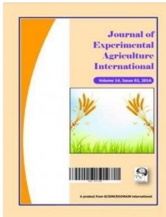

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Genetic Diversity Analysis for Economically Important Traits of Sugarcane (*Saccharum officinarum* L.) Ratoon Crop

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Authors' contributions

This work was carried out in collaboration among all authors. Author AA designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors FAK and AAK managed the analyses of the study. Author SU managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Study on correlation and path coefficient analysis for cane yield and yield related traits in 20 accessions of sugarcane (*Saccharum officinarum* L.) ratoon crop was conducted in the field of Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan. Analysis of variance indicated highly significant differences (p = 0.01) among the accessions for all the traits as shown in Table 2. Among the traits studied cane weight had positive correlation both at genotypic and phenotypic level with plant height, leaf area, cane diameter, no. of nodes per plant, internodal distance, juice contents dry matter contents and bagasse weight (Table 3). Also cane weight has negative correlation with no. of tillers per plant and no. of millable canes per plant significant at phenotypic level (Table 3). The study of path coefficient analysis for yield related traits depicted that baggas weight exerts maximum direct effect on cane yield followed by juice contents and internodal distance and indirect effects of these traits via each other were also found maximum

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compared to other traits (Table 4) while Dry matter contents, Leaf area and No. of tillers per plant had negative direct effect on cane yield. Cluster analysis revealed that cluster II (BF-129, CPF-234, CP-77-400, TRITON and SPSG-26) showed highest values (Table 7) for most of the traits like plant height, leaf area, cane diameter, No. of nodes, juice contents, dry matter contents, bagasse weight and cane weight. The similar trend is also shown by PCA biplot. So best performing sugarcane accessions like cluster II viz BF-129, CPF-234, CP-77-400, TRITON and SPSG-26 if selected for breeding against highly correlated variables of bagasse weight, juice contents and internodal distance with cane weight, can increase our yield qualitatively and quantitatively.

Keywords: Sugarcane; cane diameter; brix value; dry matter contents; correlation.

1. INTRODUCTION

Sugarcane has importance as food and cash crop in tropical and subtropical regions of the world particularly in Pakistan. It is grown in a range of environments from hot humid near sea level to cool and moist environment at higher elevations. It forms essential items for industries like sugar, chipboard and paper. Pakistan ranks at the fifth position in cane acreage and production and almost 16^{th} position in sugar production in the world [1]. The national average cane yield is (~ 51.5 t ha-1) is far below the existing potential [2]. The recovery of sugar can be increased from the current average of 8.32% to 10/11% by better cane varieties [3].

Sugarcane ratoons have an additional advantage of better juice quality and sugar recovery in comparison to plant crop of same variety under similar conditions. In the Punjab only, about 50 percent of sugarcane acreage comes under ratoon crop. However, due to improper attention towards ratoons, the farmers lose more than 35 percent productivity. Certain other essential features of ratooning are; short crop cycle, better utilization of monsoon climate, extended milling period with an early start and sowing of wheat crop well in time. In major cane growing countries, taking of two or more ratoons is a normal practice [4].

In Pakistan area under sugarcane production was 1241 thousand hectares and total sugarcane production for the year 2015-16 was 63.9 million tons. Sugarcane shares in value added of Agriculture and GDP are 4.5% and 0.9% respectively [5]. Sugarcane varieties in commercial cultivation are complex polyploid [1,6]. The heterozygosity and polyploidy in sugarcane has resulted in generation of greater genetic variability in sugarcane [7]. In Pakistan the main efforts are made to improve the tonnage while sucrose recovery remained low. Correlation and path coefficient studies in sugarcane ratoon crop are of great value for a breeder in selecting desired plant types e.g., for a planned breeding program to improve cane yield and juice quality in sugarcane ratoon crop and inter relationship in different characters. Keeping in view the above facts these investigations will be undertaken to assess the genotypic and phenotypic correlation and path coefficient analysis in some economically important traits that effect cane yield and sucrose recovery in *S. officinarum*. Multivariate statistical analysis techniques like Principal Component Analysis (PCA) and Cluster Analysis techniques could be used for evaluating genetic divergence among sugarcane genotypes [8]. It is hoped that these efforts will help for the development of cane varieties with better commercial value ratoon crops.

2. MATERIALS AND METHODS

The present study reported was conducted in the experimental area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan. Twenty accessions of sugarcane viz (COJ-84, CPF-235, COL-54, SPSG-26, COJ-64, SPF-232, CP-77-400, CP-72-2086, BF-129, TRITON, CPF-234, KATHA, No. 61, CP-43-33, No. 31/77, SPF-213, HSF-242, HSF-240, S.97.US.297 and CPF-237) were sown in a Randomized Complete Block Design with three replications.

Plant to plant and row to row distances were maintained at 30 cm and 75 cm respectively. All the recommended agronomic practices were followed for growing the crop. The crop was sown in September 2010 and harvested in early march, 2011 and later was left for ratooning the following cultivars. The ratoon crop of sugarcane was concluded in the experiment. At maturity, five guarded canes per replication were selected at random for quantitative parameters study. The data were recorded for the following characters.

