



Studies on Genetic Variability and Character Association in Sweet Sorghum (*Sorghum bicolor* (L.) Moench)

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ABSTRACT

The genotypic and phenotypic coefficients of variation, heritability, genetic advance and the relationship between ethanol yield and its components were estimated in eleven genotypes of sweet sorghum. The genotypes exhibited considerable amount of variability for all the traits. The traits such as plant height, fresh stalk yield and grain yield exhibited high heritability estimates coupled with high genetic advance indicating that heritability of these characters was most likely due to additive gene effects. Correlation studies revealed that selection could be practiced for days to 50 per cent flowering, days to maturity, plant height, brix percent, total soluble solids, total sugar index, total biomass, fresh stalk yield and juice yield. Path coefficient analysis showed that plant height, total sugar index, juice yield and fresh stalk yield were the main contributors for ethanol yield. Hence, it was concluded that ethanol yield could be increased by improving plant height, total sugar index, juice yield and fresh stalk yield.

Key words : Correlation, Genetic advance, Heritability, Path analysis, Sweet sorghum Variability.

Sweet sorghum (*Sorghum bicolor* (L.) Moench) is a special purpose crop with sugar rich stalk, which is used for ethanol production. It is a potential raw material for production of ethanol that on blending with petrol is expected to meet the energy demand and address the environmental issues. Since, the sorghum stalks are harvested at physiological maturity stage of the crop, grain can also be harvested from the same crop making sweet sorghum as dual purpose crop (Reddy and Sanjana Reddy, 2003). Ethanol yield, which is a complex character is the sum total of contribution made by different yield attributing traits. Studies on genetic variability will help in developing a selection scheme to enhance the genetic potential of this crop. Although, genetic improvement for quantitative traits depends on nature and amount of variability present in existing material and heritability pattern of desirable characters, the knowledge on relative contribution of different yield components and their direct and indirect impact towards ethanol yield is of immense value in selection of superior genotypes. Therefore, the present investigation was undertaken to assess genotypic variability, heritability and genetic advance for ethanol yield and its components. Further, correlation and path analysis were carried out to understand the character association and the extent and nature of direct and indirect effects of component traits on yield.

MATERIAL AND METHODS

The present study comprised of eleven genotypes received from Directorate of Sorghum Research (DSR), Hyderabad and were evaluated in RBD replicated thrice during Kharif, 2010 at experimental farm of DSR, Rajendranagar, Hyderabad, Mahatma Phule Krishi Vidyapeeth, Rahuri and Centre for Plant Breeding and Genetics farm, Tamil Nadu Agricultural University, Coimbatore. Each entry was sown in two rows of 4m length with a spacing of 60 cm between rows and 15 cm between plants. The crop was raised as per recommended package of practices. Five competitive plants were selected at random from each replication for recording the observations on days to 50 per cent flowering, days to maturity, plant height (cm), brix per cent, total soluble solids (%), total sugar index ($t\ ha^{-1}$), total biomass ($t\ ha^{-1}$), fresh stalk yield ($t\ ha^{-1}$), juice yield ($l\ ha^{-1}$), juice extraction percent, grain yield ($t\ ha^{-1}$), and ethanol yield ($l\ ha^{-1}$). Genotypic and phenotypic coefficients of variation (GCV and PCV) were calculated as per Burton (1952). Heritability ($h^2_{(b)}$) and genetic advance as per cent of mean (GAM) were estimated as per Allard (1960). The genotypic and phenotypic correlation coefficients were calculated as suggested by Falconer (1964) and path coefficient analysis was done following Dewey and Lu (1959).

Table 1. Pooled analysis of variance of RBD for eleven parents of sweet sorghum over three locations.

