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Study of Combining Ability and Nature of Gene Action for Yield and Yield Related Traits in Maize (*Zea mays* L.)

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present investigation was carried out using thirty eight genotypes (eight parents, twenty eight F_1's and two checks) using Griffing's half diallel mating design. The experiment was laid out in a randomized complete block design with three replications during *kharif* 2017 at the research farm of Bihar Agriculture College, Sabour. Observations were recorded for six pre-harvest characters *viz* days to 50% anthesis, days to 50% silking, anthesis silking interval, days to 75% brown husk, plant height, ear height and seven post-harvest characters *viz* cob length, cob diameter, number of kernel rows per cob, number of kernels per row, 1000 seed weight, shelling percentage and grain yield at 15% moisture. The mean sum of square of treatments was found to be significant for days to 75% brown husk and shelling per cent and highly significant for all other characters. The mean sum of square for GCA was found to be significant for cob length, no. of kernel row per cob, no. of kernels per row and highly significant for remaining all the characters except days to 75% brown husk and shelling%. The mean sum of square for SCA was significant for days to 75% brown husk and highly

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significant for all the remaining characters. On the basis of GCA effect for grain yield at 15% moisture, the parents BML-7, VQL-1 and SML-1 were found to be good general combiners. The ratio of GCA variance to SCA variance was found to be less than 1 for all the traits which indicated the preponderance of non-additive gene action. On the basis of SCA effects better performing crosses for grain yield at 15% moisture were DTPYC-9 × LM-13, CLQRCY-44 × VQL-1, CML-161 × SML-1 and CML-161× BML-7.

Keywords: Combining ability; gene action; cereal crop; yield related traits; maize.

1. INTRODUCTION

Maize (*Zea mays* L.; 2n=20) is the third most important cereal crop after paddy and wheat in India. It has assumed greater significance owing to its demand as food for human (13%), feed for livestock (13%) and poultry (47%) and as raw material for industries which finally manufacture starch (14%) processed food (7%), bio-fuel, textile dyes, dextrose etc. (Maize Vision, 2022; Federation of Indian Chambers of Commerce and Industries & Pricewaterhouse Coopers). The total production of maize in India has taken a giant leap from merely 1.73 million tonnes in the year 1950-1951 to 21.81 million tonnes in the year 2015-2016, which is almost 12.6 times that of 1950-1951. It covered an area of 8.7 m ha with mean yield of 2.51 t ha^{-1}. Because of its higher yield per hectare as compared to other cereals, maize has aptly been referred to as 'Queen of Cereals'. Bihar is one of the leading maize producing states with annual production of 2.4 million tonnes followed by Andhra (indicate annual production figure & acreage) and Karnataka (Indicate annual production). The average yield of maize in Bihar accounting for 3.42 t ha^{-1}, was higher than the country's average yield *i.e.* 2.51 t ha^{-1}.

The major maize producing districts of Bihar in terms of area are Samastipur, Begusarai, Bhagalpur, Araria & Madhepura which have emerged as corn belt and transformed Bihar into powerhouse of maize hence accounting for nearly 10% of country's total production (indicate Ref). Local lines of maize exhibit more adaptability and have preferred taste but they are poor yielders. Estimation of both combining ability and heterosis are considered as prerequisites for developing a good economically viable hybrid maize variety. Combining ability analysis is one of the powerful tools for the identification of best combiners that may be used in crosses either to exploit heterosis or to accumulate productive genes. The ratio of GCA variance to SCA variance is employed to determine the prevailing gene actions (additive or non-additive) of a quantitative trait. The closer the ratio is to unity, the greater the performance of the progeny selected based on GCA values [1]. The present investigation was carried out to study the nature of gene action by estimating the general combining ability (GCA) and specific combining ability (SCA) for yield and yield related traits among thirty eight rice genotypes.

2. MATERIALS AND METHODS

2.1 Study Location

The experiment was carried out at the research farm of Bihar Agricultural College (Bihar Agricultural University), Sabour, Bhagalpur, Bihar which lies at 25° 14' 11" N latitude and 87° 04' 16" E longitude at an altitude of 37.19 m above the mean sea level in the Eastern Indo-Gangetic Plain of North India.

2.2 Germplasm Used in the Study

The experimental materials consisted of eight diverse inbred lines of maize derived from indigenous and exotic maize germplasm maintained in the Department of Plant Breeding and Genetics at Bihar Agricultural University, Sabour, Bhagalpur. During *Rabi* 2016 and 2017.

