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Estimation of Heterosis and Inbreeding Depression in crosses derived from Grain Sorghum × Sweet Sorghum [*Sorghum bicolor* (L.) Moench]

Vemanna Iraddi, T Dayakar Reddy, A V Umakanth, Ch Rani and M Ganesh
Department of Genetics and Plant Breeding, Hyderabad - 30, Andhra Pradesh

ABSTRACT

An investigation on heterosis and inbreeding depression was carried out in four crosses for fresh stalk yield, juice yield and its attributing traits in Sweet sorghum [*Sorghum bicolor* (L.) Moench]. High heterosis coupled with low inbreeding depression was observed for stem girth in two crosses *viz.,* 27 B × SSV 84 and ICSB 38 × SSV 74 while significant mid parent heterosis coupled with low inbreeding depression for stem girth, brix per cent, total soluble sugars and bioethanol yield was recorded in 296 B × URJA cross indicating additive and additive × additive gene action in the genetic control of these traits. Contrary to this in all four crosses, high heterosis coupled with high inbreeding depression was noticed for total biomass, fresh stalk yield, grain yield, juice yield and sugar yield indicating non-additive gene action in their genetic control. Maximum heterosis was recorded for sugar yield followed by juice yield and fresh stalk yield.

Key words : Additive, Inbreeding depression, Heterosis, Non additive gene action, Sweet sorghum.

In India, CSH 22SS sweet sorghum hybrid is the only hybrid released for general cultivation till date. Moreover, performances of those hybrids which are in the breeder's pipeline are unable to surpass the desirable characters of this hybrid. Though, sweet sorghums have not been a major focus of commercial breeding programmes but yet hybrids have been developed between grain sorghum and sweet sorghum, usually for fodder or dual purpose use (grain and fodder). Thus, increasing stalk sugar and green cane yield is becoming an important objective in sweet sorghum breeding (Murray *et al.,* 2009). Genetic enhancement of this crop for increased sugar and green cane yield is very critical to make more remunerative to the farmers and the industry, while sustaining grain yield, juice volume, plant height, plant girth and other important components. In this regard, the present study reports about heterosis and inbreeding depression for fresh stalk yield, juice yield and its attributing traits in four promising newfangled crosses of sweet sorghum.

MATERIAL AND METHODS

Seven divergent parents *viz.,* 27 B, ICSB 38, 296 B, SSV 84, SSV 74, URJA and NSSV - 13 and four each F_1 and F_2 populations were grown in randomized complete block design with three replications at Directorate of Sorghum Research (*erstwhile* National Research Centre for Sorghum), Rajendranagar, Hyderabad. In the experimental plot, parents and F_1's were represented by 5 rows each, whereas backcrosses and F_2 families by 15 and 20 rows, respectively per block. A uniform inter and intra row spacing of 45 cm and 15 cm with a row length of 5 m was maintained for raising all the generations. Observations were recorded on five randomly selected plants in parents and F_1's while on 50 competitive plants in each back cross progeny and on 200 competitive plants from each F_2 populations in each block for 14 quantitative characters. Heterosis and inbreeding depression estimates were computed by following standard procedures.

RESULTS AND DISCUSSION

The results of magnitude of heterosis over mid parent, better parent and standard check (CSH 22SS) as well as deviation of F_2 mean from F_1 mean in terms of inbreeding depression in four crosses of sweet sorghum for fourteen quantitative traits are tabulated in Table 1 and 2 and discussed here under.

In '27 B × SSV 84' cross, among 14 traits studied, plant height, nodes per plant, stem girth, total biomass, fresh stalk yield, grain yield, juice yield and sugar yield exhibited significant mid parent as well as better parent heterosis in desirable direction indicating role of overdominance in the expression of these traits. Moreover, this cross also exhibited positive and significant heterosis over standard check (CSH 22SS) for total biomass, fresh stalk yield, juice yield, juice extraction per cent and sugar yield. Inbreeding depression was of low magnitude with respect to days to 50% flowering, days to maturity, stem girth and juice extraction per cent; moderate for nodes per plant. However, few among the remaining characters *viz.,* plant height, total biomass, fresh stalk yield, grain yield, juice yield and sugar yield exhibited high magnitude of inbreeding depression. Contrary to this, albeit low but negative inbreeding depression was recorded for brix per cent, total soluble sugars and bioethanol yield. High heterosis coupled with low inbreeding depression in respect of stem girth indicated additive and/or additive × additive variance which is fixable in segregating generations. On the other hand, high heterosis coupled with high inbreeding depression in respect of plant height, total biomass, fresh stalk yield, grain yield, juice yield and sugar yield indicated non-additive gene action.

