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Heterosis and combining ability studies for quality protein maize

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ABSTRACT

Ten maize inbreds were crossed as lines to eight testers (Quality Protein Maize donors) in Line X Tester mating design to generate eighty F1 crosses. The ninety-nine genotypes including 80 F1 hybrids along with their 18 parents and a check were evaluated in Randomized Block Design to estimate the General Combining Ability (GCA), Specific Combining Ability (SCA) and Heterosis of F1 crosses. Analysis of Variance revealed significant differences among genotypes, parents and crosses for all the traits. The interaction of Line × Tester was highly significant for all the traits. Both, non-additive and additive types of gene action were observed to influence the expression of traits among the crosses. Among the lines, CM 141, V335 and V351 were promising as observed to be the superior general combiner. Cross CM 141 × CML 161 was among 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. Standard heterosis for grain yield ranged from -56.45 to 53.31 %. Based on combining ability and hybrid vigour, the lines V335 and V351 figured to be potential lines to be converted in to QPM lines to develop local QPM hybrids. The QPM donor CML 141 based on its GCA, SCA and heterosis estimates seems to be most promising donor for conversion programme.

Keywords: combining ability, grain yield, heterosis, maturity, quality protein maize *zea mays* L.

Abbreviations:
GYP: Grain Yield Per Plot; QPM: Quality Protein Maize,
DMR: Directorate of Maize Research; BHU: Banaras Hindu University;
VPKAS: Vivekananda Institute of Hill Agriculture

Introduction

Maize *(Zea mays* L.) is the third most important cereal crop among the cereals grown in India and is one of the promising crops for food, feed, fodder and industrial utilization. However, its protein is deficit in essential amino acids particularly, lysine and tryptophan. To overcome this deficiency, Quality Protein Maize (QPM) donors with sufficiently higher quantity of lysine and tryptophan have been developed at CIMMYT Mexico (Vasal, 1999). The development of QPM donor stocks led to a large scale QPM germplasm development effort in different genetic backgrounds representing tropical, subtropical and highland maize germplasm involving different maturity as well as grain colour and texture. Potentially useful normal maize populations were identified for QPM conversion program. A number of advanced maize populations in CIMMYT maize program were converted to QPM using modified backcrossing-cum-recurrent selection procedure. Some of the QPM versions have given competitive performance in yield and other agronomic traits as compared to normal counterparts (Vasal, 1999).

The choice of QPM donor is just as critical as that of the recipient. The choice of a poor donor could prove to be very expensive and wasteful. In a QPM programme , a QPM line or OPV chosen as a donor for a conversion programme, by virtue of being elite, should possess good modifiers and should have high combining ability and the ability to pass them further when crossed (Vivek et al., 2008). The QPM hybrid initiative at CIMMYT was introduced in 1985. Combining ability studies in QPM germplasm have been conducted and published. Inbred line development efforts have been strengthened and evaluated for combining ability. Several hybrid combinations have been tested internationally and some of them have performed equal or even better than some of the local checks (Vasal, 1999). The value of any inbred line in hybrid breeding ultimately depends on its ability to combine very well with other lines to produce superior hybrids. For development of superior QPM hybrids, the QPM lines should combine well with local inbred lines with high combining ability as well as heterosis. Heterosis has been extensively studied in maize because of (i) its large expression for grain yield (100-200 %), (ii) its intensive exploitation in hybrid breeding of maize, and (iii) the favourable biological prerequisites such as large multiplication coefficient and ease of both self and controlled cross-fertilization. Combining ability analysis and heterosis are useful to assess the potential inbred lines and also helps in identifying the nature of gene action involved in various quantitative characters. Hence, combining ability and heterosis are useful biometric tools to the plant breeders for formulating an efficient breeding programme (Jebaraj et al., 2010). A good number of inbreds developed recently are available in the maize breeding programme at Institute of Agricultural Sciences, BHU, Varanasi, However, combining ability of these inbred lines has not yet been studied for utilization in QPM inbred development programme. Most efficient use of such materials would be possible only when adequate information on the amount and type of genetic variation, combining ability effects and heterotic effects in the materials is available. In this context, L × T analysis (Kempthorne, 1957) has been widely used for evaluation of inbred lines by crossing them with testers. The present investigation was undertaken for estimation of combining ability and heterosis of normal inbred lines with QPM donors as tester for initiating a successful quality protein maize conversion programme.

Materials and methods

The experimental materials

A total of ninety-nine genotypes including 80 F_1 crosses, their 18 parents and one check were used for the present study. Ten maize inbreds *viz.* HUZM185, HUZM97-1-2, HUZM509, HKI 287, HUZM478, V336, V341, V351, CM 141 and V335 obtained from BHU(Banaras Hindu University),Varanasi, India; VPKAS(Vivekananda Institute of Hill Agriculture), Almora, India; were used as lines (female). Many of these lines were early and medium duration. Eight tropical and subtropical Quality Protein Maize (QPM) donor inbreds *viz.* CML 141, CML 193, DMRQPM 58, HKI 164-7-6, HKI 162, CML 169, CML 176 and CML 161 obtained from Directorate of Maize Research (DMR), New Delhi, India were used as testers (males). The tester used in present study are widely used QPM donors in many national maize breeding programme to convert local lines in to QPM version and study combining ability. These testers also have good ability to discriminate the inbred lines in to different heterotic groups. The characteristic features, origin and source of these parents (lines as well as testers) are given in Table 1.The check Malviya Makka 2 is medium maturing single cross local hybrid.

Field plot technique and layout

Ten lines and eight testers were crossed in a line × tester fashion in the *Kharif* (rainy) season of 2012 and in the following *Rabi* (winter) season of 2012-13 all the F_1s along with their parents and check were grown in Randomized Block Design (RBD) with three replications at the Agriculture Research Farm, Institute of Agricultural Sciences, BHU, Varanasi, UP, India. Varanasi is situated at 25.2° N latitude and 83.0° E longitude with an altitude of 128.93 m above mean sea level. Each experimental plot comprised 3 m long two rows whereas, row to row and plant to plant spacing were 60 cm and 25 cm, respectively. One healthy seedling per hill was maintained. Fertilizers were applied @ 160, 80 and 60 kg/ha of N, P and K, respectively. One border row was maintained at end of each replication to minimize border effect. The recommended agronomic packages of practices were adopted to raise a good and healthy crop.

