

Morphological and agronomical characterization of different accessions of sweet potatoe (*Ipomoea batatas*) in Cameroon

A.G.N. Fongod^{*1}, A.M. Mih¹ and T.N. Nkwatoh¹

¹Department of Botany and Plant Physiology, University of Buea, PO Box 63, Buea, Cameroon

A field experiment was carried out, to characterize nineteen sweet potato accessions (Bafia, Bambui Orange, Bokito, Buea Local, IRAD048, IRAD122, Jonathan, Jewel440031, Jewel 56638, Kemkem1, Kemkem2, Mbouda, North Carolina, Santchou, SPK Kakamega, T1b1, T1b2, Tianung and Zapallo) collected from different agro ecological zones, within and out of Cameroon, to ascertain the diversity of these accessions. The accessions were characterized agronomically as well as morphologically using 26 International Potato Centre (CIP) descriptors. Cluster analysis revealed the existence of three major groups, with a similarity index range of 0.42 to 1.00 before maturity and 0.34 to 1.00 at maturity based on their Euclidean distance. Analysis of variance revealed significant differences among accessions in agronomic and morphological characters. Santchou had the highest average root yield (52.8t/ha). Kemkem2 had the highest dry matter content (33.5%). Principal component analysis reduced the data set to seven significant components at maturity in a multivariate analysis that cumulatively explained 76.4% of the variation. This indicated a high variation among the sweet potato accessions. The collection therefore represents a rich diversity in form, and yield that can form a good basis for selection in relation to transformation.

Keywords: Sweet potato (*Ipomoea batatas*), Morphological traits, Agronomical traits, Variability, Accession, Characterization.

INTRODUCTION

Sweet potato is a native of tropical America and is normally propagated by asexual means (Chen *et al.*, 1992). Globally, it ranks the seventh most important crop after wheat (*Triticum aestivum* (L.), rice (*Oryza sativa* (L.), maize (*Zea mays* (L.), Irish potato (*Solanum tuberosum* (L.), barley (*Hordeum vulgare* (L.), and cassava (*Manihot esculenta* Crantz.) (Hironori *et al.*, 2007). Sweet potato is considered the second important root crop after cassava in many tropical countries (FAOSTAT, 2006), and the third most important tuber in Sub-Saharan Africa after cassava (*Manihot esculenta* Crantz.) and yam (*Dioscorea spp* (L.), Karyeija *et al.* (1998). It is also considered as the future food crop which can be used to alleviate food shortage and to overcome hunger (Nani, 2003). In Africa, the crop is grown in

small scale, primarily to help ensure food security of the rural households (Ewell and Mutuura, 1994). In Cameroon sweet potato is an important subsistence food crop grown in almost all agro-ecological zones for its storage roots, which are used for human consumption and to a lesser extent its vines used as animal feed. Sweet potato exhibits great phenotypic and genotypic diversity due to its out crossing nature, combined with vegetative propagation (Chen *et al.*, 1992). Several authors, Oliveira *et al.* (2000), Daros *et al.* (2002), Ritschel *et al.* (1998), Tiaro *et al.*, 2008; Veasey *et al.*, 2007 have characterized sweet potato accessions.

An understanding the nature and magnitude of variation among sweet potato (*Ipomoea batatas* (L.) Lam) genotype for traits of economic importance is vital to plan effective breeding programs (Tsegaye *et al.*, 2008). Phenotypic, agronomic and biochemical parameters have been widely used in the evaluation of various crops, and the exploitation of such traits increases our knowledge of

Table 1. Accessions and their area of collection

Accession No	Pedigree	Area of collection
1	Bafia	Central Region
2	Bambui orange	North West Region
3	Bokito	Central Region
4	Buea local	South West Region
5	IRAD048	IRAD Ekona
6	IRAD112	IRAD Ekona
7	Jonathan	America
8	Jewel440031	America
9	Jewel 56638	America
10	Kemkem1	Western Region
11	Kemkem2	Western Region
12	Mbouda	Western Region
13	North Carolina	America
14	Santchou	Litoral Region
15	SPK Kakamega	America
16	T1b1	IRAD Ekona
17	T1b2	IRAD Ekona
18	Tianung	Kenya
19	Zapallo	Kenya

Table 2. Major groups, minor groups and accession (s) before maturity

Major groups	Minor groups	Accession (s)
1	1a	Bambui orange, Jewel 440031, and Jewel 56638
	1b	IRAD048, IRAD112, Kemkem1, Kemkem1, Mbouda, Santchou and North Carolina
	1c	Bafia and Bokito
	1 d	Tianung
	1e	Jonathan and SPK Kakamega
2	2a	Zapallo
3	3a	Buea local, T1b1 and T1b2

genetic variability (Kaemmer *et al.* (1992). In addition, genetic variability and diversity needs to be described and measured if it is to be effectively incorporated into breeding strategies and the management of plant genetic resources (Bouvet *et al.*, 2004).

Sweet potato is a highly heterozygous and cross pollinated crop in which many of the traits show continuous variation. Since it is highly heterozygous, there is an extensive variability within the species, which is available for exploitation by plant breeders (Jones *et al.*, 1986). Therefore applying quantitative and qualitative methods of approaches for exploiting this extensive variability, (which depends on good estimates of the phenotypic, genetic and agronomic characters) is of paramount importance. The estimates of these parameters form good basis for selection in relation to transformation in breeding and hybridization.

