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Gene action and heterosis for yield and kernel quality traits in experimental hybrids in sweet corn relevant for Indian conditions

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ABSTRACT

Analysis of combining ability of twenty newly derived sweet corn lines was undertaken and pooled analysis of Line × Tester trial over two seasons was significant for all the traits studied. General and specific combining ability for all the traits including agronomical and quality traits were found significant, suggesting both additive and dominance variance operating for these traits. Among the parental lines, IPSA-2707 and IPSA-2713 were good general combiners for grain yield, TSS and Protein while IPSA-2710 and IPSA-2697 were good general combiners for grain yield, 100 kernel weight, total sugar and non reducing sugar. For improvement of both grain yield and quality traits, these elite inbreds could be utilized as potential sources in future breeding programs in sweet corn. Based on high *per se* performance, SCA effect and standard heterosis, promising cross combinations were identified, while IPSA-2715 × T1 was superior for grain yield, reducing sugar and oil content, IPSA-2696 × T2 for grain yield, total sugar and non reducing sugar. For quality traits, IPSA-2710 × T3 showed as a best cross for total sugar, TSS and non reducing sugar. For exploitation of hybrid vigour in commercial level, these crosses could be used for development of hybrids with high grain yield along with high sugar content in sweet corn.

Key words: *Zea mays* var. *saccharata*, Additive variance, Combining ability, Dominance variance, Heterosis.

INTRODUCTION

Maize is the most important cereal crop globally and nationally next to rice and wheat. Its cultivation is also more versatile comprising of all the three seasons in India viz., *Kharif* (rainy), *Rabi* (winter) and *Zaid* (summer). Maize is also very unique in terms of diverse uses like sweet corn and baby corn which form part of specialty corn. These are getting more importance and relevance due to less input requirement, short duration to complete crop cycle and suitable for direct human consumption. Further being considered as vegetables, they fetch more income to the marginal and small farmers in India due to emerging and continuously enhancing requirement at semi urban and urban parts of the country. Sweet corn is characterized by thinner pericarp layer, consumed at 18 to 22 days after fertilization that is milky grain stage of endosperm. Sweet corn is different from the other maize types by the presence of gene/genes like sugary (*su*), sugary enhancer (*se*) and super sweet (*sh*2) which alter endosperm starch synthesis resulting in enhanced sweetness in ears (Mishra *et al.*, 9). The success of single cross hybrid development in maize breeding evident since last decade could be extended to sweet corn improvement considering the enormous scope and prospects.

Availability of improved cultivars with high yield and kernel quality traits are need for sweet corn crop improvement programme. To obtain higher yield and quality traits in sweet corn, the availability of parental lines for breeding programs are necessary. For this, the identification of breeding materials to use as parents for particular traits is an important strategy in sweet corn improvement. To understand the nature and magnitude of gene action of such characters can help to identify and use them in breeding strategy. The knowledge of general and specific combining ability of parental lines and their performance in the expression of heterosis for yield and quality traits could help in crop improvement programs (Gadag *et al.*, 5).

The line × tester mating design can help to choose the parental lines based on their performance and also as a best experimental crosses (Kempthorne, 6). The information obtained from line × tester experimental crosses could be utilized in sweet corn crop improvement. Computation and comparing of heterosis facilitates identifying of elite cross combination(s) which will be useful as hybrid cultivar after extensive evaluations. So the present study was undertaken to evaluate twenty sweet corn inbreds for their *per se* performance, combining ability effect and heterosis in yield and their kernel quality traits of hybrid combinations.

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MATERIALS AND METHODS

For this study a set of twenty sweet corn inbred lines were used as female lines and three popular sweet corn composites namely Win orange, Madhuri and Priya as male parents and crosses were done in line × tester mating design. The evaluation of entries comprising of sixty F_1s, twenty parents alongwith three testers were evaluated in *Rabi* and *Kharif* 2010 in a Randomized Block Design with three replications at IARI Experimental Farm, New Delhi. The experimental plots were laid as two rows each of 5m length having plant-to-plant spacing of 20cm and row to row of 75cm and recommended packages of practices were followed to raise a healthy crop. The observations viz., grain yield, 100 kernel weight, total soluble solids (TSS) and quality traits were recorded. Data on grain yield and 100 kernel weight were recorded after harvest at dry maturity stage as the average of five ears randomly selected from each plot. From single plant grain yield computation of grain yield per hectare was done. For the estimation of TSS at fresh harvest stage, ie. 20 to 22 days after pollination as the average of five randomly selected dehusked green ears per plot were used. Juice was collected from this sample by crushing the kernels and centrifuged to extract supernatant from the debris for one minute at 5,000 rpm, using pocket Refractometer (Atago company, India) measured the total soluble solids, (Brix content, as an indicator of sugar concentration) from supernatant of the juice extract (Elayaraja *et al.*, 3).