Data collection

Ten competitive plants in each plot were randomly selected and tagged at tasseling to record observations for yield and maturity traits. Details of observational procedure for each trait are : *Days to 50 per cent tasseling* was recorded as the number of days from planting to the day on which 50 per cent of the plants in a plot showed full tassel emergence; *Days to 50 per cent silking* was recorded as the number of days from planting to the day on which 50 per cent of the plants in a plot produces 2-3 cm long silk; *Days to 75 per cent brown husk* was recorded as the number of days from planting to the day on which 75 per cent of plants in a plot got first husk cover on the ear dried and turned brown and grain yield/ ha was computed from grain yield per plot and expressed in t/ha by the following formula (Elmyhum, 2013):

$$\text{Grain Yield} = [10 \times \text{GYP (kg)}] / (3.6\text{m}^2)$$

Statistical analysis

The mean data for yield and maturity traits were used for statistical analysis using Windostat 9.1 software program (Indostat Services, Hyderabad). Further analysis was done according to line × tester analysis to partition the mean square due to crosses into lines, tester and line × tester interaction (Singh and Chaudhary, 1985) using Windostat 9.1 software program. Further genetic analyses were carried out for traits that showed significant differences among the genotypes excluding the check according to line × tester analysis method (Kempthorne, 1957) to partition the mean square due to crosses in to lines effect, tester effect and line × tester effect using Windostat 9.1 software program. The mid-parent heterosis (MPH), heterobeltiosis (BPH) and standard heterosis (SH) were estimated as deviation of F_1 value from the mid-parent, better-parent and standard check values as suggested by Matzinger et al. (1962); Fonsecca and Patterson (1968); Turner(1953) and Hayes et al. (1955), respectively. Heterosis values were mathematically calculated by using the Windostat 9.1 software program. The following formulae were used for the estimation of MPH, BPH and SH for yield and maturity traits.

Heterosis over mid-parent (MPH %) $= [(F1\text{-}MP)/MP \times 100]$

SE (F1-MP) $= (3\ Me/2r)^{1/2}$

Heterosis over better-parent (BPH %) $= [(F1\text{-}BP/BP \times 100]$

SE (F1-BP) $= (2\ Me/r)^{1/2}$

Heterosis over standard check (SH %) $= [(F1\text{-}SC)/SC \times 100]$

SE (F1-SC) $= (2Me/3r)^{1/2}$

where, Me = error mean squares for parents and F_1s; MP = mean mid-parent value = (P1+P2)/2; P1 = mean performance of parent one; P2 = mean performance of parent two; BP = mean better-parent value; SC = mean standard-check value; r = number of replications. The significance of MPH, BPH and SH were tested by 't' test using respective SE values in all the characters.

Results and discussion

Analysis of variance

The analysis of variance revealed that treatments, crosses and parents differed significantly for all the characters, indicating sufficient genetic variability present among them which is encouraging for selection of desirable genotypes (Table 2). The mean sum of square for crosses was highly significant, which indicated the diverse performance of different cross combinations for all traits viz. days to tasseling, days to silking, days to brown husk and grain yield. The parents *versus* hybrids mean sum of squares were highly significant for all traits, indicating the presence of heterosis due to the significant difference in the mean performance of hybrids and parents.

Analysis of variance for combining ability presented in Table 3, revealed that mean squares due to line effect showed significant differences for all the characters, whereas due to tester effect significant differences were revealed for days to tasseling, days to silking and days to brown husk. This indicated that there was a high level of genetic difference brought out by the lines for all the characters while testers had its impact on days to 50% tasseling, days to 50% silking and 75% brown husk. The significant difference in variances due to line × tester interaction effect indicated that the inbred lines performed differently in their respective hybrids depending on the type of testers used. The study revealed the importance of non additive gene action for grain yield and additive gene action for maturity traits in the expression of these traits. These results are in agreement with those of Joshi et al. (2002), Kanagarasu et al. (2010), Premlatha et al. (2011) and Kambe et al. (2013), whereas contrarily Sharma et al. (2004) reported preponderance of additive genetic effects. The grain yield was controlled by non-additive gene action since *SCA* variance was greater than *GCA* variance (Table 4), whereas the traits like days to tasseling, days to silking, days to brown husk were controlled by additive gene action. The importance of non additive gene action for grain yield and some other traits have been reported earlier by Singh and Singh (1998), Prasad and Pramod Kumar (2003), Subramaniyan and Subbraman (2006), Jayakumar and Sundram (2007), Vijayabharathi et al. (2009) and Kambe et al. (2013) whereas contrarily importance of additive gene effects was reported by Alamnie et al. (2006). So additive as well as non additive type of gene action prevails in expression of the grain yield per plant.

General combining ability (GCA) effects

A wide range of variability for *GCA* effects was observed among the parents for different characters (Table 5). Estimates of GCA effects for grain yield showed that out of ten inbred lines studied, four expressed positive and highly significant *GCA* effect. Inbred line CM 141 exhibited the maximum *GCA* effect (10.55 t/ha) whereas HUZM97-1-2 exhibited the lowest and negative *GCA* effect (-9.71 t/ha). Inbred line V351 exhibited desirable significant *GCA* effect for all the traits. Among the testers, CML 141 was the best as it expressed highest *GCA* effect (3.23 t/ha) whereas HKI 162 exhibited the lowest *GCA* effect (-2.30 t/ha) for grain yield. It was observed from the *GCA* effects that none of the parents individually showed good general combiner for all the characters. Both positive and negative *GCA* effects have been reported in maize by various studies (Fan et al., 2008; Kambe et al., 2013; Abrha et al, 2013 and Elmyhum, 2013). Both negative and positive *GCA* effects were observed for days to tasseling, silking and brown husk indicating possibilities of early as well as late hybrids. The V351 potential line for early hybrids as it exhibited highest negative and significant *GCA* effect (-3.26 days) followed by V335 (-1.47 days) and CM 141(-1.26 days) for days to tasseling. The similar trend was observed for days to silking, whereas for days to brown husk, V351 displayed maximum negative *GCA* effect (-2.98 days) followed by HUZM185 (-1.90 days) and HUZM97-1-2 (-1.31 days). The high *GCA* effect in negative direction indicates that they were good general combiner for earliness. Higher estimates of *GCA* effect in negative direction are desirable for days to brown husk. Among the testers, DMRQPM 58 was good general combiner for days to tasseling, silking and brown husk with *GCA* estimates of -1.10, -0.57 and -2.12 days, respectively. Xingming et al. (2002) found CML 161 as good general combiner in their study. Uddin et al. (2006) and Sundararajan and Kumar (2011) revealed the importance of negative *GCA* effect for days to tasseling and days to silking to develop early maturing varieties. Non QPM Parents *viz.*, V335, CM 141, V351 and V341; and QPM lines CML 141, CML 161 and DMRQPM 58, were identified as good general combiners and these parents could be used in hybridization programme to develop specific local hybrids.

