RESEARCH ARTICLE

GENETIC VARIABILITY, CORRELATION AND PATH ANALYSIS FOR CANE YIELD AND JUICE QUALITY TRAITS IN EARLY MATURING SUGARCANE CLONES

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Abstract: Nineteen early maturing sugarcane clones were evaluated in randomized block design with three replications at research farm ofCCS Haryana Agricultural University, Regional Research Station, Uchani, Karnal during *springseason*, 2020-21. The objective of the investigation was to study genetic variability, correlation and path analysis for seventeen characters among nineteen diverse early maturing sugarcane clones. Significant differences were observed among the genotypes for all the characters studied. GCV values were highest for number of tillers at 120 DAP, commercial cane sugar (t/ha), number of shoots at 240 DAP, single cane weight, cane yield and number of millable canes at harvest.High heritability coupled with high genetic advance as per cent of mean was observed for number of tillers at 120 DAP, commercial cane sugar (t/ha) and germination per cent suggesting that these characters are governed by additive gene action and selection for these characters will be effective for further improvement in cane yield. The characters commercial cane sugar (t/ha), single cane weight, purity per cent at 8 months, cane length, number of millable canes at harvest and number of shoots at 240 DAP showed high significant and positive association with cane yield at both genotypic and phenotypic level. Path coefficient analysis revealed that commercial cane sugar (t/ha) exhibited high positive direct effect on cane yield followed by brix per cent at 10 months, commercial cane sugar at 8 months, purity per cent at 8 months, brix per cent at 8 months, cane length and number of millable canes at harvest.These characters merit special attention in formulating selection strategy in sugarcane for developing high yielding and early maturing sugarcane clones.

Keywords: Sugarcane, Genetic variability, Heritability, Genetic advance, Correlation, path Cofficient analysis

INTRODUCTION

Sugarcane (*Saccharum spp.* Complex)is an important cash crop of the country next to cotton. India has emerged as the largest producer of sugar in the world. It is widely grown in tropics and subtropics as a source of energy providing food, fuel and feed and also contributes 75 % of the total world sugar.It is cultivated in most of the states of India with total area of 4.86 million hectare with average productivity of 77.6 tons per hectare. Sugarcane was cultivated in 0.11million hectare area with average cane yield of 80.65 tons per hectare during 2019-20 in Haryana.

Sugarcane (Saccharum spp. Complex) belongs to the group of tall perennial grasses of family Poaceae. It is a polyploid and highly heterozygous clonal crop with wide variation in chromosome number, and it is considered to be a difficult crop from breeding point of view. It is cultivated in tropical and subtropical regions of the world in a range of climates from hot dry environments near sea level to cool and moist at about 609 meters elevation (Elahi and Ashraf, 2001).

The ploidy level of sugarcane is very high which makes it more challenging for the breeders to develop new cultivars. Sugarcane possesses interspecific hybrid genome which is the result of unevenly inherited genetic material from both parental species and this uneven distribution of genetic material make its genome more complex than that of its parental species (D'Hont*et al.*, 1996). Due to its highly heterozygous and polyploidy nature sugarcane possess wide genetic variability.

Genetic improvement for quantitative traits depends on the nature and amount of variability present in the genetic stock and the extent to which the desirable traits are heritable. Genetic variability is the prerequisite of selection. Synthesis of ideotypes requires the qualitative assessment of variability in respect of the important yield contributing characters. The efficiency of selection depends on the identification of genetic variability which can be determined with the help of genotypic coefficient of variation, heritability and genetic advance estimates.

The concept of correlation was first proposed by Galton (1888) and later it was elaborated by Fisher (1918). In plant breeding, correlation coefficient analysis measures the mutual relationship between various plant characters and determining the component character on which selection can be based for genetic improvement of yield. A positive genetic correlation between two desirable traits makes the job of plant breeder easy for improving both traits simultaneously. The lack of correlation is also useful for the individual improvement of two traits. On the other hand, a negative correlation between the desirable traits impedes or make it difficult to achieve a significant improvement in the two traits. However, simple correlation does not give an insight into the true biological relationship of these traits

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with yield. Yield being quantitative in nature is a complex trait with low heritability and depends on several other components with high heritability.

