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Research Article

Heterosis analysis for grain yield traits in Maize (*Zea mays* L.)

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Abstract

In the present study 6 inbreds were used as parents to make crosses in all possible cross combination in full diallel fashion to obtain total 30 possible F_1 hybrids. These 30 F_1's were subjected to heterosis analysis for midparental, heterobeltiosis and standard heterosis, where 900M a prominent hybrid was used as standard check. For judging good F1 hybrids, negative heterosis was considered to be better for five traits (days to tasseling, days to silking, anthesis silking interval, days to maturity and plant height), while positive heterosis was considered to be desirable for the remaining traits (ear length, ear girth, number of kernel rows per ear, number of kernels per row, ear weight, shelling per cent, 100 grain weight and grain yield per plant). A perusal of standard heterosis revealed that out of 30 crosses studied, none of the hybrids were found to possess significant standard heterosis for all the traits studied. A total of eight hybrids exhibited significant and favourable standard heterosis for grain yield and its component traits. Among the eight hybrids, the hybrid UMI 133 x UMI 122 for seven traits and the remaining hybrids *viz* UMI 112 x UMI 66, UMI 112 x UMI 122, UMI 112 x UMI 133, UMI 122 x UMI 66, UMI 133 x UMI 112, UMI 133 x UMI 213 and UMI 213 x UMI 112 for five traits recorded significant and favourable standard heterosis and these could be adjudged as promising hybrids. Though the hybrids UMI 213 x UMI 176, UMI 133 x UMI 66 showed significant and favourable standard heterosis for maximum number traits, they were not considered as best ones due to the non significant standard heterosis of those hybrids for most important trait i.e. grain yield per plant. The extent of heterosis for grain yield per plant over check hybrid was found to be the maximum followed by ear weight. The heterosis over check hybrid recorded for anthesis silking interval was the maximum among the traits for which negative heterosis was favourable followed by plant height.

Keywords

Maize, heterosis, diallel, inbred, standard heterosis.

Introduction

Few agronomic improvements during the 20^{th}century rival the development of hybrid maize (*Zea mays* L.) Duvick (2001). Yields increased dramatically as breeders moved away from open-pollinating cultivars (OPVs) and began developing hybrids. The pure-line hybrid concept traces its roots back to experiments on heterosis and its complement inbreeding conducted by Shull (1908). They observed that when maize plants are selfed, their vigor and grain yield declines rapidly. However, when two inbred lines are crossed, both vigor and grain yield of the F1 hybrid often exceeds the mean of the two parents. It was this observation, made over 90 years ago, and methodology outlined by Shull (1909) that gave rise to the modern maize industry. 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 favorable biological prerequisites such as large multiplication coefficient and ease of both self- and controlled cross-fertilization. Although many hypotheses have been suggested to explain heterosis, its genetical, physiological, and biochemical bases still remain largely unexplained. Heterosis is a major yield factor in all breeding categories except line breeding. To systematically exploit heterosis in hybrid breeding, the concept of heterotic groups and patterns was suggested. Melchinger and Gumber (1998) defined a heterotic group "as a group of related or unrelated genotypes from the same or different populations, which display similar combining ability and heterotic response when crossed with genotypes from other genetically distinct germplasm groups. By comparison, the term heterotic pattern refers to a specific pair of two heterotic groups, which express high heterosis and consequently high hybrid performance in their cross." The concept of heterotic patterns includes the subdivision of the germplasm available in a hybrid breeding program in at least two divergent populations, which are improved with inter-population selection methods. Heterotic patterns have a strong impact in crop improvement because they predetermine to a large extent the type of germplasm used in a hybrid breeding program over a long period of time. looking to the importance of heterosis experiment was conducted with the objective to study of heterotic pattern of grain yield parameters in maize.