There are several accessions of sweet potato in Cameroon but information on their diversity and variability among the accessions for traits of economic importance is lacking. In addition the diverse system of naming accessions in Cameroon limits their proper identification and hinders proper monitoring and follow-up of newly released improved accessions from research stations once they reach the farmer. Therefore, comprehensive information concerning available sweet potato germplasm is of vital importance for any advanced breeding work. To overcome these constraints there is the need to ascertain the diversity of different sweet potato accessions collected from different agroecological zones in Cameroon, by characterizing them using both agronomic and morphological traits.

The study therefore sought to characterize sweet potato accessions collected from different agroecological

zones in Cameroon, in order to provide baseline information for agriculturalists and plant breeders.

MATERIALS AND METHODS

Study site

This research work was conducted in, Buea, located at the foot of Mount Cameroon in Fako Division, South West Region of Cameroon, located between latitudes 3° 57' and 4° 27' N and longitudes 8° 58' and 9° 25' E. This area has a humid tropical climate with an annual sunshine between 900 to 12000 hours per annum, average relative humidity of range 80 to 85% (Fraser *et al.*, 1998) and a mean annual temperature of 28°C. The annual rainfall is about 2000mm, most of which is received between June and September (Peguy *et al.*, 1999). Soil type here is basically volcanic (Cable and Chicks, 1998) making it agriculturally productive (Yerima and Van Ranst, 2005)

Planting material

Vine cuttings of the nineteen different accessions were obtained from the University of Buea germplasm collection that was established in October 2008.

Field layout and plant establishment

A plot of 361m² was cleared, raked and tilled. The prepared piece of land was divided into three blocks separated by 1m paths. Nineteen raised ridges of length 5m and width 0.5 m were made in each of the three replicates. The accessions were assigned randomly to each of these replicates. The experiment was therefore a completely randomized design on an area of 19 by 19m. Planting was done on April, 8th 2009. Ten vines per accession, each having a minimum of three nodes were planted some few centimeters (5cm) into the soil on each ridge. The planting distance between plants was 0.5m by 0.5m with a feeding area of 0.25m². Established plants were weeded three times for the entire period of production to avoid competition with weeds.

Data collection

Morphological characterization was based on aerial and below ground parts. Data was collected monthly before maturity (from 30 to 90 days) and at maturity (after 90 days). Characterization was achieved using standard descriptors; morphological and agronomical descriptors developed by 'Centro Internacional de la papa' (CIP (Huaman, 1992) as shown on Tables 3 and 4. Data was

collected monthly, for three months at each stage, before and at maturity. Quantitative measurements were taken for internode length, internode diameter, leaf area, leaf size (length from the base to the tip of the leaf) to know the differences in their development. Morphological character states related to length and size were scored on the basis of the average value of measurements made on several plants of each accession.

The petiole length, internode length, matured leaf size (distance from the tip to the base) of the leaf were measured using a meter rule. The internode diameter was measured using an electronic caliper (G02022 165). Leaf area measurements were done using a leaf area measuring system (Delta T devices. Model RS232). The characters of vines and leaves were recorded from the section located in the middle portion of the stem. To have fairly reliable data for qualitative morphology for each accession, an average of 10 plants were scored once every month within a period of five-month intervals for each of the three replicates in the field.

Storage root dry matter content determination

Determination of dry matter content (DMC) was done using the method described by Carey and Reynoso (1996) using an oven and an electronic balance with an accuracy of 0.1 g. In order to avoid post harvest changes in DMC prior to DMC determination, fresh weight was measured within 24 hours after harvest. Medial sections of five undamaged market-size roots were chopped into small flakes mixed thoroughly and a 400 g sample measured. The samples of 400g fresh weights were placed in paper bags and dried at 60°C in a hot box oven for 72 hrs or to a constant weight. The dried samples were weighed and dry matter content calculated as follows:

$$\% \text{ DMC} = (\text{dry weight} / \text{fresh weight}) \times 100.$$

Data analysis

Multivariate analysis

The data collected comprised mainly of primary data collected at the level of the field before maturity and at maturity for the various accessions. Each character was scored as a number (Huaman, 1992). The major tests carried out were; principal component analysis, one-way analysis of variance and cluster analysis. The data was first of all entered; variables defined and cleaned up before the analysis. 26 characters were introduced into MINITAB Version 15 software for Principal Component Analysis while one way ANOVA was carried out on all quantitative characters (leaf size, leaf area, petiole length, internode length, internode diameter, yield etc) to determine variation among agronomic and measured

Table 3. List of descriptors considered as key for characterization of the aerial parts