Source of Variation	df	Mean sum of squares											
		DFF	DM	PH(cm)	Brix(%)	TSS(%)	TSI (t ha ⁻¹)	TB(t ha ⁻¹)	FSY(t ha ⁻¹)	JY(l ha ⁻¹)	JE(%)	GY(t ha ⁻¹)	EY(l ha ⁻¹)
Replications	2	32.03*	45.37*	206.25	2.28	0.14	0.02	4.81	27.45	1932439.50	16.80	509044.44***	3812.49
Locations	2	891.76***	3588.53***	66797.71***	68.84***	225.65***	0.61***	11097.94***	1686.91***	198139616.00***	2913.71***	12189.71	2345522.25***
Treatments	10	369.25***	383.26***	40725.74***	9.87***	12.14***	0.50***	1860.55***	909.93***	89951704.00***	59.97	1685735.25***	780883.06***
Error	80	9.87	13.95	1173.28	2.56	2.49	0.09	164.36	56.67	10425997.00	44.15	34387.27	105082.66

* Significant at 5% level; ** Significant at 1% level; *** Significant at 0.1% levels

DFF: Days to 50% flowering; DM: Days to maturity; PH: Plant height; TSS: Total soluble solids; TSI: Total sugar index; TB: Total biomass; FSY: Fresh stalk yield; JY: Juice yield; JE: Juice extraction; GY: Grain yield; EY: Ethanol yield.

RESULTS AND DISCUSSION

The analysis of variance revealed significant differences among the genotypes studied for all the 12 characters indicating the presence of genetic variability and furnished in Table 1. The range was highest for juice yield (3583 – 12011 l ha⁻¹) followed by ethanol yield (257 - 1017 l ha⁻¹), plant height (127 – 325 cm), total biomass (29 – 68 t ha⁻¹) and fresh stalk yield (24 – 52 t ha⁻¹) (Table 2). The wider range for ethanol yield and its components indicated more genetic variability, which is a pre-requisite in any breeding. The phenotypic variances were higher than the respective genotypic variances for all the traits studied (Table 2.) indicating that apparent variability in these characters may not only be due to genotypes but also due to environmental factors influencing the expression of these characters. Kachapur *et al.* (2009) also observed that PCV was higher than GCV for all the traits. Higher magnitude of PCV and GCV were noticed for plant height (29.31%, 26.04%), total sugar index (41.52%, 24.06%), total biomass (37.68%, 27.54%), fresh stalk yield (33.55%, 26.54%), juice yield (57.30%, 38.81%), grain yield (33.02%, 30.30%) and ethanol yield (66.00%, 42.61%) whereas PCV and GCV registered moderate and low values respectively for days to 50 per cent flowering (10.09%, 9.03%), brix per cent (10.96%, 5.38%), total soluble solids (13.59%, 7.46%) and juice extraction per cent (18.60%, 3.64%). For days to maturity both PCV and GCV values were low (6.84%, 5.91%). For juice yield high genetic variability was noticed by Sankarapandian *et al.* (1996).

As heritability in broad sense includes both additive and epistatic gene effects, it will be reliable only if accompanied by high genetic advance. The estimates of heritability in broad sense varied from 9 (low) for juice extraction per cent to 86% (high) for grain yield whereas the GAM speckled between 5.43% (low) and 57.28% (high) (Table 2). High heritability was found to be associated with high genetic advance for plant height (79%, 47.65%), fresh stalk yield (63%, 43.26%) and grain yield (84%, 57.28%) indicating that inheritance of these characters was most likely due to additive gene effects. Latha Chaudhary *et al.* (2001) for grain yield and Sankarapandian *et al.* (1996) for plant height, green stalk yield and juice yield reported similar results. High heritability coupled with moderate genetic advance was observed for the traits days to 50 per cent flowering (80%, 16.66%) and days to maturity (75%, 10.52%) indicating the role of both additive and non-additive gene action hence hybridization followed by selection would be

Table 2. Estimates of genetic parameters for 12 characters among 11 parents of sweet sorghum.