Kernel quality traits, viz., total, reducing as well as non-reducing sugars, starch, protein, oil and moisture percentage were recorded from dry mature grain. All the observations were recorded with the help of Near Infra Red Spectroscopy, except reducing and non-reducing sugar. Reducing sugar was analyzed by Nelson Somogeyi method (Nelson, 10) and non-reducing sugar was obtained through subtracting the reducing sugar from the total sugar. The components were recorded in the Biochemistry Lab of Directorate of Maize Research, New Delhi. The combining ability analysis was carried out by line × tester procedure given by Kempthorne (6) and Arunachalam (1). Statistical analysis was done using computer software SPAR-I developed by ICAR-Indian Agricultural Statistical Research Institute (IASRI), New Delhi for all statistical and biometrical analysis of different parameters under study. Heterosis was estimated according to Turner (15).

Table 1. ANOVA for parents and hybrids of yield and kernel quality traits in L×T analysis.

Source	d.f.	Grain yield (kg/ha)	100 kernel weight (g)	Total soluble solids (TSS) (%)	Total Sugar (%)	Reducing sugar (%)	Non reducing sugar (%)	Starch (%)	Protein (%)	Moisture (%)	Oil (%)
Locations	1	181435.10**	1.62	946.26**	231.45**	7.19**	325.08**	149.69**	496.85**	23.20**	14.89**
Repl/Loc	4	364659.20**	0.96	1.10	3.20**	0.27**	2.96*	27.74*	5.25**	2.68**	1.24
Parents	22	1198446.00**	13.05**	5.45**	7.49**	1.13**	4.78**	41.95**	2.44**	5.04**	4.06**
Females	19	946508.30**	14.53**	5.58**	8.46**	1.28**	5.45**	42.47**	2.35**	5.44**	4.55**
Males	2	178901.30*	3.16*	6.70**	1.14	0.27**	0.30	20.73	4.50**	3.37**	1.28
Female vs Males	1	8024320.00**	4.84**	0.46	1.80*	0.04	1.17	74.57**	0.00	0.84	0.34
Hybrids	59	983184.60**	7.89**	13.87**	11.37**	0.53**	8.81**	53.46**	2.08**	2.48**	2.97**
Par vs Hyb	1	64724100.00**	129.76**	131.64**	0.02	3.27**	4.29**	0.66	0.23	6.67**	1.63
Parxloc	22	159151.50	3.50*	5.19**	6.97**	0.63**	5.11**	24.28*	0.77	3.22**	1.17
Femalexloc	19	182125.60*	3.89*	5.61**	7.12**	0.67**	5.39**	24.89*	0.73	3.55**	1.33
Malexloc	2	19096.90	0.40	3.69*	0.02	0.02	0.06	27.96*	0.36	0.87	0.03
(Fvsm)Xloc	1	2751.96	2.29	0.29	17.96**	1.05**	9.91**	5.32	2.38**	1.62*	0.57
Hybridsxloc	59	233530.20**	2.15	4.43*	3.33**	0.52**	2.45**	38.54**	1.76*	2.48**	1.78
(Par vs Hyb) Xloc	1	74948.89	1.34	224.54**	60.66	5.51**	28.34**	27.28*	1.01	0.73	5.42**
Error	328	85729.46	1.69	1.71	0.84	0.05	0.72	11.72	0.75	0.67	0.89

* and ** indicate significance level at 5 and 1% respectively.

Table 2. ANOVA for combining ability analysis of yield and kernel quality traits in L×T analysis.

