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ESTIMATION OF HETEROSIS IN FIELD CORN AND SWEET CORN AT MARKETABLE STAGE

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ABSTRACT
Heterosis of 40 crosses derived from a line × tester mating system involving eight sweet corn and five field corn inbreds were studied in both *rabi* (winter) and *kharif* (Rainy) season (2009-10). A total of 54 treatments comprising 13 parents (eight sweet corns and five field corns), their 40 crosses and one standard check (Madhuri sweet corn) were evaluated in a randomized block design with three replications. Each experimental plot has one 4 m row. The traits evaluated plant height, dehusked ear length, ear girth without husk, number of kernel per row, 100 kernel weights, marketable yield per hectare and total soluble solid at the time of fresh ear stage (marketable yield). The crosses DMSC4 × HUZM185, Dulce Amanillo × HUZM536, DMSC36 × HKI323 and Win Sweet Corn × HUZM 536 exhibited high positive significant heterosis over better parent and standard check for marketable yield and yield related traits as well as quality traits like, dehusked ear length, ear girth without husk, number of kernel per row, 100 kernel weight, and total soluble solid in winter and rainy season (2009-10). These crosses in future could be exploited commercially for higher yield and better quality in maize.

INTRODUCTION

Maize is consumed in various forms like sweet corn, baby corn, pop corn, waxy corn, quality protein maize, high oil corn etc. Sweet corn (*Zea mays* var. *saccharata*) is type of maize with high sugar content and evolved due to naturally occurring recessive mutation in genes which control conversion of sugar to starch inside the endosperm of corn kernel. It is a very delicious and rich source of energy, Vitamin A and C. Field corn is dried on the stock and used for livestock feed, cornstarch, corn syrup and producing ethanol amongst other things.

Heterosis works as a basic tool for improved production of crops in the form of F_1 hybrids. The heterotic studies can provide the basis for the exploitation of valuable hybrid combinations in the future breeding programmes and their commercial utilization. Hybrid maize production has been successfully used by the grower in each area. The present research is emphasizing on betterment of sweet corn hybrids. Morphological and molecular variability in sweet corn is small compared to field corn (Revilla and Tracy, 1995). The genetic base of sweet corn used presently in breeding programs is relatively narrow, and genetically related inbreds are often crossed to meet strict requirements of market quality and appearance (Tracy, 1994).

In general, sweet corn has some drawbacks, such as low field emergence, susceptibility to disease and pest, low vigor and low adaptability, which result in reduced fresh ear yield. So for the improvement of sweet corn, usefulness of field corn germplasm is very important (Tracy, 1990). Heterotic patterns of sweet corn cultivars have been defined by Revilla and Tracy (1997), who found a significant heterotic pattern when ‘Country Gentleman’ was crossed to ‘Golden Bantam’, ‘Pease Crosby’, and ‘Linsey Meyer Blue’. Sweet corn breeders have not relied on heterotic patterns in the development of commercial hybrids. Establishment and improvement of new heterotic patterns in sweet corn could be helpful for improving agronomic performance and adaptation of sweet corn in new regions of production.

Field corn has been used to improve agronomic performance of sweet corn in the United States (Tracy, 1994) and in Europe (Cartea *et al*., 1996; Malvar *et al*., 1997). Field corn heterotic patterns may be transferable into sweet corn. However, field × sweet corn crosses could unmask new off-flavors not heterofore seen due to gene interactions, dosage effects, disruption of linkage groups, etc., that should be taken into account in any subsequent breeding program. Therefore, the objective of present study to identify the heterotic combination for marketable yield, yield traits, quality trait and per unit production in sweet corn × field corn crosses.

MATERIALS AND METHODS

Parent genotypes consisted of eight sweet corn inbreds namely DMSC 4, DMSC 6, DMSC 9, DMSC19, Dulce Amanillo (*Su Su*), DMSC 35, DMSC 36 and Win sweet corn used as female parents (line) and five field corn inbreds namely HUZM 185, HKI 323, HKI 1105, CM 119 and HUZM 536 as male (testers) parents that were crossed in Line × Tester mating design during *Kharif* (Rainy) 2009. The 40 crosses, 13 parents and standard check (Madhuri) were planted in experimental plots 3 m long with 70 cm between rows and 25 cm between hills during *Rabi* 2009-10 and *Kharif* (Rainy) 2010 in Completely Randomized Block Design with three replications at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India. The sweet corn genotypes were obtained from Directorate of Maize Research, New Delhi, India and field corn genotypes from Department of Genetics and Plant Breeding, Institute of Agricultural Sciences, BHU, Varanasi.

Each row was thinned to single plant to achieve a final density of about 66,000 plants/ha. After 22 days of pollination (fresh ear stage) the traits plant height (cm) from the soil to the tassel top, dehusked ear length (cm), ear girth (cm) without husk, number of kernel row/ear, number of kernel/row, total soluble solid (Brix%), 100-kernel weight (g) and marketable yield per hectare (tons) were recorded. At green ear stage the husks are considered as marketable when cover the ear compactly.

