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MULTILOCATIONAL EVALUATION OF SWEET-STALK SORGHUM GENOTYPES FOR ALTERNATE USES [1]

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ABSTRACT

We evaluated 100 sweet-stalk sorghum genotypes (G) for stalk sugar percentage (Brix reading), grain and biomass yields and other agronomic traits during 1987. We used the following three environments (E) for evaluation: Anantpur (shallow soil and low rainfall), Parbhani (adequate rainfall), and Patancheru (postrainy season; irrigated). Significant effects of G, E and G x E interactions were observed for all the characters studied. Most of the genotypes belonged to medium maturity group (108 to 150 days). Genotype IS 6962, IS 7555, IS 8801, IS 18162, IS 18164, IS 19674 and IS 21005 gave high grain (1.34 - 2.49 t/ha) and biomass yields (13 to 20.6 t/ha) across environments; these lines may be suitable for breeding dual-purpose sorghums. IS 131, IS 11498, IS 15102, IS 19674, IS 11152 showed consistently high stalk sugar (17-21%) and biomass (13-21 t/ha) in all three environments; they could be used as parents for breeding sweet-stalk sorghums. IS 776, IS 18162 and IS 18184 showed appreciable grain yield and high percentage of stalk sugar and the last two accumulated high biomass; these lines may be useful as parents for breeding multipurpose sorghums. IS 3940 was early, and showed least differences (± 2.9) in time to flower across all the three envriónments, and showed high stalk sugar (15.5%) levels except at Anantpur.

Key words : germplasm, alternate uses, grain and biomass productivity

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] exhibits wide geographic and climatic adaptation. It has relatively low water and fertilizer requirements (Nathan, 1978), and has high yield potential in the semi-arid tropics. In recent years there is increasing change in consumer preference to rice and wheat. So the demand for sorghum as food grains is decreasing. Hence, there is an urgent need to develop sorghums for alterna[illegible] (Ghanekar *et al.*, 1988; Lipinisky *et al.*, 1978). Increasing

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demand for fodder is also favouring production of dual purpose sorghums. Sweet sorghum lines accumulate high level of sugar in their stalks, and produce high biomass. There have been several studies in Brazil and in the USA on sweet sorghums as a source of fermentable sugars for ethanol production (Miller and Creelman, 1980; Keshar *et al.*, 1987).

Juice from sweet stalks can also be used for production of jaggary, glucose and fructose. It can also be used to prepare pops, papad, baby food and many bakery products (Subramanian and Jambunathan, 1989). Technological aspects ' sweet sorghum utilization and the scope for breeding sorghum for multiple uses have already discussed during the two symposia at Parbhani (Ingle *et al.*, 1987) and at Bulawayo(SADCC/ICRISAT, 1988). Thus, we need to evaluate germplasm in a wide range of target environments and recommended a small number of genotypes as parents for crossing. Further, we need to distinguish parents for breeding exclusively for sweet stalks, and for dual-purpose sorghum (for grain and fodder with sweet stalk). In this paper we have reported the results from the tirals conducted at three locations in semi-arid India and have suggested the use of specific lines for breeding sorghums for different alternate uses.

MATERIALS AND METHODS

One hundred genotypes of sweet-stalk of sorghum were evaluated at the following three locations (Environments :E) : Anantpur, Parbhani (both during 1987 rainy season), and at Patancheru (1988 postrainy season). A plot size of 2 rows of 4 m length, and a randomized block design with three replications were used. Seeds were hand-dibbled at 0.12 m spacing at Anantpur and Parbhani and machine-sown at Patancheru. The sowing date was May 22, 1987 at Parbhani, June 29, 1987 at Anantpur, and December 1, 1987 at Patancheru. Intensive plant protection measure were taken to keep the crops free from insects, diseases, and weeds. The times of 50% flowering and physiological maturity were recorded. At harvest maturity (one week after physiological maturity), plant height (m), sugar percentage (in the basal 3 modes of the stock brix reading), and grain yield were determined. Field-dried stover was weighed, and biomass was estimated as the total of stover and panicle weights. From these, the following were computed: duration of grain-filling period(d), harvest index (percentage), per day grain or biomass productivity (grain or biomass divided by days to physioogical maturity; Kg $ha^{-1}d^{-1}$).

RESULTS AND DISCUSSION

Conditions for crop growth were good at Parbhani (501 mm during the first month, and 120 mm during the third month from sowing; deep Vertisol) and Patancheru (regularly irrigated at 10 days interval). The crop suffered from drought at Anantpur where the soils are shallow and sandy. Only 9 mm of rains fell from sowing to 47 days. Subsequently there was a drought spell of 18

Table 1. Characteristics of sweet stalk sorghum evaluated at Anantapur, Parbhani (Rainy season, 1987) and Patancheru (Postrainy season, 1987) (Total of 100 genotypes.)

