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GENETIC ANALYSIS OF DIALLEL CROSSES IN MAIZE

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ABSTRACT

The present investigation aimed to evaluate eight inbred lines of maize in diallel mating design. Twenty-eight crosses were constituted at Sedment Elgabal, Horticulture Research Station, Beni-Swef Governorate in the 2015 season, whereas parents and crosses were evaluated during 2016 season in a randomized complete block design with three replications. Results revealed highly significant variation among parents and among F_1 crosses for the studied characters. Both general (GCA) and specific (SCA) combining ability variances were significant for most studied traits, revealing the important role of both additive and dominance components in the inheritance of the studied traits. The GCA/SCA ratio was less than unity for all studied characters, except for days to 50% silking, days to 50% tasseling, ear diameter and number of rows ear^{-1}, indicating a greater contribution of non-additive than additive effects of genes in the genetic expression for these traits. The parental inbred lines P_1 (INB.24), P_6 (INB.72) and P_7 (INB.82) were effective combiners for grain yield. The results showed that all F_1's, except (INB.24 P_1 x P_3 INB.42) and (INB.37 P_2 x P_5 INB.64) reflected highly significant and positive SCA effects for grain yield. Heritability in the broad sense (h^2_b%) estimates was generally high for all studied traits. High heritability values coupled with high genetic advance were recorded for all studied traits, except days to 50 % silking and tasseling, and 100 kernels weight, indicating that selection would be effective in early generations.

Key words: ***Maize, Additive, Dominance, Combining ability, Heritability.***

INTRODUCTION

Maize (*Zea mays* L.) is the world's important food crop after wheat and rice. Maize, being a short duration crop, can be grown successfully twice a year and fits well in our existing cropping systems. Maximizing food and agricultural production, depends mainly on promoting high yielding maize hybrids to cover the mounting consumption of maize. This depends mostly on the utilization of hybrid vigor in maize breeding programs. The evaluation of crosses among inbred lines is an important step towards the development of hybrid varieties in maize. The effects of general combining ability (GCA) and specific combining ability (SCA) are important indicators of potential values for inbred lines in hybrid combinations. The concept of GCA and SCA has become increasingly important to plant breeders because of the widespread use of hybrid cultivars in many crops. One of the important tools for distinguishing high yielding hybrids is the identification of parents' kind and dimension of gene action type and their combining ability. Diallel mating pattern is usually used in maize breeding programs to detect the combining ability types. Bidhendi *et al* (2012), Khan *et al* (2014), and El-Hosary (2015) and El-Hosary *et al* (2018) stated that inheritance of quantitative characters, detection of genetic diversity, selection of suitable parental lines for hybridization, classification of heterotic pattern, estimation of hybrid vigor, and evolution of hybrid all depend on gene action information of maize genotypes. Thus, variances due to GCA and SCA are associated with the type of gene action implicated. In this frame, highly general combining ability (GCA) and specific combining ability (SCA) effects leading to high heterosis were asserted by Girma *et al* (2015), Al-Naggar *et al* (2016) and Al-Naggar *et al* (2017 a and b). The current work aimed to 1- study the general and specific combining abilities of parents and crosses, respectively for some economic traits and 2- identify promising hybrids for yielding ability with suitable physiological and agronomic traits.

MATERIALS AND METHODS

Plant materials. The materials used in this study were eight inbred lines of maize derived from maize Research Section, Field Crops Research Institute, Agricultural Research Center. The origin and pedigree of the eight parents are presented in Table (1).

Table 1. The name and pedigree of maize inbred lines used as parents in this study.

No.	Genotypes	Pedigree *
P_1	Inb.24	Local Bred (H-230 1969, Mexico)
P_2	Inb.37	Improved by BC. With (64 X 213)
P_3	Inb.42	Surcropper (Texas)
P_4	Inb.56	g.s. (Beida X ci64) (sc-14)
P_5	Inb.64	g.s. (Sanjman X 303) (G216 X M02RF))
P_6	Inb.72	g.s. (Syn. Laposta X 303) (G216 X M02RF)
P_7	Inb.82	g.s. (Sanjman X 307) (sc-14)
P_8	Inb.102	g.s. (Syn. Laposta X 307) (sc-14)

***Source: Plant Genetic Resources Research Department (Bahteem Gene Bank), FCRI, ARC, Egypt.**

Field experiments. This investigation was carried out at Sedment Elgabal, Horticulture Research Station, Beni-Swef Governorate during the two growing seasons of 2015 and 2016. In 2015 season, all possible cross combinations, excluding the reciprocals were made among the eight inbred lines by hand method giving a total of 28 crosses. In 2016 season, parents along with the resultant 28 F_1 single crosses were evaluated in a randomized complete block design with three replications. Each experimental plot consisted of one ridge six meters long and 80 cm apart. Hills were spaced 25 cm with three kernels per hill. The seedlings were thinned to one plant per hill. All other agricultural practices were carried out according to the standard commercial recommendation for maize.

Recorded data. The data were collected on 10 guarded plants (random samples) from parents and their F_1 crosses as follows:

Agronomic traits

1- Days to 50% silking (DS). 2- Days to 50% tasseling (DT).

3- Plant height (PH) in cm. 4- Ear height (EH) in cm.

Grain yield traits

1- Ear length (EL) in cm. 2- Ear diameter (ED) in cm.

3- Number of rows ear^{-1} (RE). 4- Number of kernels row^{-1} (KR).

5- 100 kernels weight (100 KW) in g. 6- Grain yield plant^{-1} (GYP) in g.

Both grain yield and 100-kernel weight were adjusted to 15.5% moisture content.

Statistical analysis. Analysis of variance for randomized complete block design was run according to Steel and Torrie (1997). Combining ability variances; general combining ability (GCA), specific combining ability (SCA) and their effects were calculated according to the method-2 model-1 (Fixed model) according to half diallel analysis of Griffing (1956). Estimates of genotypic and phenotypic coefficients of variation, heritability in the broad sense and genetic advance (% mean) were determined through variance component method as outlined by Johnson *et al* (1955).