Twining	Ability of vines to climb stems or plants: non-twining, slightly twining, moderately twining, twining, very twining.
Plant Type	Determined by length of the main vines: erect (<75cm), semi-compact (75-150cm), spreading (151-125cm), extremely spreading (>250).
Internode Diameter	Very thin (<4mm), thin (4-6mm), intermediate (7-9mm), thick (10-12mm), very thick (>250mm). Measured with a digital caliper.
Internode Length	Very short (<3cm), short (3-5cm), long (10-12cm), very long (>12cm). Measured with a metre rule.
Predominant Vine Colour	Green, green with few purple spots, green with many purple spots, green with many dark spots, mostly purple, mostly dark purple, totally purple, totally dark purple.
Secondary Vine Colour	Absent, green base, green tips, green nodes, purple base, purple tips, -purple nodes, other.
Vine Pubescence Tip	None, sparse, moderate, heavy, very heavy.
General Leaf Outline	Round, reniform (kidney-shape), cordate (heart-shape), triangular, hastate (trilobular, spear-shape with the basal lobes more or less divergent), lobed, almost divided (Figure 1).
Type of Leaf Lobe	No lateral lobes (entire), very slight (teeth), slight, moderate, deep, very deep (Figure 2).
Number of Leaf Lobes	0, 1, 3, 5, 7 and 9 (Figure 3).
Abaxial Leaf Vein Pigmentation	Green, yellow, purple spots at base of main rib, purple spots in several veins, main rib partially purple, main rib mostly or totally purple, all veins partially purple, all veins mostly or totally purple, lower surface and veins totally purple (Figure 4).
Shape of Central Leaf Lobe	Absent, teeth, triangular, semi-circular, semi-elliptic, elliptic, lanceolate, oblanceolate, linear (broad), linear (narrow) (Figure 5).
Matured Leaf Size	Length from tip of central lobe to leaf base (Figure 6).
Matured Leaf Colour	Yellow-green, green, green with purple edge, grayish (due to heavy pubescence), green with purple veins on upper surface, slightly purple, mostly purple, green upper, purple lower, purple on both surfaces.
Immature Leaf Colour	Yellow-green, green, green with purple edge, grayish (due to heavy pubescence), green with purple veins on upper surface, slightly purple, mostly purple, green upper, purple lower, purple on both surfaces.
Petiole Pigmentation	Green, green with purple near leaf, green with purple near stem, green with purple at both ends, green with purple spots through out petiole, green with purple stripes, purple with green near leaf, some petiole purple, others green, totally or mostly purple.
Petiole Length	Measured from leaf base to vine (Figure7). Very short (<10cm), short (10-20cm), intermediate (21-30cm), long (31-40cm), very long (>40cm). (Figure 7)

morphological parameters, for determination of any significant differences between accessions. Cluster analysis was done on all the 26 characters, based on Euclidean distance. An initial cluster analysis was done, evaluated on possible distance for divergence, and based on this; the final three clusters were determined and generated. Pearson's correlation was done to determine the relationship between agronomic parameters and measured morphological parameters. The results obtained from the above-mentioned statistical analyses were represented using tables, graphs and dendrograms.

RESULTS AND DISCUSSION

Above 50% of the accessions were similar in characters such as vine tip pubescence, type of leaf lobes, and number of leaf lobes, mature leaf colour, immature leaf colour, predominant skin colour, and predominant flesh colour, indicating that these might be the most important and informative characters in this study.

Most of the accessions were similar with respect to plant type pattern, predominant vine colour and short vine internode length. They were also similar with respect to

Table 4. List of descriptors considered as key for characterization of belowground parts

Storage Root Shape	Round, round elliptic, elliptic, obvate, and ovate, oblong, long oblong, long elliptic, long irregular or curved. (Figure 8)
Storage Root Defects	Absent, alligator's like skin, shallow horizontal constrictions, deep horizontal constrictions, shallow longitudinal grooves, deep longitudinal grooves, deep constrictions and deep grooves, others. (Figure 9)
Predominant Skin Colour	White, cream, yellow, orange, brownish orange, pink, red, purple-red, dark purple.
Intensity of Predominant Skin Colour	Pale, intermediate, dark.
Secondary Skin Colour	Absent, white, cream, yellow, orange, brownish orange, pink, red, purple red, dark purple.
Predominant Flesh Colour	White, cream, dark cream, pale yellow, dark yellow, pale orange, intermediate orange, dark orange, strongly pigmented with anthocyanins.
Secondary Flesh Colour	Absent, white, cream, yellow, orange, pink, red, purple-red, purple, dark purple.
Distribution of Secondary Flesh Colour	Absent, narrow ring in cortex, broad ring in cortex, scattered spots, narrow ring in flesh, broad ring in flesh, ring and other areas in flesh, in longitudinal sections, covering most of the flesh, covering all flesh. (Figure 10)
Storage Root Arrangement	Closed cluster, open cluster, dispersed, very dispersed. (Figure 11)

Source: CIP Guide 1996

leaf, skin and tuber characters, while few descriptors scored low values with respect to the percentage expressed by the accession and thus showed low similarity. These results indicate that there might be few morphological characters that are important in taxonomic differentiation of accessions, and hence the need for other methods of characterization.

A good number of the accessions under study had cream flesh (52.63%) as predominant flesh colour. Cream as the predominant storage root flesh colour was also observed for 70% of the accessions by Ritschel *et al.* (1998) and for 50% of the accessions evaluated by Daros *et al.* (2002). Veasey *et al.*, 2007 also observed 73% of cream predominant flesh colour among accessions in Vale Do Ribeira. For skin colour, only 5.2% had pink skin colour indicating that they are very rare. This result is contrary to that Daros *et al.* (2002) who observed pink in 50% of the 14 sweet potato accessions of the State University of North Fluminense. This difference in results might have been due to differences in the accessions under study (Figure 1, 2 and 3).

Results from principal component analysis revealed that the following characters; mature leaf colour, immature leaf colour, internode diameter, predominant vine colour, internode length, secondary vine colour, storage flesh colour, intensity of skin colour, plant type storage root arrangement, leaf size and storage root shape contributed very much to the variability of these accessions. The contribution of the different major characters (four components before maturity-78.2%; five at maturity -76.4%) to the total variability is sufficient to make a logical distinction between accessions, indicating that morphological characters could be suitable for use in

distinguishing accessions and are important in indicating slight differences among the different accessions of sweet potato in Cameroon. These results are consistent with those of Oliveira *et al.* (2000) and Veasey *et al.* (2007) using similar number of characters. These results are however contrary to the findings of Tiaro *et al.* (2008) who reported a relatively low value of 58.5% in Tanzania using six characters, indicating that the number of characters is crucial to a proper delineation of accessions.