Correlation coefficients can be misleading sometimes and thus, require portioning into direct and indirect effects. Path coefficient is an excellent means of studying direct and indirect effects of interrelated components of a complex trait (Kang *et al*., 1989). This is a measure of direct influence of one variable on another. Each correlation coefficient between a predictable variable and the response variable is partitioned into its component parts: the direct effect for the predictable variable and the indirect effects, which involve the product of a correlation coefficient between two predictor variables with the appropriate path coefficient in the path diagram (Dewey and Lu, 1959). The better understanding of both direct and indirect effects of the specific components can be attained by determining the interrelationships among yield components (James, N.I., 1971).As we know yield and yield attributing traits are complex in nature so path coefficient helps us to understand this complexity via direct and indirect effects partitioning. On the basis of these direct and indirect effects an effective breeding strategy can be devised.

MATERIALS AND METHODS

The experiment material for the present study consists of nineteen early maturing sugarcane clones evaluated in randomized block design with three replications, each genotype planted in four rows of six-meter length with plot size of 21.6 m^2 during spring, 2020 at CCS Haryana Agricultural University, Regional Research Station, Uchani, Karnal. The growth characters viz.,number of tillers at 120DAP, number of shoots at 240DAP, number of millable canes and cane yield at harvest were recorded on plot basis. The observations were recorded on five randomly tagged plants for single cane weight, cane length, cane girth, Brix, sucrose, purity and CCS % were recorded at 8 and 10 months, respectively. Analysis of variance was done for partitioning the total variation due to treatments and replications according to the procedure given by Panse and Sukhatme (1967). PCV and GCV were calculated by the formula given by Burton (1952), heritability in broad sense (h^2) by Burton and De Vane (1953) and genetic advance was calculated by using the procedure given by Johnson *et al.* (1955). Correlation coefficient and path coefficient was worked out as method suggested by Al Jibouri*et.al.* (1958) and Dewey and Lu (1959), respectively. The estimated values were compared with table values of correlation coefficient to test the significance of correlation coefficient prescribed by Fisher and Yates (1967).

RESULTS AND DISCUSSION

Estimates of Variability

The analysis of variance for all the characters under study revealed significant differences thereby indicating presence of substantial genetic variation among the genotypes. The estimates of variability parameters for cane yield and its component characters in 19 sugarcane genotypes are presented in Table 1. In the present investigation, high range was observed for majority of the characters viz., number of tillers at 120 DAP, number of shoots at 240 DAP, number of millable canes at harvest, cane length, cane yield and germination per cent which suggested sufficient amount of genetic variability among the genotypes for the above said characters. In general, the phenotypic coefficient of variation (PCV) was higher than its corresponding genotypic coefficient of variation (GCV) (Table 2). This indicated the role of environment in the expression of these characters. Wide range of differences for GCV was observed which varied from 0.83 for purity per cent at 10 months to 16.36 for number of tillers at 120 DAP indicating the presence of considerable amount of variability among the genotypes. GCV values were highest for number of tillers at 120 DAP, commercial cane sugar (t/ha), number of shoots at 240 DAP, single cane weight, cane yield and number of millable canes at harvest indicating availability of sufficient variation and thus exhibiting scope for genetic improvement through selection for these characters. Similar findings were also reported by Kumar *et al.* (2018) and Ahmed *et al.* (2019) in sugarcane.

The proportion of genetic variability which is transmitted from parent to offspring is reflected by heritability. Estimates of heritability in broad sense ranged from 36.55 for purity per cent at 10 months to 90.84 for pol per cent at 8 months, while cane yield showed 59.37 per cent heritability. High heritability coupled with high genetic advance as per cent of mean was observed for number of tillers at 120 DAP, commercial cane sugar (t/ha) and germination per cent suggesting that these characters are governed by additive gene action and selection for these characters will be effective for further improvement in cane yield. High heritability in association with moderate genetic advance as per cent of mean was recorded for single cane weight, cane length, brix, pol and commercial cane sugar per cent at 8 months. These results were akin with the findings of Agarwal and Kumar (2017), Ahmed *et al.* (2019) and Kumari*et al.* (2020).