Character	Mean	Range	GCV (%)	PCV (%)	H ² _(b) (%)	GA at 5 %	GAM (5%)
Days to 50 Per cent Flowering	70	61 – 77	9.03	10.09	80	11.66	16.66
Days to Maturity	108	99 – 115	5.91	6.84	75	11.40	10.52
Plant Height (cm)	255	127 – 325	26.04	29.31	79	121.32	47.65
Brix Per cent	16.76	15.43 – 18.64	5.38	10.96	24	0.91	5.43
Total Soluble Solids (%)	13.88	11.84 – 15.52	7.46	13.59	30	1.17	8.44
Total Sugar Index (t ha ⁻¹)	0.89	0.62 – 1.28	24.06	41.52	34	0.26	28.71
Total Biomass (t ha ⁻¹)	50	29 – 68	27.54	37.68	53	20.67	41.46
Fresh Stalk Yield (t ha ⁻¹)	37	24 – 52	26.54	33.55	63	15.87	43.26
Juice Yield (l ha ⁻¹)	7660	3583 – 12011	38.81	57.30	46	4147.43	54.14
Juice Extraction Per cent	36.44	30.55 – 39.38	3.64	18.60	4	0.53	1.47
Grain Yield (t ha ⁻¹)	1	1 – 2	30.30	33.02	84	809.77	57.28
Bioethanol Yield (l ha ⁻¹)	643	257 - 1017	42.61	66.00	42	364.42	56.66

GCV – Genotypic Coefficient of Variation

PCV – Phenotypic Coefficient of Variation

H²_(b) - Heritability in broad sense

GA – Genetic Advance at 5% level

GAM – Genetic Advance as per cent of Mean at 5% level

effective. Sankarapandian *et al.* (2002) reported similar finding for days to maturity in forage sorghum. Medium heritability estimates coupled with low genetic advance was noticed for total soluble solids (30%, 8.44%) and total sugar index (34%, 28.71%). This suggested that non-additive gene action was playing an important role in the inheritance of these traits. Hence simple selection would be ineffective. On contrary to these Sankarapandian *et al.* (1996) ascertained high heritability coupled with high genetic advance for total soluble solids. The traits total biomass (53%, 41.46%), juice yield (46%, 54.14%) and ethanol yield (42%, 56.66%) expressed moderate heritability with high genetic advance revealing that additive gene effects governed these characters. The moderate heritability exhibited might be due to high environmental effects. Hence, selection would be effective for these traits. Sandeep (2009) observed high genetic advance for juice yield in sweet sorghum. The traits brix per cent (24%, 5.43%) and juice extraction per cent (4%, 1.47%)

showed lower estimates for both heritability and genetic advance suggesting that these characters are highly influenced by environment and simple selection would be ineffective. On contrary to this Sandeep (2009) found high heritability coupled with high genetic advance for brix and juice extraction per cent. From the above results it is evident that the characters plant height, fresh stalk yield and grain yield had high PCV, GCV and high heritability coupled with high genetic advance indicating variation in these traits was most likely due to additive gene effects. Hence simple directional selection may be effective to improve these traits. Therefore, utilization of these genotypes in hybridization programme may yield transgressive segregants in future generations for these traits.

The values of genotypic correlation coefficients (r_g) were higher than phenotypic correlation coefficients (r_p) for all the characters studied. This means there was a strong association between the two characters genetically, but

Table 3 . Phenotypic (P) and genotypic (G) correlation coefficients among ethanol yield and its attributes traits in parents