Investigation of genetic diversity in germplasm is frequently done by analyzing morphological and agronomic traits with cluster and principal components. The feasibility of this method in germplasm characterization has been demonstrated for many crops (Sauza and Sorells, 1991). Within species accessions differed in relation to various characteristics which is the reason why they were classified in distinct groups in the cluster analyses with morphological and agronomic data (Figure 4).

All accessions were classified into three major groups, and further divided into separate subgroups which are considered to be closely related. The three major groups we had could be explained by the fact that the accessions that formed the second and the third group, though with purple vines and petiole, were significantly different from each other and shared very few characters with members of group one, these two accessions being alien. These findings contradict those of Tiaro *et al.* (2008) who divided the 280 accessions into two major groups based on six morphological descriptors. Cluster analysis revealed a high variability among the different accessions in Cameroon. Oliveira *et al.* (2000) also

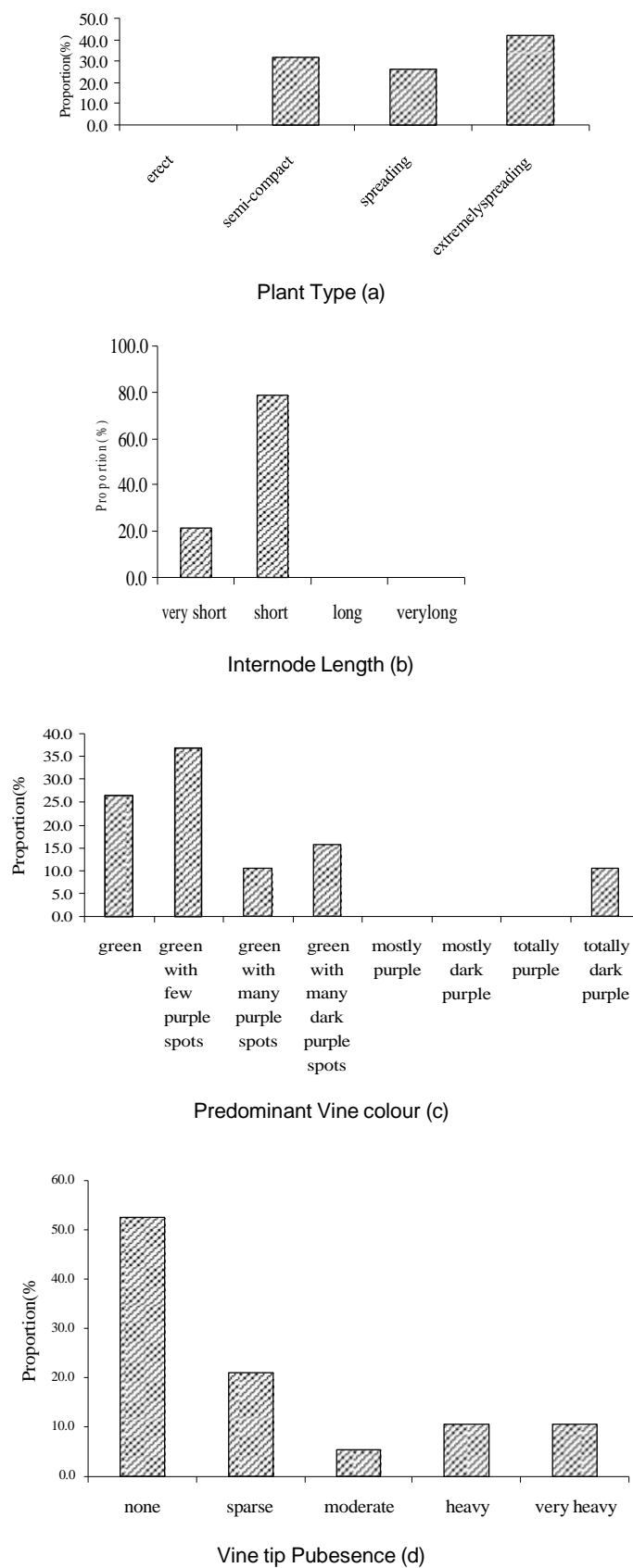


Figure 1. Vine character descriptors; plant type (a) predominant vine colour (c) and vine tip pubescence (d)

