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Short communication

Genetic variation and trait inter-relationship in F_1 hybrids of sweet sorghum (*Sorghum bicolor* (L.) Moench)

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Abstract

Productivity of sweet sorghum [*Sorghum bicolor* (L.) Moench], a raw material for ethanol production, is determined by stalk yield and sugar content. To understand the inherent differences and relationship between ethanol yield and its related traits, 30 F_1 hybrids in L × T fashion were grown in three different locations and estimated their genotypic and phenotypic variations, heritability, genetic advance, and the relationship between ethanol yield and its components. The hybrids exhibited considerable variability for all traits. Grain yield exhibited high heritability coupled with high genetic advance implying additive gene effects. Selection could be done for plant height, brix %, total soluble solids, total sugar index, total biomass, fresh stalk yield, and juice yield as these characters manifested positive significant correlation with ethanol yield. Path coefficient analysis showed that fresh stalk yield (r=0.83), juice yield (0.57) and brix % (0.55) were the main contributors for ethanol yield.

Keywords: Brix, Ethanol yield, Total sugar index.

Sweet sorghum [*Sorghum bicolor* (L.) Moench], a potentially valuable source for biofuel production, has high energy conversion efficiency. Green stalk yield, stalk sugar content, stalk juice extractability, and grain yield are key contributors of energy production in this crop. Establishing genotypic variability for stalk yield associated traits and sugar concentration of stalk juice is very important in developing elite sweet sorghum varieties. To understand the genetics and relationship of ethanol yield related traits, we investigated the variability, heritability, and strength of association between ethanol yield and its traits at three locations in peninsular India.

Thirty F_1 hybrids were produced by crossing five lines with six testers in a L × T mating design during *rabi* 2009. The hybrids were planted in a randomized complete block design (RCBD) in three replications during *kharif* at the experimental farms at Rajendranagar (Hyderabad), Mahatma Phule Krishi Vidyapeeth (Rahuri), and the Centre for Plant Breeding and Genetics (Coimbatore). Each entry was sown in two rows (4 m long) at 60 x 15 cm spacing. Five plants were selected at random from each replication for recording days to 50% flowering, days to maturity, plant height, brix % (from the composite juice using an Atago PAL-1 digital hand-held pocket refractometer with automatic temperature compensation ranging from 0 to 50^{o}C at the hard dough stage), total biomass at physiological maturity, fresh stalk yield, juice yield (using an electrically operated three-roller stalk crusher with a minimum of three passings of the selected stalk), and grain yield (at 14% seed moisture). Total soluble solids (%) = 0.1516 + (Brix % × 0.8746),

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total sugar index (Mg ha^{-1})

$$= \left(\frac{\text{sugar (\%)}}{100}\right) \times \left(\frac{\text{juice yield (L ha}^{-1}\text{)}}{1000}\right),$$

$$\text{juice extraction \%} = \frac{\text{juice weight (kg)}}{\text{Fresh stalk yield (kg)}} \times 100,$$

and ethanol yield (L ha^{-1})

$$= \left(\frac{\text{Total sugar yield (Mg ha}^{-1}\text{)}}{5.68}\right) \times 3.78 \times 1000 \times 0.8$$

were also computed. The error variances in the trials conducted at three locations were homogeneous, as revealed by Bartlett's test (Bartlett 1937), providing statistical validity to carry out combined ANOVA. 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 done following Dewey and Lu (1959).

Grain yield exhibited high PCV (37.32%), GCV (34.58%), heritability (86%), and genetic advance (66%), implying additive gene effects (Table 1). It also suggests that simple directional selection may be effective to improve this trait. Therefore, utilization of these genotypes in hybridization programme may yield transgressive segregants in future generations as grain yield is governed mostly by additive gene action. There was a strong association between ethanol yield with its related traits genetically ($r_g > r_p$) and intensive selection based on plant height (r_g = 0.56***), brix % (r_g = 0.53***), total soluble solids (r_g = 0.48***), total sugar index (r_g = 0.66***), total biomass (r_g = 0.69***), fresh stalk yield (r_g = 0.98***) and juice yield (r_g = 0.95***) will be effective in improving ethanol yield (Table 2). Partitioning of correlation coefficients into direct and indirect effects revealed that fresh stalk yield (r=0.83), juice yield (0.57) and brix per cent (0.55) were the major ethanol yield contributing characters on which selection pressure is to be applied for ethanol yield improvement (Table 2). These results were in conformity with the findings of Sandeep et al. (2010). Critical analysis of character association and path analysis suggests that more importance should be given in selection programmes for traits such as brix %, fresh stalk yield, and juice yield.

Table 1. Estimates of genetic parameters for 12 characters among 30 hybrids of sweet sorghum grown at three locations in peninsular India.

