American Journal of Biology and Life Sciences
2016; 4(5): 33-40
http://www.openscienceonline.com/journal/ajbls
ISSN: 2381-3784 (Print); ISSN: 2381-3792 (Online)

Characterization of Five Sugarcane Landraces in Western Cameroon

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To cite this article

Doris Besem Arrey, Afui Mathias Mih. Characterization of Five Sugarcane Landraces in Western Cameroon. *American Journal of Biology and Life Sciences*. Vol. 4, No. 5, 2016, pp. 33-40.

Received: July 25, 2016; **Accepted**: August 3, 2016; **Published**: September 23, 2016

Abstract

Sugarcane (*Saccharum officinarum* L.) is a major source of sugar in the world. Other emerging uses of the crop necessitate selection from adapted landraces. This makes proper characterization of landraces compelling. Five landraces cultivated in western Cameroon were characterized using comparative morphology. The landraces showed significant variation in quantitative and qualitative characters used for evaluation. Multivariate analysis showed that the five landraces formed three clusters; the first cluster has one landrace NBFAg53, the second has two (SBK36 and SMU58) and the third has two (NBFPc48 and SNC16). Three Principal Components accounted for over 66% of variation. Regression analysis also showed that the actual leaf area of sugarcane leaf (y) can be reliably estimated from the length and breadth at the broadest portion, by the equation: $Y = 0.0615x + 62.3cm^2$. ($R^2 = 0.782$, $p \leq 0.001$).

Keywords

Sugarcane, Landraces, Comparative Morphology, PCA, Cameroon

1. Introduction

Sugarcane (*Saccharum officinarum* L.) is grown in many countries of the world for many uses. Different sugarcane varieties resemble each other in appearance, but each variety has different morphological characters [1]. All morphological characters are important in sugarcane characterization [1-3]. Characterization and estimation of genetic diversity is very important in crop breeding as it helps in the selection of desirable genotypes and identifying diverse parental combination for populations [4]. Comparative morphology remains the cheapest and most available tool for identification in developing countries. Agronomic and morphological traits are useful in the study of genetic diversity [5]. This is evident with many authors who have used comparative morphology to study sugarcane in other parts of the world. For example, [6] reported on morphological characters of some exotic sugarcane varieties in Pakistan. Ref. [1] also used morphological characterization in identifying some sugarcane varieties.

The development of any economically important crop requires the use of improved high yielding varieties to facilitate production efforts. Description of the available germplasm is necessary because the knowledge of the interaction among descriptors will help in the selection of superior genotypes [7]. Despite the economic importance of sugarcane production in Cameroon, to date no major descriptive study has been carried out to identify the different landraces and to estimate the genetic diversity of the breeding materials. Other emerging uses of sugarcane, like its use in biofuels, will necessitate selection from adapted landraces.

The aim of this work was to characterize five sugarcane landraces most widely grown in western Cameroon using morphological characters and to study the interaction among descriptors. Genetic diversity information derived from this characterization will help to identify outstanding morphological and agronomic characters present in sugarcane in this study area.

2. Materials and Methods

Five landraces of sugarcane namely SMU58, SBK36, SNC16, NBfPc48 and NBfAg53 were used in the present study. The germplasm was collected from Southwest, Northwest and West regions of Cameroon (Fig. 1). Setts were raised in a nursery pots filled with fine mixed garden topsoil and poultry manure (3:1 v/v). Ethoprophos (Mocap10G) was applied to the nursery at the rate of 5kg ha^{-1} to keep away insects and rodents. The nursery was irrigated as necessary. The setts from the nursery were planted out at the experimental plot of the Department of Botany and Plant Physiology, University of Buea, Cameroon during the crop season 2011-2012. The crop was planted at the early month of March and harvested during February. The five landraces were planted in completely randomized design with three replications. Each landrace was accommodated in plot having three rows of 20m lengths with row- to- row spacing of 1m and plant- to - plant spacing of 50cm. The compound fertilizer N.P.K (20.10.10.) was used in a four equal - split application at the rate of 230kg ha^{-1}. The first split was applied as top dressing before planting and the rest at three months intervals. The plots were irrigated as needed in the first two months of planting before the rains become steady. Weed control was done manually by hoeing. Detrashing of canes was monthly after the first three months of planting and an insecticide Cypermethrine as Plantac 20WP, was applied in the field at a rate of 4kg ai ha^{-1}. Birds were controlled by using scarecrows.

