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Evaluation of Combining Ability and Heterosis for Yield and its Components Traits of Five Maize Inbreds under Normal and Stress Nitrogen Fertilization

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ABSTRACT

A half diallel cross among 5 inbred lines of maize was evaluated under two different nitrogen rates for yield and yield components characters i.e., ears No. plant^{-1}, ear length, ear diameter, 100-kernel weight, grain yield plant^{-1} and shelling percentage to evaluate the role of GCA and SCA of inbred lines in hybrids performance under normal and stress of nitrogen levels and to establish the magnitude of heterosis. Mean squares of genotypes were highly significant for all studied traits under both nitrogen levels, except shelling percentage under normal nitrogen level. General and specific combining ability (GCA and SCA) mean squares were significant or highly significant for all studied traits, except shelling percentage under normal nitrogen level at GCA and SCA. GCA/SCA ratios revealed that the non-additive gene action for all studied traits under both nitrogen levels was detected. The best combiners were P_4 (Inb.204) and P_5 (Inb.213) for most of studied traits under normal and stress nitrogen levels. This result indicated that these inbred lines could be considered as good combiners for improving these traits. The best crosses for ears No. plant^{-1} were P_1 (Inb.84) ×P_3 (Inb.144) and P_3 (Inb.144) ×P_4 (Inb.204), for ear length was P2 (Inb.95) ×P_4 (Inb.204), for ear diameter was P_1 (Inb.84) ×P_5 (Inb.213), for 100-kernel weight was P_2 (Inb.95) ×P_4 (Inb.204) and for grain yield plant^{-1} was P_1 (Inb.84) ×P_3 (Inb.144) under both nitrogen levels. These crosses could be selected and used in breeding programs for improving these traits. Results showed significant or highly significant heterosis over mid or better parents for all studied traits, except shelling percentage under normal nitrogen level. The best crosses over both their mid-parents and better-parent for ears No. plant^{-1} was P_3 (Inb.144) ×P_4 (Inb.204), for ear length was P_2 (Inb.95) ×P_4 (Inb.204), for ear diameter was P_1 (Inb.84) ×P_5 (Inb.213), for 100-kernel weight was P_2 (Inb.95) ×P_4 (Inb.204), for grain yield plant^{-1} was P_1 (Inb.84) ×P_3 (Inb.144) under both nitrogen levels and for shelling percentage was P_1 (Inb.84) ×P_3 (Inb.144) under stress nitrogen level.

Key words: Maize, GCA, SCA, heterosis, nitrogen stress

INTRODUCTION

Based on area and production, maize is the 3rd most important cereal crop after wheat and rice, all over the world for production and consumption. In addition to its use as a human food, it is also utilized as a poultry and livestock feed. Moreover, it is also used for many industrial purposes.

Nitrogen is the most important nutritive element for the worldwide production of cereals (wheat, barley, rice, sorghum and maize). It is mostly supplied to the soil in the form of inorganic fertilizers and to a lesser extent as organic manure. A considerable portion of N-fertilizer is lost through gaseous plant emissions, soil denitrification, surface runoff, ammonia volatilization and leaching (Akintoye *et al*., 1999; Raun and Johnson, 1999).

The affordability of N in the developed countries has led to its misuse and over application (Raun and Johnson, 1999) and created growing environmental concerns from increased nitrate leaching that may lead to ground water contamination. In contrast, the rates of N fertilizers in most developing countries are considerably low because of the limited access to fertilizers and the low purchasing power of small farmers due a high fertilizer/cereal grain price ratio. El-Badawy (2013) found that nitrogen rates, genotype, parents, hybrids and parents vs. crosses mean squares were significant for all traits. Sallah *et al*. (1996) found that genotypic variance was greater at high N for grain yield and at low N for the other traits.

The two main genetic parameters of diallel analysis are GCA and SCA which are essential in developing breeding strategies. El-Absawy (2002) cleared that GCA mean squares were significant for grain yield per plant^{-1}, ear diameter and 100-grain weight and also added that the mean squares of SCA were significant for ear diameter and 100-grain weight. In this concern, several investigators reported that additive gene action was responsible for the inheritance of growth characters (Sedhom, 1994; Ahmed *et al*., 2000; Al-Naggar *et al*., 2002; Alamnie *et al*., 2006; El-Badawy, 2006). However, Dadheech and Joshi (2007), Barakat and Osman (2008) and Irshad-El-Haq *et al*. (2010) reported that non-additive gene action was more important in the inheritance of grain yield and most other agronomic traits in maize.