Source	d.f.	Grain yield (kg/ha)	100 kernel weight (g)	Total soluble solids (TSS) (%)	Total Sugar (%)	Reducing sugar (%)	Non reducing sugar (%)	Starch (%)	Protein (%)	Moisture (%)	Oil (%)
Locations	1	252518.4**	2.86*	333.6**	290.16**	1.09**	328.71**	59.42**	339.60**	20.79**	4.34**
Repl/Loc	4	280576.0**	0.68	1.60	2.24*	0.14**	2.20**	49.93**	5.76**	1.08	0.53
Females	19	1158408.0**	6.81**	24.19**	12.33**	0.90**	8.25**	56.03**	1.25	4.93**	2.96**
Males	2	1263582.0**	10.14**	0.79	13.81**	1.10**	7.24**	32.40**	1.06	3.91**	5.62**
Femalexmale	38	880815.5**	8.32**	9.40**	10.76**	0.32**	9.18**	53.28**	2.55**	1.18	2.83**
Femalexloc	19	286076.9**	2.94*	5.68**	5.39**	0.55**	3.44**	54.08**	2.19**	3.92**	1.65*
Malexloc	2	13824.0	2.50*	3.84**	3.32**	0.59**	4.99**	13.79**	2.32**	1.52*	0.19
Fxmxloc	38	218875.5*	1.74	3.84**	2.30*	0.50**	1.82*	32.07**	1.52*	1.81**	1.93*
Error	236	86140.4	1.14	1.97	0.76	0.04	0.72	11.13	0.69	0.66	0.86

* and ** indicate significance level at 5 and 1% respectively.

RESULTS AND DISCUSSION

Analysis of variance (ANOVA) for lines, testers and hybrids was carried out for yield and kernel quality traits (Table 1). The experiment was conducted in two seasons and ANOVA was performed individually as well as combined analysis of variance of data pooled over season, after testing for homogeneity of error variance using Bartlett's test. Pooled ANOVA results revealed that the variation between the seasons was significant (1%) for all traits studied, except 100 kernel weight. The 100 kernel weight of dried sweet corn lines is not expected to vary much season to season and this can the possible explanation of insignificant difference in two seasons for this trait. However, this trait has shown significant difference between lines and testers as well as in the hybrids. Female parents showed highly significant variation for grain yield, 100 kernel weight and quality traits. Male parents (testers) did not show significant variation for all the studied traits. But TSS was highly significant and 100 kernel weight and grain yield were found to be exhibiting significant variation. On the other hand for quality traits, testers were highly significant for reducing sugar, protein and moisture content. Females vs. males component was significant for grain yield and 100 kernel weight at 1%, and total sugar at 5% significant level but TSS was not significant. It implies that sweetness can be incorporated from testers to lines (Kumari *et al.*, 8). The variation in hybrids was significant for grain yield, 100 kernel weight and quality traits. The significant difference between the hybrids implies that varying performance of cross combinations as manifested in the field performance of these hybrids.

In parents vs. hybrids component, significant variation was evident for grain yield and 100 kernel weight. Among the quality traits, TSS, reducing sugar, non-reducing sugar, and moisture were varying significantly. It implies the presence of heterosis in the experimental crosses evaluated in this study and as reported earlier also (Kumari *et al.*, 8). However, the other biochemical component traits like total sugar, starch, protein and oil did not show significant difference between parents and hybrids. The ANOVA revealed high level of variability for all the traits between lines, testers and hybrids. This shows that the material used for the study is diverse for all the agronomic and quality traits. Comparatively, with reference to different types of corns, the sweet corn lines have narrower genetic base (Srdic *et al.*, 13). The ANOVA for combining ability indicated the significance of line × tester interaction for all yield related traits and among the quality traits except moisture percentage (Table 2). All the traits in the study viz., grain yield, 100 kernel weight and quality traits have shown significant GCA and SCA variance indicating both additive and dominance gene action is operating for these traits (Sadaiah *et al.*, 11). And also additive variance component was higher in magnitude than the dominance component in all the traits except 100 kernel weight, non reducing sugar and protein. This information on these new Indian inbred lines is of great importance in further improving the agronomical and quality traits in future efforts and approaches. The presence of higher GCA variance indicates that the improvement in grain yield and total sugar is still possible through selection.

The knowledge of general combining ability along with high *per se* performance of parental lines

Table 3. GCA effects of sweet corn parental lines for yield and kernel quality traits in L×T analysis.