Random sample of 50 leaves (10 per landrace) were collected. The actual leaf area (ALA) of each leaf was measured using a leaf area meter. The corresponding relative leaf area (RLA) was determined as a product of the leaf length and the width at the broadest portion. A correlation analysis between the ALA and RLA was done and the regression equation determined. For each landraces, four canes, one each from the center of four randomly selected non-border stools per replicate were harvested for data collection. The following character states were measured as shown below (Table 1). Collected data were rank transformed and subjected to one-way analysis of variance using Statistical Analysis System [8] software package. Data matrix of 5 x 11 was prepared and averages were analyzed using Ward's linkage cluster analysis (WLCA) and Principal Component Analysis and a dendrogram was done. Computation of Pearson coefficient of correlation among descriptors was carried out. All descriptors for qualitative characters like leaf sheath margin, leaf sheath pubescence, auricle shape and colour, dewlap shape and colour, ligule shape and colour, bud shape, colour, bud position on growing ring, stalk colour under wax, presence of ivory marks and growth crack, leaf canopy, leaf top, presence of leaf scar, and spine on leaf and internode alignment were based on the methods of [9]. Qualitative data were subjected to descriptive statistics.

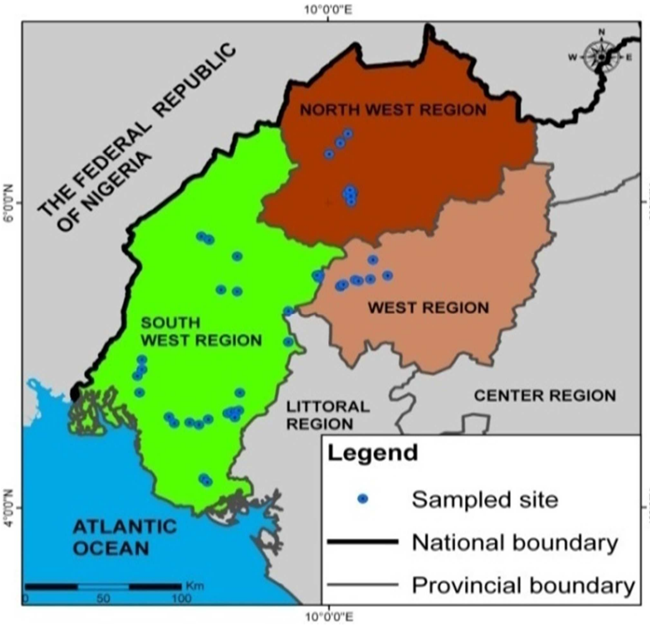

Fig. 1. *Survey communities for sugarcane landraces in Western Cameroon.*

Table 1. *Quantitative estimation of morphological traits of five landraces from Western Cameroon.*

SN	Character state	Codes	Technique of measurement
1	Leaf length	LL	Distance between the leaf tip and the base measured on the fourth fully opened leaf from the top
2	Leaf width	LW	Width of the broadest portion of fourth fully opened leaf from the top
3	Number of green leaves	NGL	Count of the total number of green leaves
4	Stalk height	SH	Length from base of stalk to the top most node
5	Stalk diameter	SD	Diameter at three points (25cm above base of stalk, 25cm below the topmost node and from the center of stalk and then averaged
6	Number of stalk per stool	NS	Count of the total number of tillers
7	Internodes number	IN	Count of the total number of internode per stalk
8	Internode length	IL	Measured from top, middle and bottom, then averaged
9	Bud length	BL	Measured from tip to the base of bud
10	Bud diameter	BD	Measured at the broadest portion