Materials and Methods

A field experiment in maize crop was conducted in the department of Plant Breeding and Genetics, Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal during the year 2012-2013. The materials used and methods adopted for the conduct of the experiment is given in detail as below. The materials used for the study is six maize inbreds one standard commercial check (Table 1). These inbreds were crossed by adopting full diallel mating design. A total of thirty hybrid combinations including direct, reciprocals and six parental combinations were obtained during *Rabi* season, 2012. All the six parental inbreds were raised during *Rabi* season, 2012 in two staggered sowings at five days interval to get the synchronization of flowering. All the recommended cultural practices were followed.. Ear shoot of maize emerging from the leaf sheath was bagged by using butter paper cover placed over the tassel to protect the silk from contamination of alien pollen through wind pollination. Ear shoots were covered two days before silk emergence. Brown paper cover was covered over the tassel of the male parents on the day previous to pollination to collect pollen. The pollen collected from the desired male tassel bag was dusted over the silk of the corresponding females after removing the butter paper cover and it was replaced immediately to avoid other pollen contamination. The tassel bag was replaced on the same plant for further pollen collection. The manual hand pollination was carried out between 9 am and 10 am during the hours of bright sunshine. Selfing was done by dusting the pollens collected from the same plant. All the three types of heterosis for each of the 30 hybrids were estimated using the following formulae (Fonseca and Patterson, 1968). For Relative heterosis (di) = F1-MP/MP X 100, Heterobeltiosis (dii) = F1-BP/BP X 100 and Standard heterosis (diii) [(F1 - SH) / SH] x 100 Where, F1 = mean value of the F1 hybrid, MP = mid parental value, BP = mean of better parental value, SH = mean of the standard check hybrid (900 M). Test of significance: Significance of heterosis was tested by t test as per the following formula. The t test for mid parent$= \frac{\text{parameter}}{\sqrt{3/2\sigma 2_e}}$, t test for better and standard parent $=\frac{\text{parameter}}{\sqrt{2\text{EMS}/r}}$.

Results and Discussion

Variable magnitude of three types of heterosis *viz*., relative heterosis, heterobeltiosis and standard heterosis for 30 hybrids for all the traits are presented in a trait wise here under. For days to tasseling, the range of heterosis over mid parent for this trait was between -11.82 per cent (UMI 66 x UMI 213, UMI 213 x UMI 66) and 2.58 per cent (UMI 122 x UMI 66). Fifteen out of 30 hybrids recorded significantly negative relative heterosis. Eighteen hybrids recorded significant heterosis over better parent in negative direction which ranged from -14.29 per cent (UMI 66 x UMI 213, UMI 213 x UMI 66) to 2.58 per cent (UMI 122 x UMI 66). The heterosis over standard check hybrid varied between -9.27 per cent (UMI 133 x UMI 66) and 10.60 per cent (UMI 112 x UMI 66). Ten out of 30 hybrids recorded significantly negative heterosis over the standard check (Table 10). For days to silking, the highest and the lowest value of 5.39 per cent and -13.20 per cent was exhibited by the crosses UMI 122 x UMI 213 and UMI 122 x UMI 176 respectively for mid parental heterosis. A total of 20 cross combinations were assumed negative significance for this trait. Negatively significant heterosis over better parent was observed in 24 cross combinations. Out of 30 hybrids evaluated for standard heterosis, seven combinations have deviated towards negative direction than the standard parent. The range of relative heterosis for Anthesis silking interval was from -54.84 per cent (UMI 133 x UMI 213) to 40.74 per cent (UMI 122 x UMI 213). Negatively significant heterosis over mid parent was observed in 15 cross combinations. The heterobeltiosis ranged from -58.82 per cent (UMI 122 x UMI 66) to 31.25 per cent (UMI 213 x UMI 176). A total of 17 hybrids registered significant negative heterosis over better parent. For standard heterosis, the highest and lowest value was recorded by the hybrids UMI 213 x UMI 176, UMI 122 x UMI 112 (75.00 per cent) and UMI 122 x UMI 66 (-41.67 per cent). Three hybrids showed significant negative heterosis over standard check hybrid Table 1. The mid parental heterosis for days to maturity trait was between -4.55 per cent (UMI 133 x UMI 122) and 7.63 per cent (UMI 112 x UMI 122). The hybrids UMI 133 x UMI 176 and UMI 213 x UMI 133 expressed significant negative heterosis against the mid parent. The range of heterobeltiosis was from -9.47 per cent (UMI 213 x UMI 176) to 7.42 per cent (UMI 112 x UMI 122). A total of 16 hybrids were manifested by significant negative heterosis against better parents. For the standard heterosis, the