The better parent and standard check (Madhuri) a sweet corn variety were used for calculation of heterosis for seasons *rabi* 2009-10 and *kharif* (Rainy) 2010 using procedures adopted by Hallauer and Miranda (1995) and Fehr (1993) as under:

$$\text{Heterobeltiosis} = \frac{(\bar{F}_1 - \overline{BP})}{\overline{BP}} \times 100$$

$$\text{Economic heterosis} = \frac{(\bar{F}_1 - \bar{C})}{\bar{C}} \times 100$$

Where, $\bar{F}_1$ = mean performance of $\bar{F}_1$, $\overline{BP}$ = mean performance the best parent and $\bar{C}$ = mean performance of standard check variety. The heterosis estimates were tested for their significance using t-tests.

RESULTS AND DISCUSSION

The per cent heterosis over the better parent and standard check expressed by F_1's for different characters are presented in Table 1and 2. The level of heterosis varied widely among the cross.

Plant height

For better parent and standard parent heterosis, only positive values are described because sweet corn inbreds have dwarf height, we need to increase in the height of sweet corn for better economic value. During *rabi* (winter) season, all the crosses for better parent and 38 crosses for standard check showed significant and positive heterosis. The top three crosses DMSC36 × HUZM185 (73.32%), DMSC19 × HUZM536 (64.90%) and DMSC9 × HKI323 (53.28%) observed for better parent heterosis and the crosses DMSC36 × HUZM185 (45.70%), DMSC19 × HUZM536 (38.18%) and Dulce Amanillo × CM119 (28.14%) showed high standard parent heterosis. The degree of increase in plant height ranged from 16.52% to 73.32% for better parent and from 5.31% to 45.70% for standard parent.

During *Kharif* (rainy) season, The cross DMSC19 × HKI323 (24.76%) expressed highest magnitude of standard heterosis followed by DMSC19 × HUZM185 (24.64%) and DMSC9 × CM119 (22.52%), while the crosses Dulce Amanillo × HKI323 (48.76%), Dulce Amanillo × HUZM536 (48.51%) and DMSC6 × HKI323 (48.21%) showed high better parent heterosis. Significant and positive heterosis observed for most of the crosses over better parent ranging from 4.58% to 48.76%. Therefore, magnitude of economic heterosis varied from -6.21% to 24.76%. These results are greatly supported by Muraya *et al*. (2006), Frascaroli *et al*. (2007) and Amanullah *et al*. (2011) as they observed a different ratio of heterotic values for plant height in their F_1 population, (Table 1 & 2). During both the season, out of top five selected crosses, the cross DMSC19 × HUZM536 gave stable performance. So this cross can use for increasing height of sweet corn.

Dehusked ear length

The significant heterosis was observed among the F_1's during both the seasons. Increase length is associated with more number of kernels/row which resulted increasing the yield. Highest value of heterosis recorded by crosses DMSC6 × HUZM185 (38.46%) followed by DMSC36 × HUZM536 (38.19%), DMSC35 × HKI1105 (35.66) over better parent and the crosses DMSC35 × HKI1105 (48.24%), DMSC36 × HKI1105 (29.83%), DMSC6 × HUZM185 (29.24%) over standard check. The minimum heterosis over better parent was 8.27% and maximum 38.46% while the magnitude of standard parent heterosis was from 10.63% to 48.24% in winter season (Table 1 & 2).

In rainy season, the increase in ear length ranged from 8.86% to 41.24% for heterobeltiosis and economic heterosis range was 9.02% to 30.26%. The cross DMSC6 × HUZM536 (30.26%) showed highest magnitude of standard heterosis followed by DMSC6 × HUZM185 (29.99%) and DMSC36 × HUZM536 (26.98%), whereas, the crosses DMSC35 × HKI323 (41.24%), DMSC19 × HKI323 (38.25%) and DMSC6 × HUZM536 (37.90%) exhibited high better parent heterosis. The cross DMSC36 × HUZM536 and Win Sweet Corn × HUZM536 showed highest heterosis in both the season. It means for increasing the ear length can select above cross. These results are generally in accordance with the findings of Saleh *et al*. (2002) as they obtained similar heterosis values for dehusked ear length.

Ear girth without husk

Significantly positive heterosis was observed in 15 crosses over better parent and 17 crosses over standard check during *rabi* season. The highest magnitude of heterosis was in the crosses DMSC9 × HKI1105 (20.69%), DMSC4 × HUZM185 (15.96%) and Dulce Amanillo × HKI1105 (14.71%) for standard check as well as for better parent. The range of heterosis was from -10.47% to 20.69% for standard check and from -9.88% to 18.93% for better parent.