Specific combining ability (SCA) effects

For grain yield estimates due to *SCA* effect were observed in both, negative and positive directions (Table 6). High *SCA* estimates for yield of the crosses CM 141 × CML 161, HUZM509 × CML 176, V351 × CML 141 and V335 × CML 141 indicated high and desirable specific combining ability, whereas crosses HUZM478 × CML 161, HKI 287 × HKI 164-7-6, V335 × CML 176 and CM 141 × DMRQPM 58 were poor specific combiners for grain yield. The Cross CM 141 × CML 161 exhibited maximum significant and positive *SCA* effect of 21.64 t/ha followed by V351 × CML 141 (15.79 t/ha).The higher estimates of *SCA* effects in the present study is deviation from the prediction based on their parental performance. The crosses with significant and positive estimates of *SCA* effect are very useful for QPM maize hybrid development programme. The results of the current study are in agreement with the findings of Abrha et al. (2013) who reported high and significant *SCA* effects in most of the crosses they studied for grain yield in maize. In case of days to tasseling, cross HUZM185 × DMRQPM 58 expressed highest negative *SCA* effect (-3.36 days) followed by HUZM509 × HKI 164-7-6 (-3.08 days) and CM 141 × CML 161 (-2.71 days), whereas HUZM478 × DMRQPM 58 expressed high and positive *SCA* effect (2.47 days) followed by V 336 × CML 176 (2.22 days). For days to silking, cross CM 141 × CML 161 (-3.82 days) followed by V341 × CML 176 (-2.97 days) and HUZM509 × HKI 164-7-6 (-2.63 days) were promising for earliness, whereas crosses HKI 287 × HKI 164-7-6 (3.54 days) followed by HUZM509 × CML 141 (3.17 days) indicated their tendency for lateness. In case of days to brown husk, Cross V351 × DMRQPM 58 (-3.79 days) followed by HUZM509× CML 169 (-3.30 days) and CM 141 × CML 161(-2.76 days) were effective for earliness, whereas V335 × HKI 162 (2.30 days) was promising for developing late hybrids. In the present study we are looking for early QPM hybrids so the negative *SCA* estimates are desirable. Uddin et al. (2006) reported eleven and fourteen hybrids with negative *SCA* effects for days to tasseling and days to silking, respectively. The present results showed that, the crosses (CM 141 × CML 161 and V335 × CML 141) with higher estimates of *SCA* effect involved the parents with higher *GCA* effect for grain yield. Ivy and Howlader (2000) reported that *GCA* effect of the parents did not reflect in their *SCA* effect for all the traits. However, Amiruzzaman et al. (2011) pointed out that the *SCA* is a result of the interaction of G*CA* effects of the parents and that it can improve or deteriorate the hybrid vigour of a particular trait.

A critical evaluation of the results particularly for specific combining ability effects showed that few cross combinations exhibited desirable significant *SCA* effects for all the characters. The highest yielding cross CM 141 × CML 161 also revealed significant and positive *SCA* effects for grain yield along with significant negative *SCA* effects for early maturing traits and was the outcome of high (CM 141) × moderate (CML 161) general combining parents. Chaudhary et al. (2000) and Surya and Ganguli (2004) have also reported high positive specific combining ability effects along with high *per se* performance for grain yield. The superiority of crosses involving high × low combiners could be explained as the result of interaction between positive alleles from good combiners and negative alleles for the poor combiners. The high yield of such crosses would be non-fixable and thus could be exploited for heterosis breeding. The superior cross combinations involving low × low general combiners could result from over dominance and epistasis.

Heterosis

The crosses displayed heterosis in both negative as well as positive direction for all the characters (Table 7). For grain yield, fifteen, sixty two and seventy crosses exhibited positive heterosis over standard check, better parent and mid parent, respectively. The heterosis for grain yield over standard check, better parent and mid parent ranged from -56.45 to 53.31%, from -40.65 to 278.57% and from -30.11 to 294.68%, respectively. The maximum standard heterosis for grain yield was exhibited by the cross CM 141 × CML 161(53.31%) followed by V335 × CML 141 (34.71%). This may be mentioned here that the lines involve in development of best hybrids have come from diverse genetic background. The hybrids with over 20 per cent of Standard heterosis have high commercial value in almost all crops with special reference to maize. The result is in conformity with that of Saxena et al. (1998) who opined that hybrids produced from inbred lines having diverse origins tended to have greater consistent yield levels than hybrids of parental lines originating from the narrow source population. The present results particularly the parents of best yielding cross CM 141 × CML 161 have its origin from diverse maize population viz. Pool 33 and P 25 QPM (Table 1), respectively. These results are in agreement with Dagne (2008). In case of days to tasseling, negative estimates of heterosis are desirable in maize hybrids. Twenty two, forty and seventy crosses expressed negative standard, better parent and mid parent heterosis, respectively; for days to tasseling however, high and significant negative standard heterosis (-4.48%) was manifested by HUZM185 × DMRQPM 58 and V351 × HKI 164-7-6 followed by V351 × CML 161(-3.79%) for this trait. For days to silking, the maximum significant and negative standard heterosis was expressed by cross V351 × HKI 164-7-6 (-5.69%) followed by V351 × CML 161(-4.68%). In case of days to brown husk, the extent of standard heterosis was in positive direction, whereas better parent and mid parent heterosis were mostly in negative direction, however, eight crosses manifested significant and negative standard heterosis for this trait. The maximum significant and negative standard heterosis was recorded by cross V351 × HKI 164-7-6 (-5.00%) followed by cross V351 × DMRQPM 58 (-4.25%). Singh (1979) and Amiruzzaman et al. (2013) reported that earliness is associated with days to silking. Heterosis responses of hybrids largely depend on genetic diversity of parents and environmental conditions (Hallauer and Miranda, 1988).

Per se performance along with gca, sca effects and heterosis

Five best crosses for grain yield per hectare, days to tasseling, days to silking and days to brown husk based on *per se* performance along with *SCA* effects, *GCA* effects and heterosis are presented in Table 8. The crosses selected on the basis of *per se* performance had high positive *SCA* effects and standard heterosis for grain yield. For days to tasseling, days to silking and days to brown husk, some of the crosses selected on the basis of *per se* performance had high negative *SCA* effects and standard heterosis. Out of eighty crosses, cross HUZM185 × DMRQPM 58 recorded minimum *per se* performance along with significant negative SCA effect and standard heterosis for days to tasseling followed by CM 141 × CML 161._Further, the cross CM 141 × CML 161 also recorded lower *per se* performance along with significant negative SCA effect and standard heterosis for days to silking, whereas, cross V351 × HKI 164-7-6 recorded minimum *per se* performance along with significant and negative SCA effect and standard heterosis for days to brown husk. None of the crosses was found desirable simultaneously for all the characters i.e., different crosses expressed desirable significant *SCA* effects and standard heterosis for different characters. However, out of eighty crosses, crosses CM 141 × CML 161 and V351 × HKI 164-7-6 were found desirable simultaneously for most of the characters with significant and negative *SCA* effects and standard heterosis for earliness. The results obtained in the present study are indicating similar trend as reported by Pal and Prodhan (1994), Rao et *al.* (1996), Mahto and Gunguli (2003), Malik et al. (2004) and Kanagarasu et al. (2010) for grain yield. It is evident that the best five crosses exhibiting high *per se* performance along with desirable *SCA* effects for grain yield had involvement of parents with high as well as low *GCA* estimates.

Based on the overall performance of the hybrids and parental lines, some of the lines could be used as parents of single cross hybrid maize with high quality and high yield potential. Hence, the information from this study may possibly be useful for researchers who would like to develop high yielding and high quality protein inbred lines and hybrids.

