Diallel Cross Analysis for some White Maize Inbred Lines under Two Nitrogen Levels

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Abstract: A half diallel cross among seven white inbred lines of maize was made in 2016 growing season. The resulted of 28 F_1 crosses along with the check hybrid SC130 were evaluated under two different nitrogen levels, *i.e.,* 90 and 120 kg N/ fed using a randomized complete block design (RCBD) with three replications at the Experimental Farm, Faculty of Agriculture, Kafrelsheikh University in 2017 growing season, to estimate general (GCA) and specific (SCA) combining ability effects and their interactions with nitrogen levels as well as identify type of gene action controlling the inheritance of the studied traits. Data were recorded on days to 50% silking, plant height, ear height, ear length, ear diameter, No. of rows/ear, No. of kernels/row and grain yield (ard/fed). The results showed that, the mean squares due to nitrogen levels (D), genotypes (G), crosses (Cr.), G × N and Cr. × N interactions were significant for all the studied traits. General (GCA) and specific (SCA) combining ability mean squares were highly significant for all the studied traits under both and across nitrogen levels. Both GCA and SCA effects were significantly interacted with nitrogen levels for all the studied traits, except GCA × N for ear diameter. The non-additive gene action played an important role in the inheritance of all the studied traits under the two nitrogen levels and the combined data, except days to 50% silking under N1 level. The inbred lines P_1 and P_7 showed the best desirable GCA effects for earliness and P_2 and P_6 for shorter plants and lower ear placement. Whereas, P_2, P_3 and P_4 were the best general combiners for grain yield. The crosses $P_1 \times P_3$, $P_2 \times P_7$, $P_3 \times P_6$, $P_4 \times P_5$ and $P_5 \times P_7$ had the best SCA effects for grain yield as well as one or more of its components under both and across nitrogen levels. The two crosses $P_2 \times P_7$ and $P_4 \times P_5$ exhibited significant and positive superiority over SC 130 under both and across nitrogen levels.

Keywords: Maize, nitrogen levels, diallel analysis, gene action

INTRODUCTION

Maize (*Zea mays* L.) is the third important cereal crop in the world after wheat and rice (Adu *et al.,* 2018). It is essential for human and animal fed. Also, it is used as a raw material for industrial products (El-Hosary *et al*., 2018). Therefore, increasing the productivity of such crop is the main goal of maize breeders in Egypt in order to decrease its import and respond to its high consumption (Kamara and Rehan, 2015). The knowledge of combining ability is important for selecting suitable parents for hybridization and identification of promising hybrids in breeding programs (Oyekunle *et al*., 2015). Diallel analysis is commonly used to gain information on gene action controlling traits of interest, and the combining ability of the parents (Griffing, 1956). Relative importance of both additive and non-additive gene effects is also estimated by diallel analysis. The additive gene effects have been reported to be important in the genetic expression of maize grain yield (Badu-Apraku and Oyekunle, 2012; Abd El-Mottalb *et al*., 2013; Abo El-Haress, 2015; El-Hosary *et al*., 2018). However, other researchers reported that the non-additive genetic effects were represented the major role in the inheritance of maize grain yield and most of its components (Makumbi *et al*., 2011; Attia *et al*., 2015; Kamara, 2015; Wani *et al*, 2017). There is no agreement among the researchers on the type of gene action controlling maize yield or its related characters, and this due to differences in the genetic materials and the environments under which the experiments were performed. Much effort has been dedicated to estimate the interactions between genetic components and environments. Nitrogen (N) is a vital nutrient required for the maize plants growth, metabolically active and photosynthesis (Haque *et al*., 2001). Abd El -Aty and Darwish (2006), Mosa *et al.* (2010) and Kamara *et al.* (2014) obtained significant GCA × N and SCA ×N interactions for grain yield and other traits, an indication of variation of general and specific coming ability under different environments. This study was designed to estimate general (GCA) and specific (SCA) combining ability effects and their interactions with nitrogen levels as well as identify type of gene action controlling the inheritance of the studied traits.

MATERIALS AND METHODS

Plant materials:

Seven white inbred lines of maize (*Zea mays* L.) were used as parents in this study. The parental codes, names and sources of these inbred lines are presented in Table (1).

In 2016 growing season, all possible combinations excluding reciprocals were made among the seven inbred lines giving a total of 21 F1 crosses. In 2017 growing season, the resulted 21 F1 hybrids and the commercial check hybrid SC130 were evaluated in two separate experiments represented two different nitrogen levels; 90 (N1) and 120 (N2) kg N/fed at the Experimental Farm, Faculty of Agriculture, Kafrelsheikh University, Egypt. A randomized complete block design with three replications was used for each experiment.

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Each plot consisted of two ridges, 5 m long and 0.70 m width. Planting was made in hills spaced at 0.25 m with three kernels per hill on one side of the ridge. The seedlings were thinned to one plant per hill after 21 days from planting. Nitrogen fertilizer was added in two equal doses before 1st and 2nd irrigations.

All other agricultural practices were carried out according to standard commercial recommendations for maize production.

Table (1): The code, name and pedigree of the parental maize inbred lines

Parent code	Name	Source
P_1	Inb. 17	Agricultural Research Center, Egypt
P_2	Inb. 51	Agricultural Research Center, Egypt
P_3	Inb. 60	Agricultural Research Center, Egypt
P_4	Inb. 84	Agricultural Research Center, Egypt
P_5	Inb. 92	Agricultural Research Center, Egypt
P_6	Inb. 144	Agricultural Research Center, Egypt
P_7	CML23	CIMMYT, Mexico

Data were collected for number of days from planting to 50% silking (day), plant height (cm), ear height (cm), ear length (cm), ear diameter (cm), number of rows/ear, number of kernels/row and grain yield ardab/feddan adjusted to 15.5% moisture content (one ardab = 140 Kg, one feddan = 4200 m^2). The obtained data were statistically analyzed for the analysis of variance according to Steel and Torrie (1980). The combined analysis was done whenever homogeneity of variance was detected. General and specific combining ability were estimated according to Griffing (1956), method-4, model-1.

