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Estimation of mid parent heterosis, heterobeltiosis and economic heterosis in sweet corn (*Zea mays* L. Ssp. *saccharata*) hybrids over different environments

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Abstract
The present study was conducted to estimate mid parent heterosis, heterobeltiosis and economic heterosis in sweet corn (*Zea mays* L. Ssp. *saccharata*) hybrids and to screen out hybrids having high green cob and fodder yield and high TSS content. A total 66 genotypes comprising of 45 sweet corn hybrids, 18 parental lines and 3 standard checks (Priya, Madhuri and Sugar-75) were evaluated in RBD in three different environments (E_1 at Instructional Farm, RCA, Udaipur during Kharif-2019, E_2 at ARS, Banswara during Kharif-2019 and E_3 at Instructional Farm, RCA, Udaipur during Rabi-2019-20) in RBD with three replications for twenty diverse traits. A number of crosses exhibited heterosis for green cob and fodder yield, while only few hybrids reported to exhibit heterosis for TSS and protein content. Maximum and positively significant heterosis over the best check was shown by the sweet corn hybrid L_7 x T_1 (73.68%) for green cob weight/ plant. Highest and positively perceptible economic heterosis for green fodder yield (kg/ ha) and TSS content of green grain was observed for the sweet corn hybrids L_4 x T_2 (86.24%) and L_{11} x T_1 (17.89%) respectively.

Keywords: Green cob yield, heterosis, heterobeltiosis, sweet corn, TSS

Introduction

Sweet corn is a field corn in an arrested state of development (Erwin, 1951) [4]. With high nutritional values, delicate texture and sweet taste within pericarp and endosperm, it is treated as vegetable. The flavor, texture and sweetness of sweet corn kernels is due to presence of some endosperm mutant genes *viz*., *brittle1 (bt1), brittle2 (bt2), shrunken2 (sh2), amylase extender (ae1), dull1 (du1), sugary1 (su1), sugary enhancer (se)* and *waxy1 (wx1)* (Hassan *et al*., 2019) [5] which alter the starch biosynthesis pathway in endosperm. The most useful mutations among them, *sh2*, *bt1*, *su1* and *se*, function either by accumulating sugar at the expense of starch or by changing types and proportions of different polysaccharides stored in endosperm (Boyer and Shannon 1984) [2]. Total sugar content in sweet corn at milky stage ranges from 25-30% as compared to 2-5% of normal corn (Sadaiah *et al*., 2013) [10]. Sweet corn breeding aims to improve quality and appearance as well as cob yield however, the genetic base of sweet corn breeding programme is relatively narrow and related inbreds often are crossed to make hybrids that meet the strict market requirements on quality and appearance (Tracy, 1994) [11]. The development of superior hybrids is more difficult in sweet corn because the heterotic patterns are poorly defined (Revilla and Tracy, 1997) [8]. Generally, all commercial sweet corn hybrids are based on one or more defective endosperm mutants, and production of high quality seed is more difficult for sweet corn than for most types of corn (Tracy, 1994) [11]. Sweet corn breeders have often focused on improving quality and ear appearance, rather than on enhancing yield (Tracy, 1993) [12]. But emphasis on kernel sweetness along with yield needs to be considered as the major objective of sweet corn improvement. Keeping in view the above facts and the growing demand of sweet corn in the domestic and international market, development of hybrids exhibiting hybrid vigor has been taken as objective of first importance of the research.

Material and Methods

Eighteen diverse sweet corn inbred lines, collected from different parts of the country were used as parents (fifteen females and three testers) (Table 1). The crosses were made in line x tester matting design at Instructional Farm, RCA, Udaipur during *kharif* 2018. Total 66 genotypes comprising of 45 sweet corn hybrids, 18 parental lines and 3 standard checks (Priya, Madhuri and Sugar-75) were evaluated in RBD in three different environments (E_1 at Instructional Farm, RCA, Udaipur during Kharif-2019, E_2 at ARS, Banswara during Kharif-2019 and E_3 at Instructional Farm, RCA, Udaipur during Rabi-2019-20) in RBD with three replications.

