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Genetic variability, association and path coefficient studies in sugarcane

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Abstract
A set of forty-six genotypes of sugarcane were analysed at Sugarcane Research Station, Nayagarh during 2019-2021 for three seasons to study heritability, genetic advance, correlation and path analysis of twenty-two characters. Analysis of variance revealed significant differences among the genotypes for all the characters under study indicating the existence of genetic variation. Coefficients of variation at genotypic and phenotypic levels and heritability (broad sense) with expected genetic advance (as percent of mean) were high for single cane weight, germination per cent, plant height, cane girth, number of internodes per cane, internodal length, number of millable canes, sugar yield and cane yield indicating that selection for these characters would be more reliable. The number of tillers, single cane weight, number of millable canes, number of shoots, germination per cent and cane yield exhibited significantly strong positive association with sugar yield. Analysis of path coefficient indicated that the highest direct contribution to sugar yield was manifested by number of millable canes, brix per cent at 10 months, sucrose per cent at 12 months and purity per cent at 12 months. Hence, the findings revealed the importance of number of millable canes, single cane weight and sucrose per cent at 12 months as the selection criteria for sugar yield improvement of the advanced genotypes of sugarcane with appropriate package of practices.

Keywords: Variation, genetic advance, path coefficient, sugar yield, sucrose, sugarcane

Introduction

Sugarcane (*Saccharum officinarum* L.) is a C4 industrial crop grown widely across various parts of India. The global scenario of sugarcane as an industrial crop contributed more than 112 million tonnes of sugar production. India is the largest producer of sugarcane among all the countries with 4.86 million hectare area and 377.8 million tonnes sugarcane production (MoAFW, 2019-20) [8]. Knowledge of genetic variation among the lines with high cane yielders and high sugar yielders is vital for an efficient selection and development of new varieties. Therefore, the present investigation was undertaken to study the nature of character association among the different sugar yield attributing and quality traits through phenotypic and genotypic correlations and path coefficient analysis for selection of superior genotypes from the diverse population.

Materials and Methods

Forty-six advanced breeding lines of sugarcane were evaluated for three seasons at Sugarcane Research Station, Nayagarh of Odisha University of Agriculture and Technology during 2019-2021 in a randomized block design with two replications. Each plot consisted of four rows of 6m length with a spacing of 0.9m. Five plants were chosen at random from each plot for recording observations on twenty-two commercial traits (Table 1) and for study of variance and covariance, the pooled data over three seasons were considered for analysis (Panse and Sukhatme, 1967) [6]. Application of irritants around the hernial ring. When the hernia is big and unreducible, radical surgery is required (Kumar and Amresh, 1996) [6].

From the variance and covariance components, coefficients of variation at phenotypic (PCV) and genotypic (GCV) levels (Burton, 1952) [1], expected genetic advance (GA) (Johnson *et al*., 1955) [3] and heritability in broadsense (H) (Lush *et al*., 1940) [4] were calculated. The genotypic and phenotypic correlation coefficients (Miller *et al*., 1958) [5] aided for path coefficient analysis at genotypic and phenotypic levels (Dewey and Lu, 1959) [2].

Table 1: Genetic parameters of variability for sugar yield and quality traits in 46 lines of sugarcane