Therefore, the objectives of this study were to evaluate the role of GCA and SCA of inbred lines in hybrids performance and to establish the magnitude of heterosis under high and low nitrogen fertilization rates.

MATERIALS AND METHODS

Plant materials: Five inbred lines of corn (*Zea mays* L.) were used as parents in this study i.e., P_1(Inb. 84), P_2(Inb95), P_3(Inb. 144), P_4(Inb. 204) and P_5(Inb. 213). These inbred lines were obtained from Agriculture Research Center (ARC), Egypt.

Field experiments: The field trials were started in the 2011 growing season in the Experimental Farm of the Faculty of Agric., Mansoura Univ. and lasted in 2012. In 2011 growing season, the five parental inbred lines were planted on April 21st and May 7th and each inbred line was grown in two rows, to overcome the differences in flowering date and to secure enough hybrid seeds. During this season, all possible cross combinations, without reciprocals, were made giving a total of 10 F_1's hybrid seeds. In 2012 growing season, 16 entries (10 F_1's along with their 5 parental inbred lines plus one check cultivar (S.C.10)) were grown in two experiments representing two different nitrogen levels, which were 60 kg N fad^{-1} (stress) and 120 kg N fad^{-1} (normal) by using distance of 70 cm between ridges and 25 cm between hills. Each experiment was designated in a Randomized Complete Blocks Design (RCBD) with three replicates. Each plot consisted of one ridge three meters long. Hills were thinned after seedling emergence to secure one plant per hill. Each experiment was hoed twice, before first and second irrigations. Phosphorus in the form of calcium super phosphate (15.5% P_2O_5) at a rate of 200 kg fad^{-1}, was added to the soil during seedbed preparation and potassium sulphate (48% K_2O) at a level of 50 kg fad^{-1} was applied after thinning.

Moreover, nitrogen in the form of Urea (46% N) at a rate studied (60 and 120 kg N fad^{-1}) was added in two equal split doses, before the first and the second irrigation. Other agriculture practices were applied as recommended.

Studied traits: The following measurements were recorded: The ears No. plant^{-1}, ear length (cm), ear diameter (cm), 100-kernel weight (g), grain yield plant^{-1} (g) and shelling percentage.

Statistical analysis: The obtained data were statistically analyzed for analysis of variance by using computer statistical program MSTAT-C. The Ten single crosses comprise a half diallel among 5 inbred parents. Data of all 10 single crosses at each nitrogen level treatment were analyzed as randomized blocks. The sum squares of genotypes were partitioned to general and specific combining ability, following method 2 model 1 (fixed) of Griffing (1956).

RESULTS AND DISCUSSION

Results in Table 1 indicated that mean square of genotypes were highly significant for all studied traits under both nitrogen levels, except shelling percentage under normal nitrogen level. Mean squares of General Combining Ability (GCA) were significant or highly significant for all studied traits under both nitrogen levels, except shelling percentage under normal nitrogen level which was non-significant. Mean squares of Specific Combining Ability (SCA) were highly significant for all studied traits under both nitrogen levels, except shelling percentage under normal nitrogen level. The GCA/SCA ratio was less than unity for all studied traits, this means that these traits are predominantly controlled by non-additive gene action under both nitrogen levels, as shown in Table 1. Similar results were obtained by El-Hosary *et al.* (1994), Hoballah and Radwan (1996), Gado *et al.* (2000), Abdel-Moneam *et al.* (2009) and El-Badawy (2013).