RESULTS AND DISCUSSION

Analysis of variance:

The analysis of variance showed highly significant mean squares due to nitrogen levels (N) for all the studied traits (Table 2), indicating overall differences between the two nitrogen levels. Genotypes (G) and crosses (Cr.) mean squares were found to be highly significant for all the studied traits at each and across nitrogen levels, indicating a wide diversity among the genetic materials used in the present study. Mean squares due to genotypes × nitrogen levels (G × N) and crosses × nitrogen levels (Cr. × N) interactions were significant for all the studied traits, revealing that the tested genotypes behaved differently from nitrogen level to another. These results corroborate the findings of Abd El-Aty *et al.* (2014) and Al-Naggar *et al.* (2015). Mean squares due to crosses vs. check were significant for all the studied traits, except days to 50% silking under N2 level and the combined data, plant height and ear diameter under both nitrogen levels and the combined data and No. of rows/ear under N2 level. Insignificant interaction mean squares between crosses vs. check and nitrogen levels were observed for all the studied traits, except plant height and ear length. This result suggests that the heterotic effects were not differed by nitrogen levels changes. Mosa *et al*. (2010), El-Badawy (2013) and Katta *et al*. (2013) reached to the same conclusion for grain yield and most of its components.

Mean performance:

Mean performance of the 21 F_1 crosses and the check hybrid SC130 for all the studied traits under both and across nitrogen levels are shown in Table (3).

In general, the mean values of the 21 F_1 crosses and the check SC130 were higher under the N2 level (120 kg N/ fed) as compared to those under N1 level (90 kg N /fed) for all the studied traits, except days to 50% silking. The increase in mean performance of these traits at high nitrogen level might be attributed to the simulating effect of nitrogen on metabolic process in maize plants. According to Kaur *et al*. (2012) the increase in maize plant height with increase nitrogen level was due to the positive effect of nitrogen element on plant growth that leads to progressive increase in internodes length and consequently plant height. The increase in maize grain yield is largely due to an increase in metabolic process which in turn stimulates growth and increase total dry matter distributed to the grain and ultimately increase the most of yield components (Medici *et al*., 2004; Ngaboyisonga *et al*., 2009; Adu *et al*., 2018). Concerning the performance of the F_1 crosses in comparison with the check hybrid SC130, data in Table (3) showed that, the crosses $P_1 \times P_3$, $P_1 \times P_4$ and $P_1 \times P_7$ under N2 level and the combined data and $P_1 \times P_5$, $P_1 \times P_6$ and $P_2 \times P_7$ under both and across nitrogen levels were found to be significantly earlier than the check hybrid SC130. Earliness in maize is favorable character for saving water irrigation and escaping destructive injuries caused by the stem corn borers. Three crosses P1×P6, $P_2 \times P_6$ and $P_5 \times P_6$ at both nitrogen levels and the combined data were exhibited significantly deceased values as compared to the check hybrid SC130 for plant height. Also, the crosses *i.e.*, $P_2 \times P_4$ and $P_3 \times P_4$ at N1 and $P_1 \times P_2$, $P_2 \times P_5$, $P_2 \times P_7$, $P_5 \times P_7$ and $P_6 \times P_7$ at N2 and combined data were significantly shorter than the check hybrid SC130. With respect to ear height, the ten crosses $P_1 \times P_6$, $P_2 \times P_4$, $P_2 \times P_5$, $P_2 \times P_6$ $P_2 \times P_7$, $P_3 \times P_4$, $P_4 \times P_6$, $P_4 \times P_7$, $P_5 \times P_6$ and $P_5 \times P_7$ at both and across nitrogen levels had significantly lower ear placement than the check hybrid SC130. Concerning ear length, the three crosses $P_1 \times P_5$, $P_2 \times P_7$ and $P_4 \times P_5$ under both nitrogen levels and the combined data significantly surpassed the check hybrid SC130. Regarding ear diameter, the cross $P_6 \times P_7$ at the combined data and the four crosses $P_1 \times P_4$, $P_1 \times P_5$, $P_2 \times P_7$ and $P_4 \times P_5$ at both and across nitrogen levels were significantly superior than the check SC130. The three crosses $P_3 \times P_6$, $P_4 \times P_5$ and $P_4 \times P_6$ gave the highest mean value for No. of rows/ear and significantly surpassed the check hybrid SC130.

Table (2): Mean squares from ordinary and combining ability analysis for all the studied traits under the two nitrogen levels as well as the combined analysis across them