RESULTS AND DISCUSSION

Analysis of variance. The analysis of variance of the agronomic and grain yield traits for 36 maize genotypes (8 maize parents and their 28 F_1 crosses) is presented in Table (2). Results indicated that mean squares due to genotypes were highly significant for all studied traits. Also, highly significant parent mean squares were observed for all studied traits, except for grain yield while the crosses mean squares were highly significant for all studied traits, except for days to 50% silking, plant height and ear diameter. However, the mean squares due to parents *vs.* crosses were highly significant for all studied traits.

Table 2. Mean squares for agronomic and grain yield traits for 36 maize genotypes (8 maize parents and their 28 F_1 crosses).

SOV	df	Agronomic traits				Grain yield traits					
		Days to 50% Silking (DS)	Days to 50% Tasseling (DT)	Plant height ((PH)	Ear height ((EH)	Ear length (EL)	Ear diameter (ED)	Rows ear^{-1} (R/E)	Kernels row^{-1} (K/R)	100-kernels weight (100KW)	Grain yield $plant^{-1}$ (GY/P)
		Mean squares MS									
Replications	2	10.561	7.06	331.1	271.5	0.287	0.039	0.02	11.71	0.528	5.78
Genotypes	35	32.57**	69.21**	5028.3**	1998.4**	21.70**	1.115**	11.39**	394.4**	92.02**	14557.9**
Parents (P)	7	58.57**	100.3**	765.8**	756.7**	11.62**	0.813**	4.77**	24.97**	39.81**	65.31
Crosses (C)	27	3.42	5.837*	130.9	320.2**	6.04**	0.278	5.16**	54.68**	76.45**	2771.44**
P Vs. C	1	637.7**	1562.4**	67096.8*	56000.7**	514.9**	25.82**	225.7**	12151.6**	877.7**	434241.0**
GCA	7	34.92**	69.82**	615.39**	1413.7**	19.56**	1.253**	12.19**	64.81**	38.01*	2650.20**
SCA	28	31.99**	69.06**	6131.6**	2144.6**	22.23**	1.081**	11.18**	476.75**	105.52**	17534.91**
GCA/SCA		1.09	1.01	0.10	0.66	0.88	1.16	1.09	0.14	0.36	0.15

*** and **: Significant at 0.05 and 0.01 probability levels, respectively.**

These findings provided evidence for the presence of considerable amount genetic variability among the parental maize inbreds and their respective hybrids (F_1), which may facilitate genetic improvement using such genetic material of maize.

In this concern, according to the above mentioned results, the detailed analysis of combining ability and type of gene action are therefore appropriate for characterizing the traits investigated through this study. Results reported that diallel analysis revealed highly significant general and specific combining ability (GCA and SCA) variances for all studied agronomic and yield attributes (Table 2). The GCA variance contains additive effects, while SCA variance contains non-additive as outlined by Griffing (1956). Hence, the significant estimates of both GCA and SCA variances suggested that each of additive and non-additive nature of gene action was involved in controlling these characters through all maize genotypes.

The GCA/SCA ratio of mean squares was less than unity for all studied traits, except for days to 50% silking, days to 50% tasseling, ear diameter and number of rows ear^{-1}. Therefore, a greater contribution of non additive than additive effects of genes in the genetic expression of most studied traits. In contrast, additive gene action was found to be important for the aforementioned four traits only. However, it could be emphasized that GCA/SCA ratio may not always project the true picture of the gene action for a particular traits. Similar results were reported by Amer (2005), El-Hosary *et al* (2006), and El Hosary (2015).

Mean performance. The mean performance of eight parents and their respective crosses are presented in Table (3). Results indicated that the earliest genotypes for days to 50% silking and 50% tasseling were the parents P_1 INB.24 and P_3 INB.42, recording (64.30 and 59.67 days) and (61.7 and 59 days), respectively. However, the two parents P_7 INB.82 and P_8 INB.102 were the latest genotypes. Considering the crosses, no significant differences were obtained among crosses for days to 50% silking as mentioned before in Table (2). Concerning days to 50% tasseling, the cross (INB.37 P_2 x P_3 INB.42) was the earliest one recording 56.67 days, while the six crosses (INB.24 P_1 x P_2 INB.37), (INB.24 P_1 x P_4 INB.56), (INB.37 P_2 x P_5 INB.64), (INB.37 P_2 x P_8 INB.102), (INB.64 P_5 x P_8 INB.102) and (INB.82 P_7 x P_8 INB.102) were the latest ones, recording 61 days. These results indicated that the two parents P_1 INB.24 and P_3 INB.42 could be used as a source of earliness in maize breeding programs.

Results presented in Table (3), indicated that the parent P_8 INB.102 had the tallest plants, recording 165.3 cm while the parent P_5 INB.64 had the shortest plants, recording 122.3 cm. As mentioned before in Table (2), no significant differences were found among crosses for plant height.

For ear height, the parental genotype P_8 INB.102 exhibited the highest mean recording 103.3 cm while the parents P_3 INB.42 and P_5 INB.64 recorded the lowest values being 54.50 and 54.70 cm, respectively. With respect to the crosses, the highest values were observed by cross (INB.37 P_2 x P_8 INB.102) recording 160.60 cm while the cross (INB.42 P_3 x P_6 INB.72) recorded the lowest ear height being 109.70 cm.

It is showed that the parent P_6 INB.72 gave the highest values of ear length and ear diameter recording 15.0 and 4.53 cm, respectively. Meanwhile, the crosses of (INB.24 P_1 x P_2 INB.37), (INB.37 P_2 x P_6 INB.72) and (INB.64 P_5 x P_6 INB.72) had the maximum values of ear length, recording 18.70, 20.30 and 18.10 cm, respectively. On the other hand, no significant differences were found among crosses averages for ear diameter.

Table 3. Mean performance of parents and their hybrids for all studied traits.

