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Research Article

Heterosis and combining ability studies in single cross hybrids synthesized with diverse inbred lines of maize (*Zea mays* L.)

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Abstract

Combining ability and heterosis analysis were performed in ten lines, five testers and their fifty hybrid combinations of maize using line x tester analysis. Combining ability analysis among the sixteen traits revealed significant line x tester interaction for most of the traits studied. Variance due to *sca* was found to be more than *gca* for all the traits studied which indicated the preponderance of non-additive gene action. Among the parents, the lines *viz.*, N67, N10-65-3, N10-153-1-2 and the tester UMI 1210 exhibited higher *per se* along with positive *gca* effects and found to be good general combiners among the parents. Standard heterosis was calculated by comparing TNAU maize hybrid CO 6 as the standard check. Considering the *per se*, *sca* and standard heterosis, single cross hybrid N10-65-3 x E.No.8 was identified as the best hybrid for grain yield and other major yield contributing traits followed by the hybrid N44 x UMI 1221.

Keywords

Maize, Line x tester analysis, General combining ability, Specific combining ability, Heterosis

Introduction

Maize (*Zea mays* L.,2n = 2x = 20) commonly known as the "queen of cereals" belongs to the grass family *Gramineae* and tribe Maydeae. It is the second most important cereal crop in the world's economy and also ranks first in both productivity and production among the cereals. The crop shows broad morphological variability and geographical adaptability which is attributed to its cross-pollinating nature. Maize kernel contains about 60-70 per cent starch and about 9 per cent protein. Oil content in maize is about 4.5 per cent and is rich in polyunsaturated fatty acids like oleic and linoleic acids. Hence, the crop is in much demand for food, feed and silage purposes. The productivity barriers in maize can be overcome by developing single cross hybrids having high yielding ability and heterotic potential (Dhillon and Khehra.,1989).Combining ability analysis is an important tool among the breeders for selecting parents with good general combining ability, which helps further in developing promising hybrids with better specific combining ability. It also aids in understanding the nature of gene action of a particular character. This information is useful for the breeder in selecting diverse parents inorder to generate cross combinations possessing high heterotic potential. Line x tester analysis developed by Kempthorne (1957) is an efficient method for the study of combining ability and also the gene action involved. It's an appropriate method to identify superior parents based on general combining ability and hybrids based on specific combining ability. Estimation of heterosis helps to identify hybrids having high yielding ability along with high heterotic potential by comparing them with the available standard checks. The heterosis per cent will be more for the hybrids generated by crossing the inbred lines belonging to the distinct heterotic groups (Hosana *et al.*, 2015). With this perspective, the present study was undertaken to assess the combining ability and heterotic potential of ten lines, five testers and their fifty hybrid combinations in maize.

Material and Methods

The material for study consisted often lines, five testers and their fifty L x T cross combinations with the standard check TNAU maize hybrid CO6, making a total of sixty six entries. The experiment was carried out at the Millet Breeding Station, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore during the year 2017 – 2018.The inbred lines were obtained from Millet Breeding Station, Department of Millets, Tamil Nadu Agricultural University, Coimbatore. All the parents were raised in two staggered sowings at three days interval in order to achieve the programmed cross combinations. Tassel bag method was used for synthesizing a total of 50 cross combinations.

All the single crosses synthesized were grown along with their parents and check hybrid in two rows of four meter length adopting randomized block design and replicated thrice. The recommended fertilizer dose of 150: 75: 75 kg NPK/ha was applied. Nitrogenous fertilizer was given in three split doses. The row-to-row and plant-to-plant distance was 60 and 25 cm respectively. The recommended agronomic and plant protection practices were followed to maintain healthy stand of cross combinations and parental lines.

Observations were recorded on thirteen yield attributing traits *viz*., days to 50% tasseling (days), days to 50% silking (days), anthesis silking interval (ASI) (days), plant height(cm), cob placement height(cm), cob length(cm), cob breadth(cm), number of kernel rows per cob, number of kernels per row, cob weight (g), hundred seed weight (g), shelling percent (%), grain yield per plant (g) and three quality traits *viz.,* crude protein (%) , crude fibre (%) and carotene content (mg/100g).While recording the biometrical observations, the days to 50 per cent tasseling and days to 50 per cent silking were taken on plot basis whereas, other observations were recorded on five randomly tagged plants in each replication for each genotype and the data recorded on these plants were used to arrive at the replication mean which was then subjected to line x tester analysis for analyzing the heterosis and combining ability. Estimates of combining ability were computed according to kempthrone (1957). Heterosis was estimated in terms of three parameters, *i.e.* relative heterosis, heterobeltiosis and standard heterosis. Mean values per replication for all traits studied were subjected to analysis of variance according to Panse and Sukhatme (1964) for randomized block design.