2.3 Development of the F_1 Hybrids

All the eight inbreds were raised in a breeding nursery and were crossed in all possible combinations using Griffing's half diallel mating design. A total of twenty eight crosses were generated.

2.4 Evaluation of the F_1 Hybrids

In *Kharif* 2017, the crosses along with eight parents and two checks were evaluated in a randomized complete block design (RCBD) with three replications.. The intra-row spacing was kept at 0.6 m and inter-row spacing was 0.2 m.

The crop was raised following all the recommended cultural practices and plant protection measures.

3. RESULTS AND DISCUSSION

Selection of parents solely on the basis of phenotypic performance may be often misleading, since phenotypically superior lines may yield poor hybrid combinations. It is, therefore essential that parents should be selected on the basis of their genetic parameters (indicate a ref, these are not your words). The prime objective of estimating the genetic parameters is to predict the breeding behaviour of the parents with respect to yield and its associated components.

The knowledge of general and specific combining ability [2] helps the breeder in assessing lines to be used as parents in the hybridization programmes and exploiting the gene action involved in the inheritance of a particular trait [2]. The magnitude of heterosis is highly dependent on genetic variability and combining ability of parents. Of the various mating designs used for assessing the breeding value of the parents in terms of variance and combining ability effect, diallel analysis developed by Jinks [3] and Hayman [4] is an efficient method for the study of combining ability and the gene action of the characters under study.

The analysis of variance for the design of experiment revealed that there were significant differences among the parents for all the thirteen traits except for days to 75 percent brown husk, cob length, number of kernels per row, 1000 seed weight, shelling per cent and grain yield at 15 percent moisture. Among the hybrids significant differences were found for all the thirteen traits except for anthesis silking interval (ASI) and shelling per cent. In case of parents vs. hybrids, differences were significant for all the thirteen traits except anthesis silking interval (ASI) and number of kernels per row. This indicated existence of considerable genetic variability among the parents as well as the crosses for the traits studied (Table 1).

For developing hybrids with desirable traits information about combining ability of parents and crosses is very important [5,6,7]. Identification of parents with superior combining ability is one of the important prerequisite for the development of elite hybrids which further decides the success of any crop improvement programme (Ref). The combining ability analysis elucidates the nature and magnitude of gene action involved in the expression of quantitative traits and provides useful information for the selection of desired parents for different traits. The entire genetic variability observed for each trait was partitioned into its components *i.e.,* general and specific combining ability [2]. General Combining Ability (GCA) is used to designate the average performance of a genotype in a series of hybrid combinations while Specific Combining Ability (SCA) defines those cases in which certain combinations do relatively better or worse than expected on the basis of the average performance of the genotypes involved. The General Combining Ability (GCA) effects are due to the additive type of gene action whereas Specific Combining Ability (SCA) effects are due to the genes which are non-additive i.e. either dominant or epistatic in nature [2]. Among the various techniques available for the genetic analysis of quantitative traits, diallel cross analysis has been found to be efficient and easiest method for the identification of the best donors for hybridization (Ref). Similar results were reported by Hussein et al. [8]. The information, thus obtained, helps in the selection of suitable parents which when crossed will give rise to more desirable F_1 hybrid and /or segregates.

The analysis of variance for combining ability for diallel mating design (Table 1) revealed that the mean sum of square due to GCA was found to be significant for all the studied traits except days to 75 per cent brown husk and shelling per cent. On the other hand the mean sum of square due to SCA was found to be significant for all the studied traits. The significant estimates of GCA and SCA variances suggested the importance of both additive and non-additive gene actions for the expression studied traits. This indicated the existence of variability among the different cross combinations for all the thirteen characters under study. Similar observations were also recorded by Matin et al. [9], Synrem et. al. [10], Alamrew and Warsi [11].

