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RESEARCH PAPER

Effect of male sterility inducing cytoplasm on hybrid mean performance for bioenergy traits in sweet sorghum [*Sorghum bicolor* (L.) Moench]

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Abstract : Influence of male sterility inducing cytoplasm on mean performance 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), and Bangalore. Presence of significant cytoplasmic differences in hybrid means performance for mean cane height, mean cane weight, juice yield, juice extraction per cent and ethanol yield. No definite trend favouring any particular cytoplasm was observed.

Key Words : Male sterility inducing cytoplasm, Cytoplasmic difference, Sweet sorghum, Bioenergy

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INTRODUCTION

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 report in literature on the effects of male sterility inducing cytoplasm on mean performance of hybrids on bioenergy traits in sweet sorghum. In the present study, the mean 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.

MATERIALS AND METHODS

The material consisted 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

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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^{0}C. 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. Mean performances of (A×R) and (B×R) crosses for each of the trait was estimated. The differences in mean performances 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 were 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. The results clearly demonstrated the presence of significant cytoplasm differences in hybrid mean performance for mean cane height, cane weight, mean juice yield, juice extraction per cent and ethanol yield when average performance of male sterile and male fertile based hybrids as separate groups were examined (Table 1). These results are in conformity with those reported by Moran and Rooney (2003) and Ramesh *et al*. (2006) in sorghum. However, a perusal of pair-wise hybrids mean performances indicated significant cytoplasm differences in four nuclear genetic background for mean cane weight, four nuclear genetic background for extraction per cent and in three nuclear genetic background for ethanol yield per plant, only in one nuclear genetic background for mean cane height and in only one nuclear genetic background for juice yield as indicated by significant differences between (A×R) and (B×R) crosses. However, the magnitude and direction of the cytoplasmic differences varied with the trait and the nuclear genetic background for traits whose expression was significantly influenced by cytoplasm. For example, the hybrids such as (ICSA 631 × ICSV 700, ICSA 631 × ICSV 111, ICSA 731 × ICSV 700, ICSA 324 × ICSV 111, ICSA 84 × SEREDO) manifested higher mean performance than their counterpart (B×R) crosses, the reverse was true in three nuclear genetic backgrounds (ICSB 631 × E 36-1, ICSB 38 × ICSV 700 and ICSB 731 × E 36-1, ICSB 84 × E 36-1) for mean cane height. In another instance, (A×R) crosses manifested higher mean performance in a few nuclear genetic backgrounds such as ICSA 631× SEREDO, ICSA 500 × ICSV 700, ICSA 500× E 36-1 and ICSA 500 × ICSV 111, the reverse was true in (B×R) crosses such as ICSB 631× ICSV 111, ICSB 324 × ICSV 700 and ICSB 324 × E 36-1 for mean cane weight. In yet another instance, (B×R) crosses exhibited higher mean performance than (A×R) crosses in some of the nuclear genetic backgrounds such as ICSB 631 × ICSV 700, ICSB 38 × ICSV 700 and ICSB 324 × ICSV 700 for juice yield; the reverse was true in a few other nuclear genetic backgrounds such as ICSA 38 × E 36-1, ICSA 731 × ICSV 700, ICSA 324× SEREDO and ICSA 324 × ICSV 111 for juice yield. For juice extractability, a few (A×R) crosses manifested higher mean performance in some of the nuclear genetic backgrounds such as ICSA 631 × ICSV 111, ICSA 38 × ICSV 700, ICSA 324 × SEREDO and ICSA 500 × ICSV 700 than their counter part (B×R) crosses. On the contrary, (B×R) crosses manifested higher mean performance than (A×R) crosses in a few other nuclear genetic backgrounds such as ICSB 631 × ICSV 700, ICSB 38 × SEREDO, and ICSB 500 × ICSV 700 for juice extraction per cent.

For ethanol yield, the end product of sweet sorghum juice a few (A×R) crosses manifested higher mean performances in some of the nuclear genetic backgrounds such as ICSA 38 × ICSV 111, ICSA 731 × ICSV 700 and ICSA 324 × ICSV 111 than their counter part (B×R) crosses. On the contrary, (B×R) crosses manifested higher mean performances than (A×R) crosses in a few other nuclear genetic backgrounds such as ICSB 631 × ICSV 111, ICSB 324 × SEREDO and ICSB 500 × ICSV 700 for ethanol yield per plant. In all the instances, the differences in mean performances between (A×R) and (B×R) crosses were small enough to have any practical significance between two hybrid groups for any of the traits investigated. Thus, where cytoplasmic effects were detected, there was no definite trend favouring any particular cytoplasm

Table 1: Mean performance of (A×R) and (B×R) hybrids and their difference for ethanol yield and its contributing traits in sweet sorghum

