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Research Note

Heterosis studies in single crosses of inbred lines in maize (*Zea mays* L.)

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Abstract

Information on heterosis is very important in the assimilation of desirable traits into maize (*Zea mays* L.) germplasm. Identification of suitable germplasm, knowledge of combining ability and heterotic group of the identified germplasm is a prerequisite in successful improvement of crop varieties. The objective was to assess the heterotic relationship among ten maize inbreds. The ten inbreds and their diallel crosses (45 F_1's) excluding reciprocals were evaluated for thirteen characters viz., days to 50% tasseling, days to 50% silking, days to 75% husk browning, plant height, ear height, cob length, cobs plant^{-1}, kernel rows cob^{-1}, kernels row^{-1}, cob diameter, 100-seed weight, protein content and grain yield plant^{-1}. The hybrids and a commercial check were evaluated across two locations in 2011. High level of heterosis over check was observed for grain yield and its component as well as other desirable agronomic traits. The most desirable cross combination viz., NAI-113 x NAI-123 for seed yield plant^{-1} also showed desirable heterosis for cob length, kernel rows cob^{-1}, kernels row^{-1}, cob diameter and 100-seed weight (over check). The cross combination W3 x W5 (ear height) NAI-143 x NAI-147 (cobs plant^{-1}), W3 x NAI-142 (kernel rows cob^{-1}), NAI-137 x NAI-143 (kernels row^{-1}), NAI-152 x NAI-137 (cob diameter), W5 x NAI-116 (100-seed weight) and NAI-143 x NAI-116 (protein content) showed highest heterosis over check. The negative heterosis observed for maturity traits for some hybrids, coupled with high grain yield is a desirable attribute for hybrid production. W5 x NAI-116 was most desirable cross combination for early maturity coupled with other desirable traits. These cross combinations also revealed high *per se* performance.

Keywords

Maize (*Zea mays* L.) inbreds, combining ability, heterosis.

Maize (*Zea mays* L.) is third most important cereal crop in India next to rice and wheat. It is gaining significant importance on account of its growing demand for diversified uses, especially feed and industrial uses. Maize owes its importance and its high cultivation area to its adaptation ability to a wide variety of climatic conditions. That is why it is recognized as the main crop of temperate, hot-temperate, sub-tropical and humid zones .Heterosis, or hybrid vigor, is the better performance of a hybrid relative to the parents, and is the outcome of the genetic and phenotypic variation. Most traits of economic importance are qualitative and controlled by several to many major genes. Generally heterosis can be divided into two broad categories, true heterosis and pseudoheterosis. In case of true heterosis, there is an increase in general vigor, yield and adaptation. In case of pseudoheterosis, the F1 hybrid exhibits increase in vegetative growth only. It refers to the superiority of F1 over the standard commercial check variety. So, it is also called economic heterosis or superiority over checks Sharief *et al*. (2009). Recently it has been divulged that the utilization of heterosis is extremely effective for the genetic improvement of different traits and that the concepts of combining ability are the fundamental tools for enhancing and specific combining ability (SCA). At present, almost the whole maize cultivation area is devoted to hybrids varieties. Therefore, it seems that one of the ways to increase yield in most agronomic and horticultural plants, to produce food for the ever-increasing world's population, is the use of heterosis phenomenon and introducing hybrids varieties.

Exploitation of hybrid vigour in maize has gained much significance in view of its tremendous yield increase. There is a continuous need to evolve new hybrids, which should exceed the existing hybrids in yield and quality. The present work aims to evaluate the expression of heterosis in crosses of ten inbreds, following the diallel mating scheme.