3. Results

The scattered plot of relative leaf area against actual leaf area is shown on Fig. 2. The regression analysis showed a strong predictive relationship between ALA and RLA ($P \leq 0.001$). The regression equation was determined to be:

$$Y = 0.615X + 62.3, \text{ where } Y = ALA \text{ and } X = RLA, R^2 = 0.782$$

There were significant differences between sugarcane landraces for all traits measured with an exception of stalk diameter (Table 2). NBfAg53 recorded the highest actual leaf area (ALA) (779.4cm^2), stalk height (SH) (3.88m), internode length (IL) (18.44mm), internode number (IN) (13.4) and bud length (BL) of 14.09mm.

Principal component analysis showed variation among the 11 characters considered (Fig. 3). The first three PCs had Eigen values greater than 1 and accounted for 66.3% of the total variation (Table 3). The PC_I alone accounted 35% variability while PC_2 and PC_3 accounted for 19.9% and 11.4% respective of the total variability. The most effective traits in the first principal component were leaf width, actual leaf area, stalks height and internode length. For the second component, leaf length, bud length and bud diameter and for the third component number of green leaves and number of stalks per stool.

The projection trait on PC_1 and PC_2 showed that the length of five vectors; leaf width, actual leaf area, leaf length, bud length and bud diameter where greater than the others, followed by stalk height and internode length (Fig. 4). In PC_1 and PC_2 together, the stalk diameter had minimum variability proportion. The number of green leaves, bud diameter, bud length, intermodal length, leaf width, actual leaf area, stalk height, intermodal number, leaves length and number of stalks exhibited higher proportion of variability. Stalk diameter, leaf width, stalk height, internode number, etc. were positively correlated with the actual leaf area (Fig. 4) while the bud diameter and number of green leaves were negatively correlated to the actual leaf area.

The highest level of similarity was between NBFPc48 and SNC16 landraces (Fig. 5). The cluster center between these two landraces was closed at 93.4% to form a cluster (cluster 2). The level of similarity between SBK36 and SMU58 was closed at 85.7% sufficient for them to form a cluster (cluster 3). Cluster 1 is formed by NBFAg53 only. There is a high Euclidean distance between cluster 1 and cluster 3 (264.8) (Table 4). These landraces had significant similarity only in stalk diameter.

Leaf width had positive significant correlations with stalk height and internode number. Actual leaf area was positively and significantly correlated with stalk height and internode length (Table 5). Number of green leaves was negatively correlated with stalk diameter. Stalk height was positively correlated with stalk diameter and internode number. Stalk diameter had a positive and significant correlation with internode number.

There was considerable variation in the comparative morphological characters among the landraces (Table 6). Falcate and long lanceolate auricles were observed on the landraces. Orbicular- crescent and crescent ligules were also observed on the landraces. The colour of ligules varied from light brown to dark brown. The dewlap shape ranged from deltoid dewlap (NBFAg53, NBFPc48 and SNC16) to crescent shaped dewlap in SBK36 and a rhomboid dewlap in SMU58. The dewlap colour ranged from apple green colour to purple colour, yellowish green and purple colour (Table 6). There were also variations in leaf canopy, leaf tops, leaf margin and presence or absence of leaf scar.

Stalk colour varied among the landraces (Fig. 6). The shape of internode was cylindrical in three of the landraces (Fig. 7), but was conoidal and abconoidal for SBK36 and SNC16 respectively (Table 6). Internode alignment varied from straight to zigzag. Split and ivory markings were absent in all landraces except in SMU58 that were occasionally present.

Bud groove was present in SBK36 only which was short and shallow (Table 6).

Shape of bud was different for the landraces while bud colour was similar for all landraces (Table 6). Bud shape varied from oval to beaked to obvate and to triangular-pointed (Fig. 8). Position of bud with respect to the growth ring varied among the landraces (Fig. 9). The bud was placed either on the growth ring or on an intermediate position on the growth ring.