	Character	Abbrv.	Mean	GCV (%)	PCV (%)	H (%)	GA	GA as % of mean
1.	Germination % at 45DAP	G%45	46.47	11.33	14.94	57.50	7.61	17.70
2.	Plant height (cm)	PH	225.06	5.57	7.43	56.30	0.19	8.62
3.	Cane Girth (cm)	CG	2.31	5.83	8.25	50.10	0.19	8.50
4.	Single Cane Weight (kg)	SCW	1.30	11.29	14.25	62.80	0.24	18.42
5.	Number of internodes per cane	NC	23.70	7.77	11.21	48.00	2.63	11.09
6.	Internodal length (cm)	INL	13.32	9.82	10.82	82.50	2.45	18.39
7.	Number of tillers '000/ha (120DAP)	T120	113.06	8.77	11.53	57.80	15.53	13.73
8.	Number of shoots '000/ha (240DAP)	S240	86.73	11.62	14.73	62.20	16.37	18.88
9.	Number of millable canes'000/ha (300DAP)	NMC	82.12	11.73	14.96	61.50	15.56	18.95
10.	Cane Yield (t/ha)	CY t/ha	87.76	13.54	20.67	42.90	16.03	18.26
11.	CCS per cent at 10 month	CCS10M	11.57	1.68	1.88	80.50	0.62	3.12
12.	Brix per cent at 10 month	Brix10M	20.09	1.64	1.83	80.70	0.81	3.04
13.	Sucrose per cent at 10 month	S 10M	17.07	1.44	1.53	88.50	0.68	2.79
14.	Purity per cent at 10 month	PU 10M	78.81	1.82	2.50	52.90	1.71	2.73
15.	CCS per cent at 12 month	CCS 12M	11.77	1.63	1.78	84.00	0.62	3.09
16.	Brix per cent at 12 month	Brix12M	20.19	1.66	1.85	80.50	0.82	3.07
17	Sucrose per cent at 12 month	S 12M	17.28	1.42	1.48	91.10	0.68	2.79
18.	Purity per cent at 12 month	PU 12M	85.74	2.31	2.83	66.80	2.64	3.89
19.	CCS (t/ha) at 12 month	CCS t/ha	10.34	14.58	21.32	46.80	2.12	20.54
20.	Pol per cent at 12 month	Pol 12M	14.94	1.29	1.37	88.10	0.56	2.50
21.	Fibre per cent at 12 month	Fib 12M	13.70	2.81	2.93	91.80	1.20	5.54
22.	Juice extraction per cent at 12 month	JE 12M	52.70	2.66	4.81	30.60	1.41	3.03

Results and Discussion

The phenotypic coefficients of variations (PCV) ranged from 1.37% for pol per cent to 21.32% for sugar yield t/ha (Table 1). The estimation of PCV showed that the phenotypic variability was low (below 10%) for CCS per cent, brix per cent, sucrose per cent, purity per cent, pol per cent, fibre per cent, juice per cent, plant height and cane girth (1.37 to 8.25%); moderate (10-20%) for internodal length, number of internodes per plant, tillers count, cane weight, germination% and shoots, millable canes count(10.82 to 14.96%); high (above 20%) for cane and sugar yield (20.67 to 21.32%). The genotypic coefficient of variation (GCV) ranged between 1.29% for pol % to 14.58% for sugar yield and followed almost a similar trend as phenotypic coefficient of variation. GCV for pol% was low (1.29%) indicating the limited scope for its improvement.

Estimates of broadsense heritability (H) ranged from 30.60% for juice per cent to 91.80% for fibre per cent.The character like pol %, purity %, germination %, plant height, cane girth, millable canes count, sugar yield, cane weight, nodes count, shoots count, cane yield, tillers count showed moderate heritability (<80%) and the characters like internodal length, CCS%, brix%, sucrose %, pol %, fibre % exhibited very high heritability (>80%). The expected genetic advance (GA) for different characters, expressed as percentage of means, ranged from 2.50% for pol % to 20.54% for sugar yield. The relative expected genetic advance was moderate (10- 20%) for number of nodes per plant, tillers count, germination %, cane yield, shoots count, tillers count, internodal length and cane weight; high (above 20%) for sugar yield. High to moderate heritability coupled with high genetic advance (expressed as per cent of mean) was observed in case of number of millable canes and sugar yield, which indicated that these characters were controlled by additive gene action and phenotypic selection for these characters would be effective.

At the genotypic level, the sugar yield was positively and significantly correlated with germination per cent, plant height, single cane weight, millable canes, CCS per cent, brix per cent, sucrose per cent at 10 and 12 months, pol per cent at 12 month and purity per cent at 10 month (Table 2). At the phenotypic level, almost a similar trend was observed by Singh *et al.*, 2019 [7] and the sugar yield per hectare was positively and significantly correlated with cane yield per plant (0.979) (Table 3). Single cane weight, number of millable canes, plant height, internodal length, purity per cent at 12 months, brix per cent and sucrose per cent at 12 months had positive direct effects on sugar yield at phenotypic level (Table 4). Path analysis showed low residual effect (0.0036) indicating that there were negligible factors left out other than those included in present study which influence sugar yield.