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heterotic values ranged from -6.67 per cent (UMI 133 x UMI 122) to 5.56 per cent (UMI 66 x UMI 112, UMI 66 x UMI 112). Eight hybrids exhibited significant negative heterosis against the standard check . For plant height (cm), the heterosis over mid parent for this trait was between -13.29 per cent (UMI 176 x UMI 122) and 26.29 per cent (UMI 112 x UMI 133). Seven out of 30 hybrids recorded significant negative relative heterosis. The range of heterobeltiosis was from -21.54 per cent (UMI 176 x UMI 122) to 25.98 per cent (UMI 112 x UMI 133). Significant negative heterosis was observed in 16 hybrids against the better parent. The magnitude of standard heterosis varied from -9.41 per cent (UMI 176 x UMI 122) to 14.57 per cent (UMI 213 x UMI 133). Heterosis over standard check was observed to be significant and negative in direction for 10 hybrids. The heterosis over mid parent for this trait was between -8.32 per cent (UMI 213 x UMI 176) and 39.47 per cent (UMI 133 x UMI 66) for ear length (cm). Out of 30 hybrids, 23 hybrids showed positively significant mid parent heterosis. The better parent heterosis ranged from -16.40 per cent (UMI 122 x UMI 112) to 36.88 per cent (UMI 213 x UMI 122). Significant positive heterosis over its better parents was expressed by 20 out of 30 hybrids. Heterosis over standard check was least in the hybrid UMI 122 x UMI 112 (-19.79 per cent) and high in UMI 213 x UMI 122 (30.47 per cent). Out of 30 hybrids studied, 11 hybrids expressed positively significant heterosis over the standard parent. The trait ear girth shown the range of relative heterosis for this trait was from -20.74 per cent (UMI 112 x UMI 122) to 26.83 per cent (UMI 213 x UMI 112). Out of 30 hybrids 17 have registered significant mid parent heterosis in positive side. The better parent heterosis ranged from -25.26 per cent (UMI 112 x UMI 122) to 20.60 per cent (UMI 213 x UMI 133). Seven hybrids have registered significant heterosis in positive side than the better parent. The highest and the lowest standard heterosis were recorded by the hybrids UMI 213 x UMI 112 (21.59 per cent) and UMI 112 x UMI 122 (-16.21 per cent). Significant standard heterosis was observed in six hybrids. Number of kernel rows per ear have Maximum positive significant relative heterosis was recorded by the hybrid UMI 213 x UMI 66 (40.20 per cent). The relative heterosis ranged from -13.79 per cent (UMI 112 x UMI 122) to 40.20 per cent (UMI 213 x UMI 66). Out of 30 hybrids studied, 13 hybrids showed significant positive relative heterosis. The maximum and minimum heterobeltiosis of 31.85 per cent and -22.67 per cent was recorded by UMI 213 x UMI 66 and UMI 213 x UMI 122 respectively. Significant positive heterobeltiosis was shown by seven hybrids. The extent of heterosis over standard check ranged between -13.63 per cent (UMI 176 x UMI 133) and 17.86 per cent (UMI 66 x UMI 112). Out of seven hybrids showing significant value, six hybrids attained positively significant heterosis over standard check. The relative heterosis of the hybrids for number of kernels per row exhibited a range from -9.74 per cent (UMI 176 x UMI 112) to 29.64 per cent (UMI 112 x UMI 66). Out of 30 hybrids, 16 hybrids showed significant positive relative heterosis. Heterosis over better parent varied from -12.34 per cent (UMI 176 x UMI 66) to 24.84 per cent (UMI 112 x UMI 66). Out of 30 hybrids, 16 hybrids were found to exhibit positively significant heterobeltiosis. Out of 15 hybrids with significant standard heterosis, 12 hybrids exhibited positive significant standard heterosis over standard hybrid check. For ear weight, the minimum and the maximum relative heterosis was -11.47 and 24.74 per cent as manifested by the hybrids UMI 122 x UMI176 and UMI 133 x UMI176 respectively. Out of 30 hybrids, 22 hybrids expressed significant relative heterosis positive side. Out of 30 hybrids, 21 hybrids have recorded significant heterobeltiosis in positive direction and the range was from -12.54 per cent (UMI 122 x UMI 176) to 23.22 per cent (UMI 133 x UMI 66). A total of 16 hybrids have recorded positively significant heterotic value against the standard check. The hybrid UMI 122 x UMI 66 has expressed the highest heterotic values for relative heterosis, heterobeltiosis and standard heterosis with an extent heterotic values of 24.04 per cent, 17.15 per cent and 20.91 per cent respectively, while the hybrid UMI 122 x UMI 213 exhibited the least heterotic values for relative heterosis, heterobeltiosis and standard heterosis with heterotic values of -27.51 per cent, -34.46 per cent and -25.63 per cent respectively. Out of 30 hybrids studied, ten each for relative heterosis, standard heterosis and five for heterobeltiosis exhibited significant heterosis positively. For shelling per cent, the highest relative heterosis was recorded by the hybrid UMI 122 x UMI 176 (28.35 per cent) and the least relative heterosis was expressed by the hybrid UMI 112 x UMI 176 (-5.70). Out of 30 hybrids studied, 21 hybrids showed significant positive relative heterosis. The maximum and the minimum heterobeltiosis value of 26.91 per cent and -12.34 per cent were recorded by UMI 122 x UMI 176 and UMI 133 x UMI 213 respectively. Significant positive heterobeltiosis was explored by 17 hybrids. The extent of heterosis over standard check ranged between -15.69 per cent (UMI 112 x UMI 176) and 15.10 per cent (UMI 133 x UMI 122). Ten hybrids attained positively significant standard