During *kharif* season, cross Dulce Amanillo × HUZM536 (35.01%) expressed highest magnitude of heterosis over standard check followed by Win sweet corn × HKI323 (29.97%) and Dulce Amanillo × HKI1105 (29.67%), while crosses Win sweet corn × HKI323 (25.24%), DMSC35 × HKI323 (22.22%) and DMSC4 × HKI323 (22.19%) over better

Table 1: Estimation of heterosis in sweet x field corn hybrids during *rabi* season 2009-10 (at green ear stage)

Crosses	Plant height (cm)		Dehusked ear length (cm)		Ear girth without husk (cm)		Number of kernel/ row		100 kernel weight (g)		Marketable yield/ hectare (tons)		Total soluble solid	
	BPH%	SCH%	BPH%	SCH%	BPH%	BPH%	BPH%	SPH%	BPH%	SCH%	BPH%	SCH%	BPH%	SPH%
DMSC4 × HUZM185	7.89**	6.39**	11.68**	13.59**	4.44	13.95*	33.90**	26.77**	24.35**	80.43**	49.60**	90.29**	-5.40**	4.81**
DMSC4 × HKI323	4.59	-6.21**	23.15**	9.02*	22.19**	27.01**	39.18**	27.04**	25.02**	95.04**	76.27**	59.39**	-2.04	8.59**
DMSC4 × HKI1105	23.54**	10.78**	8.86*	14.96**	9.12	19.58**	12.92**	34.48**	2.28*	93.80**	90.73**	82.04**	-5.60**	4.62**
DMSC4 × CM119	7.60**	14.42**	16.84**	8.06	9.27	18.99**	27.32**	35.18**	3.61**	101.31**	11.27**	45.95**	-1.59	9.04**
DMSC4 × HUZM536	22.21**	9.59**	30.20**	21.24**	11.64*	28.19**	53.74**	46.01**	13.04*	100.48**	58.07**	70.23**	-4.44**	5.92**
DMSC6 × HUZM185	14.46**	12.86**	27.80**	29.99**	7.79	17.80**	17.11**	10.88**	15.36**	67.40**	23.53**	57.12**	6.54**	4.55**
DMSC6 × HKI323	48.21**	14.39**	25.07**	18.10**	12.67*	16.91**	48.79**	34.26**	12.43**	75.40**	146.07**	62.14**	7.60**	5.60**
DMSC6 × HKI1105	34.42**	4.53*	3.88	9.70*	8.66	18.99*	16.44**	38.66**	4.92**	98.76**	73.79**	65.86**	2.12	0.20
DMSC6 × CM119	1.11	7.52**	8.08	2.05	6.55	16.02*	17.71**	24.97**	4.00**	102.07**	-0.33	30.74**	4.35**	2.41
DMSC6 × HUZM536	45.60**	15.10**	37.90**	30.26**	6.81	22.55**	52.74**	45.05**	9.67**	94.56**	24.60**	34.14**	6.26**	4.23**
DMSC9 × HUZM185	20.52**	18.84**	10.92*	12.84**	6.52	16.32**	60.13**	51.61**	14.58**	66.30**	25.05**	59.06**	-0.15	4.42**
DMSC9 × HKI323	39.96**	15.18**	18.85**	18.85**	17.05**	21.66**	40.69**	26.95**	15.49**	80.15**	58.06**	25.40**	-2.09	2.41
DMSC9 × HKI1105	36.25**	12.13**	5.26	11.20*	12.82*	23.74**	11.61**	32.89**	5.95**	100.76**	79.60**	71.52**	-0.5	4.03**
DMSC9 × CM119	15.22**	22.52**	21.81**	21.79**	17.55**	27.89**	29.01**	36.94**	6.42**	106.82**	39.43**	82.85**	0.48	5.07**
DMSC9 × HUZM536	28.62**	5.85**	22.45**	22.47**	11.98*	28.49**	44.47**	37.21**	10.81**	96.55**	51.75**	63.43**	-1.39	3.12*
DMSC19 × HUZM185	26.41**	24.64**	8.26	10.11*	9.24	19.29**	50.92**	42.89**	17.87**	71.05**	14.12**	45.15**	6.67**	5.79**
DMSC19 × HKI323	36.10**	24.76**	38.25**	14.82**	14.00**	18.40**	26.91**	14.49**	2.53*	59.96**	118.86**	50.81**	3.87**	2.99*
