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Combining ability and gene action for some quantitative and qualitative parameters in quality protein maize (*Zea mays* L.) genotypes

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Abstract
A set of six diverse inbred lines were crossed as per diallel analysis (Griffing 1956 Model I and Method II) in *Rabi*-2015 to generate 15 crosses (direct crosses). These 15 crosses were evaluated along with 6 parents and 1 check *viz.,* Shakthiman-5 in Randomized Block Design along with three replications in a five rows plot of 5 meter length having 60 x 20 cm crop geometry during *kharif*-2016 at the Field Experimentation Centre of Department of Genetics and Plant Breeding, Naini Agricultural institute, Sam Higginbottom University of Agriculture, Technology and sciences, Allahabad. The data were recorded on ten characters to study the pattern of heterosis and combining ability. The crosses HKI-17-2 X HKI-164-4 (1-3)-2 recorded highly positive significant heterosis at all the three levels for oil content (92.39**, 52.29** and 3.25**) high *per se* performance for oil (4.50), and starch content (15.23**, 14.04** and 10.74**) high *per se* performance for starch content (80.43) and for grain yield per plant (34.93**, 19.68** and 19.68**) respectively. This hybrid also possess highest *per se* performance for grain yield per plant 150.00 (g). Another single cross hybrid CML (CML 161, CML451)-B X HKI-164-4 (1-3)-2 exhibited maximum significant heterosis (24.43**, 21.14** and 9.56**) for all three types of heterosis along with highest *per se* performance (9.93) for protein content. Combining ability analysis revealed that estimate of specific combining ability SCA variances were higher than general combining ability GCA variances for all the traits under study, indicating predominance of non-additive gene action of these traits. The parents HKI-17-2, HKI-164-4 (1-3)-2 and CML (CML 161, CML451)-B were identified as good combiners for yield and quality traits. The best experimental hybrid, on the basis of *per se* performance, SCA and standard heterosis for grain yield per plant and quality traits was HKI-17-2 X HKI-164-4 (1-3)-2. Gene action analysis revealed preponderance of non-additive genes for yield and quality traits.

Keywords: Heterosis, combining ability, gene action, grain yield and maize (*Zea mays* L.)

Introduction
Among the maize growing countries, India rank 4th in area and 7th in production, representing around 4% of the world maize area and 2% of total production. During 2018-19 in India, the maize area has reached to 9.2 million ha (DACNET, 2020). During 1950-51 India used to produce 1.73 million MT maize, which has increased to 27.8 million MT by 2018-19, recording close to 16 times increase in production. The average productivity during the period has increased by 5.42 times from 547 kg/ha to 2965 kg/ha, while the area increased nearly by three times. Among Indian states Madhya Pradesh and Karnataka has highest area under maize (15% each) followed by Maharashtra (10%), Rajasthan (9%), Uttar Pradesh (8%) and others. After Karnataka and Madhya Pradesh Bihar is the highest maize producer. Andhra Pradesh is having the highest state productivity. Some districts like Krishna, West Godavari etc. records as high as 12 t/ha productivity. Protein plays an important role in development of on human body. Protein Deficiency leads to a) Kwashiorkor (reduction of growth and abdominal enlargement) b) Marasmus (loss in weight and dehydration) Protein-containing foods are necessary for the rapid growth of children and in some countries maize is a primary weaning food for babies. India was among the first countries in the world to focus on improvement of maize quality soon after the nutritional benefits of opaque-2 mutation were brought to light In India, three opaque-2 composites have been released around the turn of this century. But these composites were not favored by the farmers due to poor yield, susceptibility to disease and storage problem. Quality protein maize (QPM) is bio fortified maize with increased lysine and tryptophan levels.

QPM contains higher amount of lysine and tryptophan in the endosperm ensuring higher biological value and availability of protein to human and animal so it can help to get rid of human malnourishment (Hussain *et al.,* 2016) [30]. The biological value of common maize is 45% whereas that of QPM is about 80%. Therefore, the present study is an attempt to determine the general combining ability (GCA) and specific combining ability (SCA) in order to identify superior male and female combiners as well as desirable experimental hybrids for further exploitation in QPM breeding programme. Diallel analysis which involves the crossing of all lines in all possible combinations is an efficient method for the study of combining ability and also the gene action of the characters under study. (Kumar and Babu 2016) [47]. Combining ability analysis is of special importance in cross-pollinated crops like maize as it helps in identifying potential parents that can be used for producing hybrids and synthetics. Heterosis is the enhancement in size, growth, fertility and yield in progeny compared to parents. Hallauer and Miranda (1988) [95] manifested that heterosis depends on the genetic divergence of two parental varieties; also genetic divergence of the parents is inferred from the heterotic patterns manifested in a series of cross combination.

Materials and methods

In order to develop and identify nutritionally superior and industrially important single cross hybrids, a set of six diverse inbred lines were crossed as per diallel analysis (Griffing 1956 Model I and Method II) in *Rabi*-2015 to generate 15 crosses (direct crosses). These 15 crosses were evaluated along with 6 parents and 1 check *viz.,* Shakthiman-5 in Randomized Block Design along with three replications in a five rows plot of 5 meter length having 60 x 20 cm crop geometry during *kharif*-2016 at the Field Experimentation Centre of Department of Genetics and Plant Breeding, Naini Agricultural institute, Sam Higginbottom University of Agriculture, Technology and sciences, Allahabad. The recommended fertilizers of N, P and K were applied in the ratio of 120: 80: 60 kg ha-1. The entire P and K and half dose of nitrogen was applied as basal, while remaining half dose of N in two equal split doses at knee height and tasselling stages. Weeding operations, necessary plant protection measures were taken up to protect the crop from pests and diseases as per the recommendations along with the timely irrigation schedules to raise a healthy crop. The data were recorded were Days to 50% tasselling, Days to 50% silking, Anthesis silking interval, Plant height (cm), Cob height (cm), Tassel length (cm), Leaf area index (cm^2), Days to maturity, Cobs weight (g). Cob length (cm), Cob girth (cm), Number of grain rows/cob, Grains/row, Cobs grain weight (g), 100-grains weight (test weight) (g), Grain yield/plant (g), Protein content %, Starch content %, Oil content %.

Results and Discussion

The analysis of variance revealed the presence of significant amount of variability among parents, their crosses (F_1) and among parents vs. Crosses (F_1) for all the characters studied.