Table 2: Estimation of genotypic correlation co-efficients among various traits of 46 sugarcane lines

Character	G%45	PH	CG	SCW	NC	INL	T120	S240	NMC	CCS10M	Brix10M	S 10M	PU 10M	CCS 12M	Brix12M	S 12M	PU 12M	CY t/ha	Pol 12M	Fib 12M	JE 12M
PH	0.260*																				
CG	-0.102NS	0.092NS																			
SCW	-0.102NS	0.186NS	0.035NS																		
NC	0.051NS	0.561**	-0.253*	-0.052NS																	
INL	0.066NS	0.440**	-0.084NS	-0.043NS	0.117NS																
T120	0.722**	0.000NS	-0.062NS	-0.466**	-0.105NS	0.220*															
S240	0.624**	0.015NS	-0.009NS	-0.446**	-0.058NS	0.203NS	0.968**														
NMC	0.726**	0.058NS	0.058NS	-0.496**	-0.049NS	0.135NS	0.949**	0.956**													
CCS10M	0.250*	0.006NS	0.034NS	0.193NS	-0.236*	-0.090NS	0.248*	0.142NS	0.217*												
Brix10M	0.028NS	0.269**	-0.151NS	0.286**	0.057NS	-0.059NS	0.078NS	0.001NS	-0.048NS	0.376**											
S 10M	0.208*	0.108NS	-0.034NS	0.261*	-0.165NS	-0.092NS	0.227*	0.114NS	0.153NS	0.933**	0.683**										
PU 10M	0.217*	-0.188NS	0.138NS	-0.026NS	-0.270**	-0.030NS	0.169NS	0.128NS	0.234*	0.686**	-0.414**	0.381**									
CCS 12M	0.236*	0.028NS	0.038NS	0.193NS	-0.208*	-0.092NS	0.230*	0.126NS	0.199NS	0.998**	0.390**	0.937**	0.675**								
Brix12M	0.027NS	0.272**	-0.147NS	0.280**	0.055NS	-0.059NS	0.079NS	0.002NS	-0.046NS	0.379**	1.000**	0.686**	-0.409**	0.394**							
S 12M	0.195NS	0.131NS	-0.028NS	0.260*	-0.138NS	-0.095NS	0.208*	0.098NS	0.136NS	0.923**	0.698**	0.998**	0.361**	0.932**	0.701**						
PU 12M	0.185NS	-0.218*	0.153NS	-0.077NS	-0.223*	-0.035NS	0.132NS	0.108NS	0.215*	0.553**	-0.560**	0.219*	0.984**	0.543**	-0.556**	0.201NS					
CY t/ha	0.679**	0.229*	0.104NS	0.341**	-0.119NS	0.068NS	0.608**	0.608**	0.626**	0.568**	0.293**	0.561**	0.320**	0.553**	0.291**	0.544**	0.233*				
Pol 12M	0.186NS	0.041NS	-0.070NS	0.208*	-0.202NS	-0.193NS	0.173NS	0.056NS	0.129NS	0.921**	0.511**	0.923**	0.504**	0.929**	0.514**	0.924**	0.369**	0.489**			
Fib 12M	-0.039NS	0.174NS	0.113NS	0.063NS	0.185NS	0.267*	0.038NS	0.087NS	-0.025NS	-0.235*	0.304**	-0.066NS	-0.464**	-0.235*	0.304**	-0.063NS	-0.489**	-0.012NS	-0.439**		
JE 12M	-0.001NS	-0.182NS	0.044NS	0.068NS	-0.012NS	-0.124NS	-0.234*	-0.211*	-0.095NS	0.324**	-0.065NS	0.227*	0.348**	0.327**	-0.072NS	0.226*	0.349**	0.005NS	0.381**	-0.477**	
CCS t/ha	0.691**	0.228*	0.110NS	0.344**	-0.092NS	0.096NS	0.617**	0.642**	0.641**	0.402**	0.225*	0.404**	0.209*	0.384**	0.222*	0.385**	0.143NS	0.981**	0.325**	0.049NS	-0.065NS

