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HETEROTIC EFFECTS IN QUALITY PROTEIN MAIZE FOR YIELD AND QUALITY TRAITS

Preeti Sharma*, Mehar Chand Kamboj, Narender Singh and Mehar Chand
CCS Haryana Agricultural University Regional Research Station, Karnal -132001, Haryana

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Maize is one of the most important crops in the world agricultural economy after wheat and rice. It plays a significant role in human food, livestock nutrition and industrial production. Production of maize is increasing day by day in our country due to its high yield potentiality, versatile uses, and almost year round growth ability and higher yield potential than other cereals. Major breakthrough in yield of maize came with the release of hybrids with high yield potential (Sharma *et al*., 2016). In the development of hybrids, the foremost step is the development and evaluation of the inbred lines and to know the nature and magnitude of heterosis for grain yield and its component traits. Heterosis is the deviation of F_1 from the reference for the particular character. Heterosis of varying magnitude has been observed in almost all the crop plants. This heterosis has been successfully exploited in many cross pollinated crops among which maize is the major one. Maize is a highly cross pollinated crop and hand emasculation (detasseling) and wind borne pollination are used to produce hybrid seeds on a commercial scale. This phenomenon of heterosis attracted the consideration of plant breeders due to its prominent effect on economic characters especially grain yield, maturity and quality traits. The single cross quality protein maize hybrids have become popular all over the world due to their high yield potential and excellent uniformity along with increased level of lysine and tryptophan as the normal maize is deficient in these two essential amino acids. The success depends on the availability of productive diverse quality protein maize inbred lines and clear knowledge of gene action for specific traits to develop QPM hybrids (Sharma *et al*., 2017). Unless the productivity of QPM is comparable or better than the conventional maize varieties currently in use, farmers may be reluctant to produce it. This requires a rigorous inbred line development and evaluation work to identify potential parental lines for hybrid variety development (Abebe *et. al*., 2020). Therefore the objectives of this study were to determine the extent of heterosis in respect of yield and its component traits and quality traits and to identify best experimental hybrids having balanced level of grain yield and quality traits.

*Corresponding author : sharmapreeti.genetics@gmail.com
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The study materials involved twenty eight QPM inbred lines (seventeen inbred lines from station and eleven received from biofortification trials received from Winter Nursery, Hyderabad). These best performing parental inbred lines *viz*., HKI 170 (1+2), HKI 193-1, HKI 165, HKI 161, HKI 5072-2BT (1-2), IMR 336, IMR 373, HKI 26-2 (1+2), Sr. No. 74 QPM, HKI 191-2-5 , IMR 362, HKI 169, HKI 193-2, HKI 164-7-2, IMR 343, IMR 344, HKI 193-2-6, Bio Sr. No. 52, HKI 323 , IMR 144, HKI 190 , HKI 191-2-6, IMR 357, HKI 164-7-4 , IMR 356, HKI 164-1-4(1-3), IMR 337 and HKI 5072-2BT(1-2)1-3 were crossed in a half diallel mating design to produce twenty experimental hybrids during *Rabi* 2016-17 and *Rabi* 2017-18. These hybrids were raised in Randomized Complete Block Design with three replications during *Kharif* 2018 at CCSHAU, Regional Research Station, Karnal, Haryana, which is located at latitude of 29^0 43ˈ42.19˝ N longitude of 76^0 58ˈ49.88˝ E and at an altitude of 253 meters above mean sea level. The plot size was two rows of 4.0m length with 0.70 m between rows and 0.20m between plants within a row. All the agronomic practices were followed to raise a good crop. These genotypes were evaluated for phenological traits *viz*., days to 50 % tasselling, days to 50 % silking and days to maturity, yield traits *viz*., plant height, ear height, 100-grain weight, grain yield and quality traits *viz*., protein content, tryptophan content, lysine content, oil content and starch content.