Table 1.1: Analysis of variance for 19 characters in Quality Protein Maize

S. No	Characters	Mean Sum of Squares						
		Replications (DF)	Treatments (DF)	Parents (DF)	Hybrids (DF)	Parent Vs. Hybrids (DF)	Error (DF)	Total
		(2)	(20)	(5)	(14)	(1)	(40)	(62)
1.	Days to 50% tasseling	2.33	13.42**	7.30**	11.42**	72.01**	1.77	5.54
2.	Days to 50% silking	4.63	13.72**	7.82*	10.27**	91.43**	2.73	6.34
3.	Anthesis silking interval	0.76	8.30**	2.53*	10.95**	0.00	0.76	3.19
4.	Plant height	0.17	210.94**	39.61**	273.06**	197.90**	0.18	68.17
5.	Cob height	0.18	71.31**	16.69**	80.53**	215.19**	0.14	23.10
6.	Tassel length	1.96	60.46**	78.30**	18.34**	560.85**	1.22	20.35
7.	Leaf area index	55.50	190.31**	793.68**	143.74**	139.55**	179.91	729.16
8.	Days to maturity	8.68	65.60**	179.56**	28.58**	14.03	7.85	26.50
9.	Cobs weight	411.09	148.16**	203.53**	430.62**	135.63**	140.24	570.86

**Significant at1% and *Significant at 5% level

Table 1.2: Analysis of variance for 19 characters in Quality Protein Maize

S. No	Characters	Mean Sum of Squares						
		Replications (DF)	Treatments (DF)	Parents (DF)	Hybrids (DF)	Parent Vs. Hybrids (DF)	Error (DF)	Total
		(2)	(20)	(5)	(14)	(1)	(40)	(62)
10.	Cob length	0.85	23.24**	23.51**	11.54**	185.72**	0.60	7.91
11.	Cob girth	0.11	12.05**	16.21**	2.78**	121.06**	0.35	4.11
12.	Grain rows/ cob	0.03	4.98**	11.65**	1.58**	19.24**	0.43	1.88
13.	Grains/ row	0.79	133.67**	130.32**	27.03**	1643.34**	6.14	47.11
14.	Cobs grain weight	862.32	111.06**	185.17**	305.67**	869.94**	317.05	360.84
15.	100-Grains weight	0.28	80.15**	151.52**	38.19**	310.65**	1.76	27.00
16.	Grain yield/ plant	9.08	415.33**	724.29**	112.50**	310.25**	18.61	1351.12
17.	Protein content	0.02	3.09**	2.01**	3.26**	6.14**	0.11	1.07
18.	Starch content	0.16	32.32**	8.94**	42.62**	5.16**	0.20	10.56
19.	Oil content	0.04	6.95**	15.00**	4.54**	0.53**	0.03	2.26

**Significant at1% and *Significant at 5% level

Table 2.1: Mean performance of parents and hybrids for different characters in Quality Protein Maize

S. No	Genotypes	Days to 50% tasseling	Days to 50% silking	Anthesis silking interval	Plant height (cm)	Cob height (cm)	Tassel length (cm)	Leaf area index (cm^2)	Days to maturity	Cobs weight (g)	Cob length (cm)
1.	HKI-17-2 (P_1)	53.33	57.33	4.00	144.16	37.90	29.06	326.77	93.00	443.33	12.04
2.	CML (161, CML451)-B (P_2)	53.00	55.00	2.00	147.16	44.66	23.69	246.21	79.00	44.50	7.72
3.	HKI-164-4 (1-3)-2 (P_3)	51.00	53.33	2.33	147.70	41.90	37.70	397.75	86.66	738.33	15.76
4.	HUZM QPM-1 (P_4)	53.33	55.33	3.66	144.26	40.76	25.44	370.16	83.66	235.00	10.83
5.	HUZM QPM-6 (P_5)	55.33	57.33	2.00	140.36	39.06	26.32	341.91	74.33	182.33	9.40
6.	HKI-193-1 (P_6)	55.00	57.00	2.00	138.56	40.30	25.28	327.83	72.66	90.00	9.55
7.	HKI-17-2 X CML (161, CML451)-B	49.66	51.33	1.66	133.36	42.43	36.73	401.47	79.66	603.33	16.49
8.	HKI-17-2 X HKI-164-4 (1-3)-2	51.00	53.00	2.00	146.10	40.73	36.45	443.54	80.00	685.00	16.60
9.	HKI-17-2 X HUZM QPM-1	49.66	51.00	1.33	157.80	40.40	32.89	485.37	80.00	683.33	13.90
10.	HKI-17-2 X HUZM QPM-6	50.33	52.33	2.00	164.86	47.83	38.60	419.44	86.66	593.33	17.47
11.	HKI-17-2 X HKI-193-1	52.00	54.33	4.66	152.16	53.80	35.05	384.08	84.00	576.66	16.03
12.	CML (161, CML451)-B X HKI-164-4 (1-3)-2	49.66	51.33	2.00	157.10	44.66	32.79	466.63	83.00	498.33	14.01
13.	CML (161, CML451)-B X HUZM QPM-1	53.00	54.33	1.33	149.46	43.00	35.37	422.92	86.66	472.76	12.89
14.	CML (161, CML451)-B X HUZM QPM-6	54.00	55.66	3.00	148.40	35.40	37.21	475.53	87.66	555.00	12.75
15.	CML (161, CML451)-B X HKI-193-1	50.33	52.33	2.00	143.86	36.63	31.00	357.09	80.00	464.00	12.83
16.	HKI-164-4 (1-3)-2 X HUZM QPM-1	51.33	53.33	2.00	152.80	46.06	31.62	400.14	83.00	600.00	11.87
17.	HKI-164-4 (1-3)-2 X HUZM QPM-6	52.00	54.00	1.66	151.66	49.70	36.77	591.84	83.66	576.66	14.70
18.	HKI-164-4 (1-3)-2 X HKI-193-1	53.66	51.00	2.00	151.56	49.10	33.43	459.66	77.33	507.33	12.36
19.	HUZM QPM-1 X HUZM QPM-6	48.00	55.33	4.00	137.36	50.33	33.44	503.88	85.33	687.33	14.44
20.	HUZM QPM-1 X HKI-193-1	48.33	52.00	8.66	134.80	48.13	35.96	479.18	80.00	850.00	18.00
21.	HUZM QPM-6 X HKI-193-1	54.00	57.00	1.66	133.10	44.63	30.50	298.38	82.00	850.00	15.93
22.	SHAKTHIMAN-5	52.33	56.00	3.66	141.80	41.43	32.72	543.05	88.00	623.33	14.82
	Mean	51.83	54.07	2.71	146.29	43.58	32.63	415.58	82.56	525.45	13.65
	Range Highest	55.33	57.33	8.66	164.86	53.80	38.60	591.84	93.00	850.00	18.00
	Range Lowest	48.00	51.00	1.33	133.10	35.40	23.69	246.21	72.66	44.50	7.72
	S.E.	0.75	0.93	0.50	0.24	0.26	0.62	24.54	0.61	1.61	0.47
	C.D. 5%	2.15	2.66	1.42	0.69	0.76	1.78	70.04	1.76	4.59	192.46

Table 2.2: Mean performance of parents and hybrids for different characters in Quality Protein Maize