Results and Discussion

The analysis of variance for combining ability revealed that both lines and testers along with their interaction showed significant differences for all the sixteen characters studied (Table 1).Among the crosses all the traits except cob length showed significant differences which revealed the diverse nature of the hybrids studied. Variance due to specific combining ability was found higher than that of the general combining ability for all the characters studied including both yield and quality traits which indicated the preponderance of non additive gene effects rather than additive gene effects in controlling the expression of these traits. Similar results revealing the preponderance of non additive gene effects were earlier reported by Kanagarasu *et al.*(2010)**,** Lal *et al.*(2011), Rajitha *et al.*(2014) and Varaprasad and Shivani (2015).

The *gca* effects of parents is presented in Table 2.High general combining ability for a parent indicates its potential to combine well with each other besides revealing the presence of additive gene effects for that trait(Sprague and Tatum,1942).Among the parents, the lines, *viz*.,N09-160-5, N67, N53 and N44exhibited positive and significant *gca* effects for grain yield whereas, none of the testers showed positive significant *gca* effects for grain yield. The line, N10-153-1-2 showed positive and significant *gca* effects for days to fifty per cent silking. Whereas, the lines *viz.*,N67, N53, N10-105 and the tester, E.No.8 exhibited significant positive *gca* effects for both days to fifty per cent tasseling and days to fifty per cent silking. The lines N10-153-1-2 and N53 and the testers E.No.4 and UMI 1221 showed significant positive *gca* effects for anthesis silking interval. While breeding for early maturing genotypes the lines with negative significant *gca* effects for days to fifty per cent tasseling and days to fifty per cent silking *viz*., N10-86-5 and N10-65-3 could be exploited. The lines N44, N67, N162-1 and the tester UMI 1210 with significant negative *gca* effects for anthesis silking interval could be utilized for generating drought tolerant hybrids.

Significant positive *gca* effects for plant height and cob placement height was exhibited by the lines *viz*., N44, N53, N09-160-5 and N10-153-1-2 and the testers *viz*., UMI 1210 and UMI 1221.The line N162-1 and the tester UMI 1210registered significant positive *gca* effect for both cob length and cob breadth. The lines *viz*.,N67, N53, N09-160-5 and tester E.No.4exhibited significant positive *gca* for number of kernel rows per cob**.** Whereas, for number of kernels per rowonly the lines *viz***.,**N09-160-5, E.No.15, N162-1 exhibited significant positive *gca* effects. Lines N44, N67, N53 and N09-160-5 showed significant positive *gca* for cob weight. Significant positive *gca* effects for hundred seed weight was exerted by the lines *viz*.,N53, N09-160-5 and N10-86-5 and the tester UMI 1210.Among the parents, the lines *viz*., N44, E.No.15, N09-160-5,N10-65-3 and N10-153-1-2 and the testers *viz*., E.No.4 and E.No.8 were observed to be good combiners for shelling per cent.

For the quality traits, the lines E.No.15, N53 and N10-105 with significant positive *gca* effect for crude protein per cent were observed to be the best combiners for crude protein content. Whereas, for crude fibre content, the lines E.No.15 and N10-105 and for carotene content, the line N10-65-3 were observed to be good combiners. Among the testers, the tester UMI 1210 was found to be the best combiner for all the three quality traits. Among the parents, the lines *viz*.,N09-160-5, N44, N53, N162-1, E.No.15, N10-65-3, N67 and the tester UMI

1210 which showed significant positive *gca* for most of the traits were found to be the best general combiners. Hence, these parents can be further exploited in breeding programmes for developing superior single cross hybrids.

The standard heterosis of all the fifty hybrids is presented in Table 3. For the trait anthesis silking interval (ASI), most of the hybrids showed significant negative standard heterosis. Whereas, for cob length, two hybrids *viz.*, E.No.15 x UMI 1210, N44 x UMI 1221 showed significant positive standard heterosis. For number of kernel rows per cob, eleven hybrids showed significant positive standard heterosis, A total of eight hybrids exhibited significant positive standard heterosis for number of kernels per row. Similarly, five hybrids showed significant positive standard heterosis for cob weight and thirty eight hybrids exhibited significant positive standard heterosis for hundred seed weight. Of the six hybrids which registered significant positive standard heterosis for grain yield, the hybrid N10-65-3 x E.No.8 has recorded the highest positive significant standard heterosis.

Most of the crosses which showed significant *sca* effects also showed desirable standard heterosis. Among the hybrids, N10-65-3 x E.No.8 was found to be the best hybrid with desirable *per se* performance, *sca* and heterosis for grain yield per plant along with major yield contributing traits *viz.*, cob weight and hundred seed weight. In addition to this, the hybrids *viz.*, N44 x UMI 1210 and N10-153-1-2 x E.No.4 were found to be best hybrids for grain yield.