Parent	Grain yield (Kg/ha)	100 kernel weight (g)	Total soluble solids (TSS) (%)	Total Sugar (%)	Reducing sugar (%)	Non reducing sugar (%)	Starch (%)	Protein (%)	Moisture (%)	Oil (%)
L1	-455.78** (3544.68)	0.06 (12.44)	-0.98** (17 20)	0.04 (11.82)	-0.11** (2.34)	0.15** (9.48)	-0.49* (46.88)	0.01 (15.35)	-0.15** (11.77)	-0.60** (11.26)
L2	279.96** (3066.18)	0.54* (15.44)	-0.43 (16.24)	1.31** (11.67)	0.12** (2.35)	1.18** (9.32)	-0.80** (52.14)	0.47** (14.68)	-0.11* (9.77)	0.38** (11.46)
L3	-229.52** (2668.04)	-0.20 (9.35)	-0.45 (18.35)	-0.14* (11.15)	-0.14** (2.31)	0.11* (8.84)	-0.69** (52.08)	-0.21** (14.48)	0.40* (10.58)	0.15* (11.53)
L4	67.14 (3477.33)	1.68** (12.79)	-1.38** (16.44)	0.69** (10.85)	0.26** (2.05)	0.32** (8.81)	-3.62** (51.37)	0.07 (14.50)	0.02 (12.09)	-0.11 (11.04)
L5	-54.31 (3735.97)	-0.99** (11.93)	-1.27** (17.79)	-0.45** (14.16)	0.18** (3.35)	-0.58** (11.14)	2.45** (47.97)	-0.34** (15.35)	1.39** (12.69)	-0.21** (11.26)
L6	106.64 (2997.72)	0.52* (10.63)	0.43 (16.47)	0.29** (13.43)	0.09** (2.68)	0.20** (10.75)	-0.31 (51.41)	-0.36** (15.22)	-0.12* (9.77)	0.44** (13.25)
L7	-454.15** (3961.94)	-1.09** (12.21)	-0.50 (15.33)	0.99** (11.07)	0.34** (2.24)	0.64** (8.84)	2.23** (54.10)	-0.27** (13.44)	-0.26* (11.07)	-0.41** (11.26)
L8	-223.48** (3237.02)	0.09 (13.15)	2.34** (19.09)	0.89** (11.78)	0.19** (2.68)	0.70** (9.11)	0.51* (50.84)	0.13** (15.29)	-0.32** (11.01)	-0.17** (11.67)
L9	165.36** (3737.31)	0.02 (12.58)	0.50 (18.92)	-0.38** (9.88)	-0.01 (2.43)	-0.37** (7.45)	1.41** (51.25)	-0.18** (14.22)	-0.12* (10.97)	-0.03 (11.53)
L10	114.82* (3232.91)	0.09 (11.17)	1.47** (16.87)	-1.67** (13.32)	-0.68** (2.85)	-0.99** (10.47)	1.34** (49.88)	-0.30** (14.68)	0.25* (11.96)	-0.24** (11.71)
L11	-101.51 (3303.49)	0.05 (12.26)	0.08 (18.14)	-1.42** (12.14)	-0.08** (2.59)	-1.33** (9.55)	-1.06** (51.82)	0.21** (15.49)	0.43** (12.48)	-0.29** (9.94)
L12	283.85** (3852.24)	0.12 (12.63)	2.81** (17.67)	-0.37** (13.31)	0.15** (2.73)	-0.53** (10.58)	0.48* (54.72)	0.38** (14.13)	0.25** (12.08)	0.18** (11.38)
L13	-3.73 (3175.00)	-0.66** (11.16)	-0.05 (17.93)	-0.77** (12.56)	-0.24** (3.12)	-0.53** (9.44)	2.99** (53.40)	0.15** (14.53)	0.89** (10.92)	-0.76** (12.51)
L14	-213.88** (2867.56)	0.07 (12.95)	-0.15 (16.77)	-0.78** (11.66)	-0.14** (2.67)	-0.64** (8.99)	0.91** (45.96)	0.02 (15.01)	-0.55** (12.25)	0.23** (10.15)
L15	453.39** (2594.57)	0.67** (12.62)	-1.24** (16.89)	1.27** (12.78)	0.14** (2.98)	1.13** (9.80)	-2.33** (48.09)	-0.12* (15.29)	0.06 (11.85)	0.92** (11.31)
L16	-151.79** (3293.04)	-0.40 (9.78)	0.12/(17.07)	-0.26** (12.83)	0.10** (2.67)	-0.36** (10.16)	-1.13** (48.92)	0.31** (14.39)	-0.89** (11.09)	0.44** (12.59)
L17	-62.50 (3280.26)	-0.41 (8.32)	-0.69* (17.29)	0.61** (12.11)	0.09** (3.75)	0.52** (8.37)	1.94** (50.95)	-0.21** (15.53)	-0.69** (11.11)	-0.40** (12.96)
L18	354.87** (3770.43)	-0.03 (11.07)	1.01** (16.62)	0.41** (12.57)	-0.01 (2.99)	0.42** (9.57)	-0.47* (50.25)	0.36** (15.18)	0.10* (12.32)	0.25** (10.83)

Contd...