Table 2. *Quantitative parameters of five sugarcane landraces from Western Cameroon.*

Landraces	Mean value of parameters										
	LL (cm)	WL (cm)	ALA (cm^2)	NGL	SH (m)	SD (mm)	IL (cm)	BL (mm)	BD (mm)	SN	IN
NBFAg53	151.8ab	7.74a	779.4a	9.7b	3.88a	40.9a	18.44a	14.09a	8.51b	12b	13.4a
NBFPc 48	153a	6.76b	697.7a	13.1a	3.45b	38.5a	17.5a	10.76a	9.88a	11.4bc	12.3ab
SBK 36	149.1ab	5.99c	533.8b	11.8ab	3.34bc	38.83a	12.08c	9.61b	7.61ab	10c	12.2ab
SMU58	136.7b	5.07d	496b	13.6a	3.05c	37.4a	13.4c	11.15a	9.73a	12b	11.2b
SNC16	161.9a	5.64cd	704.4a	10.5b	3.42b	39.4a	15.1b	9.66b	7.57b	13a	12.3b

Values represent means. Means with the same letter within the column are not statistically different at P≤ 0.05. LL = Leaf length, LW = Leaf width, ALA = Actual leaf area, NGL = Number of green leaves, SH = Stalk length, BL = Bud length, BD = Bud diameter, IN = Internode number NS = No. of stalks

Table 3. *Principal component of five sugarcane landraces from Western Cameroon for 11 characters.*

Variable	Eigen vectors		
	PC_1	PC_2	PC_3
Eigen value	3.8493	2.1890	1.2570
Proportion	0.350	0.199	0.114
Cumulative	0.350	0.549	0.663
LL (cm)	0.220	-0.464*	0.220
LW (mm)	0.444 *	0.105	0.170
ALA (cm^2)	0.441 *	-0.162	-0.020
NGL	-0.251	0.192	0.350*
SH (m)	0.354 *	-0.090	-0.187

Variable	Eigen vectors		
	PC_1	PC_2	PC_3
SD (mm)	0.274	-0.090	-0.187
IL (cm)	0.381 *	0.286	-0.077
BL (mm)	0.260	0.492 *	-0.102
BD (mm)	-0.007	0.606 *	0.015
IN	0.270	-0.102	0.241
NS	0.106	-019	-0.765*

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Table 4. *Euclidean distances between cluster centers for five landraces from Western Cameroon.*

Clusters	Cluster 1	Cluster 2	Cluster 3
Cluster 1	0.000	78.755	264.784
Cluster 2	78.755	0.00	186.758
Cluster 3	264.784	186.758	0.000

Table 5. *Pearson's Correlation coefficients among descriptors of five landraces from Western Cameroon.*

	LL	LW	ALA	NGL	SH	SD	IL	BL	BD	IN
LW	0.342									
	0.573									
ALA	0.724	0.785								
	0.166	0.116								
NGL	-0.649	-0.551	-0.695							
	0.236	0.335	0.192							
SH	0.544	0.936*	0.881*	-0.804						
	0.344	0.019	0.048	0.101						
SD	0.601	0.799	0.818	-0.942*	0.955*					
	0.283	0.105	0.091	0.017	0.011					
IL	0.390	0.809	0.898*	-0.388	0.773	0.608				
	0.516	0.097	0.039	0.519	0.125	0.277				
BL	-0.181	0.723	0.514	-0.394	0.674	0.58	0.696			
	0.771	0.167	0.375	0.512	0.212	0.305	0.191			
BD	-0.566	0.016	-0.117	0.711	-0.260	-0.501	0.317	0.286		
	0.320	0.980	0.851	0.179	0.673	0.390	0.603	0.641		
IN	0.591	0.915*	0.853	-0.831	0.992*	0.966*	0.703	0.594	-0.357	
	0.293	0.029	0.066	0.081	0.001	0.008	0.186	0.291	0.555	
SN	0.450	-0.163	0.443	-0.354	0.088	0.195	0.315	0.041	-0.113	0.043
	0.447	0.793	0.455	0.559	0.888	0.754	0.605	0.948	0.857	0.947

*= Significant at 0.05 level of probability; LL = Leaf length, LW = Leaf width, ALA = Actual leaf area, NGL = Number of green leaves, SH = Stalk height, SD = Stalk diameter, IL = Internode length, BL = Bud length, BD = Bud diameter, IN = Internode number, NS = No. of stalks.

