Factor wise contribution of some morphological traits to sugar contents in *Sacharum officinarm*

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Abstract: The aim of present study was to enhance the efficiency of selection by developing Dm artificial variables which serve as selection criterion. 12 genotypes were planted it the research area of the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad, following Randomized Complete Block Design with three replications. Data was recorded for 11 morphological and quality traits. Genotypic and phenotypic correlation coefficients among the characters under study were estimated. Data recorded also analyzed by Principal component analysis to reduce the original variables into smaller number of principal components which help in selection for high yield improvement. Plant height and cane height were positively and highly significantly correlated. Both of these showed positive significant association with number of canes per stool, juice contents and dry matter content. Strong positive correlation was found between Sugar contents and number of cane per stool. The PCA revealed that first 4 PCs explained more than 83.23% of the total variation. The contribution of PC1 32.57% to the total variation while the contribution of PC2 was 20.43%. The contribution of PC3 and PC4 was 15.91% and 14_39% respectively. The remaining seven PCs explained only about 17% of the total variation. By probing screen plot it was evident that first seven PCs have considerable variability while in remaining four PCs differences were negligible. Scatter plot showed that genotypes CPF-240, HSF-240, CPF-335 and CP72-2086 are not much &verse from each other as they are congested to same area. While genotypes HSF¬247, SGH-2924, COJ-84, CP-246, CPF-248, L-118, CP-77-400 and CPF-234 are 'present at distance from other genotypes with respect to PC 1 and PC2 so more &verse. Biplot revealed that In the PC1 and PC2 together internodal length, juice contents and yield per m2 showed minimum differences while other traits showed more differences. The information thus acquired from the research could be utilized to frame the suitable selection scheme to develop clones of the best commercial writs, suitable for cultivation in different environments. The genotypic correlations were split into direct and indirect effects of various traits on yield per m2. The direct effects of brix value and dry matter contents were positive on yield per m2. Cluster analysis was performed. Cluster analysis procedure grouped the 12 genotypes in to three clusters at a linkage distance with cluster I having five, cluster II having two and duster III having five genotypes respectively.

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Key words: cane height, cane girth, number of canes per stool, juice contents, brix value, sugar content

1. Introduction

Sugarcane is a tropical grass native to Asia where it has been grown in gardens for 4000 years ago. It is the product of interbreeding four species of the genus *Saccharum* (*Saccharum officinarum, Saccharum barberi, Saccharum sinense* and *Saccharum aneum*) as a result a giant, robust and sugary cane plant is obtained. Chromosome are different for all sugarcane species ranging from about 48 to more than 148. for manufacturing sugar from sugarcane were developed in India about 400 B.C. 62 percent of the world's sugar is obtained from sugarcane (Jiskani, 2004; Qamar *et al*., 2015). Sugarcane crop has a vital place in economy of the Pakistan and is supreme important run the huge sugar industry. It is the source of byproducts and raw material for clip board, paper and ethanol. The share of sugarcane in value added in agriculture sector and GDP is 3.4% and 0.7%, respectively. In Pakistan, it occupies a significant position in the agricultural economy and covers an area of about 1.173 Million hectares which showing an increase of 3.9% with an average yield of 1400 Mounds/Hec (Pakistan Economic Survey, 2014-15). In Pakistan, sugarcane is the raw material for the sugar industry. It is the source of income for the growers and occupation for many farm labors all-round the year. At present 60% of the sugarcane is used in sugar mills for sugar production, 25% is used for gur and shaker making remaining 10-15% is reserved for seed, chewing and fodder (Hussain *et al*., 2008). Bagasse, molasses, filter cake and wax are the by-products of the sugar industry. is utilized for the production of paper, hardboard and cattle feedstuff as well as fuel boilers in sugar mills. Molasses can be utilized in the production of alcohol, cattle and compost. Filter cake contains a lot of organic matter and macro and micro is with little modification may be used as manure. Wax obtained from filter cake is in manufacturing of shoe polish and fruit coating. There are a number of causes for low yield of sugarcane; most important is inviable seed (fuzz) production due to non-availability of proper flowering condition in Pakistan. Sugarcane is a photo-thermal sensitive crop and it produce flowers at 5-23° latitude while Pakistan is located at 24-37° latitude. Pakistan is located exterior to the flowering region of sugarcane. Additional circumstances obligatory for altering vegetative to reproductive stage are temperature range of 28-35°C for 70 days, humidity 70-80% for 70 days and day length 11.5 -12.5 hours for 70 days. These conditions are partially available only at three places in Pakistan i.e. Murree in Punjab, Sajawal in Sindh and Dargai in KPK but fuzz produced here is poor or have very low viability percentage. For breeding, fuzz is imported from abroad and only selection is done at sugarcane research institute, so the scientist working here on sugarcane have to face the problems for creation of variability. Ratoon crop is grown on moat 50% sugarcane area of Pakistan which decreases the yield. In addition, most of the misting sugarcane varieties are susceptible to different diseases like sugarcane mosaic virus, Rot and Pokha Boeng etc. Considering the constraints of seed production of sugarcane in the country, the chances for genetic improvement of the crop through conventional breeding means are very remote. In Pakistan, mostly the efforts have been made to improve the tonnage while sucrose recovery remained low. The genetic variability and correlation studies in sugarcane are of great value in selecting desired types e.g. for a planned breeding program to improve cane yield and juice quality, complete information on the genetic variability and interrelationship in different characters is necessary.

The inheritance patterns of yield and yield components are complex phenomenon and are influenced by a number of morpho-genetic characters which in turn are made up of their awl component traits. The study of yield and yield components through genetic correlations make available the evidence that how intensely these characters are genetically related to each another. Correlation studies provide understanding of yield components, which help the plant breeder during selection (Johnson *et al*., 1955; Ahsan *et al*., 2011; Ahsan *et al*., 2013; Ali *et al*., 2012; Ali *et al*., 2013; Ali *et al*., 2014ab; Ali *et al*., 2015; Ali and Ahsan, 2015). It provides information about the cause and effect situation and helps in understanding the cause of association between two variables. The benefit of association study is that it allows the separation of correlation coefficient into its constituents and has been employed by plant breeders to help in recognizing characters that are valuable as selection standards for the increase in crop yield (Dewey and Lu, 1959). It permits the examination of association of various characters with yield. Therefore via the assessments of genotypic and phenotypic association, it defines the yield constituents and as a consequence it provides the foundation for selection of the best genotypes from different breeding populations. Correlation study is an important tool in the hands of plant breeder to determine the relationship between yield and other traits. It gives knowledge about various factors contributing to the yield. Sometimes improvement in one character is through other character due to association among them. Therefore it is necessary to determine the character -association by correlation studies (Salahuddin *et al*., 2010). Path coefficient analysis provides effective means for partitioning correlation coefficients into components of direct and indirect effects of various variables. Path coefficient analysis was probably applied for the first time, by Dewey and Lu (1959) on crested wheat grass. Since then this technique has been used in other crops by conventional breeder. Principal component analysis (PCA) is a valuable method, which works by g inter-relationship among variables. By using PCA, we not only compare t treatments, but the meaningfulness of comparing treatments is also increased (Sneedon, 1970). PCA is well-defined such as "a technique of data reduction to elucidate the on among two or more traits and to split the whole variation of the original traits into restricted number of un-associated new variables". PCA can be implemented on two kinds conditions; a variance-covariance condition and a correlation condition. With traits of t scales, a correlation matrix systematizing the original data set is favored. The core of using PCA over cluster analysis is that each statistics can be allocated to one only (Khodadadi *et al*., 2011).

