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# Characterization of sugarcane germplasm collection and its potential utilization for evaluation of quantitative traits

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**This study was designed to determine the accession series with the most outstanding characteristics and the interrelationships among the variables. It also evaluated variability among the principal components and determined sugarcane accessions studied with similar characteristics from forty sugarcane accessions. Twelve quantitative traits were selected for data analysis. Series C accessions exhibited the most desirable characteristics. Four groups (PC1, PC2, PC3 and PC4) emerged from the principal component analysis. The four components with eigen values greater than one accounted for 75.92% of all variability in the forty accessions. Strong positive correlations were observed between plant height and stalk height (r=0.89); relative leaf area and leaf width (r=0.84); relative leaf area and leaf length (r=0.76); internode thickness and leaf width (r=0.73); relative leaf area and internode thickness (r=0.64); relative leaf area and internode length (r=0.51). In addition, positive and significant relationships were observed in internode length and leaf length (r=0.58); internode thickness and length of scarious border (r=0.54); length of scarious border and leaf width (r=0.55). These characters have a direct impact on the yield of sugarcane. Based on the analysis, the above traits could be considered as useful characters in yield improvement.**

**Key words:** Sugarcane, quantitative traits, characterization, principal component analysis (PCA), evaluation.

## INTRODUCTION

Sugarcane is grown in all the agro ecological zones of Cameroon. Even though it is a well-known economic crop, local sugarcane varieties are not being utilized in the manufacture of sugar which is the main product derived from processed sugarcane stalks. The major sugar agro-industry, SOSUCAM (Société Sucrière du Cameroun), utilizes mainly exotic cultivars. Production of these local varieties is entirely the business of smallholders who

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mostly sell to consumers as chewing cane, especially during the dry season when atmospheric temperature is high and people feel thirsty and dehydrated (Sumbele et al., 2018). Prior to this study, no local sugarcane gene bank existed to conserve all genotypes from which desirable traits could be selected for breeding improved varieties after a characterization procedure. Recently, it is common knowledge that the demand for sugar and bio-energy is on the rise due to the consistent increase in human population. This simply implies that the present low production is not enough to meet the increasing demand (Ong'ala et al., 2015).

Generally, there are traits that could be utilized during breeding to obtain improved varieties that could tackle the issue of low production. Some of these traits include good germination, abundant tillering, rapid early stalk elongation, vigorous growth, high tolerance to dry conditions, erect stalk, uniform stalk length at maturity, absence of flowering tendency, greater stalk diameter, early maturing, quality on maturity, high sucrose content and free trashing (Khan et al., 2012). Specifically, there are two useful traits that are indicative of high sugar yield: cane yield and sucrose content. Superior genotypes can be developed from the interactions of these characteristics (Terzi et al., 2009; Chohan et al., 2007; Alvarez et al., 2009).

Several authors have carried out characterization in different parts of the world by merely giving a detailed description of the morphological characters that each variety possesses (Akhtar et al., 2001, 2006; Nosheen and Ashraf, 2001; Ekpélikpézé et al., 2016; Wajih et al., 2004). However, in using the principal component analysis (PCA) (Rukundo et al., 2015), visual differentiation is allowed among entries and possible associations are identified (Mohammadi and Prasanna, 2003) by providing a two dimensional scatter plot. Recently, five landraces from three regions of Cameroon were identified through morphological characterization (Arrey and Mih, 2016), the cheapest and most available tool in developing countries. Nonetheless, sugarcane remains under-researched in Cameroon. This lack of information prevents breeders from taking advantage of the potential of sugarcane. Conserving and characterizing local sugarcane germplasm in Cameroon is essential for progress in breeding improved varieties that can be suitable for the diverse and huge potential of the crop especially in biofuel and energy production. This will secure its existing diversity and build a wide base for its genetic diversity thus meeting the demands of present and future users.

## Aim

The main aim of this study is to determine the accession series with outstanding characteristics that could be utilized in breeding new improved varieties and to study the interrelationships among measured variables in order to identify those that affect the yield. This research also sought to evaluate variability among the principal components and determine sugarcane accessions studied with similar characteristics.

## MATERIALS AND METHODS

### Sugarcane plants

These plants were obtained from five out of the ten administrative regions in Cameroon, representing the five-agroecological zones of the country. The collection was done during a baseline survey of smallholder sugarcane farmers in Cameroon, precisely in the South West (SW), Centre (C), West (W), Adamawa (AD) and North (N) Regions (Table 1).

The Institute of Agricultural Research for Development (IRAD) Ekona has since 2015 maintained this germplasm in the field. The initial collection was multiplied so as to expand the genetic base of these landraces. For each accession, three-bud setts were planted at the experimental field of IRAD Ekona. A randomized complete block design was put in place and replicated three times, with a distance of 1 m between rows and 1 m between plants. 168-112-112 kg NPK/ha was applied to the plants as urea, single super phosphate and potash (MOP), respectively. The crop was re-planted in May 2016 and harvested in August 2017. Uniform agronomic practices and pest control measures were put in place when necessary.