Mean performance of traits: Means of ears No. plant^{-1} as affected by normal and stress nitrogen levels are presented in Table 2. The better parent in ears No. plant^{-1} was P_2(Inb.95) under both nitrogen levels. The better cross in ears No. plant^{-1} was $p_3 \times p_4$ under both nitrogen levels. The better parent in ear length was P_5 (Inb.213) under both nitrogen levels. The better cross in ear length was check S.C.10 under both nitrogen levels. The better parent in ear diameter was P_2(Inb.95) under both nitrogen levels. The better cross in ear diameter was $P_1 \times P_5$ under both nitrogen levels. The better parent in 100-kernel weight was P_1(Inb.84) under both nitrogen levels. The better cross in 100-kernel weight was check S.C.10 under both nitrogen levels. The better parent in grain yield plant^{-1} was P_4(Inb.204) under both nitrogen levels. The better cross in grain

Table 1: Mean squares of genotypes, GCA and SCA for studied maize yield and yield components traits under normal and stress nitrogen levels conditions

Traits		Ears No. plant^{-1}		Ear length (cm)		Ear diameter (cm)		100-Kernel weight (g)		Grain yield plant^{-1} (g)		Shelling percentage	
S.V.	d.f.	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Genotypes	14	0.26**	0.23**	29.06**	27.680**	11.27**	1.32**	32.69**	37.350**	27547.50**	18208.80**	19.11	23.98**
GCA	4	0.08**	0.06**	0.94**	0.970**	0.09**	0.06**	3.04**	6.310**	2657.70**	1822.70**	4.39	2.86*
SCA	10	0.09**	0.08**	3.19**	12.530**	0.56**	0.59**	14.04**	14.910**	11792.40**	7768.40**	7.16	10.05**
Error	28	0.00	0.00	0.10	0.140	0.00	0.00	0.470	0.620	51.47	46.23	6.42	0.84
GCA/SCA		0.89	0.75	0.07	0.080	0.16	0.10	0.220	0.420	0.23	0.23	0.61	0.20

*and**significant at 5 and 1% probability levels, respectively

Table 2: Means of studied traits for maize inbreds and their F1 crosses under normal and stress nitrogen levels conditions

Traits	Ears number plant^{-1}		Ear length (cm)		Ear diameter (cm)		100-Kernel weight (g)		Grain yield plant^{-1} (g)		Shelling percentage	
genotypes	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
P_1 (84)	1.07	0.93	16.80	15.07	3.52	3.23	39.27	35.00	42.90	32.20	77.09	75.02
P_2 (95)	1.33	1.20	16.23	14.13	3.72	3.42	33.33	30.27	60.30	51.70	79.86	77.83
P_3 (144)	1.20	1.07	17.30	15.03	3.52	3.22	35.63	32.10	57.30	44.10	80.04	75.40
P_4 (204)	1.13	1.00	16.57	14.40	3.15	2.92	34.67	29.27	72.50	57.50	75.65	74.34
P_5 (213)	1.33	1.07	19.23	16.73	3.53	3.25	36.63	33.97	42.40	34.50	76.97	73.42
Mean	1.21	1.05	17.23	15.07	3.49	3.21	35.91	32.12	55.10	44.00	77.92	75.20
$P_1 \times P_2$	1.07	1.00	22.33	19.83	5.00	4.67	40.00	35.87	179.6	143.6	80.23	78.75
$P_1 \times P_3$	1.67	1.53	23.40	20.93	4.77	4.43	42.33	40.37	312.8	254.2	85.17	83.80
$P_1 \times P_4$	1.47	1.33	23.20	20.77	4.68	4.50	40.33	36.97	292.1	247.7	84.49	82.10
$P_1 \times P_5$	1.00	1.00	23.53	21.20	5.08	4.77	42.33	40.17	163.8	134.4	79.75	79.52
$P_2 \times P_3$	1.40	1.27	24.13	21.33	4.85	4.68	43.00	38.07	204.5	163.8	81.99	80.08
$P_2 \times P_4$	1.73	1.47	23.87	21.83	4.58	4.40	42.67	39.13	190.1	144.5	80.19	79.11
$P_2 \times P_5$	1.40	1.13	23.47	21.73	4.82	4.52	41.33	38.20	195.7	145.2	80.66	79.38
$P_3 \times P_4$	1.87	1.80	23.63	20.87	4.57	4.37	41.33	37.40	307.2	242.3	81.11	79.36
$P_3 \times P_5$	1.67	1.60	23.53	21.37	4.77	4.60	44.00	40.03	228.3	176.7	81.09	78.67
$P_4 \times P_5$	1.87	1.60	23.10	21.40	4.57	4.35	41.67	37.57	221.5	178.6	80.15	78.99
Check S.C.10	1.80	1.47	26.33	23.53	5.07	4.80	44.63	41.10	315.3	239.6	80.78	76.67
Mean	1.54	1.48	23.68	21.34	4.80	4.56	42.15	38.63	237.4	188.2	81.42	79.68
L.S.D. 0.05	0.18	0.19	0.930	1.090	0.13	0.18	1.990	2.270	20.78	19.69	-	2.65
L.S.D 0.01	0.24	0.26	1.250	1.480	0.17	0.25	2.690	3.07	28.03	26.57	-	3.58