Correlation Coefficients

Correlation coefficient analysis measures natural relation between various plant characters and determining the component characters on which selection can be used for genetic improvement in cane yield. Genotypic and Phenotypic correlation coefficients between the characters under study are depicted in Table 3. The results revealed that genotypic correlation coefficients were higher than the phenotypic ones implied that association was largely due to the genetic factors, suggested that selection can be done on the basis of phenotype. However, in few cases phenotypic coefficients were higher than genotypic coefficients indicating that environment suppressing the expression of that character at phenotypic level. The characters commercial cane sugar (t/ha), single cane weight, purity per cent at 8 months, cane length, number of millable canes at harvest and number of shoots at 240 DAP showed high significant and positive association with cane yield at both genotypic and phenotypic level. The positive and significant association of these characters implied that selection on the basis of these characters would be rewarding. Hiremath and Nagaraja (2016) observed strong positive and significant genotypic and phenotypic correlation of commercial cane sugar (t/ha) with cane yield and moderate positive and significant association with number of millable canes at harvest. Abbanandan and Eswaran (2018) studied that cane yield/ plot showed positive and significant correlation with cane thickness, single cane weight, brix, sucrose and commercial cane sugar per cent. Commercial cane sugar (t/ha) exhibited positive and significant association with cane yield, germination per cent, number of shoots at 240 DAP, number of millable canes at harvest, single cane weight, cane length, cane girth, brix, pol, purity and commercial cane sugar per cent at both 8 and 10 months respectively. Similar results had been reported by Singh *et al* (2005), Gowda and Saravanan (2016) and Ahmed *et al* (2019) in sugarcane for majority of the above mentioned characters.

Table 1. Analysis of Variance for different characters in Sugarcane

S. No.	Characters	Mean sum of squares		
		Replications (df : 2)	Treatments (df : 18)	Error (df : 36)
1	**Cane Yield (t/ha)**	18.85	226.34**	42.05
2	**CCS (t/ha)**	0.85	5.79**	0.70
3	**Germination %**	47.24	114.63**	14.09
4	**No. of Tillers at 120 days**	1779.40	1958.11**	115.33
5	**No. of Shoots at 240 days**	444.65	589.38**	129.36
6	**No. of Millable canes at Harvest**	53.28	255.26**	48.61
7	**Single cane wt.(kg)**	0.01	0.02**	0.00
8	**Cane length(cm)**	53.16	636.76**	63.14
9	**Cane Girth (cm)**	0.04	0.06**	0.01
10	**Brix % (8M)**	0.14	4.46**	0.16
11	**Pol % (8M)**	0.05	4.59**	0.15
12	**Purity% (8M)**	0.02	2.54**	0.09
13	**CCS % (8M)**	0.18	4.19**	0.81
14	**Brix % (10M)**	0.71	2.05**	0.19
15	**Pol % (10M)**	0.77	1.97**	0.14
16	**Purity % (10M)**	0.41	1.08**	0.08
17	**CCS % (10M)**	0.72	2.65**	0.97

** Significant at 1% level

Table 2. Genetic variability parameters for different characters in Sugarcane

Characters	Mean	Range		Coefficient of Variation		Heritability (%)	Genetic Advance (%)	Genetic Advance as per cent of mean
		Max.	Min.	Genotypic (%)	Phenotypic (%)			
CaneYield (t/ha)	85.15	97.93	72.09	9.20	11.95	59.37	12.44	14.61
CCS (t/ha)	11.22	13.57	8.83	11.62	13.80	70.93	2.26	20.16
Germination %	43.04	55.60	33.97	13.45	16.03	70.41	10.01	23.25
No. of Tillers at 120 days	151.48	184.80	100.55	16.36	17.83	84.19	46.85	30.93
No. of Shoots at 240 days	118.28	151.15	94.52	10.47	14.22	54.24	18.79	15.88