The hybrids *viz.*,N162-1 x E.No.4 and N10-65-3 x UMI 1221with significant negative *sca* and standard heterosis coupled with low *per se* performance were found to be suitable for earliness. However, selecting the hybrid s*viz.*,N67 x E.No.8 and N10-105 x E.No.4 will be rewarding for developing single cross hybrids with medium to late maturity. The hybrids *viz*., E.No.15 x E.No.8, N10-65-3 x E.No.35, N10-86-5 x UMI 1210, N10-105 x E.No.4, N10-105 x E.No.8 with low mean, negative *sca* and standard heterosis for anthesis and silking interval were found to be superior for drought tolerance and could be exploited for drought prone and rainfed areas (Saidaiah *et al*., 2008).

For the trait cob length, the hybrid E.No.15 x UMI 1210 was observed as the best. Whereas, for cob breadth, the crosses N53 x E.No.35 and N10-153-1-2 x E.No.4 were found to be more desirable based on their *per se*, *sca* and standard heterosis. Significant positive standard heterosis for cob breadth was earlier observed by Kumar *et al.* (2013). The hybrid N09-160-5 x E.No.8 was found superior for number of kernel rows per cob, where in the trait showed non additive gene action which were similar to the findings of (Wali *et al.*, 2010); Lal *et al.*(2011) and Purushottam *et al.* (2017). Hybrid E.No.15 x E.No.4 with significant positive standard heterosis for number of kernels per row (Kumar *et al.*, 2015)was selected promising for the respective trait. As far as the quality traits were concerned, the hybrid N162-1 x E.No.35 was preferred for quality traits *viz.*, crude protein and crude fibre content.

The results obtained from the present study were encouraging and it indicated the tremendous scope for increasing the yield and quality components. Assessing the hybrids based on *per se*, *sca* effects along with the standard heterosis, gave a complete picture about the hybrid performance. Besides all these parameters for effective selection, the hybrids should have both the parents as good combiners or at least one parent as a good combiner, as insisted by Premlatha and Kalamani (2010) and Lal *et al.* (2011). It is evident from the present study that, the hybrid N10-65-3 x E.No.8 which came out to be the superior and desirable hybrid for most of the traits had both the parents possessing significant positive *gca* indicating that both were good combiners, similar findings were earlier reported by Kanagarasu *et al.* (2010) and Dar *et al*. (2017).

For earliness, the hybrid N162-1 x E.No.4 was found out to be the desirable one which was the combination of two moderate combiners. For quality traits like crude protein and crude fibre, low x low and high x low combination of *gca* effects were promising for the desirable performance. Whereas, for carotene content high x high *gca* effects showed desirable performance. Hence, it was concluded that most of the superior cross combinations were the result of crosses between high x high, low x high, medium x medium general combiners and it is understood that in order to get a better hybrid combination, involvement of any one good combiner is essential (Dar *et al.*,2017). The interaction between the positive alleles from the good combiners and negative alleles from the poor combiners might be the reason behind the high *sca* performance for the crosses with high and low combiners imparting the predominance of additive x dominance type of interaction. This result is in collaboration with the earlier findings of Kumar and Bharathi (2009), Rajitha *et al.*(2014) and Dar *et al.* (2017).

Based on the results of the study, the best hybrids and parents emerged were presented in table.4. It was concluded from the study that non additive gene action was prevalent for most of the yield traits studied indicating their exploitation through heterosis breeding. Among the parents,N53, N67,N10-65-3,N10-153-1-2used as lines and UMI 1210,UMI 1221 and E.No.4 used as testers were selected as good combiners based on their *per se* and *gca* effects. Hence, these parents could be utilized in heterosis breeding programme to develop single cross maize hybrids. Among the fifty hybrids N10-65-3 x E.No.8 was identified as the best hybrid for grain yield and other major yield contributing traits. Whereas, N162-1 x E.No.35 emerged to be the best hybrid in terms of quality. However, these hybrids are to be further evaluated over different locations and years to confirm their stable performance over various agro-climatic regions.

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Table 1.Analysis of variance for combining ability in yield components and quality traits