* r ≥ 0.220 (Significant at 5%); **r ≥ 0.309 (Significant at 1%)

Table 3: Estimation of phenotypic correlation co-efficients among various traits of 46 sugarcane lines

Character	G%45	PH	CG	SCW	NC	INL	T120	S240	NMC	CCS10M	Brix10M	S 10M	PU 10M	CCS 12M	Brix12M	S 12M	PU 12M	CY t/ha	Pol 12M	Fib 12M	JE 12M
PH	0.209*																				
CG	-0.104NS	0.067NS																			
SCW	-0.097NS	0.087NS	0.036NS																		
NC	0.057NS	0.523**	-0.221*	-0.064NS																	
INL	0.026NS	0.334**	-0.066NS	-0.032NS	0.134NS																
T120	0.565**	0.073NS	-0.043NS	-0.405**	-0.075NS	0.162NS															
S240	0.531**	0.079NS	0.001NS	-0.404**	-0.026NS	0.137NS	0.946**														
NMC	0.583**	0.115NS	0.067NS	-0.437**	-0.019NS	0.109NS	0.931**	0.953**													
CCS10M	0.207*	-0.018NS	0.018NS	0.181NS	-0.226*	-0.081NS	0.175NS	0.096NS	0.162NS												
Brix10M	0.014NS	0.223*	-0.130NS	0.285**	0.055NS	-0.046NS	0.061NS	-0.004NS	-0.044NS	0.322**											
S 10M	0.174NS	0.070NS	-0.037NS	0.254*	-0.162NS	-0.082NS	0.167NS	0.079NS	0.116NS	0.932**	0.643**										

PU 10M	0.166^{NS}	-0.172^{NS}	0.103^{NS}	-0.027^{NS}	-0.247*	-0.041^{NS}	0.105^{NS}	0.079^{NS}	0.169^{NS}	0.721**	-0.418**	0.423**									
CCS 12M	0.203^{NS}	-0.008^{NS}	0.026^{NS}	0.180^{NS}	-0.195^{NS}	-0.086^{NS}	0.155^{NS}	0.080^{NS}	0.143^{NS}	0.993**	0.331**	0.930**	0.708**								
Brix12M	0.010^{NS}	0.229*	-0.127^{NS}	0.280**	0.060^{NS}	-0.047^{NS}	0.064^{NS}	-0.003^{NS}	-0.043^{NS}	0.327**	0.999**	0.647**	-0.411**	0.338**							
S 12M	0.167^{NS}	0.084^{NS}	-0.029^{NS}	0.251*	-0.131^{NS}	-0.088^{NS}	0.148^{NS}	0.062^{NS}	0.097^{NS}	0.920**	0.653**	0.994**	0.405**	0.930**	0.660**						
PU 12M	0.165^{NS}	-0.197^{NS}	0.116^{NS}	-0.078^{NS}	-0.210*	-0.043^{NS}	0.076^{NS}	0.069^{NS}	0.155^{NS}	0.597**	-0.558**	0.270**	0.978**	0.597**	-0.552**	0.261*					
CY t/ha	0.523**	0.192^{NS}	0.091^{NS}	0.379**	-0.096^{NS}	0.060^{NS}	0.608**	0.605**	0.640**	0.479**	0.260*	0.487**	0.254*	0.462**	0.258*	0.468**	0.183^{NS}				
Pol 12M	0.165^{NS}	0.018^{NS}	-0.069^{NS}	0.209*	-0.187^{NS}	-0.176^{NS}	0.128^{NS}	0.030^{NS}	0.095^{NS}	0.909**	0.482**	0.919**	0.518**	0.918**	0.488**	0.924**	0.395**	0.427**			
Fib 12M	-0.041^{NS}	0.124^{NS}	0.104^{NS}	0.049^{NS}	0.159^{NS}	0.238*	0.011^{NS}	0.065^{NS}	-0.028^{NS}	-0.193^{NS}	0.280**	-0.049^{NS}	-0.385**	-0.192^{NS}	0.279**	-0.046^{NS}	-0.403**	-0.018^{NS}	-0.423**		
JE 12M	0.012^{NS}	-0.034^{NS}	0.054^{NS}	0.048^{NS}	0.064^{NS}	-0.107^{NS}	-0.092^{NS}	-0.089^{NS}	0.013^{NS}	0.243*	-0.055^{NS}	0.174^{NS}	0.261*	0.250*	-0.060^{NS}	0.176^{NS}	0.261*	0.085^{NS}	0.298**	-0.363**	
CCS t/ha	0.520**	0.192^{NS}	0.098^{NS}	0.381**	-0.069^{NS}	0.068^{NS}	0.618**	0.637**	0.655**	0.308**	0.206*	0.328**	0.128^{NS}	0.287**	0.203^{NS}	0.307**	0.075^{NS}	0.979**	0.265*	0.025^{NS}	0.046^{NS}