The basic material in the present study comprises 10 diverse maize (*Zea mays*) inbred lines. 45 F_1 cross combinations (excluding reciprocals) were generated through a 10 x 10 diallel mating design during *kharif* 2010 at Experimental Farm, Division of Plant Breeding and Genetics, SKUAST-Kashmir Shalimar. The experimental material, therefore, comprised of 10 parental lines, 45 F_1 cross combinations and a check namely C_{15} (composite). The 45 F_1 progenies along with their parents (10 inbred lines) and a check C_{15} were evaluated at two diverse locations of Kashmir valley i.e. Shalimar (E_1) and Khudwani (E_2) during Kharif, 2011 separately in a complete randomized block design using three replications in both the environments. The plot size of each genotype was a single row of four meters. The intra and inter row spacing was maintained at 20 cm and 50 cm, respectively. One row of non-experimental material was planted on either side of each replication to avoid the border effects. Standard agronomic practices were followed to raise a good crop stand. The experimental plot comprised 1 row each of 4 meter length. Recommended agronomic practices were followed to raise a good crop at both the locations. Heterosis (pooled over environments) was estimated as heterobeltiosis and standard heterosis over check namely C_{15}, widely grown high yielding maize composite especially in higher altitudes. This was calculated as increase or decrease of F_1's over check. It was mathematically calculated by the following formula:

Heterosis (%) over standard check (HSC) = $$\frac{\overline{F}_1 - S\overline{C}}{S\overline{C}} \times 100$$

The manifestation of heterosis in percentage for different characters over check is given in Tables 1. The details of results obtained for each character are described as; days to 50% tasseling indicated negative heterosis over check in 17 crosses with highest negative significant value expressed by cross NAI-123 x W3 (-8.37%), 23 crosses in 50% silking with highest negative significant value expressed by cross NAI-123 x W3 (8.84%) and 9 crosses in 75% husk browning with highest negative significant value expressed by cross NAI-113 x W3 (-4.92). For plant height 3 crosses indicated negative heterosis and 17 crosses showed positive significant over check. Significant negative heterosis over check was exhibited by 18 crosses for ear height in the desired direction. Positive and significant heterosis over check was exhibited by the entire crosses in cob length (cm) with significant positive heterosis was exhibited by the cross W5 x NAI-143 (24.41%). and 25 crosses in no. of cobs plant^{-1} with high value in cross NAI-143 x NAI-147 (16.00%). In case of no. of kernel rows cob^{-1}, 34 cross combinations reveal heterosis over check, the best heterotic combination W3 x NAI-142 (27.84%). 40 cross combinations in no. of grains row^{-1} with best cross combination NAI-137 x NAI-143 (35.03%) and 39 cross combinations in cob diameter (cm) of which NAI-152 x NAI-137 (35.34%) cross showed the highest estimate. Significant positive heterosis over check for 100-seed weight was noticed in 38 crosses among which high estimates were expressed by W5 x NAI-116 (49.82%) followed by NAI-152 x NAI-143, W3 x W5 and NAI-113 x W3. For seed yield plant^{-1}, the estimate of relative heterosis over check was revealed by 42 crosses among which maximum positive heterosis was observed in NAI-113 x NAI-123 (89.94%) followed by NAI-113 x W3, NAI-152 x NAI-137 and W5 x NAI-116. In case of protein content, the extent of heterosis over check was revealed by 42 crosses in the desired direction.The phenomenon of heterosis, though widely reported and utilised in allogamous crop species, has also been commercially exploited in some autogamous crop species. However, the economic exploitation of heterosis in crop plants is largely governed by the technical feasibility besides the manifestation of heterotic effect for different economic traits and other attributes. In the present study, heterosis over check for each trait was computed over pooled environments. The results revealed a wide range of heterotic patterns for all the traits studied. The per cent standard heterosis expressed by the F_1 hybrids over the check C_{15} for yield and other characters in maize. The degree of heterosis in F_1 hybrids varied from character to character or from cross to cross. Negative heterosis was considered desirable for days to 50 per cent tasseling, days to 50 per cent silking and days to 75 per cent husk browning. The crosses NAI-123 x W3, NAI-152 x NAI-123, NAI-113 x W5 and NAI-152 x W5 showing highest negative heterosis for days to 50 per cent tasseling, NAI-123 x W3, NAI-152 x NAI-123, NAI-113 x W5 and NAI-152 x W5 showing higher negative heterosis for days to 50 per cent silking and NAI-113 x W3, NAI-152 x NAI-143, W5 x NAI-116, NAI-123 x W3, NAI-152 x NAI-123 showing negative heterosis for earliness over check for days to 75 per cent husk browning. Desirable negative heterosis for early flowering attributes have also been reported by Altinbas, (1995). Similarly desirable negative heterosis has been reported for days taken to silking, Srivastava and Singh, (2003); number of days from planting to tassel emergence and maturity, Rezaei *et al*. (2004) and for early maturity traits (Chattopodhyah and Dhuman, 2006). Negative heterosis for flowering and maturity traits is desirable for developing early maturity single cross hybrids. Plant height and ear height, the two morphological traits in which several cross combination revealed significant negative heterobeltiosis over check were noted in NAI-152 x NAI-142, NAI-113 x NAI-137 and NAI-137 x W5 and the cross combinations depicting positive significance with least value include NAI-113 x NAI-147, NAI-113 x NAI-152 and NAI-113 x W3 in the desired direction for plant height and for ear height. Similar results were reported for plant height and ear height by Muraya *et al* (2006) and Wang-Tang *et al*., (2006). More