S. No	Genotypes	Cob girth (cm)	Grain rows/ cob	Grains/ row	Cobs grain weight (g)	100-grains weight (g)	Grain yield/ plant (g)	Protein (%)	Starch (%)	Oil (%)
1.	HKI-17-2 (P_1)	10.58	13.33	14.53	491.66	24.13	97.00	6.60	72.63	2.80
2.	CML (161, CML451)-B (P_2)	7.88	12.00	9.76	19.33	16.93	3.50	7.76	69.06	7.26
3.	HKI-164-4 (1-3)-2 (P_3)	12.98	13.53	27.26	633.33	26.64	125.33	8.20	70.53	4.81
4.	HUZM QPM-1 (P_4)	8.39	11.93	15.06	173.33	21.36	29.33	8.23	71.90	9.00
5.	HUZM QPM-6 (P_5)	7.24	13.80	13.73	133.30	10.00	28.20	8.33	68.70	7.52
6.	HKI-193-1 (P_6)	7.01	8.50	8.86	75.00	10.00	16.33	9.06	72.50	7.30
7.	HKI-17-2 X CML (161, CML451)-B	11.89	13.63	31.26	500.00	21.62	101.66	9.13	70.20	6.10
8.	HKI-17-2 X HKI-164-4 (1-3)-2	12.80	13.60	24.40	751.66	27.74	150.00	7.80	69.66	7.33
9.	HKI-17-2 X HUZM QPM-1	12.28	13.23	28.40	558.33	26.35	114.00	8.33	70.13	6.43
10.	HKI-17-2 X HUZM QPM-6	12.18	14.00	29.10	543.33	24.91	110.66	6.96	67.20	6.13
11.	HKI-17-2 X HKI-193-1	12.04	13.80	29.66	503.33	21.33	102.00	9.40	71.33	5.33
12.	CML (161, CML451)-B X HKI-164-4 (1-3)-2	11.56	14.76	27.40	426.66	18.78	82.00	9.93	80.43	4.50
13.	CML (161, CML451)-B X HUZM QPM-1	11.61	13.40	23.30	408.86	24.95	85.00	7.90	70.53	7.62
14.	CML (161, CML451)-B X HUZM QPM-6	11.61	13.96	24.96	500.00	20.93	103.33	9.53	68.43	6.33
15.	CML (161, CML451)-B X HKI-193-1	9.9733	12.4000	25.63	383.33	19.0000	77.0000	9.3667	69.33	5.36
16.	HKI-164-4 (1-3)-2 X HUZM QPM-1	12.47	12.26	19.73	530.00	26.67	107.66	6.73	69.30	5.12
17.	HKI-164-4 (1-3)-2 X HUZM QPM-6	12.32	14.40	28.30	476.66	22.00	88.00	8.36	74.16	6.62
18.	HKI-164-4 (1-3)-2 X HKI-193-1	11.33	13.13	23.33	415.66	19.00	82.00	8.23	77.93	4.42
19.	HUZM QPM-1 X HUZM QPM-6	11.59	12.56	25.90	460.00	22.00	78.33	9.13	68.30	5.83
20.	HUZM QPM-1 X HKI-193-1	13.27	13.20	24.03	573.33	20.63	89.33	9.76	75.30	8.34
21.	HUZM QPM-6 X HKI-193-1	14.26	12.73	27.23	685.00	30.57	115.33	10.06	70.86	8.25
22.	SHAKTHIMAN-5	12.89	14.26	29.96	573.33	24.28	123.00	9.06	71.93	5.15
	Mean	11.28	13.11	23.26	446.15	21.81	86.77	8.55	71.36	6.25
	Range Highest	14.26	14.76	31.26	751.66	30.57	150.00	10.06	80.43	9.00
	Range Lowest	7.01	8.50	8.86	19.33	10.00	3.50	6.60	67.20	2.80
	S.E.	0.33	0.37	1.44	11.45	0.80	2.47	0.19	0.25	0.09
	C.D. 5%	0.95	1.05	4.13	32.68	2.29	7.06	0.55	0.72	0.27

The perusal mean value of yield and yield contributing characters revealed that among parents genotypes HKI-164-4 (1-3)-2 (125.33), HKI-17-2 (97.00), HUZM QPM-1 (29.33) and HUZM QPM-6 (28.20 g) exhibited maximum value of grains yield per plant along with other contributing traits *viz*., Cob length (15.76, 12.04, 10.83 and 9.40) Cob girth (12.98, 10.58, 8.39 and 7.24 cm) Number of grain rows per cob (13.53, 13.33, 11.93 and 13.80) Number of grains per row (27.26, 14.53, 15.06 and 13.73) and Test weight (26.64, 24.13, 21.36 and 10.00 g). Among the hybrids cross HKI-17-2 x HKI-164-4 (1-3)-2 exhibited maximum value of grains yield per plant (150.00 g) along with cob length (16.60 cm) Cob girth (12.80 cm) Number of grain rows per cob (13.60) Number of grains per row (24.40) and Test weight (27.74 g). The parents genotype HKI-193-1 (9.06) exhibited maximum value of protein content followed by HUZM QPM-6 (8.33), HUZM QPM-1(8.23) and HKI-164-4 (1-3)-2 (8.20%), Parent genotypes HKI-17-2 (72.63) exhibited maximum value of starch content followed by HKI-193-1 (72.50), HUZM QPM-1 (71.90) and HKI-164-4 (1-3)-2 (70.83%) and maximum value of oil content HUZM QPM-1 (9.00) followed by HUZM QPM-6 (7.52), HKI-193-1 (7.30) and CML (161, CML451)-B (7.26%). On the basis of *per se* performance for grains yield per plant, best high yielding hybrid identified as HKI-17-2 x HKI-164-4 (1-3)-2. Genotypes showed high grain yield and qualitative parameters can be on immense use in the future breeding programme.

3.1 Heterosis, Heterobeltiosis and Economic heterosis for different quantitative and qualitative parameters

Heterotic responses can be obtained in the direction (+ve and –ve). In the present study heterosis in negative direction was considered for days to 50% tasseling, days to 50% silking and days to maturity. Whereas, the other characters it was desirable in positive direction. The character wise heterosis, heterobeltiosis and standard heterosis are presented in table

Table 3.1: Heterosis (Ha), Heterobeltiosis (Hb) and Economic heterosis (Hc) for Days to 50% tasseling, Days to 50% silking, and Anthesis silking interval