		Yield ($t\ ha^{-1}$)		Time to flower (d)	Phy. Mat (d)	Plant height (m)	Stalk sugar (%)	HI (%)	Per day productivity ($kg\ ha^{-1}\ d^{-1}$)	
		Grain	Biomass						Grain	Biomass
Anantapur	Min.	0.0	1.3	61	93	0.8	0.0	0.0	0.0	8.3
	Max.	2.6	5.7	147	179	3.9	21.9	61.2	19.6	39.1
	Mean	0.9	3.0	120	152	2.3	12.6	28.0	6.5	20.6
Parbhani	Min.	0.0	5.9	63	106	0.9	10.4	0.1	0.1	40.3
	Max.	0.6	35.9	152	194	3.9	21.5	4.0	4.4	192.7
	Mean	0.8	17.8	106	151	3.0	16.6	0.6	0.6	11.1
Patancheru	Min.	1.4	10.3	58	94	0.9	0.0	4.2	11.2	99.7
	Max.	7.4	56.7	100	130	3.1	24.8	29.7	68.2	492.7
	Mean	3.6	24.2	71	108	2.0	16.8	15.9	33.4	223.5
	Mean	1.53	15.1	99	137	2.5	15.4	14.9	13.5	121.7
	SE±	1.03	9.7	2.9	3.0	8.8	1.5	1.8	0.7	7.3
	CV(%)	20.2	19.4	8.7	6.6	10.7	28.6	36.2	15.5	18.0

Table 2 Stalk sugar (%, brix reading), grain and biomass yields, and time to flower in selected lines suggested for breeding dual purpose sorghums. Data represents means across three test environments (see Table 1 for SE±, CV%).

Genotype	Brix (%)	grain ($t\ ha^{-1}$)	Biomass ($t\ ha^{-1}$)	Flower (d)
IS 776	21.0	1.83	13.0	90
IS 6962	20.6	1.45	14.5	92
IS 7555	17.8	1.77	18.6	121
IS 9901	18.2	2.49	19.8	92
IS 18162	21.1	1.32	20.6	87
IS 18164	18.8	2.03	16.3	89
IS 19674	18.2	1.34	18.5	92
IS 20503	13.9	2.13	18.6	82
IS 20888	12.9	2.19	16.3	105
IS 21005	16.8	2.48	13.8	96
Mean	15.4	1.53	16.0	95
Min.	5.9	0.48	7.2	69
Max.	21.1	3.16	26.6	132

days; following this 120, and 155 mm of rainfall were received during the third and fourth months. The Genotypes (G), environments (E), and G X E interaction effects were significant for all the characters studied (Table 1).

Time to flower and physiological maturity : Mean time to flower was 71 days at Patancheru, 106 days at Parbhani and 120 days at Anantpur (Table 1). G X E interactions were significant, and accounted for 36% of total sums of squares (SS). However, amongst the genotypes studied, IS 3940 showed minimum variation in flowering time across different environments. It flowered at 64, 70 and 72 days after sowing at Patancheru, Parbhani and Anantpur, respectively. It also showed moderate levels of stalk sugars (see below). Time to physiological maturity was positively and strongly correlated (+ 0.994*, P < 0.001) with time to flower (Table 4). Duration of grai filing phase was on the average 38 days, but reduced by 5 days under drought stress at Anantpur (Table 1).

Grain and biomass yields, harvest index and per day productivity : Maximum grain yield was recorded at Patancheru(mean 7.4 t ha^{-1} in IS 18164). Mean biological yield was also highest at Patancheru (36.7 t/ha^{-1} for IS 1333, stover was sun-dried in the field). Drought reduced both grain and biomass yields at Anantpur (Table 1). IS 12639 totally failed to yield any grain in this environment because of failure of panicle exertion due to late flowering (> 100 days). Across environments, G X E interactions accounted for 10 and 18% of SS, respectively for grain and biomass. The G X E interactions were significant for this trait also. Hence, it is difficult to select common genotypes for all environments. However, some genotypes like IS 6992, IS 7555, IS 9901, IS 18162, IS 18164 and IS 19674 showed high grain and biomass yields, and high stalk sugar percentages across locations (Table 2). IS 20503 and IS 20868 also yielded more than 2.0 t ha^{-1} of grain, with above-average stalk sugar levels except at Anantpur; IS 20888, being late, also yielded 16.3 t ha^{-1} of biomass, on the average. We suggest the use of IS 20503 and IS 20888 lines in breeding for dual purpose sorghums. Harvest index was low at all locations (overall mean = 15%), but it was extremely low at Anantpur where the grain yields were poor. Per day grain and biomass productivity paralleled the trends in grain and biomass yields (Table 1).