DMSC19 × HKI1105	26.16**	15.65**	4.76	10.66*	10.92*	21.66**	10.83**	31.97**	2.84**	94.83**	83.95**	75.57**	-2.65	-3.45*
DMSC19 × CM119	7.58**	14.39**	23.32**	14.00**	9.45	18.99**	35.71**	44.08**	3.96**	102.00**	39.64**	83.17**	1.44	0.59
DMSC19 × HUZM536	33.13**	22.04**	14.30**	6.42	6.12	21.66**	33.91**	27.17**	5.06**	86.35**	41.58**	52.43**	-0.09	-0.91
D. A. × HUZM 185	11.85**	10.29**	0.83	2.59	2.26	11.57*	28.97**	22.10**	26.67**	83.80**	19.67**	52.27**	1.40	-4.36**
D. A. × HKI 323	48.76**	17.17**	16.39**	2.32	16.76**	21.36**	55.30**	40.11**	22.15**	90.56**	145.66**	78.48**	8.51**	2.34
D. A. × HKI 1105	40.06**	10.31**	17.27**	23.84**	18.23**	29.67**	25.21**	49.10**	2.64*	94.49**	102.09**	92.88**	6.94**	0.85
D. A. × CM 119	10.54**	17.54**	24.55**	15.16**	-4.27	4.15	24.71**	32.41**	3.07**	100.28**	1.89	33.66**	0.69	-5.01**
D. A. × HUZM 536	48.51**	17.40**	28.07**	19.26**	17.76**	35.01**	51.04**	43.42**	25.59**	122.74**	112.88**	129.13**	3.70*	-2.21
DMSC35 × HUZM185	12.22**	10.65**	5.86	7.72	7.34	17.21**	26.29**	19.59**	15.77**	68.02**	9.16*	38.83**	8.20**	0.78
DMSC35 × HKI323	38.56**	6.94**	41.24**	17.28**	22.22**	28.49**	49.67**	35.05**	17.89**	83.87**	131.84**	64.24**	2.98	-4.10**
DMSC35 × HKI1105	45.69**	13.29**	11.34**	17.62**	11.46*	22.26**	7.99**	28.58**	-1.19	87.18**	53.45**	46.44**	9.13**	1.63
DMSC35 × CM119	3.17	9.71**	11.67*	3.28	15.91**	26.11**	12.82**	19.77**	2.39*	98.97**	17.56**	54.21**	9.92**	2.34
DMSC35 × HUZM536	40.01**	10.68**	20.29**	12.02**	8.62	24.63**	18.01**	12.07**	13.46**	101.24**	57.77**	69.90**	9.97**	2.41
DMSC36 × HUZM185	11.43**	9.88**	15.49**	17.49**	9.60	19.58**	33.20**	26.11**	13.74**	65.06**	46.33**	86.25**	5.86**	-2.02
DMSC36 × HKI323	27.75**	-1.41	23.99**	15.10**	16.00**	20.47**	53.65**	38.62**	24.11**	93.59**	137.60**	98.38**	7.08**	-0.91
DMSC36 × HKI1105	43.59**	11.67**	16.79**	23.36**	15.25**	26.41**	16.13**	38.31**	1.65	92.56**	89.21**	80.58**	6.00**	-1.89
DMSC36 × CM119	8.68**	15.56**	19.74**	11.13*	14.55**	24.63**	9.54**	16.29**	1.34	96.90**	24.63**	63.43**	7.34**	-0.65
DMSC36 × HUZM536	38.75**	9.68**	36.38**	26.98**	8.28	24.33**	46.85**	39.45**	1.45	79.94**	52.91**	64.56**	10.59**	2.34
WSC × HUZM 185	18.80**	17.14**	3.98	5.80	15.13**	25.82**	35.11**	27.92**	6.47**	54.51**	26.16**	60.52**	4.44**	10.15**
W SC × HKI323	27.35**	21.12**	24.73**	6.22	25.24**	29.97**	69.95**	53.32**	15.88**	80.77**	65.37**	82.85**	4.26**	9.95**
WSC × HKI1105	9.96**	4.59*	1.85	7.58	9.48	19.88**	11.11**	32.32**	1.10	91.52**	52.98**	69.09**	3.60**	9.30**
WSC × CM119	4.58*	11.19**	29.25**	19.54**	16.55**	26.71**	17.50**	24.75**	3.26**	100.69**	41.65**	85.76**	1.25	6.83**
WSC × HUZM536	12.51**	7.01**	34.33**	25.07**	12.33*	28.78**	50.96**	43.37**	1.19	79.46**	90.00**	110.03**	3.62**	9.37**
SEd (H)	2.74	3.17	0.55	0.64	0.16	0.18	0.71	0.82	0.25	0.28	0.30	0.35	0.19	0.22