1. Plant height
2. Leaf area
3. Number of tillers per plant
4. Number of millable canes per plant
5. Cane diameter
6. No of nodes per plant
7. Internodal distance
8. juice contents
9. Brix value
10. Dry matter contents
11. Bagasse weight
12. Cane weight

2.1 Correlation Analysis

Genotypic and phenotypic correlation coefficients among the characters under study were estimated according to the statistical techniques outlined by Kwon and Torrie [9] which is as follows:

$r_g = Cov_{g}\ ij / \surd\ (var_{g\ i})\ (Var_{gj})$
r_g = Genotypic correlation coefficient
$Cov_{g\ i\ j}$ = Genotypic covariance of ith and jth traits
$\delta^2_{g\ i},\ \delta^2_{g\ j}$ = variances of trait i and j
$r_p = M\ i\ j / \surd\ (M\ i\ i)\ (M\ j\ j)$

Where

r_p = Phenotypic correlation coefficient
M i j = Mean product of accessions of ith and jth traits
M i i and M j j = Genotypic mean square for ith and jth traits respectively.

2.1.1 Significance test for correlation

Genotypic and phenotypic correlations were tested for their statistical significance by using the methodology given below.

2.1.2 Significance test for genotypic correlation

$$SE\ (r_g) = 1 - r_g^2 / \surd 2\ \surd\ [(SEh^2_i / h^2_j)\ (SEh^2_j / h^2_j)]$$

Where

SE (r_g) = Standard error for genotypic correlation.
r_g = Genetic correlation.
h^2_i and h^2_j = heritability coefficients of traits i and j, respectively.
SEh^2_i and SEh^2_j = Standard error for heritability associated with ith and jth traits respectively.

A genotypic correlation was considered significant statistically if its absolute value exceeds the twice of the respective standard error.

2.1.3 Significance test for phenotypic correlation

Statistical significance of phenotypic correlation was determined by using t-test as described by Steel, Torrie [10].

$$t = r / [\surd\ (1- r^2) / (n-2)]$$

Where

r = Phenotypic correlation coefficient
n = Number of observations

Phenotypic correlation was considered significant if t-calculated was greater than t-tabulated and value of genotypic correlation is significant if it is greater than twice of its standard error.

2.2 Path Coefficient and Principal Component Analysis

Path coefficient analysis was performed according to the method given by Dewey and Lu [11], in yield related traits keeping cane yield as resultant variable and yield related traits such as plant height, leaf area, number of tillers per plant, number of millable canes per plant, cane diameter, no. of nodes per plant, internodal distance, juice contents, brix value, dry matter contents and bagasse weight as causal variables. As path coefficient analysis determines the effect of individual traits on overall cane yield, principal component and cluster analysis were also performed to determine the performance of individual advance lines and their effect on different variables. Principal component analysis (PCA) reflects the importance of the largest contributor to the total variation at each axis of differentiation [12]. Principal component analysis relies upon Eigen vector decomposition of the covariance or correlation matrix [13]. In present study the correlation matrix was used for Principal component analysis.

3. RESULTS AND DISCUSSION

From the experiment under study, data collected were subjected to analysis of variance, which showed significant differences among all the traits studied. For cane weight there were highly significant differences among all the genotypes.

It was revealed that BF-129 had the maximum cane weight (4350.0 g) followed by SPF-234 (3446.0 g) while KATHA had the minimum value (601.3 g) out of five guarded cane plants.

The experiment was performed for genetic evaluation of the Characters studied. Various estimates showed valuable results which are discussed below.

Correlation analysis was performed between variables to determine the extent of relationship between them. It was found that Bagasse weight, juice contents, dry matter contents, cane diameter, leaf area, plant height, no. of nodes per plant, intermodal distance and brix value have positive and significant correlation with cane weight. These results are in accordance with Ishaq, Misari [14] but other traits like no. of tillers and no. of millable canes per plant had negative correlation with cane weight significant at phenotypic level. Plant height had significant and positive correlation both at genotypic and phenotypic level with leaf area, cane diameter, internodal distance, juice contents, dry matter contents, bagasse weight and cane weight. Similar findings have been reported by Das, Jena [15] that plant height was positively associated with stalk thickness. Also Arshad, Bakhsh [16] reported that plant height was positively and significantly associated with grain yield in chickpea. But plant height was negatively correlated with No. of tillers/plant significantly at phenotypic level but non- significantly at genotypic level. It means breeding of sugarcane for increase tillering, we would have to suffer from decreased plant height.

Also leaf area had positive and significant correlation with cane diameter, no. of nodes/plant, internodal distance, juice contents, brix value, bagasse weight, dry matter contents and cane weight at genotypic and phenotypic level. But negatively correlated with No. of tillers/plant and No. of millable canes/plant non-significantly at genotypic level but significantly at phenotypic level. The results are in accordance with Khan, Iqbal [17] who reported that leaf area had positive and significant correlation with Plant height, cane diameter, Internodal distance and baggase weight both at genotypic and phenotypic level. So selection of plants with more leaf area to capture more light and increase overall cane weight is beneficial in this respect.