Table 3 contd...

Parent	Grain yield (Kg/ha)	100 kernel weight (g)	Total soluble solids (TSS) (%)	Total Sugar (%)	Reducing sugar (%)	Non reducing sugar (%)	Starch (%)	Protein (%)	Moisture (%)	Oil (%)
L19	243.23** (2948.48)	0.35 (11.11)	-0.68* (16.75)	0.20** (11.31)	-0.08** (2.49)	0.28** (8.83)	-2.67** (53.08)	0.14** (13.75)	-0.26** (11.83)	0.29** (11.05)
L20	-118.59* (3739.64)	-0.47* (12.49)	-0.94** (18.49)	-0.47** (9.45)	-0.16** (1.68)	-0.31** (7.78)	-0.69** (44.97)	-0.26** (15.68)	-0.32** (9.34)	-0.06 (11.13)
SE	57.33	0.21	0.27	0.06	0.01	0.05	0.21	0.05	0.05	0.06
Tester										
T1	-8.37 (3892.47)	0.10 (12.36)	-0.07 (18.17)	0.07 (11.89)	0.04 (2.48)	0.02 (9.41)	-0.28 (53.35)	0.05 (15.09)	-0.20 (11.69)	-0.15 (11.30)
T2	106.48** (3998.07)	0.23** (13.09)	0.09 (16.27)	0.30 (12.34)	0.07 (2.69)	0.24 (9.65)	0.60 (54.12)	-0.11 (13.84)	0.03 (10.27)	-0.10 (11.75)
T3	-98.11** (4230.04)	-0.33** (11.63)	-0.02 (18.02)	-0.37* (12.76)	-0.11** (2.91)	-0.25 (9.86)	-0.32 (50.59)	0.06 (15.51)	0.16 (11.39)	0.25 (10.82)
SE	18.60	0.07	0.09	0.17	0.04	0.17	0.65	0.16	0.16	0.18

* and ** indicate significance level at 5 and 1% respectively. ( ) within the parenthesis mean value given
L1- IPSA2696 L2- IPSA2697 L3- IPSA2698 L4- IPSA2699 L5- IPSA2700 L6- IPSA2701 L7- IPSA2702 L8- IPSA2703 L9- IPSA2704 L10- IPSA2705 L11- IPSA2706 L12- IPSA2707 L13- IPSA2708 L14- IPSA2709 L15- IPSA2710 L16- IPSA2711 L17- IPSA2712 L18- IPSA2713 L19- IPSA2714 L20-IPSA 2715 T1- Win Orange T2- Madhuri T3- Priya

could be utilized in single cross hybrid development in Maize. High GCA effects coupled with high *per se* performance are suitable for selecting parental lines for hybrid development programme (Kumara *et al*., 7). Among the twenty parental lines evaluated, high *per se* performance with significant general combining ability were recorded for specific traits in lines viz., IPSA-2710, IPSA-2713, IPSA-2707 and IPSA-2697 for grain yield, IPSA-2699, IPSA-2710 and IPSA-2697 for 100 kernel weight, IPSA-2707, IPSA-2703 and IPSA-2705 for total soluble solids and IPSA-2697, IPSA-2710 and IPSA-2702 for total sugar (Table 3). Among the inbred lines, IPSA-2699 showed significant GCA effect for 100 kernel weight, total sugar and starch content; and IPSA-2713 for grain yield, TSS and protein content; IPSA-2702 for total sugar, non reducing sugar, and oil content; IPSA-2707 and IPSA-2713 for grain yield, TSS and protein. The parents having positive GCA effect and high mean value revealed that *per se* performance of parents is the useful parameter for studying the combining ability of the parents. Favourable alleles for grain yield present in the parental lines viz., IPSA-2710, IPSA-2713, IPSA-2707 and IPSA-2697 for improvement of yield in sweet corn these lines could be utilized in the breeding programs (Sugiharto *et al*., 14). Based on overall performance, IPSA-2707 and IPSA-2713 were identified as good general combiners for grain yield, TSS and Protein. It implying the presence of additive gene action for expression these traits in these parental lines. Inbred IPSA-2710 and IPSA-2697 were considered as good general combiners for grain yield, 100 kernel weight, total sugar and non reducing sugar, but not significant GCA for TSS. Hence, correlation between total sugar and TSS was not found positively. Hence TSS concentration could not reliably predict the sugar content in sweet corn lines. For improvement of grain yield and quality traits, IPSA-2710, IPSA-2697, IPSA-2707 and IPSA-2713 could be used as a potential parental lines in future breeding programs for enhancing respective traits in the experimental crosses and subsequently in the hybrids. These findings were similar to the results reported by Kumara *et al*. (7) and Dhasarathan *et al*. (2). Preponderance of high GCA in these parental lines indicates the presence of additive gene action (Elayaraja *et al*., 4). So selection could be an ideal breeding method to improve respective traits in sweet corn.