The study is important because of the following reasons:

The genetic variability and the information on correlation coefficients between yield and quality contributing characters have always been helpful as basis for selection in breeding programs, correlation analysis estimates association between economical characters and yield is and it provides base for selection of the best performing genotypes from the breeding populations. The objective of this study was to decrease the number of variables and to construct new (principal components) that will be responsible for majority of the variation. These principle components obtained could be used as criterion for selection and subsequent analysis.

2. Material and Methods:

The study was conducted in the research area of the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad. The twelve genotypes (CP72- 6, CPF-234, HSF-240, CP-246, HSF-247, L-118, CPF-248, COJ-84, SGH-2924, CPF¬5. CPF-240, CP-77-400,) were sown in Randomized Complete Block Design with three locations. Plant to plant distance and row to row distance was maintained 30 cm and 75 cm respectively. All the recommended agronomic practices were applied. At maturity ten is from each replication were selected for recording data on these morphological quality traits. **Traits**: plant height (cm), cane height (cm), grith of Cane (cm), leaf area (cm square), internodal distance (cm), number of canes per stool, juice contents (L), brixvalue (%), sugar content (%), dry matter content (g), Yield per (m^2).

Statistical Analysis

Calculation for mean (X), standard deviation (SD) and coefficient of variability (CV) were calculated according to standard technique.

GCV= Genotypic coefficient of variability is given

PCV= Phenotypic coefficient of variability is given

Where

GV= Genetic variance

PV= Phenotypic variance

The collected data of all measured traits was analyzed by standard analysis of variance technique as given by Steel *et al*. (1997). The treatment means were compared using Duncan's Multiple Range Test (DMRT) at 5 % probability level according to Gomez and Gomez (1984).

Correlation analysis

Genotypic and phenotypic correlation coefficients among the characters under study were estimated according to the statistical techniques outlined by Kwon and Torrie (1964).

Principal Component Analysis: The data was analyzed by using the Principal component analysis (Ogunbayo *et al*., 2005) and from a number of observed variables a smaller number of new/artificial variables (principal components) were developed. PCA can be performed on two types of data matrices; a variance-covariance matrix and a correlation matrix. With characters of different scales, a correlation matrix standardizing the original data set is preferred.

Path coefficient Analysis

The procedure for path coefficient was used as given by Dewey and Lu (1959) by the solution of simultaneous equation using genotypic correlations where sucrose percentage was kept as resultant variable and sucrose controlling characters as casual variables. The path diagram was drawn which indicate the direct effects of different characters an cane yield and indirect effects through alternative pathways.

3. Results and Discussions:

Analysis of variance

The analysis of variance showed that genotypes were highly significantly different for all the traits studied.

Plant height: The analysis of variance (Table 1) indicated that the performance of accessions were highly significantly different for plant height. The coefficient of variability was 10.48%. The comparison of accession means (Table 2) showed that genotype CP-77-400 was significantly different from all genotypes except HSF-240, SGH-2924, CPF-335, CPF¬248, COJ-84, CP-246 and CPF-240. Genotype CPF-335 and CPF-248 were not significantly different but CPF-335 was significantly different from CP72-2086. Genotypes CPF-248, COJ-84, CP-246 and CPF-240 were similar statistically. HSF-247, CPF-234 and L-118 were also statistically similar. The maximum plant height was produced by CP-77-400 (393.70 cm) followed by HSF-240 (360.93 cm) and SGH-2924 (359.81 cm). While minimum plant height was observed in CP72-2086 (279.58 cm).

Cane height: The analysis of variance (Table 1) pointed out that the performance of accessions was highly significantly different for cane height. The coefficient of variability was 15.08%. The comparison of accession means (Table 2) exposed that genotype CP-77-400 was significantly different from all genotypes except CP-246, COJ-84, L-118, CP72-2086 and CPF-234. The genotypes CPF-240 and HSF-240 were statistically similar and were significantly different from the genotype CPF-234. COJ-84, L-118 and CP72-2086 were similar statistically. The highest cane height was produced by CP-77-400 (227.96 cm) followed by CPF-335 (220.70 cm) and SGH-2924 (216.75 cm). The smallest cane height was observed in CPF-234 (133.28 cm).

Girth of Cane: The analysis of variance (Table 1) indicated that the performance of accessions was highly significantly different for girth of cane. The coefficient of variability was 10.31%. The comparison of accession means (Table 2) showed that genotypes CPF-248, CPF-234, COJ-84, HSF-247, SGH-2924, CP-246, HSF-240 and CP72-2086 were statistically similar and were not significantly different from each other's but significantly different from all rest of the genotypes. The maximum girth of cane was produced by CPF-248 (28.50 cm) followed by CPF-234 (28.16 cm), COJ-84 (26.66 cm) and HSF-247 (25.69 cm).

The minimum girth of cane was observed in CPF-335 (20.36 cm).

Leaf area: The analysis of variance (Table 1) indicated that the performance of accessions was highly significantly different for leaf area. The coefficient of variability was 13.98%. The comparison of accession means (Table 2) indicated that genotype CPF-234 produced the maximum leaf area and was significantly different from the genotypes included HSF-247, CPF-335, SGH-2924, CP-246, HSF-240, COJ-84, CP-77-400 and CPF-240. Genotypes CPF¬234, CP72-2086, L-118 and CPF-248 were similar statistically in respect to leaf area. The maximum leaf area was recorded in CPF-234 (485.99 cMeter square) followed by CP72- 2086 (437.56 cMeter square), L-118 (417.57 cMeter square) and CPF-248 (415.53 cMeter square). The lowest leaf area was noted in CPF-240 (304.05 cMeter square).

Internodal Distance

The analysis of variance (Table 1) directed that the performance of accessions was highly significantly different for Internodal length. The coefficient of variability was 7.41%. The comparison of accession means (Table 2) disclosed that genotype SPF-234 produced the maximum internodal length and was not significantly different from COJ-84, CPF-335, CP72-2086, CPF-240, CP-77-400, HSF-247 and CPF-248. Genotypes CPF-335, CP72-2086, CPF-240, CP-77-400 and HSF-247 were similar statistically in respect to internodal length. These were significantly different from L-118, SGH-2924, CP-246 and HSF-240. The maximum internodal length was noted in SPF-234 (13.66 cm) followed by COJ-84 (12.94 cm) and CPF-335 (12.66 cm). The smallest internodal length was detected in HSF-240 (8.39 cm).

Number of canes per stool

The analysis of variance (Table 1) indicated that the performance of accessions was highly significantly different for number of tillers. The coefficient of variability was 9.96%. The comparison of accession means (Table 2) showed that genotype HSF-240 was significantly different from all other genotypes included in the study with the exception of CPF-335, CP-77400, SGH-2924 and CP72-2086. Genotypes SPF-234 and COJ-84 were statistically similar in respect to number of canes per stool. These were significantly different from CP-246 and HSF-247. The maximum number of canes per stool were produced by HSF-240 (26) followed by CPF-335 (25.66), CP-77-400 (23.33) and SGH-2924 (23). The minimum number of canes per stool was recorded in CPF-240 (19) followed by CPF-248 (20) and L-118 (20.33).

Juice content

The analysis of variance (Table 1) indicated that the performance of accessions was highly significantly different for juice content. The coefficient of variability was 25.46%. The comparison of accession means (Table 2) showed that genotype SGH-2924 produced highest juice content and was significantly different from all genotypes included in study. Genotype CPF-248 was not significantly different from HSF-247 and CP-77-400 which were statistically similar; while it showed significant differences from other genotypes in respect of juice content. Genotypes COJ-84 was statistically similar and showed non¬-significant difference from CPF-240, CP-72, CP-246, CPF-335, HSF-240 and SPF-234. The highest juice content was produced by SGH-2924 (650 L) followed by CPF-248 (491.97 L) and HSF- 247 (476.67 L). The lowest juice content was observed in L-118 (239.33 L).

