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Exploitation of hybrid vigor for grain yield and other characters in maize (*Zea mays* L)

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ABSTRACT

An experiment was carried out in 8 × 8 diallel crosses for combining ability analysis without reciprocal of maize for grain yield, yield contributing characters, maturity and growth parameters. Analysis of variance for combining ability showed that mean square value due to GCA and SCA were highly significant for grain yield (t ha^{-1}), days to silking and ear height indicating that these traits were governed by both additive and non-additive gene action. Variances due to GCA were higher for all characters except thousand grain weight revealed that the predominance of additive gene action for all characters except thousand grain weight. Parent P8 was the best general combiner for yield and most of the yield contributing characters. Parent P1 and P4 were the best general combiner for dwarf and earliness in plant. Three crosses (P1 × P4, P2 × P3 and P4 × P8) showed positive and significant SCA effect for yield involving low × low, average × average and high × low general combining parents. Two crosses (P3 × P8 and P4 × P8) showed positive and significant heterosis in compare to standard check NK-40 and BHM 9.

Introduction

Hybrid maize has much higher yield potentiality than those of synthetics and composites. It is now gaining popularity among Bangladeshi farmers in an increasing rate to grow hybrids. The hybrid seeds currently being used are imported and involved huge amount of foreign currency. In the recent past, exploitation of hybrid vigor and selection of parents based on combining ability has been used as an important breeding approach in crop improvement. Developing of high yielding F_1 hybrids along with other favorable traits are receiving considerable attention. For developing good hybrids, information about combining ability of the parents and the resulting crosses is essential. The present study involving a 8 × 8 diallel analysis aimed to determine the better general combining parents and for isolation good cross combinations in maize for evolving suitable hybrids locally.

Materials and Methods

Eight inbred lines of maize viz. P_1 {BARI Introduced Line (BIL) 191}, P_2 (BIL 207), P_3 (BIL 170), P_4 (BIL 177), P_5 (BIL 190), P_6 {CIMMYT Maize Line (CML) 425}, P_7 (CML 423) and P_8 (CML 487) were crossed in all possible combinations excluding reciprocals in Rabi 2014-15 at BARI, Gazipur following Griffing's Method II model IV. (During rabi 2015-16, the 28 F1S produced from 8 parents) along with 2 local checks BHM9 and NK-40 were sown following Alpha Lattice Design with 2 replications on 13 November 2015. Spacing adopted was 60 × 25 cm between rows and hills, respectively. One healthy seedling per hill was kept after proper thinning. Fertilizers were applied @ 250, 55, 110, 40, 5 and 1.5 kg of N, P, K, S, Zn and B, respectively. Standard agronomic practices were followed and plant protection measures were taken when required. Ten randomly selected plants were used for recording observations on plant and ear height. Other data were recorded on whole plot basis. General combining ability (GCA) and specific combining ability (SCA) variances were estimated according to Giffing's (1956) method II and model IV. Percent heterosis was calculated by the formula as heterosis (%) = {(F1-CV)/CV} x 100. Where, F1 and CV represented the mean performances of hybrid and standard check variety. The estimated heterosis was tested according to Singh and Singh (1994).

Results and discussions

Analysis of variance

Analysis of variance for combining ability showed that mean square value due to GCA & SCA were highly significant for grain yield (t ha^{-1}), days to silking and ear height indicating that these traits were governed by both additive and non-additive gene action. Similar findings in maize were reported by Aguiar et al. (2004), Bhatnagar et al. (2004) and Motin et al. (2016). Significant GCA effect was found in cob girth, number of grain rows/ear and plant height which revealed that these characters were controlled by only additive gene action because of non-significant SCA effects were found in those traits. Ahmed (2013) & Akhi et al. (2016) also found similar phenomenon in their study. Non- significant GCA effects and significant SCA effects were observed for cob length, number of grains/row, TGW, days to tasseling and days to maturity indicated that these traits were governed by only non-additive gene action. Kadir (2010) and Hoque et al. (2016) also observed non-additive gene action for some traits of maize in their experiment. Variances due to GCA were much higher in magnitude than SCA for all characters except thousand grain weight. This indicated the preponderance of additive gene action for all characters except thousand grain weight which seemed to be controlled by non-additive gene action. Uddin et al. (2006) and Ahmed (2013) also reported greater GCA effects than SCA effects for some characters in maize.

