Archives of Agriculture Sciences Journal
Print ISSN: 2535-1680
Online ISSN: 2535-1699

ARCHIVES OF AGRICULTURAL SCIENCES JOURNAL

Volume 1, Issue 2, 2018, Pages 68–78

Available online at www.agricuta.edu.eg

The 1st International Conference on Applied Agricultural Sciences and Prospective Technology

Estimates of combining ability in seven new yellow maize inbred lines for grain yield and some agronomic traits

Mostafa M.A.A.*

Maize Research Department, Field Crops Research Institute, Agricultural Research Center, Giza, Egypt

Abstract

Diallel crosses among seven advanced yellow maize inbred lines derived from different maize populations without reciprocals were made in 2015 season at Mallawi Agricultural Research Station, Minia, Egypt. The resultant 21 crosses along with two commercial check hybrids *i.e.* SC 162 and SC 168 were evaluated in a Randomized Complete Block Design with four replications at two locations *i.e.* Mallawi and Sakha Stations, Egypt during 2016 summer season. Mean squares due to crosses, G.C.A. and S.C.A. were significant for all studied traits. The ratio of G.C.A. variance to S.C.A. variance exceeded the unity for all studied traits, except for number of kernels per row, indicating that the greater importance of the additive gene effects than the non-additive gene effect in the inheritance of these traits. The parental lines 3, 5 and 7 had significant positive GCA effects for grain yield, in addition lines 5 and 7 had significant negative (preferred) GCA effects for days to 50% silking. Also, inbred line 4 had negative significant GCA effects for both 50% silking and plant height. Nine crosses (P1xP3, P1xP4, P1xP7, P2xP6, P3xP4, P4xP5, P4xP7, P5xP6 and P6xP7) showed significant positive SCA effects for grain yield. Among these crosses, Three crosses ($L_1 \times L_4$, $L_2 \times L_6$, $L_4 \times L_5$) exhibited the highest SCA effects and also its gave the highest mean performance for grain yield. These crosses may be released as commercial hybrids by the Maize Research Program after further testing and evaluation. Despite cross ($L_1 \times L_4$) was insignificant higher than SC.168 but was significantly earlier and relatively shorter. The crosses ($L_1 \times L_7$) and ($L_2 \times L_5$) had higher yield, while, the first one was significantly earlier than SC.168, while the second one was significantly shorter than SC.168. These promising single crosses should undergo more testing across years and location before submission to the Varity Registration Committee, (VRC).

Keywords: maize, diallel crosses, gene effect, combining ability.

*Corresponding author: Mostafa M. A. A.
E-mail address: mahmoudabdelfatah638@yahoo.com

1. Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops in Egypt. It ranks third among cereal crops, after wheat and rice. Maize is used as food, feed, and fodder crop. It also has several industrial uses such as oil extraction, starch, gluten, fructose, glucose, ethanol production and many more products. The conventional hybrid breeding methodology mainly depends upon the development of inbred lines from open pollinated varieties or other heterogeneous sources and the evaluation of these inbred lines through different techniques and selects the best hybrids for commercial use. The choice of inbred lines to be included in a hybrid development of program is based on the results of diallel analysis tests. The diallel analysis techniques have been widely used to estimate the combining ability of parents in hybrids. Such information serves as a useful guide in the determination of the promising hybrid combinations. Griffing (1956) gave a complete analysis of diallel crosses for fixed and random set of parents. El-Shamarka (1995), Mostafa *et al.* (1996), Abd El-Aty and Katta (2002) and Ibrahim *et al.* (2010) reported that specific combining ability effects were much more important than general combining ability in the inheritance of grain yield and its components. Meanwhile, Beck *et al.* (1991), El-Hosary *et al.* (1999), Abd El-Moula (2005) and Vivek *et al.* (2010) reported that general combining ability was more important in determining yield and other characters. El-Hosary and Sedhom (1990), Mohamed (1993) and Sedhom (1994) concluded that the additive genetic variance was more affected by genotype x environment interaction than the non-additive variance for grain yield per plant. On the contrary, Nawar *et al*. (2002), El-Hosary *et al*. (2006) and Sedhom *et al*. (2007) reported that the non-additive effects were more affected by interaction with environments than the additive effects for grain yield. The present study was planned to 1) obtain information on relative importance of general and specific combining ability for grain yield, and some agronomic traits. 2) Identify the best promising crosses.