Traits / Genotypes	Agronomic traits			
	Days to 50% Silking (DS)	Days to 50% Tasseling (DT)	Plant height (cm) (PH)	Ear height (cm) (EH)
P_1 (INB.24)	64.30	59.67	158.50	56.60
P_2 (INB.37)	71.00	68.33	126.70	64.70
P_3 (INB.42)	61.70	59.00	128.70	54.50
P_4 (INB.56)	72.00	70.33	138.70	61.00
P_5 (INB.64)	71.70	71.33	122.30	54.70
P_6 (INB.72)	70.70	70.67	154.30	67.70
P_7 (INB.82)	<u>73.30</u>	<u>72.20</u>	139.40	66.90
P_8 (INB.102)	<u>74.00</u>	<u>73.33</u>	<u>165.30</u>	<u>103.30</u>
P_1 x P_2 (INB.24 x INB.37)	65.33	<u>61.00</u>	228.90	114.90
P_1 x P_3 (INB.24 x INB.42)	62.00	58.33	241.30	114.80
P_1 x P_4 (INB.24 x INB.56)	63.33	<u>61.00</u>	233.00	112.30
P_1 x P_5 (INB.24 x INB.64)	63.33	57.67	225.70	114.60
P_1 x P_6 (INB.24 x INB.72)	64.00	58.33	243.30	111.50
P_1 x P_7 (INB.24 x INB.82)	60.67	57.67	229.00	122.50
P_1 x P_8 (INB.24 x INB.102)	64.33	57.33	232.70	123.10
P_2 x P_3 (INB.37 x INB.42)	63.33	56.67	245.30	121.30
P_2 x P_4 (INB.37 x INB.56)	64.33	58.67	230.00	116.50
P_2 x P_5 (INB.37 x INB.64)	64.00	<u>61.00</u>	226.40	119.50
P_2 x P_6 (INB.37 x INB.72)	63.67	58.67	243.00	118.70
P_2 x P_7 (INB.37 x INB.82)	64.33	60.33	241.70	137.00
P_2 x P_8 (INB.37 x INB.102)	62.00	<u>61.00</u>	251.70	<u>160.60</u>
P_3 x P_4 (INB.42 x INB.56)	64.00	57.67	239.70	110.60
P_3 x P_5 (INB.42 x INB.64)	64.00	59.67	233.20	113.40
P_3 x P_6 (INB.42 x INB.72)	64.00	57.33	243.40	109.70
P_3 x P_7 (INB.42 x INB.82)	64.33	56.67	235.70	119.00
P_3 x P_8 (INB.42 x INB.102)	64.67	59.00	244.50	123.70
P_4 x P_5 (INB.56 x INB.64)	64.67	59.67	229.30	117.70
P_4 x P_6 (INB.56 x INB.72)	64.00	58.67	237.30	115.20
P_4 x P_7 (INB.56 x INB.82)	63.67	60.33	231.20	120.00
P_4 x P_8 (INB.56 x INB.102)	64.67	59.33	240.90	126.90
P_5 x P_6 (INB.64 x INB.72)	65.00	60.00	231.00	112.90
P_5 x P_7 (INB.64 x INB.82)	65.67	59.67	231.30	120.30
P_5 x P_8 (INB.64 x INB.102)	65.33	<u>61.00</u>	235.20	121.90
P_6 x P_7 (INB.72 x INB.82)	64.67	59.00	241.00	127.70
P_6 x P_8 (INB.72 x INB.102)	63.67	59.33	233.50	136.30
P_7 x P_8 (INB.82 x INB.102)	64.67	<u>61.00</u>	238.80	124.30
LSD 5%	2.45	2.81	14.70	14.10
LSD 1%	3.18	3.65	19.20	18.40

Table 3. Cont.

Traits / Genotypes	Grain yield traits					
	Ear length (cm.) (EL)	Ear diameter (cm.) (ED)	Rows ear^{-1} (R/E)	Kernels row^{-1} (K/R)	100-kernels weight(g) (100KW)	Grain yield plant^{-1} (g) (GY/P)
P_1 (INB.24)	10.30	3.13	9.60	9.40	41.70	76.70
P_2 (INB.37)	12.30	3.27	9.87	11.00	40.70	77.30
P_3 (INB.42)	9.00	4.00	11.67	14.70	34.30	64.70
P_4 (INB.56)	12.00	3.60	12.20	15.70	34.00	54.70
P_5 (INB.64)	10.70	3.93	10.53	11.50	35.00	45.00
P_6 (INB.72)	15.00	4.53	13.20	18.10	37.00	67.30
P_7 (INB.82)	9.00	4.00	12.20	11.70	34.70	60.00
P_8 (INB.102)	11.00	3.93	10.80	12.10	30.70	50.00
P_1 x P_2 (INB.24 x INB.37)	18.70	4.93	13.73	44.00	43.30	204.43
P_1 x P_3 (INB.24 x INB.42)	16.60	4.80	14.27	37.30	43.30	137.77
P_1 x P_4 (INB.24 x INB.56)	16.50	5.53	15.60	40.10	41.70	217.77
P_1 x P_5 (INB.24 x INB.64)	16.60	4.93	16.60	35.80	36.70	158.33
P_1 x P_6 (INB.24 x INB.72)	15.80	4.93	15.07	40.00	45.00	158.90
P_1 x P_7 (INB.24 x INB.82)	14.90	4.93	16.13	39.00	38.30	202.77
P_1 x P_8 (INB.24 x INB.102)	16.50	4.80	14.53	43.90	43.30	166.67
P_2 x P_3 (INB.37 x INB.42)	17.90	5.13	12.80	41.90	43.30	169.43
P_2 x P_4 (INB.37 x INB.56)	16.70	5.07	14.80	34.60	50.00	150.00
P_2 x P_5 (INB.37 x INB.64)	17.90	4.80	14.07	36.80	40.00	122.23
P_2 x P_6 (INB.37 x INB.72)	20.30	5.33	13.73	50.80	43.30	212.77
P_2 x P_7 (INB.37 x INB.82)	17.50	4.60	12.93	45.20	38.30	189.43
P_2 x P_8 (INB.37 x INB.102)	17.00	4.87	12.00	39.10	35.00	130.57
P_3 x P_4 (INB.42 x INB.56)	13.40	5.00	14.67	31.10	38.30	138.90
P_3 x P_5 (INB.42 x INB.64)	17.30	4.80	15.00	30.70	36.70	206.10
P_3 x P_6 (INB.42 x INB.72)	16.40	5.33	12.93	37.10	43.30	155.57
P_3 x P_7 (INB.42 x INB.82)	15.30	4.80	14.73	36.10	43.30	218.90
P_3 x P_8 (INB.42 x INB.102)	15.50	5.07	14.13	36.90	45.00	150.00
P_4 x P_5 (INB.56 x INB.64)	15.90	5.00	16.53	37.50	46.70	150.00
P_4 x P_6 (INB.56 x INB.72)	16.70	5.33	15.67	40.30	43.30	215.57
P_4 x P_7 (INB.56 x INB.82)	14.90	5.67	16.00	36.10	50.00	176.67
P_4 x P_8 (INB.56 x INB.102)	16.40	5.80	15.73	40.90	50.00	176.67
P_5 x P_6 (INB.64 x INB.72)	18.10	5.53	14.07	42.20	35.00	150.57
P_5 x P_7 (INB.64 x INB.82)	14.30	5.03	14.40	35.30	41.70	182.77
P_5 x P_8 (INB.64 x INB.102)	15.60	5.00	14.67	37.00	46.70	134.43
P_6 x P_7 (INB.72 x INB.82)	15.20	5.47	17.87	33.50	50.00	226.10
P_6 x P_8 (INB.72 x INB.102)	15.20	5.40	16.00	38.30	35.00	184.43
P_7 x P_8 (INB.82 x INB.102)	16.80	4.93	13.93	37.00	53.30	172.77
LSD 5%	1.32	0.25	0.88	3.35	7.31	11.70
LSD 1%	1.71	0.33	1.15	4.37	9.51	15.23