General combining ability effects

The GCA effects of the parents for different characters are presented in Table 3. A wide range of variability for GCA effects was observed among the parents for different traits. The parent P_8 showed highly significant and positive GCA effects for yield, cob girth and number of grain rows per ear. Sharma et al. (1982) reported that parents with good general combiners for grain yield generally shows good performance for various yield components. Similar views have been given by Malik et al. (2004), Ahmed et al. (2008) and Abdel-Moneam et al. (2009). Significant and positive GCA was observed in P_2 for thousand grain weight, in P_4 for cob length and number of grains per row, in P_5 for number of grain rows per ear. So, the parent P_2, P_5 and P_8 could be used to develop high yielding maize hybrid. Hoque et al. (2016) and Kumar and Babu (2016) also found some promising parents for grain yield and yield related characters in maize. For maturity and growth parameters, significant and negative GCA effect is desirable for dwarf and earliness in plant. Highly significant and negative GCA effects were observed in P_1 for days to 50% tasseling, days to 50% silking, days to maturity plant height and ear height, in P_2 for days to 50% tasseling, in P_3 for plant height, P_4 for days to 50% tasseling, days to 50% silking, days to maturity and ear height. So, the parent P_1 and P_4 could be used to develop early maturing dwarf hybrid. Akhi et al. (2016) and Motin et al. (2016) also observed negative and significant GCA effects for earliness and dwarfness in maize plants in their studies.

Specific combining ability effects

The specific combining ability for different characters are presented in Table 4. For yield and yield component, significant and positive SCA is desirable. Three crosses ($P_1 \times P_4$, $P_2 \times P_3$ and $P_4 \times P_8$) exhibited significant positive SCA effect for grain yield involving low × low, average × average and high × low general combining parents. High estimates of SCA effects of these hybrids indicate the preponderance of non-additive gene action revealing their potential exploitation in terms of grain yield (Anyanwu, 2013). Amiruzzaman et al. (2013) and Ahmed (2013) also reported significant SCA effects in some crosses involving the parents of average x average, average x low and low x low general combining parents for grain yield. Significant and positive SCA effects were observed in $P_2 \times P_3$, $P_2 \times P_6$, $P_3 \times P_6$, $P_4 \times P_8$, $P_5 \times P_8$ and $P_7 \times P_8$ for thousand grain weight, $P_2 \times P_5$, $P_3 \times P_7$ and $P_3 \times P_8$ for cob length, $P_4 \times P_5$ for number of grain rows/ ear and $P_4 \times P_8$ & $P_6 \times P_8$ for number of grains/row. Akhi et al. (2016) and Ahmed and Amiruzzaman (2010) also observed positive and significant SCA effects for the said characters in their maize experiment. Although the cross $P_3 \times P_8$ involved high x average general combiners, exhibited non-significant SCA effect but noticed 1st highest mean value for grain yield (Table 2). The cross $P_4 \times P_8$ involved high x low general combining parents but showed 3rd highest SCA effects and possessed 2nd highest mean value for yield. The GCA effects of the parents were not reflected of SCA effects of the crosses in most of the studied traits. This is corroborated with several findings of Debnath and Sarker (1987), Paul and Debnath (1999) and Hussain et al. (2003). On the other hand, Ram et al. (2015) found the best cross as the cross recorded positive and significant SCA effect, high heterosis and high per se performance for grain yield and other important traits.

For maturity and growth parameters negative SCA is desirable for dwarf and earliness in maize plant. Significant and negative SCA effects were observed in high yielding hybrid P3 x P8 for days to tasseling and ear height, in P4 x P8 for days to tasseling, days to silking and maturity. Significant & negative SCA effects were observed in 8 crosses for days to 50% tasseling, 7 crosses for days to 50% silking, 6 crosses for days to maturity, 2 crosses for plant height and 5 crosses for ear height. Uddin (2006), Amiruzzaman (2010) & Kumar and Babu (2016) also observed significant and negative SCA effects in some crosses for maturity and growth parameters in maize.

Heterosis

The percent standard heterosis expressed by F_1 hybrids over the commercial hybrid check variety are presented in Table 5. For yield, the percent standard heterosis is expressed by F_1 hybrids over both the commercial hybrid check varieties. Other than yield, rest of the characters was compared with highest yielding check variety NK-40. The degree of heterosis in F_1 hybrids varied from characters to characters or from cross to cross.

