Quantitative Analysis of Heterosis and Combining Ability in Maize Hybrids Using Line × Tester Analysis

Deleted: : Significance for Breeding and Genetic Improvement

ABSTRACT

Fifty hybrids were obtained by crossing twenty five lines with two testers and were evaluated to study heterosis and combining ability for kernel yield per plant and its components traits. The experiment was laid out in simple lattice design with two replications during *kharif* 2019 at Agricultural Research Station, Peddapuram, East Godavari District, Andhra Pradesh. Heterosis studies revealed that 12 out of 50 crosses recorded significant positive relative heterosis, five out of 50 crosses registered significant positive heterobeltiosis and single cross exhibited significant positive heterosis over the standard check DHM117 for the trait kernel yield per plant. The cross PDM1732 × BML6 recorded significant heterosis over mid parent, better parent and standard check in desirable direction for kernel yield per plant. Out of the 25 lines evaluated in the present investigation, the line PDM1733 for protein content and kernel yield per plant was found to be good general combiner in desirable direction and can be utilized as parent for production of good hybrids by crossing with other divergent lines and can also be employed in the development of synthetic varieties. None of the fifty crosses recorded significant *sca* effect for kernel yield per plant.

Commented [H1]: a single

Commented [H2]: It is required to identify more than one inbred lines with high general combining ability for grain yield and recommend including it in a crossbreeding program to produce hybrids according to Diallel Crosses .

Commented [H3]: It is changed throughout the manuscript to grain yield

Key words: Maize, Line x Tester analysis, Heterosis and Combining ability

1. INTRODUCTION

Maize, also known as corn, is a cereal grain of origin Southern America, belongs to the family Poaceae and is a versatile crop with wider genetic variability. It is one of the most important cereal crops grown next to rice and wheat in area and production across the world. Globally, maize is known as “queen of cereals” because of its high genetic yield potential among the cereals. The success of any crop improvement programme depends on the selection of elite genotypes. In this perspective, L x T analysis (Kempthome, 1957) has widely been used to evaluate inbred lines by crossing them with testers. Combining ability is the ability of the genotypes to combine among each other during hybridization process such that desirable characters are transmitted to their progenies. It helps in the selection of desirable parents for hybridization and also in the identification of superior cross combinations. The *gca* effect gives the measure of additive gene action and helps in identification of best combiners (parents) for hybridization. The *sca* effect gives the measure of non-additive gene action and helps in the identification of superior hybrid combinations for the commercial exploitation of heterosis. Information on *gca* effects helps a breeder to exploit existing variability in breeding materials to choose genotypes having desirable characters and to distinguish relatedness among the breeding materials (Sprague and Tatum, 1942). The *sca* effects help breeders to determine heterotic patterns among populations or

Deleted: for evaluation of

inbred lines to identify promising single crosses and assign them into heterotic groups (Lahane *et al.*, 2014). Studies on the magnitude of heterosis in hybrids are helpful in the assessment of the ability of lines to transmit their desirable alleles to hybrids through hybridization. Keeping all these in view, an experiment was conducted to study *gca* effects, *sca* effects and magnitude of heterosis for kernel yield and its component traits.

2. MATERIAL AND METHODS

The experimental material consisted of 50 hybrids obtained by crossing 25 inbred lines of maize with two testers in Line × Tester design along with four checks. The experiment was laid out in simple lattice design with two replications during *kharif* 2019 at ARS, Peddapuram, East Godavari District, Andhra Pradesh. Each entry was sown in two rows of 4 m length with a spacing of 70 cm between the rows and 20 cm between the plants within the rows. The observations were recorded for 12 traits *viz*., Days to 50% tasseling, Days to 50% silking, Days to maturity, Plant height (cm), Ear placement height (cm), Ear length (cm)**,** Ear girth (cm), Kernel rows per ear, number of kernels per row, Test weight (g), Protein content (%) and kernel yield per plant (g) were recorded. Line x Tester analysis was carried out according to Kempthorne (1957). The heterosis was estimated in terms of three parameters, *i.e*. relative heterosis, heterobeltiosis and standard heterosis. The estimates of general and specific combining ability and their variances were obtained by using covariance of half sibs and full sibs. The relative importance of general and specific combining ability can be assessed by estimating the components of variance and expressed in the ratio $2\sigma^2$ gca / $2\sigma^2$ gca + σ^2 sca (Baker, 1978).

Deleted: of

Commented [H4]: State the type of tester used: whether it is hybrid, synthetic variety, or other

3. RESULTS AND DISCUSSION

Analysis of variance for combining ability of 12 quantitative traits under study is represented in Table1. The results revealed that variance due to females (lines) was highly significant for all characters under study except for days to maturity and protein content while variance due to males (testers) and female × male interaction none of them were significant.

Table 1. Analysis of variances for combining ability for grain yield and yield component traits in maize (*Zea mays* L.)

Source	d.f.	Days to 50% Tasseling	Days to 50% Silking	Plant Height (cm)	Ear Placement Height (cm)	Days to Maturity	Ear Length (cm)	Ear Girth (cm)	Kernel Rows Ear^{-1}	Number of Kernels Row^{-1}	Test Weight (g)	Protein Content (%)	Kernel Yield per Plant (g)
Replications	1	0.65	0.03	314.29	166.23	1.10	10.97*	1.68	0.07	27.86	84.39*	247.37**	2709.59**
Treatments	76	2.43**	3.09**	651.64**	308.87**	2.43**	4.27**	2.59**	3.48**	30.07**	33.64**	6.35	952.33**
Parents	26	3.12**	3.90**	891.81**	399.39**	0.12	7.11**	3.67**	4.92**	49.72**	34.80**	5.71	1215.62**
Lines	24	3.36**	4.15**	952.42**	420.83**	0.13	7.43**	3.74**	5.14**	53.68**	34.61**	6.03	1290.52**
Testers	1	0.25	1.00	225.00	225.00	0.00	3.61	0.56	1.00	0.09	39.06	1.69	544.52
Lines *vs.* Testers	1	0.03	1.00	104.04	59.26	0.04	3.01	5.22	3.72	4.26	35.20	2.04	89.08
Crosses	49	1.74	2.33	451.58**	247.39**	2.72**	2.53	0.90	1.93	9.84	31.56**	6.05	598.05*
Parents *vs.* Hybrids	1	18.35**	19.28**	4210.06**	967.84**	48.21**	15.75**	57.55**	42.49**	510.23**	105.27**	37.40*	11466.46**
Error	76	1.37	1.62	148.17	92.88	0.40	1.63	0.99	1.78	13.52	14.99	6.61	381.28
Total	153	1.89	2.34	399.34	200.65	1.41	3.00	1.79	2.61	21.83	24.71	8.05	680.16

D.f. : Degrees of freedom ** Significant at 1% level * Significant at 5% level

Table 2. Estimates of genetic components of variance and proportional contribution of lines, testers and line × tester interactions to total variance for different characters in maize (*Zea mays* L.)