Whereas, in another cross 'ICSB 38 × SSV 74', mid parent heterosis was significant and positive for plant height, nodes per plant, stem girth, total biomass, fresh stalk yield, grain yield, juice yield, juice extraction per cent and sugar yield indicating partial dominance. This cross exhibited significant and positive better parent heterosis for plant height, nodes per plant, total biomass, grain yield, juice yield, juice extraction per cent and sugar yield indicating presence of overdominance in the genetic control of these traits. Contrary to this, most of the traits barring plant height and nodes per plant exhibited positive and significant heterosis over standard check. The magnitude of inbreeding depression was low in respect of stem girth and juice extraction per cent which exhibited significant mid parent as well as better parent heterosis indicating role of additive and additive × additive gene action in the genetic control of these traits. However, few among the remaining traits *viz.,* plant height, nodes per plant, total biomass, fresh stalk yield, grain yield, juice yield and sugar yield exhibited high magnitude of inbreeding depression. High heterosis coupled with low inbreeding depression in respect of stem girth indicated additive and/or additive × additive variance which is fixable in segregating generations. On the other hand, high heterosis coupled with high inbreeding depression in respect of plant height, nodes per plant, total biomass, fresh stalk yield, grain yield, juice yield and sugar yield indicated non-additive gene action.

In '296 B × URJA' cross, out of 14 quantitative traits, plant height, stem girth, total biomass, fresh stalk yield, grain yield, brix per cent, juice yield, juice extraction per cent, total soluble sugars, sugar yield and bioethanol yield exhibited significant mid parent heterosis in desirable direction indicating role of overdominance in the expression of these traits. Many of these traits except stem girth and juice extraction per cent recorded significant positive better parent heterosis. Moreover, this cross exhibited positive and significant heterosis over standard check (CSH 22SS) for most of the traits barring grain yield. The magnitude of inbreeding depression was high in respect of total biomass, fresh stalk yield, grain yield, juice yield and sugar yield, coupled with high better parent heterosis indicating the operation of non-additive gene action including dominance and additive × dominance or dominance × dominance gene interactions which cannot be fixed in segregating generations. However, inbreeding depression was low in respect of stem girth, brix per cent, total soluble sugars and bioethanol yield which exhibited significant mid parent heterosis indicating role of additive and additive × additive gene action in the genetic control of these traits which is fixable in segregating generations. High heterosis coupled with high inbreeding depression in respect of total biomass, fresh stalk yield, grain yield, juice yield and sugar yield indicated non-additive gene action.

In the fourth cross *i.e.,* '27 B × NSSV 13', among 14 traits studied, plant height, stem girth, total biomass, fresh stalk yield, grain yield, juice yield, juice extraction per cent and sugar yield exhibited significant mid parent heterosis in desirable direction indicating role of partial dominance in the expression of these traits. On the other hand, total biomass, fresh stalk yield and grain yield registered positive significant better parent heterosis indicating operation of over dominance. Contrary to this, it exhibited positive and significant heterosis over standard check (CSH 22SS) for total biomass, fresh stalk yield, grain yield, brix per cent,

Table 1. Heterosis and Inbreeding depression in respect of 14 quantitative characters in the crosses ‘27 B × SSV 84’ and ‘ICSB 38 × SSV 74’ of Sweet sorghum.

Sl. No.	Character	‘27 B × SSV 84’ Heterosis percent over			Inbreeding Depression (%)	‘ICSB 38 × SSV 74’ Heterosis percent over			Inbreeding Depression (%)
		MP	BP	SC		MP	BP	SC	
1	Days to 50% flowering	-1.91**	-2.53**	-1.28**	2.08	-2.44**	-3.61**	2.56**	-0.34
2	Days to maturity	-1.27**	-1.68**	-0.85**	1.37	-1.64**	-2.44**	1.69**	-0.22
3	Plant height (cm)	52.53**	32.18**	-5.51**	21.19	42.77**	6.87**	-1.38**	21.03
4	Nodes per plant	13.79**	12.24**	-13.61**	11.32	17.02**	4.64**	-5.50**	22.01
5	Stem girth (cm)	44.17**	48.60**	4.72	6.70	20.26**	-7.24*	11.02**	8.24
6	Total biomass (g / plant)	103.16**	47.01**	25.37**	38.24	81.21**	8.21**	52.41**	52.02
7	Fresh stalk yield (g / plant)	138.54**	72.51**	25.16**	38.21	76.17**	1.87	49.50**	55.00
8	Grain yield (g / plant)	80.62**	66.24**	3.98	35.13	88.04**	27.48**	12.75**	39.97
9	Brix per cent	-4.89	-9.70**	2.15	-5.10	3.77	-6.21*	11.69**	-2.37
10	Juice yield (g / plant)	120.06**	35.27**	93.63**	37.82	111.76**	15.14**	164.71**	54.29
11	Juice extraction per cent	3.80	-21.50**	55.03**	0.76	45.44**	12.95*	77.30**	-1.40
12	Total soluble sugars (%)	-4.83	-9.60**	2.12	-5.04	3.73	-6.15*	11.55**	-2.33
13	Sugar yield (g / plant)	102.88**	22.39**	97.81**	33.83	101.69**	8.00*	194.71**	52.55
14	Bioethanol yield (ml / plant)	-4.83	-9.60**	2.12	-5.04	3.73	-6.15*	11.55**	-3.21

*Significant at P = 0.05
**Significant at P = 0.01

MP = Mid-parent; BP = Better parent (SSV 84 & SSV 74, respectively) and SC = Standard check (CSH 22SS)

Table 2. Heterosis and Inbreeding depression in respect of 14 quantitative characters in the crosses '296 B × URJA' and '27 B × NSSV 13' of Sweet sorghum.