2. Materials and methods

Seven newly developed yellow maize (*Zea mays* L.) inbred lines selected with a wide range of diversity for several traits, were crossed in a half diallel mating scheme in 2015 season at Mallawi Agricultural Research Station, Minia, Egypt by hand method giving a total of 21 single crosses seed. The resultant 21 crosses along with two commercial check hybrids i.e. (SC 162 and SC 168) were evaluated in a Randomized Complete Block Design with four replications at two locations *i.e.* Mallawi and Sakha Stations, Egypt in 2016 season. The experimental plot was one ridge, six m length and 0.80 m width. Planting was made in hills evenly spaced at 25 cm along the row with two kernels per hill on one side of the ridge. Seedlings were thinned to one plant per hill. Agricultural practices were done as recommended for maize cultivation. Data were recorded for no. of days to 50% silking, plant height (cm), ear height (cm), number of kernels per row, ear diameter (cm) and grain yield /fad adjusted to 15.5 percent grain moisture and calculated in ardab per faddan (ard/fad^{-1}) (ardab= 140 kg and faddan= 4200 m^2). Bartlett test was used to test the homogeneity of error variance between the two locations. Analysis of variance was performed for the combined data over the two locations according to Steel and Torri (1980). General and specific combining abilities were computed using method 4, model 1 of Griffing (1956).

3. Results and Discussion

3.1 Analysis of variance

Analysis of variance for all studied traits over the two locations is presented in Table 1. Locations mean squares were significant or highly significant for plant height; no. of kernels /row; ear height and grain yield, indicating that the two locations differed in their environmental conditions for these traits. Crosses mean squares were either significant or highly significant for all the studied traits indicating the wide diversity of the parental materials used in this investigation. Significant interaction mean squares between crosses and locations were obtained for plant height, kernel number, ear diameter and grain yield, indicating that the performance of these crosses differed from location to another. Insignificant interaction mean squares between crosses and locations were detected for days to 50% silking and ear height, revealing the performance of crosses responded similarly to location changes. Mean squares due to G.C.A. and S.C.A. were either significant or highly significant for all studied traits, indicating that both additive and non-additive gene effects were important in the inheritance of the studied traits. The mean squares of interaction between locations and G.C.A were significant for all the studied traits, except for days to 50 % silking, indicating that the additive type of gene action varied from location to another. So, it would not be effective to make selection on the basis of a single location performance and more locations (environments) are needed. Mean squares due to S.C.A. x locations were significant for plant height, kernel number, ear diameter and grain yield indicating that the non-additive gene action was affected by the environmental conditions. Same results were obtained by El-Hosary (1989), Barakat *et al*. (2003) and Osman *et al.* (2012), who found highly significant interactions between both types of combining ability and the environment for the same traits. High GCA/SCA ratios, exceeding the unity, were obtained for all traits, except for kernel number, revealing the predominance of additive and additive by additive gene effects for these traits. The same results were reported by Abd El-Aty and Katta (2002) and Bujak *et al.* (2006) who found that ear length was mostly determined by additive gene action**.** Abd El-Moula (2005), Vivek *et al*. (2010), Ibrahim (2012) and Mostafa and Mostafa (2017) found that the additive gene action was more important than the non-additive for grain yield. However, Salama *et al*.

(1995), Sadek *et al*. (2001), Singh and Roy (2007), Abdallah and Hassan (2009) and Osman *et al*. (2012), reported that the non-additive type of gene action appeared to be more important in the inheritance of grain yield. The ratio for SCA x L / SCA was higher than the ratio of GCA x L / GCA for days to 50% silking, plant height and grain yield indicating that non-additive genetic effects were more influenced by the environmental conditions than additive genetic effects for these traits. These results are in agreement with those reported by Gilbert (1958). While the additive genetic effects were more influenced by the environmental conditions than non-additive genetic effects for the exceptional traits i.e. ear height, kernel number and ear diameter, were reported by Motawei (2006), Ibrahim *et al.* (2010) and Ibrahim (2012) for grain yield.

Table (1): Combined analysis of variance for studied traits over two locations, 2016 season.