Recommended agronomic practices were used to raise a healthy crop. Observations were recorded for 20 yield attributing quantitative and qualitative characters like days to 50 per cent tasseling, days to 50 per cent silking, plant height, ear height, number of leaves/ plant, length of leaf, breadth of leaf, days to green cob harvest, number of ear/ plant, ear length, ear girth, number of grain rows/ ear, number of grains/ row, 100 fresh seed weight, green cob weight/ plant, moisture per cent of green grain, green cob yield, green fodder yield, TSS content of green grain and protein content.Ten plants were taken from each row for recording observations from each replication. TSS content was recorded using hand refrectrometer. Estimation was done over the three environments on pooled basis. Heterosis over mid-parent and better parent was calculated with the standard formula. Estimates of standard heterosis was calculated according to Virmani *et al*. (1982) [13] and the significance of heterosis was tested Using ‘t’ test.

Table 1: List of genotypes used

S. No	Symbol	Pedigree	S. No	Symbol	Pedigree
1.	L_1	SC-7-2-1-2-6-1	10.	L_{10}	BAJ-SC-17-2
2.	L_2	SC-18728	11.	L_{11}	BAJ-SC-17-1
3.	L_3	BAJ-SC-17-6	12.	L_{12}	DMSC-28
4.	L_4	BAJ-SC-17-10	13.	L_{13}	Mas Madu (sh2 sh2)
5.	L_5	BAJ-SC-17-12	14.	L_{14}	MRCSC-12
6.	L_6	BAJ-SC-17-9	15.	L_{15}	SC-33
7.	L_7	BAJ-SC-17-11	16.	T_1	SC-35
8.	L_8	BAJ-SC-17-8	17.	T_2	SC-32
9.	L_9	BAJ-SC-17-4	18.	T_3	DMRSC-1

Result and Discussion

The degree and direction of heterotic response varied not only from character to character but also hybrid to hybrid over the three environments. For characters related to crop duration like days to tasseling, silking and maturity and ear placement, negative heterosis is desirable. For yield characters like green cob yield, green fodder yield and green cob weight/ plant and for quality characters like sugar content and protein content, heterosis in positive and significant direction is desirable.

The estimation of standard heterosis was done over the best check Sugar-75 over the three environments for all the characters under study (Table 2**)**. The analysis of data for economic heterosis for green cob yield over the three environments revealed that the sweet corn hybrid L_7 x T_1 exhibited highest estimates of positively significant standard heterosis against the best check Sugar-75 (71.40%). Maximum and positively significant heterosis over the best check was shown by the sweet corn hybrid L_7 x T_1 (73.68%) for green cob weight/ plant. Highest and positively perceptible economic heterosis for green fodder yield (kg/ ha) and TSS content of green grain was observed for the sweet corn hybrids L_4 x T_2 (86.24%) and L_{11} x T_1 (17.89%) respectively. The present findinds were in close agreement with earlier findings of Dagla *et al*. (2014) [3] and Kumari *et al*. (2018) [6]. None of the sweet corn hybrids were reported to exhibit significant economic heterosis in required direction for the characters days to 50 per cent tasseling, plant height, days to green cob harvest, ear girth and protein content over the three environments against the best check Sugar-75.

Estimates for relative heterosis were found positively significant for 42 hybrids for green cob yield over the environments among which the sweet corn hybrid L_8 x T_3 (354.12%) exhibited maximum and positively significant heterosis. The hybrid L_8 x T_3 also exhibited positively significant mid parent heterosis for green cob weight/ plant (335.15%). For green fodder yield, 41 hybrids showed significantly positive relative heterosis over the environments, where the hybrid L_1 x T_3 (274.98%) exhibited maximum vigour over the mid parents. Over all 28 hybrids manifested significant heterosis in positive direction for TSS content of green grain where maximum mid parent heterosis was shown by the hybrid L_{14} x T_2 (28.46%). The sweet corn hybrid L_{15} x T_2 (1.70%) evinced highest and positively significant mid parent heterosis for protein content.