Table 3: Estimates of G.C.A. effects of five parents of maize genotypes for all studied yield and yield components traits

Traits	Ears No. plant^{-1}		Ear length (cm)		Ear diameter (cm)		100-Kernels weigh (g)		Grain yield plant^{-1} (g)		Shelling percentage	
parents	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
P_1 (Inb.84)	-0.16**	-0.12**	-0.3	-0.26	0.07**	0.04	0.60	0.80*	0.63	3.42	0.29	0.56
P_2 (Inb.95)	-0.03	-0.05	-0.27	-0.24	0.09**	0.08*	-0.83*	-0.85*	-19.90**	-17.13**	0.15	0.38
P_3 (Inb.144)	0.07*	0.10**	0.17	-0.01	-0.01	0.00	0.36	0.33	19.65**	14.95**	1.10	0.34
P_4 (Inb.204)	0.10**	0.09*	-0.17	-0.14	-0.19**	-0.15**	-0.59	-1.16*	18.99**	15.38**	-0.65	-0.29
P_5 (Inb.213)	0.02	-0.02	0.57**	0.64**	0.04*	0.03	0.46	0.88*	-19.37**	-16.62**	-0.88	-0.99*
S. E. (gi)1	0.02	0.02	0.11	0.13	0.01	0.02	0.23	0.27	2.43	2.30	0.86	0.31
S. E. (gi - gj)2	0.03	0.04	0.17	0.20	0.02	0.03	0.37	0.42	3.83	3.63	1.35	0.49

*, **Significant at 0.05 and 0.01 level of probability, respectively, S.E.(gi), standard error for an GCA effects, S.E.(gi-gj), standard error for the difference between two estimates of GCA effects

yield plant^{-1} was $P_1 \times P_3$ under stress nitrogen level and cross check S.C.10 under normal nitrogen level. It may indicated that grain yield plant^{-1} is greatly influenced by different agronomic treatments. Shelling percentage ranged from 73.42 to 77.83% under stress nitrogen level. The highest value was recorded by P_2(Inb.95) under stress nitrogen levels. Shelling percentage ranged from 76.67 to 83.80% under stress nitrogen level. The highest value was recorded by $P_1 \times P_3$ under stress nitrogen level. These results are in agreement with findings of Abdel-Moneam (2000), Soares *et al*. (2011) and El-Badawy (2013).

General combining ability: Based on GCA estimates, it could be concluded that the best combiners for ears No. plant^{-1} were inbred lines P_3 (Inb144) and P_4(Inb.204); for ear length was P_5(Inb.213); for ear diameter was P_2(Inb.95); for 100-kernel weight was P_5(Inb.213) and for grain yield plant^{-1} was P_3(Inb.144) and P_4 (Inb. 204) under both nitrogen levels, (Table 3). These results indicated that these inbred lines could be considered as good combiners for improving these traits.

Table 4: Estimates of S.C.A. effects of 10 single crosses maize for yield and yield component traits under normal and stress nitrogen levels