The sum of squares was calculated by Analysis of Variance. The estimate of heterosis over standard check (standard heterosis) was calculated as follows

$$\frac{\overline{F}_1-\overline{CC}}{\overline{CC}} \times 100$$

Where CC = mean performance of commercial cultivar

F_1 = mean performance of a cross

The statistical analysis was done using OPSTAT software.

Analysis of variance carried out to test the significance of genotypic differences among entries was found significant for all the characters (Table 1). It implies that these experimental hybrids have differences for all the characters under study. The pertinent results based on *per se* performance of 20 hybrids and 2 checks are presented in Table 2 and percentage of heterosis measured as increase or decrease best checks have been presented in Table 3. Considerable amount of heterosis was observed for all the characters under study, however, the magnitude varied with characters. In the present study, out of twenty experimental hybrids studied, standard heterosis for grain yield per plant was significant (more than 10 % increase over check) in six hybrids over both the checks HQPM 1 and HQPM 4. However, ten hybrids recorded positive standard heterosis. Among them, HKI 164-7-4 × IMR 356 showed highest magnitude of standard heterosis for this trait followed by HKI 170 (1+2) × HKI 169, HKI 193-2 × IMR 337, HKI 193-2 × HKI 169 and HKI 165 × HKI 161. These results coincide with the earlier findings of Shrestha *et al*. (2018), Kumari *et al*. (2018), Sharma *et al*. (2017) and Sorsa *et al*. (2014) where standard heterosis was observed for this trait. Negative heterosis was observed for phonological traits. For days to 50 per cent taselling and days to 50 per cent silking, negative standard heterosis was recorded in seventeen hybrids over the check HQPM 1 and fourteen hybrids over the check HQPM 4. The range of standard heterosis was from -14.12 (HKI 164-7-4 × IMR 356) to -4.89 (HKI 170 (1+2) × HKI 169) over check HQPM 1 (early maturing). For maturity traits, eight crosses showed negative heterosis over HQPM 1 in which HKI 5072-2BT (1-2) × IMR 336 recorded minimum no. of days to maturity followed by HKI 170 (1+2) × IMR 373 and HKI 164-7-4 × IMR 356. Heterosis in earliness was observed by Shrestha *et al*. (2018), Kumari *et al*. (2018), Sharma *et al*. (2017), Netravati *et al*. (2013), Elmyhum (2013) and Raghu *et al*. (2012). In case of plant height, medium height is desirable as very tall height tends to lodge and low height is generally not preferred because high plant height and high cob placement have direct correlation with grain yield (Sharma *et al*., 2016, 2017). For this trait, only five and three hybrids were found to have positive standard heterosis over check HQPM and HQPM 4, respectively and among them highest heterosis was recorded by HKI 190 × IMR 373. For ear height, none of the hybrid has standard heterosis over both the hybrid checks. For tallness, heterotic responses were also observed by Praveen *et al*. (2014) and Netravati *et al*. (2013). The standard heterosis for eight and six hybrids were found over HQPM 1 and HQPM 4, respectively, for 100- grain weight and highest heterosis was recorded for HKI 170 (1+2) × HKI 169 but it was found to be less than 10% superiority. These results are in agreement with earlier findings of Rajesh e*t al*. (2014), and Sorsa *et al*. (2014). High and significant heterosis for grain yield accompanied by significant heterosis for one or more yield contributing characters was earlier reported by several workers (Shrestha *et al*., 2018; Kumari *et al*., 2018; Sharma *et al.,* 2017; Shazia *et al.,* 2017; Sorsa *et al.*, 2014; Raghu *et al.*, 2012; Jawaharlal *et al*., 2012 and Appunu *et al*., 2007).