S.O.V.	df	MS					
		Days to 50% silking	Plant height (cm)	Ear height (cm)	Number of kernels/row	Ear diameter (cm)	Grain yield (ard fad^{-1})
Loc. (L)	1	1.52	20971.01**	15067.148**	55.77*	0.01	435.51**
Reps/Loc.	6	4.88	215.38	62.89	25.02	0.89	8.02
Crosses (C)	20	16.25**	4902.08**	1576.56**	118.12**	2.98*	247.46**
GCA	6	24.32**	6922.63**	2333.24**	116.98**	0.17*	369.92**
SCA	14	12.79**	4036.13**	1252.26**	118.60**	0.14*	194.97**
C x L	20	1.88	331.91**	103.15	54.03**	3.29**	18.22**
GCA x L	6	0.71	421.41**	162.23*	78.75**	0.25**	21.89**
SCA x L	14	2.39	293.55*	77.83	43.44*	0.13*	16.64**
Error	120	1.49	159.37	64.52	16.36	0.06	3.90
GCA/SCA		1.901	1.715	1.863	0.986	1.214	1.897
GCA x L/ GCA		0.029	0.060	0.069	0.673	1.471	0.059
SCA x L/SCA		0.187	0.072	0.062	0.366	0.928	0.085
C.V.%		1.97	5.70	6.76	13.71	5.71	7.95

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

3.2 Mean performance

Mean performance of the 21 crosses along with the two check hybrids for all studied traits are presented in Table 2. For no. of days to 50% silking, all crosses except for P_1 x P_6 were significantly earlier than the latest check hybrid SC 162. While, eleven crosses were significantly earlier than the earliest check hybrids SC 168. The earliest cross was the cross P_4xP_5, while, the cross P_1xP_6 was the latest one. With respect to plant height and ear height, all crosses were significantly shorter than the check hybrid SC 162. While, only eight crosses were of significantly shorter plants than the shorter check hybrid SC 168. For ear height, all cross were of significantly lower ear placement than the better (lower) check hybrid, ie.SC168, with the exception of the two cross (P_1 x $P_{2)}$ and (P_6x P_7) which exhibited similar performance the check hybrid. Cross with short plant and low ear placement allow for better stand ability and increased plant population density. Meanwhile cross of tall plants may be preferred for silage production. For number of kernels/row none of the crosses surpassed the high value of the check hybrid SC 162. While, one cross P_4xP_5 differ significantly from the check hybrid SC 168. Regarding to ear diameter, one cross surpassed superiority over the highest value of the check hybrid SC 168 i.e. P_3xP_7. While, nineteen crosses showed significant difference from the check hybrid SC 162. The highest mean value for this trait was detected by the cross P_3xP_7 (4.87 cm). Concerning grain yield, nine crosses had significant superiority over the check hybrid SC 162. While, only one cross (P_4xP_5) had significant superiority over the check hybrid SC 168 which come out to be significantly superior to check hybrid SC 162. However, out the 21 crosses, 15 crosses exhibited a similar yield performance to that of the higher yielding check hybrid, since no significant differences. The crosses which exhibited significant increase in one or more of the traits other than grain yield such as P_1 x P_3 , P_3 x P_7 and P_4 x P_5 may be consider release as commercial hybrids after further testing and evaluation.

Table (2): Combined mean performance of 21 crosses and two check hybrids, for all traits, 2016 season.

Crosses	Days to 50% silking	Plant height (cm)	Ear height (cm)	Number of kernels/row	Ear diameter (cm)	Grain yield (ard fad^{-1})
P_1xP_2	62.50	250.25	133.50	41.15	4.72	26.51
P_1xP_3	60.75	247.00	129.50	38.50	4.70	28.30
P_1xP_4	60.00	234.62	123.37	39.15	4.55	28.75
P_1xP_5	61.00	235.12	127.00	39.58	4.80	26.48
P_1xP_6	65.75	188.50	98.25	34.43	4.35	12.46
P_1xP_7	61.87	237.25	124.87	39.58	4.47	29.30
P_2xP_3	62.12	231.87	126.25	40.02	4.65	25.90
P_2xP_4	64.00	184.37	97.50	31.55	4.37	14.30
P_2xP_5	63.12	225.62	119.37	38.47	4.75	29.30
P_2xP_6	62.00	234.25	129.25	41.15	4.65	28.19
P_2xP_7	62.12	211.62	121.62	38.30	4.60	27.20
P_3xP_4	60.75	232.62	121.12	40.72	4.75	26.50
P_3xP_5	61.75	242.37	127.75	38.65	4.70	28.78
P_3xP_6	63.50	184.12	98.87	30.65	4.45	15.29
P_3xP_7	61.12	211.37	117.50	34.03	4.87	27.15
P_4xP_5	59.75	231.87	121.62	41.72	4.63	29.71
P_4xP_6	63.25	158.25	80.62	27.20	4.53	14.07
P_4xP_7	61.12	200.25	107.75	35.70	4.70	26.65
P_5xP_6	61.75	231.87	125.25	37.60	4.72	26.43
P_5xP_7	60.50	236.12	130.00	38.35	4.60	26.49
P_6xP_7	61.50	241.00	132.87	39.90	4.57	24.08
Checks:						
SC 162	66.37	272.37	156.12	40.87	4.20	24.73
SC 168	63.00	241.37	138.75	37.30	4.52	27.35
LSD 0.05	1.18	13.08	8.38	3.96	0.25	2.04