Significant and negative heterosis is desirable for maturity and growth parameters for a breeder. Negative heterosis is desirable for plant height and ear height which helps for developing short statured plant leading tolerant to lodging. Heterosis ranged for grain yield was -49.19 to 15.34%. Only two crosses ($P_3 \times P_8$ & $P_4 \times P_8$) exhibited significant and positive heterosis over both the check varieties. The cross P_3 x P_8 showed 10.32% and 15.34% heterosis over NK 40 & BHM 9, respectively. The cross P_4 x P_8 showed 9.31% and 14.29% heterosis over NK 40 & BHM 9, respectively. Akhi et al. (2016) also found the percent of standard heterosis varied from -37.73 to 0.84% in case of grain yield and found significant and positive heterosis in only two crosses for it. Hoque et al. (2016) also found the percent of standard heterosis varied from -43.26 to 8.18% in case of grain yield and found significant and positive heterosis in only two crosses for it. The cross $P_3 \times P_8$ showed significant positive heterosis for number of grains/row also. The cross $P_4 \times P_8$ had significant positive heterosis for cob length, cob girth, TGW and number of grains/row also. Appreciable percentage of heterosis for cob length, cob girth, TGW and number of grains/row were also observed by Kumar and Babu (2016) and Ahmed (2013) and Ahmed and Amiruzzaman (2016). Negative heterosis is desirable for plant height and ear height which helps for developing short statured plant leading tolerant to lodging. Heterosis for different crosses ranged from -26.42 to 6.29% and -40.0 to 6.71%, respectively, for plant and ear height. Sixteen crosses exhibited significant and negative heterosis for plant height and twenty one crosses showed significant and negative heterosis in respect to ear height. Significant and negative heterosis for both these traits was observed in 16 crosses. This result was corborated with Alam et al. (2008) and Amiruzzaman (2010). Out of 28 crosses, 27 crosses showed significant and negative heterosis for days to 50% tasseling, days to 50% silking and days to maturity. Similar results were also observed by Ahmed (2013), Hoque et al. (2016).

Conclusion

The parent P_2, P_5 & P_8 could be used to develop high yielding maize hybrid. Parent P_1 & P_4 were the good general combiner for both dwarf & earliness in plant. The cross $P_3 \times P_8$ and $P_4 \times P_8$ could be used as commercial variety after verifying them in different locations.

Table 1. Analysis of variance for yield, yield Components, maturity and growth parameters

Source	d.f	Mean square										
		Cob length (cm)	Cob girth (cm)	Grain row/ear (no.)	Grain/ear (no.)	1000 grain wt (g)	Yield (t ha^{-1})	Days to tasseling	Days to silking	Days to maturity	Plant height (cm)	Ear height (cm)
Rep	1	0.29	0.45	1.78	7.14	1197.87**	0.10	11.16**	13.01**	16.07**	157.78	2.57
Crosses	27	3.80**	1.33*	2.42**	26.79**	1409.12**	4.07**	29.23**	28.92**	12.16*	599.46**	338.51**
GCA	7	2.92	1.57**	2.70**	22.85	502.07	5.19**	25.50	26.33*	7.09	960.57**	259.72**
SCA	20	1.53**	0.35	0.69	10.09**	775.21**	0.93**	10.80**	10.31**	5.72**	68.43	49.92**
Error	27	0.45	0.29	0.45	3.79	85.62	0.13	0.56	0.32	0.35	38.83	6.66
GCA/SCA		1.90	4.48	3.91	2.26	0.65	5.58	2.36	2.55	1.23	14.03	5.20