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than 70 per cent cross combinations revealed significant positive heterosis over commercial check except for number of cobs plant^{-1} for yield contributing traits viz, cob length, number of cobs plant^{-1}, number of kernel rows cob^{-1}, number of grains row^{-1}, cob diameter and 100-seed weight. High range of significant positive heterosis for 100-seed weight has been reported by Srivastava and Singh, (2003); for cob length by Dicker and Tracy, (2002); for number of kernel rows cob^{-1} by Rezaei *et al*. (2004) for cob length and kernel yield by Wang-Tang *et al*., (2006) and for cob diameter and 100-seed weight by Sofi *et al*. (2007). High estimates of heterosis were observed for grain yield in the study (Table 1). Among 45 cross combinations analysed, NAI-113 x NAI-123 was identified as the best combination for grain yield plant^{-1} followed by NAI-113 x W3, NAI-152 x NAI-137, W5 x NAI-116, W3 x W5 and NAI-137 x NAI-142 revealing high values in the desired direction. Desirable positive heterosis for grain yield have also been reported by earlier workers Stuper *et al*. (2008); Abdel-Moneam *et al*. (2009). Positive heterosis is considered desirable for protein content. The cross combination NAI-143 x NAI-116 possess high value for this trait followed by W5 x NAI-143, NAI-152 x NAI-143, NAI-113 x W5, NAI-152 x NAI-116.