* and ** indicates significance level at 1% and 5%, respectively, BPH = Best-Parent Heterosis, SCH = Standard-Check Heterosis, cm = centi-meters, g = grams. D.A. = Dulce Amanillo, W.S.C. = Win Sweet Corn

parent. The range of economic heterosis was from 11.57% to 35.01% and heterobeltiosis from 10.92% to 25.24%. Twenty one crosses over better parent and 39 crosses over standard check showed significantly positive heterosis. The high positive heterosis was observed for ear diameter by Ojo *et al*. (2007) and Abdel-Moneam *et al*. (2009). For the above trait improvement can use cross Dulce Amanillo × HKI1105, out of top five crosses because it gave stable performance during both the season.

Number of kernels per row

Increasing the number of kernels row^{-1} associated with the yield. Highly positive significant economic and better parent heterosis was observed for most of the crosses during both the seasons. In winter season, the top ranking crosses were DMSC19 × CM119 (46.82%), DMSC9 × HKI 1105 (42.12%) and DMSC9 × HKI 1105 (42.12%) for economic heterosis, while DMSC19 × HKI323 (36.52%), DMSC9 × HUZM536 (36.30%) and Dulce Amanillo × HUZM536 (36.17%) for heterobeltiosis. The range of economic heterosis was 4.18% to 46.82% and range of heterobeltiosis was from -22.43% to 36.52% (Table 1 & 2).

In rainy season, all the crosses exhibited highly significant and positive heterosis. The cross Win Sweet Corn × HKI323 (53.32%) revealed highest estimates of standard heterosis followed by DMSC9 × HUZM185 (51.61%) and Dulce Amanillo × HKI 1105 (49.10%), while the estimates 69.95%, 60.13% and 55.30% for better parent heterosis in above crosses. Standard heterosis of above traits ranged from 10.88% to 53.32% and heterobeltiosis range 7.99% to 69.95%. On the basis of top five crosses, the cross Dulce Amanillo × HKI 1105 is good and can used further exploitation of heterosis. The present results are in corroboration with the findings of Revilla *et al*. (2000), Alvi *et al*. (2003), Kumari *et al*. (2006), (2008), Amiruzzaman *et al*. (2011) and Bhavana *et al*. (2011) who also observed varying levels of heterosis for both the traits in F_1 studies.

Hundred kernel weight

It is evident from that highly significant difference among F_1's and their parents were found regarding 100-kernel weight (table 1 & 2). All the crosses showed appreciable values of heterosis over standard parent which ranged from 62.94% to 125.23% and most of the crosses showed heterosis over better

Table 2: Estimation of heterosis in sweet × field corn hybrids during *kharif* season 2010 (at green ear stage)