SOV	df	Mean squares							
		Days to 50% silking	Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	No. of rows/ear	No. of kernels/ row	Grain yield (ard/fed)
		N1 (90 kg N /fed)							
Genotypes (G)	**21**	29.21**	782.43**	295.87**	9.58**	0.23**	2.74**	27.97**	39.25**
F$_1$ Crosses (C)	**20**	30.28**	817.66**	289.06**	9.93**	0.24**	2.80**	28.96**	40.53**
GCA	**6**	67.47**	1589.33**	620.15**	7.98**	0.23**	4.48**	54.52*	64.14**
SCA	**14**	14.34**	486.94**	147.16**	10.76**	0.24**	2.09**	18.01**	30.41**
C *vs.* Check	**1**	7.86*	77.91	432.01**	2.52*	0.03	1.42*	8.12*	13.80**
Error	**42**	1.19	58.73	19.13	0.58	0.02	0.19	1.58	2.27
K^{2}GCA/K^{2}SCA		1.02	0.71	0.94	0.15	0.19	0.45	0.64	z0.44
		N2 (120 kg N /fed)							
Genotypes (G)	**21**	29.22**	824.58**	310.35**	14.20**	0.30**	4.75**	36.54**	41.23**
F$_1$ Crosses (C)	**20**	30.67**	856.85**	315.26**	14.03**	0.32**	4.96**	37.54**	42.42**
GCA	**6**	60.89**	1498.32**	395.09**	4.82**	0.24**	6.38**	58.64**	74.40**
SCA	**14**	17.72**	581.94**	281.05**	17.97**	0.35**	4.35**	28.49**	28.71**
C *vs.* Check	**1**	0.21	179.15	212.03*	17.56*	0.004	0.55	16.63*	17.50*
Error	**42**	2.11	42.86	25.19	0.40	0.05	0.37	2.33	1.81
K^{2}GCA/K^{2}SCA		0.75	0.54	0.29	0.05	0.12	0.30	0.43	0.54
		Combined across the two nitrogen levels							
Nitrogen (N)	**1**	210.87**	19963.5*	9079.72**	109.20**	6.45**	42.87*	630.70**	436.69**
Rep/N	**4**	2.75	1152.61	42.65	2.66	0.12	2.48	9.56	14.83
Genotypes (G)	**21**	54.19**	1489.56**	559.49**	22.21**	0.47**	6.70**	59.91**	75.53**
Crosses (Cr.)	**20**	56.64**	1563.52**	556.23**	22.49**	0.50**	6.94*	61.70**	77.75**
GCA	**6**	123.60**	2960.05**	945.29**	11.66**	0.45**	10.12**	108.76**	130.23**
SCA	**14**	27.94**	965.00**	389.48**	27.12**	0.52**	5.57**	41.54**	55.25**
Cr. *vs.* Check	**1**	5.32	10.39	624.67**	16.69**	0.02	1.87*	23.99*	31.20**
G × N	**21**	4.24**	117.45**	46.73**	1.56**	0.06*	0.79**	4.60**	4.96**
Cr. × N	**20**	4.31**	110.99**	48.10**	1.47**	0.06*	0.83**	4.80**	5.20**
GCA × N	**6**	4.76**	127.60*	69.95**	1.14*	0.01	0.73*	4.40*	8.31**
SCA × N	**14**	4.12**	103.87*	38.73**	1.61**	0.08**	0.86**	4.97**	3.86*
Cr. *vs.* Check × N	**1**	2.76	246.67*	19.37	3.39*	0.02	0.10	0.75	0.11
Error	**84**	1.65	50.79	22.16	0.49	0.03	0.28	1.95	2.04
K^{2}GCA/K^{2}SCA		0.93	0.64	0.50	0.08	0.17	0.37	0.54	0.48
K^{2}GCA × N/ K^{2}SCA × N		0.25	0.29	0.58	0.12	0.001	0.16	0.16	0.69

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

The two crosses $P_2\times P_7$ and $P_4\times P_5$ under nitrogen levels and the combined data as well as the cross $P_2\times P_4$ under N1 significantly possessed higher No. of kernels/row than the check hybrid SC130. Superiority percentage for grain yield (ard/fed) relative to the check hybrid SC130 (Table 3) revealed that the cross $P_3\times P_6$ under N1 and the two crosses $P_2\times P_7$ and $P_4\times P_5$ under both nitrogen levels and the combined data had positive and significant superiority percentage over the check hybrid SC130. The crosses $P_1\times P_3$, $P_2\times P_3$ and $P_2\times P_6$ gave positive superiority percentage over the check hybrid SC130, but it was not significant. Therefore, it could be concluded that these crosses could be efficient and prospective in maize breeding programs since they showed high values for grain yield and one or more of yield components traits. These results are in harmony with those obtained by El-Badawy (2013), El-Shamarka *et al.* (2015), El-Hosary *et al.* (2018). They found positive and significant superiority percentages compared to the check hybrids for maize grain yield. The fluctuation of hybrids performance from nitrogen level to another was detected for most traits. These results could be due to significant interaction between crosses and nitrogen levels.

Table (3): Mean performance of the 21 F_1 crosses for all the studied traits under the two nitrogen levels and their combined data as well as superiority percentage relative to check hybrid SC130 for grain yield trait

Crosses	**Days to 50% silking**			**Plant height (cm)**			**Ear height (cm)**			**Ear length (cm)**		
	N1	**N2**	**Comb.**	**N1**	**N2**	**Comb.**	**N1**	**N2**	**Comb.**	**N1**	**N2**	**Comb.**
$P_1\times P_2$	62.0	60.7	61.3	198.8	230.7	214.8	104.6	119.8	112.2	18.5	20.1	19.3
$P_1\times P_3$	61.5	58.8	60.2	243.8	267.5	255.7	131.5	144.0	137.8	15.0	17.6	16.3
$P_1\times P_4$	63.5	58.3	60.9	241.3	255.7	248.5	124.0	146.0	135.0	16.0	18.0	17.0
$P_1\times P_5$	61.0	57.0	59.0	248.9	270.3	259.6	124.3	137.3	130.8	19.8	22.6	21.2
$P_1\times P_6$	59.0	58.0	58.5	190.7	210.9	200.8	102.1	111.0	106.6	16.5	17.0	16.8
$P_1\times P_7$	61.5	58.5	60.0	233.5	263.8	248.7	134.8	148.0	141.4	18.8	19.0	18.9
$P_2\times P_3$	68.9	66.7	67.8	213.8	265.3	239.6	115.5	143.5	129.5	18.8	20.0	19.4
$P_2\times P_4$	64.7	61.5	63.1	215.6	231.3	223.5	113.0	132.3	122.7	16.0	17.2	16.6
$P_2\times P_5$	63.5	60.9	62.2	208.8	224.8	216.8	116.8	128.5	122.6	17.0	18.0	17.5
$P_2\times P_6$	65.2	64.3	64.8	190.2	223.8	207.0	100.5	127.3	113.9	19.0	20.0	19.5
$P_2\times P_7$	60.5	59.3	59.9	202.9	225.6	214.3	110.5	124.0	117.3	19.7	22.6	21.2
$P_3\times P_4$	66.3	60.5	63.4	218.8	235.5	227.2	118.5	131.3	124.9	15.0	16.0	15.5
$P_3\times P_5$	67.4	64.8	66.1	217.5	241.2	229.4	129.3	144.0	136.6	14.0	15.6	14.8
$P_3\times P_6$	66.0	66.3	66.1	230.0	250.0	240.0	123.0	147.3	135.1	18.0	21.2	19.6
$P_3\times P_7$	63.5	61.7	62.6	217.8	256.3	237.1	120.5	142.3	131.4	17.5	20.5	19.0
$P_4\times P_5$	68.5	66.0	67.3	221.3	243.8	232.6	128.0	140.0	134.0	19.8	23.1	21.5
$P_4\times P_6$	68.8	67.3	68.1	215.0	238.8	226.9	110.5	128.0	119.3	16.6	18.0	17.3
$P_4\times P_7$	65.0	63.0	64.0	212.5	238.3	225.4	108.0	121.0	114.5	18.3	20.0	19.2
$P_5\times P_6$	70.3	63.5	66.9	196.7	222.5	209.6	106.8	126.9	116.8	14.7	18.1	16.4
$P_5\times P_7$	67.9	65.5	66.7	206.8	235.0	220.9	121.0	132.8	126.9	15.6	18.2	16.9
$P_6\times P_7$	62.8	60.9	61.9	205.3	227.5	216.4	112.0	136.5	124.3	15.8	16.7	16.3
Crosses mean	64.7	62.1	63.4	215.7	240.9	228.3	116.9	133.9	125.4	17.2	19.0	18.1
Check SC130	63.0	61.8	62.4	210.5	248.8	229.7	129.2	142.5	135.9	18.1	21.5	19.8
LSD 0.05	1.8	2.4	1.5	12.6	10.8	8.2	7.2	8.3	5.4	1.3	1.0	0.8
LSD 0.01	2.4	3.2	2.0	16.9	14.5	10.9	9.7	11.1	7.2	1.7	1.4	1.1