Table 1. Characteristic Features, Pedigree, Sources of Lines (10) and Testers (8) used in present study

Inbred Name	Pedigree & Source	Characteristic Features
Local Inbred Lines (Lines)		
HUZM185	Seedtec-1250-1-2-2-1-# # BHU, Varanasi	Yellow, Flint kernel, Medium duration, Tassels and Leaf angle is small, Tall height and Good grain yield.
HUZM97-1-2	Devaki × VCZ BHU, Varanasi	Yellow kernel, Early duration, Wide leaf angle.
HUZM509	BHU, Varanasi	Yellow kernel, Late duration, Leaf angle small with narrow tassel angle.
HKI 287	CML 287, Karnal	Yellow kernel, Late duration, Leaf and Tassel angle is wide, Tall height with high grain yield.
HUZM478	BH-3427, BHU, Varanasi	Yellow, Flint kernel, Late duration, Leaf angle is wide with narrow tassel angle.
V336	CML 145,P 63 CDHC 181-3-2-1-4 #2-BBBB #F-BBBBB # VPKAS, Almora	Yellow, Flint kernel, Medium duration, Leaf and Tassel angle is small, Straight leaf attitude.
V341	Mexico Acc No. 3136@-3-2-3-8-1, VPKAS Almora	Yellow, Flint kernel, Early duration, Tall with drooping leaf attitude, straight tassel.
V351	Shakti (So) HE 25,VPKAS, Almora	Orange yellow, Flint kernel, Early duration, Straight leaf attitude and better grain yield.
CM 141	Pool 33 (Alm), VPKAS, Almora	Yellow kernel, Late duration, Curved tassel.
V335	TZI-25, VPKAS, Almora	Orange, Flint kernel, Medium duration, Straight tassel.
QPM Lines (Testers)		
CML 141	Pop 62, CIMMYT	White, Flint kernel, Late duration, Dwarf height.
CML 193	CY0162-B-1-1-B (S.Africa),CIMMYT	Yellow, Flint, Medium to late duration, Medium height
DMRQPM 58	Shakti 1, DMR	Orange yellow, Flint kernel, Early duration, Tall height
HKI 164-7-6	CML164, Karnal	Yellow, Semi Dent, Late duration, Medium height, Dark green plant, Sparse tassel.
HKI 162	CML162, Karnal	Yellow, Flint kernel, Late duration, Tall plant, Small tassel, Erect and Narrow leaves.
CML 169	P 26 QPM, CIMMYT	Yellow, Flint kernel, Medium duration, Curved tassel.
CML 176	(P 63-12-2-1/P67-5-1-1)-1-2-B-B, CIMMYT	White kernel, Medium to Late duration.
CML 161	P 25 QPM,CIMMYT	Orange yellow, Flint kernel, Late duration, Dwarf height with small leaf angle and straight leaf attitude.

Table 2. Analysis of variance for parents and crosses for yield and maturity traits in maize

Sources of Variation	DF	Mean Square			
		Grain Yield	Days to 50% tasseling	Days to 50% silking	Days to 75% Brown Husk
Replications	2	0.12	0.18	0.13	0.82
Treatments	97	3.56**	21.65**	25.96**	21.53**
Parents	17	1.75**	35.41**	42.82**	42.58**
Parents (Line)	9	2.24**	32.46**	42.36**	63.93**
Parents (Testers)	7	0.75**	14.55**	17.52**	19.05**
Parents (L vs T)	1	4.35**	208.03**	224.13**	15.17*
Parents vs Crosses	1	73.28**	258.63**	294.50**	251.08**
Crosses	79	3.07**	15.69**	18.93**	14.09**
Error	194	0.20	2.06	3.27	3.72
Total	293	1.31	8.53	10.76	9.59

* and **, significant at 5 and 1 per cent level of significance, respectively.

Table 3. Analysis of variance of combining ability for yield and maturity traits in maize

Sources of Variation	D F	Mean Square			
		Grain Yield (t/ha)	Days to 50% tasseling	Days to 50% silking	Days to 75% Brown Husk
Replications	2	0.40	0.58	0.43	4.39
Crosses	79	3.07**	15.69**	18.93**	14.09**
Line Effect	9	11.23**	73.91**	76.71**	59.13**
Tester Effect	7	1.16	25.60**	45.66**	26.66**
Line × Tester Effect	63	2.12**	6.27**	7.70**	6.26**
Error	158	0.23	2.11	3.17	3.22
Total	239	1.17	6.58	8.35	6.82

* and **, significant at 5 and 1 per cent level of significance, respectively.

Table 4. Estimates of components of variance (s2 A and s2 D) and degree of dominance for yield and maturity traits in maize

Traits	Components				
	σ^2 gca	σ^2 sca	σ^2 D	σ^2 A	Degree of Dominance
Grain Yield (t/ha)	0.22	0.63	0.63	0.44	1.20
Days to 50 % tasseling	1.77	1.41	1.41	3.53	0.63
Days to 50 % silking	2.15	1.48	1.48	4.29	0.59
Days to 75 % Brown Husk	1.45	0.85	0.85	2.90	0.54

Table 5. General combining ability (GCA) effects of parents for yield and maturity traits in maize

S.No.	Inbreds	Grain Yield	Days to 50% tasseling	Days to 50% silking	Days to 75% Brown Husk
			Lines		
1	HUZM185	-0.22*	-0.68*	-0.30	-1.90**
2	HUZM97-1-2	-0.97**	-0.68*	0.53	-1.31**
3	HUZM509	-0.66**	1.41**	1.20**	0.77
4	HKI 287	-0.73**	0.91**	1.36**	-0.02
5	HUZM478	-0.04	2.49**	1.95**	1.19**
6	V336	0.01	1.62**	1.45**	1.10**
7	V341	0.30**	0.91**	0.40	1.52**
8	V351	0.26**	-3.26**	-3.85**	-2.98**
9	CM 141	1.06**	-1.26**	-0.85*	1.56**
10	V335	0.99**	-1.47**	-1.89**	0.06
SE± GCA (Line)		0.09	0.29	0.37	0.39
CD 5 % GCA (Line)		0.18	0.58	0.73	0.78
CD 1 % GCA (Line)		0.24	0.76	0.96	1.03
SE± Gi- Gj (Line)		0.13	0.41	0.52	0.56
CD 5 % Gi- Gj (Line)		0.25	0.82	1.03	1.10
CD 1 % Gi- Gj (Line)		0.33	1.08	1.36	1.45

Continuing table 5

S.No.	Inbreds	Grain Yield	Days to 50% tasseling	Days to 50% silking	Days to 75% Brown Husk
			Testers		
11	CML 141	0.32**	0.1	-0.34	-0.15
12	CML 193	-0.21**	1.20 **	1.43**	0.75*
13	DMRQPM 58	-0.04	-1.10**	-0.57	-2.12**
14	HKI 164-7-6	0.14	-1.47**	-2.20**	0.25
15	HKI 162	-0.23**	-0.07	-0.04	0.45
16	CML 169	-0.14	0.80**	1.43**	0.35
17	CML 176	0.00	0.70**	0.93**	0.81*
18	CML 161	0.16**	-0.17	-0.64	-0.32
SE ±GCA(Tester)		0.08	0.26	0.33	0.35
CD 5 % GCA (Tester)		0.16	0.52	0.65	0.70
CD 1 % GCA (Tester)		0.21	0.68	0.86	0.92
SE ±Gi – Gj (Tester)		0.11	0.37	0.47	0.50
CD 5 % Gi- Gj (Tester)		0.23	0.73	0.92	0.98
CD 1 % Gi- Gj (Tester)		0.30	0.97	1.22	1.30

* and **, significant at 5 and 1 per cent level of significance, respectively.