### Site

Ekona is a locality in the South West Region of Cameroon, precisely under Muyuka sub division in Fako Division. It lies between latitude 4° 16´ 44˝ N and longitude 9° 17´ 50˝ E and is located at an altitude of about 450 m above sea level. High mean temperatures ranging from 23.7°C in the rainy season (March - September) to 34.4°C in the dry season (November - February), as well as high rainfall with mean annual rainfall of 2,284 mm are characteristic of its humid tropical climate.

### Data collection

Forty (40) sugarcane accessions were selected from this germplasm collection (Table 1) for data collection. Seemingly, similar accessions were classified under the same series based on visual observations. In total, there were eight series representing the 40 accessions studied, with each series having 5 accessions (Table 1). A sugarcane descriptor form proposed by Wagih et al. (2004) was used as a guide in data collection. Data collection was carried out when the plants were 15 months old. Observations and measurements were done for twelve quantitative parameters (Table 2).

### Data analyses

Data from quantitative variables were analyzed using a one-way ANOVA. Significant differences among the different accession series were defined using the Tukeys test. Relationships between the quantitative variables under study were evaluated using Pearson's correlation coefficient. To group all studied accessions and determine their similarities, PCA was performed. Then, an agglomerative hierarchical clustering analysis was used to classify

**Table 1.** List of sugarcane accessions studied and their geographic origin.

| S/N | Accession number | Collection sites | Division | Region | Series |
|---|---|---|---|---|---|
| 1 | CMF-G06 | Ahala II | Mfoundi | Centre | |
| 2 | WME-G139 | Fongo Tongo | Menoua | West | |
| 3 | WNO-G141 | Foumbot | Noun | West | G |
| 4 | SWK-G238 | Tombel | Kupe Muanenguba | South West | |
| 5 | SWL-G237 | Menji | Lebialem | South West | |
| 6 | CHS-A18 | Nkoteng | Haute Sanaga | Centre | |
| 7 | CHS-A25 | Mbandjock | Haute Sanaga | Centre | |
| 8 | NF-A82 | Mango | Faro | North | A |
| 9 | WNO-A159 | Foumbot | Noun | West | |
| 10 | AV-A85 | Lac Tizon | Vina | Adamawa | |
| 11 | CHS-E42 | Nkoteng | Haute Sanaga | Centre | |
| 12 | CMF-E10 | Ahala II | Mfoundi | Centre | |
| 13 | SWL-E228 | Menji | Lebialem | South West | E |
| 14 | SWF-E250 | Muea | Fako | South West | |
| 15 | WNO-E152 | Foumbot | Noun | West | |
| 16 | AM-S98 | Nganhi Roblin | Mbere | Adamawa | |
| 17 | AM-S101 | Nganhi Roblin | Mbere | Adamawa | |
| 18 | AM-S104 | Nganhi Roblin | Mbere | Adamawa | S |
| 19 | SWK-S244 | Mbulle | Kupe Muanenguba | South West | |
| 20 | NF-S74 | Mango | Faro | North | |
| 21 | AV-D120 | Lac Tizon | Vina | Adamawa | |
| 22 | AV-D121 | Lac Tizon | Vina | Adamawa | |
| 23 | AV-D122 | Lac Tizon | Vina | Adamawa | D |
| 24 | WNO-D161 | Foumbot | Noun | West | |
| 25 | SWF-D189 | Molyko | Fako | South West | |
| 26 | SWF-C190 | Molyko | Fako | South West | |
| 27 | NB-C135 | Lagdo | Benoue | North | |
| 28 | NB-C138 | Lagdo | Benoue | North | C |
| 29 | CHS-C21 | Mbandjock | Haute Sanaga | Centre | |
| 30 | CLK-C61 | Obala | Lekie | Centre | |
| 31 | SWF-F182 | Bonakanda | Fako | South West | |
| 32 | NB-F134 | Lagdo | Benoue | North | |
| 33 | AM-F100 | Nganhi Roblin | Mbere | Adamawa | F |
| 34 | AM-F102 | Nganhi Roblin | Mbere | Adamawa | |
| 35 | AM-F103 | Nganhi Roblin | Mbere | Adamawa | |
| 36 | CMF-H02 | Ahala II | Mfoundi | Centre | |
| 37 | SWF-H185 | Bonakanda | Fako | South West | |
| 38 | SWF-H186 | Bonakanda | Fako | South West | H |
| 39 | CHS-H66 | Nkoteng | Haute Sanaga | Centre | |
| 40 | CHS-H58 | Mbandjock | Haute Sanaga | Centre | |

the accessions based on their similarities into main groups and subgroups. Statistical significance was set at 5% ($p < 0.05$) and XLSTAT (Addinsoft XLSTAT, 2018 version) was used for all the analyses.