Source	df	DFS	DFS	ASI	PH	CPH	CL	CB	NKPR	NKRPC	CW	SP	HSW	GY/PLT	CP	CF	CTN
Crosses	49	13.50**	14.11**	0.84**	775.61**	340.10**	2.93	1.60**	20.11**	5.08**	740.25**	21.29**	30.19**	832.57**	2.18**	1.73**	0.20**
Lines	9	38.703**	37.710**	2.0081**	367.978**	600.983**	2.559**	4.119**	32.819**	11.248**	998.145**	55.6812**	17.8489**	677.593**	677.5926**	2.7363**	1.4889**
Tests	4	3.673**	8.24**	1.3267**	28.888**	967.729**	4.818**	1.004**	6.727**	9.973**	312.403*	36.4015**	59.56**	134.739**	134.7388**	2.2095**	1.1361**
L vs T	36	8.296**	8.858**	0.4989**	488.258**	205.140**	2.8098**	1.042**	18.421**	2.996**	695.543**	23.129**	17.9007**	559.957**	559.9567**	2.0367**	1.8616**
Error	98	1.624	1.478	0.1528	24.667	10.517	0.3999	0.1947	1.993	0.7298	112.223	1.0087	1.5434	73.892	73.8922	0.0132	0.0444
V_A		0.154	0.1552	0.0102	8.4947	3.9897	0.0035	0.0166	0.0616	0.05	1.3218	0.1003	0.2088	8.059	0.0042	0.0038	0.0005
V_D		2.2238	2.4602	0.1154	154.5304	64.8745	0.8033	0.2825	0.7553	5.4761	861.1067	5.4524	7.3735	495.3548	0.6745	0.6057	0.0602
V_A/ V_D		0.0693	0.0631	0.0884	0.055	0.0615	0.00436	0.0586	0.08156	0.00913	0.00154	0.0184	0.02832	0.01627	0.00623	0.00627	0.00831

*Significant (5% level)**Significant (1%level)

DFT : Days to 50 % tasseling, DFS : Days to 50 % silking, ASI : Anthesissilking interval, PH : Plant height, CPH : Cob placement height, CL : Cob length, CB : Cob breadth , NKRPC : Number of kernel rows per cob, NKPR : Number of kernels per row, CW : Cob weight, SP : Shelling per cent, HSW : Hundred seed weight , GY/PLT : Grain yield per plant, CP : Crude protein, CF : Crude fibre, CTN : Carotene content

Table 2. Estimation of *gca* effects for yield components and quality traits

Parents	DFT	DFS	ASI	PH	CPH	CL	CB	NKRPC	NKPR	CW	HSW	SP	GY/PLT	CP	CF	CTN
Lines																
N44	0.19	-0.07	-0.35 **	19.26 **	10.68 **	0.27	0.11	-0.03	0.52	5.73 *	0.99 **	1.09 **	7.47 **	-0.27 **	-0.39 **	-0.14 **
N53	0.73 *	1.19 **	0.29 **	7.86 **	5.65 **	0.14	0.02	0.91 **	0.49	17.44 **	-0.61	-0.45	12.27 **	0.13 **	-0.35 **	0.10 **
N67	3.39 **	2.86 **	-0.51 **	-7.34 **	-5.82 **	-0.29	0.29 *	1.44 **	-2.58 **	21.11 **	1.52 **	-0.92 **	13.43 **	-0.62 **	0.24 **	0.11 **
N162-1	0.41	-0.74 *	-0.31 **	-3.70 **	-3.59 **	0.49 **	0.41 **	-0.29	1.02 **	-2.17	-0.35	0.28	-1.33	-0.18 **	0.42 **	-0.18 **
E.No.15	-1.47 **	-1.74 **	-0.25 *	-15.50 **	-10.12 **	-0.06	-0.23	-0.56 *	1.52 **	-4.04	-0.08	1.19 **	-0.23	0.32 **	0.37 **	-0.05 **
N09-160-5	0.39	0.46	0.12	4.90 **	4.85 **	0.20	0.26 *	0.77 **	1.69 **	10.80 **	-0.88 **	1.99 **	13.46 **	-0.27 **	-0.24 **	0.00
N10-65-3	-2.54 **	-2.61 **	-0.01	-2.50	-1.35	-0.43 **	-0.31 **	-0.29	0.65	-4.46	-0.21	0.90 **	-1.71	0.74 **	0.03	0.05 **
N10-86-5	-1.21 **	-1.01 **	0.15	0.06	1.85 *	-0.30	-0.17	-0.69 **	-0.81 *	-6.68 *	1.52 **	-0.07	-5.50 *	-0.20 **	-0.36 **	0.00
N10-105	0.86 *	0.99 **	0.15	-6.27 **	-5.22 **	-0.64 **	-1.17 **	-1.49 **	-2.28 **	-37.60 **	-1.95 **	-4.91 **	-39.99 **	0.57 **	0.23 **	-0.08 **
N10-153-1-2	0.06	0.66 *	0.72 **	3.23 *	3.08 **	0.63 **	0.77 **	0.24	-0.21	-0.13	0.05	0.91 **	2.12	-0.22 **	0.04	0.19 **
Testers																
E.No.4	-0.07	0.09	0.15 *	-5.44 **	-4.70 **	-0.28 *	-0.04	0.97 **	-0.03	-0.94	-1.88 **	1.01 **	2.44	-0.30 **	0.08 *	0.01 *
E.No.8	0.59 *	0.76 **	0.09	-9.24 **	-5.47 **	-0.18	-0.01	-0.09	0.49	-4.13 *	-0.35	1.37 **	-0.05	-0.16 **	0.18 **	-0.12 **
E.No.35	-0.27	-0.31	-0.05	-1.79	-1.47 *	0.14	0.14	-0.23	0.47	2.67	-0.08	-0.96 **	-0.66	-0.05 *	-0.26 **	0.12 **
UMI 1210	-0.24	-0.64 **	-0.35 **	11.15 **	7.70 **	0.64 **	0.19 *	-0.56 **	-0.40	3.82	2.05 **	-0.59 **	1.39	0.10 **	0.15 **	0.07 **
UMI 1221	-0.01	0.09	0.15 *	5.31 **	3.95 **	-0.31 **	-0.28 **	-0.09	-0.53 *	-1.42	0.25	-0.82 **	-3.11 *	0.41 **	-0.15 **	-0.08 **