Characters	DFF	DM	PH	Brix	TSS	TSI	TB	FSY	JY	JE	GY	EY
DFF	P 1.0000	0.9719***	0.6417***	0.4858***	0.5651***	0.4153***	0.4920***	0.5244***	0.4504***	-0.2633**	-0.6782***	0.5179***
	G 1.0000	0.9970***	0.8602***	0.7400***	0.8499	0.8244**	0.8739***	0.8387***	0.8667***	-0.7286***	-0.8268***	0.9238***
DM	P 1.0000	0.6561***	0.4706***	0.4706***	0.5543***	0.4352***	0.5041***	0.5360***	0.4476***	-0.2797**	-0.6398***	0.5116***
	G 1.0000	0.8936***	0.7047***	0.7047***	0.8194***	0.8324**	0.8897***	0.8719***	0.8826**	-0.8628***	-0.8158***	0.9433***
PH	P 1.0000	1.0000	0.2123*	0.2123*	0.2928**	0.4416**	0.6895***	0.7415***	0.6343***	-0.1236	-0.5740***	0.6563***
	G 1.0000	0.6089***	0.6089***	0.6089***	0.9398***	0.7937***	0.8992***	0.8855***	0.8612***	-1.0000***	-0.6539***	0.9592***
Brix	P 1.0000	1.0000	1.0000	1.0000	0.5584***	0.3310***	0.2437*	0.2840**	0.2427*	-0.1330	-0.3909***	0.3646***
	G 1.0000	0.8602***	0.8602***	0.8602***	0.8602***	0.8416***	0.9258***	0.8948***	1.0000***	0.5032***	-0.9650***	0.9426***
TSS	P 1.0000	1.0000	1.0000	1.0000	1.0000	0.1994	0.1836	0.2351*	0.2035**	-0.1750	-0.3507***	0.2746**
	G 1.0000	0.8466***	0.8466***	0.8466***	1.0000	0.8466***	1.0000***	0.9635***	1.0000***	0.1207	-0.7891***	1.0000***
TSI	P 1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8269***	0.7137***	0.4896	-0.1713	-0.3452***	0.5072***
	G 1.0000	0.9301***	0.9301***	0.9301***	1.0000	1.0000	0.9301***	0.9780***	1.0000***	-0.4837***	-0.6361***	1.0000***
TB	P 1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8813***	0.7210***	-0.0016	-0.5155***	0.6601***
	G 1.0000	0.9965***	0.9965***	0.9965***	1.0000	1.0000	1.0000	0.9965***	1.0000***	-0.6034***	-0.7399***	1.0000***
FSY	P 1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.8828***	0.0099	-0.5616***	0.8060***
	G 1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000***	-0.7329***	-0.7188***	0.9986***
JY	P 1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.3621***	-0.5490***	0.8276***
	G 1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	-0.6735***	-0.7610***	0.9668***
JE	P 1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	-0.0004	0.1181
	G 1.0000	0.4844***	0.4844***	0.4844***	1.0000	1.0000	1.0000	1.0000	1.0000	0.4844***	-1.0000***	1.0000***
GY	P 1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	-0.5633***
	G 1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	-0.8257***

*, **, and *** Significance at 5%, 1% and 0.1% levels

DFF: Days to 50% flowering; DM: Days to maturity; PH: Plant height; TSS: Total soluble solids; TSI: Total sugar index; TB: Total biomass; FSY: Fresh stalk yield; JY: Juice yield; JE: Juice extraction per cent; GY: Grain yield; EY: Ethanol yield.

Table 4. Path co-efficient analysis of ethanol yield and its component traits in parents.

	DFE	DM	PH	Brix	TSS	TSI	TB	FSY	JY	JE	GY	'r' with EY
DFE	P	0.0847	0.0559	0.0424	0.0493	0.0362	0.0429	0.0457	0.0393	-0.0230	-0.0591	0.5179***
	G	0.0885	0.0761	0.0655	0.0752	0.0729	0.0773	0.0742	0.0767	-0.0645	-0.0732	0.9238***
DM	P	-0.1162	-0.0784	-0.0562	-0.0663	-0.0520	-0.0602	-0.0641	-0.0535	0.0334	0.0765	0.5116***
	G	-0.2589	-0.2321	-0.1830	-0.2128	-0.2162	-0.2311	-0.2265	-0.2292	0.2241	0.2119	0.9433***
PH	P	0.1127	0.1152	0.0373	0.0514	0.0775	0.1211	0.1302	0.1114	-0.0217	-0.1008	0.6563***
	G	0.8167	0.8484	0.5781	0.8922	0.7535	0.8537	0.8407	0.8176	-1.0410	-0.6208	0.9592***
Brix	P	0.0637	0.0278	0.1311	0.0732	0.0434	0.0319	0.0372	0.0318	-0.0174	-0.0512	0.3646***
	G	0.0396	0.0326	0.0535	0.0461	0.0451	0.0496	0.0479	0.0548	0.0269	-0.0517	0.9426***
TSS	P	-0.0119	-0.0062	-0.0117	-0.0210	-0.0042	-0.0039	-0.0049	-0.0043	0.0037	0.0074	0.2746**
	G	0.0311	0.0344	0.0314	0.0366	0.0310	0.0386	0.0352	0.0391	0.0044	-0.0289	1.0000***
TSI	P	0.0441	0.0469	0.0352	0.0212	0.1062	0.0878	0.0758	0.0520	-0.0182	-0.0367	0.5072***
	G	0.3595	0.3461	0.3670	0.3692	0.4361	0.4056	0.4265	0.4487	-0.2109	-0.2774	1.0000***
TB	P	-0.0849	-0.1189	-0.0420	-0.0317	-0.1426	-0.1725	-0.1520	-0.1244	0.0003	0.0889	0.6601***
	G	-1.1742	-1.2083	-1.2440	-1.4202	-1.2498	-1.3437	-1.3390	-1.3976	0.8109	0.9942	1.0000***
FSY	P	0.0508	0.0519	0.0275	0.0228	0.0691	0.0853	0.0968	0.0854	0.0010	-0.0543	0.8060***
	G	0.4168	0.4333	0.4447	0.4788	0.4860	0.4952	0.4969	0.4993	-0.3642	-0.3572	0.9986***
JY	P	0.3124	0.3105	0.1683	0.1412	0.3396	0.5001	0.6124	0.6937	0.2512	-0.3808	0.8276***
	G	0.4325	0.4405	0.5109	0.5341	0.5135	0.5191	0.5014	0.4991	-0.3361	-0.3798	0.9668***
JE	P	0.0240	0.0255	0.0121	0.0160	0.0156	0.0001	-0.0009	-0.0330	-0.0912	0.0000	0.1181
	G	-0.0632	-0.0749	0.0437	0.0105	-0.0420	-0.0524	-0.0636	-0.0584	0.0868	0.0420	-1.0000***
GY	P	0.0360	0.0340	0.0208	0.0186	0.0183	0.0274	0.0298	0.0292	0.0000	-0.0532	-0.5633***
	G	0.2355	0.1863	0.2748	0.2247	0.1812	0.2107	0.2047	0.2168	-0.1380	-0.2848	-0.8257***