Traits	Ears No. $plant^{-1}$		Ear length (cm)		Ear diameter (cm)		100-Kernels weight (g)		Grain yield $plant^{-1}$ (g)		Shelling percentage	
crosses	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
$P_1 \times P_2$	-0.15*	-0.10	1.54**	1.22**	0.49**	0.45**	0.32	-0.38	27.21**	20.61**	-0.5	-0.57
$P_1 \times P_3$	0.34**	0.29**	2.17**	2.09**	0.36**	0.30**	1.46*	2.94**	120.89**	99.06**	3.49	4.52**
$P_1 \times P_4$	0.11	0.10	2.31**	2.05**	0.46**	0.52**	0.41	1.04	100.89**	92.17**	4.55	3.45**
$P_1 \times P_5$	-0.27**	-0.12	1.91**	1.70**	0.63**	0.61**	1.37*	2.19**	10.91	10.90	0.05	1.57
$P_2 \times P_3$	-0.06	-0.06	2.88**	2.47**	0.43**	0.52**	3.56**	2.29**	33.09**	29.24**	0.45	0.97
$P_2 \times P_4$	0.25**	0.16*	2.95**	3.10**	0.34**	0.38**	4.17**	4.86**	19.42*	9.47	0.4	0.64
$P_2 \times P_5$	0.00	-0.07	1.81**	2.22**	0.35**	0.32**	1.79*	1.88*	63.38**	42.25**	1.1	1.60
$P_3 \times P_4$	0.28**	0.34**	2.28**	1.91**	0.43**	0.43**	1.65*	1.94*	96.90**	75.19**	0.37	0.92
$P_3 \times P_5$	0.16**	0.25**	1.44**	1.63**	0.40**	0.48**	3.27**	2.53**	56.39**	41.67**	0.59	0.93
$P_4 \times P_5$	0.33**	0.27**	1.35**	1.79**	0.38**	0.39**	1.89*	1.56*	50.29**	43.10**	1.39	1.89*
S. E. (Sij)	0.05	0.06	0.28	0.33	0.04	0.06	0.6	0.69	6.26	5.93	2.2	0.80
S. E. (Sij-Sik)	0.08	0.09	0.42	0.49	0.06	0.08	0.9	1.03	9.39	8.90	3.32	1.20
S. E. (Sij-Skl)	0.07	0.08	0.38	0.45	0.05	0.08	0.82	0.94	8.57	8.13	3.03	1.10

*, **Significant at 0.05 and 0.01 level of probability, respectively, SE(Sij), standard error for an SCA effects, SE(Sij-Sik), standard error for the difference between two SCA effects for a common parent, SE(Sij-Skl), standard error for the difference between two SCA effects for a non-common parent

Specific combining ability effects (S_{ij}): Significant SCA effects were found in all studied traits for most crosses under both nitrogen levels (Table 4). Based on SCA effects, it could be concluded that under both nitrogen levels significant or highly significant positive SCA effects for ears No. $plant^{-1}$ was recorded with $P_1 \times P_3$, $P_2 \times P_4$, $P_3 \times P_4$, $P_3 \times P_5$ and $P_4 \times P_5$; for ear length and ear diameter were all studied crosses; for 100-kernel weight was $P_1 \times P_3$, $P_1 \times P_5$, $P_2 \times P_3$, $P_2 \times P_4$, $P_2 \times P_5$, $P_3 \times P_4$, $P_3 \times P_5$ and $P_4 \times P_5$; for grain yield $plant^{-1}$ was all studied crosses, except $P_1 \times P_5$ under both nitrogen levels and $P_2 \times P_4$ under stress nitrogen level and for shelling percentage was $P_1 \times P_3$, $P_1 \times P_4$ and $P_4 \times P_5$ under stress nitrogen level. These crosses could be selected and used in hybridization programs for improving these traits.

Heterosis over mid-parents and better-parent: Results showed that the highest positive and significant heterosis over mid-parents was demonstrated by cross $P_3 \times P_4$ (60.5 and 73.9%) followed by $P_4 \times_5$ (52 and 54.6%) under both normal and stress nitrogen levels, respectively. For better parent of ears No. $plant^{-1}$, cross $P_3 \times P_4$ (55.8 and 68.2%) followed by $P_4 \times P_5$ (40.6 and 49.5%) showed maximum positive and significant heterosis under both nitrogen levels, respectively. The highest positive significant heterosis over mid-parents were recorded by $P_2 \times P_4$ (45.5%) followed by $P_2 \times P_3$ (43.9%) under normal nitrogen level, whereas under stress nitrogen level, cross $P_2 \times P_4$ (53%) gave maximum over mid-parents for ear length followed by cross $P_2 \times P_3$ (46.3%). For better-parent of ear length under normal nitrogen level, cross $P_2 \times P_4$ (44.1%) showed maximum positive and significant heterosis followed by $P_2 \times P_3$ (39.5%), whereas under stress nitrogen level, maximum positive and highly significant heterosis of better-parent were showed by crosses $P_2 \times P_4$ (51.6%) followed by $P_2 \times P_3$ (41.9%). The highest positive significant heterosis over mid-parents was recorded by $P_1 \times P_5$ (44.1%) followed by $P_1 \times P_4$ (40.3%) under normal nitrogen level; whereas under stress nitrogen level, cross $P_1 \times P_5$ (47.2%) gave maximum over mid-parents for ear diameter followed by cross$P_1 \times P_4$ (46.3%). For better-parent of ear diameter under normal nitrogen level, cross $P_1 \times P_5$ (43.9%) showed maximum positive and significant heterosis followed by $P_1 \times P_3$ (35.5%); whereas under stress nitrogen level, maximum positive and highly significant heterosis of better-parent were showed by crosses