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

The results presented in Table (3) indicated that the parent P_6 INB.72 had the highest values for number of rows ear^{-1} (13.2) and number of kernels row^{-1} (18.1) followed by parent P_4 INB.56 recording 12.20 and 15.70, respectively. However, the crosses (INB.24 P_1 x P_5 INB.64), (INB.56 P_4 x P_5 INB.64) and (INB.72 P_6 x P_7 INB.82) gave the highest values of the number of rows ear^{-1} recording 16.6, 16.53 and 17.87, respectively while the three crosses of (INB.24 P_1 x P_2 INB.37), (INB.24 P_1 x P_8 INB.102) and (INB.37 P_2 x P_7 INB.82) gave the highest mean number of kernels row^{-1} recording 44.0, 43.90 and 45.20, respectively.

It is obvious that the parents P_1 INB.24 and P_2 INB.37 gave the maximum values for 100 kernel weight (41.70 and 40.70 g), respectively. Also, the same two parents had the highest values for grain weight plant^{-1} (76.70 and 77.30 g), respectively. However, the crosses (INB.37 P_2 x P_4 INB.56), (INB.56 P_4 x P_7 INB.82), (INB.56 P_4 x P_8 INB.102), (INB.72 P_6 x P_7 INB.82) and (INB.82 P_7 x P_8 INB.102) gave the highest values of 100 kernel weight recording 50 and 53.3 g, respectively while the crosses (INB.24 P_1 x P_4 INB.56), (INB.42 P_3 x P_7 INB.82), (INB.56 P_4 x P_6 INB.72) and (INB.72 P_6 x P_7 INB.82) had the highest values of grain weight plant^{-1} recording 217.77, 218.9, 215.57 and 226.1 g, respectively. Significant differences among maize genotypes for grain yield and its components were reported by Abd El-Aty and Katta (2002), Ali *et al* (2014), Saad El-Deen *et al* (2015) and Al-Naggar *et al* (2016).

It is worthy to note that INB.24 P_1 showed the highest GY/P, and 100-KW, also it was the earliest in DS. On the contrary, INB.37 P2 was high in GY/P and 100-KW but it was amongst the latest parents in DS. Moreover, INB.72 P_6 showed high GY/P, El, ED, R/E and K/R. These results agreed with the previous expectations when these genotypes were chosen as parents for the present investigation.

It is worthy to note that the parents INB.24 P_1, INB.37 P_2, INB.72 P_6, and INB.82 P_7 were involved in the highest F_1 crosses in GY/P ((INB.24 P_1 x P_4 INB.56), (INB.42 P_3 x P_7 INB.82), (INB.56 P_4 x P_6 INB.72) and (INB.72 P_6 x P_7 INB.82)) and these crosses had two advantages, i.e., earliness in DS and high-yielding ability. Therefore, these genotypes could be recommended for developing early days to 50% tasseling (DS) and high-yielding.

General combining ability (GCA) effects. The estimates of GCA effects for inbred maize parents are listed in Table (4), which differed from one individual parent to another and from trait to trait. Significant and positive GCA effects were found for most of all studied traits, except days to 50% silking and tasseling which had significant and negative GCA effects. It could be concluded that the best combiners for earliness traits, i.e. days to 50% silking and tasseling were the parental inbred lines P_1 (INB.24) and P_3 (INB.42), indicating that these two parents could be considered as good source for improving the earliness traits in maize crop. Results also showed a great concordance between per se performances and GCA effects of the parents for earliness trait. Early parents (per se) were good general combiners for this trait and the opposite was true.

Table 4. Estimates of general combining ability (GCA) effects for agronomic traits, grain yield and its components.