**Table 2.** Quantitative parameters measured during the characterization process.

| S/N | Quantitative parameter | Units | Code |
|---|---|---|---|
| 1 | Number of leaves at the top of the leaf stalk | / | NL |
| 2 | Number of stalks in a stool (tillers) | / | NS |
| 3 | Number of green leaves | / | NGL |
| 4 | Plant height | Cm | PH |
| 5 | Stalk height | Cm | SH |
| 6 | Leaf length | Cm | LL |
| 7 | Leaf width | Cm | LW |
| 8 | Relative leaf area | $cm^2$ | RLA |
| 9 | Length of Scarious border | Cm | LSB |
| 10 | Internode length | Cm | IL |
| 11 | Internode thickness | Cm | IT |
| 12 | Length of Bud groove | Cm | LBG |

**Table 3.** Correlation between the quantitative parameters.

| Variable | NL | NS | NGL | PH | SH | LL | LW | LSB | IL | IT | LBG | RLA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NL | **1** | | | | | | | | | | | |
| NS | 0.062 | **1** | | | | | | | | | | |
| NGL | 0.170 | **0.329** | **1** | | | | | | | | | |
| PH | **0.334** | 0.295 | 0.154 | **1** | | | | | | | | |
| SH | 0.206 | 0.279 | 0.284 | **0.886** | **1** | | | | | | | |
| LL | 0.034 | -0.106 | -0.297 | 0.296 | 0.024 | **1** | | | | | | |
| LW | -0.144 | **-0.471** | -0.302 | 0.178 | 0.108 | **0.316** | **1** | | | | | |
| LSB | -0.023 | **-0.446** | -0.305 | -0.030 | -0.017 | 0.107 | **0.547** | **1** | | | | |
| IL | -0.128 | 0.052 | **-0.405** | 0.160 | -0.111 | **0.584** | 0.269 | -0.054 | **1** | | | |
| IT | 0.006 | **-0.347** | -0.079 | 0.262 | 0.191 | 0.263 | **0.728** | **0.536** | 0.016 | **1** | | |
| LBG | 0.107 | -0.070 | 0.131 | -0.251 | -0.259 | -0.073 | -0.027 | -0.069 | 0.071 | 0.182 | **1** | |
| RLA | -0.095 | **-0.367** | **-0.357** | 0.291 | 0.091 | **0.763** | **0.848** | **0.410** | **0.509** | **0.637** | -0.047 | **1** |

Values in bold are different from 0 at a significance level of α=0.05.

## RESULTS

### Analysis of variance

Table 4 shows the different mean values for the variables measured for each series. Number of tillers was highest for series C and G accessions. Number of leaves at the top of the leaf stalk, number of green leaves, plant height and stalk height were also highest for series C. Series A had the highest internode thickness, whereas Series S had the highest internode length; while Series H had the highest leaf width and length of scarious border. Series D had the highest leaf length, bud groove length and relative leaf area.

### Correlation analysis

***Relationship between quantitative parameters***

A correlation analysis of all the parameters was performed and the p-values of the significant relationships are shown in bold in Table 3. Using Pearson's correlation coefficient, the results indicate a positive and statistically significant association between plant height and stalk height (r=0.89), as well as between relative leaf area and leaf width (r=0.84). In addition, positive and statistically significant differences were also found between relative leaf area and leaf length (r=0.76); internode thickness and leaf width (r=0.73); relative leaf area and internode thickness (r=0.64) as well as relative leaf area and internode length (r=0.51). Positive and significant relationships were equally observed between internode length and leaf length (r= 0.58); internode thickness and length of scarious border (r=0.54) and between length of scarious border and leaf width (r=0.55). However, associations between number of stalks/stool and leaf width, length of scarious border, internode thickness and relative leaf area were negative, as well as those between number of green leaves and internode length and relative leaf area (Table 4).