Table (3): Cont.

Crosses	Ear diameter (cm)			No. of rows/ear			No. of kernels/row			Grain yield (ard/fed)			Superiority % relative to SC130		
	N1	N2	Comb.	N1	N2	Comb	N1	N2	Comb	N1	N2	Comb	N1	N2	Comb
$P_1 \times P_2$	4.6	5.2	4.9	12.3	13.6	13.0	34.3	38.0	36.2	24.0	31.6	27.8	-12.7**	0.3	-5.8*
$P_1 \times P_3$	4.8	5.0	4.9	13.3	14.2	13.8	30.0	33.0	31.5	27.6	31.5	29.5	0.3	0.0	0.2
$P_1 \times P_4$	5.0	5.5	5.3	13.0	14.2	13.6	35.0	41.0	38.0	21.0	28.6	24.8	-23.6**	-9.1*	-15.9**
$P_1 \times P_5$	5.0	5.5	5.3	13.7	14.0	13.9	31.5	38.0	34.8	19.5	22.4	21.0	-29.1**	-28.9**	-29.0**
$P_1 \times P_6$	4.2	4.7	4.5	13.5	14.0	13.8	32.0	39.5	35.8	19.5	21.0	20.3	-29.0**	-33.3**	-31.3**
$P_1 \times P_7$	4.8	5.1	5.0	11.7	13.0	12.4	28.0	30.0	29.0	21.0	24.0	22.5	-23.6**	-23.8**	-23.7**
$P_2 \times P_3$	4.2	4.9	4.6	12.3	15.0	13.7	36.8	38.0	37.4	28.4	33.5	31.0	3.3	6.3	4.9
$P_2 \times P_4$	4.6	4.9	4.8	14.0	14.5	14.3	37.2	40.0	38.6	27.6	30.0	28.8	0.4	-4.8	-2.4
$P_2 \times P_5$	4.5	4.6	4.6	13.0	14.0	13.5	33.2	41.0	37.1	23.3	30.7	27.0	-15.3**	-2.5	-8.5**
$P_2 \times P_6$	4.3	4.7	4.5	13.3	14.3	13.8	33.2	39.5	36.4	27.5	32.0	29.8	0.0	1.6	0.8
$P_2 \times P_7$	5.0	5.5	5.3	14.0	15.9	15.0	39.0	43.0	41.0	30.6	34.5	32.6	11.3*	9.5**	10.3**
$P_3 \times P_4$	4.6	4.9	4.8	14.7	15.6	15.2	35.8	39.7	37.8	25.0	29.0	27.0	-9.1*	-7.9*	-8.5
$P_3 \times P_5$	4.7	5.1	4.9	13.0	13.0	13.0	34.3	37.8	36.1	20.0	24.0	22.0	-27.3**	-23.8**	-25.4**
$P_3 \times P_6$	4.8	5.2	5.0	15.0	18.0	16.5	34.7	39.0	36.9	30.6	31.5	31.1	11.4*	-0.1	5.3
$P_3 \times P_7$	4.6	5.1	4.9	12.7	13.0	12.9	29.5	35.0	32.3	26.0	28.8	27.4	-5.5	-8.6*	-7.1*
$P_4 \times P_5$	5.0	5.9	5.5	14.9	16.1	15.5	39.0	44.5	41.8	30.7	34.0	32.4	11.6*	7.9*	9.7**
$P_4 \times P_6$	4.1	4.7	4.4	14.9	16.2	15.6	32.0	37.8	34.9	27.3	29.9	28.6	-0.7	-5.1	-3.1
$P_4 \times P_7$	4.8	4.9	4.9	14.0	15.0	14.5	32.0	35.0	33.5	28.6	31.0	29.8	4.0	-1.6	1.0
$P_5 \times P_6$	4.6	5.1	4.9	12.0	13.0	12.5	31.8	35.0	33.4	24.4	27.1	25.8	-11.2*	-14.0**	-12.7**
$P_5 \times P_7$	4.4	5.1	4.8	12.7	13.9	13.3	28.8	32.0	30.4	25.7	28.5	27.1	-6.5	-9.5**	-8.1**
$P_6 \times P_7$	4.9	5.4	5.2	13.3	15.3	14.3	31.5	36.8	34.2	23.0	26.0	24.5	-16.4**	-17.5**	-16.9**
Crosses mean	4.6	5.1	4.9	13.4	14.6	14.0	33.3	37.8	35.6	25.3	29.0	27.2	-	-	-
Check SC130	4.8	5.1	4.9	14.1	15.0	14.6	35.0	40.2	37.6	27.5	31.5	29.5	-	-	-
LSD 0.05	0.2	0.4	0.2	0.7	1.0	0.6	2.1	2.5	1.6	2.5	2.2	1.6	-	-	-
LSD 0.01	0.3	0.5	0.3	1.0	1.3	0.8	2.8	3.4	2.1	3.3	3.0	2.2	-	-	-