Table 6. Specific combining ability (SCA) effects of F1 crosses for yield and maturity traits in maize

S. No.	Crosses	Grain Yield	Days to 50% tasseling	Days to50% silking	Days to 75% Brown Husk
1	HUZM185 × CML 141	0.58*	-1.56	-1	-1.47
2	HUZM185 × CML 193	0.88**	-1.33	-1.76	-0.04
3	HUZM185 × DMRQPM 58	0.74**	-3.36**	-1.76	-0.5
4	HUZM185 × HKI 164-7-6	0.54*	1.67	0.87	-0.87
5	HUZM185 × HKI 162	-0.94**	1.94*	0.7	-0.07
6	HUZM185 × CML 169	-0.14	-0.59	-0.43	-0.3
7	HUZM185 × CML 176	-0.69**	1.84*	1.4	1.56
8	HUZM185 × CML 161	-0.97**	1.38	1.97	1.7
9	HUZM97-1-2× CML 141	-0.81**	0.11	-0.16	1.61
10	HUZM97-1-2× CML 193	0.38	-1.33	-2.60*	-2.62*
11	HUZM97-1-2× DMRQPM 58	-0.38	-0.69	0.07	-0.09
12	HUZM97-1-2× HKI 164-7-6	-0.13	0.68	0.37	1.88
13	HUZM97-1-2× HKI 162	0.92**	-0.06	-0.46	-0.99
14	HUZM97-1-2× CML 169	0.07	0.41	0.4	0.11
15	HUZM97-1-2× CML 176	-0.06	0.51	1.57	-0.69
16	HUZM97-1-2× CML 161	0.01	0.38	0.8	0.78
17	HUZM509 × CML 141	-1.2**	2.03*	3.17**	2.2
18	HUZM509 × CML 193	0.47	1.92	0.74	0.63
19	HUZM509 × DMRQPM 58	0.10	-0.77	-0.26	0.16

Continuing table 6

S. No	Crosses	Grain Yield	Days to 50% tasseling	Days to 50% silking	Days to75% Brown Husk
20	HUZM509 × HKI 164-7-6	-0.33	-3.08**	-2.63*	0.13
21	HUZM509 × HKI 162	-0.38	-0.81	-0.46	-0.07
22	HUZM509 × CML 169	-0.19	0.32	-0.26	-3.30**
23	HUZM509 × CML 176	1.46**	-0.57	-1.1	1.23
24	HUZM509 × CML 161	0.14	0.96	0.8	-0.97
25	HKI 287 × CML 141	-0.03	-0.14	0	-2.01
26	HKI 287 × CML 193	-0.13	1.42	0.9	0.75
27	HKI 287 × DMRQPM 58	-0.46	-0.61	-0.1	-1.38
28	HKI 287 × HKI 164-7-6	-1.34**	2.09*	3.54**	1.59
29	HKI 287 × HKI 162	0.20	-0.64	-0.96	-0.28
30	HKI 287 × CML 169	0.87**	-1.51	-1.76	1.15
31	HKI 287 × CML 176	0.68**	-0.08	-0.93	0.69
32	HKI 287 × CML 161	0.22	-0.54	-0.7	-0.51
33	HUZM478 × CML 141	-0.96**	-0.06	-0.58	-0.22
34	HUZM478 × CML 193	0.85**	0.51	0.32	-0.45
35	HUZM478 × DMRQPM 58	0.00	2.47**	1.32	0.75
36	HUZM478 × HKI 164-7-6	0.41	-1.16	-0.38	-0.29
37	HUZM478 × HKI 162	0.47	-0.89	-1.55	-1.49
38	HUZM478 × CML 169	0.14	-0.76	0.32	0.28
39	HUZM478 × CML 176	0.55*	-0.32	-0.18	-0.52
40	HUZM478 × CML 161	-1.47**	0.21	0.72	1.95
41	V 336 × CML 141	-0.13	-0.18	0.25	-0.47
42	V 336 × CML 193	-0.15	0.38	0.82	-0.04
43	V 336 × DMRQPM 58	0.03	-2.65**	-2.51*	-0.84
44	V 336 × HKI 164-7-6	0.89**	-0.28	-1.21	0.13
45	V 336 × HKI 162	-0.17	-1.35	-1.38	-0.74
46	V 336 × CML 169	0.41	0.45	0.49	1.03
47	V 336 × CML 176	-0.78**	2.22**	1.65	-1.1
48	V 336 × CML 161	-0.09	1.42	1.89	2.03
49	V 341 × CML 141	0.57*	-0.14	-0.7	-0.89
50	V 341 × CML 193	-0.28	0.76	1.2	0.21
51	V 341 × DMRQPM 58	0.30	1.39	0.2	1.75
52	V 341 × HKI 164-7-6	-0.68**	2.09**	3.16**	-0.62

Continuing table 6

S. No	Crosses	Grain Yield	Days to 50% tasseling	Days to50% silking	Days to 75% Brown Husk
53	V 341 × HKI 162	0.93**	0.03	0	0.85
54	V 341 × CML 169	0.32	-0.51	-0.14	0.61
55	V 341 × CML 176	0.02	-2.41**	-2.97**	-1.52
56	V 341 × CML 161	-1.18**	-1.21	-0.74	-0.39
57	V 351 × CML 141	1.57**	-0.64	0.55	1.61
58	V 351 × CML 193	-1.12**	-0.41	-0.22	1.38
59	V 351 × DMRQPM 58	0.85**	0.89	-0.22	-0.42
60	V 351 × HKI 164-7-6	-0.51**	-0.41	-0.92	-3.79**
61	V 351 × HKI 162	0.29	0.52	0.58	0.01
62	V 351 × CML 169	-1.04**	0.66	-0.22	1.11
63	V 351 × CML 176	-0.93**	0.43	1.95	1.98
64	V 351 × CML 161	0.89**	-1.04	-1.49	-1.89
65	CM 141 × CML 141	-0.69**	0.69	-0.79	0.07
66	CM 141 × CML 193	-0.15	0.26	2.11*	0.84
67	CM 141 × DMRQPM 58	-1.29**	1.89*	1.78	1.04
68	CM 141 × HKI 164-7-6	0.44	-0.41	-1.92	1.67
69	CM 141 × HKI 162	-1.06**	0.86	2.25*	0.47
70	CM 141 × CML 169	-0.38	1.33	2.11*	0.9
71	CM 141 × CML 176	0.98**	-1.91*	-1.72	-2.23*
72	CM 141 × CML 161	2.16**	-2.71**	-3.82**	-2.76*
73	V 335 × CML 141	1.16**	-0.1	-0.75	-0.43
74	V 335 × CML 193	-0.74**	-2.20**	-1.51	-0.66
75	V 335 × DMRQPM 58	0.09	1.43	1.49	-0.46
76	V 335 × HKI 164-7-6	0.71**	-1.2	-0.88	0.17
77	V 335 × HKI 162	-0.23	0.4	1.29	2.30*
78	V 335 × CML 169	-0.04	0.2	-0.51	-1.6
79	V 335 × CML 176	-1.22**	0.3	0.32	0.6
80	V 335 × CML 161	0.28	1.17	0.55	0.07
SE± (SCA)		0.26	0.83	1.04	1.11
CD 5 %		0.51	1.64	2.06	2.20
CD 1 %		0.67	2.16	2.72	2.90
SE± (Sij - Skl)		0.36	1.17	1.48	1.57
CD 5 %		0.72	2.31	2.92	3.11
CD 1 %		0.95	3.05	3.85	4.10

* and **, significant at 5 and 1 per cent level of significance, respectively.