$P_1 \times P_5$ (46.8%) followed by $P_3 \times P_5$ (41.5%). The highest positive significant heterosis over mid-parents was recorded by $P_2 \times P_4$ (25.5%) followed by $P_2 \times P_3$ (24.7%) under normal nitrogen level, whereas under stress nitrogen level, cross $P_2 \times P_4$ gave maximum (31.4%) over mid-parents for 100-kernel weight followed by cross $P_2 \times P_3$ (22.1%). For better-parent of 100-kernel weight under both nitrogen levels, cross $P_2 \times P_4$ (23.1 and 29.3%) showed maximum positive and significant heterosis followed by $P_2 \times P_3$ (20.7 and 18.6%) under normal and stress nitrogen levels, respectively. For grain yield plant^{-1}, the highest positive significant heterosis over mid-parents was recorded by $P_1 \times P_3$ (524.2 and 566.5%) followed by $P_1 \times P_4$ (406 and 452.1%) under normal and stress nitrogen levels, respectively. For better-parent of grain yield plant^{-1} under both nitrogen levels, cross $P_1 \times P_3$ (445.9 and 476.7%) showed maximum positive and significant heterosis followed by $P_3 \times P_4$ (323.5%) and $P_1 \times P_4$ (330.6%), respectively. The highest positive significant heterosis over mid-parents was recorded under stress nitrogen level for cross $P_1 \times P_3$ (11.4%) over mid-parents for shelling percentage followed by cross $P_1 \times P_4$ (9.9%). For better- parent of shelling percentage under normal nitrogen level, cross $P_1 \times P_4$ (9.6%) showed maximum positive and significant heterosis; whereas under stress nitrogen level, cross $P_1 \times P_3$ (11.1%) showed maximum positive and significant heterosis followed by $P_1 \times P_4$ (9.4%). It could be concluded that cross $P_1 \times P_3$ recorded maximum positive and significant heterosis over mid and better-parents for shelling (%) under stress nitrogen level, (Table 5).

Table 5: Percentage of heterosis over mid-parent (M.P) and better parent (B.P) for F1 crosses of studied maize flowering and vegetative traits under normal and stress nitrogen levels