It was also evident from Table 3 that association of number of tillers per plant with no. of millable canes was positively significant at genotypic and phenotypic level but negative and non significant with no. of nodes and internodal distance. It also had negative correlation with cane diameter, juice contents, brix value, dry matter contents, baggase weight and cane weight significantly at phenotypic level but non-significant at genotypic level.

For number of millable canes there was a positive and significant correlation with internodal distance at genotypic while non-significant and positive correlation at phenotypic level. No. of millable canes had negative correlation with cane diameter, juice contents, brix value, dry matter, bagasse weight and cane weight significant at phenotypic level but negative and non-significant at genotypic level.

Table 3 also shows that cane diameter had positive and significant correlation with no. of nodes, juice contents, dry matter contents, bagasse weight and cane weight, but negatively correlated with internodal distance, No. of tillers/plant and No. of millable canes/plant both at Genotypic and Phenotypic level. Chaudhary and Singh [18] also showed that cane thickness was positively correlated with cane yield.

The no. of nodes per plant had positive correlation with dry matter contents, baggase weight, cane weight, both at genotypic and phenotypic level, but negative correlation with internodal distance significant at phenotypic level but non-significant at genotypic level. Internodal distance had positive and significant association with juice contents and cane weight, both at genotypic and phenotypic level. But positive and non-significantly correlated with brix value.

Juice contents had positive and significant association with dry matter, bagasse contents and cane weight at both genotypic and phenotypic levels (Table 3). Brix value had positive and significant association with dry matter, bagasse weight and cane weight at genotypic and non-significant at phenotypic levels (Table 3). Also Dry matter contents had positive and significant association with bagasse weight and cane weight at both genotypic and phenotypic levels (Table 3). Dry matter had negative correlation with no. of tillers per plant and no. of millable canes significant at phenotypic level while non-significant at genotypic level.

Table 1. Traits means of genotypes for important agronomical and quality traits of sugarcane ratoon crop

Genotypes	Name	PH	LA	Till	MC	CD	Nodes	ID	JC	BV	DM	BW	CW
1	COJ-84	238.3	265.541	8.73	4.1	2.355	14.0	6.1	786	21.0	305.5	1082	1931
2	CPF-235	264.8	247.503	13.20	8.1	2.190	13.3	7.4	885	20.5	391.5	1381	2346
3	COL-54	185.2	189.006	14.20	4.7	2.353	12.3	6.3	981	19.0	388.4	1278	2250
4	SPSG-26	280.7	293.165	10.07	6.3	2.303	11.4	7.1	1085	18.5	489.4	1632	2900
5	COJ-64	238.1	179.915	18.07	7.4	2.020	11.1	7.5	783	19.7	254.0	977	2049
6	SPF-232	289.0	312.396	11.07	8.1	2.131	12.1	7.0	736	22.1	301.6	1230	2250
7	CP-77-400	316.4	283.531	11.93	8.2	2.133	9.3	9.0	1384	16.5	303.6	1281	2500
8	CP-72-2086	279.0	289.177	11.20	8.9	2.262	11.1	7.5	934	21.0	326.0	1077	2245
9	BF-129	289.0	315.144	11.00	6.4	2.517	12.3	9.5	1839	17.1	746.4	2233	4350
10	TRITON	294.2	402.812	12.60	9.7	2.407	13.8	8.2	1334	18.2	411.5	1378	2999
11	CPF-234	320.5	356.409	11.20	8.9	2.708	15.9	10.1	1285	21.0	389.0	1377	3446
12	KATHA	247.2	177.137	19.27	15.3	1.597	9.4	8.9	185	20.1	88.7	379	601
13	No. 61	245.4	124.646	23.27	19.3	1.794	13.1	7.5	487	16.0	173.3	630	1100
14	CP-43-33	224.1	198.177	9.33	5.7	1.878	11.1	7.7	535	19.3	236.7	627	1200
15	No. 31/77	217.9	192.093	14.20	11.9	1.666	10.8	8.7	385	14.1	166.5	529	801
16	SPF-213	249.9	236.509	15.33	7.4	2.345	9.4	8.5	785	19.0	253.3	928	1753
17	HSF-242	276.5	370.470	12.00	7.0	2.151	10.3	10.6	1235	21.1	362.2	1328	2599
18	HSF-240	289.1	305.399	11.40	9.3	1.969	11.1	9.3	1033	20.3	283.6	1176	2546
19	S.97.US.297	267.8	248.521	13.33	10.3	1.914	9.9	10.3	1184	21.1	434.3	1375	2808
20	CPF-237	276.2	313.509	13.20	10.2	2.232	10.9	10.7	1084	21.0	332.6	1150	2747

PH, plant height (cm); LA, leaf area (cm^2); Till, Number of tillers; MC, millable cane; CD, cane diameter; Nodes, Number of nodes; ID, internodal distance; JC, juice contents BV, brix value (°Bx); DM, dry matter (g); BW, Baggas weight (g); CW, cane weight (g)

Table 2. Mean squares table for important agronomical and quality traits of sugarcane ratoon crop