For quality traits, all the hybrids have positive standard heterosis over both the checks for protein content and highest was recorded for HKI 191-2-5 × IMR 362, HKI 164-7-2 × IMR 343, HKI 165 × HKI 161 and HKI 193-2 × IMR 337. For lysine content, HKI 164-7-4 × IMR 356, HKI 193-2 × HKI 169, HKI 193-2 × HKI 169 recorded highest standard heterosis for lysine content. Crosses HKI 170 (1+2) × HKI 169, HKI 165 × HKI 161, HKI 193-2 × HKI 169, HKI 164-7-4 × IMR 356 have high heterosis for tryptophan content. HKI 191-2-5 × IMR 362, HKI 170 (1+2) × HKI 169, HKI 5072-2BT(1-2)1-3 × IMR 336, HKI 164-7-4 × IMR 356 and HKI 164-1-4(1-3) × IMR 356 recorded more than 10% superiority over both the checks for oil content. In case of starch content, none of the hybrid have more than10 % superiority over either of the checks. However, HKI 164-7-4 × IMR 356 and HKI 164-1-4(1-3) × IMR 356 have recorded highest heterosis for this trait. For quality characters, similar heterotic response was observed by Sharma *et al*. (2017), Sorsa *et al*. (2014), Singh *et al*. (2013) and Elmyhum (2013).

A perusal of heterotic behaviour and magnitude of heterosis in the superior experimental hybrids revealed that heterosis for grain yield may be because of the fact that at least one parent involved in these crosses is desirable, should also taken into account for heterosis breeding. The most promising combinations selected separately on the basis of heterotic effect over best checks *i.e* HQPM 1 and HQPM 4, therefore, suggested that these five top performing experimental hybrids viz., HKI 164-7-4 × IMR 356, HKI 170 (1+2) × HKI 169, HKI 193-2 × IMR 337, HKI 193-2 × HKI 169 and HKI 165 × HKI 161 manifested high heterotic effect for grain yield and other traits also. Among them, hybrid HKI 164-7-4 × IMR 356 were found the best combination for grain yield coupled with early maturity and tryptophan, lysine content, starch content and oil content, HKI 170 (1+2) × HKI 169 was best for grain yield with other traits *viz*., early maturity, hundred grain weight, tryptophan and oil content, HKI 193-2 × HKI 169 for tryptophan and lysine content along with grain yield and HKI 165 × HKI 161 for protein and tryptophan as well as for grain yield. Parents of these highly heterotic crosses explained the existence of genes with some degree of dominance controlling the character. Expression of heterosis also depends on the divergence between genotypes, as differences in allele frequencies are required at loci involved in the expression of desirable characteristics. Whereas, low heterotic effect is likely due to low genetic complementarily of loci with non-additive effects, possibly because these crosses displayed some degree of parental relationship. These results indicated that these crosses could be selected and used in breeding programs for improving these traits. The most

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Table 1. Analysis of variance of maize hybrids for various traits

Source of variation	D.F	Days to tasselling	Days to silking	Days to maturity	Plant height	Ear height	100-grain weight	Grain yield/ ha(q)	Protein content	Lysine content	Tryptophan content	Oil content	Starch content
Replication	2	1.73	9.100	6.100	392.433	50.158	1.679	3.873	3.873	0.025	0.003	0.060	0.207
Treatment	19	49.61**	49.45**	39.03**	1,315.03**	117.19**	14.649**	153.176**	1.236**	0.62**	0.028**	0.333**	16.10**
Error	38	0.375	0.234	0.348	76.883	28.562	2.660	0.317	0.212	0.023	0.005	0.033	2.004