Table No. 1 Combined ANOVA for different traits in Sugarcane

Traits	Replication (DF=2)	Genotype (DF=11)	Error (DF=22)	CV %
Plant Height	682.26	37123.86**	26074.23	10.48
Cane Height	2589.71	31156.96 **	16000.83	15.08
Girth of cane	12.21	179.13**	143.81	10.31
Leaf area	11115.01	118422.86**	57836.46	13.98
Cane Internodal Length	3.89	85.01**	45.78	7.41
Number of Canes Per Stool	7.38	155.63**	105.94	9.96
Juice Contents	7649.38	403114.55**	233346.61	25.46
Brix Value	1.22	36.20**	27.78	5.58
Sugar Contents	0.82	26.46**	20.98	5.39
Dry Matter Contents	645.86	87172.60**	3798.31	6.77
Yield Per Meter square	0.13	207.37**	6.63	4.13

Brix value

The analysis of variance (Table 1) showed that the performance of accessions was highly significantly different for brix value (brix percentage). The coefficient of variability was 5.58%.

The comparison of accession means (Table 2) showed that genotype SPF-234 was in¬significantly different from CPF-335 and COJ-84, while it was significantly different from all other genotypes. Genotypes HSF-240 and CP-77-400 were statistically alike and presented significant dissimilarity from SPF-234 and CPF-335. The comparison exposed that genotypes SGH-2924, CP72-2086, CP-246, L-118, CPF-240, HSF-247 and CPF-248 were statistically alike and these were significantly dissimilar from HSF-240 and CP-77-400. The highest brix value was recorded in SPF-234 (22.56%) followed by CPF-335 (21.36%) and COJ-84 (20.7%). The lower most brix value was found in CP-77-400 (18.96%).

Sugar content

The analysis of variance (Table 1) indicated that the performance of accessions was highly significantly different for sugar percentage. The coefficient of variability was 5.39%. The comparison of accession means (Table 2) showed that genotypes SPF-234 and CPF-335 were similar statistically and significantly different from CPF-248, CPF-240 and CP-77-400. HSF-240, HSF-247, CP-246, L-118 and CP72-2086 were similar in respect to sugar percentage. The maximum sugar percentage was recorded in SPF-234 (19.43%) followed by CPF-335 (19.32%) and SGH-2924 (18.93%). The minimum sugar percentage was found in CP-77-400 (16.67%).

Dry matter contents

The analysis of variance (Table 1) indicated that the performance of accessions was highly significantly different for dry matter. The coefficient of variability was 6.77%.The comparison of accession means (Table 2) showed that genotype HSF-247 was non-significantly different from HSF-240, CP-246, COJ-8 and CPF-248, while significantly different from all other genotypes. Genotypes CPF-335 and CP72-2086 were statistically similar and were significantly different from all others genotypes under study. Similarly, the genotype CPF-240 was statistically significantly different from all others genotypes under study. The maximum dry matter was documented in HSF-247 (248.4 g) followed by HSF¬240 (230.3 g) and CP-246 (227.9 g). The lowest dry matter was found in CP72-2086 (101.5 g) followed by CPF-335 (104.38 g) and CPF-240 (130.33 g).

Yield per Meter square

The analysis of variance (Table 1) indicated that the performance of accessions was highly significantly different for commercial cane sugar (CCS) percentage. The coefficient of variability was 4.13%.

The comparison of accession means (Table 2) showed that genotypes HSF-240 was significantly different from all other genotypes included in the study. Similarly, the genotype CP72-2086 also significantly different from all the genotypes under study. Genotypes SPF-234 and HSF-247 were statistically similar but significantly different from all other genotypes. Comparison revealed that SGH-2924, CP-77-400 and L-118 were statistically similar and significantly different from all other genotypes. The maximum yield per Meter square was found in HSF-240 (17.78kg) followed by CP72- 2086 (16.63kg) and SPF-234 (15.03kg). The minimum yield per Meter square percentage was observed in CPF-335 (9.66kg).

Correlation studies

In biological system, most of the characters are associated with each other and such correlation may be the product of some pleiotropic effects of a gene, existence of two genes on the same chromosome, chromosomal segmental affiliation or due to environmental influences. Correlation analysis figures out the intensity of relationship between the two traits. To estimate the genetic inter-relationship of the two characters under study, phenotypic (rp) and genotypic (gp) correlation coefficients were computed and measured for all possible combinations of 11 characters of 12 genotypes of Saccharum officinarum L. and are given in Table 3.

Correlation of plant height with other traits

It was revealed that (Table 3) correlation of plant height with cane height, number of canes per stool and juice content was positive and significant at genotypic level and positive but highly significant at phenotypic level. It was also found that correlation of plant height with sugar contents was negative and non-significant at both genotypic and phenotypic level. The association of plant height with leaf area was negative and highly significant at phenotypic level while negative and significant association at genotypic level. The negative but significant association was found between plant height and girth of canes, internodal distance, brix value and yield per Meter square at genotypic level and negative non-significant at phenotypic level. The correlation of plant height with dry matter content was positive and significant at genotypic level but non-significant at phenotypic level. Deng *et al*. (1995) showed that plant height is positively correlated with cane weight. This result is in accordance with our findings. Soomro *et al*. (2006) also concluded that there was positive correlation between plant height and cane weight. Chen *et al*. (1991) showed that there was positive significant correlation between plant height and brix percentage. This finding is against the results of our research. This may be due to different environmental conditions and genotypes used in the experiment.

Correlation of cane height with other traits

Correlation studies showed that (Table 3) association of cane height with plant height, number of canes per stool and juice content was positive and significant atgenotypic level and positive but highly significant at phenotypic level. It was also found that correlation of cane height with girth of cane and leaf area was negative and significant at genotypic level and highly significant at phenotypic level. Cane height was negatively and significantly correlated with internodal distance, brix value, sugar contents, dry matter contents and yield per Meter square at genotypic level while negative and non-significant at phenotypic level. Madhavi *et al.* (1991) and Singh *et al.* (2005) concluded that there was positive correlation between cane length and cane weight. Chaudhary and Joshi (2005) reported positive association of single cane weight with cane length. Chaudhary and singh (1994) showed that there was positive correlation of cane height with cane diameter. Nosheen and Ashraf (2003) reported negative correlation between cane length and number of tillers. Panhwar *et al.* (2003) showed that cane length was positively correlated with cane diameter. Rao *et al.* (1983) concluded that cane length should be selected for high yield. Arif (2003) reported that cane length had positive effects of sugar yield in ratoon crop.

Correlation of girth of cane with other traits

Correlation studies showed that (Table 3) association of girth of cane with cane height and dry matter contents were positive and significant at genotypic level and positive but highly significant at phenotypic level. The association of girth of cane with number of canes per stool was negative and significant at genotypic level and negative but highly significant at phenotypic level. The correlation between girth of cane and leaf area was positive and significant both at genotypic and phenotypic level. The correlation of girth of cane with juice contents and yield per Meter square was positive and significant at genotypic level and non-significant at phenotypic level. The correlation between girth of canes and internodal distance, brix value and sugar contents was non-¬significant both at genotypic and phenotypic level.

Madhavi *et al.* (1991) and Verma *et al.* (1999) showed the positive association of cane diameter with cane weight. Pratap *et al.* (2013) concluded that there was positive correlation between cane diameter and sucrose content. Kumar *et al.* (2009) reported significantly positive association between cane girth and cane weight. Mali *et al.* (2009) showed the positive association of cane diameter with sucrose percentage. Chohan *et al.* (2014) reported positive correlation between cane thickness and sugar yield. Chaudhary (2001) reported that cane diameter had high heritability and its selection was effective for yield improvement. Cane diameter was important constituent of yield.