Table 7. Percent (%) Standard heterosis (SH), better parent heterosis (BPH) and mid parent heterosis (MPH) for yield and maturity traits in Maize

S. No.	Crosses	Grain Yield			Days to 50% tasseling			Days to 50% silking			Days to 75% Brown Husk		
		SH	BPH	MPH	SH	BPH	MPH	SH	BPH	MPH	SH	BPH	MPH
1	HUZM185×CML 141	-2.48	67.14**	101.97* *	-1.38	-0.69	-5.61**	-0.33	0.34	-5.10**	-2.75*	-2.75*	-5.24**
2	HUZM185×CML 193	-7.44	58.64**	63.98 * *	0.00	0.69	-2.68**	0.67	1.35	-2.27	-1.00	-1.00	-2.70**
3	HUZM185×DMRQPM 58	-6.61	41.25**	50.07 * *	-4.48**	-3.82**	-5.30**	-1.34	-0.67	-2.48	-3.50**	-2.77*	-3.14**
4	HUZM185×HKI 164-7-6	-7.02	59.35**	69.68 * *	0.34	1.04	-1.02	-0.33	0.34	-1.65	-2.00	-2.00	-2.61*
5	HUZM185×HKI 162	-45.45**	-6.52	8.55	2.07	2.78*	0.34	1.67	2.36	-0.65	-1.25	-1.25	-1.37
6	HUZM185×CML 169	-27.27**	15.79	20.05	0.34	1.04	-2.51*	2.01	2.69	-0.97	-1.50	-1.50	-2.84**
7	HUZM185×CML 176	-35.54**	10.48	23.22	2.76*	3.47**	0.34	3.34*	4.04**	0.49	0.25	0.25	-1.11
8	HUZM185×CML 161	-38.02**	6.23	25.42	1.38	2.08	-1.67	2.34	3.03	-0.97	-0.50	-0.50	-1.49
9	HUZM97-1-2×CML 141	-46.69**	-39.15**	-15.13	0.34	3.19*	-3.00**	1.34	3.41*	-2.88*	0.00	4.71**	-0.37
10	HUZM97-1-2×CML 193	-33.06**	-23.58**	-5.81	0.00	2.84*	-1.69	0.67	2.73	-1.63	-2.50*	2.09	-2.01
11	HUZM 97-12×DMRQPM58	-45.45**	-37.74**	-29.03 **	-1.72	1.06	-1.55	1.00	3.41*	0.50	-2.75*	1.83	-0.13
12	HUZM97-1-2×HKI 164-7-6	-36.43**	-27.44	-8.43	-0.69	2.13	-1.03	0.00	2.05	-0.66	0.50	5.24**	2.16
13	HUZM97-1-2×HKI 162	-22.31**	-11.32	19.75	0.00	2.84*	-0.68	1.34	3.41*	-0.33	-1.50	3.14*	0.64
14	HUZM97-1-2CML 169	-38.02**	-29.25**	-17.58*	1.38	4.26**	-0.51	3.68**	5.80**	1.31	-0.75	3.93**	0.13
15	HUZM97-1-2×CML 176	-38.02**	-29.25**	-7.41	1.38	4.26**	0.00	4.35**	6.48**	2.13	-1.00	3.66**	-0.13
16	HUZM97-1-2×CML 161	-33.06**	-23.58**	4.52	0.34	3.19*	-1.69	2.01	4.10**	-0.65	-0.75	3.93	0.51

Continuing table 7

S. No.	Crosses	Grain Yield			Days to 50% tasseling			Days to 50% silking			Days to 75% Brown Husk		
		SH	BPH	MPH	SH	BPH	MPH	SH	BPH	MPH	SH	BPH	MPH
17	HUZM509×CML 141	-49.72**	15.43	23.27	4.48**	0.66	-2.10*	5.35**	-0.63	-2.78*	2.00	-0.49	-1.81
18	HUZM509 × CML 193	-24.79**	37.88**	53.33**	5.52**	1.66	0.49	4.68**	-1.26	-1.57	1.50	-0.98	-1.46
19	HUZM509 × DMRQPM 58	-28.93**	7.50	29.62*	0.34	-2.02	-2.68**	1.67	-1.30	-2.72*	-1.00	-0.25	-1.86
20	HUZM509×HKI 164-7-6	-34.21**	28.39	38.80**	-2.41*	-5.67**	-5.82**	-2.34	-5.50**	-6.71**	0.75	-0.49	-1.10
21	HUZM509×HKI 162	-42.98**	30.93	33.08*	1.38	-2.33*	-2.49*	2.01	-3.17*	-3.48**	0.75	0.50	-0.62
22	HUZM509×CML 169	-37.19**	0.00	18.10	3.45**	-0.33	-1.64	3.68**	-2.21	-2.52*	-1.75	-4.15**	-4.26**
24	HUZM509 × CML 161	-23.97**	74.57**	80.92**	3.10*	-0.66	-2.13*	2.68	-3.15*	-3.76**	-0.50	-2.45*	-2.69*
25	HKI 287 × CML 141	-25.62**	1.35	33.28**	1.72	-1.99	-4.68**	2.34	-0.65	-4.23**	-1.75	-5.07**	-5.87**
26	HKI 287 × CML 193	-38.84**	-16.67	-4.39	4.48**	0.66	-0.49	5.02**	1.95	0.16	1.00	-2.42*	-2.42*
27	HKI 287 × DMRQPM 58	-42.15**	-21.17*	-17.06	0.00	-2.36*	-3.01**	2.01	-0.97	-0.97	-2.75*	-2.02	-4.07**
28	HKI 287 × HKI164-7-6	-56.45**	-40.65**	-30.11**	2.41*	-1.00	-1.16	4.01**	0.97	0.81	1.25	0.00	-1.10
29	HKI 287 × HKI 162	-32.16**	-7.66	17.43	1.03	-2.66*	-2.82**	1.67	-1.30	-2.41	0.00	-0.25	-1.84
30	HKI 287 × CML 169	-16.39*	13.74	22.78*	1.03	-2.66*	-3.93**	2.34	-0.65	-2.39	1.00	-1.70	-2.06*
31	HKI 287 × CML 176	-17.36*	12.61	38.12**	2.41*	-1.33	-2.14*	2.68	-0.32	-1.92	1.00	-1.70	-2.06*
32	HKI 287 × CML 161	-23.55**	4.17	34.25**	1.03	-2.66*	-4.09**	1.34	-1.62	-3.66**	-0.75	-2.70*	-3.41**
33	HUZM478 × CML 141	-30.58**	-3.45	26.08*	3.45**	-3.23**	-4.46**	2.34	-3.77**	-5.70**	0.50	-2.43*	-3.48**