** Significant at 5 % and 1% level

Table 2. Mean performance of maize hybrids for various traits

Treatment	Days to tasselling	Days to silking	Days to maturity	Plant height	Ear height	100-grain weight	Grain yield/ ha(q)	Protein content	Lysine content	Tryptophan content	Oil content	Starch content
HKI 170 (1+2) × HKI 193-1	60.00	63.00	91.00	202.00	90.67	23.06	67.70	10.56	2.55	0.57	3.87	70.38
HKI 165 × HKI 161	56.33	59.33	86.67	224.00	104.00	26.03	73.47	10.05	2.68	0.63	3.94	67.35
HKI 5072-2BT (1-2) × IMR 336	51.00	53.67	81.67	182.66	84.67	25.40	60.67	9.86	2.61	0.53	3.74	70.81
HKI 170 (1+2) × IMR 373	52.00	54.33	82.33	202.00	90.67	23.06	68.57	10.56	2.45	0.57	3.87	70.38
HKI 26-2 (1+2) × Sr. No. 74 QPM	59.33	62.33	90.33	174.33	87.33	22.07	59.17	9.90	2.63	0.55	3.73	67.37
HKI 191-2-5 × IMR 362	60.67	62.67	90.67	161.66	85.00	22.23	57.30	9.42	2.33	0.54	4.65	71.09
HKI 193-1 × HKI 169	59.33	63.33	91.33	208.33	97.33	22.63	69.47	9.53	2.37	0.56	3.36	68.22
HKI 193-2 × HKI 169	57.66	60.33	85.33	221.00	101.33	26.52	74.56	9.82	2.72	0.58	3.57	71.44
HKI 170 (1+2) × HKI 169	58.33	61.33	87.67	218.66	104.33	27.46	75.53	9.39	2.60	0.68	4.27	69.20
HKI 164-7-2 × IMR 343	62.33	64.33	92.33	188.00	97.00	20.32	59.40	11.45	2.12	0.52	3.36	66.73
HKI 193-2 × IMR 344	61.00	63.00	91.00	166.33	93.00	25.96	53.97	10.44	2.55	0.50	3.76	68.13
HKI 193-2-6 × Bio Sr. No. 52	62.33	65.33	93.33	194.33	89.67	21.93	70.40	10.43	2.33	0.48	3.79	70.34
HKI 323 × IMR 144	61.00	63.33	91.33	171.33	92.00	18.76	60.60	10.11	2.59	0.45	3.77	67.53
HKI 190 × IMR 373	53.33	56.33	84.33	232.00	84.83	27.16	65.95	9.57	2.61	0.57	3.84	70.35
HKI 191-2-5 × IMR 362	59.33	62.67	90.67	188.33	93.00	20.23	59.00	11.62	1.46	0.33	3.67	68.36
HKI 191-2-6 × IMR 357	60.33	63.00	91.00	184.33	87.33	22.07	60.33	9.90	1.51	0.39	3.73	67.37
HKI 164-7-4 × IMR 356	52.67	55.33	83.33	221.66	85.33	27.24	75.83	9.34	2.78	0.58	4.23	72.96
HKI 164-1-4(1-3) × IMR 356	60.33	63.33	91.33	200.00	85.33	23.14	62.50	9.34	2.55	0.55	4.23	72.96
HKI 193-2 × IMR 337	53.67	56.66	84.66	228.45	94.00	26.82	74.60	9.96	2.69	0.58	3.74	67.39
HKI 5072-2BT(1-2)1-3 × IMR 336)	62.33	64.67	92.67	189.32	94.00	19.30	62.43	10.41	2.33	0.56	4.44	68.42
HQPM 1 (Check 1)	61.33	64.33	89.00	218.00	105.00	25.22	63.60	9.20	2.52	0.52	3.84	68.22
HQPM 4 (Check 2)	60.33	63.00	91.33	222.00	113.00	25.96	65.82	9.14	2.49	0.51	3.78	67.86
C.D.	1.02	0.80	0.98	14.55	8.87	2.71	0.94	0.76	0.25	0.12	0.30	2.35
SE(m)	0.35	0.28	0.34	5.06	3.09	0.94	0.33	0.27	0.09	0.04	0.10	0.82
SE(d)	0.50	0.40	0.48	7.16	4.36	1.33	0.46	0.38	0.12	0.06	0.15	1.16
C.V.	1.06	0.80	0.67	4.54	5.81	7.29	0.85	4.57	8.12	15.44	4.65	2.06

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Table 3a. Heterotic effects of maize hybrids for various traits over standard checks