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heterosis. The trait grain yield per plant has the heterosis over mid parent for this trait was ranged between -22.25 per cent (UMI 122 x UMI 213) and 42.42 per cent (UMI 122 x UMI 66). 18 out of 30 hybrids recorded significant positive relative heterosis. The range of heterobeltiosis was from -28.84 per cent (UMI 122 x UMI 213) to 39.59 per cent (UMI 122 x UMI 66). Significant positive heterosis was observed in 13 hybrids against the better parent. The magnitude of standard heterosis varied from -24.86 per cent (UMI 122 x UMI 112) to 30.01 per cent (UMI 122 x UMI 66). Heterosis over standard check was observed to be significant and positive in direction for 15 hybrids (Table 2).

The objective of hybridization is to exploit the magnitude of heterosis on commercial basis by selecting promising cross combinations. Cross pollinated crops like maize offers tremendous scope for heterosis breeding owing to its out crossing nature. Heterosis in cross pollinated crop has long been known to offer good potentialities for increased yield. In the present investigation, the heterosis of direct and reciprocal cross combinations derived from the six parental inbreds through diallel mating was estimated over mid parent (di), better parent (dii) and standard hybrid (diii). However, the productive hybrids are weighed not merely by the expression of heterosis over the parents but also in relation to the standard check hybrid. Hence the standard heterosis (diii) was taken as an important criterion for evaluation of hybrids. The commercial hybrid 900M was used as the standard check to estimate the standard heterosis. The 30 hybrids in the present study were evaluated based on the standard heterosis. For judging good F1 hybrids, negative heterosis was considered to be better for five traits (days to tasseling, days to silking, anthesis silking interval, days to maturity and plant height), while positive heterosis was considered to be desirable for the remaining traits (ear length, ear girth, number of kernel rows per ear, number of kernels per row, ear weight, shelling per cent, 100 grain weight and grain yield per plant) A perusal of standard heterosis revealed that out of 30 crosses studied, none of the hybrids were found to possess significant standard heterosis for all the traits studied. A total of eight hybrids exhibited significant and favourable standard heterosis for grain yield and its component traits. Among the eight hybrids, the hybrid UMI 133 x UMI 122 for seven traits and the remaining hybrids *viz* UMI 112 x UMI 66, UMI 112 x UMI 122, UMI 112 x UMI 133, UMI 122 x UMI 66, UMI 133 x UMI 112, UMI 133 x UMI 213 and UMI 213 x UMI 112 for five traits have recorded significant and favourable standard heterosis and these could be adjudged as the best hybrids. The same trend of high standard heterosis was reported by Dodiya and Joshi (2003). Though the hybrids UMI 213 x UMI 176, UMI 133 x UMI 66 showed significant and favourable standard heterosis for maximum number of traits, they were not considered as best ones due to the non significant standard heterosis of those hybrids for most important trait grain yield per plant. The extent of heterosis for grain yield per plant over check hybrid was found to be the maximum followed by ear weight. The heterosis over check hybrid recorded for anthesis silking interval was the maximum among the traits for which negative heterosis was favourable and was followed by plant height. This is in line with the findings of Nagda *et al*. (1995), Revilla *et al.* (2006), Saidaiah *et al.* (2006) and Amiruzzaman *et al*. (2011).