*,** indicates significant at 5% and 1% respectively

Table 2. Mean Value for yield; yield Components, maturity and growth parameters

Crosses	CL	CG	R/E	G/R	TGW	Yield(t/ha)	Days to tasseling	Days to silking	Days to maturity	Plant height(cm)	Ear height(cm)
$P_1 \times P_2$	13.5	12.0	13	25.0	325	5.5	74	78	134	122	51
$P_1 \times P_3$	14.0	11.5	12	27.0	324	6.3	76	81	136	121	68
$P_1 \times P_4$	14.0	12.0	12	27.0	335	7.5	72	78	134	124	51
$P_1 \times P_5$	12.0	11.5	14	21.5	355	6.5	76	83	136	117	50
$P_1 \times P_6$	13.5	12.0	11	25.5	375	5.0	72	75	133	123	48
$P_1 \times P_7$	12.5	12.0	13	24.0	400	6.9	80	83	136	117	52
$P_1 \times P_8$	13.5	13.5	14	23.5	297	7.8	72	77	135	146	74
$P_2 \times P_3$	14.5	12.0	14	29.5	360	9.1	77	82	136	151	64
$P_2 \times P_4$	15.0	12.0	14	27.5	363	6.9	78	83	138	157	70
$P_2 \times P_5$	16.0	13.0	13	27.0	335	8.1	77	83	135	162	72
$P_2 \times P_6$	12.5	11.5	13	24.5	393	7.6	76	81	134	164	75
$P_2 \times P_7$	14.5	13.0	14	27.0	326	7.5	77	84	136	165	70
$P_2 \times P_8$	15.0	14.0	15	29.5	334	10.3	79	84	137	169	77
$P_3 \times P_4$	14.0	12.0	13	26.5	334	5.2	79	83	135	131	61
$P_3 \times P_5$	16.0	13.0	14	30.5	327	8.0	78	83	135	137	58
$P_3 \times P_6$	16.0	13.0	12	31.0	374	8.0	81	84	136	138	67
$P_3 \times P_7$	16.0	12.0	14	32.5	290	6.9	79	85	135	139	60
$P_3 \times P_8$	14.5	13.0	14	29.5	325	10.9	79	84	137	146	65
$P_4 \times P_5$	14.5	12.5	16	33.0	340	7.4	77	82	135	139	55
$P_4 \times P_6$	15.0	12.0	14	28.5	330	7.3	75	80	135	146	55
$P_4 \times P_7$	15.0	13.0	13	30.5	323	8.1	78	82	136	161	64
$P_4 \times P_8$	18.0	14.5	14	37.5	386	10.8	78	82	133	163	77
$P_5 \times P_6$	14.5	13.0	14	27.0	341	8.0	76	81	134	121	57
$P_5 \times P_7$	14.0	13.5	14	30.0	345	8.8	74	80	134	157	74
$P_5 \times P_8$	14.5	13.5	14	29.0	360	8.0	90	84	145	163	83
$P_6 \times P_7$	14.0	13.0	13	29.5	370	8.7	82	88	140	159	72
$P_6 \times P_8$	17.0	14.0	14	34.5	351	10.1	83	89	140	162	82
$P_7 \times P_8$	12.5	12.5	16	22.0	361	9.7	81	87	139	160	74
BHM9	15.0	13.0	14	29.0	356	9.5	93	95	146	197	101
NK 40	16.0	14.0	14	24.0	380	9.9	91	93	143	159	80
Overall mean	14.57	12.72	13.64	28.1	347.17	8.01	78.67	83.13	136.6	147.2	66.9

CL=Cob length (cm), CG=Cob girth (cm), R/E= Grain row/ear (no.), G/R=Grain/row (no.), TGW= 1000 grain wt. (g)

Table 3. General combining ability effect for yield, yield Components, maturity and growth parameters

Entry	TGW	CL	CG	R/E	G/R	Yield (t ha^{-1})	Days to tasseling	Days to silking	Days to maturity	Plant height (cm)	Ear height (cm)
P_1	-1.5625**	-1.4167**	-0.6875*	-1.0417**	-4.00**	-1.465**	-3.77**	-3.93**	-1.17**	-24.2**	-10.42**
P_2	2.6875**	-0.0533	-0.1875	0.125	-1.2500	-0.0417	-1.104**	-0.6	-0.41	12.46**	3.75**
P_3	-14.1458**	0.5833	-0.3542	-0.375	1.500	-0.0642	0.9792*	0.48	-0.41	-8.63**	2.41*
P_4	-1.4792**	0.6667*	0.1042	0.125	2.167*	-0.3508*	-1.19**	-1.44**	-1.17**	0.96	-3.92**
P_5	-2.8125**	-0.6667*	0.2292	0.625*	0.0833	-0.0892	0.57	0.97**	0.25	-3.047	-1
P_6	-19.1042**	0.1667	-0.0208	-0.7083*	0.500	-0.0775	0.06	-0.1	0.08	-0.38	0.08
P_7	-0.7292**	-0.5	0.0625	0.2917	-0.333	0.2242	1.31**	1.64**	0.67	7.29*	1.42
P_8	-0.0625	0.5837	1.0625**	0.9583**	1.333	1.91**	3.15**	2.98**	2.17**	15.54**	12.5**
SE(gi)	3.53	0.26	0.207	0.256	0.743	0.136	0.286	0.217	0.226	2.38	0.986
LSD (0.05)	8.35	0.614	0.489	0.605	1.75	0.321	0.676	0.513	0.534	5.62	2.33
LSD (0.01)	12.36	0.909	0.724	0.895	2.59	0.475	0.998	0.759	0.790	8.32	3.45