No. of Millable canes at Harvest	104.70	116.74	90.28	7.93	10.35	58.63	13.09	12.50
Single cane wt.(kg)	0.84	0.95	0.68	9.53	11.32	70.81	0.14	16.52
Cane length (cm)	218.79	246.53	187.53	6.32	7.29	75.18	24.70	11.29
Cane Girth (cm)	2.49	2.83	2.10	5.45	6.66	67.06	0.23	9.19
Brix % (8M)	19.42	21.07	16.37	6.17	6.50	90.06	2.34	12.06
Pol % (8M)	17.00	18.43	14.13	7.16	7.51	90.84	2.39	14.06
Purity % (8M)	87.48	89.10	83.73	1.21	1.59	58.17	1.67	1.91
CCS % (8M)	11.86	12.90	9.67	7.62	8.03	90.00	1.77	14.89
Brix % (10M)	20.65	21.83	18.63	3.82	4.36	76.43	1.42	6.87
Pol % (10M)	18.60	19.72	16.60	4.20	4.66	81.35	1.45	7.81
Purity % (10M)	90.08	92.32	88.62	0.83	1.38	36.55	0.93	1.04
CCS % (10M)	13.16	13.93	11.67	4.40	4.90	80.90	1.07	8.16

Table 3. Phenotypic and Genotypic correlation coefficients among seventeen characters in sugarcane

Characters	Cane yield (t/ha)	CCS (t/ha)	Germination %	No. of Tillers at 120 days (000/ha)	No. of Shoots at 240 days (000/ha)	No. of Millable canes at harvest (000/ha)	Single cane wt.(kg)	Cane length (cm)	Cane girth (cm)	Brix (%) at 8 m	Sucrose (%) at 8 m	Purity (%) at 8 m	CCS (%) at 8 m	Brix (%) at 10 m	Sucrose (%) at 10 m	Purity (%) at 10 m	CCS (%) at 10 m
Cane yield (t/ha)	**1.000**	0.931**	0.479**	0.306*	0.502**	0.616**	0.847**	0.667**	0.384**	0.397**	0.466**	0.719**	0.490**	0.296*	0.354**	0.542**	0.372**
CCS (t/ha)	0.934**	**1.000**	0.602**	0.115	0.437**	0.538**	0.871**	0.603**	0.393**	0.670**	0.722**	0.870**	0.741**	0.604**	0.666**	0.642**	0.683**
Germination %	0.306*	0.447**	**1.000**	0.251	0.438**	0.165	0.677**	0.542**	0.225	0.622**	0.642**	0.697**	0.654**	0.579**	0.579**	0.19	0.566**
No. of Tillers at 120 days (000/ha)	0.226	0.105	0.215	**1.000**	0.856**	0.668**	-0.147	0.265*	-0.177	-0.255	-0.249	-0.198	-0.243	-0.273*	-0.316*	-0.331*	-0.334*
No. of Shoots at 240 days (000/ha)	0.328*	0.326*	0.284*	0.687**	**1.000**	0.888**	-0.014	0.167	-0.18	0.057	0.079	0.146	0.087	0.163	0.101	-0.280*	0.077
No. of Millable canes at harvest (000/ha)	0.586**	0.528**	0.085	0.507**	0.730**	**1.000**	0.067	0.203	0.026	0.011	0.045	0.197	0.058	0.191	0.142	-0.094	0.119
Single cane wt.(kg)	0.631**	0.700**	0.530**	-0.022	-0.02	-0.007	**1.000**	0.618**	0.395**	0.660**	0.691**	0.754**	0.702**	0.362**	0.478**	0.756**	0.519**
Cane length (cm)	0.413**	0.420**	0.340**	0.192	0.08	0.032	0.505**	**1.000**	-0.022	0.422**	0.453**	0.542**	0.466**	0.198	0.227	0.314*	0.217
Cane girth (cm)	0.245	0.289*	0.114	-0.045	-0.059	0.019	0.419**	0.000	**1.000**	0.206	0.212	0.211	0.21	0.255	0.245	0.075	0.242
Brix (%) at 8 m	0.253	0.512**	0.565**	-0.228	0.054	0.035	0.524**	0.326*	0.169	**1.000**	0.996**	0.863**	0.993**	0.833**	0.892**	0.531**	0.901**
Sucrose (%) at 8 m	0.304*	0.555**	0.582**	-0.207	0.051	0.037	0.579**	0.372**	0.193	0.986**	**1.000**	0.902**	0.999**	0.836**	0.896**	0.554**	0.907**
Purity (%) at 8 m	0.387**	0.537**	0.479**	-0.075	-0.004	0.015	0.614**	0.430**	0.249	0.623**	0.744**	**1.000**	0.916**	0.778**	0.823**	0.539**	0.836**
CCS (%) at 8 m	0.317*	0.565**	0.587**	-0.197	0.053	0.039	0.597**	0.386**	0.198	0.976**	0.998**	0.777**	**1.000**	0.838**	0.899**	0.563**	0.910**
Brix (%) at 10 m	0.131	0.441**	0.497**	-0.204	0.106	0.08	0.312*	0.157	0.207	0.755**	0.759**	0.567**	0.761**	**1.000**	0.984**	0.275*	0.966**
Sucrose (%) at 10 m	0.191	0.523**	0.509**	-0.237	0.11	0.074	0.399**	0.198	0.209	0.794**	0.801**	0.590**	0.801**	0.955**	**1.000**	0.446**	0.997**
Purity (%) at 10 m	0.215	0.342**	0.174	-0.144	0.028	-0.016	0.376**	0.197	0.062	0.25	0.262*	0.196	0.263*	0.039	0.319*	**1.000**	0.510**
CCS (%) at 10 m	0.204	0.537**	0.502**	-0.25	0.111	0.062	0.419**	0.196	0.204	0.785**	0.793**	0.584**	0.793**	0.910**	0.991**	0.428**	**1.000**