Characters	σ^2gca	σ^2sca	$2\sigma^2$gca/ $2\sigma^2$gca + σ^2sca	Contribution of Lines (%) (female)	Contribution of testers (%) (male)	Contribution of Line x tester (%) (female x male)
Days to 50% tasseling	0.0027	0.3572	0.0149	36.98	19.71	43.31
Days to 50% silking	-0.0010	0.6678	-0.0030	44.42	5.04	50.54
Plant height (cm)	0.2972	171.2978**	0.0035	51.33	2.09	46.58
Ear placement height (cm)	0.3068	79.6152**	0.0076	29.21	26.33	44.46
Days to maturity	0.0275	0.0656	0.4561	84.25	3.63	12.12
Ear length (cm)	0.0008	0.6084	0.0026	52.16	0.00	47.84
Ear girth (cm)	0.0011	0.2266	0.0096	55.26	0.17	44.58
Kernel rows ear^{-1}	0.0048	0.3020	0.0308	52.20	7.90	39.90
Number of kernels row^{-1}	-0.0034	2.0463	-0.0033	43.27	6.50	50.23
Test weight (g)	-0.0004	9.9193	-0.0001	49.74	1.23	49.03
Protein content (%)	-0.0038	1.2378	-0.0062	45.74	3.01	51.26
Kernel yield per plant (g)	-1.6459	181.8483**	-0.0184	36.99	3.99	59.02

The parents *vs.* hybrids mean sum of squares were found to be significant for all the twelve characters under study which suggested the presence of considerable amount of heterosis in crosses for majority of the characters (Table 1). The nature of gene action determines the choice of an efficient breeding method for incorporation of concerned genes into new materials. The ratio of *gca* variance to total genetic variance was low indicating the predominance of non additive gene action for all the characters under study (Table 2).

The proportional contribution of lines, testers and their interaction to total hybrid variances for the twelve characters are represented in Table 2. The contribution towards total hybrid variance was found to be higher from females (lines) than males (testers) for all the 12 characters under study. The proportional contribution of Line x Tester interaction to the total variance was higher than that of males for all the 12 characters. Whereas, the contribution of the Line x Tester interaction was higher than that of females for days to 50% tasseling, days to 50% silking, ear placement height, number of kernels row^{-1}, protein content and kernel yield per plant, but was lower than that of females for plant height, days to maturity, ear length, ear girth, kernel rows ear^{-1} and test weight. This indicates that specific cross combinations interact significantly to develop the *per se* values for important characters of kernel yield.

The general combining ability effects of parents for all the characters studied are represented in Table 3. Out of the 25 lines in the present investigation, significant *gca* effects in desirable direction were recorded by the line PDM3F for days to 50% tasseling, lines PDM3F and PDM5F for days to 50% silking, lines PDM6F, PDM1730 and PDM1733 for plant height, the line PDM1729 for ear placement height, the line PDM1732 for ear length, test weight and kernel yield per plant, the line PDM5F for ear girth, the line PDM1733 for protein content and kernel yield per plant. Nine lines were found to be good general combiners for days to maturity. Whereas, the tester BML6 recorded significant *gca* effects in desirable direction for days to 50% tasseling, ear placement height and days to maturity. This combining ability is not fixed property of the line but it depends upon the tester population used (Rissi and Hallauer, 1991). The results of specific combining ability effects of crosses for all the traits studied are represented in Table 4. Among the fifty 50 combinations, the cross PDM7M × BML7 recorded significant *sca* effects

Table 3. Estimates of general combining (*gca*) effects of lines and testers for different characters in maize (*Zea mays* L.)

Parents	Days to 50% Tasseling	Days to 50% Silking	Plant Height (cm)	Ear Placement Height (cm)	Days to Maturity	Ear Length (cm)	Ear Girth (cm)	Kernel Rows Ear^{-1}	Number of Kernels Row^{-1}	Test Weight (g)	Protein Content (%)	Kernel Yield per Plant (g)
LINES												
PDM1M	-0.86	-0.99	5.20	4.70	2.42**	0.16	0.69*	0.33	-0.27	2.70	0.13	5.3
PDM1F	0.14	0.01	2.70	-0.30	0.67	0.37	0.12	-0.67	0.68	-0.30	0.53	-3.04
PDM3M	-0.36	-0.99	-29.8**	-4.05	-0.08	-1.29*	-0.78*	0.03	-0.52	-4.43*	-1.99*	-15.87
PDM3F	-1.11*	-1.24*	-9.8*	5.95	-0.08	-0.13	0.19	-0.17	1.18	2.25	0.88	11.63
PDM4F	1.39**	1.26*	6.45	5.95	0.42	-0.48	-0.78*	0.63	1.58	-5.88**	-0.98	-10.71
PDM5F	-0.86	-1.24*	5.20	4.70	2.17**	-1.09	0.77*	-0.22	-0.72	3.37	0.43	2.96
PDM6M	-0.11	0.26	2.70	3.45	-0.08	-0.18	-0.06	0.93	0.73	-0.83	0.88	1.79
PDM6F	-0.11	1.01	13.95**	4.70	0.67	0.21	0.17	0.33	1.23	-0.13	1.3	1.79
PDM7M	0.39	0.26	-13.55**	-7.80	0.67	0.82	-1.16**	-1.77**	1.13	0.22	0.92	-11.29
PDM7F	-0.61	-0.99	6.45	-1.55	-0.08	0.32	0.67*	-0.07	0.48	-0.65	0.8	6.63
PDM9M	-0.86	-0.24	1.45	-4.05	0.92*	-0.69	0.44	0.88	-0.72	0.10	0.26	0.8
PDM1729	-0.11	0.01	6.45	10.95**	0.17	0.42	-0.03	0.63	2.18	-2.53	1.09	4.3
PDM1730	-0.11	-0.74	13.95**	8.45*	-0.08	0.41	-0.61*	0.03	1.73	-4.00*	0.87	-12.87
PDM1732	0.39	0.01	7.70	-1.55	0.42	1.97**	-0.31	-1.42**	-0.72	7.67**	0.49	24.79*
PDM1733	-0.11	-0.24	15.20**	7.20	1.67**	1.06	0.44	-0.07	1.13	3.40	2.01*	23.96*
PDM1734	0.39	0.51	-1.05	-1.55	0.42	0.12	-0.26	0.13	0.53	-1.35	-0.88	-2.71
PDM1735	0.39	0.76	-3.55	-12.80**	-0.83*	-0.69	0.52	0.93	-1.62	-1.80	-1.23	-7.87
PDM1736	0.64	1.01	-9.8*	-6.55	-1.58**	0.24	-0.46	-0.75	-2.92*	1.10	-3.2**	6.3
PDM1737	0.14	0.01	1.45	-5.30	-1.08**	0.96	-0.16	-0.47	1.78	2.02	0.56	7.79
PDM1738	-0.36	-0.49	1.45	7.20	-1.08**	-0.23	0.37	0.63	-1.02	-1.83	-0.91	-5.37
PDM1739	0.39	0.51	8.95	-4.05	-1.33**	0.26	-0.08	-0.57	-2.22	2.22	-1.35	1.3
PDM1740	0.14	0.01	-19.80**	-1.55	-1.08**	-1.84	-0.21	0.83	-3.27*	-0.38	-0.62	-16.21
PDM1741	0.14	0.76	-9.80*	-1.55	-1.08**	-0.54	0.37	0.18	-1.27	0.07	-1.03	-7.29
PDM1742	0.39	0.26	-8.55	-1.55	-1.08**	-0.79	-0.21	0.53	0.43	-1.23	0.59	-9.21
PDM1743	0.64	0.51	6.45	-9.05*	-1.08**	0.62	0.34	-0.77	0.53	0.22	0.42	3.13
CD at 5 %	1.29	1.47	13.24	11.49	1.05	1.59	0.86	1.40	3.48	4.87	2.792	26.85
CD at 1 %	1.72	1.96	17.66	15.31	1.40	2.12	1.14	1.86	4.64	6.50	3.7226	35.80
S.Em±	0.64	0.73	6.59	5.71	0.52	0.79	0.43	0.69	1.73	2.42	1.389	13.35

Table 3 (cont.)