The information regarding general combining ability (GCA) effects of the parents is of immense importance for the successful prediction of genetic potential of the crosses. GCA effects of the parents for thirteen traits revealed that it was difficult to pick up a single good combiner for all the characters. However, the parental line P_4 had significant positive GCA effect for grain yield at 15 per cent moisture, 1000 seed weight, number

Table 1. ANOVA for combining ability in method-II model-I of diallel analysis for pre-harvest and post-harvest traits of maize

Source of variation	DF	Pre-harvest traits						Post-harvest traits						
		D50%A	D50%S	ASI	D75 %BH	PH (cm)	EH (cm)	CL (cm)	CD (cm)	KR/Cob	K/R	1000 SW (g)	S%	GY @15%M (kg/ha)
GCA	7	09.29**	10.31**	0.38**	7.69	116.28**	65.99**	0.86*	0.05**	0.68*	4.09*	658.01**	0.73	772260.81**
SCA	28	10.44**	11.02**	0.26**	9.78*	672.74**	200.40**	2.30**	0.09**	1.92**	6.40**	1570.92**	26.97**	2183913.00**
GCA/SCA Ratio	-	0.08	0.09	0.18	0.05	0.01	0.03	0.03	0.05	0.02	0.05	0.04	0.078	0.03
Error	70	0.84	0.83	0.12	4.98	21.22	5.62	0.32	0.01	0.26	1.46	35.87	12.2	32886.6

, (rearrange like this, * Significant at 5 % and ** significant at 1 % level of probability).*

Rewrite like this D50%A = Days to 50 % anthesis, D50%S = Days to 50 % silking etc...Do for all the traits for each table. Days to 50 % anthesis (D50%A); Days to 50 % silking (D50%S); Anthesis-Silking interval (ASI); Days to 75 % brown husk (D75%BH); Plant height (PH); Ear height (EH)Cob length (CL); Cob diameter (CD); Number of kernel rows per cob (KR/Cob); Number of kernels per row (K/R); 1000 seed weight (1000SW); Shelling percentage (S%); Grain Yield at 15 % moisture (GY @15%M)

Table 2. Estimates of GCA effects of parents for pre-harvest and post-harvest traits of maize

Parents	Pre-harvest traits						Post-harvest traits						
	D50%A	D50%S	ASI	D75%BH	PH (cm)	EH (cm)	CL (cm)	CD (cm)	KR/Cob	K/R	1000 SW (g)	S%	GY@ 15%M
P_1	0.22	0.23	0.02	-0.20	-1.37	0.66	0.14	0.00	0.12	0.11	2.11	0.18	259.25**
P_2	1.02**	1.00**	-0.02	0.50	0.67	-0.94	0.1	0.10**	0.18	0.08	-5.19**	0.04	-147.42**
P_3	1.12**	1.37**	0.25*	1.43*	1.47	-2.68**	-0.54**	-0.01	0.18	-0.76*	-2.04	0.36	-344.13**
P_4	-0.62*	-0.80**	-0.18	-0.70	5.07**	4.52**	0.18	0.02	-0.15	0.84*	9.87**	-0.06	482.29**
P_5	-0.55*	-0.90**	-0.35**	-0.67	1.80	-0.84	0.05	-0.03	-0.08	0.21	12.27**	-0.12	120.95*
P_6	-0.95**	-0.80**	0.15	-0.87	-3.53*	-3.48**	-0.25	-0.11**	0.25	0.04	-13.00**	0.09	-267.29**
P_7	1.02**	1.00**	-0.02	1.03	1.63	0.79	-0.11	0.09**	-0.55**	-1.09**	-2.14	-0.56	15.89
P_8	1.25**	-1.10**	0.15	-0.53	-5.73**	1.96**	0.42*	-0.06*	0.05	0.58	-1.87	0.07	-119.53*
S.E.(g_i)	0.27	0.27	0.10	0.66	1.36	0.70	0.17	0.03	0.15	0.36	1.77	1.03	53.64
S.E. (g_i-g_j)	0.41	0.41	0.16	0.99	2.06	1.06	0.25	0.04	0.23	0.54	2.68	1.56	81.10