Correlation of leaf area with other traits

Correlation studies showed that (Table 3) association of leaf area with plant height and cane height was negative and significant at genotypic level and negative but highly significant at phenotypic level. The association of leaf area with internodal distance and brix value was positive and significant both at genotypic and phenotypic level but association with juice contents negative both level. The association of leaf area with number of canes per stool and dry matter contents was negative and significant at genotypic level while non-significant at phenotypic level. Leaf area was positive and significantly associated with sugar contents and yield per Meter square at genotypic level and positive but non-significantly associated at phenotypic level. Ilyas and Khan (2010) showed that leaf area was positively correlated with sucrose value and cane diameter. Thippeswamy *et al.* (2003) reported that leaf area was positively correlated with commercial cane sugar yield and sugar yield. Bathla *et al.* (1981) concluded that there was positive correlation between leaf area and sugar yield. Leaf area influenced cane yield positively. Khan *et al.* (2001) found that leaf area contributed positively for yield components and increased the overall cane and sugar yield.

Correlation of internodal length with other traits

The correlation of internodal length with brix value was positive and significant at genotypic level but positive and highly significant at phenotypic level. Correlation of internodal distance with leaf area was positive and significant at both levels. Correlation of internodal distance with plant height, cane height, juice content and yield per Meter square was negative and significant at genotypic level, negative and non-significant at phenotypic level (Table 3). The association for dry matter content was negative and significant at genotypic level as well as phenotypic level. Internodal length was positively and non-significantly correlated with girth of cane and sugar contents at both genotypic level and phenotypic level. The association for number of canes per stool was negative but non-significant Pratap *et al.* (2013) showed different results that internodal length was positively correlated with sucrose percentage. This may be due to different environmental conditions and genotypes used in the experiment. Amalraj *et al.* (2011) reported that there was positive correlation between internodal length and plant height.

Correlation of number of canes per stool with other traits

Correlation studies showed that (Table 3) association of number of canes per stool with sugar contents was positive and significant at genotypic level and positive but highly significant at phenotypic level. The association of number of canes per stool with juice contents and dry matter contents was negative and significant at genotypic level but non¬significant at phenotypic level. The correlation of number of canes per stool with brix valu was positive and non-significant at both genotypic and phenotypic level.

Kumar and Singh (1999) showed the positive correlation between number of tillers and cane height. Similarly Khan *et al*. (2007) concluded that number of tillers per plant was positively correlated with number of leaves and cane height. Babu *et al*. (2009) reported that there was negative correlation between number of tillers and cane diameter while number of tillers and cane height possessed positive correlation. Yahaya *et al*. (2009) concluded that there was positive correlation between number of tillers and cane diameter. Khan *et al*. (2003) reported positive correlation between number of tillers and cane weight. Reddy and Reddi (1986) found that number of tillers were the major constituent of yield. Hapase and Repale (1999) reported the positive association of cane yield and total sugar yield with number of tillers. Number of tillers was a major component of yield.

Correlation of juice content with other traits

Correlation studies showed that (Table 3) association of juice content with plant height and cane height was positive and significant at genotypic level and positive but highly significant at phenotypic level. It was also found that juice content was positively significantly correlated with girth of cane and dry matter contents at genotypic level but non-significantly at phenotypic level. It was also found that juice content was negatively significantly correlated with internodal distance, number of canes per stool, brix value, sugar contents and yield per Meter square at genotypic level but non-significantly at phenotypic level. The correlation of juice content with leaf area was negative and significant at both genotypic and phenotypic level. Singh *et al*. (2005) reported that juice contents were positively correlated with cane weight and cane height. Ishaq *et al*. (1998) concluded that there was positive correlation between juice contents and sugar yield. Juice contents also contributed significantly to total cane yield.

Correlation of brix value with other traits

Correlation studies showed that (Table 3) association of brix value with internodal distance and sugar content was positive and significant at genotypic level and positive but highly significant at phenotypic level. The correlation of brix value with plant height, cane height, juice contents and dry matter contents was negative at both levels and significant only at genotypic level. The correlation of brix value with leaf area was positive and significant at both genotypic and phenotypic level. Positive non-significant association at both levels was observed for brix value with girth of cane and number of canes per stool. While the relationship between brix value and yield per Meter square was negative and non-significant at both genotypic and phenotypic levels.

Tyagi and Singh (2000) and Nosheen and Ashraf (2003) found that positive and significant correlation of brix value with sucrose contents. Kang *et al*. (2013) also found the similar results and showed that brix value was positively and significantly correlated with cane diameter, leaf area, dry matter contents and sucrose percentage. Pillai and Ethirajan (1993) found that correlation between components of cane yield (plant height, cane diameter etc.) and quality parameters (sucrose, brix etc.) were not significant. Kumar and Kumar (2014) concluded that there was negative correlation between brix value and yield components of sugarcane.

Correlation of sugar content with other traits

Correlation studies showed that (Table 3) association of sugar content with number of canes per stool and brix value were positive and significant at genotypic level and positive but highly significant at phenotypic level. Non-significant negative correlation was detected for sugar content with plant height at both genotypic and phenotypic level. Non-significant positive correlation was detected for sugar content with girth of cane, internodal distance and yield per Meter square at both genotypic and phenotypic level.

The relationship of sugar content with cane height was negative and significant at genotypic level. Correlation of sucrose content with leaf area and dry matter contents was positive at both levels but significant only at genotypic level. Gill *et al*. (1983) found that sucrose percentage was positively correlated with leaf area. Patel *et al*. (1993) and Das *et al*. (1996) found that there was positive and significant correlation between sucrose percentage and commercial cane sugar (CCS). Singh *et al*. (1983) reported positive significant association between number of tillers and sucrose percentage. Ram and Hemaprabha (1991) showed that sucrose percentage was positively correlated with cane height, cane diameter and number of leaves. Chang (1996) concluded that genotypic and phenotypic correlation had the highest value for association between sucrose percentage and brix value. Ram *et al*. (1997) found that percent sucrose was important trait for sugar yield. Mujahid *et al*. (2001) concluded that sucrose percentage were best variable for selection of sugar yield.

Correlation of dry matter content with other traits

Correlation studies showed that (Table 3) association of dry matter content with girth of cane was positive and significant at genotypic level and positive but highly significant at phenotypic level. It was also found that dry matter content was positively and significantly associated with plant height, juice contents, sugar contents and yield per Meter square at genotypic level but at phenotypic level this association was non¬-significant. For internodal length this association was negative and significant at both genotypic and phenotypic level. Negative correlation was found for dry matter content with cane height, leaf area, number of canes per stool and brix value was significant at genotypic level.

Ilyas and Khan (2010) reported that dry matter contents, cane weight, brix value and number of leaves were positively and significantly correlated with each other. Kang *et al*. (2013) also reported positive significant association between dry matter contents and brix value.

Correlation of yield per Meter square with other traits

Correlation studies showed that (Table 3) association yield per Meter square with girth of cane, leaf area, number of canes per stool and dry matter contents was positive and significant at genotypic level and positive but non-significant at phenotypic level The association of yield per Meter square with plant height, cane height, internodal distance and juice contents was negative and significant at genotypic level while negative and non-significant at phenotypic level. The correlation of yield per Meter square with sugar contents was positive and non-significant at both levels. The correlation of yield per Meter square with brix value was negative and non-significant at both genotypic and phenotypic levels.