Crosses	Plant height (cm)		Dehusked ear length (cm)		Ear girth without husk (cm)		Number of kernel/ row		100 kernel weight (g)		Marketable yield/ hectare (tons)		Total soluble solid	
	BPH%	SCH%	BPH%	SCH%	BPH%	BPH%	BPH%	SPH%	BPH%	SCH%	BPH%	SCH%	BPH%	SPH%
DMSC4 × HUZM185	7.89**	6.39**	11.68**	13.59**	4.44	13.95*	33.90**	26.77**	24.35**	80.43**	49.60**	90.29**	-5.40**	4.81**
DMSC4 × HKI323	4.59	-6.21**	23.15**	9.02*	22.19**	27.01**	39.18**	27.04**	25.02**	95.04**	76.27**	59.39**	-2.04	8.59**
DMSC4 × HKI1105	23.54**	10.78**	8.86*	14.96**	9.12	19.58**	12.92**	34.48**	2.28*	93.80**	90.73**	82.04**	-5.60**	4.62**
DMSC4 × CM119	7.60**	14.42**	16.84**	8.06	9.27	18.99**	27.32**	35.18**	3.61**	101.31**	11.27**	45.95**	-1.59	9.04**
DMSC4 × HUZM536	22.21**	9.59**	30.20**	21.24**	11.64*	28.19**	53.74**	46.01**	13.04*	100.48**	58.07**	70.23**	-4.44**	5.92**
DMSC6 × HUZM185	14.46**	12.86**	27.80**	29.99**	7.79	17.80**	17.11**	10.88**	15.36**	67.40**	23.53**	57.12**	6.54**	4.55**
DMSC6 × HKI323	48.21**	14.39**	25.07**	18.10**	12.67*	16.91**	48.79**	34.26**	12.43**	75.40**	146.07**	62.14**	7.60**	5.60**
DMSC6 × HKI1105	34.42**	4.53*	3.88	9.70*	8.66	18.99*	16.44**	38.66**	4.92**	98.76**	73.79**	65.86**	2.12	0.20
DMSC6 × CM119	1.11	7.52**	8.08	2.05	6.55	16.02*	17.71**	24.97**	4.00**	102.07**	-0.33	30.74**	4.35**	2.41
DMSC6 × HUZM536	45.60**	15.10**	37.90**	30.26**	6.81	22.55**	52.74**	45.05**	9.67**	94.56**	24.60**	34.14**	6.26**	4.23**
DMSC9 × HUZM185	20.52**	18.84**	10.92*	12.84**	6.52	16.32**	60.13**	51.61**	14.58**	66.30**	25.05**	59.06**	-0.15	4.42**
DMSC9 × HKI323	39.96**	15.18**	18.85**	18.85**	17.05**	21.66**	40.69**	26.95**	15.49**	80.15**	58.06**	25.40**	-2.09	2.41
DMSC9 × HKI1105	36.25**	12.13**	5.26	11.20*	12.82*	23.74**	11.61**	32.89**	5.95**	100.76**	79.60**	71.52**	-0.5	4.03**
DMSC9 × CM119	15.22**	22.52**	21.81**	21.79**	17.55**	27.89**	29.01**	36.94**	6.42**	106.82**	39.43**	82.85**	0.48	5.07**
DMSC9 × HUZM536	28.62**	5.85**	22.45**	22.47**	11.98*	28.49**	44.47**	37.21**	10.81**	96.55**	51.75**	63.43**	-1.39	3.12*
DMSC19 × HUZM185	26.41**	24.64**	8.26	10.11*	9.24	19.29**	50.92**	42.89**	17.87**	71.05**	14.12**	45.15**	6.67**	5.79**
DMSC19 × HKI323	36.10**	24.76**	38.25**	14.82**	14.00**	18.40**	26.91**	14.49**	2.53*	59.96**	118.86**	50.81**	3.87**	2.99*
DMSC19 × HKI1105	26.16**	15.65**	4.76	10.66*	10.92*	21.66**	10.83**	31.97**	2.84**	94.83**	83.95**	75.57**	-2.65	-3.45*
DMSC19 × CM119	7.58**	14.39**	23.32**	14.00**	9.45	18.99**	35.71**	44.08**	3.96**	102.00**	39.64**	83.17**	1.44	0.59
DMSC19 × HUZM536	33.13**	22.04**	14.30**	6.42	6.12	21.66**	33.91**	27.17**	5.06**	86.35**	41.58**	52.43**	-0.09	-0.91
D. A. × HUZM 185	11.85**	10.29**	0.83	2.59	2.26	11.57*	28.97**	22.10**	26.67**	83.80**	19.67**	52.27**	1.40	-
4.36**D. A. × HKI 323	48.76**	17.17**	16.39**	2.32	16.76**	21.36**	55.30**	40.11**	22.15**	90.56**	145.66**	78.48**	8.51**	2.34
D. A. × HKI 1105	40.06**	10.31**	17.27**	23.84**	18.23**	29.67**	25.21**	49.10**	2.64*	94.49**	102.09**	92.88**	6.94**	0.85
D. A. × CM 119	10.54**	17.54**	24.55**	15.16**	-4.27	4.15	24.71**	32.41**	3.07**	100.28**	1.89	33.66**	0.69	-5.01**
D. A. × HUZM 536	48.51**	17.40**	28.07**	19.26**	17.76**	35.01**	51.04**	43.42**	25.59**	122.74**	112.88**	129.13**	3.70*	-2.21
DMSC35 × HUZM185	12.22**	10.65**	5.86	7.72	7.34	17.21**	26.29**	19.59**	15.77**	68.02**	9.16*	38.83**	8.20**	0.78
DMSC35 × HKI323	38.56**	6.94**	41.24**	17.28**	22.22**	28.49**	49.67**	35.05**	17.89**	83.87**	131.84**	64.24**	2.98	-4.10**
DMSC35 × HKI1105	45.69**	13.29**	11.34**	17.62**	11.46*	22.26**	7.99**	28.58**	-1.19	87.18**	53.45**	46.44**	9.13**	1.63
DMSC35 × CM119	3.17	9.71**	11.67*	3.28	15.91**	26.11**	12.82**	19.77**	2.39*	98.97**	17.56**	54.21**	9.92**	2.34
DMSC35 × HUZM536	40.01**	10.68**	20.29**	12.02**	8.62	24.63**	18.01**	12.07**	13.46**	101.24**	57.77**	69.90**	9.97**	2.41
DMSC36 × HUZM185	11.43**	9.88**	15.49**	17.49**	9.60	19.58**	33.20**	26.11**	13.74**	65.06**	46.33**	86.25**	5.86**	-2.02
DMSC36 × HKI323	27.75**	-1.41	23.99**	15.10**	16.00**	20.47**	53.65**	38.62**	24.11**	93.59**	137.60**	98.38**	7.08**	-0.91
DMSC36 × HKI1105	43.59**	11.67**	16.79**	23.36**	15.25**	26.41**	16.13**	38.31**	1.65	92.56**	89.21**	80.58**	6.00**	-1.89
DMSC36 × CM119	8.68**	15.56**	19.74**	11.13*	14.55**	24.63**	9.54**	16.29**	1.34	96.90**	24.63**	63.43**	7.34**	-0.65
DMSC36 × HUZM536	38.75**	9.68**	36.38**	26.98**	8.28	24.33**	46.85**	39.45**	1.45	79.94**	52.91**	64.56**	10.59**	2.34
WSC × HUZM 185	18.80**	17.14**	3.98	5.80	15.13**	25.82**	35.11**	27.92**	6.47**	54.51**	26.16**	60.52**	4.44**	10.15**
W SC × HKI323	27.35**	21.12**	24.73**	6.22	25.24**	29.97**	69.95**	53.32**	15.88**	80.77**	65.37**	82.85**	4.26**	9.95**
WSC × HKI1105	9.96**	4.59*	1.85	7.58	9.48	19.88**	11.11**	32.32**	1.10	91.52**	52.98**	69.09**	3.60**	9.30**
WSC × CM119	4.58*	11.19**	29.25**	19.54**	16.55**	26.71**	17.50**	24.75**	3.26**	100.69**	41.65**	85.76**	1.25	6.83**
WSC × HUZM536	12.51**	7.01**	34.33**	25.07**	12.33*	28.78**	50.96**	43.37**	1.19	79.46**	90.00**	110.03**	3.62**	9.37**
SEd (H)	2.74	3.17	0.55	0.64	0.16	0.18	0.71	0.82	0.25	0.28	0.30	0.35	0.19	0.22