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S. No	Crosses	Days to 50% tasseling	Days to 50% silking	Days to 75% husk browning	Plant height (cm)	Ear height (cm)	Cob length (cm)	No. of cobs plant^{-1}	No. of kernel rows cob^{-1}	No of grains row^{-1}	Cob diameter (cm)	100 seed weight (gm)	Grain yield plant^{-1} (gm)	Protein content (%)
1.	NAI-113 x NAI-152	-4.22*	-4.84*	-3.32*	6.84*	0.57	11.75**	5.67*	17.05**	4.97	15.62**	18.07**	61.95**	11.27*
2.	NAI-113 x NAI-137	-0.74	-1.81	0.24	-12.47**	8.02**	7.90*	3.00*	24.24**	4.03	29.59**	2.34	43.93**	-4.00
3.	NAI-113 x NAI-123	-2.48	-3.63*	-3.69*	-0.29	-2.03	18.93**	5.33*	13.09**	24.69**	18.63**	21.06**	89.94**	9.33*
4.	NAI-113 x W3	-6.63*	-7.67**	-4.92*	-2.00	-20.14**	20.66**	0.00	9.50*	12.83*	18.36**	42.29**	85.63**	7.76*
5.	NAI-113 x W5	-7.50**	-7.87**	0.36	0.76	5.19*	-0.72	0.00	9.86*	11.28*	23.01**	32.98**	71.77**	28.97**
6.	NAI-113 x NAI-142	0.13	-1.00	0.49	4.92	4.20*	22.17**	4.67*	7.48*	28.93**	12.33**	7.39*	64.51**	11.03*
7.	NAI-113 x NAI-143	-2.26	-3.03*	-1.71	1.04	32.73**	16.53**	0.00	11.08**	18.38**	12.05**	23.72**	71.85**	12.55**
8.	NAI-113 x NAI-147	-1.40	-2.42	0.49	6.77*	-11.67**	18.26**	10.33**	13.09**	21.45**	13.97**	6.88*	71.10**	21.15**
9.	NAI-113 x NAI-116	0.56	-1.21	0.24	-4.92	-14.58**	17.91**	0.67	14.32**	18.76**	18.36**	20.32**	73.65**	21.52**
10.	NAI-152 x NAI-137	0.56	-0.81	0.73	3.53	2.84	23.71**	0.00	10.72**	11.86*	35.34**	39.13**	81.95**	16.24**
11.	NAI-152 x NAI-123	-7.94**	-8.08**	-4.05*	0.55	-4.94*	16.53**	0.00	5.90*	13.97*	15.62**	33.53**	70.20**	13.58**
12.	NAI-152 x W3	-4.10*	-5.05*	0.36	15.90**	11.32**	19.63**	4.00*	5.11*	11.86*	16.44**	36.79**	76.65**	20.73**
13.	NAI-152 x W5	-7.06**	-7.87**	-0.36	15.54**	-0.36	15.51**	0.00	9.50*	12.45*	21.64**	32.48**	72.24**	21.15**
14.	NAI-152 x NAI-142	-3.36*	-3.84*	-0.12	-13.18**	-3.87	6.95*	13.33**	12.66**	12.62*	12.60**	-1.28	49.98**	13.15**
15.	NAI-152 x NAI-143	-4.45*	-5.05*	-4.79*	2.85	-4.80*	12.45**	1.67	9.50*	-1.34	11.78*	48.21**	71.86**	29.09**
16.	NAI-152 x NAI-147	-5.10*	-5.85*	-1.84	8.05*	2.32	11.06**	4.00*	24.68**	3.07	15.89**	16.56**	64.49**	10.97*
17.	NAI-152 x NAI 116	-5.53*	-6.46*	-3.44*	1.08	-2.00	14.50**	0.00	15.90**	1.14	25.75**	38.53**	71.49**	28.55**
18.	NAI-137 x NAI-123	-0.95	-2.21	0.61	4.28	-3.02	22.69**	4.00*	5.47*	23.76**	18.08**	24.91**	79.08**	21.88**
19.	NAI-137 x W3	0.56	-0.60	1.97	7.81*	1.68	19.61**	0.67	10.72**	19.52**	26.30**	25.78**	76.93**	12.67**
20.	NAI-137 x W5	-3.14*	-3.63*	-2.95	-9.23*	6.13*	12.43**	0.00	3.88	24.69**	12.88**	29.17**	76.76**	6.48*
21.	NAI-137 x NAI-142	2.74	1.81	2.33	10.57**	13.88**	8.68*	14.67**	6.26*	27.21**	10.14*	10.18*	80.37**	14.61**
22.	NAI-137 x NAI-143	4.48*	3.63*	4.30*	16.24**	18.81**	22.65**	5.00*	13.45**	35.03**	16.99**	2.11	73.51**	15.70**
23.	NAI-137 x NAI-147	-2.95	-3.63*	-0.73	9.82*	10.98**	16.88**	8.00**	14.68**	25.48**	23.56**	5.00*	72.34**	10.30*
24.	NAI-137 x NAI-116	4.93*	4.03*	0.91	10.36**	0.82	16.88**	8.00**	7.48*	22.41**	20.27**	19.68**	79.61**	20.91**

Table 1: Estimation of F_1 heterosis over check for grain yield and different characters in maize.