S. No	Genotypes	Days to 50% tasseling			Days to 50% silking			Anthesis silking interval		
		Ha	Hb	Hc	Ha	Hb	Hc	Ha	Hb	Hc
1	HKI-17-2 X CML (161, CML451)-B	-6.58**	-6.87**	-10.24**	-8.61**	-10.12**	-10.47**	-44.44*	-56.73**	-58.33**
2	HKI-17-2 X HKI-164-4 (1-3)-2	-2.24	-4.37*	-7.83**	-4.22	-7.56**	-7.56**	-36.84	-46.00**	-50.00**
3	HKI-17-2 X HUZM QPM-1	-6.87**	-6.87**	-10.24**	-9.47**	-10.60**	-11.05**	-65.22**	-64.67**	-66.67**
4	HKI-17-2 X HUZM QPM-6	-7.36**	-8.09**	-9.04**	-8.72**	-8.45**	-8.72**	-33.33	-45.00**	-50.00**
5	HKI-17-2 X HKI-193-1	-4.00*	-5.45**	-6.02**	-4.96*	-4.65*	-5.23*	55.56*	16.67	16.67
6	CML (161, CML451)-B X HKI-164-4 (1-3)-2	-4.49*	-6.29**	-10.24**	-5.23*	-6.67**	-10.47	-7.69	-14.29	-50.00**
7	CML (161, CML451)-B X HUZM QPM-1	-0.31	-0.62	-4.22*	-1.51	-1.81	-5.23**	-52.94*	-63.64**	-66.67**
8	CML (161, CML451)-B X HUZM QPM-6	-0.31	-1.65	-2.41	-0.89	-1.76	-2.91	50.00	50.00	-25.00
9	CML (161, CML451)-B X HKI-193-1	-6.79**	-8.48**	-9.04**	-6.55	-8.19**	-8.72**	0.00	0.00	-50.00**
10	HKI-164-4 (1-3)-2 X HUZM QPM-1	-1.60	-3.75	-7.23**	-1.84	-3.61	-6.98**	-33.33	-45.45*	-50.00**
11	HKI-164-4 (1-3)-2 X HUZM QPM-6	-2.19	-5.45**	-6.02**	-2.41	-4.21*	-5.81*	-23.08	-28.57	-58.33**
12	HKI-164-4 (1-3)-2 X HKI-193-1	1.26	-2.42	-3.01	-7.55	-10.53**	-11.05**	-7.69	-14.29	-50.00**
13	HUZM QPM-1 X HUZM QPM-6	-11.66**	-13.08**	-13.25**	-1.78	-3.23	-3.49	41.18	9.09	0.00
14	HUZM QPM-1 X HKI-193-1	-10.77**	-12.12**	-12.65**	-7.42	-8.77**	-9.30**	205.88**	136.36**	116.67**
15	HUZM QPM-6 X HKI-193-1	-2.11	-2.19	-2.41	-0.29	-0.34	-0.58	-16.67	-16.67	-58.33**

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

Table 3.2: Heterosis (Ha), Heterobeltiosis (Hb) and Economic heterosis (Hc) for Plant height, Cob height and Tassel length

S. No	Genotypes	Plant height			Cob height			Tassel length		
		Ha	Hb	Hc	Ha	Hb	Hc	Ha	Hb	Hc
1	HKI-17-2 X CML (161, CML451)-B	-8.44**	-9.38**	-9.70**	2.79**	-4.07**	-5.00**	39.24**	26.36**	-2.57
2	HKI-17-2 X HKI-164-4 (1-3)-2	0.11	-1.08**	-1.08**	2.09**	-2.78**	-8.81**	9.20**	-3.31	-3.67
3	HKI-17-2 X HUZM QPM-1	9.42**	9.38**	6.84**	2.71**	-0.90	-9.55**	20.68**	13.15**	-12.76**
4	HKI-17-2 X HUZM QPM-6	15.89**	14.36**	11.62**	24.30**	22.44**	7.09**	39.37**	32.80**	2.39
5	HKI-17-2 X HKI-193-1	7.64**	5.55**	3.02**	37.60**	33.50**	20.45**	28.99**	20.58**	-7.03**
6	CML (161, CML451)-B X HKI-164-4 (1-3)-2	6.56**	6.36**	6.91**	3.20**	0.00	0.00	6.83*	-13.02	-13.09**
7	CML (161, CML451)-B X HUZM QPM-1	2.57**	1.56**	1.20**	0.66**	-3.34**	-3.73**	44.00**	39.04**	-6.16*
8	CML (161, CML451)-B X HUZM QPM-6	3.22**	0.84**	0.47	-15.45**	-20.12**	-20.75**	48.79**	41.34**	-1.30
9	CML (161, CML451)-B X HKI-193-1	0.70**	-2.24**	-2.60**	-13.77**	-17.09**	-17.99**	26.61**	22.63**	-17.77**
10	HKI-164-4 (1-3)-2 X HUZM QPM-1	4.67**	3.45**	3.45**	11.45**	9.94**	3.13**	0.15	-16.13**	-16.13**
11	HKI-164-4 (1-3)-2 X HUZM QPM-6	5.30**	2.69**	2.69**	22.77**	18.62**	11.27**	14.87**	-2.46	-2.46
12	HKI-164-4 (1-3)-2 X HKI-193-1	5.89**	2.44**	2.62**	19.46**	17.18**	9.93**	6.17*	-11.32**	-11.32**
13	HUZM QPM-1 X HUZM QPM-6	-3.48**	-4.78**	-7.00**	26.10**	23.47**	12.69**	29.21**	27.04**	-11.28**
14	HUZM QPM-1 X HKI-193-1	-4.68**	-6.56**	-8.73**	18.75**	18.07**	7.76**	41.79**	41.33**	-4.62
15	HUZM QPM-6 X HKI-193-1	-4.57**	--5.18**	-9.88**	12.47**	10.75**	-0.07	18.21**	15.86**	-19.09**

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

Table 3.3: Heterosis (Ha), Heterobeltiosis (Hb) and Economic heterosis (Hc) for Leaf area, Days to maturity and Cobs weight

S. No	Genotypes	Leaf area index			Days to maturity			Cobs weight		
		Ha	Hb	Hc	Ha	Hb	Hc	Ha	Hb	Hc
1	HKI-17-2 X CML (161, CML451)-B	40.13**	22.86*	0.93	-7.36**	-12.40**	-14.34**	147.35**	36.09	-18.28
2	HKI-17-2 X HKI-164-4 (1-3)-2	22.44**	10.63	11.51	-10.95**	-13.41**	-13.98**	15.94	-7.22	-7.22
3	HKI-17-2 X HUZM QPM-1	39.29**	31.12**	22.03*	-9.43**	-13.14**	-13.98**	101.47**	54.14*	-7.45
4	HKI-17-2 X HUZM QPM-6	25.45**	22.68*	5.45	3.59	-6.09**	-6.81**	89.66**	33.83	-19.64
5	HKI-17-2 X HKI-193-1	17.35	17.16	-3.44	1.41	-8.04**	-9.68**	116.25**	30.08	-21.90
6	CML (161, CML451)-B X HKI-164-4 (1-3)-2	44.92**	16.20	17.32	0.20	-4.23	-10.75**	27.32	-32.51	-32.51*
7	CML (161, CML451)-B X HUZM QPM-1	37.23**	14.25	6.33	6.56*	3.59	-6.81**	238.29**	101.18*	-35.97**
8	CML (161, CML451)-B X HUZM QPM-6	61.71**	39.08**	19.56*	14.35**	10.97**	-5.73*	389.35**	204.39**	-24.83
9	CML (161, CML451)-B X HKI-193-1	24.41*	8.93	-10.22	5.49	1.27	-13.98**	589.96**	415.56**	-37.16**
10	HKI-164-4 (1-3)-2 X HUZM QPM-1	4.22	0.29	0.60	-2.54	-4.23	-10.75**	23.29	-18.74	-18.74
11	HKI-164-4 (1-3)-2 X HUZM QPM-6	60.03**	42.21**	48.80**	3.93	-3.46	-10.04**	25.27	-21.90	-21.90
12	HKI-164-4 (1-3)-2 X HKI-193-1	26.70**	15.13	15.57	-2.93	-10.77**	-16.85**	22.49	-31.29*	-31.29*
13	HUZM QPM-1 X HUZM QPM-6	41.53**	36.12**	26.68**	8.02**	1.99	-8.24**	229.39**	192.48**	-6.91
14	HUZM QPM-1 X HKI-193-1	37.30**	29.45**	20.47*	2.35	-4.38	-13.98**	423.08**	261.70**	15.12
15	HUZM QPM-6 X HKI-193-1	-10.90	-12.73	-12.73	11.56**	10.31**	-11.83**	524.24**	366.18**	15.12