Sr. No.	Crosses A/B	Mean cane height (cm) Crosses (A×R)	(B×R)	Difference	Mean cane weight (g/plant) Crosses (A×R)	(B×R)	Difference	Mean juice yield (g/plant) Crosses (A×R)	(B×R)	Difference	Juice extraction (%) Crosses (A×R)	(B×R)	Difference	Ethanol yield (ml/plant) Crosses (A×R)	(B×R)	Difference
1.	ICS 631 × ICSV 700	170.4	126.4	44	283.5	363.8	80.3	104	137.5	33.5	36.67	39.99	3.32	4.34	1.74	2.6
2.	ICS 631 × SEREDO	172.2	191.2	19	349.5	165.5	184.0*	137.5	66.5	71	40.99	40.24	0.76	5.17	3.3	1.88
3.	ICS 631 × E36-1	105	174.2	69.2	326	395.5	69.5	135	164	29.5	39.43	42.56	3.13	12.2	7.96	4.24
4.	ICS 631 × ICSV 111	283.2	238	45.2	172	406	234*	163.4	165.5	2.1	61.93	40.86	21.07*	1.58	5.75	4.16
5.	ICS 38 × ICSV 700	100.6	136.4	35.8	137.5	261.5	124	86.5	121.1	34.6	68.46	46.82	21.63*	1.44	2.3	0.86
6.	ICS 38 × SEREDO	180	170.4	9.6	207	284	77	76	128	52	36.7	45.14	8.44	2.76	1.82	0.94
7.	ICS 38 × E36-1	109.6	109	0.6	236	169	67	101.5	61	40.5	50.08	42.47	7.6	4.7	4.27	0.43
8.	ICS 38 × ICSV 111	230	230	0	555.5	602	46.5	240.5	203	37.5	43.3	33.41	9.88	15.89	7.24	8.65**
9.	ICS 731 × ICSV 700	174	141.4	32.6	257	269.5	12.5	95	55.5	39.5	36.95	23.08	13.87	7.73	1.88	5.84*
10.	ICS 731 × SEREDO	129.8	160.8	31	356.5	330.5	26	115.5	101	14.5	32.36	29.41	2.96	5.27	5.85	0.58
11.	ICS 731 × E36-1	143.2	191.2	48	230.5	323.5	93	100	112	12	46.81	34.41	12.4	3.58	6.05	2.48
12.	ICS 731 × ICSV 111	191.4	228.4	37	475	483	8	212.5	232.8	20.3	44.98	48.21	3.22	11.14	11.42	0.28
13.	ICS 324 × ICSV 700	126	149.2	23.2	189	319	130	85.5	129.5	44	46.37	40.61	5.77	4.26	5.24	0.98
14.	ICS 324 × SEREDO	206	196	10	426	475	49	164.5	109.5	55	38.45	22.33	16.12	5.51	10.34	4.83
15.	ICS 324 × E36-1	97.6	194.6	97	287	354	67	108.5	132.5	24	38.27	36.71	1.56	7.23	2.88	4.34
16.	ICS 324 × ICSV 111	214	132	82.0**	490.5	393.5	97	259	173.5	85.5*	51.8	44.11	7.69	24.44	8.86	15.57**
17.	ICS 84 × ICSV 700	152.6	138	14.6	286	225.5	60.5	117.5	87.5	30	41.25	38.51	2.73	1.65	2.86	1.21
18.	ICS 84 × SEREDO	169.6	125.8	43.8	274	263	11	104.5	77.5	27	38.67	29.52	9.14	4.6	5.43	0.83
19.	ICS 84 × E36-1	112.2	185.6	73.4	283	321	38	127	137	10	45.73	43.02	2.7	8.38	5.37	3
20.	ICS 84 × ICSV 111	252.6	218.2	34.4	547.5	453	94.5	219	182.8	36.2	40.07	40.35	0.28	7.68	11.07	3.38
21.	ICS 500 × ICSV 700	124	211	87	250.5	528.8	278.3**	100.5	282	181.5	39.79	53.29	13.5	1.12	10.41	9.29
22.	ICS 500 × SEREDO	148.8	144.4	4.4	292	319.5	27.5	111.5	121.5	10	37.79	37.9	0.11	4.03	5.42	1.39
23.	ICS 500 × E36-1	101.6	128	26.4	356.5	185	171.5*	137	65	72	38.02	34.71	3.31	0.87	1.12	0.25
24.	ICS 500 × ICSV 111	180	158	22	429	175	254.0**	155	197.5	42.5	38.21	58.64	20.43*	5.29	3.25	2.05
C.D. (P=0.05)				60.77			168.36			81.41			20.38			5.06
C.D. (P=0.01)				80.52			223.08			107.87			27.01			6.21

* and ** indicate significance of values at P=0.05 and 0.01, respectively

Table 2 : 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 values at P=0.05 and 0.01, respectively

with respect to mean performances for any of the trait investigated. Significant cytoplasmic difference/effects on hybrid mean performances with varying magnitude as a function of nuclear genetic backgrounds were also reported by Young and Virmani (1990) and Faiz *et al.* (2007) and Ramesh *et al*. (2006) in sorghum and Tuteja *et al*. (2008) and Gill *et al.* (2007) in cotton, Kumar and Sagar (2010 and 2009) in pearl millet.

Differential trends in cytoplasm differences in some of the nuclear genetic backgrounds of hybrids could be attributed to the interaction of cytoplasm with nuclear genes of A, B lines and of R-lines in such hybrids. However, the distinction between cytoplasm effects and cytoplasm nuclear interactions is complicated. This is not surprising considering that the very differentiation of CMS types is primarily based on the interaction of genes present on mitochondrial DNA and the corresponding nuclear restorer genes (Ramesh *et al.* 2006).

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