, Significant at 5% and 1%,respectively (do the same as in Table 1).*

Traits: Days to 50 % anthesis (D50%A); Days to 50 % silking (D50%S); Anthesis-Silking interval (ASI); Days to 75 % brown husk (D75%BH); Plant height (PH); Ear height (EH); Cob length (CL); Cob diameter (CD); Number of kernel rows per cob (KR/Cob); Number of kernels per row (K/R); 1000 seed weight (1000SW); Shelling percentage (S%); Grain Yield at 15 % moisture (GY @15%M). Parents: BML-7 (P_1); CLO-2450 (P_2); LM-13 (P_3); VQL-1 (P_4); SML-1 (P_5); DTPYC-9 (P_6); CML-161 (P_7); CLQRCY-44 (P_8)

of kernels per row and also had negative significant GCA effect for days to 50 per cent anthesis and days to 50 per cent silking. The parent P_5 also proved to be a good general combiner for grain yield at 15 per cent moisture, 1000 seed weight, days to 50 per cent anthesis, days to 50 per cent silking and anthesis silking interval. What does the positive and negative GCA imply? Explain briefly. Thus good combining ability for yield was associated with good general combining ability for yield components. Similar observation was found by Matin et al. [9]. P_6 and P_8 showed desirable and significant negative GCA effects for earliness for days to 50 per cent anthesis, days to 50 per cent silking and for plant height what does the negative GCA effects imply?. The parents P_7 and P_2 showed desirable and positive significant GCA effect for cob diameter.

Specific Combining Ability helps in the identification of superior cross combinations for the development of promising varieties or hybrids. The crosses showing high SCA effects involving parents with high GCA effect, may give rise to desirable segregates in future generation. The estimates of SCA effects revealed that out of twenty eight F_1 hybrids, significant SCA effects in favourable direction were exhibited by three hybrids for days to 50 per cent anthesis and days to 50 per cent silking. One hybrid (namely xx) exhibited negative significant SCA effect for each (incomplete statement, for each what), anthesis silking interval and days to 75 per cent brown husk. For plant height three hybrids (which ones) exhibited negative significant SCA effects and for ear height two hybrids (name them) exhibited negative significant SCA effects. On the other hand out of the twenty eight hybrids, positive significant SCA effects were exhibited by three hybrids (which hybrids) for cob length, twelve hybrids for cob diameter, seven hybrids (name them) for number of kernel rows per cob, two hybrids for number of kernels per row, twelve hybrids for 1000 seed weight, and seventeen hybrids for grain yield at 15 per cent moisture. Seventeen hybrids exhibited positive and highly significant sca effect for grain yield at 15 per cent moisture (you presented the results well you have not explained the implication of the results). The hybrid P_6 × P_3 (1804.89) recorded higher significant sca effect in positive direction followed by P_8 × P_4 (1720.71) and P_7 × P_5 (1662.97) indicating that they were better performing crosses for grain yield at 15 per cent moisture. In contrast, five hybrids recorded negative significant sca effects for the same trait. In most of the cases, positive SCA effects for grain yield was associated with higher or average SCA effect for most of the yield contributing components (ref).indicate similar studies conducted by some researchers to back up your results.

Table 3. Estimate of SCA effects of F_1 hybrids for six pre-harvest traits of maize

Hybrids	Traits					
	D50%A	**D50%S**	**ASI**	**D75%BH**	**PH(cm)**	**EH(cm)**
P_2 × P_1	3.45**	3.21**	-0.24	2.14	9.00*	10.61**
P_3 × P_1	2.69**	2.18*	-0.51	1.88	1.2	-0.33
P_4 × P_1	0.75	0.34	-0.41	-2.99	16.60**	3.14
P_5 × P_1	-0.65	-0.89	-0.24	0.64	-15.47**	-10.16**
P_6 × P_1	-3.25**	-3.66**	-0.41	-1.49	13.53**	7.14**
P_7 × P_1	2.45**	3.21**	0.76*	2.28	40.70**	19.87**
P_8 × P_1	0.05	-0.36	-0.41	1.84	24.40**	11.04**
P_3 × P_2	0.89	0.41	-0.47	0.84	1.16	-0.73
P_4 × P_2	2.95**	3.58**	0.63	5.31*	-3.1	-0.59
P_5 × P_2	2.22*	2.68**	0.46	2.28	2.83	1.77
P_6 × P_2	1.29	0.91	-0.37	-3.52	0.16	-3.93
P_7 × P_2	1.99*	1.78*	-0.21	1.24	18.00**	11.81**
P_8 × P_2	0.59	0.54	-0.04	0.81	18.70**	8.64**
P_4 × P_3	0.52	0.21	-0.31	0.38	15.76**	8.81**
P_5 × P_3	3.79**	4.31**	0.53	4.34*	16.03**	9.51**
P_6 × P_3	2.19*	2.21*	0.03	3.54	14.70**	5.47**
P_7 × P_3	1.22	0.41	-0.81*	-3.02	-0.14	5.21*
P_8 × P_3	0.49	0.18	-0.31	0.88	19.23**	2.71
P_5 × P_4	-1.48	-1.19	0.29	-5.52*	19.76**	9.31**
P_6 × P_4	-2.08*	-2.29**	-0.21	-2.32	11.10*	5.61*

