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RESEARCH ARTICLE

Influence of maleterility inducing cytoplasm on hybrid heterosis for bioenergy traits in sweet sorghum [*Sorghum bicolor* (L.) Moench]

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SUMMARY

Influence of male sterility inducing cytoplasm on heterosis with respect to ethanol yield and its attributing traits in sweet sorghum was studied in 48 hybrids developed by crossing six A- lines *viz.*, ICSA 631, ICSA 731, ICSA 324, ICSA 500, ICSA 38 and ICSA 84 and their corresponding B- lines with four R- lines *viz.*, SEREDO, ICSV 700, ICSV 111 and E 36-1 in a line × tester mating design. The 16 parents and their 48 hybrids were grown separately in contiguous blocks in single row of 3m length with 0.15 m × 0.60 m spacing in simple lattice design with two replications at the experimental plots of Gandhi Krishi Vignana Kendra (GKVK), University of Agricultural Sciences (UAS), Bangalore. Presence of an average level of heterosis for all the traits studied were evident as exemplified by significant mean squares due to parents *vs*. hybrids. While cytoplasmic influence was apparent for midparent heterosis under individual nuclear genetic background for all the traits, no definite trend favoring any particular cytoplasm was observed.

Key Words : Cytoplasmic influence, Heterosis, Male sterility inducing cytoplasm, Sweet sorghum

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Hybrid cultivar development in sorghum has been possible due to the discovery of workable cytoplasmic nuclear male-sterility (CMS) designated as A_1 (milo) (Stephens and Holland, 1954). A large number of milo CMS-based sorghum hybrids have been developed and released/ marketed in India and in several other countries. Devastation of 'Texas' CMS-based maize hybrids due to southern corn leaf blight (*Bipolaris maydis*) epidemic in 1970 triggered research on assessing the response of CMS-based hybrids identical in nuclear genetic background but differing in their maternal cytoplasm for biotic stresses and productivity traits in several crops such as grain sorghum (Ramesh *et al.* 2006), rice, (Katayama, 1978 and Viraktamath, 1987), and cotton (Gill *et al.*, 2007). There is no reported literature on the effects of male sterility inducing cytoplasm on heterosis of hybrids on bioenergy traits in sweet sorghum. In the present study, the performances of male sterile cytoplasm based hybrids were compared to those based on male sterile cytoplasm for ethanol yield and its attributing characters in sweet sorghum.

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MATERIALS AND METHODS

The material consists of six CMS (A) lines *viz.*, ICSA 631, ICSA 731, ICSA 324, ICSA 500, ICSA 38 and ICSA 84, their corresponding maintainer (B) lines and four restorer (R) lines *viz.*, SEREDO, ICSV 700, ICSV 111 and E 36-1 procured from International Crops Research Institute for Semi Arid Tropics

(ICRISAT), Patencheru, India. The six A-lines were crossed with the four R-lines to obtain 24 (A×R) crosses. The male-fertile counterparts (B-lines) of these six B- lines were emasculated and crossed with the same four R-lines to obtain 24 (B×R) crosses. The 24 (A×R) and 24 (B×R) crosses and their 16 parents (six A, six B and 4 R lines) were evaluated separately following contiguous blocks at the experimental plots of Gandhi Krishi Vignana Kendra (GKVK), University of Agricultural Sciences (UAS), Bangalore, Karnataka, India during *summer* 2011. The experiment was laid out in Simple Lattice Design (LSD) with two replications. Each hybrid and parent entry was grown in a single row of 3m length consisting of 20 plants spaced 0.6m between rows and 0.15 m between plants within a row. All the recommended agronomic practices were followed with protective irrigation to raise a healthy crop. Five randomly selected plants in each hybrid and parent in each replication were tagged to record data on cane height, cane weight, juice volume, juice extraction per cent and ethanol yield. Cane height was measured from base of the plant to the upper most node of the plant and expressed in centimeter (cm). Cane weight was recorded as the weight of defoliated canes harvested at physiological maturity (when the hilum of the grains turns black) and expressed in grams. Juice was extracted from the defoliated canes using electric motor crusher and the volume was measured using a calibrated cylinder and expressed in milliliters (ml). Juice extraction per cent was computed as [(Juice volume/Cane weight) × 100]. Extracted juice from each of the canes harvested from tagged plants was fermented and distilled at 85^0C. The resulting ethanol was measured calorimetrically which was then converted into milliliters (ml) per plant of absolute alcohol ml (ml).