3.3 Combining ability effects

3.3.1 General combining ability effects

Estimates of GCA effects ($\hat{g}_i$) of the parental inbred lines for each trait are presented in Table 3. The significant positive values are desired for traits such as grain yield, ear diameter and number of kernels per rows. While significant negative values are preferred for days to 50% silking, plant height and ear height. The parental inbred line P_4 and P_6 exhibited significant negative $\hat{g}_i$ effects for plant and ear heights, indicating that these inbred lines could be good combiner for developing hybrids characterized by short plants and low ear placement. The parental inbred lines P_4 , P_5 and P_7 possessed highly significant negative effects for days to 50% silking, indicating that these inbred lines are good combiners for developing early maturity genotypes. In addition, P_5 showed significant positive $\hat{g}_i$ effects for kernel number, ear diameter and grain yield, and it gave significant (undesirable) $\hat{g}_i$ effects for plant and ear heights traits. The parental inbred line P_1, P_2 and P_5 expressed significant positive $\hat{g}_i$ effects for kernel number. While, the parental inbred line P_4 exhibited significant negative $\hat{g}_i$ effects for days to 50% silking. In addition, it gave significant (desirable) $\hat{g}_i$ effects for plant and ear heights.The parental inbred line P_3 and P_5 had the best combiner for ear diameter. The parental inbred line P_3, P_5 and P_7 expressed significant desirable $\hat{g}_i$ effects for grain yield. In addition, P_5 and P_7 gave significant $\hat{g}_i$ effects for days to 50% silking. From the previous result, it could be concluded that the parental inbred line $\mathbf{P_4}$ seemed to be the best general combiners for days to 50% silking, plant and ear height; $\mathbf{P_5}$ for kernel number, ear diameter and grain yield; $\mathbf{P_3}$ for ear diameter and grain yield.

Table (3): Estimates of GCA ($\hat{g}_i$) effects of 7 inbred lines for the studied traits, combined over two locations, 2016 season.

Inbred lines	Days to 50% silking	Plant height (cm)	Ear height (cm)	Number of kernels/row	Ear diameter (cm)	Grain yield (ard fad^{-1})
P_1	0.075	12.814**	4.793**	1.544*	-0.031	0.539
P_2	0.875**	1.864	2.992*	1.199*	-0.001	0.460
P_3	-0.300	4.139*	1.693	-0.236	0.074*	0.566*
P_4	-0.525**	-17.336**	-12.107**	-1.741**	-0.046	-1.825**
P_5	-0.725**	14.864**	7.693**	1.744**	0.089*	3.620**
P_6	1.250**	-18.136**	-9.482**	-2.746**	-0.096**	-5.716**
P_7	-0.650**	1.789	4.418**	0.238	0.014	2.356**
S.E. ($\hat{g}_i$)	0.178	1.847	1.176	0.592	0.035	0.289
S.E. ($\hat{g}_i$- $\hat{g}_j$)	0.272	2.823	1.796	0.904	0.054	0.441

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

Table (4): Estimates of SCA ($\hat{s}_{ij}$) effects of 21 crosses for all studied traits combined over two locations, 2016 season.