Table 3 . Standard heterosis(d_{iii}) of yield and yield contributing traits along with quality traits for all the fifty hybrids

Cross	Days to 50 per cent tasseling	Days to 50 per cent silking	AnthesisSilking Interval	Plant height	Cob placement height	Cob length	Cob breadth	No.of kernel rows per cob	No.of kernels per row	Cob weight
N44 X E.No.4	-1.85	-1.74	-5.00	-3.84 *	-4.78 *	-4.75	2.26	19.05 **	-4.91	-2.01
N44 X E.No.8	4.94 **	2.91	-30.00 **	-1.06	-1.66	4.57	4.11	-14.29 **	10.71 **	-19.05 **
N44 X E.No.35	0.00	-1.74	-30.00 **	-3.84 *	-4.78 *	1.32	2.17	4.76	4.46	4.87
N44 X UMI 1210	-2.47	-4.07 *	-30.00 **	13.00 **	8.58 **	6.41 *	6.74 **	9.52	4.46	9.86 **
N44 X UMI 1221	1.23	0.00	-25.00 **	0.25	0.33	-10.11 **	-3.15	0.00	-12.50 **	-16.04 **
N53 X E.No.4	-1.85	-2.33	-10.00	12.02 **	7.44 **	-5.27	-5.13 *	9.52	4.02	4.10
N53 X E.No.8	-2.47	-1.74	5.00	-9.07 **	-7.05 **	-6.41 *	1.52	9.52	0.89	-7.47 *
N53 X E.No.35	3.70	3.49 *	-5.00	-11.69 **	-9.47 **	4.13	9.48 **	14.29 **	-0.45	-1.36
N53 X UMI 1210	1.85	1.16	-20.00 *	-6.87 **	-6.63 **	2.90	3.48	0.00	-2.68	0.92
N53 X UMI 1221	5.56 **	5.81 **	5.00	-7.85 **	-8.05 **	-1.14	-0.22	19.05 **	0.00	3.20
N67 X E.No.4	6.79 **	4.65 **	-35.00 **	-12.43 **	-11.75 **	3.08	3.80	19.05 **	-4.02	5.57
N67 X E.No.8	9.26 **	8.14 **	-15.00	-17.50 **	-20.98 **	-11.69 **	-3.91	4.76	-12.50 **	-21.86 **
N67 X E.No.35	0.00	-1.74	-25.00 **	-18.15 **	-26.38 **	-2.55	4.04	14.29 **	-10.27 **	8.49 **
N67 X UMI 1210	7.41 **	4.65 **	-35.00 **	-12.84 **	-13.45 **	-1.76	9.11 **	19.05 **	-5.36	11.19 **
N67 X UMI 1221	8.02 **	5.23 **	-35.00 **	0.16	-0.09	-4.39	5.00 *	14.29 **	-7.14 *	2.82
N162-1 X E.No.4	-4.32 *	-5.81 **	-30.00 **	-19.79 **	-27.66 **	4.39	8.15 **	9.52	3.57	-5.39
N162-1 X E.No.8	-1.85	-1.74	-5.00	-22.40 **	-28.09 **	-5.45 *	3.70	0.00	-8.93 **	-22.56 **
N162-1 X E.No.35	-1.85	-4.07 *	-35.00 **	-12.84 **	-13.03 **	1.67	3.50	0.00	6.70 *	-0.67
N162-1 X UMI 1210	1.85	-0.58	-35.00 **	4.33 *	6.02 **	4.04	1.74	-4.76	-1.79	-2.50
N162-1 X UMI 1221	2.47	1.74	-10.00	-1.14	-0.38	-1.32	4.78 *	4.76	9.38 **	-5.93
E.No.15 X E.No.4	-1.85	-1.16	5.00	-22.40 **	-26.38 **	-0.88	-1.96	9.52	11.61 **	-10.78 **
E.No.15 X E.No.8	-2.47	-4.07 *	-35.00 **	-24.69 **	-27.38 **	-7.38 **	1.85	0.00	3.13	-3.03
E.No.15 X E.No.35	-4.94 **	-6.40 **	-25.00 **	-8.59 **	-9.62 **	-4.66	-1.63	-9.52	5.80	-12.59 **
E.No.15 X UMI 1210	-3.09	-5.23 **	-35.00 **	-8.59 **	-7.91 **	7.21 **	3.48	0.00	-5.36	-6.53 *