* and ** indicates significance level at 1% and 5%, respectively, BPH = Best-Parent Heterosis, SCH = Standard-Check Heterosis, cm = centi-meters, g = grams. D.A. = Dulce Amanillo, W.S.C. = Win Sweet Corn

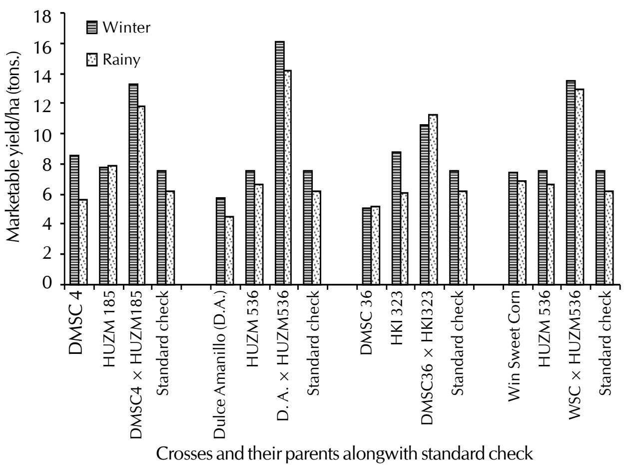

Figure 1: Marketable yield of four heterotic crosses

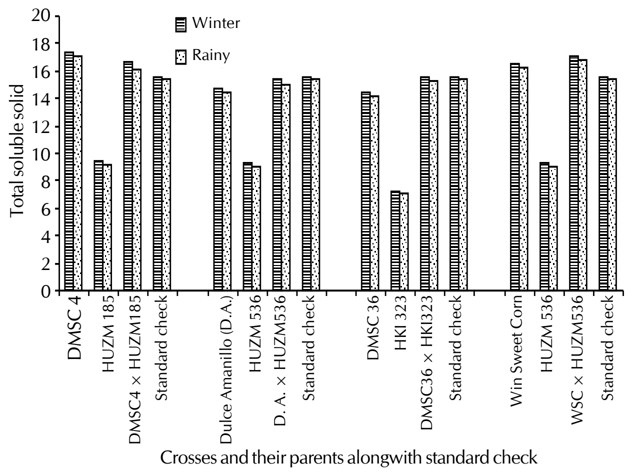

Figure 2: Total soluble solid of four heterotic crosses

parent which range was 2.17% to 44.10%. The cross Dulce Amanillo × CM119 (125.23%) expressed highest magnitude of heterosis followed by Dulce Amanillo × HUZM185 (123.92%) and Dulce Amanillo × HUZM536 (115.36%) over standard check whereas, the crosses Dulce Amanillo × HUZM185 (44.10%), Dulce Amanillo × HKI323 (36.76%) and DMSC4 × HUZM185 (31.10%) over better parent in *rabi* season.

In *kharif* season the heterosis over standard parent ranged from 54.51% to 122.74% and heterosis over better parent range was 2.28% to 26.67%. High heterosis for all the hybrids over standard check with Dulce Amanillo × HUZM536, DMSC9 × CM119, DMSC6 × CM119 having the highest values of 122.74%, 106.82% and 102.07% respectively, while the crosses Dulce Amanillo × HUZM185 (26.67%), Dulce Amanillo × HUZM536 (25.59%) and DMSC4 × HKI323 (25.02%) having the high heterosis for better parent. Present results are in agreement with the findings of Maurya *et al*. (2006), Abdel-Moneam *et al*. (2009) and Bhavana *et al*. (2011) who observed varying degree of heterosis for 100 kernel weights in F_1 studies. The cross Dulce Amanillo × HUZM536 showed stable performance during both the season, this cross can be exploited for heterosis breeding.