Patel *et al*. (1993) and Das *et al*. (1996) reported positive significant correlation between yield per Meter square and sucrose contents. Singh *et al*. (2003) showed the non¬significant positive correlation between juice sucrose, juice brix and yield per Meter square. Tyagi *et al*. (2012) reported negative non-significant correlation between sugar yield and sucrose percentage. Kundu and Gupta (1997) concluded that sugar yield was positively correlated with brix value and sucrose percentage. Singh *et al*. (1981) found that yield per Meter square was an important component of yield.

Principal Component Analysis

Principal component analysis (PCA) was performed to obtain more reliable information on how to identify groups of genotypes that have desirable yield and quality traits for breeding. The average data was analyzed by using principal component analysis. The data matrix of 11 x 12 was prepared for the analysis.

Out of 11 first four PCs exhibited more than 1 eigen value (Table 4) and the level of dissimilarity was high which indicates that the germplasm have broad genetic base. In the first principal components (Table 4) plant height, cane height and juice content were the most important traits contributing to variation that obtained about 32.57%. In the second principal component (Table 4), obtained variation of about 53.01% was caused mainly by cane diameter, brix value, sugar content and dry matter contents. Yield per Meter square percentage constituted a large part of the total variation (68.93%) explained by the third principal component (Table 4). Other important traits in the third PC were internodal length and dry matter content. The fourth principal component explained 83.32% of the total variation. It was more related to internodal length and leaf area. Internodal length was the most important trait for PC4 (Table 4). PC5 explained the 90.24% variation while PC6 explained more than 94.35 % of the total variation. The effect of PC9, PC10 and PC11 were negligible on total variation (Table 4).

The PCA revealed that first 4 PCs explained more than 83.23% of the total variation (Table 4). The PC1 contributed 32.57% share to the total variation while the share of PC2 was 20.43%. The contribution of PC3 and PC4 was 15.91% and 14.39% respectively. The remaining seven PCs explained only about 17% of the total variation. Olaoye (1999) explained that the 99% of the total variation in sugarcane was explained by the first three principal components with the PC1 explaining about 91%. While contradictory to this in our study first three principal components explain only 77% of the total variation. In our study first 2 PCs explain about 63% variation while Tahir *et al*. (2013) showed that there were two principal components accounting for 88% of the total variation in the tested breeding material. The new components were named "Vigor", and "Quality". You *et al*. (2013) detected that the first and second principal components explained 76% of the total variation while in our study first 3 PCs explained 77% of the total variation.

Gemin *et al*. (2006) reported that in Saccharum spontaneum, three principal componets were obtained which explained 82.47% cumulative variance. Thapa *et al*. (2009) also reported that principal component analysis (PCA) was a useful technique in recognizing the best genotypes based on both quantitative and qualitative data. Queme *et al*. (2010) showed that in sugarcane first two principal components (PC 1 and PC2) were greatly significant and described 73% of the variation. Smiullah *et al*. (2013) concluded that most of the diversity in sugarcane germplasm was due to two PCs. PCA revealed that number of tillers and internodal length had positive impact on genetic diversity. Carvalho *et al*. (2014) concluded on the basis of principal component analysis (PCA) that cane height, cane diameter and brix value were the most important variables. The information acquired in this experiment will be valuable for upcoming breeding programs to produce cultivars with greater genetic diversity and cultivars with greater yield and enhanced quality.

Table 4 Eigenvalues and % total variance for principal components.

Principal components	Eigenvalue	% Total - variance	Cumulative - Eigenvalue	Cumulative - cyo
PC1	3.5835	32.5772	3.5835	32.5772
PC2	2.2482	20.4384	5.8317	53.0155
PC3	1.7506	15.9146	7.5823	68.9301
PC4	1.5835	14.3952	9.1658	83.3253
PC5	0.7608	6.9162	9.9266	90.2415
PC6	0.4524	4.1128	10.379	94.3543
PC7	0.2515	2.2861	10.6305	96.6405
PC8	0.1949	1.7723	10.8254	98.4127
PC9	0.1374	1.249	10.9628	99.6618
PC10	0.0287	0.2613	10.9915	99.923
PC11	0.0085	0.077	11	100

Scree plot

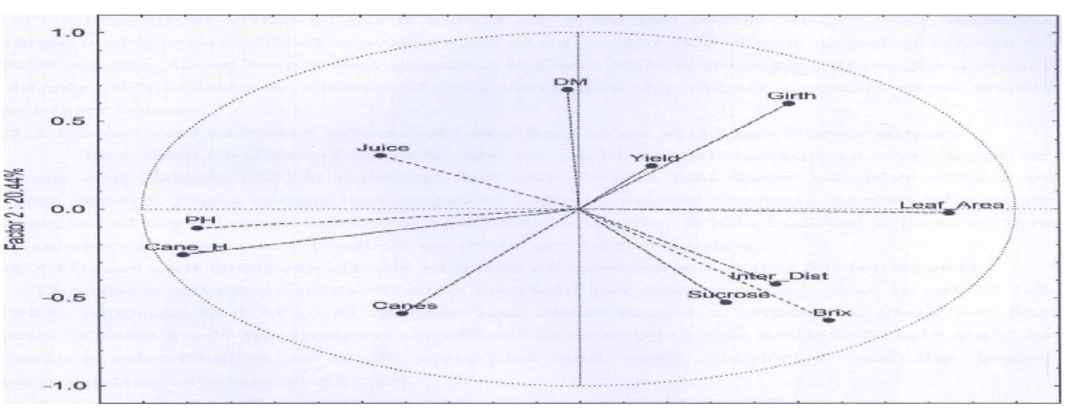
Scree plot (Figure 1) explained the percentage variance associated with each principal component obtained by drawing a graph between eigen values and principal component numbers. PC1 showed 32.58% variability with eigen value 3.5835 in germplasm.by examining scree plot it was evident that first 7 PCs have considerable variability while in remaining 4 PCs differences were negligible. The variability reduced gradually and it ended at 0.0770% at 11th PC with eigen value 0.0085. From graph it was cleared that maximum variation was present in first PC. So selection of genotypes from this PC will be useful.

Scatter plot

Principal component scatter plot (Figure 2) of the sugarcane genotypes depicted that the accessions those are closer together are perceived as being similar when rated on the 11 variables. Genotypes which were far apart were different from each other with respect to distance between them. Graph show that genotypes CPF-240, HSF-240, CPF-335 and CP72- 2086 are not much diverse from each other as they were congested to same area. While genotypes HSF-247, SGH-2924, COJ-84, CP-246, CPF-248, L-118, CP-77-400 and CPF-234 are present at distance from other genotypes with respect to PC1 and PC2 so more diverse.

Biplot

A principal component biplot (Figure 3) showed that variables are super imposed on the plot as vector. Distance of each variable with respect to PC1 and PC2 showed the contribution of this variable in the variation of germplasm. In the PC1 and PC2 together internodal length, juice contents and yield per Meter square showed minimum differences while other traits showed more differences.



-1.0 -0.5 0.0 0.5 1.0

Factor 1: 32.58%

Fig. 3: Principal components biplot of 12 sugarcane genotypes.

Direct and indirect effects of plant height on yield per Meter square

The direct effect of plant height on yield per Meter square was negative (-1.0268). Kumar and Kumar (2014) reported that plant height had direct negative effects on yield per Meter square. Cane height had negative indirect effects through internodal distance and juice contents. While indirect effects of brix value and dry matter contents were positive on yield per Meter square.

Direct and indirect effects of cane height on yield per Meter square: The direct effect of cane height on yield per Meter square was negative (-0.2223). Kumar and Kumar (2014) reported that cane height had direct negative effects on yield per Meter square. Plant height had negative indirect effects through internodal distance, girth of canes, numbers of canes per stool and juice contents. While indirect effects of brix value and dry matter contents were positive on yield per Meter square.