Treatment	Days to tasselling		Days to silking		Days to maturity		Plant height		Ear height		100- grain weight	
	HQPM 1	HQPM 4	HQPM 1	HQPM 4	HQPM 1	HQPM 4	HQPM 1	HQPM 4	HQPM 1	HQPM 4	HQPM 1	HQPM 4
HKI 170 (1+2) × HKI 193-1	-2.17	-0.55	-2.07	0.00	2.25	-0.36	-7.34	-9.01	-13.65	-19.76	-8.56	-11.17
HKI 165 × HKI 161	-8.15	-6.63	-7.77	-5.83	-2.62	-5.10	2.75	0.90	-0.95	-7.96	3.21	0.27
HKI 5072-2BT (1-2) × IMR 336	-16.84	-15.46	-16.57	-14.81	-8.24	-10.58	-16.21	-17.72	-19.36	-25.07	0.71	-2.16
HKI 170 (1+2) × IMR 373	-15.21	-13.81	-15.54	-13.76	-7.49	-9.85	-7.34	-9.01	-13.65	-19.76	-8.56	-11.17
HKI 26-2 (1+2) × Sr. No. 74 QPM	-3.26	-1.66	-3.11	-1.06	1.49	-1.09	-20.03	-21.47	-16.83	-22.72	-12.49	-14.98
HKI 191-2-5 × IMR 362	-1.08	0.56	-2.58	-0.52	1.88	-0.72	-25.84	-27.18	-19.05	-24.78	-11.86	-14.37
HKI 193-1 × HKI 169	-3.26	-1.66	-1.55	0.52	2.62	0.00	-4.44	-6.16	-7.30	-13.87	-10.27	-12.83
HKI 193-2 × HKI 169	-5.98	-4.43	-6.22	-4.24	-4.12	-6.57	1.38	-0.45	-3.50	-10.33	5.15	2.16
HKI 170 (1+2) × HKI 169	-4.89	-3.32	-4.66	-2.65	-1.49	-4.01	0.30	-1.50	-0.64	-7.67	8.88	5.78
HKI 164-7-2 × IMR 343	1.63	3.32	0.00	2.11	3.74	1.09	-13.76	-15.32	-7.62	-14.16	-19.43	-21.73
HKI 193-2 × IMR 344	-0.54	1.11	-2.07	0.00	2.25	-0.36	-23.70	-25.08	-11.43	-17.70	2.93	0.00
HKI 193-2-6 × Bio Sr. No. 52	1.63	3.32	1.55	3.70	4.87	2.19	-10.86	-12.46	-14.60	-20.65	-13.05	-15.52
HKI 323 × IMR 144	-14.12	-12.70	-1.55	0.52	2.62	0.00	-21.41	-22.82	-12.38	-18.58	-25.61	-27.73
HKI 190 × IMR 373	-13.04	-11.60	-12.44	-10.59	-5.25	-7.66	6.42	4.50	-19.21	-24.93	7.69	4.62
HKI 191-2-5 × IMR 362	-3.26	-1.66	-2.58	-0.52	1.88	-0.72	-13.61	-15.17	-11.43	-17.70	-19.79	-22.07
HKI 191-2-6 × IMR 357	-1.63	0.00	-2.07	0.00	2.25	-0.36	-15.44	-16.97	-16.83	-22.72	-12.49	-14.98
HKI 164-7-4 × IMR 356	-14.12	-12.70	-13.99	-12.17	-6.37	-8.76	1.68	-0.15	-18.73	-24.49	8.01	4.93
HKI 164-1-4(1-3) × IMR 356	-1.63	0.00	-1.55	0.52	2.62	0.00	-8.26	-9.91	-18.73	-24.49	-8.25	-10.86
HKI 193-2 × IMR 337	-12.49	-11.04	-11.92	-10.06	-4.88	-7.30	4.79	2.91	-10.48	-16.81	6.34	3.31
HKI 5072-2BT(1-2)1-3 × IMR 336)	1.63	3.32	0.53	2.65	4.12	1.47	-13.16	-14.72	-10.48	-16.81	-23.47	-25.65