Plant height :Genotypic differences in plant height were highly significant. They accounted for 48% of SS, while E, and G X E interactions accounted for 33 and 13%, respectively. Maximum height was observed at Parbhani (3.07 m in IS 12639; 3.10 m in IS1098). Drought reduced plant height significantly at Anantpur.

Stalk sugar : Highest sugar percentage was observed at Patancheru (16.8%) and the lowest at Anantpur (12.6%). G X E interactions were significant, and accounted for 38% of SS, highest among the character studied. Also, 29% of the SS were due to experimental error. This suggests, that the sampling technique for sugar estimation needs further refinement in

Table 3. Stalk sugar percentages at each of the three test environments, and the across-environment mean data on time to flower, grain and biomass yields of the lines suggested for breeding **sweet-stalk sorghums**.

Genotype	Sugar (%) at Anantapur	Sugar (%) at Parbhani	Sugar (%) at Patancheru	Mean of three locations: Sugar (%)	Grain yield (t ha^{-1})	Biomass (t ha^{-1})	Flower (d)
Lines with high stalk sugar across all locations:							
IS 131	15.8	18.8	16.5	17.0	1.46	9.0	71
IS 11152	17.7	18.1	17.0	17.6	2.36	21.2	97
IS 11496	18.9	19.5	23.6	20.7	1.10	12.1	83
IS 15102	17.2	16.3	16.5	16.7	1.34	13.8	93
IS 776	20.8	19.5	22.6	21.0	1.83	13.0	90
IS 18162	21.1	18.5	23.6	21.1	1.32	20.6	87
IS 18164	16.9	19.8	19.8	18.8	2.03	16.3	89
IS 19674	19.6	17.3	19.5	18.8	1.34	18.5	92
Early across all locations with moderately high levels of stalk sugar:							
IS 3940	7.3	14.4	15.5	12.4	1.61	10.1	69
High grain yield with moderately high levels of stalk sugar:							
IS 20503	8.2	16.1	17.3	13.9	2.13	8.6	82
IS 20888	4.2	16.0	18.5	12.9	2.19	16.3	105
Mean	12.7	16.7	16.4	15.4	1.53	15.1	99
SE±	7.1	1.6	0.6	1.5	1.03	9.7	2.9
CV (%)	55.6	17.0	43.6	28.6	20.2	19.4	8.7

Table 4. Correlations between different traits of sweet sorghum studied.

	1	2	3	4	5	6	7
1. Grain yield	1.000						
2. Biomass	-0.108	1.000					
3. Time to flower	-0.395**	0.492**	1.000				
4. Time to phy. mat	-0.402**	0.498**	0.994**	1.000			
5. Plant height	-0.372**	0.536**	0.777**	0.789**	1.000		
6. Sugar (%)	0.050	0.130	-0.114	0.105	0.091	1.000	
7. Harvest Index (%)	0.643**	-0.654**	-0.667**	-0.674**	-0.707**	-0.055	1.000

** = significant at 1% level of probability

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future studies. Neverthless some geenotypes like IS 131, IS 776, IS 11496, IS 15102, IS 19674 and IS 11152 showed minimal differences (± 1.5) in brix readings (2.2 -3.0%) across environments, and were also agronomically superior (Table 2). Such stable genotypes across environments should be selected for use as parents in breeding sorghums for multiple uses.

Correlations : Grain yield was significantly and negatively correlated with days to flowering; days to physiological maturity and plant height (Table 4). The HI was positively correlated with grain yield, but negetively with biomass. Correlation between biomass and grain yield was not significant(Table 4). With the wide range of materials used in this study, it was possible to select for hig' biomass with reasonably high level of grain yield. Such lines can be used as parents for breeding dual or multi-purpose sorghums. The correlations between biological yield and other variables showed opposite trends to those with grain yield. Generally late maturing tall plants showed high biomass, as expected. Hence, lines can be selected based on the effective length of the season at respective sites (Seetharama *et al.*, 1988); if this is not known, then one can choose early lines such as IS 3940 showing least differences in flowering across environments. Stalk sugar percentage had no relationship with the characters under study. We noted earlier the absence of relationships beetween brix readings and various primary variables studied (Seetharama *et al.* 1987, Choudhari *et al.*, 1987). However, the brix reading was strongly correlated with per day biological productivity in all the environments (P > 0.01). This would suggest the simultaneous improvement for both biomass productivity and sweet stalks is feasible. When the correlations were studied seperatly with the data from each test environment, the relationship between traits studied were similar to what has been reported above. This observation encourages us to confine initial breeding activities to any one environment (Parbhani or Patancheru). Advanced progenies, however, need to be tested across all target regions.