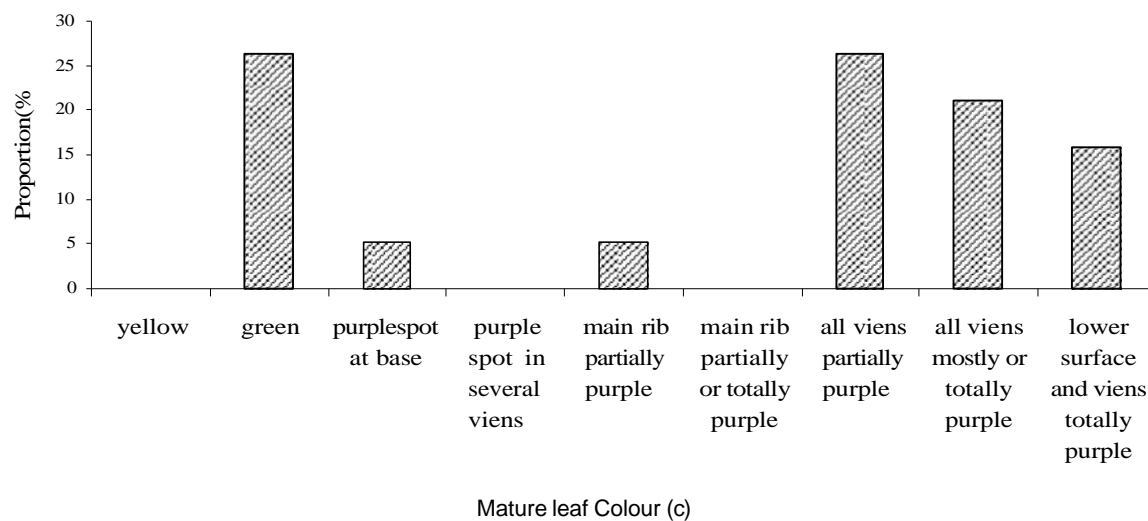
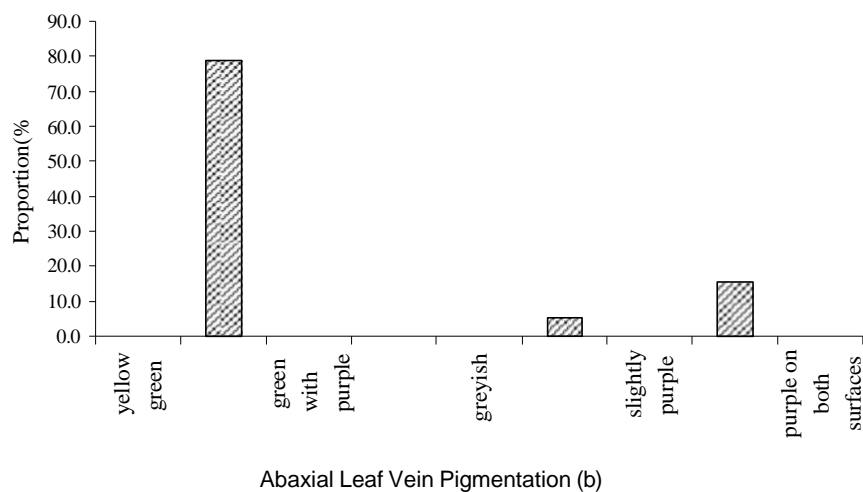
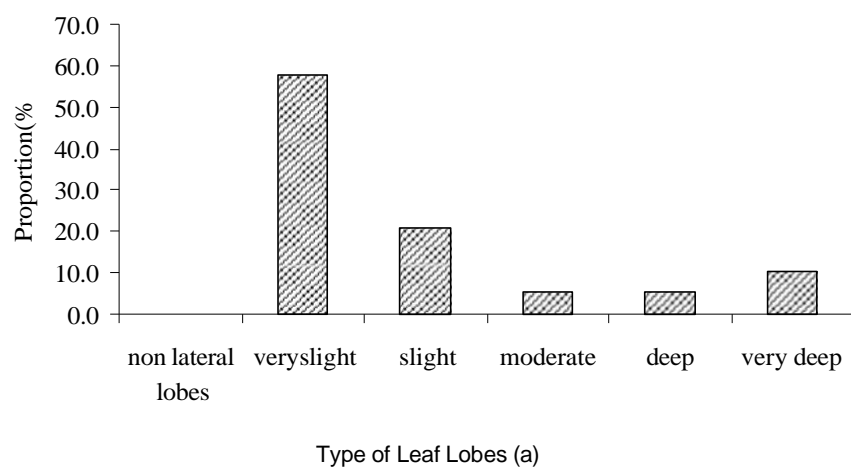