E.No.15 X UMI 1221	-1.23	-2.33	-15.00	-16.52 **	-19.71 **	-5.54 *	-0.65	0.00	0.45	-7.59 *
N09-160-5 X E.No.4	1.23	1.16	-5.00	-9.89 **	-7.77 **	-4.22	5.98 *	14.29 **	4.02	-10.21 **
N09-160-5 X E.No.8	2.47	0.58	-20.00 *	-7.52 **	-6.49 **	0.35	3.15	19.05 **	-1.79	6.45 *
N09-160-5 X E.No.35	0.00	0.00	0.00	-7.77 **	-8.05 **	0.97	6.52 **	4.76	8.04 **	-9.33 **
N09-160-5 X UMI 1210	-1.85	-2.91	-15.00	-2.94	-2.23	4.83	4.04	0.00	7.59 *	-1.66
N09-160-5 X UMI 1221	1.85	1.16	-10.00	-2.62	-2.65	-6.33 *	-2.83	9.52	0.00	1.79
N10-65-3 X E.No.4	-5.56 **	-5.23 **	5.00	-13.57 **	-16.44 **	-4.13	-2.93	9.52	0.00	-15.47 **
N10-65-3 X E.No.8	-2.47	-1.74	5.00	-12.26 **	-12.03 **	-0.44	4.37	14.29 **	1.79	17.75 **
N10-65-3 X E.No.35	-4.94 **	-6.98 **	-35.00 **	-16.93 **	-19.28 **	-5.89 *	1.41	0.00	0.45	-10.63 **
N10-65-3 X UMI 1210	-3.09	-5.23 **	-30.00 **	-3.76	-4.50 *	-3.51	-2.50	-9.52	1.79	-21.84 **
N10-65-3 X UMI 1221	-7.41 **	-7.56 **	-15.00	-2.37	-1.37	-6.94 *	-1.98	-4.76	0.00	-11.11 **
N10-86-5 X E.No.4	-1.85	-1.74	5.00	-13.41 **	-15.58 **	-9.31 **	2.09	0.00	-9.37 **	-12.06 **
N10-86-5 X E.No.8	1.23	1.74	0.00	-11.69 **	-10.04 **	0.79	-1.09	0.00	0.45	-6.20
N10-86-5 X E.No.35	-2.47	-2.91	-10.00	-9.08 **	-8.76 **	-0.26	3.04	0.00	3.13	-4.29
N10-86-5 X UMI 1210	-2.47	-4.07 *	-35.00 **	-1.06	0.62	-5.01	-0.76	4.76	-2.23	2.14
N10-86-5 X UMI 1221	-5.56 **	-5.81 **	-5.00	-7.36 **	-6.20 **	-3.60	-0.54	-9.52	-7.59 *	-25.01 **
N10-105 X E.No.4	9.26 **	6.98 **	-30.00 **	-16.84 **	-21.70 **	-17.57 **	-10.76 **	4.76	-22.77 **	-34.05 **
N10-105 X E.No.8	-1.85	-2.91	-20.00 *	-17.91 **	-22.12 **	-0.35	-1.09	0.00	3.13	-11.68 **
N10-105 X E.No.35	2.47	2.91	5.00	-3.68	-6.20 **	-11.42 **	-11.96 **	-14.29 **	-9.82 **	-29.42 **
N10-105 X UMI 1210	-0.62	-1.16	-10.00	-5.81 **	-4.64 *	-0.09	-2.93	-14.29 **	-6.25 *	-22.94 **
N10-105 X UMI 1221	-1.23	-1.16	10.00	-13.90 **	-15.44 **	2.99	-2.83 ns	-9.52	0.45	-4.78
N10-153-1-2 X E.No.4	-1.23	-1.16	10.00	-12.02 **	-11.18 **	4.66	12.50 **	14.29 **	7.59 *	10.77 **
N10-153-1-2 X E.No.8	4.32 *	4.07 *	5.00	-6.70 **	-6.49 **	-2.90	3.91 ns	0.00	6.70 *	-13.71 **
N10-153-1-2 X E.No.35	3.09	4.07 *	10.00	-1.72	-2.65	5.01	9.13 **	9.52	-4.91	-1.17
N10-153-1-2 X UMI 1210	-1.85	-1.74	5.00	-6.30 **	-5.92 **	-0.44	6.96 **	-4.76	-10.27 **	-20.50 **
N10-153-1-2 X UMI 1221	-3.70	-3.49 *	10.00	-8.10 **	-8.48 **	0.62	1.20	9.52	-6.70 *	-8.65 **
SE	**1.0253**	**0.9913**	**0.3161**	**4.0157**	**2.6213**	**0.5195**	**0.3618**	**0.6906**	**1.1416**	**8.5638**