Traits / Genotypes	Agronomic traits				Grain yield traits					
	Days to 50% Silking (DS)	Days to 50% Tasseling (DT)	Plant height (PH)	Ear height (EH)	Ear length (EL)	Ear diameter (ED)	Rows ear^{-1} (R/E)	Kernels row^{-1} (K/R)	100-kernels weight 100KW	Grain Yield plant^{-1} (GY/P)
P_1 (INB.24)	-1.59**	-1.84**	1.30	-5.22**	-0.11	-0.22**	-0.05	0.30	0.30	6.14**
P_2 (INB.37)	0.14	0.29	-1.75	3.89**	1.34	-0.20**	-1.19*	1.85**	0.27	-.59
P_3 (INB.42)	-1.79**	-2.57**	0.24	-5.75**	-0.69**	-0.04*	-0.38**	-1.54**	-1.00	-3.31**
P_4 (INB.56)	0.51*	0.49	-1.92	-3.78**	-0.27	0.31**	0.77**	-0.38*	1.60*	-0.42
P_5 (INB.64)	0.78**	1.02**	-8.14**	-4.93**	-0.03	-0.04*	0.07	-1.70**	-1.87*	-14.41**
P_6 (INB.72)	0.28	0.16	4.32**	-1.18	1.03**	0.31**	0.61**	2.26**	-0.30	9.93**
P_7 (INB.82)	0.71**	1.09**	-1.06	2.55*	-1.04**	0.01	0.47**	-1.02**	1.23*	15.02**
P_8 (INB.102)	0.98**	1.36**	7.00**	14.42**	-0.23	0.04	-0.31*	0.28	-0.23	-12.36**
S.E (gi)	0.26	0.29	1.56	1.50	0.14	0.08	0.09	0.35	0.77	1.24
S.E (gi-gj)	0.39	0.45	2.35	2.26	0.21	0.13	0.14	0.54	1.17	1.87

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

However, the parent P_5 (INB.64) showed negative and highly significant GCA effects for plant height and ear height where high negative ones would be useful from the breeder's point of view. Similarly, the three parental inbred lines P_1 (INB.24), P_3 (INB.42) and P_4 (INB.56) were also suitable combiners for ear height. Meanwhile, the inbred line P_6 (INB.72) seemed to be good combiner for ear length and ear diameter.

Results in Table (4) showed that the parents P_4 (INB.56) and P_6 (INB.72) had desirable positive and highly significant GCA effects for ear diameter and number of rows ear^{-1} indicating that the two inbred lines P_4 and P_6 are considered good donors or combiners for these traits in maize breeding programs. Also, the inbred line P_7 (INB. 82) were among the best general combiners for number of rows ear^{-1}.

It is concluded that the two inbred lines P_2 (INB.37) and P_6 (INB.72) were assumed as the most useful source of favorable alleles for number of kernels row^{-1} while the two parents P_4 (INB.56) and P_7 (INB.82) had positive and significant GCA effects for 100 kernels weight.

The parental inbred lines P_1 (INB.24), P_6 (INB.72) and P_7 (INB.82) expressed effective combiners for grain yield. It is obvious that the three parents P_3 (INB.24), P_5 (INB.64) and P_8 (INB.102) reflected undesirable or non-significant positive GCA effects for all grain yield components. Consequently, it could be concluded that the studied parental genotypes can be used in maize breeding programs and may be valuable for improving grain yield and its components. Similar findings were earlier reported by El Shouny *et al* (2003), Al-Naggar *et al* (2011) and El-Hosary and Elgammaal (2013)

Specific Combining Ability (SCA) effects. Estimates of specific combining ability (SCA) effects of 28 F_1 crosses for all studied attributes are given in Table (5). The eleven crosses (P_1xP_7), (P_2xP_4), (P_2xP_6), (P_2xP_8), (P_4xP_5), (P_4xP_6), (P_4xP_7), (P_4xP_8), (P_6xP_7), (P_6xP_8) and (P_7xP_8) showed significant or highly significant and negative SCA effects for days to 50% silking and tasseling. It is interesting to note that all these crosses were produced among late x late or early x late parents. Moreover, such good SCA crosses might came from two parents possessing poor GCA or from one with good GCA and other with poor GCA effects for earliness traits.

Unfortunately, no single cross was found to have highly significant or significant and negative SCA effects for plant height and ear height where the most crosses exhibited highly significant or significant and positive SCA effects for each of plant height and ear height.

The sex F_1 crosses (P_1xP_2), (P_1xP_4), (P_2xP_3), (P_4xP_7), (P_4xP_8) and (P_5xP_6) exhibited highly significant or significant and positive SCA effects for ear length and ear diameter. On the other hand, ten of twenty eight crosses, namely (P_1xP_2), (P_1xP_4), (P_1xP_5), (P_1xP_7), (P_1xP_8), (P_2x P_5), (P_4xP_5), (P_4xP_8), (P_5xP_8) and (P_6xP_8) showed highly significant or significant and positive SCA effects for number of rows ear^{-1} and number of kernels row^{-1}.

Concerning 100 kernels weight, the eight crosses (P_2xP_4), (P_3xP_8), (P_4xP_5), (P_4xP_7), (P_4xP_8), (P_5xP_8), (P_6xP_7), and (P_7xP_8) revealed significant or highly significant and positive SCA effects. For grain yield $plant^{-1}$, there were promising results showing that all F_1 crosses, except (P_1xP_3) and (P_2xP_5) reflected highly significant and positive SCA effects.

It is interesting to note that the cross (P_4xP_7), (P_4xP_8), (P_5xP_8), (P_6xP_7), and (P_7xP_8) showed superiority in SCA effects for 100-KW and GY/P. These crosses were also the best ones in *per se* performance for 100-KW and GY/P traits. Moreover, the highest mean performance F_1 crosses in GY/P ((INB.24 P_1 x P_4 INB.56), (INB.42 P_3 x P_7 INB.82), (INB.56 P_4 x P_6

INB.72) and (INB.72 P_6 x P_7 INB.82)) showed superiority in SCA effects and also involved at least one parent as good combiner for GY/P.

Table 5. Estimates of specific combining ability (SCA) effects for studied traits of F_1 maize crosses.