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Table 3b. Heterotic effects of maize hybrids for various traits over standard checks

Treatment	Grain yield/ha(q)		Protein content		Lysine content		Tryptophan content		Oil content		Starch content	
	HQPM 1	HQPM 4	HQPM 1	HQPM 4	HQPM 1	HQPM 4	HQPM 1	HQPM 4	HQPM 1	HQPM 4	HQPM 1	HQPM 4
HKI 170 (1+2) × HKI 193-1	6.45	2.86	14.78	15.54	1.19	2.41	9.62	11.76	0.78	2.38	3.17	3.71
HKI 165 × HKI 161	15.52	11.62	9.24	9.96	6.35	7.63	21.15	23.53	2.60	4.23	-1.28	-0.75
HKI 5072-2BT (1-2) × IMR 336	-4.61	-7.82	7.17	7.88	3.57	4.82	1.92	3.92	-2.60	-1.06	3.80	4.35
HKI 170 (1+2) × IMR 373	7.81	4.18	14.78	15.54	-2.78	-1.61	9.62	11.76	0.78	2.38	3.17	3.71
HKI 26-2 (1+2) × Sr. No. 74 QPM	-6.97	-10.10	7.61	8.32	4.37	5.62	5.77	7.84	-2.86	-1.32	-1.25	-0.72
HKI 191-2-5 × IMR 362	-9.91	-12.94	2.39	3.06	-7.54	-6.43	3.85	5.88	21.09	23.02	4.21	4.76
HKI 193-1 × HKI 169	9.23	5.55	3.59	4.27	-5.95	-4.82	7.69	9.80	-12.50	-11.11	0.00	0.53
HKI 193-2 × HKI 169	17.23	13.28	6.74	7.44	7.94	9.24	11.54	13.73	-7.03	-5.56	4.72	5.28
HKI 170 (1+2) × HKI 169	18.76	14.75	2.07	2.74	3.17	4.42	30.77	33.33	11.20	12.96	1.44	1.97
HKI 164-7-2 × IMR 343	-6.60	-9.75	24.46	25.27	-15.87	-14.86	0.00	1.96	-12.50	-11.11	-2.18	-1.67
HKI 193-2 × IMR 344	-15.14	-18.00	13.48	14.22	1.19	2.41	-3.85	-1.96	-2.08	-0.53	-0.13	0.40
HKI 193-2-6 × Bio Sr. No. 52	10.69	6.96	13.37	14.11	-7.54	-6.43	-7.69	-5.88	-1.30	0.26	3.11	3.65
HKI 323 × IMR 144	-4.72	-7.93	9.89	10.61	2.78	4.02	-13.46	-11.76	-1.82	-0.26	-1.01	-0.49
HKI 190 × IMR 373	3.69	0.20	4.02	4.70	3.57	4.82	9.62	11.76	0.00	1.59	3.12	3.67
HKI 191-2-5 × IMR 362	-7.23	-10.36	26.30	27.13	-42.06	-41.37	-36.54	-35.29	-4.43	-2.91	0.21	0.74
HKI 191-2-6 × IMR 357	-5.14	-8.34	7.61	8.32	-40.08	-39.36	-25.00	-23.53	-2.86	-1.32	-1.25	-0.72
HKI 164-7-4 × IMR 356	19.23	15.21	1.52	2.19	10.32	11.65	11.54	13.73	10.16	11.90	6.95	7.52
HKI 164-1-4(1-3) × IMR 356	-1.73	-5.04	1.52	2.19	1.19	2.41	5.77	7.84	10.16	11.90	6.95	7.52
HKI 193-2 × IMR 337	17.30	13.34	8.26	8.97	6.75	8.03	11.54	13.73	-2.60	-1.06	-1.22	-0.69
HKI 5072-2BT(1-2)1-3 × IMR 336)	-1.84	-5.15	13.15	13.89	-7.54	-6.43	7.69	9.80	15.63	17.46	0.29	0.83

promising combinations selected separately on the basis of heterotic effect over best checks therefore, suggested that as such these results will be useful for choosing populations to be used in developing new improved maize populations. Also, the acceptable level of protein quality in the QPM is very important since the protein contrast in QPM is affected by heterotic pattern indicating recognition of heterotic pattern as one step onward in the improvement of QPM varieties.