Cross	Hundred seed weight	Shelling percent	Grain yield per plant	Crude protein	Crude fibre	Carotene content
N44 X E.No.4	-8.33 **	5.78 **	3.70	-13.76 **	56.47 **	-13.70**
N44 X E.No.8	-11.67 **	3.46 **	-16.26 **	-11.84 **	40.97 **	4.11
N44 X E.No.35	-5.00 *	-1.14	3.62	-27.10 **	34.47 **	39.04 **
N44 X UMI 1210	0.00	4.03 **	14.29 **	-25.37 **	37.56 **	19.82 **
N44 X UMI 1221	-8.33 **	-4.46 **	-19.80 **	-11.49 **	39.72 **	-61.47**
N53 X E.No.4	-8.33 **	0.08	4.18	-24.33 **	34.87 **	29.95 **
N53 X E.No.8	-18.33 **	0.76	-6.76 *	-10.22 **	51.48 **	-13.80**
N53 X E.No.35	-11.67 **	1.94	0.54	-21.86 **	49.11 **	31.51 **
N53 X UMI 1210	-3.33	-6.69 **	-5.87	-4.63 **	43.53 **	103.56**
N53 X UMI 1221	-11.67 **	1.68	4.92	-5.47 **	34.01 **	16.11 **
N67 X E.No.4	-5.00 *	2.74 **	8.45 *	-24.79 **	74.46 **	62.97 **
N67 X E.No.8	-13.33 **	1.50	-20.67 **	-27.87 **	72.62 **	-59.91**
N67 X E.No.35	-3.33	-8.72 **	-0.94	-7.79 **	34.34 **	173.61**
N67 X UMI 1210	-5.00 *	-3.95 **	6.84 *	-25.40 **	45.17 **	15.10 **
N67 X UMI 1221	0.00	3.21 **	6.12	-23.86 **	44.58 **	-14.65**
N162-1 X E.No.4	-13.33 **	3.63 **	-1.97	-23.67 **	28.17 **	8.78 **
N162-1 X E.No.8	-11.67 **	3.87 **	-19.58 **	-30.30 **	49.24 **	1.46
N162-1 X E.No.35	-6.67 **	0.30	-0.38	3.62 **	67.89 **	-31.96**
N162-1 X UMI 1210	0.00	-4.45 **	-6.82 *	-6.09 **	76.95 **	-2.01
N162-1 X UMI 1221	-18.33 **	-0.89	-6.76 *	-27.45 **	66.51 **	-20.17**
E.No.15 X E.No.4	-25.00 **	2.51 *	-8.55 *	-12.49 **	69.21 **	6.67 *
E.No.15 X E.No.8	-3.33	2.82 **	-0.31	-20.35 **	38.48 **	-6.67 *
E.No.15 X E.No.35	-10.00 **	2.13 *	-10.71 **	-10.91 **	43.73 **	7.43 *
E.No.15 X UMI 1210	0.00	1.26	-5.36	-3.70 **	58.57 **	28.75 **
E.No.15 X UMI 1221	-8.33 **	-0.39	-7.95 *	-8.06 **	74.06 **	22.93 **
N09-160-5 X E.No.4	-21.67 **	3.64 **	-6.94 *	-23.48 **	64.67 **	9.88 **
N09-160-5 X E.No.8	-6.67 **	2.16 *	8.75 **	-2.47 *	49.70 **	37.63 **
N09-160-5 X E.No.35	-16.67 **	3.51 **	-6.15	-32.04 **	27.51 **	14.50 **
N09-160-5 X UMI 1210	-5.00 *	3.88 **	2.14	-22.98 **	44.65 **	46.46 **
N09-160-5 X UMI 1221	-6.67 **	0.28	2.06	-8.21 **	36.77 **	-12.54**
N10-65-3 X E.No.4	-21.67 **	1.33	-14.36 **	-3.32 **	52.53 **	-23.23**
N10-65-3 X E.No.8	0.00	-1.21	16.33 **	-14.65 **	72.95 **	0.00
N10-65-3 X E.No.35	-11.67 **	-0.81	-11.36 **	-8.94 **	20.81 **	63.67 **
N10-65-3 X UMI 1210	-11.67 **	3.94 **	-18.78 **	-14.42 **	43.34 **	33.32 **
N10-65-3 X UMI 1221	-3.33	3.23 **	-8.24 *	10.52 **	60.60 **	56.25 **
N10-86-5 X E.No.4	0.00	3.07 **	-9.38 **	-21.01 **	45.11 **	38.38 **
N10-86-5 X E.No.8	-3.33	3.51 **	-2.90	-24.71 **	36.05 **	-0.85
N10-86-5 X E.No.35	-13.33 **	-6.60 **	-10.60 **	-4.20 **	42.61 **	-6.52
N10-86-5 X UMI 1210	0.00	0.30	2.42	-20.39 **	39.26 **	31.16 **
N10-86-5 X UMI 1221	-10.00 **	-0.04	-25.04 **	-15.07 **	48.33 **	35.32 **
N10-105 X E.No.4	-26.67 **	-10.21 **	-40.83 **	-6.71 **	35.85 **	36.53 **
N10-105 X E.No.8	-13.33 **	1.22	-10.60 **	-11.68 **	59.55 **	-5.17
N10-105 X E.No.35	-10.00 **	-1.44	-30.45 **	-19.31 **	75.51 **	11.69 **
N10-105 X UMI 1210	-10.00 **	-6.27 **	-27.76 **	-4.12 **	74.26 **	-7.43 *
N10-105 X UMI 1221	-10.00 **	-14.22 **	-18.32 **	1.00	24.62 **	-4.72
N10-153-1-2 X E.No.4	-8.33 **	1.74	12.68 **	-28.26 **	48.92 **	49.82 **
N10-153-1-2 X E.No.8	-18.33 **	0.94	-12.90 **	-12.41 **	59.75 **	48.67 **
N10-153-1-2 X E.No.35	-5.00 *	-0.21	-1.38	-24.29 **	47.67 **	67.94 **
N10-153-1-2 X UMI 1210	-5.00 *	1.72	-19.13 **	-9.37 **	59.75 **	27.90 **
N10-153-1-2 X UMI 1221	-8.33 **	2.36 *	-6.53	-11.95 **	35.06 **	43.60 **
SE	**1.0044**	**0.8127**	**6.9505**	**0.0932**	**0.1705**	**0.0226**