Exploitation of hybrid vigour is considered as an outstanding accomplishment of plant breeding. The magnitude of heterosis shown by the hybrids depends largely on the heterotic pattern and genetic divergence between parental inbred lines. Development of single cross hybrids in maize depends on the *per se* performance of the inbred lines and their combining ability for important traits. Selection based on *per se* performance , *sca* effects and heterotic pattern individually led to the identification of different hybrids, but considering all the three parameters together will facilitate the breeder to choose best hybrids for the commercial exploitation of F1 heterosis (Table 3). The importance of considering the three parameters *per se*, *sca* effects and standard heterosis also reported by Dodiya and Joshi (2003) and Premalatha *et al.* (2011). Considering these views, the 30 hybrids involved in the present investigation were ranked based on the three criteria. A score chart has been prepared for hybrids by scoring significant parameters to each trait. The hybrid UMI 122 x UMI 176 recorded the highest total score (25) followed by UMI 133 x UMI 122, UMI 213 x UMI 176 with total score 19 but have failed to show significant for grain yield per plant with respect to *per se*, *sca* and standard heterosis. For grain yield per plant as shown in Table 1, hybrids *viz.*, UMI 112 x UMI 213, UMI 122 x UMI 66, UMI 66 x UMI 112, UMI 133 x UMI 176, UMI 112 x UMI 133 and UMI 66 x UMI 122 expressed favourable significant mean performance for all the three parameters (Table 4). Hence these hybrids could be better exploited for heterosis breeding by using Specific combining ability effects (Table 5).

The study was conducted to evaluate the hybrids which were suitable for Pondicherry and Tamil Nadu, Some superior hybrids have been identified in terms of grain yield from the 30 cross combinations using commercial heterotic analysis (Standard check - 900M)

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Table 1.Details of parents and check used in the study.

S. No.	Name of the inbred	Source
1.	UMI 66	MBS, TNAU, Coimbatore
2.	UMI 112	MBS, TNAU, Coimbatore
3.	UMI 122	MBS, TNAU, Coimbatore
4.	UMI 133	MBS, TNAU, Coimbatore
5.	UMI 176	MBS, TNAU, Coimbatore
6.	UMI 213	MBS, TNAU, Coimbatore
7	900M (Check)	Monsanto

UMI - University Maize Inbred; MBS - Millet Breeding Station; TNAU - Tamil Nadu Agricultural University.

Table 2. Extent of heterois (per cent) for grain yield per plant in maize

S. No.	Hybrids	Relative heterosis (d_i)	Heterobeltiosis (d_{ii})	Standard heterosis (diii)
1.	UMI 66 x UMI 112	24.62**	14.82**	6.93**
2.	UMI 66 x UMI 122	19.74**	17.36**	9.30**
3.	UMI 66 x UMI 133	-9.53**	-12.57**	-12.71**
4.	UMI 66 x UMI 176	-13.07**	-14.91**	-17.25**
5.	UMI 66 x UMI 213	10.57**	3.09**	11.03**
6.	UMI 112 x UMI 66	26.15**	16.22**	8.24**
7.	UMI 112 x UMI 122	25.67**	17.98**	5.51**
8.	UMI 112 x UMI 133	17.97**	5.34**	5.18**
9.	UMI 112 x UMI 176	-6.60**	-15.61**	-17.94**
10.	UMI 112 x UMI 213	18.23**	2.19*	10.05**
11.	UMI 122 x UMI 66	42.42**	39.59**	30.01**
12.	UMI 122 x UMI 112	-10.49**	-15.97**	-24.86**
13.	UMI 122 x UMI 133	4.13**	-1.30	-1.25
14.	UMI 122 x UMI 176	5.62**	1.38	-1.42
15.	UMI 122 x UMI 213	-22.25**	-28.84**	-23.36**
16.	UMI 133 x UMI 66	0.06	-3.30**	-3.45**
17.	UMI 133 x UMI 112	18.85**	6.13**	5.96**
18.	UMI 133 x UMI 122	19.72**	13.47**	13.30**
19.	UMI 133 x UMI 176	6.29**	4.91**	4.74**
20.	UMI 133 x UMI 213	9.15**	5.17**	13.27**
21.	UMI 176 x UMI 66	11.24**	8.89**	5.89**
22.	UMI 176 x UMI 112	4.71**	-5.39**	-8.00**
23.	UMI 176 x UMI 122	-4.45**	-8.29**	-10.82**
24.	UMI 176 x UMI 133	0.36	-0.95	-1.10
25.	UMI 176 x UMI 213	1.32	-3.60**	3.82**
26.	UMI 213 x UMI 66	-14.01**	-19.83**	-13.65**
27.	UMI 213 x UMI 112	11.71**	-3.45**	3.98**
28.	UMI 213 x UMI 122	2.64**	-6.07**	1.17
29.	UMI 213 x UMI 133	-11.81**	-15.03**	-8.49**

SE for (di) = 0.93 * Significant at 5% level ** Significant at 1%

Table 3. Score chart for evaluation of hybrids for grain yield and its attributes based on *per se*, *sca* and standard heterosis in maize.