Figure 2. continue

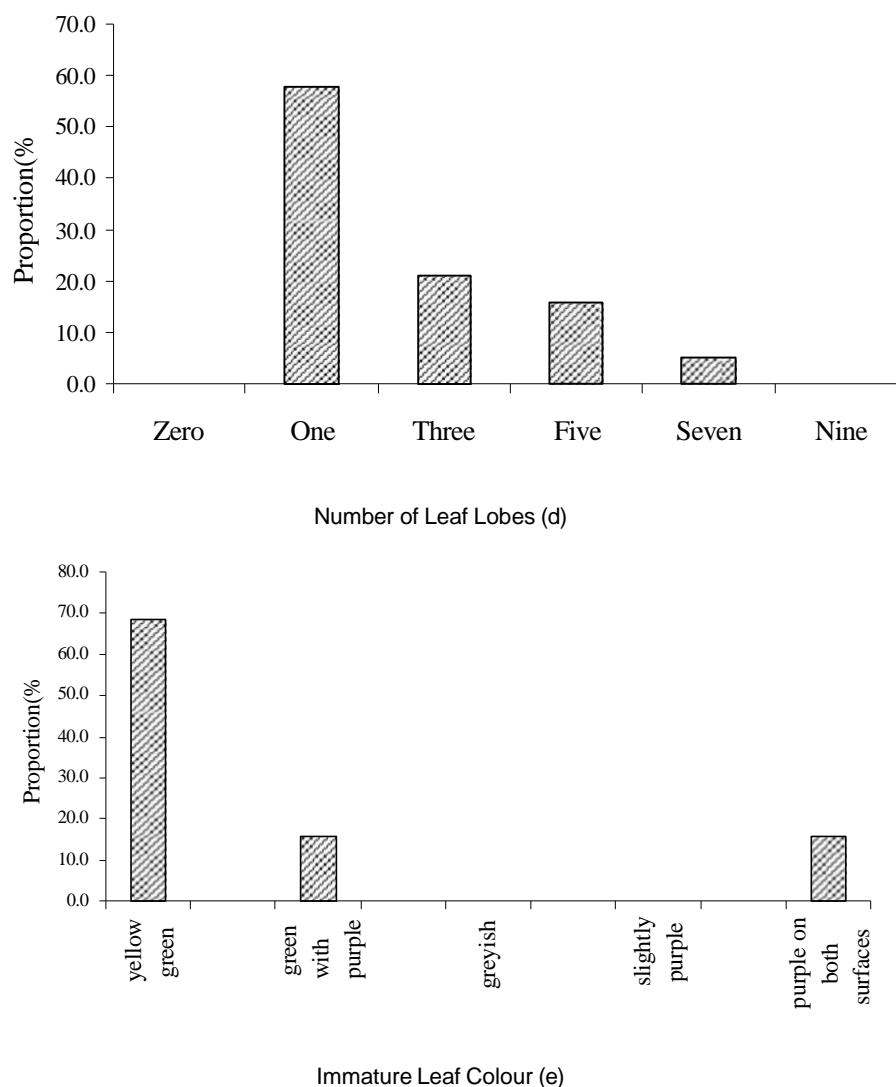


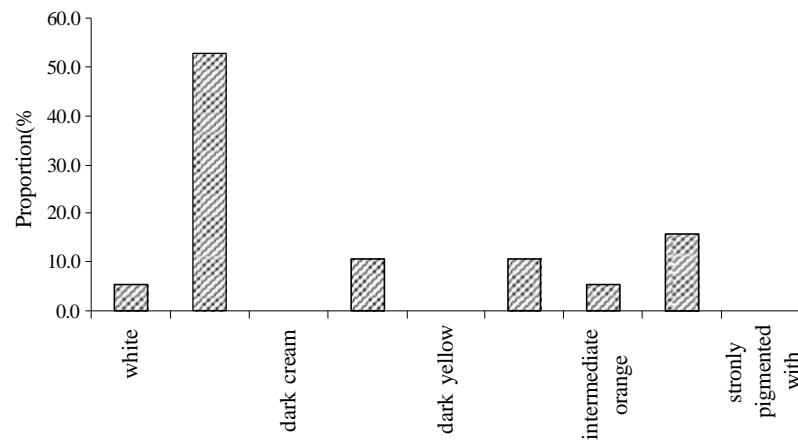
Figure 2. Leaf character descriptors; type of leaf lobes(a), mature leaf colour (b) abaxial leaf vein pigmentation (c), number of leaf lobes, immature leaf colour (e)

observed high genetic divergence between 51 clones of sweet potato originating from various Brazilian regions.

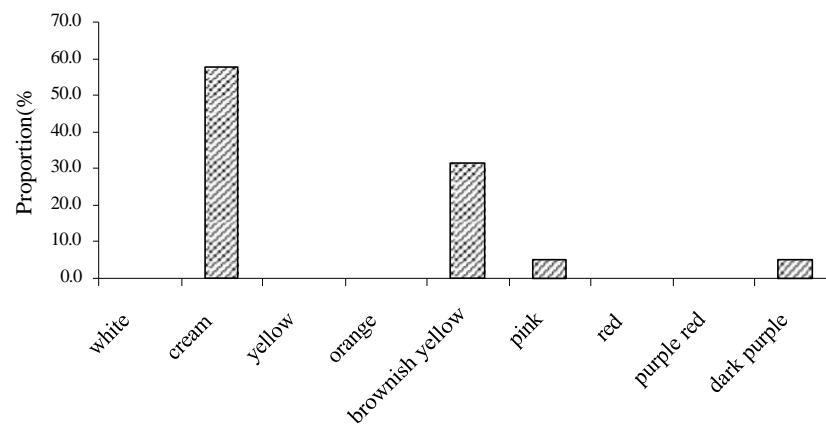
The dendrogram of the aerial morphological characters revealed that accessions such as jowel4, jowel5, and Bambi orange, T1b1 and T1b2 and IRAD112 and Kemkem1 are duplicates but the overall dendrogram of all the characters showed some slight difference. This is probably due to the fact that sweet potato is propagated via stem cuttings and adventitious buds arising from storage roots may result in accumulation of random mutation. Thus this intra-variety variability may be related to the high somatic mutation reported in this crop (Hernandez et al., 1964) (Figure 5).