TESTERS	Days to 50% Tasseling	Days to 50% Silking	Plant Height (cm)	Ear Placement Height (cm)	Days to Maturity	Ear Length (cm)	Ear Girth (cm)	Kernel Rows Ear^{-1}	Number of Kernels Row^{-1}	Test Weight (g)	Protein Content (%)	Kernel Yield per Plant (g)
BML6	-0.41**	-0.24	2.15	5.65**	-0.22*	-0.01	0.03	0.27	0.56	-0.44	-0.3	3.42
BML7	0.41**	0.24	-2.15	-5.65**	0.22*	0.01	-0.03	-0.27	-0.56	0.44	0.3	-3.42
CD at 5 %	0.37	0.42	3.75	3.25	0.30	0.45	0.24	0.39	0.98	1.38	0.79	7.59
CD at 1 %	0.49	0.55	4.99	4.33	0.39	0.60	0.32	0.53	1.31	1.84	1.05	10.13
S.Em±	0.18	0.21	1.86	1.62	0.15	0.22	0.12	0.20	0.49	0.69	0.39	3.78

** Significant at 1% level * Significant at 5% level

Table 4. Estimates of specific combining ability (*sca*) effects of hybrids for different characters in maize (*Zea mays* L.)

S. No.	Crosses	Days to 50% Tasseling	Days to 50% Silking	Plant Height (cm)	Ear Placement Height (cm)	Days to Maturity	Ear Length (cm)	Ear Girth (cm)	Kernel Rows Ear^{-1}	Number of Kernels Row^{-1}	Test Weight (g)	Protein Content (%)	Kernel Yield per Plant (g)
1.	PDM1M × BML6	-0.34	-0.51	4.10	5.60	0.22	-0.14	0.22	0.73	1.44	-4.31	0.81	1.08
2.	PDM1M × BML7	0.34	0.51	-4.10	-5.60	-0.22	0.14	-0.22	-73.00	-1.44	4.31	-0.81	-1.08
3.	PDM1F × BML6	-0.34	-0.01	-0.90	10.60	-0.53	-0.64	0.45	0.33	0.09	-0.06	-0.09	7.08
4.	PDM1F × BML7	0.34	0.01	0.90	-10.60	0.53	0.64	-0.45	-0.33	-0.09	0.06	0.09	-7.08
5.	PDM3M × BML6	-0.34	-0.51	29.10**	14.35*	-0.28	1.61*	1.15**	0.43	2.79	4.26	1.69	26.58
6.	PDM3M × BML7	0.34	0.51	-29.10**	-14.35*	0.28	-1.61*	-1.15**	-0.43	-2.79	-4.26	-1.69	-26.58
7.	PDM3F × BML6	-0.09	-0.26	1.60	1.85	0.72	1.26	-0.13	-0.37	0.79	1.64	0.72	14.41
8.	PDM3F × BML7	0.09	0.26	-1.60	-1.85	-0.72	-1.26	0.13	0.37	-0.79	-1.64	-0.72	-14.41
9.	PDM4F × BML6	0.41	0.74	-14.65*	-8.15	-0.78	-1.09	-0.30	1.03	-1.61	-4.24	-1.25	-24.59
10.	PDM4F × BML7	-0.41	-0.74	14.65*	8.15	0.78	1.09	0.30	-1.03	1.61	4.24	1.25	24.59
11.	PDM5F × BML6	0.16	0.24	4.10	0.60	-0.03	-0.09	0.30	-0.02	-0.21	1.51	2	-2.59
12.	PDM5F × BML7	-0.16	-0.24	-4.10	-0.60	0.03	0.09	-0.30	0.02	0.21	-1.51	-2	2.59
13.	PDM6M × BML6	0.41	0.24	-0.90	-5.65	-0.28	-0.59	0.02	-0.27	-1.06	-0.99	-0.74	1.91
14.	PDM6M × BML7	-0.41	-0.24	0.90	5..65	0.28	0.59	-0.02	0.27	1.06	0.99	0.74	-1.91
15.	PDM6F× BML6	-0.59	-1.01	-4.65	0.60	-0.53	0.51	0.00	-0.47	1.14	-2.49	-1.79	-5.42
16.	PDM6F × BML7	0.59	1.01	4.65	-0.60	0.53	-0.51	0.00	0.47	-1.14	2.49	1.79	5.42
17.	PDM7M × BML6	1.41*	1.74*	-19.65**	-6.90	0.47	-1.39	-0.73	-0.17	-2.26	-4.74	-2.35	-25.67
18.	PDM7M × BML7	-1.41*	-1.74*	19.65**	6.90	-0.47	1.39	0.73	0.17	2.26	4.74	2.35	25.67
19.	PDM7F × BM 6	0.41	-0.01	-7.15	-5.65	-0.28	-0.19	0.25	0.73	-1.41	0.74	-0.11	2.75
20.	PDM7F × BML7	-0.41	0.01	7.15	5.65	0.28	0.19	-0.25	-0.73	1.41	-0.74	0.11	-2.75
21.	PDM9M × BML6	0.16	0.24	2.85	-0.65	-0.28	-0.69	0.27	0.08	-1.11	-0.06	0.35	-7.09
22.	PDM9M × BML7	-0.16	-0.24	-2.85	0.65	0.28	0.69	-0.27	-0.08	1.11	0.06	-0.35	7.09
23.	PDM1729 × BML6	0.41	0.49	17.85**	11.85*	0.47	0.81	-0.20	-0.17	2.49	-0.94	0.79	6.75
24.	PDM1729 × BML7	-0.41	-0.49	-17.85**	-11.85*	-0.47	-0.81	0.20	0.17	-2.49	0.94	-0.79	-6.75
25.	PDM1730 × BML6	-1.09	-1.26	2.85	4.35	-0.78	0.31	0.12	-0.17	1.74	3.04	1.67	10.58
26.	PDM1730 × BML7	1.09	1.26	-2.85	-4.35	0.78	-0.31	-0.12	0.17	-1.74	-3.04	-1.67	-10.58
27.	PDM1732 × BML6	-0.09	-0.01	6.60	-0.65	0.22	0.66	0.12	-0.32	-0.61	4.76	0.23	15.25
28.	PDM1732 × BML7	0.09	0.01	-6.60	0.65	-0.22	-0.66	-0.12	0.32	0.61	-4.76	-0.23	-15.25
29.	PDM1733 × BML6	-0.59	-0.26	-0.90	8.10	-0.53	0.76	0.07	0.53	2.64	-1.46	0.08	0.41
30.	PDM1733 × BML7	0.59	0.26	0.90	-8.10	0.53	-0.76	-0.07	-0.53	-2.64	1.46	-0.08	-0.41
31.	PDM1734 × BML6	0.41	0.99	-7.15	-3.15	0.22	-1.29	0.37	1.53*	-1.66	-3.71	-2.06	-10.92

Table 4 (cont.)