** Significant at 1% level, * Significant at 5% level

Table 4. Direct (diagonal values) and indirect effects of different characters on cane yield at phenotypic level

Characters	CCS (t/ha)	Germination %	No. of Tillers at 120 days (000/ha)	No. of Shoots at 240 days (000/ha)	No. of Millable canes at harvest (000/ha)	Single cane wt.(kg)	Cane length (cm)	Cane girth (cm)	Brix (%) at 8 m	Sucrose (%) at 8 m	Purity (%) at 8 m	CCS (%) at 8 m	Brix (%) at 10 m	Sucrose (%) at 10 m	Purity (%) at 10 m	CCS (%) at 10 m
CCS (t/ha)	**1.1541**	0.0022	-0.0006	-0.0044	0.0086	-0.0066	0.0088	-0.0008	0.0251	-0.1035	0.0193	0.0492	0.0578	-0.2464	-0.0030	-0.026
Germination %	0.51539	**0.00482**	-0.0012	-0.00381	0.00138	-0.00499	0.0071	-0.00031	0.0278	-0.10838	0.01724	0.0511	0.06511	-0.2399	-0.00153	-0.02425
No. of Tillers at 120 days (000/ha)	0.1218	0.0010	**-0.0056**	-0.0092	0.0082	0.0002	0.0040	0.0001	-0.0112	0.0385	-0.0027	-0.0171	-0.0268	0.1118	0.0013	0.0121
No. of Shoots at 240 days (000/ha)	0.3759	0.0014	-0.0039	**-0.0134**	0.0119	0.0002	0.0017	0.0002	0.0026	-0.0095	-0.0001	0.0047	0.0139	-0.0518	-0.0003	-0.0054
No. of Millable canes at harvest (000/ha)	0.6098	0.0004	-0.0029	-0.0098	**0.0163**	0.0001	0.0007	-0.0001	0.0017	-0.0069	0.0006	0.0034	0.0104	-0.0349	0.0001	-0.0030
Single cane wt.(kg)	0.8073	0.0026	0.0001	0.0003	-0.0001	**-0.0094**	0.0106	-0.0011	0.0258	-0.1079	0.0221	0.0520	0.0410	-0.1883	-0.0033	-0.0203
Cane length (cm)	0.4846	0.0016	-0.0011	-0.0011	0.0005	-0.0048	**0.0209**	0.0000	0.0160	-0.0693	0.0155	0.0337	0.0206	-0.0932	-0.0017	-0.0095
Cane girth (cm)	0.3330	0.0006	0.0003	0.0008	0.0003	-0.0039	0.0000	**-0.0027**	0.0083	-0.0360	0.0090	0.0173	0.0272	-0.0984	-0.0005	-0.0098
Brix (%) at 8 m	0.5904	0.0027	0.0013	-0.0007	0.0006	-0.0049	0.0068	-0.0005	**0.0492**	-0.1837	0.0224	0.0850	0.0989	-0.3744	-0.0022	-0.0379
Sucrose (%) at 8 m	0.6409	0.0028	0.0012	-0.0007	0.0006	-0.0055	0.0078	-0.0005	0.0484	**-0.1864**	0.0268	0.0869	0.0996	-0.3774	-0.0023	-0.0383
Purity (%) at 8 m	0.6194	0.0023	0.0004	0.0001	0.0003	-0.0058	0.0090	-0.0007	0.0306	-0.1386	**0.0360**	0.0677	0.0744	-0.2781	-0.0017	-0.0282
CCS (%) at 8 m	0.6524	0.0028	0.0011	-0.0007	0.0006	-0.0056	0.0081	-0.0005	0.0480	-0.1860	0.0280	**0.0871**	0.0998	-0.3778	-0.0023	-0.0383
Brix (%) at 10 m	0.5090	0.0024	0.0012	-0.0014	0.0013	-0.0029	0.0033	-0.0006	0.0371	-0.1415	0.0204	0.0663	**0.1311**	-0.4502	-0.0003	-0.0440