Traits / Hybrids	Agronomic treats			
	Days to 50% Silking (DS)	**Days to 50% Tasseling (DT)**	**Plant height (cm.) (PH)**	**Ear height (cm.) (EH)**
P_1x P_2 (INB.24 x INB.37)	1.50	1.32	14.06**	7.41
P_1x P_3 (INB.24 x INB.42)	0.10	3.51**	24.46**	16.98**
P_1x P_4 (INB.24 x INB.56)	-0.87	1.12	18.29**	12.54**
P_1x P_5 (INB.24 x INB.64)	-1.14	-2.75**	17.18**	15.95**
P_1x P_6 (INB.24 x INB.72)	0.03	-1.22	22.32**	9.14*
P_1x P_7 (INB.24 x INB.82)	**-3.74****	**-2.81****	13.44**	16.41**
P_1x P_8 (INB.24 x INB.102)	-0.38	-3.42**	9.04	5.07
P_2x P_3 (INB.37 x INB.42)	-0.30	-2.28*	31.51**	14.41**
P_2x P_4 (INB.37 x INB.56)	-1.60*	-3.34**	18.34**	7.63
P_2x P_5 (INB.37 x INB.64)	-2.20**	-1.55	20.96**	11.78*
P_2x P_6 (INB.37 x INB.72)	**-2.04****	**-3.01****	25.10**	7.17
P_2x P_7 (INB.37 x INB.82)	-1.80*	-2.29*	29.22**	21.77**
P_2x P_8 (INB.37 x INB.102)	**-4.40****	**-1.88***	31.15**	33.50**
P_3x P_4 (INB.42 x INB.56)	0.00	-1.48	26.01**	11.34*
P_3x P_5 (INB.42 x INB.64)	-0.27	0.01	25.76**	15.29**
P_3x P_6 (INB.42 x INB.72)	0.23	-1.49	23.50**	7.81
P_3x P_7 (INB.42 x INB.82)	0.13	-3.08**	21.16**	13.41**
P_3x P_8 (INB.42 x INB.102)	0.20	-1.01	21.89**	6.27
P_4x P_5 (INB.56 x INB.64)	-1.90*	-3.08**	24.06**	17.65**
P_4x P_6 (INB.56 x INB.72)	**-2.07****	**-3.21****	19.60**	11.37*
P_4x P_7 (INB.56 x INB.82)	**-2.84****	**-2.49****	18.85**	12.43**
P_4x P_8 (INB.56 x INB.102)	**-2.10****	**-3.75****	20.52**	7.50
P_5x P_6 (INB.64 x INB.72)	-1.34	-2.42**	19.48**	10.18*
P_5x P_7 (INB.64 x INB.82)	-1.10	-3.67**	25.00**	13.91**
P_5x P_8 (INB.64 x INB.102)	-1.70	-2.61**	21.00**	3.65
P_6x P_7 (INB.72 x INB.82)	-1.60*	-3.48**	22.41**	17.50**
P_6x P_8 (INB.72 x INB.102)	**-2.87****	**-3.42****	6.88	14.23**
P_7x P_8 (INB.82 x INB.102)	**-2.30****	**-2.68****	17.53**	-1.50
S.E sca (ij)	**0.79**	**0.91**	**4.77**	**4.58**
S.E sca (ij-ik)	**0.96**	**1.35**	**5.76**	**5.54**
S.E sca (ij-lk)	**0.85**	**1.27**	**5.12**	**4.92**

Table 5. Cont.

Traits / Hybrids	Grain yield treats					
	Ear length (cm.) (EL)	**Ear diameter (cm.) (ED)**	**Rows Ear^{-1} (R/E)**	**Kernels row^{-1} (K/R)**	**100-kernels weight(g) (100KW)**	**Grain yield $plant^{-1}$ (g) (GY/P)**
P_1x P_2 (INB.24 x INB.37)	**2.19****	**0.54***	1.01**	8.97**	1.43	**50.07****
P_1x P_3 (INB.24 x INB.42)	**2.16****	**0.25**	0.74	5.69**	2.70	-13.86**
P_1x P_4 (INB.24 x INB.56)	**1.60****	**0.81****	0.92**	7.26**	-1.57	**63.29****
P_1x P_5 (INB.24 x INB.64)	**1.49****	**0.37**	2.62**	4.32**	-3.10	18.38**
P_1x P_6 (INB.24 x INB.72)	-0.37	0.03	0.55	4.56**	3.67	-5.97
P_1x P_7 (INB.24 x INB.82)	0.77	0.32	1.75**	6.84**	-4.53	**32.81****
P_1x P_8 (INB.24 x INB.102)	1.56**	0.16	0.93*	10.54**	1.93	24.09**
P_2x P_3 (INB.37 x INB.42)	**1.97****	**0.56***	0.40	8.74**	2.73	24.52**
P_2x P_4 (INB.37 x INB.56)	0.42	0.33	1.25**	0.25	**6.80****	2.2
P_2x P_5 (INB.37 x INB.64)	1.37**	0.23	1.22**	3.78**	0.27	-11.57**
P_2x P_6 (INB.37 x INB.72)	**2.64****	**0.41**	0.35	13.81**	2.03	**54.57****
P_2x P_7 (INB.37 x INB.82)	1.98**	-0.02	-0.32	11.49**	-4.50	26.18**
P_2x P_8 (INB.37 x INB.102)	0.64	0.22	-0.47	4.12**	-6.37**	- 5.28
P_3x P_4 (INB.42 x INB.56)	-0.89*	0.10	0.31	0.17	-3.60	- 6.17
P_3x P_5 (INB.42 x INB.64)	2.74**	0.06	1.34**	1.10	-1.80	**75.03****
P_3x P_6 (INB.42 x INB.72)	0.81	0.25	-1.26**	3.46**	3.30	0.16
P_3x P_7 (INB.42 x INB.82)	1.75**	0.01	0.68	5.74**	1.77	**58.39****
P_3x P_8 (INB.42 x INB.102)	1.20**	0.25	0.86	5.38**	**4.90***	16.88**
P_4x P_5 (INB.56 x INB.64)	0.98*	0.09	1.72**	6.67**	**5.60***	16.04**
P_4x P_6 (INB.56 x INB.72)	0.66	0.08	0.32	5.57**	0.70	**57.26****
P_4x P_7 (INB.56 x INB.82)	1.00*	0.71**	0.79	4.65**	**5.83***	13.27**
P_4x P_8 (INB.56 x INB.102)	**1.65****	**0.81****	1.30**	8.22**	**7.30****	40.66**
P_5x P_6 (INB.64 x INB.72)	**1.81****	**0.44****	-0.58	8.76**	-4.17	6.26
P_5x P_7 (INB.64 x INB.82)	0.08	0.24	-0.11	5.18**	0.97	33.37**
P_5x P_8 (INB.64 x INB.102)	0.60	0.18	0.94**	6.21**	**7.43****	12.41**
P_6x P_7 (INB.72 x INB.82)	-0.05	0.34	2.82**	-0.59	**7.73****	**52.35****
P_6x P_8 (INB.72 x INB.102)	-0.86*	0.24	1.74**	2.98*	-5.80*	38.07**
P_7x P_8 (INB.82 x INB.102)	2.82**	0.06	-0.20	4.92**	**11.00****	21.32**
S.E sca (ij)	**0.43**	**0.22**	**0.29**	**1.09**	**2.37**	**3.79**
S.E sca (ij-ik)	**0.52**	**0.31**	**0.35**	**1.31**	**2.86**	**5.61**
S.E sca (ij-lk)	**0.46**	**0.30**	**0.31**	**1.16**	**2.54**	**5.29**