Mean performance of T3 was better than other two testers for grain yield, total sugar, non-reducing sugar, starch, protein and oil. But, it has shown significant GCA only for reducing sugar in the desirable direction. Other tester T2 showed significant positive GCA effect for grain yield and 100 kernel weight which suggesting the role of additive gene action for the selection of these traits. It implies that selection and fixing of favorable alleles for these traits is possible, and similar results were obtained by Sandesh *et al.* (12) in maize.

For evaluation of hybrids, the estimate of specific combining ability is the indicator for the presence of heterosis in the crosses and expression of non additive gene action. Among the sixty crosses evaluated, based on *per se* performance and SCA effect, significant SCA effect were noticed in some of the crosses in all the studied traits (Table 4). Based on *per se* and SCA effect, highest SCA effect for grain yield was found in IPSA-2715 × T1 followed by IPSA-2696 × T2 and IPSA-2698 × T1. The hybrids showing better *per se* and SCA effect for the some of the relevant component traits include IPSA-2698 × T1, IPSA-2707 × T2 and IPSA-2704 × T3 for 100 kernel weight, IPSA-2712 × T2, IPSA-2710 × T3 and IPSA-2704 × T2 for TSS and IPSA-2696 × T2, IPSA-2700

Table 4. Top three best crosses based on SCA effect, *per se* performance, and better parent and standard parent heterosis.

S. No.	Trait	Best crosses	*Per se* performance	SCA effect	BH	SH
1	Grain yield (kg/ha)	L20 × T1	4742.21	646.11**	21.83**	12.11**
		L1 × T2	4479.90	606.14**	12.05**	5.91
		L3 × T1	4586.83	601.65**	17.84**	8.43*
2	100-kernel wt. (g)	L3 × T1	15.36	2.45**	24.3**	32.06**
		L12 × T2	15.07	1.7**	15.13**	29.5**
		L9 × T3	14.34	1.63**	13.96*	23.25**
3	Total soluble solid (%)	L17 × T2	20.58	2.69*	19.04**	14.19**
		L15 × T3	19.47	2.24**	8.01	8.01*
		L9 × T2	21.21	2.14**	12.13**	17.68**
4	Total sugars (%)	L1 × T2	14.82	2.46**	20.08**	16.12**
		L5 × T3	13.47	2.27**	-4.85	5.55
		L15 × T3	14.85	1.93**	16.21**	16.35**
5	Reducing sugar (%)	L2 × T1	2.64	- 0.36**	12.34*	-9.23*
		L20 × T1	2.39	- 0.32**	42.69**	-17.82**
		L8 × T2	2.78	- 0.32**	3.74	-4.58
6	Non reducing sugar (%)	L1 × T2	11.94	2.35**	23.7**	21.11**
		L5 × T3	10.52	2.16**	-5.61	6.72
		L15 × T3	11.77	1.7**	19.4**	19.4**
7	Starch (%)	L16 × T2	44.16	-6.02**	-9.74	-12.71**
		L4 × T3	41.56	-5.21**	-17.84**	-17.84**
		L9 × T1	48.25	-3.58**	-5.86	-4.62
8	Protein (%)	L6 × T1	15.59	1.14**	2.38	0.52
		L5 × T3	15.59	1.11**	0.55	0.55
		L3 × T3	15.53	0.91**	0.13	0.13
9	Moisture (%)	L3 × T1	11.13	-0.66**	5.2	-2.31
		L7 × T1	10.53	-0.59**	-4.82	-7.52*
		L17 × T2	10.37	-0.55**	0.96	-8.99*
10	Oil (%)	L7 × T3	9.59	-1.54**	-6.32	-11.38*
		L20 × T1	9.8	-1.27**	-11.9*	-9.39
		L9 × T1	9.98	-1.13**	-11.69*	-7.74