SOV	DF	PH	Leaf Area	Tillers	MC	CD	Nodes	ID	JC	BV	DM	BW	CW
Rep	2	337.87	200.9	0.134	0.201	0.002	0.069	0.179	3937	0.442	608.9	2904	987
Genotype	19	3414.21**	15875.2**	37.442**	37.326**	0.241**	9.000**	5.882**	448893**	12.968**	57173.6**	520592**	2414012**
Error	38	399.36	231.1	0.495	0.425	0.011	0.364	0.329	2714	0.680	959.3	5698	18475

PH, plant height (cm); LA, leaf area (cm2); Till, Number of tillers; MC, millable cane; CD, cane diameter; Nodes, Number of nodes; ID, internodal distance; JC, juice contents BV, brix value (°Bx); DM, dry matter (g); BW, Baggas weight (g); CW, cane weight (g)

Table 3. Genotypic and phenotypic correlation coefficients of all possible pairing of some characters of sugarcane plant

Variables		PH	LA	Tillers	MC	CD	Nodes	ID	JC	BV	DM	BW	CW
PH	r_g	1	0.79*	-0.36**	0.03^{NS}	0.45*	0.15*	0.55*	0.65*	0.24*	0.41*	0.54*	0.67*
	r_p		0.75**	-0.33**	0.03^{NS}	0.41**	0.14*	0.49**	0.61**	0.21*	0.38**	0.51**	0.63**
LA	r_g		1	-0.65**	-0.37**	0.67**	0.27*	0.41*	0.72*	0.37*	0.55*	0.64*	0.74*
	r_p			-0.64**	-0.37**	0.64**	0.26*	0.40**	0.71**	0.35**	0.54**	0.64**	0.73**
NT	r_g			1	0.77*	-0.52**	-0.18*	-0.01^{NS}	-0.48*	-0.34*	-0.51**	-0.51**	-0.50
	r_p				0.77**	-0.51**	-0.17*	-0.01^{NS}	-0.48**	-0.32*	-0.49**	-0.51**	-0.50**
MC	r_g				1	-0.59**	-0.09	0.23*	-0.43	-0.34*	-0.50*	-0.51**	-0.44**
	r_p					-0.58**	-0.08	0.23*	-0.43**	-0.32*	-0.49**	-0.51**	-0.44**
CD	r_g					1	0.57*	-0.01^{NS}	0.73*	0.29*	0.71*	0.75*	0.80*
	r_p						0.55**	-0.01^{NS}	0.72**	0.26*	0.69**	0.73**	0.77**
Nodes	r_g						1	-0.27	0.20*	0.09	0.29*	0.28*	0.34*
	r_p							-0.26*	0.19*	0.10	0.28*	0.28*	0.33**
ID	r_g							1	0.40*	0.08	0.15*	0.18*	0.35*
	r_p								0.39**	0.07	0.15*	0.17*	0.34**
JC	r_g								1	0.07*	0.88*	0.92*	0.95*
	r_p									0.06	0.87**	0.91**	0.95**
BV	r_g									1	0.05*	0.15*	0.22*
	r_p										0.06	0.14**	0.22*
DM	r_g										1	0.97*	0.91*
	r_p											0.96**	0.90**
BW	r_g											1	0.96*
	r_p												0.95**
CW	r_g												1
	r_p												

PH, plant height (cm); LA, leaf area (cm^2); Till, Number of tillers; MC, millable cane; CD, cane diameter; Nodes, Number of nodes; ID, internodal distance; JC, juice contents BV, brix value (°Bx); DM, dry matter (g); BW, Baggas weight (g); CW, cane weight (g)

Table 4. Direct and indirect effects of plant traits on cane yield (Cane Yield as a dependent variable)

Variables	PH	LA	NT	MC	CD	Nodes	ID	JC	BV	DM	BW
PH	0.0559	-0.0627	0.0037	0.0002	0.0450	0.0173	0.0899	0.1724	0.0174	-0.0547	0.3956
LA	0.0446	-0.0786	0.0067	-0.0022	0.0663	0.0318	0.0677	0.1905	0.0265	-0.0742	0.4668
NT	-0.0204	0.0517	-0.0102	0.0046	-0.0516	-0.0217	-0.0024	-0.1271	-0.0240	0.0678	-0.3750
MC	0.0019	0.0296	-0.0079	0.0059	-0.0590	-0.0110	0.0382	-0.1147	-0.0239	0.0675	-0.3734
CD	0.0255	-0.0528	0.0053	-0.0036	0.0988	0.0656	-0.0016	0.1926	0.0208	-0.0951	0.5465
Nodes	0.0084	-0.0217	0.0019	-0.0006	0.0563	0.1150	-0.0454	0.0530	0.0069	-0.0386	0.2076
ID	0.0309	-0.0328	0.0002	0.0014	-0.0010	-0.0322	0.1625	0.1066	0.0059	-0.0211	0.1307
JC	0.0368	-0.0572	0.0050	-0.0026	0.0726	0.0233	0.0661	0.2620	0.0049	-0.1170	0.6653
BV	0.0139	-0.0297	0.0035	-0.0020	0.0294	0.0114	0.0135	0.0184	0.0701	-0.0079	0.1083
DM	0.0230	-0.0439	0.0052	-0.0030	0.0707	0.0334	0.0257	0.2306	0.0042	-0.1329	0.7053
BW	0.0306	-0.0509	0.0053	-0.0031	0.0748	0.0331	0.0294	0.2415	0.0105	-0.1299	0.7216