Total soluble solid (TSS)

TSS is concerned with the quality traits, the high heterotic cross combination is desirable (Table 1 & 2). In winter season, 18 crosses over standard check and 23 crosses over better parent exhibited significant and positive heterosis. The top desirable crosses for standard heterosis were Win Sweet Corn × HUZM185 (11.13%), Win Sweet Corn × HKI323 (10.94%) and Win Sweet Corn × HUZM536 (10.28%). For better parent the cross DMSC36 × HUZM536 (10.70%) showed high heterosis followed by DMSC35 × CM119 (9.53%) and DMSC35 × HKI 1105 (8.75%). The economic heterosis and heterobeltiosis values ranged from -4.25% to 11.13% and from -6.41% to 10.70%, respectively.

In rainy season, the crosses Win Sweet Corn × HUZM185 (10.15%), Win Sweet Corn × HKI323 (9.95%) and Win Sweet Corn × HUZM536 (9.37%) having high heterosis over standard check while the crosses DMSC36 × HUZM536 (10.59%), DMSC35 × HUZM536 (9.97%) and DMSC35 × CM119 (9.92%) over better parent. The heterosis over standard check ranged from -5.01% (Dulce Amanillo × CM119) to 10.15% (Win Sweet Corn × HUZM185). The range of heterobeltiosis was -5.60% (DMSC4 × HKI 1105) to 10.59% (DMSC36 × HUZM536). In the top ranking crosses the cross Win Sweet Corn × HUZM185 have stable performance during both the season, which indicate that this cross can be used for hybrid breeding programme. Kumari *et al*. (2008) were observed significant heterosis for the same trait and making the cross between field corn and sweet corn lines, the cross DMB327 × SCI303 ($L_7 \times T_2$) showed high heterosis for TSS.

Marketable yield

Yield is a complex character; the highly significant and positive heterosis is desirable. The perusal of results showed that all the cross combination gave highly significant values of heterosis when compared with standard parent and better parent values, giving a range of 45.99% to 189.85% for economic heterosis. In case of better parent heterosis it ranged from 3.37% to 128.57% during winter season. The cross DMSC36 × HUZM185 (189.85%) expressed highest magnitude of standard heterosis followed by DMSC9 × HUZM1105 (185.92%) and Dulce Amanillo × HUZM536 (164.32%) whereas, crosses DMSC36 × HUZM185 (128.57%), Dulce Amanillo × HUZM536 (112.64%) and DMSC9 × HUZM536 (102.15%) showed high heterobeltiosis (Table 1 & 2).

During rainy season, all the crosses over standard check and 37 crosses over better parent showed highly significant and positive heterosis. The magnitude of heterosis of F_1 over standard parent ranged from 25.40% to 129.13% and over better parents range 9.16% to 146.07%. Positive and highly significant heterosis was obtained in Dulce Amanillo × HUZM536 (129.13%), Win Sweet Corn × HUZM536 (110.03%), DMSC36 × HKI323 (98.38%) cross combination for standard parent and in DMSC36 × HKI323 (146.07%), Dulce Amanillo × HKI323 (145.66%), DMSC36 × HKI323 (137.60%) cross combination for better parent. For the above trait improvement can use cross Dulce Amanillo × HUZM536, out of top five crosses because it gave stable performance during both the season. These results are generally analogous to the findings of Revilla *et al*. (2000), Alvi *et al*. (2003), Frascaroli *et al*. (2007), Kumari *et al*. (2008) and Amanullah *et al*. (2011) as they observed a different ratio of heterotic values for yield in their F_1 population.

Among all the crosses six cross combination namely, DMSC9 × HKI 1105, DMSC9 × HUZM536, DMSC19 × CM119, Dulce Amanillo × HUZM185, Dulce Amanillo × HUZM536 and DMSC36 × HUZM185 showed high significant and positive better parent heterosis for marketable yield and yield traits during *rabi* season. On the other hand, among all crosses five heterotic cross namely, DMSC4 × HUZM185, Dulce Amanillo × HKI 1105, Dulce Amanillo × HUZM536, DMSC36 × HKI323 and Win Sweet Corn × HUZM 536 exhibited highly significant positive standard heterosis for yield and yield traits.

Therefore, the four cross combination DMSC4 × HUZM185, Dulce Amanillo × HUZM536, DMSC36 × HKI323 and Win Sweet Corn × HUZM 536 were expressed high magnitude of standard parent and better parent heterosis for marketable yield and yield traits and quality traits over the location. Suggesting that above cross combination may be exploited to develop the hybrid and also may use in evaluation and commercial exploitation of heterosis. Thus, the present study on heterosis revealed that high heterotic response for yield resulted due to yield components governed by non-additive gene action. During *rabi* and *kharif* season these four crosses revealed significant heterotic differences for marketable yield and TSS, respectively (Figure 1& figure 2). Hallauer and Miranda (1995) also reported that heterosis varied from 4.2% to 72.0%, averaging 19.5%, high heterosis estimates have been observed for yield in crosses between races of maize among 1394 varietal crosses.

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