Table 6. *Morphological characters of five sugarcane landraces from western Cameroon.*

Character	Character state	Leaf qualitative characters of five sugarcane landraces				
		Landraces				
		NBFAg53	NBFPc48	SNC16	SMU58	SBK36
Auricle shape	Long lanceolate	+	+	-	+	+
	Falcate	-	-	+	-	-
Ligule shape	Orbicular crescent	-	+	-	+	-
	Crescent	+	-	+	-	+
Ligule colour	Light brown	-	-	+	-	-
	Dark brown	+	+	-	+	+
Dewlap shape	Deltoid	+	+	+	-	-
	Rhomboid	-	-	-	+	
	Crescent	-	-	-	-	+
Dewlap colour	Brown	+	+	+	+	+
Leaf canopy	Scanty	-	-	-	+	-
	Abundant	+	+	+	-	+
Leaf top	Open	+	+	-	+	+
	Compact	-	-	+	-	-
Leaf margin	Scarious	+	+	-	+	+
	Non-scarious	-	-	+	-	-
Leaf scar	Present	+	-	+	-	+
	Absent	-	+	-	+	-

Table 6. *Continued.*

Character	Character state	Cane stalk qualitative characters of five sugarcane landraces				
		Landraces				
		NBFAg53	NBFPc48	SNC16	SMU58	SBK36
Cane stalk colour	Yellowish green	+	-	-	-	-
	Purplish brown	-	+	-	-	-
	yellow	-	-	+	-	-
	Golden brown	-	-	-	+	-
	Reddish brown	-	-	-	-	+
Stalk shape	Cylindrical	+	+	-	+	-
	Bobbin	-	-	-	-	-
	Conoidal	-	-	+	-	-
	Abconoidal	-	-	-	-	+
Stalk alignment	Straight	+	+	+	-	+
	zigzag	-	-	-	+, occasionally	-
Stalk split	Present or absent	-	-	-	+, occasionally	-
Ivory marking	Present or absent	-	-	-	+, occasionally	-
Bud groove	Long	-	-	-	-	-
	short	-	-	-	-	-
	Deep	-	-	-	-	-
	shallow	-	+	-	-	-

+ = Present, - = Absent

Table 6. *Continued.*

Character	Character state	Bud characters of five sugarcane landraces				
		Landraces				
		NBFAg53	NBFPc48	SNC16	SMU58	SBK36
Bud shape	Oval	+	+	-	-	-
	Beaked	-	-	+	-	-
	Triangular pointed	-	-	-	+	-
	Obvate	-	-	-	-	+
Bud colour	Brown	+	+	+	+	+
Bud position as to growth ring	On	+	+	+	-	+
	Intermediate	-	-	-	+	-
	Above	-	-	-	-	-

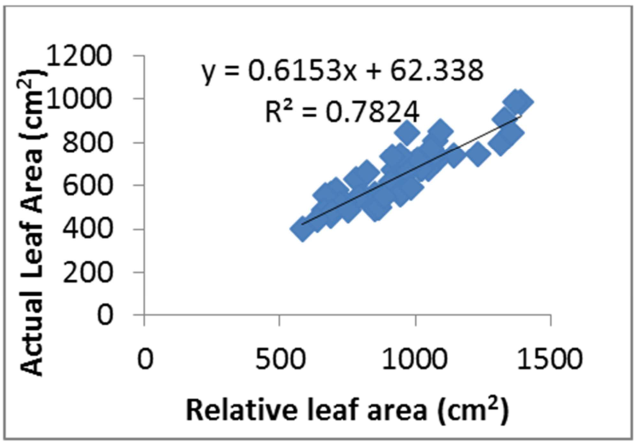

Fig. 2. *Correlation between relative leaf area and actual leaf area for five landraces from Western Cameroon.*