Estimates for better parent heterosis revealed that the hybrid L_8 x T_3 exhibited maximum positively perceptible heterosis over the better parent for green cob weight/ plant (268.63%) and green cob yield (280.33%). For TSS content of green grain, the hybrid L_{14} x T_2 (23.50%) exhibited maximum heterosis over the better parent in significantly positive direction. None of the sweet corn hybrids were reported to exhibit significant better parent heterosis over the environments for protein content. Hybrid L_1 x T_3 showed highest and significant value for heterobeltiosis in positive direction for green fodder yield (244.47%) and ear length (96.43%). The results were in conformity with the earlier findings of Rajesh *et al*. (2015), Ruswandi *et al*. (2015) [9], Wahba *et al.* **(**2016) [14], Bharti (2017) [1] and Mahato (2018) [7].

Table 2: Heterosis, heterobeltiosis and economic heterosis for sweet corn hybrids for green fodder yield, TSS content of green grain and green cob yield

S. No.	Crosses	Heterosis, heterobeltiosis and economic heterosis for sweet corn hybrids								
		Green fodder yield (kg ha^{-1})			TSS content of green grain (%)			Green cob yield (kg ha^{-1})		
		Heterosis	Heterobeltiosis	E. Heterosis	Heterosis	Heterobeltiosis	E. Heterosis	Heterosis	Heterobeltiosis	E. Heterosis
1	L_1 X T_1	154.26**	103.38**	29.37**	13.27**	0.99	10.47*	146**	92.19**	1.51
2	L_2 X T_1	119.09**	87.44**	19.23**	7.96**	-4.51*	4.51	146.03**	142.88**	28.28**
3	L_3 X T_1	200.97**	182.29**	79.57**	6.51**	-1.89	7.35	219.18**	163.91**	39.39**
4	L_4 X T_1	66.17**	61.68**	2.85	-5.68**	-11.06**	-2.7	59.31**	26.31**	13.91*
5	L_5 X T_1	66.78**	26.76**	-19.37**	5.26*	-0.63	8.74*	93.08**	72.99**	-8.63
6	L_6 X T_1	60.9**	34.95**	-14.15*	-2.27	-2.82	6.31	94.21**	84.33**	-2.64
7	L_7 X T_1	223.38**	150.73**	59.49**	13.97**	3.73	13.52**	241.52**	224.52**	71.4**
8	L_8 X T_1	17.95**	3.73	-34.02**	-3.99*	-5*	3.95	192.02**	124.47**	18.56**
9	L_9 X T_1	88.37**	60.63**	44.84**	17.99**	-0.21	9.15*	54.16**	9.04**	38.92**