Continuing table 7

S. No.	Crosses	Grain Yield			Days to 50% tasseling			Days to 50% silking			Days to 75% Brown Husk		
		SH	BPH	MPH	SH	BPH	MPH	SH	BPH	MPH	SH	BPH	MPH
34	HUZM478 × CML 193	-4.13	33.33**	51.63**	5.17**	-0.97	-1.29	5.02**	-1.26	-1.41	1.00	-1.94	-2.18*
35	HUZM478×DMRQPM 58	-18.18*	13.79	18.56	4.83**	2.36*	0.16	4.01**	0.97	-0.64	-0.25	0.50	-1.36
36	HUZM478 × HKI 164-7-6	-5.79	31.03**	53.02**	0.69	-2.67*	-4.26**	0.67	-2.59	-3.99**	0.75	-0.49	-1.35
37	HUZM478 × HKI 162	-12.40	21.84*	53.62**	2.41*	-1.66	-2.94**	1.67	-3.49*	-3.95**	0.00	-0.25	-1.60
38	HUZM478 × CML 169	-17.36*	14.94	22.70*	3.79**	-2.91*	-3.07**	5.02**	-1.26	-1.41	1.25	-1.46	-1.58
39	HUZM478 × CML 176	-5.99	31.03**	59.09**	3.79**	-1.63	-2.27*	4.01**	-2.20	-2.20	1.00	-1.70	-1.82
40	HUZM478 × CML 161	-44.46**	-22.76*	-1.18	3.45**	-3.23**	-3.23**	3.34*	-2.83*	-3.29**	2.00	0.00	-0.49
41	V 336 × CML 141	-12.40	10.42	49.03**	2.41*	0.68	-3.10**	2.68	1.32	-3.15**	0.25	-2.43*	-3.61**
42	V 336 × CML 193	-23.97**	-4.17	13.58	4.14**	2.37*	0.17	5.02**	3.63*	0.96	1.25	-1.46	-1.82
43	V 336 × DMRQPM 58	-16.53*	5.21	14.77	-1.38	-3.05*	-3.38**	-0.33	-1.65	-2.45*	-1.50	-0.76	-2.48*
44	V 336 × HKI 164-7-6	4.96	32.29**	60.76**	0.69	-1.02	-1.85	-0.67	-1.98	-2.94*	1.00	-0.25	-0.98
45	V 336 × HKI 162	-24.79**	-5.21	23.81 *	1.03	-0.68	-1.84	1.34	0.00	-1.94	0.50	0.25	-0.99
46	V 336 × CML 169	-10.74	12.50	25.58**	3.79**	2.03	-0.33	4.68**	3.30*	0.64	1.75	-0.97	-0.97
47	V 336 × CML 176	-32.51**	-14.93	7.46	5.52**	3.73**	1.83	5.35**	3.96	1.45	0.50	-2.19	-2.19*
48	V 336 × CML 161	-14.88	7.29	42.07**	3.79**	2.03	-0.50	4.01**	2.64	-0.32	2.00	0.00	-0.37
49	V 341 × CML 141	8.26	183.24**	184.78**	1.72	0.68	-3.44**	0.67	-2.59	-5.94**	0.25	-0.74	-2.79**

Continuing table 7

S. No.	Crosses	Grain Yield			Days to 50% tasseling			Days to 50% silking			Days to 75% Brown Husk		
		SH	BPH	MPH	SH	BPH	MPH	SH	BPH	MPH	SH	BPH	MPH
50	V 341 × CML 193	-20.66**	45.45**	71.43**	3.79**	2.73*	0.17	4.35**	0.97	-0.64	1.75	0.74	-0.49
51	V 341 × DMRQPM 58	-4.96	43.75**	82.54**	2.07	1.02	0.34	1.34	-1.62	-1.78	0.75	1.51	0.62
52	V 341 × HKI 164-7-6	-21.49**	53.23**	75.93**	2.41*	1.37	0.17	2.68	-0.65	-0.65	0.75	-0.25	-0.37
53	V 341 × HKI 162	4.13	147.06**	159.79**	1.72	0.68	-0.84	1.67	-1.62	-2.56*	2.00	1.75	1.37
54	V 341 × CML 169	-6.61	48.68**	85.25**	2.07	1.02	-1.66	3.01*	-0.32	-1.91	1.75	0.74	-0.12
55	V 341 × CML 176	-9.92	94.64**	113.73**	0.00	-1.02	-3.17**	-0.33	-3.56*	-4.94**	0.50	-0.50	-1.35
56	V 341 × CML 161	-31.40**	69.39**	74.74**	0.34	-0.68	-3.48**	0.33	-2.91	-4.76**	0.50	-0.50	-0.99
57	V 351 × CML 141	28.10**	121.43**	166.67**	-3.10*	0.36	-6.02**	-2.34	1.39	-5.65**	-1.25	1.80	-2.35*
58	V 351 × CML 193	-38.84**	5.71	8.82	-1.72	1.79	-3.06**	-1.34	2.43	-2.80*	-0.75	2.32	-1.00
59	V 351 × DMRQPM 58	5.62	59.75**	70.40**	-2.76*	0.71	-2.25*	-3.34*	0.35	-3.02*	-4.25**	-1.29	-2.42*
60	V 351 × HKI 164-7-6	-19.01*	40.00**	48.48**	-4.48**	-1.07	-4.48**	-5.69**	-2.08	-5.53**	-5.00**	-2.06	-4.16**
61	V 351 × HKI 162	-9.92	55.71**	80.17**	-2.07	1.43	-2.41*	-2.01	1.74	-2.82*	-2.00	1.03	-0.63
62	V 351 × CML 169	-35.74**	2.30	6.51	-1.03	2.50*	-2.55*	-1.34	2.43	-2.80*	-1.25	1.80	-1.13
63	V 351 × CML 176	-30.58**	20.00	33.33**	-1.38	2.14	-2.39*	0.33	4.17**	-0.99	-0.25	2.84*	-0.13
64	V 351 × CML 161	10.74	91.43**	125.21**	-3.79**	-0.36	-5.42**	-4.68**	-1.04	-6.40**	-4.00**	-1.03	-3.52**
65	CM 141 × CML 141	-2.48	155.14**	158.63**	0.34	-4.59**	-6.58**	-0.67	-7.48**	-8.90**	1.00	-4.04**	-5.16**
66	CM 141 × CML 193	-2.48	79.04**	112.91**	1.03	-3.93**	-4.40**	4.01**	-2.51	-2.81*	2.25	-1.21	-3.20**
67	CM 141×DMRQPM 58	-22.45**	17.29	50.13**	0.34	-2.02	-3.32**	1.67	-1.30	-3.34**	0.25	1.01	-3.14**
68	CM 141×HKI 164-7-6	17.36*	129.03**	165.42**	-2.41*	-5.67**	-6.45**	-3.68*	-6.80**	-8.57**	2.50 *	1.23	-1.91