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

Table 3.4: Heterosis (Ha), Heterobeltiosis (Hb) and Economic heterosis (Hc) for Cob length, Cob girth and Grain rows/cob

S. No	Genotypes	Cob length			Cob girth			Grain rows/cob		
		Ha	Hb	Hc	Ha	Hb	Hc	Ha	Hb	Hc
1	HKI-17-2 X CML (161, CML451)-B	66.88**	36.91**	4.61	28.82**	12.38**	-8.40	7.63	2.25	-1.21
2	HKI-17-2 X HKI-164-4 (1-3)-2	19.37**	4.99	5.29	8.69*	-1.20	-1.36	1.24	0.49	-1.45
3	HKI-17-2 X HUZM QPM-1	21.50**	15.38**	-11.84**	29.44**	16.07**	-5.39	4.75	-0.75	-4.11
4	HKI-17-2 X HUZM QPM-6	62.95**	45.05**	10.82**	36.78**	15.19**	-6.11	3.19	0.99	1.45
5	HKI-17-2 X HKI-193-1	48.46**	33.09**	1.69	36.93**	13.83**	-7.22	26.41**	3.50	0.00
6	CML (161, CML451)-B X HKI-164-4 (1-3)-2	19.33**	-11.12**	-11.67	10.90**	-10.32**	-10.89**	15.67**	9.11*	7.00
7	CML (161, CML451)-B X HUZM QPM-1	39.02**	19.05**	-18.20**	42.73**	38.36**	-10.53**	11.98**	11.67*	-2.90
8	CML (161, CML451)-B X HUZM QPM-6	48.95**	35.64**	-19.13**	53.66**	47.42**	-10.50**	8.27*	1.21	1.21
9	CML (161, CML451)-B X HKI-193-1	48.59**	34.33**	-18.60**	33.96**	26.57**	-23.16**	20.98**	3.33	-10.14
10	HKI-164-4 (1-3)-2 X HUZM QPM-1	-10.70*	-23.62**	-24.67**	16.75**	-3.88	-3.88	-3.66	-9.36*	-11.11**
11	HKI-164-4 (1-3)-2 X HUZM QPM-6	16.82**	-6.77	-6.77	21.86**	-5.08	-5.08	5.37	4.21	4.35
12	HKI-164-4 (1-3)-2 X HKI-193-1	-2.32	-21.34**	-21.56**	13.39**	-12.69**	-12.69**	19.21**	-2.96	-4.83
13	HUZM QPM-1 X HUZM QPM-6	42.73**	33.29**	-8.41	48.32**	38.13**	-10.68**	-8.94*	-8.21*	-8.94*
14	HUZM QPM-1 X HKI-193-1	76.59**	66.15**	14.16**	72.39**	58.18**	2.29	29.20**	10.61*	-4.35
15	HUZM QPM-6 X HKI-193-1	68.13**	66.78**	1.06	100.19**	97.01**	9.89*	14.20**	-7.12	-7.73

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

Table 3.5: Heterosis (Ha), Heterobeltiosis (Hb) and Economic heterosis (Hc) for Grains/row, Cobs grain weight and Test weight

S. No	Genotypes	Grains/row			Cobs grain weight			Test weight		
		Ha	Hb	Hc	Ha	Hb	Hc	Ha	Hb	Hc
1	HKI-17-2 X CML (161, CML451)-B	157.34**	115.14**	14.67	95.69**	1.69	-21.05**	5.19	-10.41*	--
2	HKI-17-2 X HKI-164-4 (1-3)-2	16.75	-10.51	-10.51	33.63**	18.68**	18.68**	9.26*	3.97	4.10
3	HKI-17-2 X HUZM QPM-1	91.89**	88.50**	4.16	67.92**	13.56**	-11.84**	15.86**	9.21	-1.09
4	HKI-17-2 X HUZM QPM-6	105.90**	100.23**	6.72	73.88**	10.51**	-14.21**	46.00**	3.25	-6.49
5	HKI-17-2 X HKI-193-1	153.56**	104.13**	8.80	77.65**	2.37	-20.53**	25.00**	-11.60*	-19.94**
6	CML (161, CML451)-B X HKI-164-4 (1-3)-2	47.97**	0.49	0.49	30.75**	-31.65**	-32.63**	-33.89**	-29.50**	-29.50**
7	CML (161, CML451)-B X HUZM QPM-1	87.65**	54.65**	54.65**	324.43**	135.88**	-35.44**	30.16**	16.79**	-6.37
8	CML (161, CML451)-B X HUZM QPM-6	112.48**	81.80**	81.80**	555.16**	275.09**	-21.05**	55.22**	23.33**	-21.44**
9	CML (161, CML451)-B X HKI-193-1	175.13**	162.46**	162.46**	712.72**	411.11**	-39.47**	40.88**	11.94	-28.70**
10	HKI-164-4 (1-3)-2 X HUZM QPM-1	-6.77	-26.13**	-27.63**	31.40**	-16.32**	-16.32**	11.13**	0.01	0.11
11	HKI-164-4 (1-3)-2 X HUZM QPM-6	38.05**	3.79	3.79	24.35**	-24.74**	-24.74**	20.07**	-17.12**	-17.44**
12	HKI-164-4 (1-3)-2 X HKI-193-1	29.15**	-13.78	-14.43	17.36**	-34.37**	-34.37**	3.69	-27.62**	-28.70**
13	HUZM QPM-1 X HUZM QPM-6	79.86**	71.90**	-5.01	200.03**	165.38**	-27.37**	40.29**	2.98	-17.44**
14	HUZM QPM-1 X HKI-193-1	100.84**	59.51**	-11.86	361.74**	230.77**	-9.47**	31.60**	-3.40	-22.55**
15	HUZM QPM-6 X HKI-193-1	141.00**	98.30**	-0.12	557.71**	413.88**	8.16**	205.73**	205.73**	14.74**

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

Table 3.6: Heterosis (Ha), Heterobeltiosis (Hb) and Economic heterosis (Hc) for Grain yield/plant and Protein content