**Table 4.** Means of parameters of the different sugarcane series.

| Series | Number of leaves at the top of the leaf stalk | Number of stalks in a stool (tillers) | Number of green leaves | Plant height (m) | Stalk height (m) | Leaf length (cm) | Leaf width (cm) | Scarious border (cm) | Internode length (cm) | Internode thickness (cm) | Bud groove (cm) | Relative leaf area ($cm^2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D | $4.60^{ab}$ | $15.600^{ab}$ | $12.40^{abc}$ | $4.75^{c}$ | $2.85^{ab}$ | $\mathbf{169.0^{b}}$ | $\mathbf{7.98^{de}}$ | $5.00^{a}$ | $\mathbf{16.86^{d}}$ | $\mathbf{4.47^{cd}}$ | $\mathbf{9.64^{c}}$ | $\mathbf{1365.2^{d}}$ |
| C | $\mathbf{6.40^{c}}$ | $\mathbf{23.20^{b}}$ | $\mathbf{16.40^{c}}$ | $\mathbf{5.60^{c}}$ | $\mathbf{3.85^{b}}$ | $148.4^{ab}$ | $6.42^{bc}$ | $5.60^{ab}$ | $9.40^{abc}$ | $3.78^{abc}$ | $4.80^{abc}$ | $953.2^{abc}$ |
| H | $\mathbf{5.20^{bc}}$ | $10.40^{a}$ | $10.20^{a}$ | $4.69^{bc}$ | $3.20^{ab}$ | $148.4^{ab}$ | $\mathbf{9.24^{e}}$ | $\mathbf{9.00^{b}}$ | $11.07^{c}$ | $4.29^{bcd}$ | $5.22^{abc}$ | $\mathbf{1364.7^{d}}$ |
| S | $4.20^{ab}$ | $16.40^{ab}$ | $10.60^{a}$ | $4.65^{bc}$ | $2.86^{ab}$ | $\mathbf{158.8^{b}}$ | $\mathbf{7.94^{de}}$ | $7.00^{ab}$ | $\mathbf{19.58^{d}}$ | $3.57^{ab}$ | $0.00^{a}$ | $1254.2^{cd}$ |
| A | $5.00^{abc}$ | $12.60^{a}$ | $11.80^{ab}$ | $4.70^{bc}$ | $3.11^{ab}$ | $145.6^{ab}$ | $7.86^{de}$ | $\mathbf{8.60^{b}}$ | $6.90^{ab}$ | $\mathbf{4.54^{d}}$ | $0.00^{a}$ | $1144.9^{bcd}$ |
| G | $4.60^{ab}$ | $\mathbf{21.60^{b}}$ | $12.40^{abc}$ | $\mathbf{4.77^{c}}$ | $\mathbf{3.38^{b}}$ | $132.6^{ab}$ | $5.72^{ab}$ | $3.60^{a}$ | $10.88^{bc}$ | $3.09^{a}$ | $1.30^{ab}$ | $768.6^{a}$ |
| E | $\mathbf{5.20^{bc}}$ | $17.20^{ab}$ | $13.00^{abc}$ | $3.66^{a}$ | $2.20^{a}$ | $136.4^{ab}$ | $4.92^{a}$ | $6.00^{ab}$ | $9.84^{abc}$ | $3.24^{a}$ | $6.50^{bc}$ | $669.8^{a}$ |
| F | $3.40^{a}$ | $14.80^{ab}$ | $\mathbf{15.40^{bc}}$ | $3.78^{ab}$ | $2.82^{ab}$ | $117.2^{a}$ | $7.28^{cd}$ | $6.20^{ab}$ | $6.15^{a}$ | $3.80^{abc}$ | $5.50^{abc}$ | $853.5^{ab}$ |
| Pr > F(Model) | 0.000 | 0.001 | 0.000 | < 0.0001 | 0.003 | 0.006 | < 0.0001 | 0.000 | < 0.0001 | < 0.0001 | < 0.0001 | < 0.0001 |
| Significant | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

Significant differences are observed for all characteristic among the series.

## *Principal component analysis*

Evaluation of variability among principal components showed eigen values greater than one for the first four components which accounted for 75.9% of the variability. This suggests that they are the most important components and that there exists four groups or clusters which give the most adequate interpretation. Since the value of the fifth component is close to one, it could also be considered as important but contributing significantly less than the previous four components to the variability observed (Figure 1 and Table 5). PC1 accounted for 31.52%, PC2 for 20.09%, PC3 for 14.25%, PC4 for 10.07 % and PC5 for 7.63% variability among accessions for studied parameters. The most relevant parameters in PC1 were relative leaf area, leaf width, leaf length, internode thickness, length of scarious border, number of stalks in a stool (tillers) and number of green leaves whereas in PC2, the most relevant ones were plant height and stalk height. In PC3, only internode length was relevant while in PC4, only the bud groove length was relevant. Finally, in PC5, only the number of leaves at the top of the leaf stalk was relevant. Most of the relevant parameters in PC1 were leaf parameters whereas PC2 had to do with height. From the five PCs, it was clear that PC1 had more relevant variables than PC2, PC3, PC4 and PC5 and that relative leaf area had the highest cosine value (Table 6).

The scree plot diagram further strengthened this information. 31.52 % variability was observed in PC1with eigen value of 3.78 which decreased with subsequent PCs (Figure 1 and Table 5) until it tended to form an almost straight line after the 6th PC, implying that little variance was observed thereafter.

## Loading plot

The projection on PC1 and PC2 revealed that the length of four variables (relative leaf area, plant height, and stalk height and leaf width) was greater than all others. This was followed by internode thickness, leaf length, and length of scarious border, number of green leaves and number of tillers (Figure 2). In conformity with the correlation results in Table 3, plant height and stalk height were positively correlated with each other, so too were leaf length, leaf width, internode thickness and relative leaf area. However, stalk height and relative leaf area were almost at right angles, so were not related to each other. Negative correlation however existed between number of leaves at the top of the leaf stalk and leaf width.