Indented key for identification of major groups

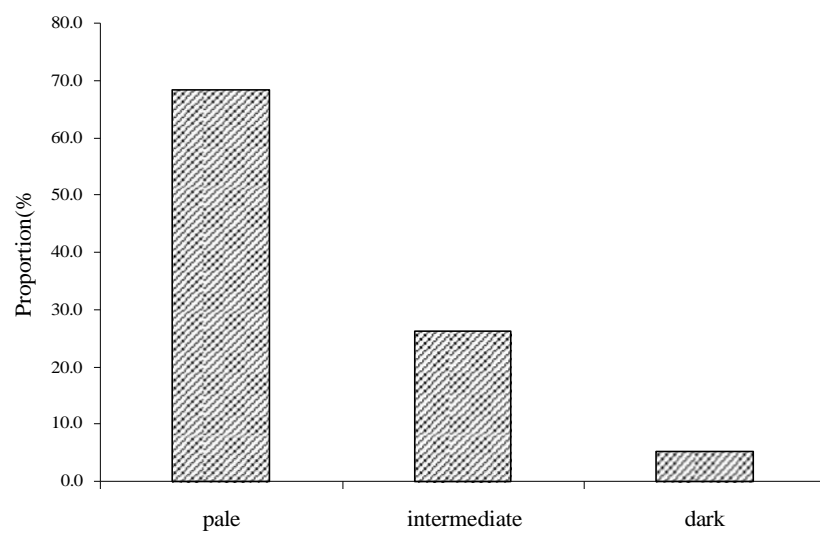
- 1a Vines totally purple and petioles totally dark purple
- 2a Very deep lobes, linear central leaf lobes, pale orange flesh and divided lobes, not spreading -----
- **Group n**
- 2b Cordate leaf lobes, leaf lobes not deep, 9 lobes before maturity and 1 at maturity, dark orange flesh -----
- **Group w**
- 1b Vines not totally purple, petioles not totally purple
- 3a flesh cream white or orange or pale yellow -----
- Group l**



Predominant Flesh Colour (a)



Predominant Skin Colour (b)



Intensity of skin colour (c)

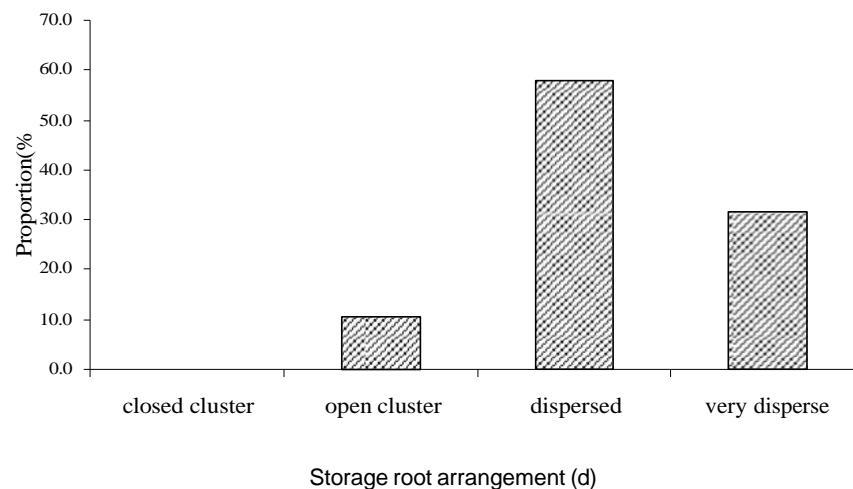
Figure 3 continue

Figure 3. Storage root descriptors; predominant flesh colour (a), predominant skin colour (b), intensity of predominant skin colour (c) Storage root arrangement (d)

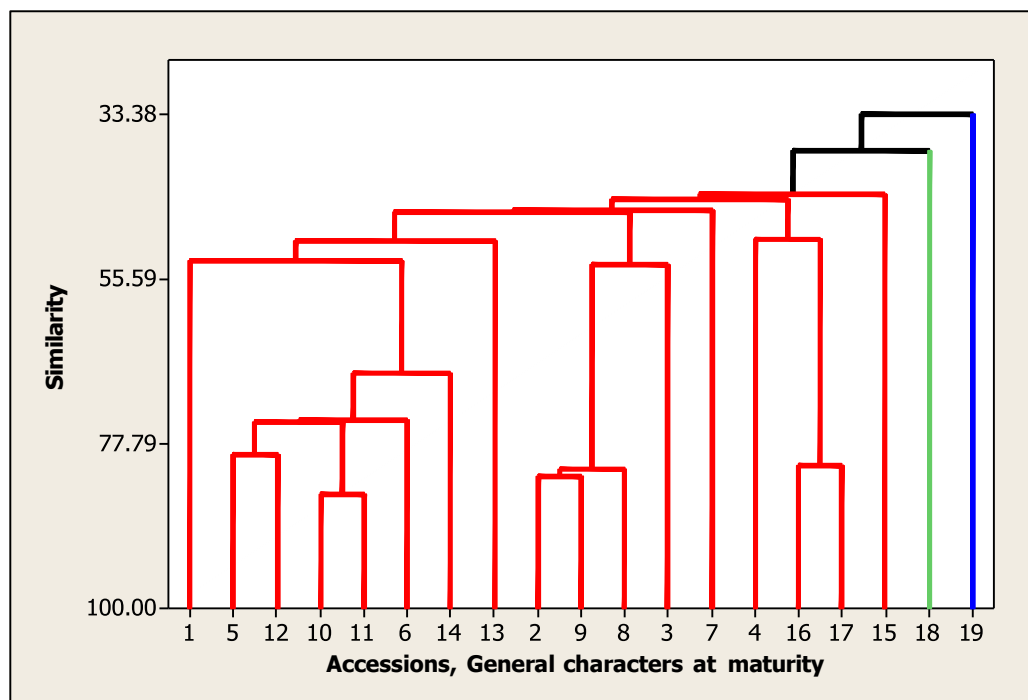


Figure 4. General characters at maturity (made up of three major groups or clusters showed by the different colours on the dendrogram) dividing the various accessions into groups, subgroups and accessions.