Conclusions : Sorghum line with combinations of high biomass, stalk sugar and resonable grain yield can be selected. We suggest the use of following lines for use in breeding : (a) : for **dual-purpose sorghums** : IS 6962, IS 7555, IS 20503, and IS 21005 : (b) : for **sweet stalk sorghums** : IS 131, IS 11496, IS 15102, IS 19674, IS 18162 and IS 18164. Genotype IS 3940 showed very little difference in time to flowering across three different environments. It can be used wherever earliness is desirable. We suggest the use of favourable environments for initial selection. Advanced testing may be carried out in diverse environments.

REFERENCES

Choudhari, S.D., D.N.Kulkarni, R.D. Chundurwar and N.G.P. Rao. 1987. Evaluation and selection of diverse sorghum genotypes for high energy grain and biomass production.

Pages 160-168 In technology and Applications for Alternate Uses of Sorghum: Proceedings of National Seminar held on 2-3 Feb 1987, Parbhani. M.A.U., Parbhani - 431 402, India.

Ghanekar, A.R., C.D.Basarkar and N.Nimbkar.1988. Potential and practice relating to sorghum as a source of sugar in parts of India. In Summary Proceedings, On uses of Sorghum and Millets, International Workshop, 8-12 Feb 1988, Bulawayo, Zimbabwe. pp 27.(Available from ICRISAT, Patancheru, A.P., 502 304, India).

Ingle, U.M., D.N. Kulkarni and S.S. Thorat (eds.) 1987. Technology and Application for Alternate Uses of Sorghum. Proceedings of the National Seminar, 2-8 Feb 1987, Parbhani. M.A.U., Parbhani - 431 402, India. 210 pp.

Keskar, V.S., M.R. Shivade, M.B. Patil, R.B.Natu, D.G. Hapse, And S.J. Jadhav. 1987. Sweet sorghum as an important feed stock for ethanol production. Bhartiya Sugar 10: 7-24.

Lipinisky, E.S., D.R. Jackson, S. Kresovinch, M.F. Arthur and W.T. Lawhoru. 1979. Carbohyderate crops as a renewable source for fuel productions. Research report to Department of Energy No. BMI-2031, Vol. 1, Battele, Columbus, Ohio, USA. 82 pp.

Miller, F.R. and R.A.Creelman.1980. High energy sorghums and other possibilities for energy production. Alcohol Fuel Symposium Proceedings. Texas A & M University, College Station, TX, USA.

Nathan, R.A.1978. Fuels from sugar crops. Technical Information Center. U.S.D.O.E. Report 71, D. 22781. 137 pp.

SADCC/ICRISAT. 1988. Proceedings of the International Workshop on Policy, Practice and Potential Relating to Uses of Sorghum and Millet. 8-12 Feb 1988, Bulawayo, Zimbabwe. (Available from ICRISAT, Patancheru, A.P., 502 324, India)

Seetharama, N., K.E. Prasada Rao, V. Subramanian, and D.S. Murthy. 1987. Screening sweet stalk sorghums, and environmental effects on stalk sugar concentrations. Pages 169-179. In Technology and Applications for Alteernate Uses of Sorghum : Proceedings of the National Seminar held on 2-3 Feb 1987, Parbhani, M.A.U., Parbhani -431 402, India.

Seetharam, N., A.K.S. Huda, K.E. Prasada Rao, S. Sivramakrishnan, B. Srinivas, T. Pullaiah, and R.V. Vidyabhushanam. 1988. Need and scope for breeding sorghums for promoting whole plant utilization, and fitting different season-lengths using novel germplasm. Presentd at the Symposium on Sweet Sorghum Imporvement during XVIII Annual Workshop of AICSIP, 2-4 May 1988, C.S. Azad Univrsity of Agri. & Technology, Kanpur - 208 002 India : National Center for Research on Sorghum, Hyderabad 500003. 29 pp. (Limited distribution)..

Subramanian, V. and R. Jambunathan. 1989. Industrial products from sorghum. Presentd at the symposium on 'Current Status and Potential of Industrial Uses of Sorghum in Nigeria,' 4-6 Dec 1989. Kano, Nigria. Available from B & N Unit, ICRISAT Center, Patancheru, A.P. 502 324, India (Limited distribution).