Crosses	Days to 50% silking	Plant height (cm)	Ear height (cm)	Number of kernels/row	Ear diameter (cm)	Grain yield (ard fad^{-1})
P_1xP_2	-0.367	14.125**	6.958*	0.965	0.132	0.657
P_1xP_3	-0.942*	8.600*	4.258	-0.250	0.032	2.347**
P_1xP_4	-1.467**	17.700**	11.933**	1.905	0.002	5.185**
P_1xP_5	-0.267	-14.000**	-4.242	-1.155	0.117	-2.529**
P_1xP_6	2.508**	-27.625**	-15.817**	-1.815	-0.148	-7.215**
P_1xP_7	0.533	1.200	-3.092	0.350	-0.133	1.554*
P_2xP_3	-0.367	4.425	2.808	1.620	-0.048	0.026
P_2xP_4	1.733**	-21.600**	-12.142**	-5.350**	-0.203**	-9.184**
P_2xP_5	1.058**	-12.550**	-10.067**	-1.910	0.037*	0.372
P_2xP_6	-2.042**	29.075**	16.983**	5.255**	0.122	8.595**
P_2xP_7	-0.016	-13.475**	-4.542	-0.580	-0.038	-0.467
P_3xP_4	-0.342	24.375**	12.783**	6.160**	0.097	2.912**
P_3xP_5	0.858*	1.925	-0.392	-0.300	-0.088	-0.254
P_3xP_6	0.633	-23.325**	-12.092**	-3.810**	-0.153*	-4.412**
P_3xP_7	0.158	-16.000**	-7.367**	-3.420**	0.162*	-0.618
P_4xP_5	-0.917*	12.900**	7.283**	3.280**	-0.043	3.063**
P_4xP_6	0.608	-27.725**	-16.542**	-5.755**	0.042	-3.242**
P_4xP_7	0.383	-5.650	-3.317	-0.240	0.107	1.265*
P_5xP_6	-0.692	13.700**	8.283**	1.160	0.107	3.679**
P_5xP_7	-0.042	-1.975	-0.867	-1.075	-0.128	-4.331**
P_6xP_7	-1.017**	35.900**	19.183**	4.965**	0.032	2.596**
S.E ($\hat{s}_{ij}$)	0.386	3.992	2.540	1.279	0.077	0.624
S.E ($\hat{s}_{ij}$ - $\hat{s}_{ik}$)	0.545	5.645	3.592	1.808	0.109	0.883
S.E ($\hat{s}_{ij}$ - $\hat{s}_{kl}$)						

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

3.3.2 Specific combining ability effects

Specific combining ability effects were only estimated whenever significant SCA variances were obtained. Specific combining ability effects of 21 crosses for all studied traits are presented in Table 4. With regard to days to 50% silking, plant height and ear height, negative SCA effects are desirable, while for other traits positive are desirable. As for days to 50% silking, five crosses expressed significant negative $\hat{s}_{ij}$ effect for earliness. Also, results indicated that the crosses P_1xP_4 and P_2xP_6 gave the highest desirable $\hat{s}_{ij}$ values. So, it could be useful in areas that require early maturing hybrids. The other crosses had either significant positive or insignificant $\hat{s}_{ij}$ effects. Regarding plant height and ear height, eight and six crosses expressed the highest significant and negative values for $\hat{s}_{ij}$ effects. Therefore, these crosses were considered the best among studied crosses for plant and ear height. This may suggest the immediate use to decrease lodging, and in turn, increase the yield potentiality. Four crosses (P_2xP_6, P_3xP_4 , P_4xP_5 and P_6xP_7) had significant positive values for $\hat{s}_{ij}$ effects for kernel number. While, only one cross P_3xP_7 showed significant positive $\hat{s}_{ij}$ effects for ear diameter. With regard to grain yield, nine crosses (P_1xP_3, P_1xP_4 ,P_1xP_7, P_2xP_6, P_3xP_4, P_4xP_5 , P_4xP_7 , P_5xP_6 and P_6xP_7) expressed significantly positive $\hat{s}_{ij}$ effects. Three crosses (P_1xP_4,

P_2xP_6, P_4xP_5) exhibited the highest $\hat{s}_{ij}$ effects (5.185, 8.595 and 3.063), respectively and also it gave the highest mean performance for grain yield (28.75, 28.19 and 29.71 ard/fed), respectively. These crosses may be released as commercial hybrids by the Maize Research Program after further testing and evaluation. Similar findings were reported earlier by Nawar and El-Hosary (1985), Soliman *et al.* (2001), Sadek *et al.* (2002), Gabr *et al.* (2008) and Abdallah *et al.* (2009).