Hybrids	Days to tasseling	Days to silking	Anthesis silking interval	Days to maturity	Plant height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernel rows per ear	No. of Kernels per row	Ear weight (g)	Shelling per cent	100 grain weight (g)	Grain yield per plant (g)
UMI 66 x UMI 112	-	-	S	-	S	-	-	MSH	S	SH	MSH	-	MSH
UMI 66 x UMI 122	-	-	MS	-	-	MH	-	-	-	S	MSH	-	MSH
UMI 66 x UMI 133	MSH	MSH	-	-	-	S	-	MSH	MSH	SH	-	MSH	-
UMI 66 x UMI 176	-	-	-	S	S	-	MH	-	-	-	-	-	-
UMI 66 x UMI 213	-	-	M	-	M	-	-	MS	-	MSH	MH	S	MH
UMI 112 x UMI 66	-	-	M	-	MSH	MS	-	-	MSH	H	MH	-	MH
UMI 112 x UMI 122	S	-	-	-	MH	-	-	-	MSH	H	M	MSH	MH
UMI 112 x UMI 133	MSH	MSH	-	-	-	MH	-	-	-	H	S	M	MSH
UMI112 x UMI 176	-	-	-	MH	-	MH	MH	-	-	-	-	-	-
UMI 112 x UMI 213	-	-	MS	-	-	MSH	S	-	MSH	MSH	-	-	MSH
UMI 122 x UMI 66	S	MSH	MH	-	S	-	-	-	-	MSH	MSH	-	MSH
UMI 122 x UMI 112	MH	MS	-	MH	MH	S	-	MH	-	S	S	MH	S
UMI 122 x UMI 133	-	-	S	MSH	-	-	MSH	MH	-	S	MH	MSH	S
UMI 122 x UMI 176	MSH	MSH	M	-	MS	MSH	MH	-	MSH	-	MSH	MSH	M
UMI 122 x UMI 213	-	-	M	-	MSH	MS	-	-	MH	SH	-	-	-
UMI 133 x UMI 66	MH	MH	S	-	S	MH	MH	-	MH	MSH	S	MSH	S
UMI 133 x UMI 112	MSH	MSH	M	MH	-	-	-	-	-	-	MH	-	MH
UMI 133 x UMI 122	S	S	MH	MSH	MH	-	S	S	MH	MH	-	MH	MH
UMI 133 x UMI 176	-	-	M	MH	S	-	-	-	MSH	MSH	-	-	MSH
UMI 133 x UMI 213	-	-	MH	-	-	MH	-	-	-	MH	MSH	-	MH
UMI 176 x UMI 66	-	S	MS	M	MSH	-	-	-	-	H	MS	MH	MH
UMI 176 x UMI 112	S	S	-	-	SH	-	-	-	-	-	MS	S	S
UMI 176 x UMI 122	MH	M	-	MH	MH	-	S	S	-	-	-	-	-
UMI 176 x UMI 133	-	S	-	MS	MSH	S	-	-	-	SH	-	-	S
UMI 176 x UMI 213	S	S	M	-	-	MH	M	MS	MSH	-	MH	S	M
UMI 213 x UMI 66	M	-	-	S	S	-	H	M	-	S	-	-	-
UMI 213 x UMI 112	-	S	-	-	-	MSH	H	M	MH	MH	S	S	SH
UMI 213 x UMI 122	-	-	-	-	S	H	-	-	-	-	S	H	-
UMI 213 x UMI 133	MSH	MSH	-	S	-	H	MS	-	-	-	MH	-	-
UMI 213 x UMI 176	MSH	M	-	MSH	MSH	-	-	MH	H	MSH	-	MSH	-

M -Significant and desirable mean value (Score 1); S-Significant and desirable *sca* effect (score 1); H-Significant and desirable heterosis percent(score 1)

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Table 4. Mean performance of hybrids for grain yield traits.