Hybrids	Traits					
	D50%A	D50%S	ASI	D75%BH	PH(cm)	EH(cm)
$P_7 \times P_4$	3.62**	4.58**	0.96**	4.44*	14.26**	17.01**
$P_8 \times P_4$	3.22**	3.34**	0.13	2.34	29.96**	11.51**
$P_6 \times P_5$	3.52**	3.48**	-0.04	4.98*	3.03	0.97
$P_7 \times P_5$	2.22*	2.34**	0.13	0.41	24.53**	15.71**
$P_8 \times P_5$	1.49	1.44	-0.04	-0.69	9.00*	4.87*
$P_7 \times P_6$	0.62	0.58	-0.04	-1.72	7.2	-5.33*
$P_8 \times P_6$	-0.78	-0.66	0.13	0.84	-14.44**	6.17**
$P_8 \times P_7$	-2.08*	-2.46**	-0.37	-106	-11.27*	0.24
S.E.$_{(sij)}$	0.83	0.83	0.32	2.02	4.18	2.15
S.E.$_{(sij-sik)}$	1.23	1.22	0.48	2.99	6.18	3.18

*,** Significant at 5% and 1%,respectively.

Traits: Days to 50 % anthesis (D50%A); Days to 50 % silking (D50%S); Anthesis-Silking interval (ASI); Days to 75 % brown husk (D75%BH); Plant height (PH); Ear height (EH).

Parents: BML-7 (P_1); CLO-2450 (P_2); LM-13 (P_3); VQL-1 (P_4); SML-1(P_5); DTPYC-9 (P_6); CML-161 (P_7); CLQRCY-44 (P_8)

Table 4. Estimates of SCA effects of F_1 hybrids for seven post-harvest traits of maize

Hybrids	Traits						
	CL (cm)	CD (cm)	KR/Cob	K/R	1000SW (g)	S%	GY @15%M (kg/ha)
$P_2 \times P_1$	-0.04	0.30**	1.16*	-1.32	20.40**	1.36	874.97**
$P_3 \times P_1$	0.45	-0.23*	-0.17	1.84	11.85**	3.67	-24.98
$P_4 \times P_1$	-0.06	0.25**	0.16	0.91	5.14	2.87	848.60**
$P_5 \times P_1$	-2.00**	0.11	0.76	-0.12	-25.06**	3.68	-413.39*
$P_6 \times P_1$	-0.81	-0.17	-1.57**	0.04	3.91	1.8	1327.51**
$P_7 \times P_1$	1.44**	0.38**	2.56**	-1.49	70.01**	0.75	1493.67**
$P_8 \times P_1$	-0.32	0.13	-0.04	0.84	10.24	2.16	1297.75**
$P_3 \times P_2$	0.13	-0.17	0.43	0.54	16.28**	2.07	510.02**
$P_4 \times P_2$	0.93	-0.01	0.76	1.28	-21.89**	3.42	220.27
$P_5 \times P_2$	-0.88	0.03	0.03	-5.09**	30.81**	2.44	876.61**
$P_6 \times P_2$	-0.31	-0.35**	-0.3	0.74	-19.06**	3.08	-255.15
$P_7 \times P_2$	-1.01	0.54**	1.83**	1.21	12.58*	-0.15	783.33**
$P_8 \times P_2$	-1.40*	0.23*	1.90**	1.88	-1.85	2.85	837.08**
$P_4 \times P_3$	-0.36	0.31**	1.43**	2.11	-18.18**	2.35	1035.98**
$P_5 \times P_3$	-1.21*	0.47**	0.7	-0.59	13.52*	2.54	288.65
$P_6 \times P_3$	0.45	0.27**	0.36	-2.09	45.69**	1.29	1804.89**
$P_7 \times P_3$	-2.98**	-0.11	-0.84	-5.96**	7.13	2.66	-789.62**
$P_8 \times P_3$	0.3	0.03	-0.1	1.38	-29.77**	4.4	257.13
$P_5 \times P_4$	-0.21	0.21*	1.03*	-0.48	82.38**	1.41	1032.90**
$P_6 \times P_4$	-0.86	-0.04	0.7	2.31*	-33.75**	3.68	-419.53*
$P_7 \times P_4$	-1.76**	-0.12	0.16	-4.22**	-11.31*	1.04	1008.29**
$P_8 \times P_4$	1.45**	0.26**	0.23	-0.56	98.45**	1.87	1720.71**
$P_6 \times P_5$	-0.47	0.16	0.63	-1.06	3.78	2.41	206.48
$P_7 \times P_5$	3.38**	-0.08	-1.24*	7.08**	32.79**	3	1662.97**
$P_8 \times P_5$	-1.73**	-0.25*	0.16	-0.92	-27.78**	2.93	618.71**
$P_7 \times P_6$	-1.95**	-0.09	0.43	-1.42	2.11	3.34	822.21**
$P_8 \times P_6$	1.01	0.31**	0.5	-0.09	17.56**	-0.35	-384.71*
$P_8 \times P_7$	-1.31*	0.20*	1.30**	-0.62	-12.97*	4.01	-412.89*
S.E.$_{(sij)}$	0.513	0.09	0.46	1.1	5.43	3.17	164.44
S.E.$_{(sij-sik)}$	0.76	0.13	0.68	1.62	8.03	4.69	243.3