Continuing table 7

S. No.	Crosses	Grain Yield			Days to 50% tasseling			Days to 50% silking			Days to 75% Brown Husk		
		SH	BPH	MPH	SH	BPH	MPH	SH	BPH	MPH	SH	BPH	MPH
69	CM 141 × HKI 162	-21.49*	86.27**	97.92**	0.34	-3.64**	-4.12**	2.68	-2.54	-3.46**	1.75	1.50	-2.16*
70	CM 141 × CML 169	-5.79	50.00**	88.71**	1.72	-3.28**	-3.91**	4.01**	-2.51	-2.81*	2.00	-0.73	-3.09**
71	CM 141 × CML 176	25.62**	171.43**	200.99**	-1.72	-6.56**	-6.71**	-0.33	-6.29**	-6.73**	0.00	-2.68*	-4.99**
72	CM 141 × CML 161	53.31**	278.57**	294.68**	-3.45**	-8.20**	-8.94**	-4.01**	-10.59**	-10.59**	-0.75	-3.19**	-5.84**
73	V 335 × CML 141	34.71**	84.18**	141.93**	-0.69	-0.35	-5.11**	-1.67	-1.34	-6.52**	-0.50	-0.75	-3.16**
74	V 335 × CML 193	-15.87*	15.03	31.78**	-1.72	-1.38	-4.52**	-0.67	-0.34	-3.73**	0.00	-0.25	-1.84
75	V 335 × DMRQPM 58	4.96	43.50**	50.74**	-0.34	0.00	-1.37	0.33	0.67	-0.99	-2.00	-1.26	-1.75
76	V 335 × HKI 164-7-6	21.49*	66.10**	95.35**	-3.45**	-3.11*	-4.92**	-3.68*	-3.36*	-5.11**	0.25	0.00	-0.50
77	V 335 × HKI 162	-5.79	28.81* *	63.44**	-0.34	0.00	-2.20*	0.67	1.01	-1.79	2.00	1.75	1.75
78	V 335 × CML 169	0.00	36.72* *	47.11**	0.34	0.69	-2.68**	0.33	0.67	-2.76*	-1.00	-1.25	-2.46*
79	V 335 × CML 176	-21.49*	7.34	31.49**	0.34	0.69	-2.18*	0.67	1.01	-2.27	1.00	0.75	-0.49
80	V 335 × CML 161	13.22	54.80**	99.27**	0.34	0.69	-2.84**	-0.67	-0.34	-4.04**	-0.25	-0.50	-1.36
SE±		0.36	0.36	0.31	1.17	1.17	1.01	1.48	1.48	1.28	1.57	1.57	1.36
CD 5 %		0.72	0.72	0.62	2.31	2.31	2.00	2.92	2.92	2.53	3.11	3.11	2.69
CD 1 %		0.95	0.95	0.83	3.05	3.05	2.64	3.85	3.85	3.33	4.10	4.10	3.55
Mean Heterosis (%)		-16.58	35.48	55.49	0.83	-4.75	-2.63	1.30	-4.87	-2.69	-0.10	-3.61	-2.01
Crosses with positive heterosis		15	62	70	58	40	10	58	35	9	46	30	7
Crosses with negative heterosis		65	18	10	22	40	70	22	45	71	34	50	73
Range		-56.45 to 53.31	- 40.65 to 278.57	-30.11 to 294.68	-4.48 to 5.52	-8.2 to 4.26	-8.94 to 1.83	-5.69 to 5.35	-10.59 to 6.48	-10.59 to 2.13	-5 to 2.5	-5.07 to 5.24	-5.87 to 2.16

* and **, significant at 5 and 1 per cent level of significance, respectively.

Table 8. Top ranking (First five) cross combinations based on Per se performance, SCA, GCA effects and Heterosis

Traits	Significant Crosses	*Per se* performance			sca effect	gca effects		Standard Heterosis
		F_1	Line	Tester		Line	Tester	
Grain Yield	CM 141 × CML 161	7.42 t/ha	1.80 t/ha	1.96 t/ha	2.16**	1.05**	0.16**	53.31**
	V 335 × CML 141	6.52 t/ha	3.54 t/ha	1.85 t/ha	1.16**	0.99**	0.32**	34.71**
	V 351 × CML 141	6.20 t/ha	2.80 t/ha	1.85 t/ha	1.57**	0.26**	0.32**	28.10**
	CM 141 × CML 176	6.08 t/ha	1.80 t/ha	2.24 t/ha	0.98**	1.05**	0.00	25.62**
	V 335 × HKI 164-7-6	5.88 t/ha	3.54 t/ha	2.48 t/ha	0.71**	0.99**	0.13	21.49*
Days to 50 % tasseling	HUZM185 × DMRQPM 58	92.33	96.00	99.00	-3.36**	-0.68*	-1.10**	-4.48**
	V 351 × HKI 164-7-6	93.00	93.33	100.00	-0.41	-3.26**	-1.47**	-4.48**
	V 351 × CML 161	93.33	93.33	103.33	-1.04	-3.26**	-0.17	-3.79**
	V 335 × HKI 164-7-6	93.33	96.33	100.00	-1.20	-1.47**	-1.47**	-3.45**
	CM 141 × CML 161		101.67	103.33	-2.71**	-1.26**	-0.17	-3.45**
Days to 50 % silking	V 351 × HKI 164-7-6	94.00	96.00	103.00	-0.92	-3.85**	-2.20**	-5.69**
	V 351 × CML 161	95.00	96.00	107.00	-1.49	-3.85**	-0.64	-4.68**
	CM 141 × CML 161	95.67	107.00	107.00	-3.82**	-0.85*	-0.64	4.01**
	V 335 × HKI 164-7-6	96.00	99.33	103.00	-0.88	-1.89**	-2.19**	-3.68*
	CM 141 × HKI 164-7-6	96.00	107.00	103.00	-1.92	-0.85**	-2.20**	-3.68*
Days to 75 % Brown Husk	V 351 × HKI 164-7-6	126.67	129.33	135.00	-3.79**	-2.98**	0.25	-5.00**
	V 351 × DMRQPM 58	127.67	129.33	132.33	-0.42	-2.98**	-2.12**	-4.25**
	V 351 × CML 161	128.00	129.33	136.00	-1.89	-2.98**	-0.32	-4.00**
	HUZM185 × DMRQPM 58	128.67	133.33	132.33	-0.50	-1.90**	-2.12**	-3.50**
	HUZM185 × CML 141	129.67	133.33	140.33	-1.47	-1.90**	-0.16	-2.75*

* and **, significant at 5 and 1 per cent level of significance, respectively.

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