S. No	Genotypes	Grain yield/plant			Protein content		
		Ha	Hb	Hc	Ha	Hb	Hc
1	HKI-17-2 X CML (161, CML451)-B	102.32**	4.81	-18.88**	27.15**	17.60**	0.74
2	HKI-17-2 X HKI-164-4 (1-3)-2	34.93**	19.68**	23.41**	5.41	-4.88	-13.97**
3	HKI-17-2 X HUZM QPM-1	80.47**	17.53**	-9.04**	15.06**	3.64	-5.88**
4	HKI-17-2 X HUZM QPM-6	76.78**	14.09**	-11.70**	-6.70	-16.40**	-23.16**
5	HKI-17-2 X HKI-193-1	80.00**	5.15	-18.62**	20.00**	3.14	3.68
6	CML (161, CML451)-B X HKI-164-4 (1-3)-2	27.30**	-32.41**	-34.57**	24.43**	21.14**	9.56**
7	CML (161, CML451)-B X HUZM QPM-1	417.77**	189.77**	-32.18**	-1.25	-4.05	-12.87**
8	CML (161, CML451)-B X HUZM QPM-6	551.95**	266.43**	-17.55**	18.43**	14.40**	5.15
9	CML (161, CML451)-B X HKI-193-1	676.47**	371.43**	-38.56**	11.29**	3.03	3.31
10	HKI-164-4 (1-3)-2 X HUZM QPM-1	39.22**	-14.10**	-14.10**	-18.05**	-18.22**	-25.74**
11	HKI-164-4 (1-3)-2 X HUZM QPM-6	14.63**	-29.79**	-29.79**	1.21	0.40	-7.72*
12	HKI-164-4 (1-3)-2 X HKI-193-1	15.76**	-34.57**	-34.57**	-4.63	-9.19**	-9.19**
13	HUZM QPM-1 X HUZM QPM-6	172.31**	167.05**	-37.50**	10.26**	9.60**	0.74
14	HUZM QPM-1 X HKI-193-1	291.24**	204.55**	-28.72**	12.91**	7.23*	7.72*
15	HUZM QPM-6 X HKI-193-1	417.96**	308.98**	-7.98**	15.71**	10.44**	11.03**

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

Table 3.7: Heterosis (Ha), Heterobeltiosis (Hb) and Economic heterosis (Hc) for Starch content and Oil content

S. No	Genotypes	Starch content			Oil content		
		Ha	Hb	Hc	Ha	Hb	Hc
1	HKI-17-2 X CML (161, CML451)-B	-0.92	-3.35**	-3.35**	21.24**	-15.96**	-32.15**
2	HKI-17-2 X HKI-164-4 (1-3)-2	-2.68**	-4.08**	-4.08**	92.39**	52.29**	3.25**
3	HKI-17-2 X HUZM QPM-1	-2.95**	-3.44**	-3.44**	8.98**	-26.52**	-28.52**
4	HKI-17-2 X HUZM QPM-6	-4.91**	-7.48**	-7.48**	18.75**	-18.48**	-31.85**
5	HKI-17-2 X HKI-193-1	-2.11**	-2.20**	-2.20**	5.41**	-27.05**	0.00
6	CML (161, CML451)-B X HKI-164-4 (1-3)-2	15.23**	14.04**	10.74**	-25.44**	-38.03**	-49.96**
7	CML (161, CML451)-B X HUZM QPM-1	0.07	-1.90	-2.89**	-6.23**	-15.26**	-15.26**
8	CML (161, CML451)-B X HUZM QPM-6	-0.65	-0.92	-5.78**	-14.31**	-15.77**	-29.59**
9	CML (161, CML451)-B X HKI-193-1	-2.05**	-4.37**	-4.54**	-26.35**	-26.55**	-40.37**
10	HKI-164-4 (1-3)-2 X HUZM QPM-1	-2.69**	-3.62**	-4.59**	-25.87**	-43.11**	-43.11**
11	HKI-164-4 (1-3)-2 X HUZM QPM-6	6.54**	5.15**	2.11**	7.38**	-11.96**	-26.41**
12	HKI-164-4 (1-3)-2 X HKI-193-1	8.97**	7.49**	7.30**	-27.06**	-39.51**	-50.89**
13	HUZM QPM-1 X HUZM QPM-6	-2.84**	-5.01**	-5.97**	-29.43**	-35.22**	-35.22**
14	HUZM QPM-1 X HKI-193-1	4.29**	3.86**	3.67**	2.37**	-7.26**	-7.26**
15	HUZM QPM-6 X HKI-193-1	0.38	-2.25**	-2.43**	11.31**	9.70**	2.19**

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

In the present study grain yield per plant had significant positive economic heterosis for 1 cross. HKI-17-2 X HKI-164-4 (1-3)-2 (19.68**) recorded maximum grain yield per plant along with cob height (-5.00**), leaf area (0.93), days to maturity (-14.34**), cob length (5.29) and test weight (4.10). The cross combination HUZM QPM-6 X HKI-193-1 had the highest positive relative heterosis, heterobeltiosis and economic heterosis for protein content followed by CML (161, CML451)-B X HKI-164-4 (1-3)-2 and HUZM QPM-1 X HKI-193-1. The cross combination HUZM QPM-1 X HKI-193-1 had the highest positive relative heterosis, heterobeltiosis and economic heterosis followed by HKI-164-4 (1-3)-2 X HKI-193-1,CML (161, CML451)-B X HKI-164-4 (1-3)-2 and HKI-164-4 (1-3)-2 X HUZM QPM-6. The cross combination CML (161, CML451)-B X HKI-164-4 (1-3)-2 the highest positive relative heterosis, heterobeltiosis and economic heterosis for oil content followed by HUZM QPM-6 X HKI-193-1. At overall the qualitative performance of relative heterosis, heterobeltiosis and economic heterosis performance for best observation was recorded in HUZM QPM-1 X HKI-193-1 followed by HUZM QPM-6 X HKI-193-1.

Combining ability analysis: The data on 15 crosses were analysed and the data on crosses further analyzed to determine the GCA and SCA variance components for all the characters.

Analysis of variance: Analysis of variance for combining ability indicates that GCA and SCA mean sum of squares were highly significant for most of the characters indicating importance of both additive and non-additive genetic effects.