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S. No	Crosses	Days to 50% tasseling	Days to 50% silking	Days to 75% husk browning	Plant height (cm)	Ear height (cm)	Cob length (cm)	No. of cobs plant^{-1}	No. of kernel rows cob^{-1}	No of grains row^{-1}	Cob diameter (cm)	100 seed weight (gm)	Grain yield plant^{-1} (gm)	Protein content (%)
25.	NAI-123 x W3	-8.37**	-8.84**	-4.67*	1.93	-8.67**	11.59**	0.00	3.53	15.90**	11.51*	27.84**	61.97**	15.15**
26.	NAI-123 x W5	-6.63*	-6.66*	-0.12	-4.54	-14.79**	12.08**	14.00**	2.30	24.72**	6.30*	8.90*	67.29**	12.12**
27.	NAI-123 x NAI-142	0.56	-0.60	-0.49	-3.20	-12.87**	8.00*	7.33**	11.08**	19.14**	6.85*	16.61**	74.96**	25.52**
28.	NAI-123 x NAI-143	-1.17	-1.81	-0.91	0.97	-13.81**	18.58**	6.33*	11.51**	21.45**	4.93	10.18*	67.54**	16.12**
29.	NAI-123 x NAI-147	-0.09	-0.81	-1.84	0.65	-17.88**	14.48**	5.67*	5.11*	22.79**	-2.74	13.72**	63.75**	28.42**
30.	NAI-123 x NAI-116	0.35	1.00	-0.73	-0.98	-8.50**	16.72**	9.00**	3.88	19.34**	7.95*	8.94*	55.47**	10.36*
31.	W3 x W5	-3.57*	-4.03*	-0.36	-3.24	-21.43**	17.91**	0.00	1.94	14.17*	19.18**	47.29**	81.01**	-8.61
32.	W3 x NAI-142	-1.83	-2.42	-0.86	10.57**	0.14	13.11**	7.33**	27.84**	10.14*	22.74**	1.33	61.78**	24.61**
33.	W3 x NAI-143	0.74	-0.40	-1.35	10.68**	3.14	10.73**	0.00	-1.73	16.28**	4.93	36.51**	64.81**	17.09**
34.	W3 x NAI-147	-1.83	-2.21	0.98	10.57**	-3.36	9.03*	0.67	3.88	16.07**	18.63**	29.36**	65.86**	20.42**
35.	W3 x NAI-116	0.95	-2.02	-1.10	10.57**	1.09	17.58**	1.67	8.27*	14.55*	20.00**	31.42**	75.07**	19.76**
36.	W5 x NAI-142	1.87	1.41	0.00	19.23**	6.82*	14.48**	5.67*	4.68	24.90**	16.16**	10.05*	60.61**	12.36**
37.	W5 x NAI-143	-1.17	-2.02	-1.84	2.26	-11.36**	24.41**	0.00	4.68	13.21*	6.03*	39.08**	74.09**	33.82**
38.	W5 x NAI-147	-4.67*	-5.05*	-3.19*	3.85	-4.94*	17.91**	4.00*	18.71**	12.24*	4.11	9.31*	59.98**	24.55**
39.	W5 x NAI-116	-5.53*	-6.46*	-4.79*	1.12	-14.36**	23.90**	0.00	4.32	10.14*	19.45**	49.82**	81.78**	26.79**
40.	NAI-142 x NAI-143	3.83*	3.03*	3.19*	4.24	-6.87*	6.46*	1.67	12.66**	19.14**	2.47	6.06*	52.86**	10.12*
41.	NAI-142 x NAI-147	-0.52	-0.81	1.10	7.05*	-3.02	7.65*	0.00	13.88**	30.28**	0.82	-9.91	41.12**	11.70*
42.	NAI-142 x NAI-116	1.21	0.40	0.36	3.77	-5.59*	10.03**	5.33*	19.06**	32.00**	11.78*	-14.27	49.89**	0.00
43.	NAI-143 x NAI-147	-0.09	-0.40	2.95	12.81**	-2.20	0.82	16.00**	3.88	18.76**	-12.33	-0.87	49.84**	18.79**
44.	NAI-143 x NAI-116	-0.95	-1.61	1.84	-0.62	-14.67**	11.06**	3.33*	9.06*	22.21**	9.86*	22.16**	77.73**	36.30**
45.	NAI-147 x NAI-116	-1.40	-2.42	0.73	0.34	-3.66	6.28*	3.33*	13.88**	13.97*	10.96*	17.94**	67.03**	16.61**