*,** Significant at 5% and 1%,respectively.

Traits: Cob length (CL); Cob diameter (CD); Number of kernel rows per cob (KR/Cob); Number of kernels per row (K/R); 1000 seed weight (1000SW); Shelling percentage (S%); Grain Yield at 15 % moisture (GY @15%M).

Parents: BML-7 (P_1); CLO-2450 (P_2); LM-13 (P_3); VQL-1 (P_4); SML-1 (P_5); DTPYC-9 (P_6); CML-161 (P_7); CLQRCY-44 (P_8)

Table 5. Estimates of GCA, SCA variance and their ratios

Traits	σ^2_{GCA}	σ^2_{SCA}	$\sigma^2_{GCA}/\sigma^2_{SCA}$
Days to 50 % anthesis	0.845	9.59	0.08
Days to 50 % silking	0.949	10.19	0.09
Anthesis silking interval	0.025	0.13	0.18
Days to 75 % brown husk	0.271	4.79	0.05
Plant height (cm)	9.506	651.52	0.01
Ear height (cm)	6.037	194.78	0.03
Cob length (cm)	0.055	1.98	0.03
Cob diameter (cm)	0.004	0.08	0.05
No. of kernel rows per cob	0.042	1.65	0.02
No. of kernels per row	0.263	4.94	0.05
1000 seed weight (g)	62.214	1535.04	0.04
Shelling %	1.147	14.76	0.08
Grain yield at 15 % moisture (kg/ha)	73937.416	2151026.40	0.03

The relative importance of general and specific combining ability can be assessed by estimating the components of variance and expressed in the form of ratio of GCA variance to SCA variance. The closer the ratio to unity, greater is the magnitude of additive gene action and *vice versa (provide ref).* The estimates of variance component revealed that the variance due to SCA was more than the respective variance due to GCA for all the traits. It indicates that all the studied traits were predominantly governed by non-additive gene action. Several researches have reported the greater importance of SCA variance than the GCA variance for grain yield and other yield contributing traits [12,13]. Similar observations have been recorded by Moneam et al. [14]; Pandey et al. [15]; Suthamathi and Nallathambi [16]; Ramegowda et al. [17].

4. CONCLUSION

Maize, the third most important cereal crop in India has greater significance owing to its demand as food for human, feed for livestock, and poultry (13%, 13% and 47% respectively) and as raw material for industries (14%) processed food (7%), bio-fuel, textile dyes, dextrose etc. The mean sum of square for SCA was significant for days to 75% brown husk and highly significant for all the remaining characters. On the basis of GCA effect for grain yield at 15% moisture, the parents BML-7, VQL-1 and SML-1 were found to be good general combiners. It was recorded that significant differences among the parents for all the thirteen traits except for days to 75 percent brown husk, cob length, number of kernels per row, 1000 seed weight, shelling per cent and grain yield at 15 percent moisture. Among the hybrids significant differences were found for all the thirteen traits except for anthesis silking interval (ASI) and shelling per cent.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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