The mean values of data recorded on these five randomly selected plants were subjected to statistical analysis. Mid parent heterosis of (A×R) and (B×R) crosses for each of the trait was estimated (Turner, 1953; Hayes *et al.* 1955) as: [(F_1-MP)/MP × 100]. The differences in mid parent heterosis between (A×R) and (B×R) crosses was estimated. The significance or otherwise of differences between (A×R) and (B×R) crosses was tested using critical difference computed based on error mean squares of combined analysis of variance (ANOVA) of (A×R) and (B×R) crosses and significant differences was considered as evidence for cytoplasmic effects.

RESULTS AND DISCUSSION

Significant mean squares due to parents and hence their hybrids (A×R) and (B×R) for all the characters justify the selection of the parents involved in the present study. Presence of an average level of heterosis for all the traits was evident from the significant mean squares due to parents *vs*. hybrids.

Occurrence of economically viable heterosis will ultimately determine the use of CMS-based hybrids. In general, midparent heterosis of male-sterile and male-fertile based hybrids differed significantly in majority of the nuclear genetic backgrounds for most of the traits. Significant cytoplasmic effects were evident in five genetic backgrounds for mean cane weight, and in four genetic backgrounds for juice volume and only in one nuclear genetic background for mean cane height as indicated by significant differences in midparent heterosis between (A×R) and (B×R) crosses. However, the direction and magnitudes of differences in mid parent heterosis between (A×R) and (B×R) crosses varied with the trait as well as nuclear genetic background of the crosses. For example, while (A×R) crosses (ICSA 38 × ICSV 700, ICSA 324 × E 36-1, ICSA 500 × ICSV 700, ICSA 631 × ICSV 111, ICSA 731 × SEREDO) manifested higher mid parent heterosis than their counterpart (B×R) crosses, the reverse was true in three nuclear genetic backgrounds (ICSB 38 × ICSV 111, ICSB 631 × SEREDO and ICSB 84 × SEREDO). In another instance, (B×R) crosses manifested higher midparent heterosis than (A×R) crosses in a few other nuclear genetic backgrounds such as ICSB 731× E 36-1, ICSB 38 × E 36-1, ICSB 84× E 36-1 and ICSB 84× SEREDO for juice yield. In yet another instance, (A×R) crosses exhibited higher mid parent heterosis than (B×R) crosses in some of the nuclear genetic backgrounds such as ICSA 500 × ICSV 111, ICSA 38 × SEREDO and ICSA 731 × ICSV 700 for juice yield; the reverse was true in a few other nuclear genetic backgrounds such as ICSB 731× E 36-1, ICSB 38 × E 36-1, ICSB 84× E 36-1 and ICSB 84× SEREDO for juice yield. For juice extractability, a few (A×R) crosses manifested higher mid parent heterosis in some of the nuclear genetic backgrounds such as ICSA 84 × E 36-1, ICSA 631 × SEREDO and ICSA 324 × ICSV 700 than their counter part (B×R) crosses. On the contrary, (B×R) crosses manifested higher mid parent heterosis than (A×R) crosses in a few other nuclear genetic backgrounds such as ICSB 731 × ICSV 111, ICSB 84 × SEREDO, and ICSB 731× E 36-1 for juice extraction per cent. For ethanol yield, the end product of sweet sorghum juice a few (A×R) crosses manifested higher mid parent heterosis in some of the nuclear genetic backgrounds such as ICSA 38 × E 36-1, ICSA 324 × E 36-1 and ICSA 731 × SEREDO than their counter part (B×R) crosses. On the contrary, (B×R) crosses manifested higher mid parent heterosis than (A×R) crosses in a few other nuclear genetic backgrounds such as ICSB 731 × E 36-1, ICSB 84 × E 36-1 and ICSB 324 × ICSV 700 for ethanol yield per plant. In all the instances, the differences in mid parent heterosis between (A×R) and (B×R) crosses were small enough to have any practical significance between two hybrid mean performances for any of the traits investigated. Thus, where cytoplasmic effects were detected, there was no definite trend favoring any particular cytoplasm with respect to mid parent heterosis for any of the trait investigated. The present findings are in congruence with those reported by Young and Virmani (1990) and Faiz *et al.* (2007) in rice, Ramesh *et al* .(2006) in sorghum, Kumar and Sagar (2010 and 2009) in pearl millet