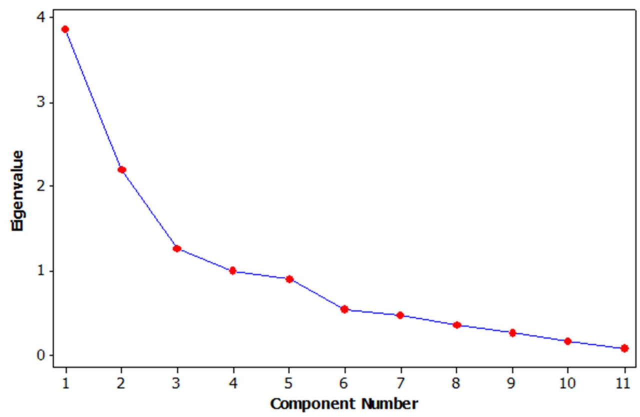

Fig. 3. *Scree plot analysis between Eigen values and number of principal components using principal component analysis for 11 characters of five.*

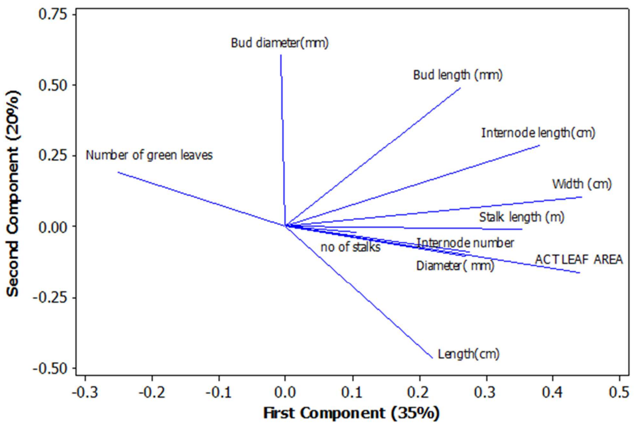

Fig. 4. PCA loading plot for relationships between parameters for axis I and II.

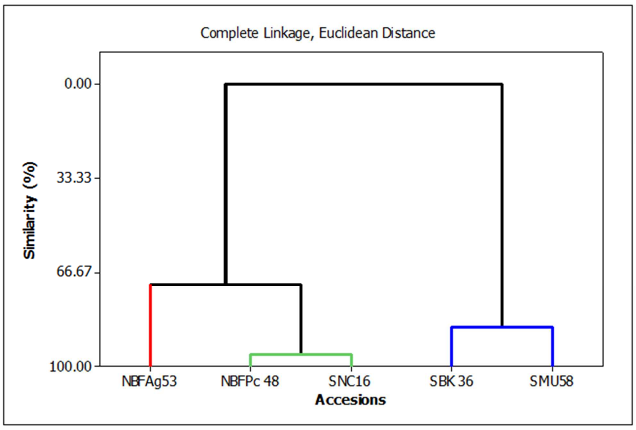

Fig. 5. Dendogram of intra and inter cluster between landraces.

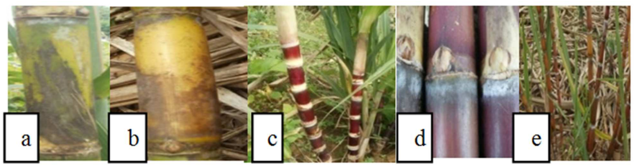

Fig. 6. Stalk colour on exposure to sun of five sugarcane landraces from Western Cameroon: (a) NBFAg53, (b) SNC16, (c) SBK36, (d) NBFPc48, (e) SMU58.