Combining ability:

Mean squares due to general combining ability (GCA) and specific combining ability (SCA) were highly significant for all the studied traits under both nitrogen levels and the combined analysis (Table 2), revealing that both additive and non-additive gene effects were important in the inheritance of these traits. The GCA/SCA ratio was less than unity for all the studied traits under both nitrogen levels and their combined data, except days to 50% silking under N1 level (90 kg N/fed), indicating that these traits were predominantly controlled by the non-additive gene action. These results are in accordance with those obtained by San *et al.* (2001), Mosa (2003), Ahmed (2013) and El-Ghonemy (2015) for plant height, Mosa (2010), Katta *et al.* (2013) and El-Hosary (2014) for ear diameter and Attia *et al.* (2015), Hassan (2015) and Wani *et al.* (2017) for grain yield. For the exceptional trait, the ratio of GCA/GCA was equal unity, indicating that additive and non-additive type of gene action have the same importance in the performance of this trait. Significant interaction mean square between nitrogen levels and both types of combining ability (GCA× N and SCA× N) were detected for all the studied traits, except GCA × N for ear diameter. These results suggested that the behavior of the two types of gene action (additive and non-additive) varied from nitrogen level to another. It is fairly evident that the ratio of GCA × N/SCA × N was less than unity for all the studied traits. This result indicated that the non-additive effects were more affected by nitrogen levels than the additive genetic effects. In this respect Mosa *et al.* (2010) and Kamara (2015) reported that the non-additive genetic effects were more influenced by nitrogen levels than additive gene actions for grain yield and most of its components.

General combining ability (GCA) effects:

Estimates of general combining ability ($\hat{g}_i$) effects of the seven inbred lines under both and across nitrogen levels are shown in Table (4). High positive values of ($\hat{g}_i$) effects would be of interest for all studied traits, except days to 50% silking, plant and ear heights where high negative values would be favored. The parental inbred line P_1 showed significant negative ($\hat{g}_i$) effects for days to 50% silking and showed significant positive effects for ear diameter under both nitrogen levels and the combined data. The parental inbred line P_2 showed significant negative ($\hat{g}_i$) effects for plant and ear heights and gave significant positive effects for ear length, No. of kernels/row and grain yield under both under both nitrogen levels and the combined data. The parental inbred line P_3 expressed significant positive ($\hat{g}_i$) effects for grain yield under both and across nitrogen levels. However, it gave significant undesirable or insignificant ($\hat{g}_i$) effects for other traits. The parental inbred line P_4 seemed to be suitable combiner for No. of rows/ear, No. of kernels/row and grain yield under both and across nitrogen levels, due to its positive and significant ($\hat{g}_i$) values in this concern. The parental inbred line P_5 behaved as a good combiner for ear diameter. The parental inbred line P_6 gave highly significant negative ($\hat{g}_i$) effects for plant and ear heights as well as showed significant positive ($\hat{g}_i$) effects for ear length and No. of rows/ear under both and across nitrogen levels. The parental inbred line P_7 expressed significant negative ($\hat{g}_i$) effects for days to 50% silking and exhibited significant positive ($\hat{g}_i$) effects for ear length and ear diameter under both nitrogen levels and the combined data.

Table (4): General combining ability ($\hat{g}_i$) effects of the seven inbred lines for all the studied traits under each and across nitrogen levels

Inbred line	**Ear diameter (cm)**			**No. of rows/ear**			**No. of kernels/row**			**Grain yield (ard/fed)**		
	N1	**N2**	**Comb.**	**N1**	**N2**	**Comb.**	**N1**	**N2**	**Comb.**	**N1**	**N2**	**Comb.**
P_1	-3.89**	-4.23**	-4.06**	12.55**	10.73**	11.64**	3.96**	0.55	2.25*	0.33	0.03	0.18
P_2	-0.52	0.19	-0.18	-12.83**	-8.75**	-10.79**	-8.11**	-5.59**	-6.85**	1.21**	0.75**	0.98**
P_3	1.13**	1.28**	1.20**	9.48**	14.09**	11.79**	7.37**	9.79**	8.58**	-0.93**	-0.65**	-0.79**
P_4	1.77**	0.84*	1.30**	6.04**	-0.39	2.83	0.12	-0.95	-0.42	-0.25	-0.37*	-0.31
P_5	2.13**	1.06**	1.59**	1.14	-1.55	-0.20	4.92**	1.23	3.07**	-0.41*	0.29	-0.06
P_6	0.83**	1.58**	1.20**	-13.28**	-14.37**	-13.82**	-9.31**	-5.28**	-7.30**	-0.47*	-0.63**	-0.55**
P_7	-1.45**	-0.70*	-1.08**	-3.10	0.23	-1.43	1.07	0.25	0.66	0.55**	0.57**	0.56**
LSD (0.05) $_{gi}$	0.53	0.70	0.61	3.70	3.16	3.39	2.11	2.42	2.24	0.37	0.31	0.33
LSD (0.01) $_{gi}$	0.71	0.94	0.81	4.95	4.23	4.49	2.83	3.24	2.97	0.49	0.41	0.44
LSD (0.05) $_{gi-gj}$	0.81	1.07	0.93	5.66	4.83	5.18	3.23	3.70	3.42	0.56	0.47	0.51
LSD (0.01) $_{gi-gj}$	1.08	1.43	1.24	7.57	6.46	6.87	4.32	4.96	4.53	0.75	0.62	0.68

Table (4): Cont.