After performing the agglomerative hierarchical clustering (AHC), the accessions were grouped into five clusters. Cluster I grouped together nine accessions (Figure 3) based on similarities. This cluster was composed of 4 accessions of series D, 4 accessions of series S and 1 accession of series H. Accessions grouped in cluster I were

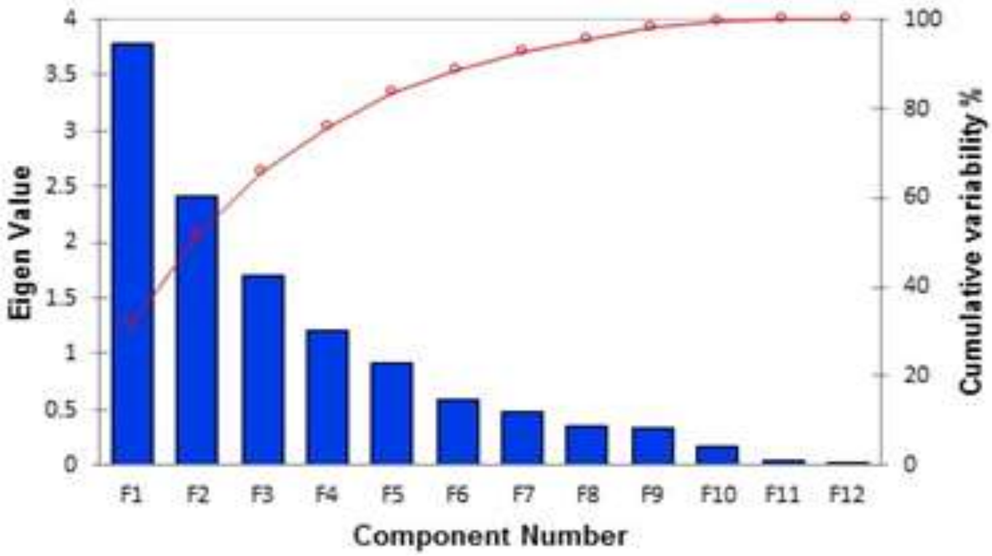


**Figure 1.** Scree plot diagram.

**Table 5.** Eigen analysis of the 12 variables.

| Component | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | F9 | F10 | F11 | F12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Eigen value | 3.782 | 2.411 | 1.710 | 1.208 | 0.916 | 0.590 | 0.484 | 0.351 | 0.325 | 0.177 | 0.043 | 0.004 |
| Variability (%) | 31.52 | 20.09 | 14.25 | 10.07 | 7.63 | 4.91 | 4.04 | 2.92 | 2.71 | 1.47 | 0.36 | 0.03 |
| Cumulative % | 31.52 | 51.61 | 65.86 | 75.92 | 83.56 | 88.47 | 92.51 | 95.43 | 98.14 | 99.61 | 99.97 | 100 |

**Table 6.** Structure of the first four principal Components.

| Variable | Principal Components | | | | |
|---|---|---|---|---|---|
| | PC1 | PC2 | PC3 | PC4 | PC5 |
| Number of leaves at the top of the leaf stalk | 0.010 | 0.163 | 0.033 | 0.189 | **0.561** |
| Number of stalks in a stool (tillers) | **0.254** | 0.241 | 0.130 | 0.002 | 0.061 |
| Number of green leaves | **0.238** | 0.156 | 0.115 | 0.085 | 0.116 |
| Plant height | 0.062 | **0.877** | 0.001 | 0.001 | 0.001 |
| Stalk height | 0.005 | **0.811** | 0.038 | 0.025 | 0.010 |
| Leaf length | **0.421** | 0.030 | 0.281 | 0.025 | 0.016 |
| Leaf width | **0.776** | 0.000 | 0.053 | 0.001 | 0.032 |
| Length of Scarious border | **0.364** | 0.033 | 0.234 | 0.040 | 0.031 |
| Internode length | 0.216 | 0.000 | **0.574** | 0.033 | 0.003 |
| Internode thickness | **0.534** | 0.014 | 0.218 | 0.046 | 0.043 |
| Length of Bud groove | 0.002 | 0.077 | 0.014 | **0.757** | 0.035 |
| Relative leaf area | **0.901** | 0.009 | 0.021 | 0.005 | 0.006 |

| | Euclidean distances between cluster centers | | | | |
|---|---|---|---|---|---|
| **Clusters** | **1** | **2** | **3** | **4** | **5** |
| 1 | 0 | 10.722 | 9.699 | 12.260 | 13.474 |
| 2 | 10.722 | 0 | 9.823 | 8.409 | 6.712 |
| 3 | 9.699 | 9.823 | 0 | 12.882 | 9.370 |
| 4 | 12.260 | 8.409 | 12.882 | 0 | 8.557 |
| 5 | 13.474 | 6.712 | 9.370 | 8.557 | 0 |

Values in bold represent highest cosine values.