Table 4.1: Analysis of variance for combining ability for different characters in Quality Protein Maize

S. No	Character	Mean Sum of Squares					
		Var-GCA	Var-SCA	Error	F-Ratio		GCA/SCA Ratio
		5	14	40	GCA	SCA	
1	Days to 50% tasseling	3.11**	4.93**	0.59	5.28	8.36	0.07
2	Days to 50% silking	5.39**	4.30**	0.91	5.91	4.71	0.17
3	Anthesis silking interval	2.54**	2.84**	0.25	10.01	11.10	0.11
4	Plant height	58.34**	74.30**	0.06	992.01	1263.5	0.10
5	Cob height	9.02**	28.69**	0.058	190.92	607.29	0.04
6	Tassel length	17.20**	21.13**	0.41	42.20	51.83	0.10
7	Leaf area index	6155.60**	6392.72**	599.97	10.25	10.65	0.12
8	Days to maturity	30.61**	18.95**	2.62	11.69	7.24	0.21
9	Cobs weight	40587.95**	52593.86**	4694.41	8.64	11.20	0.09
10	Cob length	6.17**	8.27**	0.20	31.09	41.66	0.09
11	Cob girth	3.31**	4.25**	0.12	28.50	36.58	0.10

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

Table 4.2: Analysis of variance for combining ability for different characters in Quality Protein Maize

S. No	Character	Mean Sum of Squares					
		Var-GCA	Var-SCA	Error	F-Ratio		GCA/SCA Ratio
		5	14	40	GCA	SCA	
12	Grain rows/cob	3.36**	1.09**	0.14	23.58	7.68	0.42
13	Grains/ row	18.72**	53.17**	2.05	9.14	25.96	0.04
14	Cobs grain weight	51837.49**	32123.09**	105.68	490.50	303.95	0.20
15	100-grains weight	36.46**	23.47**	0.59	62.32	40.10	0.20
16	Grain yield/plant	2328.36**	1068.47**	6.20	375.29	172.22	0.27
17	Protein content	1.50**	0.87**	0.04	39.68	23.21	0.22
18	Starch content	12.22**	10.29**	0.07	183.78	154.73	0.15
19	Oil content	4.20**	1.69**	0.01	418.66	168.68	0.31

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

Conclusion

This results showed that parents HKI-17-2 (22.12**) and HKI-164-4 (1-3)-2 (20.62**) turned out to be best combiner for grain yield per plant. The perusal of SCA effects indicated that 12 cross combinations *viz.*, HUZM QPM-6 X HKI-193-1 (47.82**), CML (161, CML451)-B X HUZM QPM-6 (41.11**), CML (161, CML451)-B X HUZM QPM-1 (25.16**), HUZM QPM-1 X HKI-193-1 (24.20**), HKI-17-2 X HKI-164-4 (1-3)-2 (22.20**), CML (161, CML451)-B X HKI-193-1 (21.50**), HKI-17-2 X HUZM QPM-1 (14.62**), HKI-17-2 X CML (161, CML451)-B (11.91**), HKI-164-4 (1-3)-2 X HUZM QPM-1 (9.79**), HKI-17-2 X HUZM QPM-6 (8.90*), HKI-17-2 X HKI-193-1 (6.95*) and HUZM QPM-1 X HUZM QPM-6 (6.49*) showed positive significant SCA effects for grain yield per plant. This results showed that parents HKI-193-1 (0.66**) and CML (161, CML451)-B (0.21**) turned out to be best combiner for protein content. The perusal of SCA effects indicated that 8 cross combinations *viz.*, CML (161, CML451)-B X HKI-164-4 (1-3)-2 (1.47**), HKI-17-2 X CML (161, CML451)-B (0.97**), HKI-17-2 X HKI-193-1 (0.80**), HUZM QPM-6 X HKI-193-1 (0.75**), HKI-17-2 X HUZM QPM-1 (0.73**), HUZM QPM-1 X HKI-193-1 (0.72**), CML (161, CML451)-B X HUZM QPM-6 (0.66**) and HUZM QPM-1 X HUZM QPM-6 (0.62*) showed positive significant SCA effects for protein content.

Table 4.3: General combining ability effects of parents for different quantitative and qualitative parameters in Quality Protein Maize

S. No	Genotypes	Days to 50% tasseling	Days to 50% silking	Anthesis silking interval	Plant height	Cob height	Tassel length	Leaf area index	Days to maturity	Cobs weight	Cob length
1	HKI-17-2 (P_1)	-0.42	-0.15	0.13	2.13**	-0.60**	1.18**	-9.90	2.53**	47.85*	1.17**
2	CML (161, CML451)-B (P_2)	0.00	-0.36	0.58**	0.12	-1.79**	-1.00**	-31.32**	-0.14	-120.39**	-1.35**
3	HKI-164-4 (1-3)-2 (P_3)	-0.37	-1.07**	-0.54**	3.63**	1.03**	2.25**	36.34**	0.53	87.31**	0.74**
4	HUZM QPM-1 (P_4)	-0.71**	-0.15	0.75**	-0.60**	0.46**	-1.03**	20.65*	0.78	14.74	-0.30*
5	HUZM QPM-6 (P_5)	0.79**	1.39**	-0.29	-1.18**	0.03	0.09	13.29	-0.26	-2.32	-0.14
6	HKI-193-1 (P_6)	0.71**	0.35	0.54**	-4.12**	0.88**	-1.49**	-29.07**	-3.43**	-27.19	-0.12

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

Table 4.4: General combining ability effects of parents for different quantitative and qualitative parameters in Quality Protein Maize

S. No	Genotypes	Cob girth	Grain rows/cob	Grains/row	Cobs grains weight	Test weight	Grain yield/plant	Protein content	Starch content	Oil content
1	HKI-17-2 (P_1)	0.49**	0.44**	1.41**	94.91**	2.29**	22.12**	-0.58**	-0.74**	-0.90**
2	CML (161, CML451)-B (P_2)	-0.75**	0.10	-1.07*	-102.90**	-1.58**	-17.42**	0.21**	-0.29**	0.04
3	HKI-164-4 (1-3)-2 (P_3)	1.00**	0.48**	2.13**	98.33**	1.95**	20.62**	-0.28**	1.65**	-0.82**
4	HUZM QPM-1 (P_4)	-0.05	-0.36**	-1.14*	-25.44**	1.43**	-7.79**	-0.14*	-0.25**	0.90**
5	HUZM QPM-6 (P_5)	-0.25*	0.48**	0.29	-18.64**	-1.43**	-5.41**	-0.13*	-1.63**	0.51**
6	HKI-193-1 (P_6)	-0.44**	-1.14**	-1.63**	-46.26**	-2.67**	-12.13**	0.66**	1.26**	0.27**

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

In the present study, an overall appraisal of GCA effects revealed that parents HKI-17-2, HKI-164-4 (1-3)-2 and HKI-193-1 were good general combiners for majority of the characters. In the present investigation, estimates of SCA effects indicated that cross HUZM QPM-6 X HKI-193-1 (12.98**) showed highest positive significant SCA effects for grains yield per plant followed by CML (161, CML451)-B X HUZM QPM-6 (41.11**), CML (161, CML451)-B X HUZM QPM-1 (25.16**), HUZM QPM-1 X HKI-193-1 (24.20**), HKI-17-2 X HKI-164-4 (1-3)-2 (22.20**) and CML (161, CML451)-B X HKI-193-1 (21.50**) Positive significant SCA effects for qualitative characters showed by the crosses CML (161, CML451)-B X HKI-164-4 (1-3)-2 and HUZM QPM-1 X HKI-193-1. Combining ability analysis revealed that parents HKI-17-2 (22.12**) and HKI-164-4 (1-3)-2 (20.62**) showed positive significant GCA effects for grains yield per plant. However, parents *viz.*, HKI-17-2 and HKI-164-4 (1-3)-2 were good general combiners for 100 grains weight. However the parent HKI-193-1 for protein content, HKI-164-4 (1-3)-2 for starch content and HUZM QPM-1for oil content (Table 4.4). Positive significant GCA effects showed by the genotypes HKI-17-2, HKI-164-4 (1-3)-2 and HKI-193-1for quantitative and qualitative characters. On the basis of present study the crosses *viz.*, HUZM QPM-1 X HKI-193-1and HUZM QPM-6 X HKI-193-1 exhibited high heterosis, heterobeltiosis, economic heterosis and significant SCA effects for grains yield.