*,** indicates significant at 5% and 1% respectively
CL=Cob length (cm), CG=Cob girth (cm), R/E=Grain row/ear (no.), G/R=Grain/row (no.) TGW=1000 grain wt. (g)

Table 4. Specific combining ability effects for yield, yield Components, maturity and growth parameters

Entry	TGW	CL	CG	R/E	G/R	Yield (t ha^{-1})	Days to tasseling	Days to silking	Days to maturity	Plant height (cm)	Ear height (cm)
$P_1 \times P_2$	-21.6*	0.5	0.21	0.3	2.03	-0.93**	1.07	-0.04	-0.2	-11.5*	-7.83**
$P_1 \times P_3$	-6.27	0.33	-0.11	-0.19	1.29	0.14	1.49*	1.87**	1.3**	9.08	15.33**
$P_1 \times P_4$	-7.94	0.25	0.13	-0.69	0.61	1.48**	0.85	0.79	0.55	2.5	0.33
$P_1 \times P_5$	13.39	-1.08	-0.7	0.8	-2.8	0.15	1.4*	2.87**	1.73**	-1	-3.58
$P_1 \times P_6$	11.97	0.25	0.04	-0.85	0.79	-0.51	-2.6	-3.05**	1.7	2.33	-7.17**
$P_1 \times P_7$	6.8	-0.08	-0.03	0.14	0.12	0.24	4.65**	2.7	0.71	-10.83	-41
$P_1 \times P_8$	-46.36**	-0.17	0.46	0.48	-2.05	-0.56	-5.18**	-5.13**	-1.73**	9.41	6.92**
$P_2 \times P_3$	25.98**	-0.5	-0.11	0.64	1.03	1.47**	-0.68	-0.46	0.55	1.91	-2.83
$P_2 \times P_4$	15.8	-0.08	-0.37	0.14	-1.63	-0.59	2.49**	2.45**	3.3	-1.67	5.17*
$P_2 \times P_5$	-10.36	1.58*	0.3	-1.35*	-0.05	0.35	-0.26	0.46	-0.61	6.83	4.25
$P_2 \times P_6$	25.73**	-2.08**	-0.95	-0.02	-2.96	-0.27	-0.77	-0.88	-1.45**	7.16	6.17*
$P_2 \times P_7$	-21.94*	0.58	0.46	-0.02	0.37	0.58	-1.01*	0.36	-0.54	0.5	-0.67
$P_2 \times P_8$	-13.6	-1.17	0.46	-0.3	1.2	0.55	-0.85	-0.96	-1.04*	-4.25	-4.25
$P_3 \times P_4$	4.14	-1.75**	-0.2	-0.35	-5.38**	-2.03**	1.4	1.37**	0.3	-6.08	2.33
$P_3 \times P_5$	-1.52	0.92	0.46	0.14	0.7	0.46	-1.35*	-1.05*	-1.11	3.92	-3.58
$P_3 \times P_6$	23.56**	0.75	0.71	-0.52	0.79	0.3	2.15**	1.04*	0.54	1.75	3.83
$P_3 \times P_7$	-40.6**	1.42*	-0.37	0.48	3.12	-0.89**	-0.6	-0.21	-1.04*	-4.42	4.5
$P_3 \times P_8$	-5.27	2.25**	-0.37	-0.19	1.55	0.53	-2.43**	2.55**	-0.54	-6.16	-10.58**
$P_4 \times P_5$	-1.19	0.67	-0.28	1.64**	2.54	-0.12	-0.18	-0.13	-0.37	-3.67	-5.58*
$P_4 \times P_6$	-33.1**	-0.17	-0.54	0.98	2.38	-0.35	-1.68*	-1.55**	0.29	0.17	-6.17*
$P_4 \times P_7$	-20.27*	-0.17	0.38	-1.02	0.45	0.29	0.57	-0.8	0.21	7.5	1
$P_4 \times P_8$	42.55**	-208**	0.88	-0.69	5.79**	1.33**	-1.76*	-2.13**	-4.28**	1.25	2.92
$P_5 \times P_6$	-21.27*	-0.33	0.13	0.48	-1.8	0.08	-2.43**	-2.96**	-2.61**	-20.33**	-6.08
$P_5 \times P_7$	2.55	0.63	0.55	-0.52	2.04	0.8	-5.68**	-5.71**	-2.7	8	8.58
$P_5 \times P_8$	18.39	0.34	0.45	-1.19*	-2.63	-1.71**	8.48**	7.45**	6.29**	5.25	6
$P_6 \times P_7$	6.14	0.72	0.29	-1.19*	1.11	0.5	2.82**	3.86**	3.46**	6.83	5
$P_6 \times P_8$	-13.02	0.83	0.29	0.14	4.45**	0.22	2.48**	3.53**	1.46**	2.08	4.42
$P_7 \times P_8$	17.3	0.29	-1.29*	1.14	-7.21**	-0.36	-0.76	-0.21	-0.99	-7.58	5.42*
SE(gi)	7.82	0.576	0.459	0.56	1.644	0.3	0.634	0.481	0.5	5.27	2.18
LSD (0.05)	16.31	1.201	0.957	1.18	3.429	0.26	1.32	1.003	1.04	10.99	4.54
LSD (0.01)	22.24	1.638	1.305	1.61	3.75	0.85	1.80	1.368	1.42	14.99	6.20