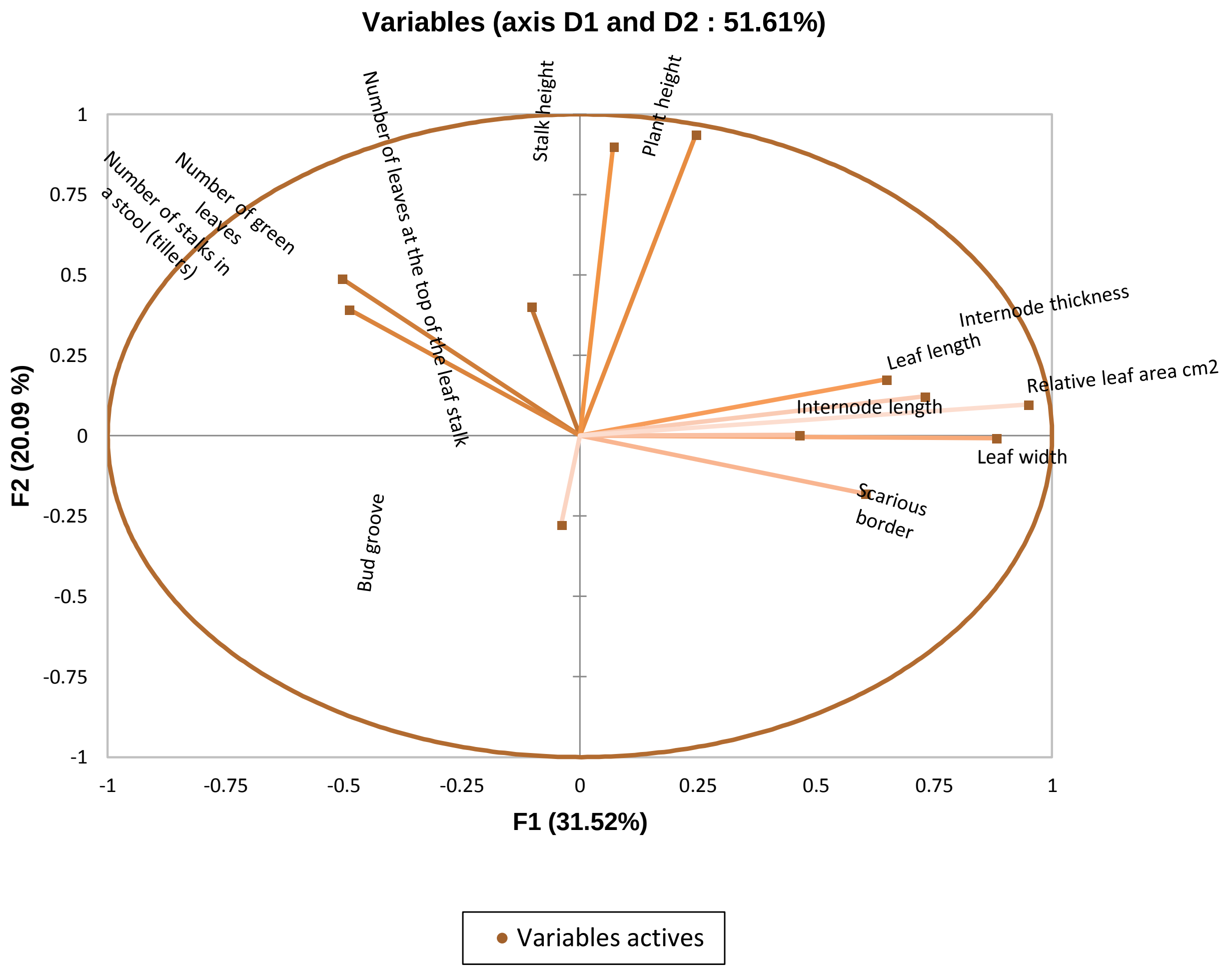


**Figure 2.** Loading plot of 40 sugarcane accessions on principal components 1 and 2.

characterized by longest leaf length, highest leaf width, longest internode length and highest relative leaf area but lower number of green leaves (Table 4). Cluster II grouped six accessions as follows: 1 series D, 4 series E and 1 series F (Figure 3). Accessions grouped in cluster II had higher number of leaves at the top of the leaf stalk, higher number of green leaves and higher number of tillers (Table 4). Cluster III had 10 accessions comprising 5 series A, 4 series H and 1 series S (Figure 3). Accessions grouped in cluster III were higher in leaf width, scarious border and internode thickness (Table 4). Cluster IV included 11 accessions composed of 5 series C, 1 series E and 5 series G (Figure 3). Accessions grouped in Cluster IV had highest values for number of leaves at the top of the leaf stalk, number of stalks per stool, number of green leaves, plant height, leaf area but lower values for leaf width, scarious border and internode thickness (Table 4). Cluster V consisted of 4 accessions, all of the series F (Figure 3). Accessions grouped in cluster V had higher number of green leaves, but lowest number of leaves at the top of the leaf stalk, shortest internode length, shortest leaf length, lower number of stalks/stool, lower plant height and lower stalk height (Table 4).