Hybrids	Days to tasseling	Days to silking	Anthesis silking interval	Days to maturity	Plant height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernel rows per ear	No. of Kernels per row	Ear weight (g)	Shelling per cent	100 grain weight (g)	Grain yield per plant (g)
UMI 66 x UMI 112	52.00	55.67	3.67	95.00	149.75	13.59	11.67	13.20**	26.53	134.23	63.51**	22.47	89.02**
UMI 66 x UMI 122	55.00	58.00	3.00**	93.00	160.38	17.13**	12.12	11.13	27	136.86	66.49**	21.61	90.99**
UMI 66 x UMI 133	47.33**	52.00**	4.67	94.67	148.91	15.32	11.85	12.88**	30.53**	138.44	52.49	24.34**	72.67
UMI 66 x UMI 176	51.67	56.33	4.66	89.33	161.13	14.79	13.14**	11.4	26.57	126.52	54.45	20.44	68.89
UMI 66 x UMI 213	55.00	58.33	3.33**	95.00	156.67	15.42	11.78	12.13**	26.54	146.62**	63.05**	23.39	92.43**
UMI 112 x UMI 66	55.67	58.33	2.66**	93.00	139.22**	16.63*	11.66	11.8	33.17**	141.14	63.85**	21.64	90.11**
UMI 112 x UMI 122	52.00	55.67	3.67	91.67	138.5**	16.45	9.7	11.07	30.60**	140.46	62.50*	25.00**	87.83**
UMI 112 x UMI 133	7.00**	51.67**	4.67	89.00	161.78	17.94**	12.16	11.6	26.9	141.42	61.93	23.70*	87.56**
UMI112 x UMI 176	53.00	56.67	3.67	84.67**	150.41	16.80**	13.80**	10.87	26.53	128.26	53.26	19.18	68.32
UMI 112 x UMI 213	52.00	55.33	3.33**	93.33	148.27	18.88**	11.91	10.67	30.22**	154.69**	59.23	21.66	91.62**
UMI 122 x UMI 66	50.33	52.67**	2.34**	92.00	155.65	13.2	12.14	11.67	26.6	146.70**	73.78**	22.55	108.12**
UMI 122 x UMI 112	47.00**	52.00**	5.00	86.00**	144.43**	12.39	12.18	12.67**	28.7	131.46	47.59	24.56**	62.56
UMI 122 x UMI 133	51.33	55.00	3.67	87.33**	148.95	13.25	12.79**	12.62**	27.73	129.59	63.44**	25.82**	82.21
UMI 122 x UMI 176	46.00**	49.33**	3.33**	90.33	159.07**	17.09**	13.06**	11.13	32.63**	116.32	70.55**	25.86**	82.07
UMI 122 x UMI 213	52.33	55.67	3.34**	91.67	144.53**	16.65*	12.35	11.73	30.60**	140.59	45.38	22.21	63.80
UMI 133 x UMI 66	45.67**	50.33**	4.66	94.33	162.07	17.42**	12.88**	11.27	31.57**	149.82**	53.66	25.05**	80.38
UMI 133 x UMI 112	47.33**	50.33**	3.00**	87.00**	149.39	14.5	9.89	11.37	27.6	135.98	64.88**	22.15	88.21**
UMI 133 x UMI 122	51.33	53.67	2.34**	84.00**	143.19**	15.88	12.18	11.67	29.43*	152.97**	61.66	26.19**	94.32**
UMI 133 x UMI 176	51.67	55.00	3.33**	85.67**	154.24	16.11	12.16	11.2	31.07**	155.00**	56.26	22.94	87.20**
UMI 133 x UMI 213	53.00	55.33	2.33**	91.67	163.46	18.39**	10.77	10.73	27.6	144.41**	65.31**	21.59	94.30**
UMI 176 x UMI 66	52.33	55.33	3.00**	88.33**	136.98**	14.8	11.48	10.93	23.2	140.70	62.66*	24.55**	88.15**
UMI 176 x UMI 112	50.67	54.67	4.00	90.33	144.1	13.5	12.26	11.07	23.93	122.03	62.76*	20.92	76.59
UMI 176 x UMI 122	48.00**	52.67**	4.67	86.00**	133.9**	15.33	10.72	10.68	26.03	131.55	56.44	22.61	74.24
UMI 176 x UMI 133	51.00	55.33	4.33	88.00**	144.48**	13.74	12.38	9.67	26.9	141.89	58.03	23.56	82.33
UMI 176 x UMI 213	51.00	54.33	3.33**	90.00	148.09	16.91**	12.61**	11.92*	31.10**	121.90	70.91**	21.82	86.43*

