5 \times P_7$. For ear height, 11 crosses exhibited negative superiority percentages over the hybrid SC. 168 check. The highest superiority percentages for ear height relative to the check hybrid SC.168 was obtained by the crosses

TABLE 5. Specific combining ability (*sca*) effects of 21 crosses for four traits across three locations

Traits (Crosses)	DTS (Days)	PH (cm)	EH (cm)	GY ard/fed
$P_1 \times P_2$	0.13	-6.42*	-3.53	-2.86**
$P_1 \times P_3$	0.17	1.47	3.50	1.26
$P_1 \times P_4$	-1.81**	2.31	-2.28	0.75
$P_1 \times P_5$	-0.61	-6.60*	-7.73**	1.98*
$P_1 \times P_6$	1.44**	-0.60	4.81*	0.87
$P_1 \times P_7$	0.68	9.84**	5.23*	-1.99*
$P_2 \times P_3$	0.46	-6.91*	-3.75	1.37
$P_2 \times P_4$	-0.52	-5.18	-3.08	-1.75*
$P_2 \times P_5$	0.13	1.91	-0.19	1.29
$P_2 \times P_6$	0.39	10.24**	6.12**	-0.50
$P_2 \times P_7$	-0.59	6.36*	4.43	2.47**
$P_3 \times P_4$	-0.36	0.49	-1.17	-2.38**
$P_3 \times P_5$	-0.16	4.13	3.05	0.23
$P_3 \times P_6$	-1.34**	-19.87**	-12.97**	-3.33**
$P_3 \times P_7$	1.24**	20.69**	11.34**	2.86**
$P_4 \times P_5$	2.86**	20.09**	16.27**	3.06**
$P_4 \times P_6$	1.24**	1.76	1.25	4.24**
$P_4 \times P_7$	-1.41**	-19.47**	-10.99**	-3.92**
$P_5 \times P_6$	-2.01**	3.18	-0.30	-4.21**
$P_5 \times P_7$	-0.21	-22.71**	-11.10**	-2.35**
$P_6 \times P_7$	0.28	5.29	1.10	2.93**
LSD Sij 5%	0.71	6.28	4.72	1.56
LSD Sij1%	0.92	8.14	6.12	2.02
LSD Sij-Sik 5%	1.09	9.73	7.31	2.41
LSD Sij-Sik1%	1.42	12.62	9.48	3.13

DTS = Days to 50 % silking, PH = Plant height, EH = Ear height and GY = Grain yield per feddan
*, ** = significant at 0.05 and 0.01 probability levels, respectively

$P_4 \times P_7$ (-24.03**), $P_5 \times P_7$ (-17.50**), $P_1 \times P_4$ (-8.15**); while three crosses, *viz.* $P_1 \times P_4$, $P_4 \times P_7$ and $P_5 \times P_7$ showed superiority percentages over the check hybrid SC.3444 for the same trait.

Cross $P_2 \times P_3$ (10.32**) demonstrated superiority percentage relative to the check hybrid SC.168 for grain yield; whereas, five crosses, *viz.* $P_1 \times P_3$, $P_1 \times P_5$, $P_2 \times P_3$, $P_2 \times P_5$ and $P_3 \times P_5$ expressed positive superiority percentages over the check hybrid SC.3444 for the same trait. Several investigators reported useful superiority for yield in maize (Ismail *et al.*, 2018; Patel *et. al.*, 2019; Aboyousef *et al.*, 2022; Karim *et al.*, 2022).

CONCLUSION

The parental inbred lines P1, P2 and P3 possessed desirable gene effects for grain yield trait. Therefore, these inbreds could be utilised in a hybridisation programmes to develop high

TABLE 6. Superiority% for 21 yellow single cross over the checks for the studied traits across three locations

Traits Crosses	DTS (Days)		PH (cm)		EH (cm)		GY ard/fed	
	SC.168	SC.3444	SC.168	SC.3444	SC.168	SC.3444	SC.168	SC.3444
$P_1 \times P_2$	-0.36	-4.70**	-0.23	-1.34	-8.15**	1.52	-6.35	1.66
$P_1 \times P_3$	2.18*	-2.26*	0.79	-0.32	-3.87	6.24	5.64	14.67**
$P_1 \times P_4$	-6.36**	-10.43**	-4.10	-5.16*	-17.34**	-8.65**	-16.22**	-9.05*
$P_1 \times P_5$	0.55	-3.83**	-4.71*	-5.76*	-14.68**	-5.70	0.38	8.97*
$P_1 \times P_6$	3.09**	-1.39	-0.93	-2.03	-5.00	4.99	-9.08*	-1.30
$P_1 \times P_7$	0.36	-4.00**	-3.12	-4.19	-11.37**	-2.05	-21.26**	-14.52**
$P_2 \times P_3$	0.55	-3.83**	3.68	2.53	0.08	10.61**	10.32**	19.75**
$P_2 \times P_4$	-6.36**	-10.43**	-0.84	-1.94	-8.71**	0.89	-19.02**	-12.09**
$P_2 \times P_5$	-0.36	-4.70**	5.27*	4.10	0.00	10.52**	2.78	11.57**
$P_2 \times P_6$	-0.73	-5.04**	10.02**	8.80**	5.16	16.22**	-8.63*	-0.82
$P_2 \times P_7$	-3.82**	-8.00**	1.82	0.69	-2.74	7.49*	-4.10	4.11
$P_3 \times P_4$	-3.64**	-7.83**	-0.75	-1.84	-8.15**	1.52	-20.68**	-13.89**
$P_3 \times P_5$	1.64	-2.78**	3.91	2.76	1.53	12.21**	-0.09	8.46*
$P_3 \times P_6$	-1.09	-5.39**	-4.89*	-5.94**	-9.52**	0.00	-16.60**	-9.47*
$P_3 \times P_7$	1.64	-2.78**	5.55*	4.38	1.45	12.12**	-2.82	5.49
$P_4 \times P_5$	1.27	-3.13**	5.36*	4.19	1.85	12.57**	-12.36**	-4.86
$P_4 \times P_6$	-2.18*	-6.43**	-1.07	-2.17	-8.47**	1.16	-15.25**	-8.00
$P_4 \times P_7$	-8.00**	-12.00**	-16.54**	-17.47**	-24.03**	-16.04**	-42.65**	-37.74**
$P_5 \times P_6$	-2.55*	-6.78**	2.66	1.52	-2.98	7.22*	-26.43**	-20.14**
$P_5 \times P_7$	-1.09	-5.39**	-14.77**	-15.71**	-17.50**	-8.82**	-25.07**	-18.66**
$P_6 \times P_7$	-1.09	-5.39**	-1.77	-2.86	-8.06**	1.60	-16.21**	-9.04*

DTS = Days to 50 % silking, PH = Plant height, EH= Ear height and GY = Grain yield per feddan
*, ** = significant at 0.05 and 0.01 probability levels, respectively

yielding maize hybrids. Cross P2×P3 (10.32**) obtained superiority percentage relative to the check hybrid SC.168 for grain yield. Whereas, five crosses *viz.* (P1×P3), (P1×P5), (P2×P3), (P2×P5) and (P3×P5) expressed positive superiority percentages over the check hybrid SC.3444 for the same trait. Thus, these crosses could be recommended to be released as commercial hybrids by Maize Research Programme after further evaluation and testing in a large scale in different environments in Egypt.

ACKNOWLEDGMENT

Maize germplasms used in this study were obtained from the Maize Research Department, Field Crops Research Institute, Agricultural Research Center, Egypt.

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