## DISCUSSION

This study evaluated morphological characteristics of 40 sugarcane accessions, which would form the basis for future breeding programs to develop cultivars through the selection of desirable characteristics by identifying parental combinations. The principal component analysis has simplified our understanding of the relationship among accessions (Shahzad et al., 2016). Forty sugarcane accessions were now reduced to five clusters, each one with peculiar characteristics. The strong positive correlation among relative leaf area, leaf width and internode thickness on the one hand and leaf width, length of scarious border and internode thickness on the other hand indicate the type of genotype that these sugarcane accessions possess.

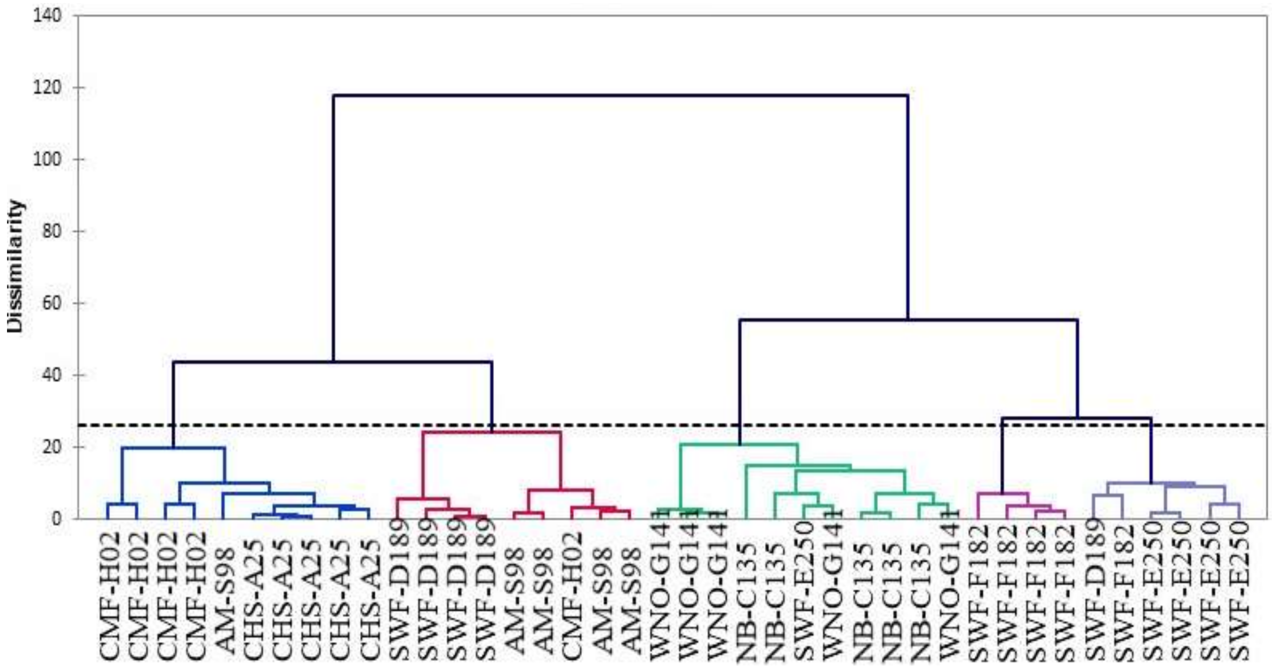


**Figure 3.** Dendrogram of 40 sugarcane accessions based on 12 morphological variables studied.

Photosynthesis takes place mostly in the leaf of the plant by absorbing photons of light energy. The greater the number of green leaves and leaf area, the greater the radiation interception and possibly the photosynthetic efficiency. Nonetheless, some authors (Smit and Singels, 2006; Inman-Bamber et al., 2008) opine that a small number of leaves in accessions is a strategy to decrease transpiration of the plant and curb the metabolic rate of tissues. In this study, a series represents similar accessions grouped together based on visual observations before the characterization exercise. Series C accessions had the highest number of green leaves (16.4) and the highest mean number of leaves at the top of the leaf stalk (6.4). However, series D accessions had the greatest mean leaf length (1.69 cm) while series H accessions had the greatest mean leaf width (9.24 cm). Overall, series D accessions had the highest relative mean leaf area (13.652 $cm^2$). In view of the results, a reduction in leaf area is probably due to a larger number of tillers, causing greater competition for water, light and nutrients among plants. This proportionally reduces the leaf area leading to the death of the youngest, weakest and worst positioned tillers (Costa et al., 2011). Similar results were obtained by Oliveira et al. (2007), who found a decline in leaf area as a function of the increased number of shoots in three varieties of sugarcane in Northeast Paraná State. In accordance with this study, series G with a smaller RLA mean (7.686 $cm^2$) had a greater mean number of tillers (21.6) while series H with almost the highest mean RLA (13.647 $cm^2$) had the lowest mean number of tillers (10.4). It is worth noting that Series C accessions had the greatest mean number of tillers (23.2). However, according to Moore and Botha (2013), the pattern of sugarcane tillering is intrinsically related to the genetic characteristic of each variety. It thus provides the plant with an appropriate number of stalks for a good yield. As such, Series C accessions present good characters for yield and should be considered in breeding programs but factors such as sunlight and adequate temperature are needed for optimum tillering in sugarcane.