BH= Better parent heterosis SH= Standard heterosis * and ** indicate significance level at 5% and 1% respectively.

× T3 and IPSA-2710 × T3 for total sugar. The cross IPSA-2696 × T2 showed significant SCA effect with high *per se* performance for grain yield, total sugar and non reducing sugar. The cross IPSA-2715 × T1 for grain yield, reducing sugar and oil content, and IPSA-2698 × T1 for grain yield, 100 kernel weight and moisture content in desirable direction. The crosses IPSA-2700 × T3 and IPSA-2710 × T3 for both total sugar and non- reducing sugar, further IPSA-2700 × T3 recorded high SCA with *per se* for protein content and IPSA-2710 × T3 for TSS also. The hybrids showing significant positive SCA effects along with high mean performance for grain yield, indicates that high *per se* performance of the respective crosses showed their potentiality for combining ability. Both the parents with low general combining ability effect in crosses IPSA-2715 × T1 and IPSA-2698 × T1 expressed significant positive SCA effect for grain yield. In IPSA-2696 × T2 lines were with low and high GCA effects but high SCA effects in the hybrids. The results found that the grain yield was highly controlled by non additive gene action that is both dominance and epistatic gene interaction. These findings were similar to the results of by Sandesh *et al*. (12). From the present study three hybrids viz., IPSA-2698 × T1, IPSA-2707 × T2 and IPSA-2704 × T3 having high SCA effect for 100 kernel weight which mentioned that involvement of non additive gene action for the expression of this trait.

The cross IPSA-2696 × T2 showed significant SCA effect for both grain yield and total sugar while IPSA-2700 × T3 had high total sugar, non reducing sugar and protein content. The expression of these traits in the hybrid was with high SCA effect but low general combining parental lines were involved. Thus, low general combining parents producing high SCA effects for total sugar, non reducing sugar and protein in sweet corn revealed that these traits are controlled by non additive gene interactions. So for improvement of specific quality traits in sweet corn, low general combining parents could be utilized for producing high SCA effects. The cross IPSA-2710 × T3 recorded high *per se* performance and SCA effect for both TSS and total sugar. It indicates that positive correlation between TSS and total sugar in the specific hybrid. Hence, time of harvest during milky stage in sweet corn could be determined by analysing TSS in field condition (Kumari *et al*., 8 and Dhasarathan *et al*., 2). Thus five elite hybrids IPSA-2696 × T2, IPSA-2698 × T1, IPSA-2700 × T3, IPSA-2710 × T3 and IPSA-2715 × T1 showing high *per se* with significant SCA effect could be further used for the improvement of respective traits in sweet corn.

The importance of heterosis along with high *per se* performance and significant SCA effect is most desirable for choosing the crosses for exploitation of heterosis in commercial scale. So identification of crosses based on all the three parameters is important. Superior performance of the hybrids over their both the parents was the heterosis. The expression of heterosis in crosses depends on the presence of non additive gene action and more genetic diversity among the parents involved in the crosses (Yowono *et al*., 16). Heterosis was calculated for yield and kernel quality traits in sixty experimental crosses, and expressed as increase or decrease over mid parental value which referred as heterosis, over better parent as heterobeltiosis and over standard check as standard heterosis (Sadaiah *et al*., 11).