Direct and indirect effects of girth of cane on yield per Meter square: The direct effect of girth of cane on yield per Meter square was negative (-1.2215). Lu (1983) reported that of girth of cane had direct negative effects on yield per Meter square. Girth of cane made the greatest contribution to single stalk weight. Single stalk weight made a major contribution to stalk yield/plot and stalk yield/plot was the major factor in determination of sugar yield/plot.

Direct and indirect effects of leaf area on yield per Meter square: Leaf area had the highest but negative direct effect on yield per Meter square (¬2.0067). Chaudhary and Joshi (2005) reported that leaf area had direct negative effects on yield per Meter square. Leaf area had negative indirect effects through plant height, cane height, girth of cane and internodal distance. While indirect effects of brix value and dry matter contents were positive on yield per Meter square.

Direct and indirect effects of internodal distance on yield per Meter square: Internodal distance had negative direct effect on yield per Meter square (-1.3419). Chaudhary and Joshi (2005) reported that internodal distance had direct negative effects on yield per Meter square. Internodal distance had negative indirect effects through plant height, cane height, girth of cane and leaf area. While indirect effects of brix value and dry matter contents were positive on yield per Meter square.

Direct and indirect effects of number of canes per stool on yield per Meter square

Number of canes per stool had negative direct effect on yield per Meter square (¬1.0096). Kumar and Kumar (2014) reported that number of canes per stool had direct negative effects on yield per Meter square. Number of canes per stool had negative indirect effects through plant height, cane height, girth of cane and leaf area. While indirect effects of brix value and dry matter contents were positive on yield per Meter square.

Direct and indirect effects of juice contents on yield per Meter square: Juice contents had negative direct effect on yield per Meter square (-1.0909). Ram and Hemaprabha (1991) reported that juice contents had direct negative effects on yield per Meter square. Juice contents had negative indirect effects through plant height, cane height, girth of cane and leaf area. While indirect effects of brix value and dry matter contents were positive on yield per Meter square.

Direct and indirect effects of brix value on yield per Meter square: Brix value had positive direct effect on yield per Meter square (1.5727). Kumar and Kumar (2014); Ali *et al*., (2011ab) reported that brix value had direct positive effects on yield per Meter square. Brix value had positive indirect effects through plant height, cane height, girth of cane, leaf area, number of canes per stool and juice contents. While indirect effects of brix value and dry matter contents were positive on yield per Meter square.

Direct and indirect effects of sugar contents on yield per Meter square: Sugar contents had negative direct effect on yield per Meter square (-0.0490). Ram and Hemaprabha (1991) reported that sugar contents had direct negative effects on yield per Meter square. Sugar contents had negative indirect effects through plant height, cane height, girth of cane, leaf area and juice contents. While indirect effects of brix value and dry matter contents were positive on yield per Meter square.

Direct and indirect effects of dry matter contents on yield per Meter square: Dry matter contents had positive direct effect on yield per Meter square (1.1424). Thippeswamy *et al.* (2003); Kumar and Kumar (2014) reported that dry matter contents had direct positive effects on yield per Meter square. Dry matter contents had positive indirect effects through plant height, cane height, girth of cane, leaf area, number of canes per stool and juice contents.

Cluster Analysis

Cluster analysis or clustering is the task of grouping a set of objects in such a way that objects in the same group (called a cluster) are more similar (in some sense or another) to each other than to those in other groups (clusters). The measure of genetic distance (GD) can be applied to any kind of organism without regard to ploidy or mating scheme, with genetic distance estimates hardly affected by the sample size. Therefore, in this study, cluster analysis procedure grouped the genotypes in to three clusters at a linkage distance of 290 with cluster I having five (L-118, CPF-234, CP72- 2086, CPF-335 and SGH-2924), cluster II having two (CP-77-400 and CPF-248) and cluster III having five (COJ-84, HSF-247, CP-246, CPF-240 and HSF-240) genotypes respectively (Fig. 4). Cluster analysis showed that there was no correspondence between the clustering of the genotypes and their geographic origin. The germplasm contained N series, CP series and HO series genotypes and were grouped in separate clusters irrespective of their geographic location. This suggests that the genotypes of different locations have genetic similarity and could have been derived from the same breeding material. Similar results were obtained by Ram and Hemaprabha (1991); Tahir *et al*. (2013) wherein they found that the progenies of a cross clustered independently of their parents.

Summary:

A comprehensive study on the analysis of variance, correlation, principal component analysis, path analysis and cluster analysis in 12 sugarcane genotypes was conducted in the research area of the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad, following Randomized Complete Block Design with three replications. Data was recorded for 11 morphological and quality traits (plant height, cane height, girth of cane, leaf area, internodal distance, number of canes per stool, juice contents, brix value, sucrose content, dry matter content and yield per Meter square).

Correlation study is an important tool in the hands of plant breeder to determine the relationship between yield and other traits. It gives knowledge about various factors contributing to the yield. Principal component analysis (PCA) is a useful technique which works by determining inter-relationship among variables. By using PCA we not only compare treatment but the meaningfulness of comparison is also increased. The objective of this study was to decrease the number of variables and to construct new variables (principal components) that will be responsible for majority of the variation. These principal components obtained could be used as criterion for selection and subsequent analysis.

The results pertaining to analysis of variance elucidated highly significant differences among genotypes for all the traits. Strong positive association was found between plant height and cane height and both of these were positively and significantly correlated with number of canes per stool, juice contents and dry matter content. While these were negatively correlated with leaf area, internodal distance, brix value and yield per Meter square this association was significant but negative. Correlation of plant height and cane height with sugar content was negative and not significant. Sugar contents and number of cane per stool were positively and highly significantly correlated. Both of these showed positive significant association with brix value, plant height and cane height and negatively correlated with girth of cane. Strong positive correlation was found between leaf area, number of canes per stool and dry matter contents with yield per Meter square. The PCA revealed that first 4 PCs explained more than 83.23% of the total variation. The PC1 contributed 32.57% share to the total variation while the share of PC2 was 20.43%. The contribution of PC3 and PC4 was 15.91% and 14.39% respectively. The remaining seven PCs explained only about 17% of the total variation. In the first principal components plant height, cane height and juice content were the most important traits contributing to variation that obtained about 32.57%. In the second principal component, obtained variation of about 53.01% was caused mainly girth of cane, brix value, sugar content and dry matter contents.

By examining screen plot it was evident that first 7 PCs have considerable variability while in remaining 4 PCs differences were negligible. The variability reduced gradually and it ended at 0.0770% at 1 1 th PC with eigen value 0.0085. Scatter plot showed that genotypes CPF-240, HSF-240, CPF-335 and CP-72 are not much diverse from each other as they are congested to same area. While genotypes HSF-247, SGH-2924, COJ-84, CP-246, CPF-248, L-118, CP77-400 and CPF-234 are present at distance from other genotypes with respect to PC1 and PC2 so more diverse. Biplot revealed that In the PC1 and PC2 together internodal length, juice contents and yield per Meter square showed minimum differences while other traits showed more differences. The genotypic correlations were split into direct and indirect effects of various traits on yield per Meter square. Plant height, cane height, girth of cane, leaf area, internodal distance, number of canes per stool, juice contents and sugar contents had negative direct effects on yield per Meter square. The direct effects of brix value and dry matter contents were positive on yield per Meter square. The maximum positive direct effect was observed for brix value and followed by dry matter contents. Maximum negative direct effects were observed for leaf area followed by internodal distance and girth of cane.