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

These findings are in agreement with El-Ghonemy and Ibrahim (2010), Mousa (2014), Abo El-Haress (2015) and El Hosary *et al* (2018).

Heritability and genetic advance. Estimates of genotypic (GCV) and phenotypic (P CV) coefficient of variation, heritability in the broad sense (h^2_b**)** and genetic advance from selection (GA%mean) are presented in Table (6). Generally, the values of (PCV) were slightly higher than their corresponding values of (GCV) for all traits which reflect somewhat influence of environment on the expression of traits. The highest estimates of genotypic and phenotypic coefficients of variation were obtained for ear height, number of kernels ear^{-1} and grain yield plant^{-1} ranging from, 23.26% to 46.99% while moderate values of (GCV) and (PCV) were observed with plant height, ear length, ear diameter, number of rows ear^{-1}and 100 kernels weight ranging from11.80 to 19.32%. In accordance, the selection among the tested genotypes would be successful and effective to improve these traits. On the other hand, the two traits days to 50% silking and days to 50% tasseling recorded the lowest estimates of genotypic (GCV) and phenotypic (PCV) coefficient of variation.

Table 6. Estimates of genetic parameters for agronomic and yield traits of maize.

Genetic parameters / Traits		Mean	Phenotypic coefficient of variation PCV	Genotypic coefficient of variation GCV	Heritability in the broad sense h^2_b (%)	Genetic advance% mean GA
Agronomic traits	Days to 50% Silking (DS)	65.28	10.19	7.48	**53.87**	4.69
	Days to 50% Tasseling (DT)	61.18	6.16	5.56	**81.46**	6.29
	Plant height (PH)	215.33	19.32	18.86	95.21	3.46
	Ear height (EH)	108.79	**24.62**	**23.26**	89.31	7.25
Grain yield traits	Ear length (EL)	15.25	18.17	17.36	91.36	**45.46**
	Ear diameter (ED)	4.84	16.22	15.71	93.81	**26.75**
	Rows ear^{-1} (R/E)	13.96	14.32	13.77	92.54	**44.65**
	Kernels row^{-1} (K/R)	32.88	**35.25**	**34.68**	96.79	**31.11**
	100-kernels weight (100KW)	41.33	12.12	11.36	**87.97**	13.19
	Grain yield plant^{-1} (GY/P)	148.78	**46.99**	**46.74**	98.93	8.11

It is important to emphasize that, without considering genetic advance (GA), the heritability values (h^2_b%) would not be practically valuable in the selection depends on phenotypic appearance. Johnson *et al* (1955) confirmed that heritability estimates in conjunction with genetic advance would give more reliable index of selection value. In the present investigation, high values of heritability coupled with high values of genetic advance (% mean) were recorded for ear length, ear diameter, number of rows ear^{-1} and kernels row^{-1} indicating that selection would be effective in early segregating generations for these traits. It is worth mentioning that plant breeders can safely make their selection when they take into consideration high values of heritability and genetic advance. It is remarkable that the high values of heritability and genetic advance for most studied characters may be attributed the huge differences between maize inbred lines and hybrids performances.

REFERENCES

Abd El-Aty, M.S. and Y.S. Katta (2002). Estimation of heterosis and combining ability for yield and other agronomic traits in maize hybrid (***Zea mays* L.**). J. Agric. Sci. Mansoura Univ.27(8):5137-5146.

Abo El-Haress, S.M. (2015). Diallel analysis for yield, downy mildew and agronomic characters in maize (Zea mays L.). Alex. J. Agric. Res. 60 (1): 25-31.

Ali, A., H. Rahman, L. Shah, K.A. Shah and S. Rehman (2014). Heterosis for grain yield and its attributing components in maize variety Azam using linextester analysis method. Academic J. Agri. Res. 2 (11): 225- 230.

Al-Naggar, A.M.M., M.M.M. Atta, M.A. Ahmed and A.S.M. Younis (2016). Mean performance, heterobeltiosis and combining ability of corn (*Zea mays* L.) agronomic and yield traits under elevated plant density. J. Appl. Life Sci. Int. 7(3):1-20.

Al-Naggar, A.M.M., R. Shabana, M. S. Hassanein , T. A. Elewa, A.S.M. Younis and A.M.A. Metwally (2017a). The effect of increasing plant density on performance and heterobeltiosis in maize testcrosses among 23 inbreds and three testers. J. Archives of Cur. Res. Int. 8(4): 1-14.

Al-Naggar, A.M.M., R. Shabana, M. S. Hassanein , T. A. Elewa, A.S.M. Younis and A.M.A. Metwally (2017b). Estimation of genetic parameters controlling inheritance of maize quantitative traits under different plant densities using Line × Tester analysis. Asian J. of Adv. Agric. Res. 2(2): 1-12.

Al-Naggar, A.M.M., R., Shabana and A.M. Rabie (2011). *Per se* performance and combining ability of 55 new maize inbred lines developed for tolerance to high plant density. Egypt. J. Plant Breed. 15(5): 59-84.

Amer, E.A. (2005). Estimates of combining ability using diallel crosses among eight new maize inbred lines. J. Agric. Res. Tanta Univ. 31(2) 67-73.