* $r \geq 0.220$ (significant at 5%); ** $r \geq 0.309$ (significant at 1%)

Table 4: Path coefficient analysis indicating direct (diagonal) and indirect effects of various traits on sugar yield at phenotypic level

	G%45	PH	CG	SCW	NC	INL	T120	S240	NMC	CCS10M	Brix10M	S 10M	PU 10M	CCS 12M	Brix12M	S 12M	PU 12M	CY t/ha	Pol 12M	Fib 12M	JE 12M	CCS t/ha
G%45	0.010	0.001	0.001	-0.006	-0.001	0.001	0.009	-0.05	0.094	-0.05	-0.005	0.078	-0.029	-0.17	0.001	0.278	0.057	0.441	-0.127	0.012	0.001	0.523**
PH	-0.002	0.004	-0.001	0.005	-0.006	0.004	0.001	-0.008	0.019	0.004	-0.075	0.031	0.03	0.007	-0.009	0.14	-0.068	0.163	-0.014	-0.036	0.001	0.192
CG	0.001	0.001	0.008	0.002	0.003	-0.001	-0.001	0.001	0.011	-0.004	0.043	-0.017	-0.018	-0.022	0.005	-0.048	0.04	0.083	0.053	-0.031	0.001	0.091
SCW	0.001	0.001	0.001	0.06	0.001	0.001	-0.006	0.038	-0.071	-0.044	-0.096	0.113	0.005	-0.15	-0.011	0.418	-0.027	0.323	-0.161	-0.014	0.001	0.379**
NC	-0.001	0.002	0.002	-0.004	-0.012	0.002	-0.001	0.002	-0.003	0.055	-0.018	-0.072	0.043	0.163	-0.002	-0.218	-0.072	-0.059	0.143	-0.047	0.001	-0.096
INL	0.001	0.001	0.001	-0.002	-0.002	0.012	0.003	-0.013	0.018	0.02	0.015	-0.037	0.007	0.072	0.002	-0.146	-0.015	0.058	0.135	-0.070	0.001	0.060
T120	-0.005	0.001	0.001	-0.024	0.001	0.002	0.015	-0.09	0.15	-0.043	-0.02	0.074	-0.018	-0.129	-0.003	0.246	0.026	0.525	-0.098	-0.003	0.001	0.608**
S240	-0.005	0.001	0.001	-0.024	0.001	0.002	0.015	-0.095	0.154	-0.023	0.001	0.035	-0.014	-0.067	0.001	0.104	0.024	0.541	-0.023	-0.019	0.001	0.605**
NMC	-0.006	0.001	-0.001	-0.026	0.001	0.001	0.014	-0.09	0.162	-0.039	0.015	0.052	-0.03	-0.12	0.002	0.161	0.053	0.555	-0.073	0.008	0.001	0.640**
CCS10M	-0.002	0.001	0.001	0.011	0.003	-0.001	0.003	-0.009	0.026	0.244	-0.108	0.416	-0.126	-0.831	-0.013	1.532	0.206	0.261	-0.699	0.057	-0.002	0.479**
Brix10M	0.001	0.001	0.001	0.017	-0.001	-0.001	0.001	0.001	-0.007	-0.079	0.335	0.287	0.073	-0.277	-0.039	1.087	-0.192	0.175	-0.37	-0.082	0.001	0.260*
S 10M	-0.002	0.001	0.001	0.015	0.002	-0.001	0.003	-0.007	0.019	-0.227	-0.215	0.446	-0.074	-0.778	-0.026	1.655	0.093	0.278	-0.707	0.014	-0.001	0.487**
PU 10M	-0.002	-0.001	-0.001	-0.002	0.003	-0.001	0.002	-0.008	0.027	-0.176	0.14	0.189	-0.175	-0.593	0.016	0.674	0.337	0.109	-0.398	0.113	-0.002	0.254
CCS 12M	-0.002	0.001	0.001	0.011	0.002	-0.001	0.002	-0.008	0.023	-0.242	-0.111	0.414	-0.124	0.837	-0.013	1.548	0.206	0.244	-0.705	0.057	-0.002	0.462**