In sugarcane, the stalks are the harvested tissue and stalk size has a major influence on sugarcane yield. The economic yield of this crop is given by the sucrose production, reducing sugars that are used in the formation of molasses and fiber, which can be used as source of energy in the plant itself (Toppa et al., 2010). According to Costa et al. (2011), increases in internode thickness occur during the sugar accumulation phase when vertical growth is reduced due to maximum growth. Series A accessions had the highest mean internode thickness (4.574 cm) which represents in total the bulk of fiber, sucrose, reducing sugar and water. Until each of these elements is determined in the section of the internode measured on each accession, then will it be possible to understand the relationship of internode thickness with the composition of that portion of the stalk.

According to Arrey and Mih (2016), SNC16 had almost the same value (161.9 cm) for leaf length as accessions of the series D (169.0 cm) but differed in leaf width. Meanwhile, the stalk height was almost similar for accessions of this study and those of Arrey and Mih

(2016). NBFAg53 had an almost similar stalk height (3.88 m) to that of series C (3.85 m). It is apparent from Table 3 that the variables plant height, stalk height, leaf width, leaf length, internode thickness or stalk diameter and relative leaf area were positively correlated with each other. They have been proven to be positively linked to overall sugarcane yield by several authors (Irum et al., 2017; Moore and Botha, 2013). Irum et al. (2017) in a similar study found stalk diameter as one of the variables that had an effect on yield. According to Sukhchain and Saini (1997), stalk length had significant positive correlation ($p < 0.05$) with internode length only in flooded environments. Kang et al. (1983) and Milligan et al. (1990) reported negative correlation between stalk number and stalk thickness. Similarly, the number of tillers and internode thickness was negatively correlated in the present study (Table 3). This is rational since the more stalks a plant has, the less resources it has to allocate for thickening of these stalks. Therefore, in using varieties with high tillering capacity with a propensity for high yield, other resources like soil fertility, sunlight and temperature are supposed to be maximum.

Characterization and accurate estimation of genetic diversity is very important in crop breeding as it helps in the selection of desirable genotypes, identifying diverse parental combination for further improvement through selection in the segregating populations (Mohammadi and Prasanna, 2003). The use of multivariate statistical analysis like PCA has the potential to increase the comprehension of relationship among variables. This could be helpful in understanding the nature of traits (Al-Sayed et al., 2012). The conducted PCA allowed the reduction of 12 variables to 5 PCs. The first component consisted of internode thickness, leaf stalk variables and tillering. Hence, it was directly linked to the photosynthetic process and yield. The second component had to do with plant height and stalk height. Hence, it was referred to as the elongation/growth component. The third component consisted of the internode length and could also be called the elongation component. Eigen values of the principal component analysis explain the partitioning of the total variability accounted for by each principal component. In the present study, eigen values corresponding to the first four variables were considered because they all had eigen values greater than one. The first 4 PCs exhibited 75.92% variation. PC1 justified highest variability (31.52%). In like manner, Muyco (2000) found 4 principal components giving rise to 76% variation in the data. However, contrary to our results, Shahzad et al. (2016) found seven principal components giving rise to 72% variation. The results of the loading plot indicated that plant height had a positive and strong association with stalk height, so too was relative leaf area with leaf length and leaf width and internode thickness with leaf width as the angle between these variables was very small (acute angle < 90°). Unlike Shahzad et al. (2016), internode thickness had a negative correlation with number of stalks per stool.

Cluster analysis showed that on the basis of series, accessions from different series were grouped in the same cluster despite their different geographic origin. So too, accessions from the same geographic origin were found in different clusters. As can be seen in Table 4, series C accessions had the greatest number of highest values for those characters considered as useful for improvement of sugarcane varieties as compared to the other series.

## Conclusion

Based on the PCA, it is justifiable to say that relative leaf area, internode thickness, internode length; length of scarious border, stalk height, number of stalks, plant height, leaf width and leaf length could be useful characters for consideration in yield improvement. Considering that sugarcane yield is directly influenced by these parameters, it is right to propose that accessions of series C should be considered as the parents for future breeding programs as this will possibly result in high yields.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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