Table 1 : Analysis of variance for ethanol yield and its contributing traits in parents and hybrids of sweet sorghum

Source of variation	df	Mean sum of squares									
		Mean cane height (cm)		Cane weight (g/plant)		Juice volume (ml/plant)		Juice extraction (%)		Ethanol yield (ml/plant)	
		(A × R)	(B × R)	(A × R)	(B × R)	(A × R)	(B × R)	(A × R)	(B × R)	(A × R)	(B × R)
Replication	1	543.24	301.98	1236.76	420.01	36.76	191.11	56.32	7.34	0.013	0.27
Entries	33	7314.64**	6799.61**	42586.11**	41801.05**	8629.61**	6878.95**	257.47**	138.62**	46.16**	19.52**
Hybrids	23	5786.13**	5316.05**	35474.3**	32318.22**	8140.15**	5554.05**	321.3**	170.63**	52.57**	18.32**
Parents	9	9173.61**	9173.61**	40961.0**	40961.49**	4679.11**	4679.11**	68.65**	68.65**	8.95**	8.9**
Parents Vs. hybrids	1	25739.56**	19555.38**	220779.5**	267462.04**	55441.56**	57150.22**	488.56**	32.05	233.69**	142.35**
Error	33	722.6	227.32	503.46	608.84	528.52	265.81	18.27	18.43	0.88	0.93

* and ** Indicate significance of value at P=0.05 and 0.01, respectively

Table 2: Estimates of mid parent heterosis of (A×R) and (B×R) crosses for ethanol yield and its contributing traits in sweet sorghum