10	L_{10} X T_1	45.23**	33.84**	0.99	-0.86	-2.75	6.38	105.95**	76.58**	30.47**
11	L_{11} X T_1	132.3**	122.23**	41.36**	9.4**	7.75**	17.89**	98.32**	68.95**	26.78**
12	L_{12} X T_1	217.87**	151.19**	59.79**	23.59**	5.35*	15.26**	162.82**	153.18**	33.72**
13	L_{13} X T_1	172.3**	168.48**	75.71**	7.4**	-7.46**	1.25	123.21**	99.66**	33.66**
14	L_{14} X T_1	65.3**	57.17**	10.89	11.38**	-2.11	7.07	128.69**	123.16**	23.85**
15	L_{15} X T_1	-31.26**	-44.13**	-64.46**	-11.23**	-11.54**	-2.5	-26.47**	-38.06**	-67.29**
16	L_1 X T_2	139.26**	101.08**	12.68*	6.58**	4.12	-6.45	148.52**	91.9**	4.75
17	L_2 X T_2	155.14**	130.53**	29.19**	6.38*	3	-7.49	153.41**	146.18**	34.37**
18	L_3 X T_2	132.06**	131.39**	29.67**	-2.12	-3.34	-10.96*	197.22**	142.62**	32.43**
19	L_4 X T_2	220.53**	209.52**	86.24**	-12.05**	-15.26**	-17.89**	46.3**	17.43**	5.9
20	L_5 X T_2	223.51**	157.24**	44.16**	17.59**	13.16**	9.92*	180.36**	147.61**	35.15**
21	L_6 X T_2	-20.95**	-30.08**	-60.82**	-6.61**	-14.53**	-7.56	-19.34**	-24.62**	-58.85**
22	L_7 X T_2	146.77**	100.52**	12.37*	21.32**	21.27**	8.95*	166.74**	149.58**	36.22**
23	L_8 X T_2	91.1**	77.85**	-0.33	-5.95**	-13.53**	-7.42	225.45**	147.33**	35**
24	L_9 X T_2	10.55**	-10.37**	-19.19**	20.11**	10.63**	-0.62	18.21**	-15.57**	7.57
25	L_{10} X T_2	71.37**	49.32**	12.67*	0.87	-6.52**	-1.6	30.69**	13.62*	-16.05*
26	L_{11} X T_2	76.47**	73.35**	0.71	7.59**	-0.65	5.41	91.05**	65.01**	23.82**
27	L_{12} X T_2	161.2**	116.65**	21.41**	19.34**	10.89**	-0.35	130.51**	118.6**	19.32**
28	L_{13} X T_2	60.57**	49.03**	-2.47	23.03**	15.69**	3.95	77.51**	61.13**	7.86
29	L_{14} X T_2	72.2**	54.49**	9	28.46**	23.5**	10.96*	82.9**	81.39**	0.67
30	L_{15} X T_2	-3.22	-17.24**	-53.62**	-14.41**	-22.31**	-14.42**	35.8**	12.89	-38.38**
31	L_1 X T_3	274.98**	244.47**	31.43**	24.14**	16.93**	13.31**	321.68**	246.78**	3.04
32	L_2 X T_3	235.77**	186.46**	29.57**	22.81**	14.71**	11.17**	260.22**	147.15**	27.2**
33	L_3 X T_3	173.26**	114.97**	19.77**	8.72**	6.04*	2.77	233.66**	159.4**	-10.44
34	L_4 X T_3	40.71**	7.71	-35.19**	0.79	0.79	-2.29	109.08**	26.74**	14.3*
35	L_5 X T_3	146.46**	142.23**	-19.87**	8.14**	8.01**	4.92	133.19**	70**	-28.89**
36	L_6 X T_3	163.56**	129.47**	-1.11	-8.64**	-13.39**	-6.31	204.16**	113.5**	1.28
37	L_7 X T_3	233.46**	218.77**	11.67*	4.58*	0.72	-2.36	307.6**	185.9**	35.97**
38	L_8 X T_3	184.81**	136.65**	14.23*	-8.23**	-12.59**	-6.38	354.12**	280.33**	7.94
39	L_9 X T_3	31.9**	-10.68**	-19.47**	16.52**	3.74	0.55	19.67**	-31.17**	-12.3
40	L_{10} X T_3	-23.38**	-45.47**	-58.86**	12.5**	8.05**	13.73**	14.14	-28.13**	-46.9**
41	L_{11} X T_3	147.26**	91.61**	11.31	6.34**	1.74	7.98	123.48**	40.27**	5.26
42	L_{12} X T_3	95.96**	82.75**	-32.52**	-1.55	-11.61**	-14.36**	183.82**	97.46**	-3.36
43	L_{13} X T_3	72.08**	28.04**	-16.21**	21.4**	10.25**	6.87	188.63**	85.62**	24.26**
44	L_{14} X T_3	107.2**	50.51**	6.19	4.46	-3.1	-6.1	157.77**	73.37**	-3.78
45	L_{15} X T_3	52.44**	37.4**	-45.31**	-10.79**	-16.15**	-7.63	192.12**	123.43**	-19.2**
46	S.E. Diff.	573.62	662.36	-	0.31	0.36	-	380.61	439.49	-
47	CD 5%	1127.94	1302.44	3196.32	0.61	0.71	1.73	748.42	864.2	2098.92
48	CD 1%	1485.17	1714.92	4208.12	0.8	0.93	2.28	985.44	1137.89	2763.34

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Authors' contribution

Conceptualization of research (Divya Chouhan); Designing of the experiments (Dr. R. B. Dubey); Contribution of experimental materials (Dr. Dilip Singh); Execution of field/lab experiments and data collection (Divya Chouhan and Piyush Choudhary); Analysis of data and interpretation (Divya Chouhan); Preparation of the manuscript (Divya Chouhan and Dr. R. B. Dubey).

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