References

Abdallah, T. A. E., Afaf A. I. Gabr and A.A. El Khishen (2009), "Combining ability in line x tester crosses of maize (*Zea mays* L.)", *Annals of Agricultural Science Moshtohor Journal*, Vol. 47 No. 1, pp. 11–20.

Abdallah, T. A. E. and Hassan, M. M. (2009), "Combining ability analysis for grain yield and some agronomic traits in maize", *Egyptian Journal of Applied Sciences*, Vol. 24 No. 11, pp. 164–174.

Abd El-Aty, M. S. and Katta, Y. S. (2002), "Estimation of heterosis and combining ability for yield and other agronomic traits in maize hybrids (*Zea mays* L.)", *Mansoura Journal of Agricultural Science*, Vol. 27 No. 8, pp. 5137–5146.

Abd El-Moula, M. A. (2005), "Combining ability for grain yield and other traits in some newly developed inbred lines of yellow maize", *Egyptian Journal of Plant Breeding*, 9(2): 53–70.

Barakat, A. A., Abd El-Moula, M. A. and Ahmed, A. A. (2003), "Combining ability for maize grain yield and its attributes under different environments", *Assiut Journal of Agricultural Sciences*, 34(3): 15–25.

Beck, D. L., Vassal, S. K. and Crossa, J. (1991), "Heterosis and combining ability among subtropical and temperate intermediate maturity maize germplasm", *Crop Science*, Vol. 31, pp. 68–73.

Bujak, H., Jedynski, S., Karczmarek, J., Karwowska, C., Kurczych, Z. and Adamczyk, J. (2006), "Evaluation of breeding value of inbred lines of maize on the basis of multitrait analysis", *Biuletyn Instytutu Hodowli Aklimatyzacji Roslin*, Vol. 240/241, pp. 211–216.

El-Hosary, A. A. (1989), "Heterosis and combining ability of six inbred lines of maize in diallel crosses over two years", *Egyptian Journal of Agronomy*, Vol. 14 No. 1-2, pp. 47–58.

El-Hosary, A. A. and Sedhom, S. A. (1990), "Diallel analysis of yield and other agronomic characters in maize (*Zea mays* L.)", *Annals of Agricultural Science Moshtohor Journal*, 28(4): 1985–1998.

El-Hosary, A. A., Abdel-Sattar, A. A. and Motawea, M. H. (1999), "Heterosis and combining ability of seven inbred lines of maize in diallel crosses over two years", *Minufiya Journal of Agricultural Research*, Vol. 24 No. 1, pp. 65–84.

El-Hosary, A. A., El-Badawy, M. E. M. and Abdel-Tawab, Y. M. (2006), "Genetic distance of inbred lines and prediction of maize single-cross performance using RAPD and SSR markers", *Egyptian Journal of Genetics and Cytology*, Vol. 35, pp. 209–224.

El-Shamarka, Sh. A. (1995), "Estimation of heterotic and combining ability effects for some quantitative characters in maize under two nitrogen levels", *Minufiya Journal of Agricultural Research*, Vol. 20 No. 21, pp. 441–462.

Gabr Afaf, A. I., Abd E-Azeem, M. E. M. and Abdallah, T. A. E. (2008), "Combining ability analysis of grain yield and some agronomic traits of nine maize inbred lines", *Egyptian Journal of Applied Science*, Vol. 23 No. 12B, pp. 520–529.

Gilbert, N. E. G. (1958), "Diallel cross in plant breeding", *Heredity*, Vol. 12, pp. 477–492

Griffing, B. (1956), "Concept of general and specific combining ability relation to diallel crossing system", *Australian Journal of Biological Sciences*, Vol. 9, pp. 463–493.

Ibrahim, Kh. A. M. (2012), "Combining analysis of some yellow (*Zea mays* L.) inbred for grain yield and other traits", *Egyptian Journal of Agricultural Research*, Vol. 90 No. 4, pp. 33–46.

Ibrahim, Kh. A. M., Abd El-Moula, M. A. and Abd El-Azeem, M. E. M. (2010), "Combining ability analysis of some yellow maize (*Zea mays* L.) inbred lines", *Egyptian Journal of Agricultural Research*, Vol. 88 No. 1, pp. 33–50.