PH, plant height (cm); LA, leaf area (cm^2); Till, Number of tillers; MC, millable cane; CD, cane diameter; Nodes, Number of nodes; ID, internodal distance; JC, juice contents BV, brix value (°Bx); DM, dry matter (g); BW, Baggas weight (g); CW, cane weight (g);

As for as path coefficient analysis is concerned it is simply a standardized partial regression coefficient, which assesses the influence of causal variables on resultant variable directly and indirectly by partitioning the genotypic correlation coefficients. Such information may be useful in predicting correlated responses of different characters towards directional selection. Keeping cane yield as resultant variable and eleven other yield related traits as causal variables, the following results were obtained.

According to the results shown in Table 4, bagasse weight exerts maximum direct effect on cane yield followed by juice contents and internodal distance, also indirect effects of these traits via each other on cane weight were found maximum compared to other traits. So direct selection based on these traits would be effective to increase cane yield and sugar recovery. Dry matter contents had negative direct effect on yield while its genotypic correlation with cane yield is highly positive and significant; actually it has a strong positive indirect effect via bagasse weight on cane yield. All other traits studied except Leaf area and number of millable canes also exerts positive indirect effects for dry matter contents on yield, so that is the reason for its high genotypic correlation with cane yield. Other traits also showed valuable information as discussed below.

Plant height had positive direct effect on yield. The indirect effects via Leaf area and dry matter contents were negative, whereas no. of tillers, no. of millable canes, cane diameter, no. of nodes, internodal distance, juice contents, brix value and bagasse weight exerted positive indirect effects for plant height on yield. So plant height is a very important component of cane yield. Positive direct effect of plant height suggests that direct selection of this trait for high grain yield would be effective. The results were in agreement with the findings of Chaudhary, Chaudhary [19]. Also leaf area had negative direct effect on yield. Its indirect effects via Plant height, number of tillers, cane diameter, Number of nodes, internodal distance, juice contents, brix value and bagasse weight had positive influence on yield, while leaf area effected cane yield negatively by no. of millable canes and dry matter contents. Table 4 also shows that number of tillers per plant had negative direct effect on yield. Whereas it has positive indirect effects via leaf area, Number of millable canes and dry matter contents but all other traits studied had negative indirect effects via number of tillers per plant on yield. The trait like number of millable canes had positive direct effect on yield [20,21], also found similar results) its indirect effects via plant height, leaf area, internodal distance and dry matter contents were positive while via all others traits it had negative indirect effects on cane yield. It was also found from the experiment that cane diameter had positive direct effect on yield. Leaf area, No of millable canes, internodal distance and dry matter contents had negative indirect effects on yield while all others had positive indirect effects for cane diameter on yield. For no. of nodes per plant Table 4 shows that it has positive direct effect on yield. Plant height, no of tillers, cane diameter, juice contents, brix value and bagasse weight had positive indirect effects while all others had negative indirect effects for no. of nodes per plant on yield.

According to the results shown in Table 4, it was also found that internodal distance had positive direct effect on yield as explained by Chaudhary and Joshi [20]. Leaf area, cane diameter, no. of nodes and dry matter contents had negative indirect effects while all other characters studied had positive indirect effects for internodal distance on yield. Also juice contents had positive direct effect on yield. Leaf area, no. of millable canes and dry matter contents had negative indirect effects while all other characters had positive indirect effects for juice contents on yield. It was also proved from the Table 4 that brix value had positive direct effect on yield. Leaf area, no. of millable canes and dry matter contents had negative indirect effects while all other characters had positive indirect effects for brix value on yield. Also baggas weight had positive direct effect on yield. Leaf area, no. of millable cane and dry matter contents had negative indirect effects while all other characters had positive indirect effects for baggas weight on yield.

As path coefficient analysis determines the effect of individual traits on overall cane yield, principal component and cluster analysis were also performed to determine the performance of individual advance lines and their effect on different variables. Principal component analysis (PCA) reflects the importance of the largest contributor to the total variation at each axis of differentiation [12]. There are no tests to evaluate the significance of eigenvalues. Therefore, we follow the criterion established by Kaiser [22], which adapts very well to the purpose of this analysis. This criterion is based on the selection of principal components whose eigenvalues are >1. Principal component analysis reduced the original 12 quantitative characters in experiment to 4 principal components the first four principal components with eigenvalues >1 explained 87.5% of variation among 20 accessions of sugarcane ratoon crop (Table 5). The proportions of the total variance attributable to the first four PC were 52.6, 15.3, 10.6 and 9.0%. There are no clear guidelines to determine the importance of a trait coefficient for each principal component. Johnson and Wichern [23], regard a coefficient as significant that is greater than half divided by the square root of the standard deviation of the eigenvalue of the respective principal component.