Brix12M	0.001	0.001	0.001	0.017	-0.001	-0.001	0.001	0.001	-0.007	-0.08	-0.335	0.288	0.072	-0.283	-0.04	1.098	-0.19	0.172	-0.375	-0.082	0.001	0.258
S 12M	-0.002	0.001	0.001	0.015	0.002	-0.001	0.002	-0.006	0.016	-0.224	-0.219	0.443	-0.071	-0.779	-0.026	1.665	0.090	0.260	-0.71	0.014	-0.001	0.468**
PU 12M	-0.002	-0.001	-0.001	-0.005	0.002	-0.001	0.001	-0.007	0.025	-0.146	0.187	0.120	-0.171	-0.499	0.022	0.435	0.345	0.064	-0.304	0.119	-0.002	0.183
CY t/ha	-0.005	0.001	-0.001	0.023	0.001	0.001	0.010	-0.06	0.106	-0.075	-0.069	0.146	-0.023	-0.241	-0.008	0.511	0.026	0.848	-0.204	-0.007	0.001	0.979**
Pol 12M	-0.002	0.001	0.001	0.013	0.002	-0.002	0.002	-0.003	0.015	-0.222	-0.161	0.410	-0.091	-0.769	-0.019	1.538	0.136	0.225	0.768	0.125	-0.002	0.427**
Fib 12M	0.001	0.001	-0.001	0.003	-0.002	0.003	0.001	-0.006	-0.004	0.047	-0.094	-0.022	0.067	0.161	-0.011	-0.077	-0.139	0.021	0.325	-0.294	0.003	-0.018
JE 12M	0.001	0.001	0.001	0.003	-0.001	-0.001	-0.001	0.008	0.002	-0.059	0.018	0.078	-0.046	-0.209	0.002	0.292	0.09	0.039	-0.229	0.107	0.008	0.085
CCS t/ha	0.523**	0.192	0.091	0.379**	-0.096	0.060	0.608**	0.605**	0.640**	0.479**	0.260*	0.487**	0.254*	0.462**	0.258*	0.468**	0.183	0.979**	0.427**	-0.018	0.085	1.000

Unexplained variation = 0.00368 *, ** Significant at 5 and 1% level, respectively

Conclusion

The association among the sugar yield and yield attributing characters implied the nature of association of the traits among themselves through phenotypic and genotypic correlations and path coefficient analysis of the advanced lines of sugarcane developed at different locations of the country. The component traits such as number of millable canes, single cane weight, germination per cent, CCS per cent, sucrose per cent, brix per cent at 10 and 12 months, pol percent at 12 month and cane yield exhibited significant positive association with sugar yield at genotypic and phenotypic levels. Hence, the studies on genetic variability parameters and character association in sugarcane suggested that among the twenty-two traits, single cane weight, number of millable canes and sucrose per cent at 12 months were the most important components of sugar yield and can be regarded as a selection criteria for sugar yield increment in breeding lines of sugarcane.

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