*,** indicates significant at 5% and 1%, respectively
CL= Cob length (cm), CG= Cob girth (cm), R/E= Grain row/ear (no.), G/R= Grain/row (no.) TGW= 1000 grain wt. (g)

Table 5. Heterosis for yield, yield Components, maturity and growth parameters

Crosses	Yield (t ha^{-1})	Yield (t ha^{-1})	CL	CG	TGW	R/E	G/R	Days to tasseling	Days to silking	Days to maturity	Plant height (cm)	Ear height (cm)
	Compare to NK 40	Compare to BHM 9										
$P_1 \times P_2$	-44.33**	-41.80**	-15.63**	-14.29**	-14.47**	-8.45**	4.17	-18.68**	-16.13**	-6.29**	-23.27**	-36.25**
$P_1 \times P_3$	-36.23**	-33.33**	-12.50**	-17.86**	-14.74**	-15.49**	12.50**	-16.48**	-12.90**	-4.90**	-23.90**	-15**
$P_1 \times P_4$	-24.09**	-20.63**	-12.50**	-14.29**	-11.84**	-15.49**	12.50**	-20.88**	-16.13**	-6.29**	-22.01**	-36.25**
$P_1 \times P_5$	-34.21**	-31.22**	-25.00**	-17.86**	-6.58**	-1.41	-10.42**	-16.48**	-10.75**	-4.90**	-26.42**	-37.5**
$P_1 \times P_6$	-49.19**	-46.88**	-15.63**	-14.29**	-1.32	-22.54**	6.25	-20.88**	-19.35**	-6.99**	-22.64**	-40**
$P_1 \times P_7$	-30.16**	-26.98**	-21.88**	-14.29**	5.26**	-8.45**	0.00	-12.09**	-10.75**	-4.90**	-26.42**	-35**
$P_1 \times P_8$	-21.05**	-17.46**	-15.63**	-3.57**	-21.84**	-1.41	-2.08	-20.88**	-17.20**	-5.59**	-8.18**	-7.5**
$P_2 \times P_3$	-8.10**	-3.92	-9.38**	-14.29**	-5.26**	-1.41	22.92**	-15.38**	-11.83**	-4.90**	-5.03**	-20**
$P_2 \times P_4$	-30.16**	-26.98**	-6.25**	-14.29**	-4.47**	-1.41	14.58**	-14.29**	-10.75**	-3.50**	-1.26	-12.5**
$P_2 \times P_5$	-18.02**	-14.29**	0.00	-7.14**	-11.84**	-8.45**	12.50**	-15.38**	-10.75**	-5.59**	1.89	-10**
$P_2 \times P_6$	-23.08**	-19.58**	-21.88**	-17.86**	3.42*	-8.45**	2.08	-16.48**	-12.90**	-6.29**	3.14	-6.25**
$P_2 \times P_7$	-24.09**	-20.63**	-9.38**	-7.14**	-14.21**	-1.41	12.50**	-15.38**	-9.68**	-4.90**	3.77	-12.5**
$P_2 \times P_8$	4.25	8.99**	-6.25**	0.00	-12.11**	5.63**	22.92**	-13.19**	-9.68**	-4.20**	6.29**	-3.75
$P_3 \times P_4$	-47.37**	-44.97**	-12.50**	-14.29**	-12.11**	-8.45**	10.42**	-13.19**	-10.75**	-5.59**	-17.61**	-23.75**
$P_3 \times P_5$	-18.83**	-15.13**	0.00	-7.14**	-13.95**	-1.41	27.08**	-14.29**	-10.75**	-5.59**	-13.84**	-27.5**