Indented key for identification of sub groups of group I

1a Spreading plant type

2a Plant have purple nodes, mature leaves with purple veins on upper or lower surfaces; cream predominant

flesh and skin colour, petioles with purple spots, pale skin intensity

3a Vine tip pubescence present-----
-----I g

3b Vine tip pubescence absent

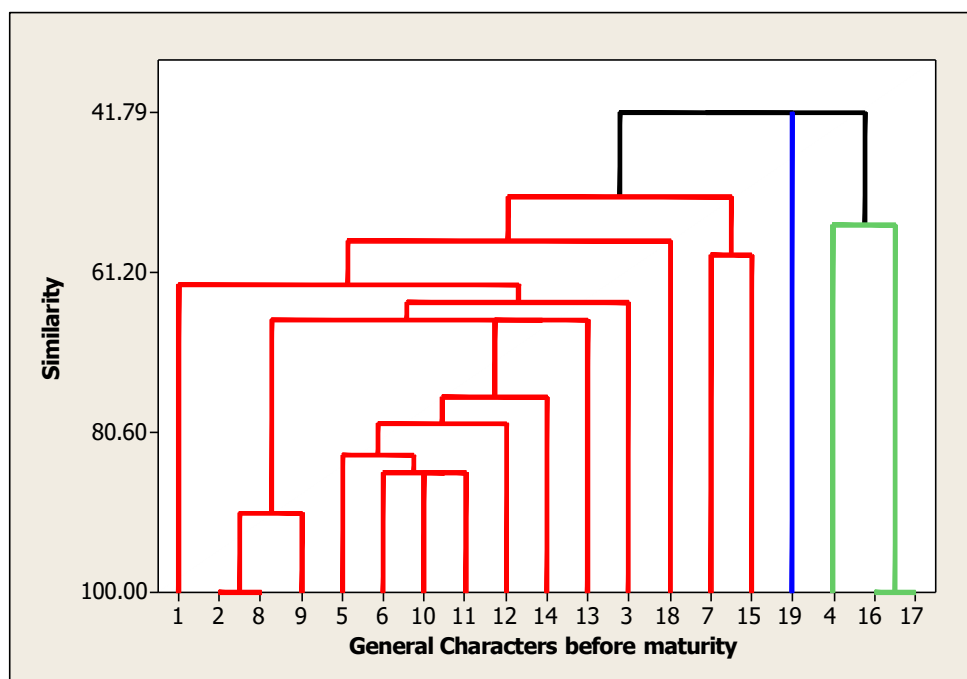


Figure 5. General characters before maturity (made up of three major groups or clusters shown by the different colours on the dendrogram)

4a Lobed leaf outline, moderate leaf lobe type, green petioles with purple spots throughout ----- **I c**

4b Triangular leaf outline, very slight leaf lobe type, green petioles with purple spots at both ends ----- **I b**

2b Plants do not have purple nodes, absence or presence of partially purple veins on mature leaves

5a Presence of vine tip pubescence and yellow green immature leaf colour, leaves are not divided.

6a Sparse pubescence, cordate leaf outline, one leaf lobe ----- **I f**.

6b Very heavy pubescence, Hastate leaf outline, 3 leaf lobes ----- **I d**

5b Absence of vine tip pubescence, green immature leaf colour with purple edges and leaves almost divided ----- **I e**

1b Plant type non-spreading

7a Vines totally green without purple nodes, abaxial leaf veins green, ----- **I a**

There was a significant variation among sweet potato accessions for morphological characters, petiole length, internode diameter, leaf area, leaf size and internode length ($p < 0.001$) and for agronomic characters; fresh weight, dry weight, dry matter content and yield ($P < 0.001$). This significant difference in characters revealed a phenotypic variance. This is an indication for the existence of immense inherent variability that remains unaltered by environment among the accessions. This confirms earlier findings by Tsegaye et al. (2007) who

also observed inherent variability amongst sweet potato accessions in Tanzania. Sweet potato is the world leading crop in dry matter content per unit time (Woolfe 1992). Seven accessions out of the 19 accessions exceeded a dry matter content of 30 %, which gives them a very high economic value as high dry matter content is the most market-preferred trait and also important traits that are required by most industries since most dry matter in sweet potato is an indicator of starch. Sorensen et al. (1997) also observed a similar value for yams (30%).

The correlation between yield and dry matter content was not significant and weakly positively correlated, indicating that yield does not determine the dry matter content partitioning of the plant and vice versa.

There was a significant variation and positive correlation between leaf area and yield, petiole length and yield and leaf area and dry weight. This could be explained by the fact that, the petiole is an important parameter in determining the orientation of leaves. Proper leaf orientation is needed for efficient trapping of solar energy. It ultimately decides the production of food and thus tuber yield, while leaf area is the major determinant of the final yield as it contributes through the process of photosynthesis. This result is similar to that of Boote et al., 1988 who confirmed that leaf area is important for crop light interception and therefore has a large influence on growth and thus yield. Tuber dry matter content and leaf area also correlated significantly, and this observation was also made by Tsegaye et al. (2007).

CONCLUSION

This study has provided preliminary morphological and agronomic characterization of the different accessions of sweet potato cultivated in the different agroecological zones in Cameroon. Grouping of accessions based on similarity and shared characters showed limitations of using only morphological traits in characterization of sweet potato. Results from clusters analysis and PCA showed high variability among the different accessions. Agronomic results also suggested variation in yield and dry matter content among the different accessions of sweet potato. There was also a positive correlation between most of the agronomic and morphological parameters. The collection therefore represents a rich diversity in form, and yield that can form a good basis for selection in relation to transformation.

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