Table 5. Eigenvalue, percentage variance and cumulative variance values of Principal component analysis (PCA)

PCA#	Eigenvalue	Proportion	Cumulative
PC1	6.3155	0.526	0.526
PC2	1.8411	0.153	0.68
PC3	1.2773	0.106	0.786
PC4	1.0797	0.09	0.876
PC5	0.588	0.049	0.925
PC6	0.3607	0.03	0.955
PC7	0.2738	0.023	0.978
PC8	0.1268	0.011	0.989
PC9	0.0749	0.006	0.995
PC10	0.0393	0.003	0.998
PC11	0.0125	0.001	0.999
PC12	0.0105	0.001	1

The importance of traits to the different PC can be seen from the corresponding Eigen vectors which are presented in Table 6. The results showed that cane weight, baggas weight, juice contents, dry matter contents, cane diameter, leaf area and brix value had the highest loadings in PC1, so PC1 is a weighted average of these seven characters indicating their significant importance for this component. On the other hand, other traits are less important to PC1. The other traits like plant height, millable cane and Internodal distance are the main traits of PC2. For PC3 No. of tillers and no. of nodes per plant were the most important traits while multiple traits contributed to the fourth PC in varying proportions.

The accessions that are close together are perce ived as being similar when rated on 12 variables on PCA biplot (Fig. 1) while accessions which are further apart are more diverse from oth er accessions. Cluster analysis performed on all 20 accessions of sugarcane clearly differentiated them into four clusters as Fig 2 based on Ward linkage, Euclidean distance. Each cluster containing accessions that were highly similar. Cluster I consisted of 08 accessions, cluster II of 05, cluster III of 04 and cluster IV of 03 accessions. Mean value for each cluster (Table 7) revealed that accessions in cluster I.

Showed almost average to low performance for each trait while accessions in cluster II (BF-129, CPF-234, CP-77-400, TRITON and SPSG-26) showed highest values for most of the traits like plant height, leaf area, cane diameter, No. of nodes, juice contents, dry matter contents, baggas weight and cane weight. The similar trend is also shown by PCA biplot (Fig. 1). Cluster III (HSF-242, CPF-237, HSF-240 and S.97.US.297) attained maximum value for the traits of Internodal distance and Brix value while Cluster IV (KATHA, No. 31/77 and No.61) gained highest values for No. of tillers and No. of millable canes but lowest values for most of the other traits as also indicated by PCA biplot (Fig. 1).

It is clearly depicted from above experiment that cluster II (BF-129, CPF-234, CP-77-400, TRITON and SPSG-26) showed highest values for most of the traits like plant height, leaf area, cane diameter, No. of nodes, juice contents, dry matter contents, baggas weight and cane weight. The similar trend is also shown by PCA biplot (Fig. 1) while cane weight has highest correlation (genotypic and phenotypic) with baggas weight followed by juice contents, dry matter contents, cane diameter, leaf area, plant height and Internodal distance. Also baggas weight exerts maximum direct effect on cane yield followed by juice contents and internodal distance and indirect effects of these traits via each other were also found maximum compared to other traits (Table 4). So best performing sugarcane accessions of cluster II viz BF-129, CPF-234, CP-77-400, TRITON and SPSG-26 if bred against highly correlated variables of bagasse weight, juice contents and internodal distance with cane weight, can increase our yield qualitatively and quantitatively.

Table 6. Principal component analysis of agronomical and quality traits of sugarcane ratoon crop

Variable	PH	LA	NT	MC	CD	Nodes	ID	JC	BV	DM	BW	CW
PC1	0.256	0.332	-0.272	-0.233	0.335	0.143	0.105	0.367	0.118	0.348	0.369	0.383
PC2	0.4	0.154	0.248	0.459	-0.202	-0.275	0.616	0.151	-0.12	-0.037	-0.004	0.095
PC3	-0.123	-0.249	0.368	0.25	0.11	0.322	-0.182	0.167	-0.642	0.274	0.206	0.135
PC4	-0.284	-0.182	-0.165	-0.357	-0.197	-0.691	0.096	0.165	-0.328	0.217	0.152	0.019
PC5	-0.297	-0.319	0.508	0.045	0.048	-0.105	0.098	0.053	0.63	0.224	0.201	0.191
PC6	-0.539	0.037	-0.108	-0.146	0.156	0.355	0.678	0.012	-0.107	-0.034	-0.228	-0.02
PC7	0.076	0.099	0.406	-0.241	0.682	-0.295	-0.04	0.141	-0.125	-0.366	-0.188	-0.054
PC8	-0.441	0.796	0.213	0.181	-0.117	-0.121	-0.201	-0.024	-0.006	0.107	0.082	-0.083
PC9	-0.032	-0.069	-0.281	0.423	0.52	-0.252	0.053	-0.457	0.002	0.41	-0.025	-0.147
PC10	-0.228	-0.12	-0.321	0.451	0.081	-0.095	-0.198	0.66	0.137	-0.121	-0.316	0.061
PC11	-0.178	-0.005	-0.136	0.141	0.02	-0.104	-0.053	-0.335	-0.09	-0.424	0.11	0.777
PC12	0.122	0.075	0.149	-0.169	-0.113	-0.022	-0.101	-0.081	-0.024	0.443	-0.743	0.388