S. No.	Crosses	Days to 50% Tasseling	Days to 50% Silking	Plant Height (cm)	Ear Placement Height (cm)	Days to Maturity	Ear Length (cm)	Ear Girth (cm)	Kernel Rows Ear^{-1}	Number of Kernels Row^{-1}	Test Weight (g)	Protein Content (%)	Kernel Yield per Plant (g)
32.	PDM1734 × BML7	-0.41	-0.99	7.15	3.15	-0.22	1.29	-0.37	-1.53*	1.66	3.71	2.06	10.92
33.	PDM1735 × BML6	-0.59	-0.76	-2.15	-4.40	0.47	-0.49	-0.90*	-0.87	-1.51	-3.61	-0.34	-20.42
34.	PDM1735 × BML7	0.59	0.76	2.15	4.40	-0.47	0.49	0.90*	0.87	1.51	3.61	0.34	20.42
35.	PDM1736 × BML6	-0.34	-0.51	-18.40**	-15.65**	0.22	0.83	0.02	0.05	-0.81	1.79	-0.58	18.41
36.	PDM1736 × BML7	0.34	0.51	18.40**	15.65**	-0.22	-0.83	-0.02	-0.05	0.81	-1.79	0.58	-18.41
37.	PDM1737 × BML6	-0.84	-1.01	-2.15	-4.40	0.22	0.66	0.07	-0.67	1.99	0.71	-0.05	15.25
38.	PDM1737 × BML7	0.84	1.01	2.15	4.40	-0.22	-0.66	-0.07	0.67	-1.99	-0.71	0.05	-15.25
39.	PDM1738 × BML6	-0.84	-0.51	-4.65	-1.90	0.22	0.26	-0.60	0.03	-0.71	-0.14	-0.15	-8.59
40.	PDM1738 × BML7	0.84	0.51	4.65	1.90	-0.22	-0.26	0.60	-0.03	0.71	0.14	0.15	8.59
41.	PDM1739 × BML6	0.91	1.49*	0.35	-5.65	-0.03	-0.44	-0.05	-0.17	-2.71	3.01	-2.2	-6.25
42.	PDM1739 × BML7	-0.91	-1.49*	-0.35	5.65	0.03	0.44	0.05	0.17	2.71	-3.01	2.2	6.25
43.	PDM1740 × BML6	0.16	-0.01	4.10	1.85	0.22	0.36	-0.43	-0.97	-0.76	3.76	1.55	-1.42
44.	PDM1740 × BML7	-0.16	0.01	-4.10	-1.85	-0.22	-0.36	0.43	0.97	0.76	-3.76	-1.55	1.42
45.	PDM1741 × BML6	1.16	1.24	6.60	1.85	0.22	-0.84	-0.70	-1.12	-0.36	-1.94	0.23	-18
46.	PDM1741 × BML7	-1.16	-1.24	-6.60	-1.85	-0.22	0.84	0.70	1.12	0.36	1.94	-0.23	18
47.	PDM1742 × BML6	-0.09	-0.26	10.35	11.85*	0.22	-0.19	0.62	0.53	1.34	0.96	1.86	6.91
48.	PDM1742 × BML7	0.09	0.26	-10.35	-11.85*	-0.22	0.19	-0.62	-0.53	-1.34	-0.96	-1.86	-6.91
49.	PDM1743 × BML6	0.16	-0.51	-7.15	-10.65	0.22	0.11	-0.03	-0.17	0.34	2.51	-0.28	3.58
50.	PDM1743 × BML7	-0.16	0.51	7.15	10.65	-0.22	-0.11	0.03	0.17	-0.34	-2.51	0.28	-3.58
	C.D. at 5%	1.83	2.08	18.73	16.24	1.48	2.25	1.21	1.97	4.92	6.89	3.95	37.98
	C.D. at 1%	2.43	2.77	24.97	21.66	1.97	3.00	1.61	2.63	6.57	9.19	5.26	50.63
	S.Em±	0.91	1.03	9.32	8.08	0.74	1.12	0.60	0.98	2.45	3.43	1.96	18.89

** Significant at 1% level * Significant at 5% level

Table 5. Average heterosis, heterobeltiosis and standard heterosis for grain yield and yield contributing characters in maize (*Zea mays* L.)

Crosses	Days to 50% Tasseling			Days to 50% Silking			Plant Height (cm)		
	Average Heterosis	Heterobeltiosis	Standard Heterosis DHM117	Average Heterosis	Heterobeltiosis	Standard Heterosis DHM117	Average Heterosis	Heterobeltiosis	Standard Heterosis DHM117
PDM1M × BML6	-5.68*	-5.68*	-5.68*	-5.49*	-5.49	-4.44	10.08	5.97	14.52*
PDM1M × BML7	-1.71	-2.27	-2.27	-1.11	-2.2	-1.11	7.32	6.45	6.45
PDM1F × BML6	-3.41	-3.41	-3.41	-2.2	-2.2	-1.11	15.25*	1.49	9.68
PDM1F × BML7	0.57	0.00	0.00	0	-1.1	0.00	19.64*	9.84	8.06
PDM3M × BML6	-4.55	-4.55	-4.55	-5.49*	-5.49	-4.44	17.54*	0	8.06
PDM3M × BML7	-0.57	-1.14	-1.14	-1.11	-2.2	-1.11	-22.22**	-31.15**	-32.26**
PDM3F × BML6	-6.21**	-6.74*	-5.68*	-6.01*	-6.52*	-4.44	0.79	-4.48	3.23
PDM3F × BML7	-3.41	-4.49	-3.41	-2.76	-4.35	-2.22	0.83	0	-1.61
PDM4F × BML6	0	-1.11	1.14	1.64	1.09	3.33	1.59	-4.48	3.23
PDM4F × BML7	0.56	-1.11	1.14	0.55	-1.09	1.11	23.33**	21.31**	19.35**
PDM5F × BML6	-6.15**	-7.69**	-4.55	-6.45*	-8.42**	-3.33	16.39*	5.97	14.52*
PDM5F × BML7	-4.49	-6.59*	-3.41	-5.43*	-8.42**	-3.33	13.79	8.2	6.45
PDM6M × BML6	-2.82	-3.37	-2.27	-1.64	-2.17	0.00	7.09	1.49	9.68
PDM6M × BML7	-2.27	-3.37	-2.27	-0.55	-2.17	0.00	10.74	9.84	8.06
PDM6F× BML6	-2.89	-4.55	-4.55	-1.11	-2.2	-1.11	5.97	5.97	14.52*
PDM6F × BML7	2.33	1.15	0.00	5.62*	5.62	4.44	14.06*	8.96	17.74**
PDM7M × BML6	2.30	1.14	1.14	2.2	2.2	3.33	-21.17***	-22.86**	-12.90*
PDM7M × BML7	-1.73	-2.3	-3.41	-3.33	-4.4	-3.33	3.82	-2.86	9.68
PDM7F × BM 6	-2.86	-3.41	-3.41	-3.87	-4.4	-3.33	0.75	0	8.06
PDM7F × BML7	-2.3	-2.3	-3.41	-1.68	-2.22	-2.22	11.81	7.58	14.52*
PDM9M × BML6	-2.33	-4.55	-4.55	-1.11	-2.2	-1.11	6.15	2.99	11.29
PDM9M × BML7	-0.58	-2.3	-3.41	0	0	-1.11	4.84	3.17	4.84
PDM1729 × BML6	-1.71	-2.27	-2.27	-0.55	-1.1	0.00	26.23**	14.93*	24.19**
PDM1729 × BML7	-1.15	-1.15	-2.27	-0.56	-1.11	-1.11	5.17	0	-1.61
PDM1730 × BML6	-4.6	-5.68*	-5.68*	-5.56*	-6.59*	-5.56*	1.37	-6.33	19.35**

Table 5 (cont.)