Among the sixty experimental hybrids analysed, desirable *per se*, SCA effect and significant positive better parent heterosis or heterobeltiosis for grain yield was recorded in crosses IPSA-2715 × T1 with 21.83% heterosis followed by IPSA-2696 × T2 and IPSA-2698 × T1. The elite crosses IPSA-2698 × T1, IPSA-2707 × T2 and IPSA-2704 × T3 for 100 kernel weight, IPSA-2696 × T2 and IPSA-2710 × T3 for total sugar and IPSA-2712 × T2, IPSA-2704 × T2 and IPSA-2710 × T3 for TSS showed superior for all the three parameters (Table 4). The trait TSS as an indicator of sugar concentration in the immature kernels can be used as a corn harvest parameter which also in accordance with the reports of Kumara *et al*. (7). The cross IPSA-2696 × T2 showed high *per se* performance, SCA effect and better parent heterosis for grain yield, total sugar and non reducing sugar, and the cross IPSA-2710 × T3 for total sugar, TSS and non reducing sugar. High heterosis for economic character like TSS was more desirable for selection of sweet corn crosses (Yowono *et al*., 16). It revealed the presence of over dominance for the manifestation of these traits. The results were corroborated with the findings of Sugiharto *et al*. (14).

Analysis of standard heterosis over Priya which is prominently cultivated in India as a sweet corn cultivar was one of the testers in the present study as T3. The results indicated that IPSA-2715 × T1 as best performer for grain yield with 12.11% standard heterosis followed by IPSA-2698 × T1 and IPSA-2696 × T2 along with high *per se* and SCA effect (Table 4). Sandesh *et al*. (12) reported that three hybrids recorded positive standard heterosis out of 22 hybrids evaluated for grain yield. The crosses IPSA-2698 × T1, IPSA-2707 × T2 and IPSA-2704 × T3 for 100 kernel weight, IPSA-2696 × T2, IPSA-2710 × T3 and IPSA-2700 × T3 for total sugar and IPSA-2704 × T2, IPSA-2712 × T2 and IPSA-2710 × T3 for TSS showed significant standard heterosis along with high *per se* and SCA effect. Similarly, IPSA-2698 × T1 was found to be more promising on the basis of high *per se,* SCA effect and standard heterosis for 100 kernel weight (32.06%), grain yield (8.43%) and moisture content. The cross IPSA-2710 × T3 for total sugar (16.35%), TSS (8.01%) and non reducing sugar (19.40%). IPSA-2696 × T2 for grain yield, total sugar and non reducing sugar, IPSA-2715 × T1 for grain yield, reducing sugar and oil content, and IPSA-2700 × T3 for total sugar, non reducing sugar and protein content. Similar approach and parameters were followed in identifying elite combinations by Kumari *et al.* (8). The cross IPSA-2704 × T1 showed high *per se* performance and SCA effect but not significant amount of standard heterosis which means that the presence of more additive gene action in the expression of these traits. It is apparent that crosses evaluated in this experiment were having high genetic potential for grain yield, 100 kernel weight, total sugar and other quality traits and there is a potential approach for corn improvement (Sugiharto *et al*., 14).

Among the sixty crosses studied, overall high *per se* performance, SCA effect and standard heterosis for grain yield recorded in crosses viz., IPSA-2715 × T1, IPSA-2696 × T2 and IPSA-2698 × T1, for total sugar in crosses viz., IPSA-2710 × T3, IPSA-2696 × T2 and IPSA-2700 × T3, and for TSS in crosses IPSA-2704 × T2, IPSA-2712 × T2 and IPSA-2710 × T3. The cross IPSA-2715 × T1 was superior cross for grain yield, reducing sugar and oil content, IPSA-2696 × T2 for grain yield, total sugar and non reducing sugar based all the three parameters. For quality traits, IPSA-2710 × T3 was found to be promising for total sugar, TSS and non reducing sugar.

Elite parental lines IPSA-2707 and IPSA-2713 found as good general combiner for grain yield, TSS and Protein were identified. Inbred IPSA-2710 and IPSA-2697 are considered as good general combiner for grain yield, 100 kernel weight, total sugar and non reducing sugar**.** For improvement of grain yield and quality traits, inbreds IPSA-2710, IPSA-2697, IPSA-2707 and IPSA-2713 could be used as a potential parental lines in the future breeding programs for enhancement of respective traits in sweet corn. The present study taking in to account various parameter and components identified elite hybrids IPSA-2715 × T1 for grain yield, reducing sugar and oil content, IPSA-2696 × T2 showed potentiality for grain yield, total sugar and non reducing sugar. For quality traits, IPSA-2710 × T3 showed as a best cross for total sugar, TSS and non reducing sugar. These crosses were having high genetic potential for grain yield, 100 kernel weight, total sugar and other quality traits. Hence they could be used for exploitation of hybrid vigour for development of high yielding cultivars with high sugar content in sweet corn.

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