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Authors' contribution

Conceptualization and designing of the research work (PS, MCK); Execution of field / lab experiments and data collection (PS, NS); Analysis of data and interpretation (PS); Preparation of manuscript (PS and MC)

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LITERATURE CITED

Appunu C, Satyanarayana E and Nageswar R T 2007. Heterosis for grain yield and its components in maize (Zea mays L.). *J. Res. ANGRAU* **70** (3): 257-263.

Abebe B, Ali W M and Chere A T 2020. Heterosis and character association of mid altitude adapted quality protein maize (Zea mays L.) hybrids at Bako, Western Ethiopia. *Open J Plant Sci* **5**(1): 13-25.

Elmyhum M 2013. Estimation of combining ability and heterosis of quality protein maize inbred lines. *Afr J Agric Res* **8**(48): 6309-17.

Jawaharlal J, Reddy G L and Kumar R S 2012. Heterosis for yield component traits in maize (*Zea mays*L.). *Indian J Agric Res* **46** (2): 184-87.

Kumari R, Singh A K and Suman S 2018. Quantitative studies on heterosis and inbreeding depression in maize (Zea mays L.). *J Appl Nat Sci* **10** (1): 64-69.

Netravati G, Shanta K, Sateesh A, Laxman M and Prakash G 2013. Heterosis Breeding for Maturity, Yield and Quality Characters in Maize (Zea mays L.). *Mol Plant Breed* **4** (6): 44-49.

Praveen K, Prashanth Y, Narsimha V, Reddy S, Sudheer Kumar and Venkateshwara P Rao 2014. Heterosis for Grain yield and its Component traits in Maize (Zea mays L.). *Int J Pure Appl Biosci* **2** (1): 106-11.

Raghu B, Suresh J, Geetha A, Saidaiah P and Sudheer K 2012. Heterosis for grain yield and its component traits in maize (Zea mays L.). *J Res ANGRAU* **40** (1): 83-90.

Rajesh V S. Sudheer K V, Narsimha Reddy and Siva Sankar A 2014. Heterosis studies for grain yield and its component traits in single cross hybrids of maize (*Zea mays* L.). *Int J Plant Anim Environ Sci* **4** (1): 304-306.

Sharma P, Kamboj M C, Singh N and Mehar Chand 2017. Heterosis for grain yield and quality traits in maize (*Zea mays* L.), *Int J Pure Appl Biosci* **5** (5): 241-48.

Sharma P, Punia M S and Kamboj M C 2016. Gene effects and combining ability for yield and quality traits in maize (*Zea mays* L.). *Res on Crops* **17** (4): 723-728.

Shazia G, Dar Z A, Lone A A, Khan M A, Bhat M A, Ali G, Yousuf N and Lone R A 2017. Genetic diversity in maize (*Zea mays* L.) inbred lines from Kashmir, *Int J Pure Appl Biosci* **5** (1): 229-35.

Shrestha J, Gurung D B and Rijal T R 2018. Standard heterosis for grain yield in maize hybrids. *Fmg & Mgmt* **3** (1) : 30-36.

Singh P K, Nitish Singh, Singh A K, Shahi J P and Rao M 2013. Heterosis in relation to combining ability in Quality protein maize (Zea mays L.). *Biolife* **1**(2):-65-69.

Sorsa Z, Mohammed H and Nigussie M 2014. Test cross performance and heterosis of selected Quality Protein Maize (QPM) (*Zea mays* L.) inbred lines. *Int J Plant Breed Genet* **8**(2): 78-88.