Crosses	Days to 50% Tasseling			Days to 50% Silking			Plant Height (cm)		
	Average Heterosis	Heterobeltiosis	Standard Heterosis DHM117	Average Heterosis	Heterobeltiosis	Standard Heterosis DHM117	Average Heterosis	Heterobeltiosis	Standard Heterosis DHM117
PDM1730 × BML7	2.89	2.3	1.14	2.25	2.25	1.11	0	-11.39	12.90*
PDM1732 × BML6	-2.27	-2.27	-2.27	-3.26	-4.3	-1.11	6.57	4.29	17.74**
PDM1732 × BML7	0.57	0.00	0.00	-1.1	-3.23	0.00	0.76	-5.71	6.45
PDM1733 × BML6	-2.89	-4.55	-4.55	-1.68	-3.3	-2.22	7.35	5.8	17.74**
PDM1733 × BML7	2.33	1.15	0.00	1.69	1.12	0.00	10.77	4.35	16.13*
PDM1734 × BML6	0.58	-1.14	-1.14	2.79	1.1	2.22	-5.88	-7.25	3.23
PDM1734 × BML7	1.16	0	-1.14	0.56	0	-1.11	4.62	-1.45	9.68
PDM1735 × BML6	-2.86	-3.41	-3.41	-2.2	-2.2	-1.11	19.27**	-2.99	4.84
PDM1735 × BML7	2.3	2.3	1.14	3.33	2.2	3.33	26.21**	6.56	4.84
PDM1736 × BML6	-1.15	-2.27	-2.27	-0.55	-1.1	0.00	-20.00**	-23.29**	-9.68
PDM1736 × BML7	2.89	2.3	1.14	3.91	3.33	3.33	2.99	-5.48	11.29
PDM1737 × BML6	-8.70**	-12.50**	-4.55	-9.38**	-13.86**	-3.33	11.67	0	8.06
PDM1737 × BML7	-2.73	-7.29**	1.14	-3.16	-8.91**	2.22	17.54*	9.84	8.06
PDM1738 × BML6	-5.14*	-5.68*	-5.68*	-3.33	-4.4	-3.33	1.54	-1.49	6.45
PDM1738 × BML7	1.15	1.15	0.00	1.12	1.12	0.00	9.68	7.94	9.68
PDM1739 × BML6	0	0	0.00	2.76	2.2	3.33	2.9	0	14.52*
PDM1739 × BML7	-1.71	-2.27	-2.27	-1.68	-2.22	-2.22	4.55	-2.82	11.29
PDM1740 × BML6	-2.82	-3.37	-2.27	-3.26	-4.3	-1.11	-6.15	-8.96	-1.61
PDM1740 × BML7	-1.14	-2.25	-1.14	-1.1	-3.23	0.00	-9.68	-11.11	-9.68
PDM1741 × BML6	-1.68	-3.3	0.00	0.54	-1.06	3.33	10	-1.49	6.45
PDM1741 × BML7	-4.49	-6.59*	-3.41	-2.73	-5.32	-1.11	3.51	-3.28	-4.84
PDM1742 × BML6	-2.27	-2.27	-2.27	-2.2	-2.2	-1.11	7.94	1.49	9.68
PDM1742 × BML7	0.57	0	0.00	1.11	0	1.11	-3.33	-4.92	-6.45
PDM1743 × BML6	1.16	-1.14	-1.14	0.56	-2.2	-1.11	-0.74	-1.47	8.06
PDM1743 × BML7	2.92	1.15	0.00	5.14*	3.37	2.22	10.08	4.41	14.52*

Table 5 (cont.)

Crosses	Ear Placement Height (cm)			Days to Maturity			Ear Length (cm)		
	Average Heterosis	Heterobeltiosis	Standard Heterosis DHM117	Average Heterosis	Heterobeltiosis	Standard Heterosis DHM117	Average Heterosis	Heterobeltiosis	Standard Heterosis DHM117
PDM1M × BML6	28.00**	14.29	33.33*	3.47**	3.47**	3.47**	0.4	-5.26	2.44
PDM1M × BML7	4.55	4.55	-4.17	3.47**	3.47**	3.47**	-4.44	-5.84	4.88
PDM1F × BML6	52.38**	14.29	33.33*	1.24*	0.99	0.99	2.93	1.65	0.00
PDM1F × BML7	5.56	-13.64	-20.83	2.73**	2.48**	2.48**	5.43	-0.73	10.57
PDM3M × BML6	48.84**	14.29	33.33*	0.5	0.5	0.50	21.70*	9.32	4.88
PDM3M × BML7	-1.51	-27.27	-33.33*	1.49**	1.49*	1.49**	-16.02	-29.20**	-21.14*
PDM3F × BML6	29.17*	10.71	29.17*	1.49**	1.49*	1.49**	25.11*	16.1	11.38
PDM3F × BML7	19.05	13.64	4.17	0.5	0.5	0.50	-5.88	-18.25	-8.94
PDM4F × BML6	12.5	-3.57	12.50	0.5	0.5	0.50	3.29	-6.78	-10.57
PDM4F × BML7	38.10*	31.82	20.83	2.48**	2.48**	2.48**	13.79	-3.65	7.32
PDM5F × BML6	20	7.14	25.00	2.97**	2.97**	2.97**	10.68	-3.39	-7.32
PDM5F × BML7	13.64	13.64	4.17	3.47**	3.47**	3.47**	3.11	-15.33	-5.69
PDM6M × BML6	0	-3.57	12.50	0.5	0.5	0.50	-4.84	-9.23	-4.07
PDM6M × BML7	12.5	3.85	12.50	1.49**	1.49*	1.49**	-2.62	-5.11	5.69
PDM6F× BML6	9.09	7.14	25.00	0.99	0.99	0.99	16.67	12.71	8.13
PDM6F × BML7	2.04	-7.41	4.17	2.48**	2.48**	2.48**	-0.4	-10.22	0.00
PDM7M × BML6	-20	-21.43	-8.33	1.98**	1.98**	1.98**	-4	-9.09	-2.44
PDM7M × BML7	-6.12	-14.81	-4.17	1.49**	1.49*	1.49**	10.04	8.03	20.33*
PDM7F × BM 6	0	-10.71	4.17	0.5	0.5	0.50	-1.55	-9.29	3.25
PDM7F × BML7	13.64	13.64	4.17	1.49**	1.49*	1.49**	-5.42	-6.43	6.50
PDM9M × BML6	4	-7.14	8.33	1.49**	1.49*	1.49**	-0.88	-5.08	-8.94
PDM9M × BML7	0	0	-8.33	2.48**	2.48**	2.48**	2.86	-8.03	2.44
PDM1729 × BML6	39.62**	32.14*	54.17**	1.99**	1.49*	1.49**	22.67*	16.95	12.20
PDM1729 × BML7	-2.13	-8	-4.17	1.49**	0.99	0.99	0	-10.95	-0.81
PDM1730 × BML6	6.45	-2.94	37.50**	0	0	0.00	2.31	-6.34	8.13
PDM1730 × BML7	-10.71	-26.47*	4.17	1.98**	1.98**	1.98**	-8.96	-10.56	3.25

Table 5 (cont.)