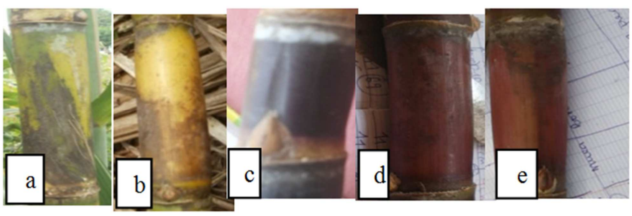

Fig. 7. Internode shapes of five sugarcane landraces from Western Cameroon: (a) NBFAg53, (b) SNC16, (c) SBK36, (d) NBFPc48, (e) SMU58.

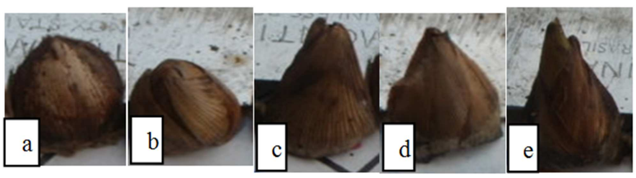

Fig. 8. Bud shape and colour of five sugarcane landraces from Western Cameroon: (a) NBFAg53, (b) SNC16, (c) SBK36, (d) NBFPc48, (e) SMU58.

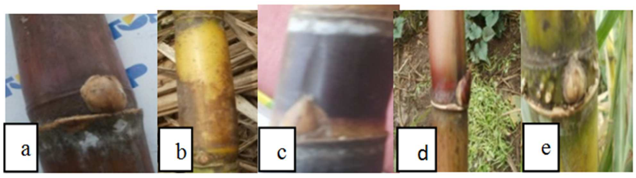

Fig. 9. Position of bud with respect to growth ring of five sugarcane landraces from Western Cameroon: (a) NBFAg53, (b) SNC16, (c) SBK36, (d) NBFPc48, (e) SMU58.

4. Discussion

Comparative morphological characterization was able to differentiate the five sugarcane landraces from western Cameroon. Variations were observed in some of the characters, though some characters were similar for the five landraces. Morphological variation within landraces was common among landraces for quantitative parameters studied except stalk diameter, indicating significant diversity. These descriptors; length and width of leaves, actual leaf area, number of green leaves, stalk length, internode length, stalk height, stalk number, internode number and bud length and diameter were very important in differentiating between the landraces. Ref. [10] also found that cane height contributed the highest to genetic divergence. Selection and evaluation of sugarcane landraces is generally done on various component traits such as number of stalks per stool, stalk height, and stalk girth, stalk weight and fiber content [2]. Significant differences between accessions for the plant height, leaf length, leaf width has also been observed in *Sesamum radiatum* collected in Benin [11]. The bud shape, stalk shape and position of bud on the growing ring were the most outstanding qualitative characters observed in this study. These characters varied in the five landraces. Ref. [12] also observed bud, dewlap, ligule and sheath auricle shapes as outstanding characters of values for identification of different sugarcane landraces. This was contrary with the findings of this study. The auricle, dewlap and ligule were almost similar in the five landraces and were not an outstanding character for the characterization of the landraces.

Leaf area is an important variable for eco-physiological studies in terrestrial ecosystems and is valuable in studies of plant nutrition, plant competition, plant-soil-water relations, plant protection measures, respiration, light reflectance, and heat transfer in plants and thus it is an important parameter in understanding photosynthesis, light interception, water and nutrient use, and crop growth and yield potential [13] and [14]. Morphologically, NBFAg53 was characterized by having the highest actual leaf area. This was an indication that in terms of yield, NBFAg53 will have the highest yield. NBFAg53 also recorded a maximum stalk height and stalk diameter of 3.88m and 40.9mm respectively. These dimensions are far greater than what was observed by [4] on the standard variety BL- 4. NBFAg53 had similar characters to those of CP85-1491 studied by [1], in terms of leaf length, number of green leaves, but had leaf width of 7.74cm as compared to 4.2cm of CP85-1491 and a stalk diameter of 40.9mm as compared to the 20.6mm in CP85-1491. Stalk diameter, bud diameter and bud length of the five landraces were higher than those of sugarcane varieties observed by [6]. The landraces in this study could have moved from other parts of the world, since there were some characters similar to canes from Pakistan. Differences in some quantitative characters might have been as a result of environmental factors.