PH, plant height (cm); LA, leaf area (cm^2); Till, Number of tillers; MC, millable cane; CD, cane diameter; Nodes, Number of nodes; ID, internodal distance; JC, juice contents BV, brix value (°Bx); DM, dry matter (g); BW, Baggas weight (g); CW, cane weight (g);

Table 7. Mean value for each cluster against all the traits studied

	Cluster1	Cluster2	Cluster3	Cluster4
No. of accessions	8	5	4	3
PH	246.05	300.16	277.4	236.8333
LA	239.778	330.2122	309.4748	164.6253
NT	12.64125	11.36	12.4825	18.91333
MC	6.8	7.9	9.2	15.5
CD	2.19175	2.4136	2.0665	1.685667
Nodes	11.8	12.54	10.55	11.1
ID	7.25	8.78	10.225	8.366667
JC	803.125	1385.4	1134	352.3333
BV	20.2	18.26	20.875	16.73333
DM	307.125	467.98	353.175	142.8333
BW	1072.5	1580.2	1257.25	512.6667
CW	2003	3239	2675	834

PH, plant height (cm); LA, leaf area (cm^2); Till, Number of tillers; MC, millable cane; CD, cane diameter; Nodes, Number of nodes; ID, internodal distance; JC, juice contents BV, brix value (°Bx); DM, dry matter (g); BW, Baggas weight (g); CW, cane weight (g)