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UMI 213 x UMI 66	48.00**	53.33	5.33	94.33	162.00	14.94	11.97	12.83**	26.63	136.61	52.62	22.25	71.88
UMI 213 x UMI 112	52.33	56.00	3.67	92.33	152.48	17.68**	14.08**	12.10**	31.67**	154.91**	55.88	20.66	86.57*
UMI 213 x UMI 122	52.00	55.33	3.33**	90.00	149.48	20.15**	11.92	10.21	26.07	137.68	61.18	24.45**	84.22
UMI 213 x UMI 133	47.33**	52.00**	4.67	89.33	169.35	15.8	12.45*	11.13	25.2	120.99	62.97**	22.53	76.18
UMI 213 x UMI 176	46.67**	51.67**	5.00	86.00**	144.66**	12.66	12.38	12.73**	30.30**	141.33	48.70	24.60**	68.81
General mean	**50.53**	**54.27**	**3.74**	**90.11**	**150.85**	**138.23**	**59.62**	**23.01**	**28.31**	**138.23**	**59.62**	**23.01**	**82.27**
SE(d)	**0.513**	0.426	0.153	0.599	1.613	0.352	0.172	0.153	0.473	.900	1.186	0.321	1.771
CD at 5 per cent	1.023	0.850	0.306	1.194	3.218	0.702	0.344	0.306	0.943	.790	2.366	0.640	3.533
CD at 1 per cent	1.358	1.128	0.406	1.586	4.272	0.931	0.457	0.406	1.252	.032	3.141	0.850	4.690

* Significant at 5 per cent level, ** Significant at 1 per cent level

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Table 5. Specific combining ability effects of direct crosses for different traits in maize.

Hybrids	Days to tasseling	Days to silking	Anthesis silking interval	Days to maturity	Plant height (cm)	Ear length (cm)	Ear girth (cm)	No. of kernel rows per ear	No. of Kernels per row	Ear weight (g)	Shelling per cent	100 grain weight (g)	Grain yield per plant (g)
UMI 66 x UMI 112	2.52**	1.42**	-1.10*	1.44*	-1.82**	0.15	-0.53	0.74*	2.17**	1.18*	5.13**	0.43	7.57**
UMI 66 x UMI 122	1.77**	0.47	-1.30**	0.86	10.01**	0.35	0.20	-0.33	-0.38	5.02**	9.12**	-1.06*	15.92**
UMI 66 x UMI 133	-3.54**	-2.72**	0.81	1.94**	3.45**	1.66**	0.60	0.83*	3.53**	5.89**	-9.58**	1.02*	-9.85**
UMI 66 x UMI 176	0.88	0.31	-0.57	-1.58*	-4.29**	0.72	-0.07	0.35	-2.15**	0.61	-2.27**	0.48	-2.30**
UMI 66 x UMI 213	0.07	0.44	0.37	-0.44	2.48**	-0.52	0.07	1.19**	-1.05	2.47**	-3.40**	0.89*	-2.88**
UMI 112 x UMI 66	-1.34**	-0.36	0.98*	0.86	0.63	-1.35**	-1.06**	-0.28	1.52**	-1.86**	-2.53**	2.20**	-4.42**
UMI 112 x UMI 122	-2.81**	-3.22**	-0.41	-0.89	10.72**	0.54	-0.82*	-0.18	-1.22*	-0.61	4.18**	-0.20	5.59**
UMI 112 x UMI 133	0.77	1.31**	0.54	0.75	1.09**	0.11	0.58	-0.26	-2.75**	-8.91**	0.61	-1.42**	-4.29**
UMI112 x UMI 176	0.80	-0.56	-1.35**	1.39*	0.70	1.62**	1.11**	-0.32	2.35**	14.60**	-0.26	-0.24	8.13**
UMI 112 x UMI 213	1.77**	0.83*	-0.94*	-2.31**	-0.50	-0.96**	0.91*	0.51	0.61	4.69**	0.86	1.37**	4.27**
UMI 122 x UMI 66	-3.65**	-3.64**	0.01	2.33**	-1.39**	1.31**	-0.30	-0.29	1.85**	-7.40**	3.62**	1.25**	-0.28
UMI 122 x UMI 112	1.21*	2.50**	1.29**	0.31	-4.38**	1.88**	0.51	-0.70*	0.24	1.65**	-7.00**	0.43	-8.64**
UMI 122 x UMI 133	1.55**	1.00**	-0.55	0.08	-2.54**	0.13	0.24	-0.28	1.16*	15.62**	-4.36**	-0.26	3.65**
UMI 122 x UMI 176	0.07	-0.36	-0.44	-0.94	10.99**	0.69	0.16	-0.25	-2.03**	-6.26**	2.22**	-1.38**	-0.10
UMI 122 x UMI 213	-2.34**	-2.17**	0.18	-1.31	-10.34**	-1.00**	0.43	1.57**	2.76**	-2.10**	-0.29	1.43**	-2.16**
SE(S_{ij})	0.50	0.35	0.45	0.67	0.47	0.36	0.34	0.33	0.55	0.57	0.53	0.41	0.63

*** Significant at 5 per cent level, ** Significant at 1 per cent level.**