Traits	Ears No. plant^{-1}				Ear length (cm)			
	Normal		Stress		Normal		Stress	
Crosses	M.P.	B.P.	M.P.	B.P.	M.P.	B.P.	M.P.	B.P.
$P_1 \times P_2$	-10.0*	-19.5**	-6.1	-16.7*	35.2**	32.9**	35.8**	31.6**
$P_1 \times P_3$	47.1**	39.2**	53.0**	43.0**	37.2**	35.3**	39.1**	38.9**
$P_1 \times P_4$	33.6**	30.1**	37.8**	33.0**	39.0**	38.1**	41.0**	37.8**
$P_1 \times P_5$	-16.7	-24.8**	0.0	-6.5	30.6**	22.4**	33.3**	26.7**
$P_2 \times P_3$	10.7	5.3	11.9	5.8	43.9**	39.5**	46.3**	41.9**
$P_2 \times P_4$	40.7**	30.1**	33.6**	22.5**	45.5**	44.1**	53.0**	51.6**
$P_2 \times P_5$	5.3	5.3	-0.4	-5.8	32.4**	22.0**	40.8**	29.9**
$P_3 \times P_4$	60.5**	55.8**	73.9**	68.2**	39.5**	36.6**	41.8**	38.9**
$P_3 \times P_5$	32.0**	25.6**	49.5**	49.5**	28.8**	22.4**	34.6**	27.7**
$P_4 \times P_5$	52.0**	40.6**	54.6**	49.5**	29.1**	20.1**	37.5**	27.9**
L.S.D. at 5%	0.2	0.2	0.2	0.2	1.1	0.9	1.3	1.1
L.S.D. at 1%	0.3	0.2	0.3	0.3	1.5	1.3	1.8	1.5
Traits	Ear diameter (cm)				100-Kernels weight (g)			
	Normal		Stress		Normal		Stress	
Crosses	M.P.	B.P.	M.P.	B.P.	M.P.	B.P.	M.P.	B.P.
$P_1 \times P_2$	38.1**	34.4**	40.5**	36.5**	10.2**	1.9	9.9*	2.5
$P_1 \times P3$	35.5**	35.5**	37.4**	37.2**	13.0**	7.8**	20.3**	15.3**
$P_1 \times P_4$	40.3**	33.0**	46.3**	39.3**	9.1**	2.7	15.0**	5.6
$P_1 \times P_5$	44.1**	43.9**	47.2**	46.8**	11.5**	7.8**	16.5**	14.8**
$P_2 \times P_3$	34.0**	30.4**	41.0**	36.8**	24.7**	20.7**	22.1**	18.6**
$P_2 \times P_4$	33.3**	23.1**	38.8**	28.7**	25.5**	23.1**	31.4**	29.3**

Table 5: Continue

	Ear diameter (cm)				100-Kernels weight (g)			
	Normal		Stress		Normal		Stress	
Traits Crosses	M.P.	B.P.	M.P.	B.P.	M.P.	B.P.	M.P.	B.P.
$P_2 \times P_5$	33.0**	29.6**	35.5**	32.2**	18.2**	12.8**	18.9**	12.5**
$P_3 \times P_4$	37.0**	29.8**	42.3**	35.7**	17.6**	16.0**	21.9**	16.5**
$P_3 \times P_5$	35.3**	35.1**	42.2**	41.5**	21.8**	20.1**	21.2**	17.8**
$P_4 \times P_5$	36.8**	29.5**	41.0**	33.8**	16.9**	13.8**	18.8**	10.6**
L.S.D. at 5%	0.2	0.2	0.2	0.2	2.4	2.0	2.8	2.3
L.S.D. at 1%	0.3	0.2	0.3	0.3	3.3	2.7	3.7	3.1

	Grain yield/plant (g)				Shelling (%)			
	Normal		Stress		Normal		Stress	
Traits Crosses	M.P.	B.P.	M.P.	B.P.	M.P.	B.P.	M.P.	B.P.
$P_1 \times P_2$	248.0**	197.9**	242.4**	177.8**	2.2	0.5	3.0	1.2
$P_1 \times P_3$	524.2**	445.9**	566.5**	476.7**	8.4	6.4	11.4**	11.1**
$P_1 \times P_4$	406.0**	302.8**	452.1**	330.6**	10.6	9.6*	9.9**	9.4**
$P_1 \times P_5$	283.9**	281.6**	302.9**	289.3**	3.5	3.5	7.1**	6.0**
$P_2 \times P_3$	247.8**	239.3**	242.1**	216.8**	2.6	2.4	4.5*	2.9
$P_2 \times P_4$	186.3**	162.1**	164.5**	151.1**	3.1	0.4	4.0	1.6
$P_2 \times P_5$	281.3**	224.8**	236.8**	180.9**	2.9	1.0	5.0*	2.0
$P_3 \times P_4$	373.2**	323.5**	376.9**	321.1**	4.2	1.3	5.8*	4.8**
$P_3 \times P_5$	358.0**	298.4**	349.7**	301.0**	3.3	1.3	5.7*	4.3*
$P_4 \times P_5$	285.5**	205.4**	288.0**	210.4**	5.0	4.1	6.9**	6.3**
L.S.D at 5%	25.5	20.8	24.1	19.7	9.0	7.4	3.3	2.7
L.S.D. at 1%	34.3	28.0	32.5	26.5	12.1	9.9	4.4	3.6

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

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