Inbred line	**Ear diameter (cm)**			**No. of rows/ear**			**No. of kernels/row**			**Grain yield (ard/fed)**		
	N1	**N2**	**Comb.**	**N1**	**N2**	**Comb.**	**N1**	**N2**	**Comb.**	**N1**	**N2**	**Comb.**
P_1	0.11**	0.11*	0.105**	-0.57**	-0.87**	-0.72**	-1.81**	-1.45**	-1.63**	-3.84**	-3.01**	-3.43**
P_2	-0.13**	-0.15**	-0.14**	-0.29**	-0.01	-0.15	2.77**	2.55**	2.66**	1.91**	3.62**	2.77**
P_3	-0.03	-0.07	-0.05	0.13	0.29	0.21	0.24	-0.85*	-0.30	1.16**	0.82	0.99**
P_4	0.05	0.05	0.05	1.02**	0.85**	0.93**	2.22**	2.25**	2.24**	1.67**	1.67**	1.67**
P_5	0.07*	0.15**	0.11**	-0.22*	-0.67**	-0.45**	-0.26	0.31	0.03	-1.64**	-1.49**	-1.56**
P_6	-0.19	-0.18**	-0.19**	0.33**	0.69**	0.51**	-0.94**	0.17	-0.38	0.11	-1.34**	-0.61
P_7	0.13**	0.11*	0.12**	-0.39**	-0.25	-0.32*	-2.22**	-2.99**	-2.60**	0.62	-0.27	0.17
LSD (0.05) $_{gi}$	0.06	0.11	0.09	0.21	0.30	0.25	0.61	0.74	0.66	0.73	0.65	0.68
LSD (0.01) $_{gi}$	0.08	0.14	0.11	0.28	0.39	0.33	0.81	0.99	0.88	0.97	0.87	0.90
LSD (0.05) $_{gi-gj}$	0.10	0.16	0.13	0.32	0.45	0.39	0.93	1.13	1.02	1.11	0.99	1.04
LSD (0.01) $_{gi-gj}$	0.13	0.22	0.17	0.43	0.60	0.51	1.24	1.51	1.35	1.49	1.33	1.38

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

The recent results, pointed out that, the inbred lines P_1 and P_7 considered as combiners for the improvement of earliness. The inbred lines P_2 and P_6 for developing were short and lower ear placement hybrids. The inbred lines P_2, P_3 and P_4 behaved as the appropriate combiner for grain yield and some of its components. Such obtained results indicated that these inbred lines possess favorable genes and that improvement in respective traits may be attained if they are incorporated in maize hybridization program. It is worth noting that the parental inbred line which possessed high ($\hat{g}_i$) effects for grain yield exhibited desirable ($\hat{g}_i$) effects for one or more of the traits contributing to grain yield. El-Shamarka *et al.* (2015) and El-Hosary *et al.* (2018) reported that ($\hat{g}_i$) effects were desirable and significant for earliness, grain yield and its components.

Specific combining ability (SCA) effects:

Estimates of specific combining ability ($\hat{S}_{ij}$) effects of the 21 F1 crosses for all the studied traits under the two nitrogen levels and their combined data are shown in Table (5). The most desirable and significant ($\hat{S}_{ij}$) effects under both nitrogen levels and the combined data were obtained by the crosses; $P_1\times P_5$, $P_2\times P_4$, $P_2\times P_5$, $P_2\times P_7$, $P_3\times P_4$, and $P_6\times P_7$ for days to 50% silking (towards earliness), $P_1\times P_2$, $P_1\times P_6$, $P_3\times P_4$ and $P_3\times P_5$ for plant height (towards shorter plants), $P_1\times$P2, $P_1\times P_6$, $P_3\times P_4$ and $P_4\times P_7$ for ear height (towards lower ear placement), $P_1\times P_5$, $P_2\times P_3$, $P_2\times P_6$, $P_2\times P_7$, $P_3\times P_6$, $P_3\times P_7$, $P_4\times P_5$ and $P_4\times P_7$ for ear length, $P_1\times P_4$, $P_1\times P_5$, $P_2\times P_7$, $P_3\times P_6$, $P_4\times P_5$ and $P_6\times P_7$ for ear diameter, $P_1\times P_5$, $P_2\times P_7$, $P_3\times P_6$ and $P_4\times P_5$ for No. of rows/ear, $P_1\times P_4$, $P_1\times P_6$, $P_2\times P_7$, $P_3\times P_6$, P4×P_5 and $P_6\times P_7$ for No. of kernels/row and $P_1\times P_3$, $P_2\times P_7$, $P_3\times P_6$, $P_4\times P_5$ and $P_5\times P_7$ for grain yield. The previous crosses might be of prime importance in breeding programs for traditional breeding procedures (EL-Hosary, 2014). It is notable that the crosses that showed high SCA effects for grain yield also showed high SCA effects for one or more traits of yield components. For example, the crosses $P_2\times P_7$, $P_3\times P_6$ and $P_4\times P_5$ which showed high SCA effects for grain yield also showed high SCA effects for ear length and No. of rows/ear No. of kernels/row. In most traits, the values of SCA effects were mostly different from nitrogen level to another. These findings coincided with that discussed elsewhere in this study where significant SCA by nitrogen levels mean squares were detected (Table 2).

Table (5): Estimates of specific combining ability ($\hat{S}_{ij}$) effects of the 21 F_1 crosses for all the studied traits under the two nitrogen levels and the combined data