Table 5.1: Specific combining ability effects for different quantitative and qualitative parameters in Quality Protein Maize

S. No	Genotypes	Days to 50% tasseling	Days to 50% silking	Anthesis silking interval	Plant height	Cob height	Tassel length	Leaf area index	Days to maturity	Cobs weight	Cob length
1	HKI-17-2 X CML (161, CML451)-B	-1.73*	-2.14*	-0.54	-15.40**	1.14**	3.91**	33.17	-5.02*	155.08*	3.07**
2	HKI-17-2 X HKI-164-4 (1-3)-2	-0.02	0.24	-0.25	-6.18**	-3.38**	0.39	7.58	-5.36*	29.05	1.09*
3	HKI-17-2 X HUZM QPM-1	-1.02	-2.68**	-2.21**	9.76**	-3.14**	0.11	65.10*	-5.61*	99.96	-0.57
4	HKI-17-2 X HUZM QPM-6	-1.85*	-2.89**	-0.50	17.40**	4.72**	4.70**	6.54	2.10	27.01	2.84**
5	HKI-17-2 X HKI-193-1	-0.10	0.15	1.33**	7.64**	9.83**	2.73**	13.53	2.60	35.22	1.38*
6	CML (161, CML451)-B X HKI-164-4 (1-3)-2	-1.77*	-1.22	0.46	6.84**	1.74**	-1.10	52.09*	0.31	10.62	1.02*
7	CML (161, CML451)-B X HUZM QPM-1	1.90*	0.86	-1.50**	3.44**	0.65*	4.77**	24.07	3.73*	57.63	0.95*
8	CML (161, CML451)-B X HUZM QPM-6	1.40	0.65	1.21*	2.95**	-6.52**	5.48**	84.05*	5.77*	156.91*	0.64
9	CML (161, CML451)-B X HKI-193-1	-2.18**	-1.64	-0.62	1.35**	-6.15**	0.85	7.96	1.27	90.79	0.70
10	HKI-164-4 (1-3)-2 X HUZM QPM-1	0.61	0.57	-0.88	3.26**	0.89**	-2.23**	-66.36*	-0.61	-22.84	-2.16**
11	HKI-164-4 (1-3)-2 X HUZM QPM-6	-0.23	-0.30	-0.17	2.70**	4.95**	1.79*	132.70**	1.10	-29.12	0.50
12	HKI-164-4 (1-3)-2 X HKI-193-1	1.52*	-2.26*	-0.67	5.54**	3.50**	0.04	42.88	-2.07	-73.57	-1.85**
13	HUZM QPM-1 X HUZM QPM-6	-3.89**	0.11	0.87	-7.36**	6.16**	1.75*	60.43*	2.52	154.12*	1.28*
14	HUZM QPM-1 X HKI-193-1	-3.48**	-2.18*	4.71**	-6.99**	3.10**	5.85**	78.08*	0.35	341.66**	4.82**
15	HUZM QPM-6 X HKI-193-1	0.69	1.28	-1.25*	-8.11**	0.03**	-0.73	-95.35**	3.39*	358.72**	2.59**

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

Table 5.2: Specific combining ability effects for different quantitative and qualitative parameters in quality Protein Maize

S. No	Genotypes	Cob length	Cob girth	Grain rows/cob	Grains/row	Cobs grains weight	Test weight	Grain yield/plant	Protein content	Starch content	Oil Content
1	HKI-17-2 X CML (161, CML451)-B	3.07**	0.95*	0.04	7.98**	67.89**	-0.79	11.91**	0.97**	-0.11	0.66**
2	HKI-17-2 X HKI-164-4 (1-3)-2	1.09*	0.10	-0.38	-2.09	118.33**	1.80*	22.20**	0.13	-2.59**	2.74**
3	HKI-17-2 X HUZM QPM-1	-0.57	0.64	0.09	5.19**	48.76**	0.93	14.62**	0.73**	-0.22	0.13
4	HKI-17-2 X HUZM QPM-6	2.84**	0.74*	0.02	4.45*	26.96*	2.36*	8.90*	-1.11**	-1.78**	0.22*
5	HKI-17-2 X HKI-193-1	1.38*	0.79*	1.44**	6.94**	14.58	0.01	6.95*	0.80**	-0.83*	-0.35*
6	CML (161, CML451)-B X HKI-164-4 (1-3)-2	1.02*	0.11	1.13*	3.39*	-8.86	-3.28**	-6.25*	1.47**	7.74**	-1.03**
7	CML (161, CML451)-B X HUZM QPM-1	0.95*	1.21*	0.61	2.56	97.10**	3.40**	25.16**	-0.70*	-0.26	0.38**
8	CML (161, CML451)-B X HUZM QPM-6	0.64	1.41**	0.33	2.79*	181.44**	2.25*	41.11**	0.66*	-0.99**	-0.52**
9	CML (161, CML451)-B X HKI-193-1	0.70	-0.04	0.39	5.38**	92.39**	1.55*	21.50**	-0.03	-2.98**	-1.25**
10	HKI-164-4 (1-3)-2 X HUZM QPM-1	-2.16**	0.32	-0.91*	-4.21*	17.01	1.59*	9.79**	-1.37**	-3.44**	-1.27**
11	HKI-164-4 (1-3)-2 X HUZM QPM-6	0.50	0.36	0.38	2.93*	-43.12**	-0.22	-12.26**	-0.01	2.81**	0.62**
12	HKI-164-4 (1-3)-2 X HKI-193-1	-1.85**	-0.43	0.74*	-0.12	-76.51**	-1.98*	-11.55**	-0.68*	3.69**	-1.34**
13	HUZM QPM-1 X HUZM QPM-6	1.28*	0.69*	-0.62	3.80*	63.98**	0.30	6.49*	0.62*	-1.16**	-1.89**
14	HUZM QPM-1 X HKI-193-1	4.82**	2.56**	1.64**	3.85*	204.93**	0.17	24.20**	0.72**	2.95**	0.87**
15	HUZM QPM-6 X HKI-193-1	2.59**	3.75**	0.33	5.62**	309.79**	12.98**	47.82**	0.75**	-0.11	1.17**

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

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