The availability of any and all characters of sugarcane is the integrated package that will influence yield. This interaction is illustrated in the PCA and Correlation analyses, providing the relationship among various characters of the landraces. The principal component loading plot gives the relationship between parameters. Those parameters varying in the same direction actually complement each other. PCA showed that PC_1 was strongly associated with the actual leaf area, leaf width, stalk height and internode length which influence yield. The most effective traits in the first principal component were leaf width, actual leaf area, stalks height and internode length, which is plant vigour. This explains why PC_1 alone account for about 35% of the total variation. PC_2 is mostly related with bud parameters (bud diameter and bud length). PC_3 is related with parameters concerning numbers (number of stalk per stool and number of green leaves per plant). Ref. [15] explained that the 99% of the total variation in sugarcane was explained by the first three principal components with the PC_1 explaining about 91%. While contradictory to this, in this study the first three principal components explained only 66.3% of the total variation. Ref. [16] reported that most of the variations in sugarcane germplasm were due to seven PCs. From their study, the first two principal components were only 32.5%. In the present study, the first two PCs explain about 54.9% variation. Ref.[17] also showed that there were two principal components accounting for 88% of the total variation in the tested breeding material. Ref. [18] observed that the first and second principal components explained 76% of the total variation of qualitative data. Ref. [19] concluded that most of the diversity in sugarcane germplasm was due to two PCs. PCA and cluster analysis allowed a natural grouping of the genotypes of wheat [20]. Ref. [21] also reported that principal component analysis was a useful technique in recognizing the best genotypes based on both quantitative and qualitative characters. Accordingly, the use of different measurement techniques can be appropriately used for genotypes grouping [22]. Principal component analysis has been used on other crop. For example, Ref. [11] used principal component analysis to group 16 variables of *Sesamum radiatum* into various components with the first three explaining 64.21% of the total variation. Ref. [23] also used principal component analysis to group 13 variables of *Vernonia hymenolepis* into 10 components with the first three explaining 69% of total variation.

Cluster analysis grouped landraces with greater genetic similarity together. Three clusters i.e., I, II and III were formed using the Ward's linkage from the five landraces. Cluster I consisted of one landrace, cluster II consisted of two landraces and cluster III consisted of two landraces. The single landrace for cluster I recorded a far higher measurements for ALA, SH, IL, BL, and IN as compared to the other landraces. Ref. [24] reported that cluster analysis identified groups of cotton cultivars that were more closely related. Ref. [25] analyzed 89 garlic germplasm of Brazil and revealed 13 clusters. Similarly, based on morphological characters, Ref. [26] studied and categorized 65 garlic accessions into six clusters. Ref. [27] also analyzed 39 genotypes of cotton and revealed two major clusters. Cluster analysis based on PCA was used in the present study. However, results showed that cluster analysis based on PCA is a more precise indicator of differences among genotypes than cluster analysis (not based on PCA) [19].

There were significant positive and negative correlations noticed in the present studies. Correlation may not indicate any direct relationship but it is useful in predicting trends. Correlation studies help in selecting suitable plant types and plant breeding procedures. Similar observations have been made in different crops, for example in sweet potato [28], and chickpea [29]. In sugarcane, the correlations observed are similar to those of other workers. The significant positive correlation between actual leaf area and stalk height and internode length agrees with the observations of [18] and [30]. Other similar results have been observed by [31 -35]. However, [31] and [30] observed that cane height had a positive and significant association with cane thickness and number of internode as was observed in the present study. The present study recorded a positive and significant correlation between internodal length and leaf area, contrarily to what was observed by [34] but had a similar result of the correlation between stalk diameter and stalk height.

5. Conclusion

The comparative morphology of five sugarcane landraces in western Cameroon indicates that there were significant variations. However, the fact that there are only five landraces grown throughout the area and which have been reduced to three clusters, shows that the genetic base is quite narrow, posing a serious problem of selection.

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