Parameter	General mean	Genotypic coefficient of variation (%)	Phenotypic coefficient of variation (%)	Heritability (broad sense) (%)	Genetic advance at 5%	Genetic advance as percentage of mean (5%)
Days to 50 % flowering	69	2.91	5.54	28	2.18	3.14
Days to maturity	107	1.95	3.88	25	2.18	2.03
Plant height (cm)	308	8.20	12.66	42	33.61	10.93
Brix per cent	17	5.28	8.52	38	1.16	6.74
Total soluble solids (%)	15	4.40	7.90	31	0.74	5.04
Total sugar index (Mg ha^{-1})	0.98	15.30	29.23	27	0.16	16.50
Total biomass (Mg ha^{-1})	62.8	16.2	30.5	28	11.1	17.7
Fresh stalk yield (Mg ha^{-1})	43.34	10.26	18.71	30	5.03	11.60
Juice yield (L ha^{-1})	10199.25	13.12	31.68	17	1141.22	11.19
Juice extraction (%)	37.22	4.52	15.01	9	1.05	2.81
Grain yield (Mg ha^{-1})	2	34.58	37.32	86	1627.51	66.00
Bioethanol yield (L ha^{-1})	811.60	14.94	33.05	20	112.86	13.91

Table 2. Path co-efficient analysis of ethanol yield and its related traits in F_1 hybrids of sweet sorghum grown at three locations in peninsular India.

	DFF	DM	PH	Brix	TSS	TSI	TB	FSY	JY	JE	GY	'r' with ethanol yield	
DFF	P	–0.0066	0.0031	0.0019	0.0300	0.0131	–0.0005	0.0026	0.0002	–0.1292	0.0018	–0.0009	–0.0847
	G	0.0866	–0.1665	0.0814	0.1577	–0.0780	0.0275	0.0848	–0.2164	–0.2073	–0.0093	0.0063	–0.2331***
DM	P	–0.0063	0.0033	0.0020	0.0291	0.0123	–0.0005	0.0031	0.0002	–0.1206	0.0011	–0.0009	–0.0772
	G	0.0871	–0.1657	0.0779	0.1542	–0.0777	0.0253	0.0886	–0.2021	–0.1984	–0.0169	0.0074	–0.2201***
PH	P	0.0010	–0.0005	–0.0123	–0.0126	0.0027	–0.0002	–0.0009	–0.0002	0.1484	0.0043	–0.0002	0.1295*
	G	–0.0342	0.0625	–0.2064	–0.1013	0.0727	–0.0098	–0.1046	0.4522	0.4049	0.0209	0.0023	0.5592***
Brix	P	–0.0013	0.0006	0.0010	0.1566	0.0776	0.0009	–0.0004	–0.0001	–0.0179	0.0041	0.0000	0.2211***
	G	0.0249	–0.0465	0.0381	0.5492	–0.3159	–0.0755	–0.0458	0.3199	0.1347	–0.0492	–0.0023	0.5315***
TSS	P	–0.0007	0.0003	–0.0003	0.0975	0.1245	0.0008	0.0003	–0.0001	–0.0160	0.0046	0.0005	0.2115***
	G	0.0188	–0.0358	0.0417	0.4821	–0.3598	–0.0348	–0.0044	0.2818	0.1239	–0.0294	–0.0043	0.4799***
TSI	P	0.0007	–0.0003	0.0006	0.0295	0.0193	0.0050	–0.0103	–0.0007	0.4430	–0.0025	0.0008	0.4849***
	G	–0.0108	0.0191	–0.0092	0.1887	–0.0571	–0.2196	–0.1598	0.5580	0.3659	–0.0035	–0.0103	0.6615***
TB	P	0.0008	–0.0005	–0.0005	0.0028	–0.0018	0.0024	–0.0215	–0.0009	0.4968	–0.0004	0.0009	0.4782***
	G	–0.0277	0.0553	–0.0812	0.0947	–0.0059	–0.1320	–0.2657	0.6590	0.4282	–0.0285	–0.0111	0.6851***
FSY	P	0.0011	–0.0006	–0.0020	0.0123	0.0107	0.0028	–0.0148	–0.0013	0.7461	0.0011	0.0010	0.7565***
	G	–0.0227	0.0405	–0.1130	0.2127	–0.1228	–0.1484	–0.2120	0.8259	0.5582	–0.0277	–0.0137	0.9770***
JY	P	0.0009	–0.0004	–0.0019	–0.0029	–0.0020	0.0023	–0.0109	–0.0010	0.9795	–0.0106	0.0007	0.9536***
	G	–0.0316	0.0578	–0.1469	0.1301	–0.0784	–0.1413	–0.2001	0.8106	0.5687	–0.0047	–0.0135	0.9508***
JE	P	0.0005	–0.0001	0.0021	–0.0257	–0.0229	0.0005	–0.0003	0.0001	0.4185	–0.0249	0.0001	0.3478***
	G	–0.0056	0.0195	–0.0301	–0.1885	0.0738	0.0053	0.0528	–0.1597	–0.0186	0.1433	–0.0041	–0.1118
GY	P	–0.0008	0.0004	–0.0004	–0.0008	–0.0079	–0.0005	0.0025	0.0002	–0.0961	0.0005	–0.0074	–0.1103
	G	0.0128	–0.0288	–0.0112	–0.0293	0.0359	0.0533	0.0690	–0.2659	–0.1798	–0.0136	0.0426	–0.3150***

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

*, ** 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.

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