Crosses	Days to 50% silking			Plant height (cm)			Ear height (cm)			Ear length (cm)		
	N1	N2	Comb.	N1	N2	Comb.	N1	N2	Comb.	N1	N2	Comb.
$P_1\times P_2$	1.86**	2.64**	2.25**	-16.60**	-12.07**	-14.34**	-8.14**	-9.05**	-8.59**	-0.19	0.29	0.05
$P_1\times P_3$	-0.40	-0.32	-0.36	6.06	1.79	3.92	3.27	-0.22	1.53	-1.55**	-0.81**	-1.18**
$P_1\times P_4$	0.96	-0.38	0.29	7.00	4.47	5.73	3.02	12.52**	7.77**	-1.23**	-0.69*	-0.96**
$P_1\times P_5$	-1.90**	-1.90**	-1.90**	19.50**	20.23**	19.86**	-1.53	1.59	0.03	2.73**	3.25**	2.99**
$P_1\times P_6$	-2.60**	-1.42*	-2.01**	-24.28**	-26.35**	-25.32**	-9.45**	-18.15**	-13.80**	-0.51	-1.43**	-0.97**
$P_1\times P_7$	2.08**	1.36	1.72**	8.34*	11.95**	10.14**	12.82**	13.32**	13.07**	0.77*	-0.63*	0.07
$P_2\times P_3$	3.74**	3.16**	3.45**	1.44	19.07**	10.25**	-0.66	5.42*	2.38	1.37**	0.87**	1.12**
$P_2\times P_4$	-1.10*	-1.60*	-1.35*	6.68	-0.45	3.11	4.09	4.96*	4.53*	-2.11**	-2.21**	-2.16**
$P_2\times P_5$	-2.66**	-2.42**	-2.54**	4.78	-5.79	-0.51	3.04	-1.02	1.01	-0.95*	-2.07**	-1.51**
$P_2\times P_6$	0.34	0.46	0.40	0.60	6.03	3.31	1.02	4.24	2.63	1.11**	0.85**	0.98**
$P_2\times P_7$	-2.18**	-2.26**	-2.22**	3.12	-6.77*	-1.83	0.64	-4.54	-1.95	0.79*	2.25**	1.52**
$P_3\times P_4$	-1.26*	-3.68**	-2.47**	-12.44**	-19.09**	-15.77**	-5.89**	-11.47**	-8.68**	-0.97**	-2.01**	-1.49**
$P_3\times P_5$	-0.52	0.40	-0.06	-8.84*	-12.23**	-10.54**	0.06	-0.90	-0.42	-1.81**	-3.07**	-2.44**
$P_3\times P_6$	-0.62	1.38*	0.38	18.08**	9.39**	13.73**	8.04**	8.86**	8.45**	2.25**	3.45**	2.85**
$P_3\times P_7$	-0.94	-0.94	-0.94	-4.30	1.09	-1.61	-4.84*	-1.67	-3.26	0.73*	1.55**	1.14**
$P_4\times P_5$	-0.06	2.04**	0.99	-1.60	4.85	1.62	6.06**	5.84*	5.95**	3.31**	4.15**	3.73**
$P_4\times P_6$	1.54**	2.82**	2.18**	6.52	12.67**	9.59**	2.79	0.35	1.57	0.17	-0.03	0.07
$P_4\times P_7$	-0.08	0.80	0.36	-6.16	-2.43	-4.30	-10.09**	-12.18**	-11.14**	0.85*	0.77*	0.81*
$P_5\times P_6$	2.68**	-1.20	0.74	-6.88	-2.47	-4.68	-5.76**	-2.93	-4.34	-1.57**	-0.59	-1.08**
$P_5\times P_7$	2.46**	3.08**	2.77**	-6.96	-4.57	-5.77	-1.89	-2.56	-2.22	-1.69**	-1.69**	-1.69**
$P_6\times P_7$	-1.34*	-2.04**	-1.69**	5.96	0.75	3.35	3.34	7.65**	5.50*	-1.43**	-2.27**	-1.85**
LSD 5% (s_{ij})	1.04	1.38	1.20	7.30	6.24	6.68	4.17	4.78	4.41	0.73	0.60	0.66
LSD 1% (s_{ij})	1.39	1.85	1.60	9.77	8.34	8.86	5.58	6.40	5.85	0.97	0.81	0.87
LSD 5% (s_{ij}-s_{ik})	1.61	2.14	1.87	11.31	9.66	10.35	6.46	7.41	4.84	1.13	0.93	1.02
LSD 1% (s_{ij}-s_{ik})	2.15	2.87	2.48	15.13	12.93	13.73	8.64	9.91	6.41	1.51	1.25	1.35
LSD 5% (s_{ij}-s_{kl})	1.39	1.86	1.62	9.80	8.37	8.97	5.59	6.42	5.92	0.98	0.81	0.88
LSD 1% (s_{ij}-s_{kl})	1.86	2.48	2.14	13.09	11.20	11.89	7.47	8.58	7.85	1.30	1.08	1.17

Table (5): Cont.