Bidhendi, N.Z., R. Choukan, F. Darvish, K. Mostafavi and E. Majidi (2012). Classifying of maize inbred lines into heterotic groups using diallel analysis. World Acad. of Sci., Engin. and Tech. 67:1368-1371.

El-Ghonemy, M.A. and M. H. A. Ibrahim (2010). **Diallel analysis of yellow maize for combining ability and heterosis.** J. Plant Production, Mansoura Univ., 1 (6): 779 – 792.

El-Hosary, A.A.A.; M. H. Motawea and A.A. Elgammaal (2018). Combining ability for yield and some of its attributes in maize across two locations. Egypt. J. Plant Breed. 22(3):625– 640.

El-Hosary, A.A., M.EL.M. El-Badawy and Y.M. Abdel-Tawab (2006). Genetic distance of inbred lines and prediction of maize single-cross performance using RAPD and SSR markers. Egypt. J. Genet. Cytol. 35: 209-224.

El-Hosary, A.A.A. (2015). Genetic analysis of water stress tolerance attributes in F_1 maize diallel crosses. Egypt. J. Plant Breed. 19 (6): 1765-1781

El-Hosary, A.A.A. and A. A. Elgammaal (2013). Utilization of line × tester model for evaluating the combining ability of some new white maize inbred lines. Egypt. J. Plant Breed. 17(1): 79-72.

El-Shouny, K.A., O.H., El-Bagoury H.Y., El- Sherbieny and S.A. Al-Ahmad (2003). Combining ability estimates for yield and its components in yellow maize (*Zea mays* L.) under two plant densities. Egypt. J. Plant Breed. 7(1):399-417.

Girma, C.H., A. Sentayehu, T. Berhanu and M. Temesgen (2015). Test cross performance and combining ability of maize (*Zea mays* L.) inbred lines at Bako, Western Ethiopia. Global J. of Sci. Fron. Res. 15(4)1:1-12.

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

Johnson, H. W., H. F. Robinson and R. E. Comstock 1955. Estimation of genetic and environmental variability in soybean. Agron. J. 47:314-318.

Khan, S.U., H. Rahman, M. Iqbal, U. Ghulam, I.A. Khalil, M. Ali, I. U. Zaid and M. R. Rehman (2014). Combining ability studies in maize (*Zea mays* L.) using populations diallel. Inter. J Basic and Applied Sci. 14(1): 17-23.

Mousa, S. Th. M. (2014). Diallel analysis for physiological traits and grain yield of seven white maize inbred lines. Alex. J. Agric. Res. 59 (1): 9-17

Saad El-Deen, O.M., H.E. Yassien, E.F.M. El- Hashash, A.A. Barakat and A.A.M. Afife (2015). Genetic improvement for protein content and some agronomic traits in a white maize population. Minufiya J. Agric. Res. 40(2): 445-456.

Steel, R.G. and J.M. Torrie, (1997). Principles and Procedures of Statistics, 3rd ed. McGraw-Hill, New York, USA.

التحليل الوراثي للهجن التبادلية في الذرة الشامية

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١. قسم المحاصيل ، كلية الزراعة ، جامعة القاهرة.

٢. قسم المحاصيل ، كلية الزراعة ، جامعة الفيوم.

تهدف الدراسة لتقييم ثمانية سلالات مرباه داخليا من الذرة الشامية فى نظام الدياليل بدون التهجينات العكسية. حيث اجريت كل التهجينان التبادلية الممكنة للحصول على ٢٨ هجين فردى بمحطة البحوث الزراعية بسيد منت الجبل بمحافظة بنى سويف خلال موسم ٢٠١٥. و قد تم تقييم الهجن الفردية بالاضافه الى الاباء (السلالات) بإستخدام تصميم القطاعات الكاملة العشوائية فى ثلاث مكررات فى موسم ٢٠١٦ .أظهرت النتائج وجود اختلافات عالية المعنوية بين التراكيب الوراثية تحت الدراسة (الآباء و الهجن) لمعظم الصفات تحت الدراسه مما يشير الى امكانية تحسين كثير من هذه الصفات بواسطة طرق التهجين والانتخاب. تبين من النتائج معنوية كل من القدرة العامة و الخاصة على الائتلاف لمعظم الصفات تحت الدراسة مما يشير الى ان كل من الفعل المضيف وغير المضيف للجين يلعب دورًا مهمًا ومعنويًا فى وراثة معظم الصفات. وقد اظهرت النتائج ان نسبة تباين القدره العامه الى القدره الخاصه على الائتلاف كانت اقل من الوحده لكل الصفات تحت الدراسه عدا صفات عدد الايام حتى ظهور حراير ٥٠% من النباتات ، عدد الايام حتى بروز متوك ٥٠% من النباتات ، قطر الكوز و عدد صفوف الكوز مما يشير الى تحكم الفعل غير المضيف للجين فى وراثة معظم الصفات. أشارت النتائج الى ان تأثيرات القدرة العامة على الائتلاف لصفة محصول الحبوب كانت معنويه وموجبه لكل من السلالات (الآباء) P_1 (INB.24), P_6 (INB.72) and P_7 (INB.82) مما يوصى باستخدامهم في برامج تربية الهجن الجديدة من الذرة الشامية بينما كانت كل الهجن الفردية الناتجة ما عدا (INB.24 P_1 x P_3 INB.42) and (INB.37 P_2 x P_5 INB.64) ذات تأثيرات قدره خاصه على الائتلاف عالية المعنوية وموجبه لصفة محصول الحبوب. تبين من النتائج ان أعلى قيم من كفاءة التوريث مصحوبة بأعلى قيم للتحسن الوراثي المتوقع بالانتخاب قد تم الحصول عليها لجميع الصفات المدروسه عدا صفات عدد الايام حتى ظهور حراير ٥٠% من النباتات، عدد الايام حتى بروز متوك ٥٠% من النباتات و وزن ١٠٠ حبه مما يظهر امكانية تحسين هذه الصفات عند الانتخاب لها على أساس الشكل الظاهري.

المجلة المصرية لتربية النبات ٢٣(٤): ٥١٥- ٥٣٠ (٢٠١٩)