Crosses	Ear Placement Height (cm)			Days to Maturity			Ear Length (cm)		
	Average Heterosis	Heterobeltiosis	Standard Heterosis DHM117	Average Heterosis	Heterobeltiosis	Standard Heterosis DHM117	Average Heterosis	Heterobeltiosi s	Standard Heterosis DHM117
PDM1732 × BML6	-5.26	-6.9	12.50	1.49**	1.49*	1.49**	19.69*	11.76	23.58*
PDM1732 × BML7	-9.8	-20.69	-4.17	1.49**	1.49*	1.49**	1.83	1.46	13.01
PDM1733 × BML6	28.30*	21.43	41.67**	1.98**	1.98**	1.98**	17.55	13.39	17.07
PDM1733 × BML7	-2.13	-8.00	-4.17	3.47**	3.47**	3.47**	-2.27	-5.84	4.88
PDM1734 × BML6	-5.45	-7.14	8.33	1.49**	1.49*	1.49**	-9.16	-14.29	-7.32
PDM1734 × BML7	-2.04	-11.11	0.00	1.49**	1.49*	1.49**	3.7	2.19	13.82
PDM1735 × BML6	7.69	-25	-12.50	0.5	0.5	0.50	20	-3.39	-7.32
PDM1735 × BML7	21.21	-9.09	-16.67	0	0	0.00	18.66	-9.49	0.81
PDM1736 × BML6	-28.30*	-32.14*	-20.83	-0.5	-0.5	-0.50	1.11	-10.2	10.98
PDM1736 × BML7	14.89	8	12.50	-0.5	-0.5	-0.50	-16.96*	-21.05*	-2.44
PDM1737 × BML6	4.35	-14.29	0.00	0	0	0.00	28.51**	20.34	15.45
PDM1737 × BML7	15	4.55	-4.17	0	0	0.00	7.5	-5.84	4.88
PDM1738 × BML6	11.11	7.14	25.00	0	0	0.00	-1.56	-8.7	2.44
PDM1738 × BML7	12.5	3.85	12.50	0	0	0.00	-12	-12.32	-1.63
PDM1739 × BML6	-23.81*	-31.43**	0.00	-0.25	-0.5	-0.50	4.2	3.33	0.81
PDM1739 × BML7	-15.79	-31.43**	0.00	0.25	0	0.00	3.5	-2.92	8.13
PDM1740 × BML6	1.82	0	16.67	0	0	0.00	-7.88	-9.76	-9.76
PDM1740 × BML7	-10.2	-18.52	-8.33	0	0	0.00	-20.00*	-24.09*	-15.45
PDM1741 × BML6	24.44	0	16.67	0.25	0	0.00	-1.75	-5.08	-8.94
PDM1741 × BML7	12.82	0	-8.33	0.25	0	0.00	4.45	-5.84	4.88
PDM1742 × BML6	33.33*	14.29	33.33*	0	0	0.00	-2.52	-3.33	-5.69
PDM1742 × BML7	-14.29	-18.18	-25.00	0	0	0.00	-6.61	-12.41	-2.44
PDM1743 × BML6	-29.82*	-31.03*	-16.67	0	0	0.00	8.57	4.72	8.13
PDM1743 × BML7	-5.88	-17.24	0.00	0	0	0.00	-0.76	-4.38	6.50

Table 5 (cont.)

Crosses	Ear Girth (cm)			Kernel Rows Ear^{-1}			Number of Kernels Row^{-1}		
	Average Heterosis	Heterobeltiosis	Standard Heterosis DHM117	Average Heterosis	Heterobeltiosis	Standard Heterosis DHM117	Average Heterosis	Heterobeltiosis	Standard Heterosis DHM117
PDM1M × BML6	16.02*	11.24	5.69	13.67	6.76	12.86	32.60*	18.5	3.44
PDM1M × BML7	8.92	1.77	2.14	2.99	0	-1.43	14.22	1.56	-10.31
PDM1F × BML6	8.21	7.81	3.20	0.7	-2.7	2.86	18.56	16.93	2.06
PDM1F × BML7	-1.63	-3.9	-3.56	-4.35	-4.35	-5.71	12.7	10.51	-2.41
PDM3M × BML6	15.56*	7.12	1.78	17.83*	2.7	8.57	38.67**	22.83	7.22
PDM3M × BML7	-6.27	-15.25*	-14.95*	11.29	0	-1.43	8.17	-4.67	-15.81
PDM3F × BML6	8.53	4.87	-0.36	1.43	-4.05	1.43	34.64*	21.65	6.19
PDM3F × BML7	6.97	0.71	1.07	6.67	4.35	2.86	22.08	9.73	-3.09
PDM4F × BML6	3.01	-3.75	-8.54	18.84*	10.81	17.14*	18.93	13.78	-0.69
PDM4F × BML7	4.28	-4.96	-4.63	3.76	0	-1.43	26.79*	20.62	6.53
PDM5F × BML6	19.05*	12.36	6.76	6.62	-2.03	3.57	33.65*	10.24	-3.78
PDM5F × BML7	10.6	1.77	2.14	6.87	1.45	0.00	2938	6.23	-6.19
PDM6M × BML6	5.9	4.12	-1.07	7.69	4.05	10.00	3.25	-4.67	-1.72
PDM6M × BML7	2.22	-2.13	-1.78	11.59	11.59	10.00	6.28	-1.33	1.72
PDM6F× BML6	5.42	5.22	0.36	2.82	-1.35	4.29	26.98*	23.23	7.56
PDM6F × BML7	2.18	-0.35	0.00	9.49	8.7	7.14	12.55	8.56	-4.12
PDM7M × BML6	-8.54	-9.74	-14.23*	-9.86	-13.51	-8.57	2.39	-3.81	-4.47
PDM7M × BML7	-0.74	-4.61	-4.27	-8.03	-8.7	-10.00	14.29	7.96	7.22
PDM7F × BM 6	7.61	4.21	5.69	2.5	0.98	10.00	-2.35	12.36	-3.78
PDM7F × BML7	0.88	0.35	1.78	-7.75	-12.13	-4.29	3.04	-7.04	2.06
PDM9M × BML6	12.48	9.74	4.27	12.14	6.08	12.14	8.18	6.69	-6.87
PDM9M × BML7	4.85	-0.35	0.00	11.11	8.7	7.14	11.9	9.73	-3.09
PDM1729 × BML6	13.93	2.62	-2.49	7.8	2.7	8.57	50.67**	32.28*	15.46
PDM1729 × BML7	13.31	-0.35	0.00	10.29	8.7	7.14	22.49	700	-5.50
PDM1730 × BML6	-0.92	-2.54	-4.27	0	-1.35	4.29	15.71	5.88	11.34
PDM1730 × BML7	-5.73	-6.74	-6.41	2.13	0	2.86	-1.24	-9.15	-4.47

Table 5 (cont.)