*Significant (5% level) **Significant (1% level)

Table 4. Summary table showing best hybrids and parents for different characters studied

Sl.No.	Characters	Best hybrids based on mean, *sca* and Standard heterosis	Best parents based on mean and *gca*	
			Lines	Testers
1	**DFT**	N162-1 x E.No.4, N10-65-3 x UMI 1221, N10-86-5 x UMI 1221(Early) N67 x E.No.8 , N67x UMI 1210, N67 x UMI 1221, N67x E.No.4, , N10-105 x E.No.4 (Late**)**	N10-65-3, E.No.15 , N10-86-5(early)N67,N44, N53(late)	-
2	**DFS**	N10-65-3 x E.No.35, N10-65-3 x UMI 1221, N162-1 x E.No.4(Early) N67 x E.No.8, N10-105 x E.No.4, N10-153-1-2 x E.No.35(Late)	N10-65-3, E.No.15 , N10-86-5 (early)N67 ,N44, N53(late)	UMI 1210 (early) E.No.8(late)
3	**ASI**	E.No.15 x E.No.8, N10-65-3 x E.No.35, N10-86-5 x UMI 1210,N10-105 x E.No.4, N10-105 x E.No.8	E.No.15	UMI 1210(selection based on drought tolerance)
4	**PH**	N53 x E.No.4, N162-1 x UMI 1210	N44, N53 , N10-153-1-2	UMI 1210 UMI 1221
5	**CPH**	N53 x E.No.4	N44, N53 , N10-153-1-2	UMI 1221
6	**CL**	E.No.15 x UMI 1210	N10-153-1-2	UMI 1210
7	**CB**	N53 x E.No.35,N10-153-1-2 x E.No.4	N10-153-1-2, N09-160-5	UMI 1210
8	**NKPR**	E.No.15 x E.No.4	-	-
9	**NKRPC**	N09-160-5 x E.No.8	N09-160-5 E.No.15	-
10	**CW**	N10-65-3 x E.No.8	N67	-
11	**HSW**	N162-1 x UMI 1210, E.No.15 x UMI 1210, N10-65-3 x E.No.8	N44, N67	UMI 1210
12	**SP**	N44 x UMI 1210, N44 x E.No.4	N09-160-5	E.No.4
13	**GY/PLT**	N10-65-3 x E.No.8, N44 x UMI 1210, N10-153-1-2 x E.No.4	N67	-
14	**CP**	N162-1 x E.No.35	E.No.15 N10-65-3	UMI 1221
15	**CF**	N162-1 x E.No.35, E.No.15 x UMI 1221	N67	E.No.4
16	**CTN**	N67 x E.No.35 , N53 x UMI 1210	N10-65-3	E.No.35

DFT : Days to 50 % tasseling, DFS : Days to 50 % silking, ASI : Anthesissilking interval, PH : Plant height, CPH : Cob placement height, CL : Cob length, CB : Cob breadth , NKRPC : Number of kernel rows per cob, NKPR : Number of kernels per row, CW : Cob weight, SP : Shelling per cent, HSW : Hundred seed weight , GY/PLT : Grain yield per plant, CP : Crude protein, CF : Crude fibre, CTN : Carotene content