Sucrose (%) at 10 m	0.6033	0.0025	0.0013	-0.0015	0.0012	-0.0038	0.0041	-0.0006	0.0390	-0.1492	0.0212	0.0698	0.1253	**-0.4713**	-0.0028	-0.0479
Purity (%) at 10 m	0.3946	0.0008	0.0008	-0.0004	-0.0003	-0.0035	0.0041	-0.0002	0.0123	-0.0487	0.0071	0.0230	0.0051	-0.1504	**-0.0088**	-0.0207
CCS (%) at 10 m	0.61994	0.00242	0.0014	-0.00149	0.001	-0.00395	0.0041	-0.00055	0.0386	-0.14779	0.02104	0.0691	0.11936	-0.4672	-0.00375	**-0.04831**

Residual are 0.00187

Path Coefficient

Path coefficient provides an effective way of finding direct and indirect sources of correlation. Path analysis forces researchers to explicitly specify how the variable relates to one another and thus encourages the development of clear and logical theories about the process influencing a particular outcome. Direct and indirect effects of these components determined on cane yield at phenotypic level are presented in Table 4. The results of path coefficient analysis revealed that commercial cane sugar (t/ha) exhibited high positive direct effect on cane yield followed by brix per cent at 10 months, commercial cane sugar at 8 months, purity per cent at 8 months, brix per cent at 8 months, cane length and number of millable canes at harvest. These findings were in accordance with the results of Somu*et al* (2020) and Ali *et al* (2021) for majority of the characters.

On the basis of above findings, it may be stated that commercial cane sugar (t/ha), single cane weight, number of tillers at 120 DAP and number of millable canes at harvest are most important morphological characters for cane yield whereas among the quality parameters CCS % at 10 months, sucrose % at 8 months, brix, sucrose and purity % at 8 and 10 months also contributes to cane yield. Path coefficient results showed the amount of contribution either directly or indirectly and also the percentage of each parameter to the cane yield. It can be concluded that commercial cane sugar (t/ha), brix per cent at 10 months, commercial cane sugar at 8 months, purity per cent at 8 months, brix per cent at 8 months, cane length and number of millable canes at harvest exhibited the highest contribution to cane yield. Therefore, these parameters are very important to be considered when selecting for sugarcane yield especially in determining possibility of obtaining yield from millable sugarcane particularly for subtropical ecology.

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