Crosses	Ear Girth (cm)			Kernel Rows Ear^{-1}			Number of Kernels Row^{-1}		
	Average Heterosis	Heterobeltiosis	Standard Heterosis DHM117	Average Heterosis	Heterobeltiosis	Standard Heterosis DHM117	Average Heterosis	Heterobeltiosis	Standard Heterosis DHM117
PDM1732 × BML6	12.94	3	-2.14	0	-12.16	-7.14	14.52	8.66	-5.15
PDM1732 × BML7	7.17	-4.61	-4.27	4.8	-5.07	-6.43	14.23	7.78	-4.81
PDM1733 × BML6	9.68	8.24	2.85	3.4	2.7	8.57	24.57*	20.66	12.37
PDM1733 × BML7	5.17	1.06	1.42	-4.23	-6.85	-2.86	-0.38	-2.95	-9.62
PDM1734 × BML6	4.27	3.31	0.00	13.1	10.81	17.14*	-1.07	-9.74	-4.47
PDM1734 × BML7	-4.33	-6.03	-5.69	-8.57	-9.86	-8.57	6.19	-2.6	3.09
PDM1735 × BML6	17.57*	1.5	-3.56	18.40*	0	5.71	30.96	1.57	-11.34
PDM1735 × BML7	28.57**	8.51	8.90	33.33**	15.94	14.29	39.55*	7.78	-4.81
PDM1736 × BML6	-0.74	-2.53	-3.91	-5.07	-5.07	0.36	-9.19	-16.28	-13.40
PDM1736 × BML7	-4.11	-4.96	-4.63	-6.29	-9.46	-4.29	-7.89	-14.62	-11.68
PDM1737 × BML6	24.77**	3.75	-1.42	16.24	-8.11	-2.86	62.28**	28.74*	12.37
PDM1737 × BML7	18.95*	-3.19	-2.85	28.57**	4.35	2.86	35.96*	7.39	-5.15
PDM1738 × BML6	1.48	0.37	-2.49	7.69	4.05	10.00	-1.98	-9.63	-6.53
PDM1738 × BML7	7.03	5.32	5.69	7.25	7.25	5.71	-1.43	-8.64	-5.50
PDM1739 × BML6	3.56	3.37	-1.78	-7.28	-9.09	0.00	-3.81	-5.51	-17.53
PDM1739 × BML7	1.09	-1.77	-1.42	-5.48	-10.39	-1.43	12.75	10.12	-2.75
PDM1740 × BML6	-2.92	-5.34	-5.34	-2.01	-2.67	4.29	-6.92	-11.39	-14.43
PDM1740 × BML7	0.18	0	0.36	11.11	6.67	14.29	-5.95	-9.96	-13.06
PDM1741 × BML6	1.12	0.37	-3.20	-4.83	-6.76	-1.43	15.68	7.48	-6.19
PDM1741 × BML7	8.14	6.03	6.41	10.71	9.15	10.71	13.26	4.67	-7.56
PDM1742 × BML6	11.24	7.49	2.14	12.86	6.76	12.86	16.51	12.45	5.50
PDM1742 × BML7	-1.69	-7.45	-7.12	5.19	2.9	1.43	1.51	-1.47	-7.56
PDM1743 × BML6	9.4	6.74	1.42	-3.5	-6.76	-1.43	14.4	11.61	2.41
PDM1743 × BML7	6.34	1.06	1.42	-1.45	-1.45	-2.86	6.87	4.87	-3.78

Table 5 (cont.)

Crosses	Test Weight (g)			Protein Content (%)			Kernel Yield per Plant (g)		
	Average Heterosis	Heterobeltiosis	Standard Heterosis DHM117	Average Heterosis	Heterobeltiosis	Standard Heterosis DHM117	Average Heterosis	Heterobeltiosi s	Standard Heterosis DHM117
PDM1M × BML6	-6.38	-11.85	-6.84	3.98	-7.56	1.82	23.71	10.48	6.43
PDM1M × BML7	13.59	9.36	24.87	-12.05	-16.69	-8.23	2.36	2.28	-1.46
PDM1F × BML6	5.81	4.29	-2.67	16.07	13	-3.15	26.15	16.28	4.39
PDM1F × BML7	-1.71	-11.84	0.67	16.4	6.15	4.58	-7.55	-10.64	-14.04
PDM3M × BML6	-2.98	-9.83	-2.00	8.69	4.6	-10.35	82.57**	45.56*	10.23
PDM3M × BML7	-34.98**	-36.55**	-27.55*	-30.02	-36.87	-37.80	-18.43	-40.12*	-42.40*
PDM3F × BML6	22.34	19.5	11.52	38.52	26.45	8.38	63.17**	63.01**	23.68
PDM3F × BML7	1.89	-9.36	3.51	18.25	1.6	0.10	7.39	-3.95	-7.60
PDM4F × BML6	-27.20*	-30.59*	-35.23**	-16.02	-17.71	-29.47	5.75	-7.72	-30.12
PDM4F × BML7	-3.44	-15.94	-4.01	11.89	2.65	1.13	40.23*	11.25	7.02
PDM5F × BML6	39.13**	23.08	14.86	57.18	35.94	16.51	73.00**	33.59	1.17
PDM5F × BML7	15.8	-5.7	7.68	3	-15.81	-17.05	45.11*	3.65	-0.29
PDM6M × BML6	-2.89	-4.81	-7.51	17.87	9.6	-6.06	22.34	10.22	4.09
PDM6M × BML7	-3.48	-10.67	2.00	32.91	16.16	14.44	-0.61	-1.52	-5.26
PDM6F× BML6	4.67	-3.76	-10.18	2.95	2.47	-12.17	14.98	3.73	-2.34
PDM6F × BML7	13.62	-4.24	9.35	40.57	30.87	28.93	6.29	5.17	1.17
PDM7M × BML6	-9.99	-10.55	-16.53	5.67	-8.4	-21.49	-18.61	-25.95	-31.58
PDM7M × BML7	14.4	3.36	18.03	61.89*	32.62	30.66	13.95	11.7	7.46
PDM7F × BM 6	3.68	1.54	-1.17	19.51	16.04	-0.54	20.72	3.9	9.07
PDM7F × BML7	-8.45	-15.2	-3.17	19.88	9.05	7.44	-2.32	-6.41	-1.75
PDM9M × BML6	3.78	1.9	-1.34	-8.78	-24.41	-1.43	25.39	24.91	-4.68
PDM9M × BML7	-3.32	-10.67	2.00	-14.7	-25.13	-2.37	17.97	5.78	1.75
PDM1729 × BML6	-10.56	-14.03	-13.02	35.72	29.67	11.14	46.52*	45.95*	10.53
PDM1729 × BML7	-10.7	-15.79	-3.84	14.88	2.95	1.43	8.2	-3.64	-7.31
PDM1730 × BML6	-6.93	-14.52	-4.67	24	13.07	17.64	7.48	-8.65	-1.17
PDM1730 × BML7	-30.92**	-31.73**	-22.04	-10.56	-12.93	-9.41	-27.32	-31.35*	-25.73

Table 5 (cont.)