Mohamed, A. A. (1993), "Effect of nitrogen fertilization levels on the performance and combining ability of maize hybrids (*Zea mays* L.)", *Annals of Agricultural Sciences*, Vol. 38 No. 2, pp. 531–549.

Mostafa, M. A., Abd El-Aziz, A. A., Mahgoub, G. M. A. and El-Sherbieny, H. Y. S. (1996) "Diallel analysis of grain yield and natural resistance to late wilt disease in newly developed inbred lines of maize", *Bulletin of Faculty of Agriculture, Cairo University*, Vol. 47, pp. 393–404.

Mostafa, A. K. and Mostafa, M. A. A. (2017), "Combining ability of nine white maize inbred lines for yield and some agronomic traits", *Menoufia Journal of Plant Production*, Vol. 2, pp. 407–417.

Motawei, A. A. (2006), "Additive and non-additive genetic variances of important quantitative traits in new maize inbred lines via line x tester analysis", *Mansoura Journal of Agricultural Science*, Vol. 31 No. 11, pp. 6855–6865.

Nawar, A. A. and El-Hosary, A. A. (1985), "A comparison between two experimental diallel cross designs", *Minufiya Journal of Agricultural Research*, Vol. 10, pp. 2029–2039.

Nawar, A. A., El-Shamarka, S. A. and El-Absawy, E. A. (2002), "Diallel analysis of some agronomic traits of maize", *Mansoura Journal of Agricultural Science*, Vol. 27 No. 11, pp. 7203–7213.

Osman, M. M. A., Ibrahim, Kh. A. M. and El-Ghomeny, M. A. M. (2012), "Diallel analysis of grain yield and some other traits in yellow maize (*Zea mays* L.) inbred lines", *Assiut Journal of Agricultural Sciences*, Vol. 43, pp. 16–26

Sadek, S. E., Soliman, M. S. M. and Barakat, A. A. (2001), "Evaluation of newly developed maize lines using commercial inbred testers", *Egyptian Journal of Applied Sciences*, Vol. 16, pp. 406–425.

Sadek, S. E., Soliman M. S. M., Barakat, A. A. and Khalifa, K. I. (2002), "Topcross analysis for selecting maize lines in the early self generations", *Minufiya Journal of Agricultural Research*, Vol. 27, pp. 197–213.

Salama, F. A., Abo El-Saad, Sh. F. and Ragheb, M. M. (1995), "Evaluation of maize (*Zea mays* L.) top crosses for grain yield and other agronomic traits under different environmental conditions", *Mansoura Journal of Agricultural Science*, Vol. 20 No. 1, pp. 127–140.

Sedhom, S. A. (1994), "Genetic study on some top crosses in maize under two environments", *Annals of Agricultural Science Moshtohor Journal*, Vol. 32 No. 1, pp. 131–141.

Sedhom, A. S., El-Badawy M. E. M., Morsy, A. M. and El-Hosary A. A. A. (2007). "Diallel analysis and relationship between molecular polymorphisms and yellow maize hybrid performance", *Annals of Agricultural Science Moshtohor Journal*, Vol. 45 No. 1, pp. 1–20.

Singh, P. K. and Roy, A. K. (2007), "Diallel analysis of inbred lines in maize (*Zea maiys* L.)", *International Journal of Agricultural Science*, Vol. 3 No. 1, pp. 213–216.

Soliman, M. S. M., Mahmoud, A. A., Gabr Afaf, A. I. and Soliman, F. H. S. (2001), "Utilization of narrow base testers for evaluating combining ability of newly developed yellow maize inbred lines (*Zea mays* L.)", *Egyptian Journal of Plant Breeding*, Vol. 5, pp. 61–76.

Steel, R. G. D. and Torrie, J. H. (1980), *Principles and Procedures of Statistics*, Mc. Graw-Hill Book Company, New York, USA.

Vivek, B. S., Odongo, O., Njuguna, J., Imanywoha, J., Bigirwa, G., Diallo, A. and Pixley, K. (2010), "Diallel analysis of grain yield and resistance to seven diseases of 12 African maize (*Zea mays* L.) inbred lines", *Euphytica*, Vol. 172, pp. 329–340.