$P_3 \times P_6$	-18.72**	-15.03**	0.00	-7.14**	-1.58	-15.49**	29.17**	-10.99**	-9.68**	-4.90**	-13.21**	-16.25**
$P_3 \times P_7$	-30.16**	-26.98**	0.00	-14.29**	-23.68**	-1.41	35.42**	-13.19**	-8.60**	-5.59**	-12.58**	-25**
$P_3 \times P_8$	10.32**	15.34**	-9.38**	-7.14**	-14.47**	-1.41	22.92**	-13.19**	-9.68**	-4.20**	-8.18**	-18.75**
$P_4 \times P_5$	-25.61**	-22.22**	-9.38**	-10.71**	-10.53**	12.68**	37.50**	-15.38**	-11.83**	-5.59**	-12.58**	-31.25**
$P_4 \times P_6$	-26.21**	-22.86**	-6.25**	-14.29**	-13.16**	-1.41	18.75**	-17.58**	-13.98**	-5.59**	-8.18**	-31.25**
$P_4 \times P_7$	-18.32**	-14.60**	-6.25**	-7.14**	-15.00**	-8.45**	27.08**	-14.29**	-11.83**	-4.90**	1.26	-20**
$P_4 \times P_8$	9.31**	14.29**	12.50**	3.57**	1.58**	-1.41	56.25**	-14.29**	-11.83**	-6.99**	2.52	-3.75
$P_5 \times P_6$	-19.23**	-15.56**	-9.38**	-7.14**	-10.26**	-1.41	12.50**	-16.48**	-12.90**	-6.29**	-23.90**	-28.75
$P_5 \times P_7$	-10.93**	-6.88**	-12.50**	-3.57**	-9.21**	-1.41	25.00**	-18.68**	-13.98**	-6.29**	-1.26	-7.5
$P_5 \times P_8$	-18.83**	-15.13**	-9.38**	-3.57**	-5.26**	-1.41	20.83**	-1.10	-9.68**	1.40**	2.52	3.75
$P_6 \times P_7$	-11.94**	-7.94**	-12.50**	-7.14**	-2.63	-8.45**	22.92**	-9.89**	-5.38**	-2.10**	0.00	-10
$P_6 \times P_8$	2.23	6.88**	6.25**	0.00	-7.63**	-1.41	43.75**	-8.79**	-4.30**	-2.10**	1.89	2.5
$P_7 \times P_8$	-2.02	2.43	-21.88**	-10.71**	-5.00**	12.68**	-8.33*	-10.99**	-6.45**	-2.80**	0.63	-7.5
Mean	-20.17	-16.54	-8.04	-8.42	-9.03	-4.17	17.26	-14.60	-11.44	-4.87	-8.80	-18.48
Std. Error	2.95	3.08	1.50	1.16	1.32	1.46	3.38	0.77	0.63	0.33	2.06	2.42
Min.	-49.19	-46.88	-25.00	-14.29	-23.69	-22.53	-29.17	-20.87	-19.35	-6.99	-26.41	-40
Max.	10.32	15.34	12.5	7.14	5.26	12.67	58.33	-1.09	-4.30	1.39	6.28	3.75
CD(0.05)	6.05	6.32	3.08	2.39	2.70	3.00	6.95	1.59	1.28	0.68	4.22	4.97
CD(0.01)	8.17	8.54	4.16	3.22	3.65	4.05	9.38	2.15	1.74	0.92	5.71	6.71

**,* indicates significant at 1% and 5% respectively
CL= Cob length (cm), CG= Cob girth (cm), R/E= Grain row/ear (no.), G/R= Grain/row (no.) TGW= 1000 grain wt. (g).

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