Crosses	Mean cane height (cm)			Mean cane weight(g/plant)			Juice volume(ml/plant)			Juice extraction per cent			Ethanol yield (ml/plant)		
	(A × R)	(B × R)	Diff	(A × R)	(B × R)	Diff	(A × R)	(B × R)	Diff	(A × R)	(B × R)	Diff	(A × R)	(B × R)	Diff
ICS 38 × E36-1	84.65**	89.98**	-5.33	74.73**	66.67**	-141.94**	84.75*	133.18**	-48.43	-16.08	-8.5	-7.58**	157.46**	-5.07	162.53**
ICS 38 × SEREDO	15.39	43.53**	-28.14	44.22**	-40.25**	84.47**	76.32**	27.63	48.69	32.17**	15.63	16.54**	70.92*	3.91	67.01**
ICS 38 × ICSV 700	69.9**	73.54**	3.84	49.29**	106.4**	42.89	69.72**	56.57**	12.95	27.21*	27.58*	-0.37	99.28**	94.79**	4.49**
ICS 38 × ICSV 111	61.31**	51.48**	9.83	-33.68**	17.68**	-51.36	43.85**	30.77**	13.08	86.95**	16.3	70.65**	70.31**	59.39**	10.92**
ICS 84× E36-1	5.22	23.19	-17.97	-9.98	120.29**	-130.27**	14.63**	18.78**	-4.15	98.23**	4.92	93.31**	33.74	154.14**	-120.4**
ICS 84 × SEREDO	8.51	65.67**	-57.16	-22.62**	6.17	-28.79	0.7	80.42**	-79.72	2.73	41.74**	-39.01**	0.1	-1.35	1.45
ICS 84 × ICSV 700	69.48**	2.81	66.67*	66.75**	33.5**	33.25	54.08**	33.91	10.17	73.15**	40.79**	32.36**	89.92**	61.34**	28.58**
ICS 84 × ICSV 111	35.96**	43.32**	-7.36	73.41**	72.49**	0.92	88.05**	92.83**	-4.78	2.92	-20.59*	23.51**	39.49**	29.95**	9.54**
ICS 324× E36-1	66.90**	27.57*	39.33	36.52**	67.86**	-31.34	34.8	89.01**	-54.21	-19.15**	-37.46**	18.31**	60.71**	-32.74	93.44**
ICS 324 × SEREDO	-0.06	-2.43	2.37	17.66**	25.58**	-7.92	27.12	66.10**	-38.98	1.51	8.41	-6.90**	1.6	28.72	-27.12**
ICS 324 × ICSV 700	52.92*	58.59**	-5.67	18.35**	36.5**	-18.15	28.9	67.44**	-38.54	40.26**	-6.86	47.12**	-0.61	93.65**	-94.26**
ICS 324 × ICSV 111	29.92*	33.5**	-3.58	14.87**	40.99**	-26.12	69.82**	59.30**	10.52	15.82	11.71	4.11*	117.30**	92.89**	24.41**
ICS 500 × E36-1	4.0	32.53**	-28.53	56.72**	109.18**	-52.46	25.1	91.51**	-66.41*	-4.11	-16.04*	11.93**	97.04**	84.63**	12.41**
ICS 500 × SEREDO	56.11**	36.67**	19.44	59.4**	77.74**	-18.34	10.59**	8.24**	22.35	-2.57	-18.17	15.6**	22.71**	31.68**	-8.97**
ICS 500 × ICSV 700	68.11**	30.45**	37.66	98.51**	89.75**	8.76	14.63**	31.36**	-16.73	-3.34	4.07	-7.41**	81.97**	81.66**	0.31
ICS 500 × ICSV 111	28.76**	29.21**	-0.45	43.08**	51.82**	-8.74	14.01**	16.55	-2.54	13.07	-3.73	16.8**	48.50**	32.38**	16.12**
ICS 631× E36-1	-4.99	-21.56*	16.57	18.92**	17.3	1.62	42.77	36.62*	6.15	-2.5	-17.00*	14.5**	-0.58	18.73**	-18.15**
ICS 631 × SEREDO	-23.71*	0.14	-23.85	5.54	50.81**	-45.27	1.48	72.41**	-70.93*	16.43	-21.2**	37.71**	45.52	79.31**	-33.79**
ICS 631 × ICSV 700	-8.66	12.69	-21.35	38.17**	33.20**	4.97	55.81*	52.41**	3.4	21.51*	14.31	7.20**	84.15**	82.37**	1.78*
ICS 631 × ICSV 111	12.06	5.54	6.52	31.14**	32.46**	-1.32	36.33**	40.51**	-4.18	-8.62	-7.98	-0.64	79.62**	55.33**	24.29**
ICS 731× E36-1	-6.4	38.26**	-44.66	53.16**	56.70**	-103.54**	31.62	147.81**	-116.19**	-16.73*	11.52	-28.25**	-32.2	193.46**	-225.61**
ICS 731 × SEREDO	-25.35*	-29.74**	4.39	3.51	-0.39	3.9	42.13*	8.94	33.19	10.05	-2.53	12.58**	52.67**	15.38	37.29**
ICS 731 × ICSV 700	34.39*	-9.68	44.07	59.57**	17.76*	41.81	25.66	-36.21*	61.87*	2.59	1.26	1.33	19.32**	-38.14	-18.82**
ICS 731 × ICSV 111	10.32	-34.3**	44.62	37.74**	-36.23**	73.97*	25.36*	61.22**	-35.86	-9.99	61.78**	-71.77**	-14.42	83.33**	-97.75**
S.E.±	23.28	13.05		9.43	21.36		19.9	14.11		3.7	3.71		0.81	0.83	
C.D. @ P = 0.05			61.14			57.77			58.83			3.45			1.72
C.D. @ P = 0.01			78.65			74.31			75.68			4.43			2.22

*and ** Indicate significane of value at P=0.05 and 0.01, respectively and Gill *et al.* (2007) in cotton.

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