Sl. No.	Character	'296 B × URJA' Heterosis percent over			Inbreeding Depression (%)	'27 B × NSSV 13' Heterosis percent over			Inbreeding Depression (%)
		MP	BP	SC		MP	BP	SC	
1	Days to 50% flowering	-7.51**	-11.11**	2.56**	-5.62	-5.52**	-9.41**	-1.28**	-7.13
2	Days to maturity	-5.14**	-7.69**	1.69**	-3.75	-3.70**	-6.40**	-0.85**	-4.69
3	Plant height (cm)	41.29**	25.59**	2.75**	19.53	19.77**	-9.12**	-7.99**	17.04
4	Nodes per plant	-4.24**	-7.95**	15.18**	15.15	-13.41**	-27.91**	-18.85**	-19.42
5	Stem girth (cm)	7.30*	-1.05	11.42**	4.01	8.89*	-7.38*	-1.18	8.00
6	Total biomass (g / plant)	43.20**	4.85**	45.99**	29.54	80.71**	22.83**	30.36**	41.15
7	Fresh stalk yield (g / plant)	71.40**	13.66**	66.70**	35.54	69.63**	5.71**	38.98**	46.63
8	Grain yield (g / plant)	94.01**	145.45**	-35.46**	26.71	101.48**	96.40**	8.76**	16.09
9	Brix per cent	14.91**	9.47**	37.95**	5.24	2.44	-12.23**	25.06**	-3.04
10	Juice yield (g / plant)	77.94**	3.73**	267.65**	39.32	80.29**	1.09	173.53**	36.76
11	Juice extraction per cent	20.97**	-8.80*	120.79**	14.39	28.25**	-4.36	97.04**	-11.46
12	Total soluble sugars (%)	14.76**	9.38**	37.48**	5.19	2.42	-12.12**	24.75**	-3.01
13	Sugar yield (g / plant)	97.34**	13.51**	404.62**	40.09	63.52**	-11.12**	240.68**	29.98
14	Bioethanol yield (ml / plant)	14.76**	9.38**	37.48**	3.82	2.42	-12.12**	24.75**	-4.49

*Significant at P = 0.05
**Significant at P = 0.01

MP = Mid-parent; BP = Better parent (URJA & NSSV 13, respectively) and SC = Standard check (CSH 22SS) juice yield, juice extraction per cent, total soluble sugars, sugar yield and bioethanol yield. The magnitude of inbreeding depression was moderate to high in respect of plant height, total biomass, fresh stalk yield, grain yield, juice yield and sugar yield which exhibited significant mid parent heterosis indicating role of non-additive gene action including dominance and additive × dominance or dominance × dominance gene interactions which cannot be fixed in segregating generations.

The above cited results of four promising crosses of sweet sorghum were by and large same and they were in accordance with the earlier reports of Rajguru *et al.* (2005), Agarwal M and Shrotria (2005), Sandeep *et al.* (2009) and Vinaykumar (2009) for plant height; Rajguru *et al.,* 2005, Sandeep *et al.* (2009) and Vinaykumar (2009) for days to 50% flowering; Meshram *et al.* (2005), Sandeep *et al.* (2009) and Vinaykumar (2009) for stalk yield; Sandeep *et al.* (2009) and Vinaykumar (2009) for juice yield; Sandeep *et al.* (2009) and Vinaykumar (2009) for plant height, nodes per plant and stem girth.

High heterosis coupled with low inbreeding depression was also earlier reported by Chiang and Smith (1967) for days to 50% flowering and stem girth; Giriraj and Goud (1981) for days to 50% flowering and number of nodes and Meenu Agarwal and Shrotria (2005) for total soluble sugars. However, moderate inbreeding depression was reported by Giriraj and Goud (1981) for plant height, stalk height and internode length. While, Kulkarni and Shinde (1985) for plant height and Meenu Agarwal and Shrotria (2005) for stem diameter and plant height reported high inbreeding depression.

From the forgoing discussion on heterosis and inbreeding depression studies in sweet sorghum revealed that among 14 quantitative traits studied, total biomass, fresh stalk yield, grain yield, juice yield and sugar yield are governed by non-additive gene action including dominance and additive × dominance or dominance × dominance which cannot be fixed in segregating generations, whereas stem girth is governed by additive and additive × additive gene action, which is fixable in segregating populations.

These studies could help the breeder to concentrate on only one or few crosses rather than handling many, since superior crosses exhibiting high heterosis were bound to through superior segregants. The improvement of sweet sorghum stalk and juice yield would be possible by employing biparental mating technique in F_2 populations and the resulting generation may be advantageous.

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