Crosses	**Ear diameter (cm)**			**No. of rows/ear**			**No. of kernels/row**			**Grain yield (ard/fed)**		
	N1	**N2**	**Comb.**	**N1**	**N2**	**Comb.**	**N1**	**N2**	**Comb.**	**N1**	**N2**	**Comb.**
$P_1 \times P_2$	-0.02	0.17	0.08	-0.23	-0.07	-0.15	0.06	-0.89	-0.42	0.62	1.94**	1.28
$P_1 \times P_3$	0.08	-0.11	-0.01	0.35	0.23	0.29	-1.74**	-2.49**	-2.12**	4.97**	4.66**	4.82**
$P_1 \times P_4$	0.20**	0.27*	0.24**	-0.84**	-0.33	-0.59*	1.28*	2.41**	1.84**	-2.14**	0.94	-0.60
$P_1 \times P_5$	0.18**	0.21*	0.20*	1.10**	0.99**	1.04**	0.26	1.35	0.80	-0.33	-2.12**	-1.23
$P_1 \times P_6$	-0.36**	-0.33**	-0.34**	0.35	-0.37	-0.01	1.44*	2.99**	2.21**	-2.05**	-3.68**	-2.87**
$P_1 \times P_7$	-0.08	-0.19	-0.13	-0.73**	-0.43	-0.58*	-1.28*	-3.35**	-2.32**	-1.08	-1.74**	-1.41*
$P_2 \times P_3$	-0.28**	0.03	-0.12	-0.93**	0.17	-0.38	0.48	-1.49*	-0.51	0.02	0.03	0.03
$P_2 \times P_4$	0.04	-0.09	-0.02	-0.12	-0.89**	-0.51*	-1.10	-2.59**	-1.85**	-1.29	-4.32**	-2.81**
$P_2 \times P_5$	-0.08	-0.49**	-0.28**	0.12	0.13	0.12	-2.62**	0.35	-1.14	-2.28**	-0.46	-1.37*
$P_2 \times P_6$	-0.02	-0.09	-0.05	-0.13	-0.93**	-0.53*	-1.94**	-1.01	-1.48*	0.17	0.69	0.43
$P_2 \times P_7$	0.36**	0.45**	0.41**	1.29**	1.61**	1.45**	5.14**	5.65**	5.39**	2.76**	2.12**	2.44**
$P_3 \times P_4$	-0.06	-0.21	-0.14	0.16	-0.09	0.03	0.02	0.51	0.26	-3.14**	-2.52**	-2.83**
$P_3 \times P_5$	0.02	-0.07	-0.02	-0.30	-1.17**	-0.74**	1.00	0.55	0.77	-4.83**	-4.35**	-4.59**
$P_3 \times P_6$	0.38**	0.33**	0.36**	1.15**	2.47**	1.81**	2.08**	1.89*	1.98**	4.06**	2.96**	3.51**
$P_3 \times P_7$	-0.14*	-0.03	-0.08	-0.43*	-1.59**	-1.01**	-1.84**	1.05	-0.40	-1.12	-0.77	-0.95
$P_4 \times P_5$	0.24**	0.61**	0.43**	0.66**	1.37**	1.01**	3.72**	4.15**	3.93**	5.36**	4.79**	5.07*
$P_4 \times P_6$	-0.40**	-0.29**	-0.34**	0.16	0.11	0.13	-2.60**	-2.41**	-2.51**	0.21	0.54	0.37
$P_4 \times P_7$	-0.02	-0.35**	-0.18*	-0.02	-0.15	-0.09	-1.32*	-2.05**	-1.69*	1.00	0.57	0.79
$P_5 \times P_6$	0.08	0.01	0.05	-1.50**	-1.57**	-1.54**	-0.32	-3.27**	-1.80**	0.65	0.91	0.78
$P_5 \times P_7$	-0.44**	-0.25	-0.34**	-0.08	0.27	0.09	-2.04**	-3.11**	-2.58**	1.43*	1.28*	1.36*
$P_6 \times P_7$	0.32**	0.35**	0.34**	-0.03	0.31	0.14	1.34*	1.83*	1.58*	-3.03**	-1.41*	-2.22**
LSD 5% (s_{ij})	0.12	0.21	0.17	0.42	0.58	0.50	1.20	1.46	1.31	1.43	1.28	1.34
LSD 1% (s_{ij})	0.17	0.28	0.22	0.56	0.78	0.66	1.60	1.95	1.74	1.92	1.71	1.78
LSD 5% (s_{ij}-s_{ik})	0.19	0.32	0.26	0.64	0.90	0.77	1.85	2.25	2.03	2.22	1.98	2.07
LSD 1% (s_{ij}-s_{ik})	0.26	0.43	0.35	0.86	1.21	1.02	2.48	3.02	2.69	2.97	2.66	2.75
LSD 5% (s_{ij}-s_{kl})	0.17	0.28	0.23	0.56	0.78	0.67	1.60	1.95	1.76	1.92	1.72	1.80
LSD 1% (s_{ij}-s_{kl})	0.22	0.37	0.30	0.75	1.04	0.89	2.14	2.61	2.33	2.57	2.30	2.38

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

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تحليل الهجن التبادلية لبعض سلالات من الذرة الشامية البيضاء تحت مستويين من التسميد النيتروجينى

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تم إجراء التهجين النصف تبادلي بين سبعة سلالات مرباه داخلياً من الذرة الشامية البيضاء في موسم ٢٠١٦م. تم تقيم الـ ٢١ هجين فردى الناتجة بالإضافة إلى هجين المقارنة (هجين فردى ١٣٠) فى تصميم القطاعات الكاملة العشوائية بثلاث مكررات تحت مستويين من التسميد النيتروجينى ٩٠ و ١٢٠ كجم نيتروجين/فدان بمزرعة كلية الزراعة - جامعة كفر الشيخ في موسم ٢٠١٧م. وذلك لتقدير تأثيرات القدرة العامة والخاصة على التآلف وتفاعلهما مع مستويات التسميد ولتحديد الفعل الجينى المتحكم في وراثة الصفات تحت الدراسة. تم دراسة الصفات التالية: عدد الأيام حتى ظهور ٥٠٪ من الحراير، ارتفاع النبات، ارتفاع الكوز، طول الكوز، قطر الكوز، عدد الصفوف/كوز، وعدد الحبوب/صف ومحصول الحبوب (أردب/فدان) .أظهرت النتائج أن التباين الراجع لكل من مستويي التسميد، التراكيب الوراثية، الهجن وتفاعل كلا من التراكيب الوراثية و الهجن مع مستويي التسميد كان معنوياً لجميع الصفات تحت الدراسة. كما أوضحت النتائج أن التباين الراجع للقدرة العامة والخاصة على التآلف كان معنوياً لجميع الصفات تحت الدراسة في كلا المستويين من التسميد والتحليل المشترك. تفاعلت كل من القدرة العامة والخاصة على التآلف معنوياً مع التسميد النيتروجينى لمعظم الصفات تحت الدراسة. كان الفعل الجيني غير المضيف هو الأكثر أهمية في وراثة جميع الصفات ما عدا صفة عدد الأيام حتى ظهور ٥٠٪ من الحراير تحت مستوى التسميد الأول (٩٠ كجم نيتروجين/فدان). أظهرت السلالات الأبوية $P_{١}$ و$P_{٧}$ أفضل القيم لتأثيرات القدرة العامة على الائتلاف للتبكير والسلالات P6 و P2 لقصر النبات وانخفض موقع الكوز بينما أظهرت السلالات الأبوية P_2 و P_3 و P_4 قدرة عامة جيدة على التآلف لصفة محصول الحبوب. كانت أفضل الهجن في تأثيرات القدرة الخاصة على التآلف هي $P_4\times P_7$, $P_3\times P_8$, $P_4\times P_5$ $P_5\times P_7$, $P_1\times P_3$ لصفة المحصول وواحد أو أكثر من مكوناته في كلا المستويين من التسميد والتحليل المشترك بينهم. تفوق محصول الهجينان $P_2\times P_7$ و $P_4\times P_5$ تفوقاً معنوياً على محصول هجين المقارنة (هجين فردى ١٣٠) في كلا المستويين من التسميد والتحليل المشترك بينهما.