Cluster analysis procedure grouped the 12 genotypes in to three clusters at a linkage distance of 290 with cluster I having five, cluster II having two and cluster III having five genotypes respectively. Cluster analysis showed that there was no correspondence between the clustering of the genotypes and their geographic origin. The germplasm contained N series, CP series and HO series genotypes and were grouped in separate clusters irrespective of their geographic location. This suggests that the genotypes of different locations have genetic similarity and could have been derived from the same breeding material. Keeping in the view all these findings it is revealed that there is genetic variability in the accessions that may be used in the next breeding programs for the identification of high yielding genotypes. The information thus obtained from the experiment could be utilized to formulate the appropriate selection strategy and crossing scheme to develop clones of the best commercial merits, suitable for cultivation in different environments.

Table No. 2 Comparison of Accession Means

Parents/ Crosses	Plant Height (cm)	Cane Height (cm)	Girth of Cane (cm)	Leaf area (cm^2)	Cane Internodal Length (cm)	Number of Canes per Stool	Juice Contents (liter)	Brix Value	Sugar Contents	Dry Matter Contents	Yield Per Mete square
	cm	cm	Cm		Cm		Liter	%	%	g	m^2
COJ-84	327.66 ABC	160.95 CD	26.663 ABC	315.08 D	12.94 AB	21.66 BCD	456.67 B	20.7 ABC	18.93 AB	225 AB	10.73 F
CP-246	325.03 ABC	169.51 BCD	25.223 ABCD	323.36 CD	8.82 DE	20.66 CD	345 BC	20.1 BC	18.66 ABC	227.9 AB	11.82 E
CP72-2086	279.58 C	145.71 CD	24.223 ABCD	437.56 AB	11.94 ABC	20.66 CD	360 BC	20.1 BC	17.86 ABCD	101.5 E	16.63 B
CP-77-400	393.70 A	227.96 A	22.833 CD	312.88 D	11.84 ABC	20.33 CD	470 AB	18.96 C	17.82 ABCD	209.1 BC	13.51 D
CPF-234	296.18 BC	133.28 D	28.167 AB	485.99 A	11.88 ABC	20 CD	400 BC	19.76 BC	16.87 CD	130.33 D	10.98 EF
CPF-240	320.04 ABC	188.11 ABC	23.473 BCD	304.05 D	11.39 ABCD	19 D	491.97 AB	19.2 BC	16.67 D	224.2 AB	11.27 EF
CPF-248	335.13ABC	177.26ABCD	28.500 A	415.53 ABC	12.66 ABC	22.33 ABCD	335 BC	21.36 AB	17.7 ABCD	104.38 E	9.66 G
CPF-335	350.37 AB	220.70 AB	20.367 D	351.93 BCD	8.39 E	23.33 ABC	326.67 BC	19.13 C	17.35 BCD	230.3 AB	17.78 A
HSF-240	360.93 AB	186.27 ABC	24.383 ABCD	319.26 CD	11.42 ABC	25.66 AB	476.67 AB	19.3 BC	18.2 ABCD	248.4 A	15.01 C
HSF-247	296.69 BC	171.87 ABCD	25.690 ABC	382.48 BCD	10.48 BCDE	26 A	239.33 C	19.76 BC	18.49 ABCD	197.65 C	13 D
L-118	295.91 BC	147.06 CD	22.743 CD	417.57 ABC	9.94 CDE	23 ABCD	650 A	20.46 BC	19.32 A	210.67 BC	13.95 D
SGH-2924	359.81 AB	216.75 AB	25.277 ABCD	332.51 CD	13.66 A	21.66 BCD	301.67 BC	22.56 A	19.43 A	218.4 B	15.03 C

Table No. 3. Genotypic and Phenotypic Correlation Coefficients.

Traits PH	CH	GC	LA	ID	NC/S	JC	BY	SC	DMC	Y
PH	0.949*	-0.448*	-1.037*	-0.294*	0.770*	0.446*	-0.616*	-0.066	0.225*	-0.186*
	0.869**	-0.270	-0.672**	-0.258	0.542**	0.424**	-0.291	-0.120	0.168	-0.164
CH		-0.831*	-0.924*	-0.190*	0.549*	0.605*	-0.550*	-0.124*	-0.142*	-0.307*
		-0.505**	-0.679**	-0.174	0.472**	0.518**	-0.295	-0.138	-0.124	-0.276
GC			0.399*	0.012	-0.915*	0.258*	0.071	0.085	0.756*	0.221*
			0.387*	0.106	-0.426**	0.286	0.137	0.122	0.611**	0.161
LA				0.299*	-0.415*	-0.735*	0.571*	0.409*	-0.067*	0.398*
				0.390*	-0.214	-0.349*	0.414*	0.256	-0.058	0.305
ID					-0.128	-0.239*	0.885*	0.131	-0.433*	-0.330*
					-0.152	-0.028	0.549**	0.157	-0.339*	-0.320
NC/S						-0.244*	0.096	0.814*	-0.184*	0.369*
						-0.050	0.121	0.468**	-0.154	0.302
JC							-0.285*	-0.081*	0.283*	-0.077*
							-0.234	-0.079	0.255	-0.094
BV								1.123*	-0.256*	-0.226
								0.756**	-0.222	-0.169
SC									0.079*	0.070
									0.069	0.082
DMC										0.205*
										0.201

PH= Plant height, CH= Cane height, GC= Girth of cane, LA= Leaf area, ID= Internodal distance, NC/S= Number of canes per stool, JC= Juice contents, BV= Brix value, SC= Sugar contents, DMC= Dry matter contents, Y= Yield per Meter square

Table 5 Principal components (PCs) for 11 morphological and quality traits in 12 genotypes of Sugarcane.

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11
PH	-0.87434	-0.10735	-0.24636	-0.19007	-0.00524	0.30435	-0.05953	0.14987	-0.06514	0.04184	0.05024
CH	-0.90755	-0.25848	-0.02308	-0.20535	-0.14235	0.00407	-0.15	-0.05006	-0.08702	-0.11604	-0.02271
GC	0.48237	0.59951	-0.3525	-0.44206	-0.05661	0.06181	0.03007	0.25096	0.11512	-0.06353	-0.00624
LA	0.84732	-0.02073	-0.08516	0.09679	-0.30239	0.13908	-0.39079	-0.03228	-0.00984	0.01921	0.00159
ID	0.45029	-0.42264	0.27815	-0.51289	-0.34808	0.30991	0.20058	-0.1397	0.03089	-0.01471	0.00797
NC/S	-0.40836	-0.5892	-0.58191	0.28111	-0.12295	0.13237	0.0269	0.03443	0.1753	0.03619	-0.04305
JC	-0.45498	0.30474	-0.18904	-0.61769	-0.40442	-0.33348	-0.0179	-0.0564	0.00533	0.06729	-0.00538
BV	0.57165	-0.62787	-0.24069	-0.35303	0.14453	-0.05831	0.03902	0.14057	-0.22213	0.02639	-0.02849
SC	0.33582	-0.5267	-0.67952	-0.18614	0.20978	-0.20891	-0.02781	-0.12515	0.07739	-0.03741	0.04408
DMC	-0.02516	0.67773	-0.54024	-0.206	0.29928	0.25259	0.00492	-0.21597	-0.07044	0.01621	-0.02228
Y	0.16739	0.24584	-0.54279	0.61242	-0.43766	-0.03124	0.16798	-0.00336	-0.14219	-0.02659	0.01371

PH= Plant height, CH= Cane height, GC= Girth of cane, LA= Leaf area, ID= Internodal distance, NC/S= Number of canes per stool, JC= Juice contents, BV= Brix value, SC= Sugar contents, DMC= Dry matter contents, Y= Yield per Meter square