Residual effect: (P): 0.1515, (G): -0.1717

*, ** and *** Significance at 5%, 1% and 0.1% levels

DFE: Days to 50% flowering; DM: Days to maturity; PH: Plant height; TSS: Total soluble solids; TSI: Total sugar index; TB: Total biomass; FSY: Fresh stalk yield; JY: Juice yield; JE: Juice extraction per cent; GY: Grain yield; EY: Ethanol yield.

phenotypic value was lessened by the significant interaction of environment (Table 3). In the present study, association of days to 50 per cent flowering ($r_g = 0.9238^{***}$), days to maturity ($r_g = 0.9433^{***}$), plant height ($r_g = 0.9592^{***}$), brix per cent ($r_g = 0.9426^{***}$), total soluble solids ($r_g = 1.0000^{***}$), total sugar index ($r_g = 1.0000^{***}$), total biomass ($r_g = 1.0000^{***}$), fresh stalk yield ($r_g = 0.9986^{***}$) and juice yield ($r_g = 0.9668^{***}$) were positively and highly significantly correlated with ethanol yield indicating that the ethanol yield was the function of these characters. It was also observed that these ethanol yield contributing characters were positively and highly significantly correlated among themselves indicating the strong inherent relationship between them. It would be therefore advisable to lay due emphasis on these ethanol yield contributing characters for a substantial ethanol yield improvement in sweet sorghum. These results are similar to the reports of earlier worker Sandeep *et al.* (2010) for cane yield and juice yield.

Path analysis partitions the total correlation coefficient into direct and indirect effects and measures the relative importance of the causal factor individually (Dewey and Lu, 1959). In the present study, ethanol yield was considered as dependent character and other characters were taken as independent characters. Plant height exerted maximum positive direct effect towards ethanol yield followed by juice yield, fresh stalk yield and total sugar index (Table 4). The indirect effects of the components viz., plant height, total sugar index, fresh stalk yield and juice yield were positive. Thus, improvement of any of these characters would simultaneously improve ethanol yield because correlated response of ethanol yield by applying strong selection pressure on these traits. On the other hand, total biomass and days to maturity which showed negative direct effect on ethanol yield had positive indirect effect via juice extraction per cent resulting in high positive correlation (Table 4). These results were in agreement with the earlier reports of Sandeep *et al.* (2010). The low residual effect in the present study indicated that the characters chosen for path analysis were adequate and appropriate. The present study indicated that selection based on plant height, total sugar index, fresh stalk yield and juice yield would result in improvement of ethanol yield.

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