Crosses	Test Weight (g)			Protein Content (%)			Kernel Yield per Plant (g)		
	Average Heterosis	**Heterobeltiosis**	**Standard Heterosis DHM117**	**Average Heterosis**	**Heterobeltiosis**	**Standard Heterosis DHM117**	**Average Heterosis**	**Heterobeltiosis**	**Standard Heterosis DHM117**
PDM1732 × BML6	42.44**	35.54**	40.07**	43.69	16.22	-0.39	64.17**	51.22**	35.96*
PDM1732 × BML7	2.23	-2.63	11.19	33.42	2.55	1.03	10.92	7.29	3.21
PDM1733 × BML6	9.39	6.43	5.01	30.75	29.39	13.26	48.75**	37.95	22.22
PDM1733 × BML7	10.59	3.07	17.70	26.3	19.26	17.50	25	20.07	15.50
PDM1734 × BML6	-16.12	-19.44	-18.36	-22.97	-25.76	-36.37	-3.65	-18.28	-11.11
PDM1734 × BML7	1.47	-4.24	9.35	23.7	11.76	10.10	-0.43	-6.19	2.04
PDM1735 × BML6	6.52	-13.77	-19.53	-3.99	-10.12	-22.97	25.3	0.39	-23.98
PDM1735 × BML7	25.05	-5.85	7.51	3.53	-8.95	-10.30	49.28*	10.03	5.85
PDM1736 × BML6	7.91	0.93	8.18	-41.07	-45.8	-44.65	37.84*	20.06	22.52
PDM1736 × BML7	-10.41	-13.16	-0.83	-27.59	-28.86	-27.35	-15.04	-17.48	-15.79
PDM1737 × BML6	30.17*	15.38	7.68	13.79	13.65	-2.37	124.4**	59.85**	21.05
PDM1737 × BML7	13.62	-7.31	5.84	13.31	6.05	4.48	37.59	-8.21	-11.70
PDM1738 × BML6	-3.84	-6.13	-8.01	-4.28	-4.42	-17.84	-3.35	-17.66	-11.40
PDM1738 × BML7	-9.68	-16.08	-4.17	-1.42	-7.7	-9.07	-4.16	-9.24	-2.34
PDM1739 × BML6	24.00*	23.67	16.03	-31.24	-32.78	-42.39	17.44	8.91	-3.51
PDM1739 × BML7	-4.98	-13.45	-1.17	18.42	8.4	6.80	9.81	5.48	1.46
PDM1740 × BML6	20.4	17.71	9.85	29.43	18.75	1.77	-0.34	-10.7	-14.62
PDM1740 × BML7	-13.78	-23.25*	-12.35	-9.42	-21.81	-22.97	-14.64	-14.9	-18.13
PDM1741 × BML6	-8.82	-15.44	-7.68	-12.25	-21.11	-15.28	-2.27	-7.72	-21.35
PDM1741 × BML7	-3.14	-5.26	8.18	-16.37	-19.83	-13.90	14.9	8.36	4.24
PDM1742 × BML6	-2.99	-9.58	-2.34	22.92	12.02	16.71	24.95	19.86	-1.17
PDM1742 × BML7	-15.25	-17.54	-5.84	-15.2	-17.5	-14.05	-9.66	-16.11	-19.30
PDM1743 × BML6	29.39*	15.38	7.68	10	9.72	-5.96	52.09*	40.93	6.72
PDM1743 × BML7	0.18	-17.84	-6.18	14.67	6.95	5.37	17.45	-1.82	-5.56

** Significant at 1% level   * Significant at 5% level   DHM117- Zonal check in desirable direction for three characters (days to 50% tasseling, days to 50% silking and plant height). The cross PDM3M × BML6 recorded significant *sca* effects in desirable direction for four characters (plant height, ear placement height, ear length and ear girth) and the cross PDM1734 × BML6 recorded significant *sca* effects in desirable direction for kernel rows ear^{-1}. These results of combining ability effects were in agreement with Anilkumar *et al*. (2018), Rajesh *et al*. (2018), Darshan and Marker (2019) and Singh *et al*. (2019).

The estimates of relative heterosis (RH), heterobeltiosis (BH) and standard heterosis (SH) over the standard check DHM117 were ranged from -8.70 to 2.92, -12.50 to 2.3 and -5.68 to 1.14 for days to 50% tasseling, -9.38 to 5.62, -13.86 to 5.62 and -5.56 to 4.44 for days to 50% silking, -0.50 to 3.47 (for all the three heterosis) for days to maturity, -22.22 to 26.23, -31.15 to 21.31 and -32.26 to 24.19 for plant height, -29.82 to 52.38, -32.14to 32.14 and -33.33 to 54.17 for ear placement height, -20.00 to 28.51, -29.20 to 20.34 and 21.14 to 23.58 for ear length, -8.54 to 28.57, -15.25 to 12.36 and -14.95 to 8.90 for ear girth, -9.86 to 33.33, -13.51 to 15.94 and -8.57 to 17.14 for kernel rows per ear, -7.89 to 62.28, -14.62 to 32.28 and -17.53 to 15.46 for number of kernels per row, -34.98 to 42.44, -36.55 to 35.54 and -35.23 to 40.07 for test weight, -41.07 to 61.89, -45.80 to 35.94 and -44.65 to 30.66 for protein content and -27.32 to 124.4, -40.12 to 63.01 and -42.40 to 35.96 for kernel yield per plant respectively (Table 5). Heterosis studies revealed that twelve out of 50 crosses recorded significant positive heterosis over mid parent, five out of 50 crosses registered significant positive heterosis over better parent and single cross exhibited significant positive heterosis over the standard check DHM117 for the trait kernel yield per plant. The cross PDM1732 × BML6 recorded significant heterosis over mid parent, better parent and standard check in desirable direction for kernel yield per plant. Similar results of significant positive heterosis over mid parent and better parent for ear placement height were recorded by Brambhatt *et al*. (2018) and Patel *et al*. (2019) and over standard check by Brambhatt *et al*. (2018) and Darshan and Marker (2019).

4. CONCLUSION

The lines with good general combining ability can be utilized in improvement of the respective traits in any breeding programme wherever hybridization is involved. Due to their good combining ability, these lines can be utilized straightaway as parents for production of good hybrids by crossing with other

Commented [H5]: It is required to identify more than one inbred lines with high general combining ability for grain yield and recommend including it in a crossbreeding program to produce hybrids according to Diallel Crosses .

divergent lines and can also be employed in the development of synthetic varieties. The crosses with high *sca* effects were recorded due to high × low, high × high, low × high and low × low *gca* combinations. So, in hybridization programmes along with good combiners one can afford to include low general combiners.

References

Commented [H6]: It needs to add references about Line × Tester analysis

Kempthorne O. An Introduction to Genetic Statistics. John Willy and Sons Inc., New York. 1957;545.

Sprague GF, Tatum LA. General vs. specific combining ability in single crosses of corn. Agronomy J. 1942;34:923-932.

Lahane GR, Chauhan RM, Patel M. Combining ability and heterosis for yield and quality traits in quality protein maize. J. of Agril. 2014;1(3):135-138.

Baker RJ. Issues in diallel analysis. Crop Science. 1978;18:533-536.

Rissi De R, Hallauer AR. Evaluation of four testers for evaluating maize lines in a hybrid development programme. Brazil J. of Genetics. 1991;14(2):467-481.

Anilkumar C, Lohithaswa HC, Uma MS, Mahadevu P. Analysis of combining ability and heterosis for yield and yield contributing traits in newly developed inbred lines of maize (*Zea mays* L.). International Journal of Agricultural Sciences. 2018;10(6):5460-5464.

Rajesh V, Sudheer Kumar S, Narsimha Reddy V, Siva Sankar A. Combining ability and genetic action studies for yield and its related traits in maize (*Zea mays* L.). International Journal of Current Microbiology and Applied Sciences. 2018;7(6):2645-2652.

Darshan SS, Marker S. Heterosis and combining ability for grain yield and its component characters in quality protein maize. Electronic Journal of Plant Breeding. 2019;10(1):111-118.

Singh B, Abhishek A, Nirala RBP, Mandal SS, Ranjan T. Study of combining ability and nature of gene action for yield and yield related traits in maize (*Zea mays* L.). Current Journal of Applied Science and Technology. 2019;33(2):1-8.

Brahmbhatt B, Kuchhadiya G, Gosai M, Joshi N, Kanjariya, K. Estimation of Heterosis through Diallel Crosses in Maize (*Zea mays* L.) for Grain Yield and Protein Content. International Journal of Current Microbiology and Applied Science. 2018;7:3458-3464.

Patel K, Gami RA, Kugashiya KG, Chauhan RM, Patel RN, Patel RM. Study on per se performance and heterosis for kernel yield and its attributing traits in maize [*Zea mays* (L.)]. Electronic Journal of Plant Breeding. 2019;10(3):980-987.