Table 6 Direct (bold diagonal) and indirect effects of different traits on sugar contents of sugar cane

Traits	**PH**	**CH**	**GC**	**LA**	**ID**	**NC/S**	**JC**	**BV**	**SC**	**DMC**
PH	**-1.0268**	-0.2111	0.5478	2.0819	0.3945	-0.7775	-0.4867	-0.9695	0.0033	0.2575
CH	-0.9752	**-0.2223**	1.0153	1.856	0.2559	-0.5545	-0.6606	-0.8657	0.0061	-0.163
GC	0.4605	0.1848	**-1.2215**	-0.8016	-0.0165	0.9245	-0.2815	0.1125	-0.0042	0.8642
LA	1.0653	0.2056	-0.488	**-2.0067**	-0.4012	0.4196	0.8021	0.8986	-0.0201	-0.0769
ID	0.3019	0.0424	-0.015	-0.6	**-1.3419**	0.13	0.2613	1.3918	-0.0064	-0.4949
NC/S	-0.7908	-0.1221	1.1185	0.8339	0.1728	**-1.0096**	0.2662	0.1511	-0.0399	-0.2111
JC	-0.4581	-0.1346	-0.3152	1.4754	0.3214	0.2464	**-1.0909**	-0.4494	0.004	0.324
BV	0.633	0.1224	-0.0874	-1.1466	-1.1876	-0.097	0.3118	**1.5727**	-0.0551	-0.2926
SC	0.0685	0.0276	-0.1038	-0.8214	-0.1763	-0.8221	0.0894	1.7675	**-0.049**	0.0904
DMC	-0.2314	0.0317	-0.924	0.1352	0.5813	0.1866	-0.3094	-0.4028	-0.0039	**1.1424**

Fig 1 Eigenvalues of correlation matrix

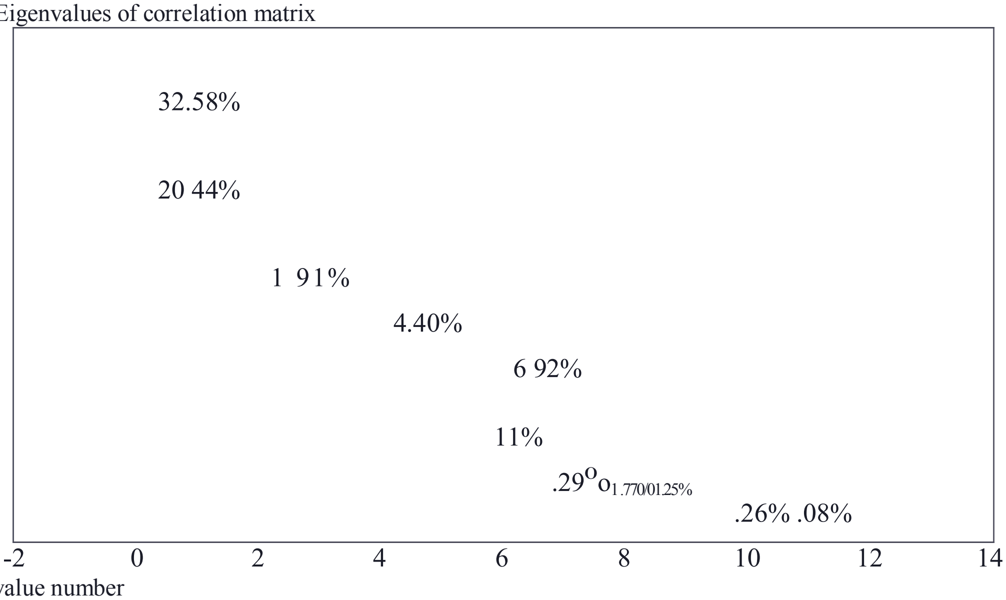


Fig. 1: Scree plot of Principal component analysis between eigen values and number of principal component

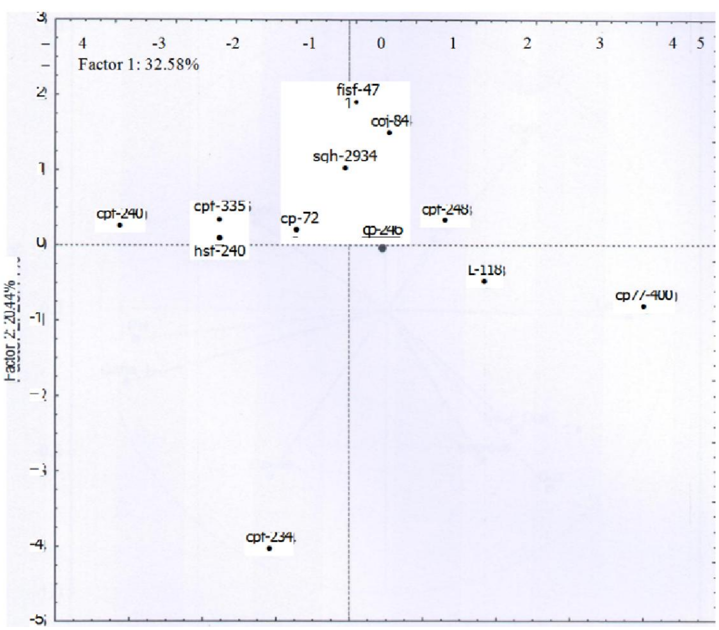


Fig. 2: Two dimensional orientations of 12 genotypes of sugarcane on principal component axis 1 and 2 (Projection of the cases on the factor-plane (1 x 2) Cases with sum of cosine square >= 0.00)

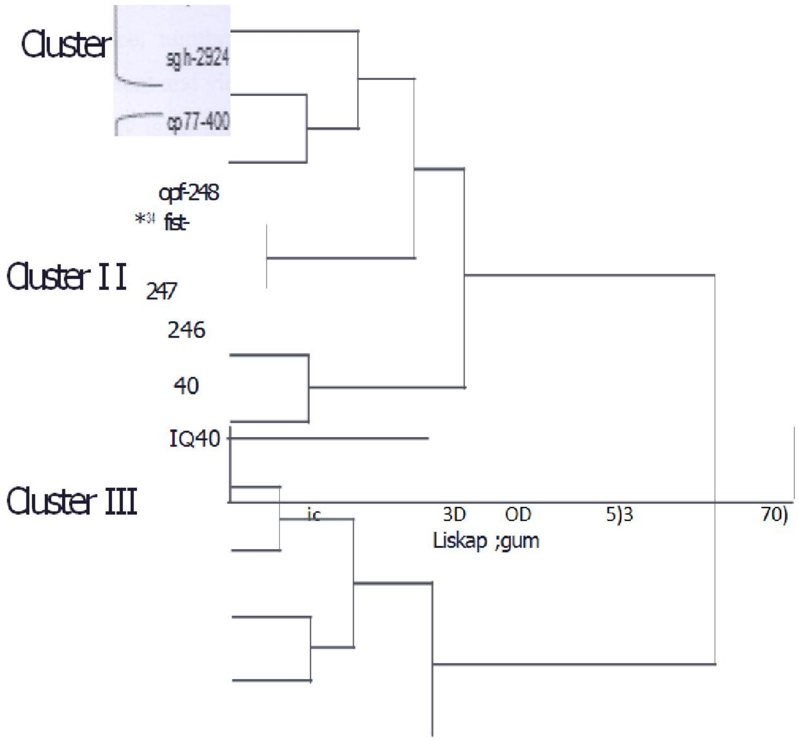


Fig. 4: Cluster analysis of 12 sugarcane genotypes using multivariate parameters of physiological and morphological characters.

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