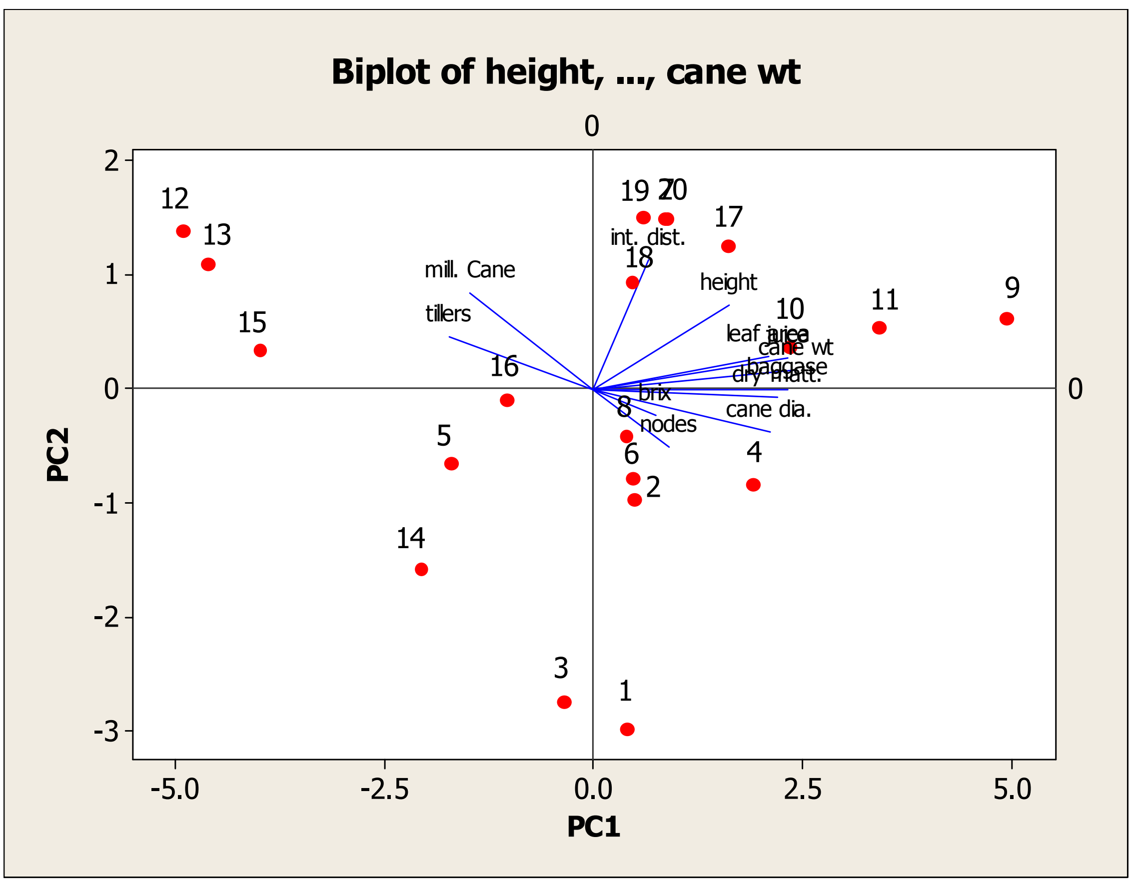

Fig. 1. Biplot analysis of first two principal components

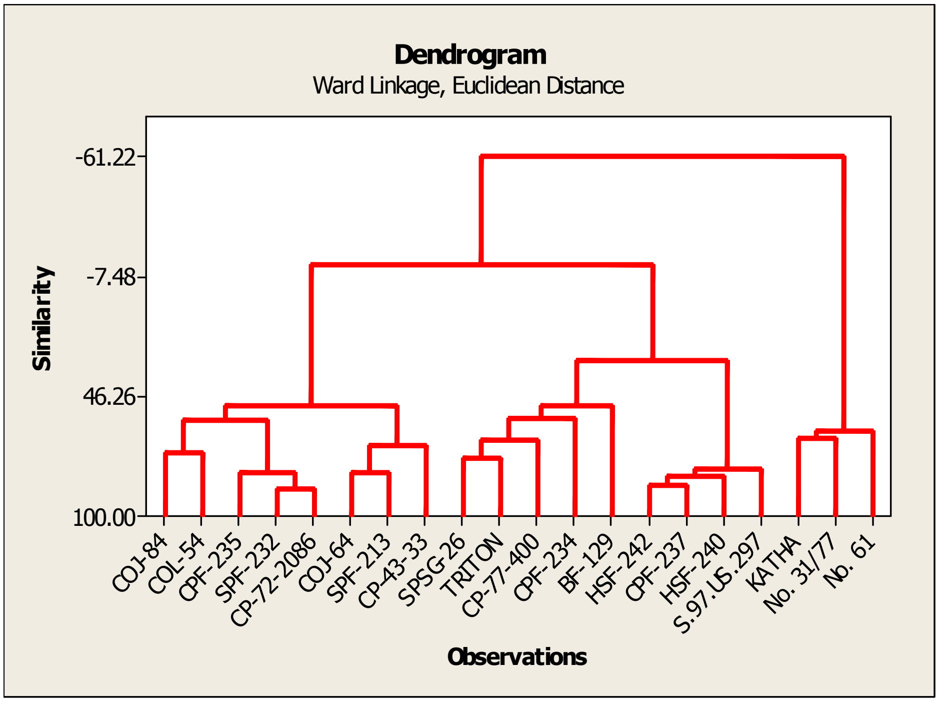

Fig. 2. Dandrogram clustering similiar sugarcane accessions

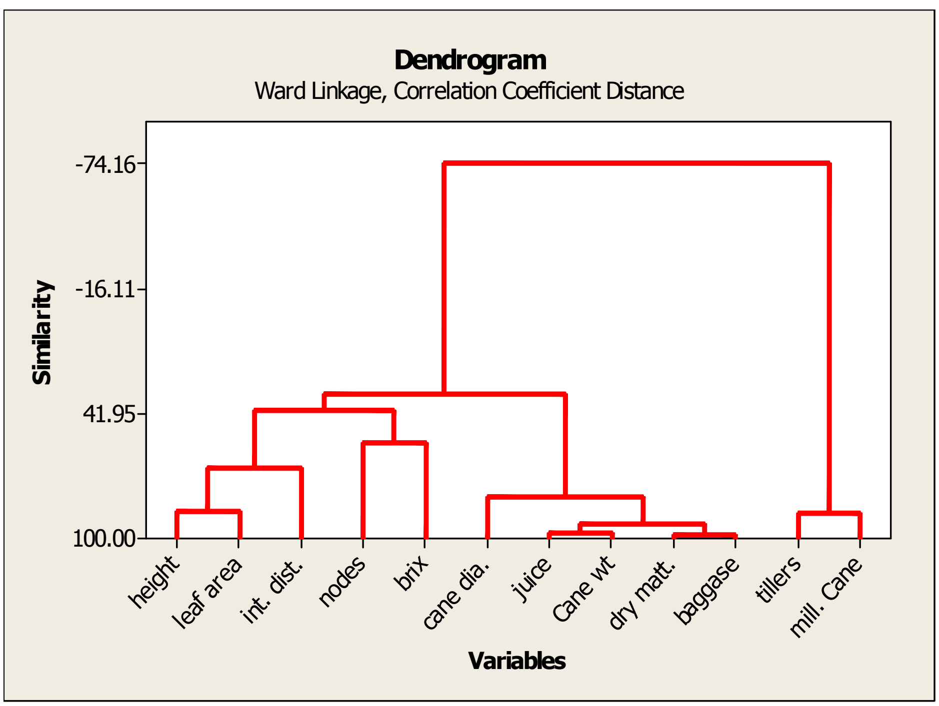

Fig. 3. Dandrogram clustering similiar sugarcane variable

4. CONCLUSION

It can be concluded from the experiment that among all the traits studied cane weight has highest correlation (genotypic and phenotypic) with Bagasse weight followed by juice contents, dry matter contents, cane diameter, leaf area, plant height and Internodal distance. The similar trend is also shown by PCA biplot (Fig. 1). Also bagasse weight exerts maximum direct effect on cane yield followed by juice contents and internodal distance and indirect effects of these traits via each other were also found maximum compared to other traits (Table 4). So best performing sugarcane accessions like cluster II viz BF-129, CPF-234, CP-77-400, TRITON and SPSG-26 if bred against highly correlated variables of bagasse weight, juice contents and internodal distance with cane weight, can increase our yield qualitatively and quantitatively.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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