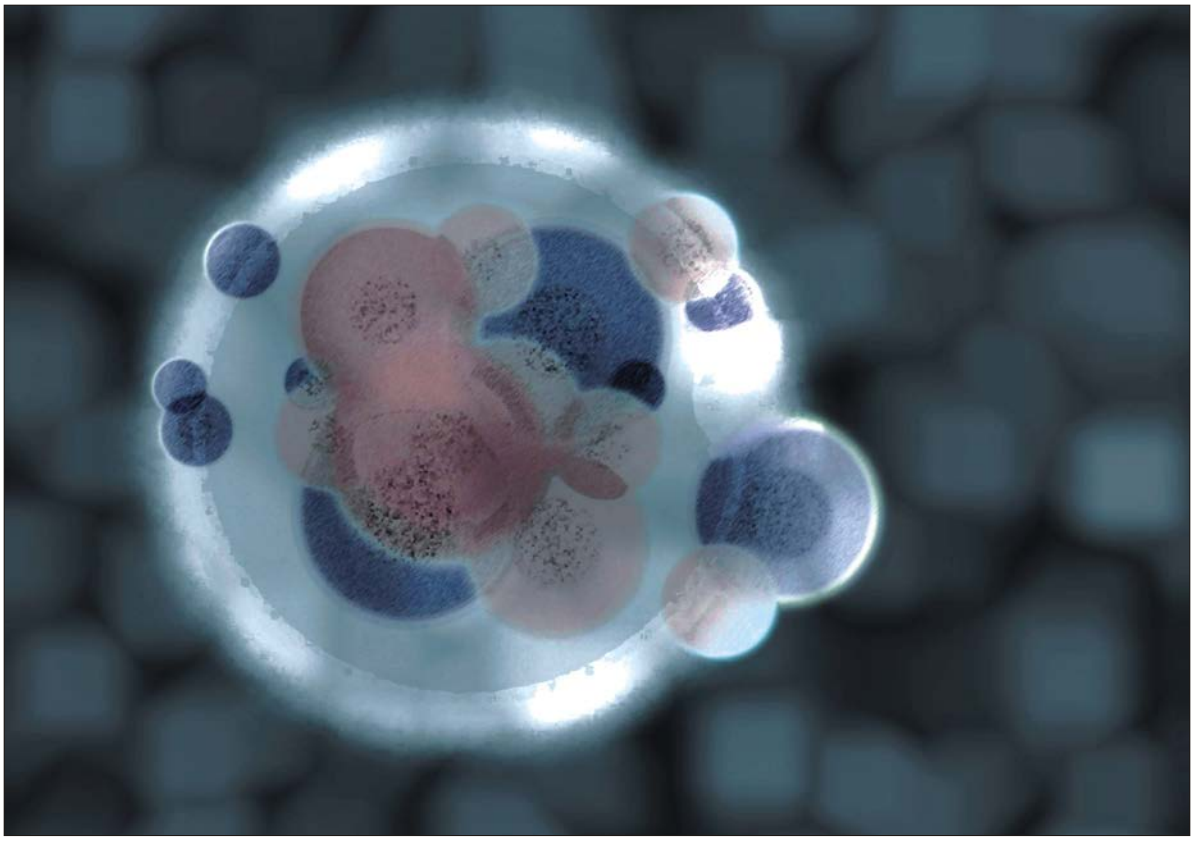

Journal of Biological Sciences

ISSN 1727-3048

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Journal of Biological Sciences 7 (1): 27-33, 2007
ISSN 1727-3048

Morphological Characterization and Agronomic Evaluation of Cocoyam (*Xanthosoma sagittifolium* L. Schott) Germplasm in Cameroon

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Abstract: Morphological (colour of leaf margin, colour of petiole, colour of main vein, colour of leaf sheath) and agronomic (number of cormels per plant, weight of cormels and weight of corms) data from a collection of genetic material representing 63 accessions of cocoyam (*Xanthosoma sagittifolium* cvs white and red) found in Cameroon were analyzed. A significant variability of these parameters was observed. The multiple component analysis of the parameters showed that they represent 70.72% of the total variability. This analysis enabled the establishment of a correlation between the direct hierarchical classification and the geographical distribution of the accessions of the white cv. Such a relationship was not observed in the accessions of the red cv. With regards to the agronomic characteristics of the 63 accessions, an evaluation of these parameters revealed a positive correlation ($p<0.01$) between the weight of the corm and the number of cormels ($r_P = 0.433$) on the one hand and the weight of the corm and the weight of the cormels ($r_P = 0.613$) on the other hand. Another positive correlation was observed between the number of cormels and the weight of the cormels ($r_P = 0.824$).

Key words: *Xanthosoma sagittifolium* (cocoyam), biodiversity, morphological characterization, Cameroon

INTRODUCTION

Cocoyam (*Xanthosoma sagittifolium*) is a food crop from Tropical America introduced in Tropical Africa around 1840 (Alamu and McDavid, 1978). Today it is cultivated in the Caribbean, Central and Tropical America, West and Central Africa, South East Asia, Oceania and New Caledonia (Giacometti and Léon, 1994). It is an important source of calories for nearly 400 million people worldwide (Onokpise *et al*., 1999). In Cameroon, cocoyam is the third most cultivated food crop after cassava and plantain (Wesphal *et al*., 1985). With the introduction of the crop in the Atlantic Coast of the United States of America where it is now consumed by Latin Americans, there has been renewed interest in its cultivation (Giacometti and Léon, 1994).

In spite of this growing importance, the production of cocoyam has been stagnant for many years. This is mainly due to (1): the low productivity of planting material (Schafer, 1999), (2): the low availability of traditional planting material (corm cuttings) and (3): viral and fungal infections (Xu *et al*., 1995). In Cameroon, the main pathogen of cocoyam is *Pythium myriotylum*, which causes root rot and is responsible for up to 90% loss in yield in some plantations (Pacumbaba *et al*., 1992).

Natural flowering of cocoyam is rare and so its cultivation is essentially by vegetative propagation. Consequently, most cultivars do not profit from genetic recombination provided by sexual reproduction. Genetic resources are of great value and need to be taken stock of, carefully conserved and protected for the implementation of cocoyam improvement. Characterization may reveal the need for molecular techniques and genetic engineering. Morphogenetic parameters used in the characterization of cultivated cocoyams are not well defined and its taxonomy is still to be precised. Cordero (1975) based on the leaf shape and color of tuber flesh identified 4 species of cocoyam: *X. Sagittifolium*, *X. Atrovirens*, *X. Violacum* and *X. Caracum*. Nzietchueng (1985) and Ngouo (1988) identified Cameroon cocoyam as belonging to the species *X. sagittifolium* and categorised them into white, red and yellow cvs depending on the colour of

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the tuber flesh. Salazar *et al.* (1985) and Monge *et al.* (1987) named the white cv. *X. sagittifolium* and the red cv *X. violatum*, while Lyonga *et al.* (1979) proposed that the yellow cv. could be *X. atrovirens*. Indeed, apart from their leaf morphology that is sagittate, there is a difference in the inflorescence and floral organisation between the yellow cv and the other two cvs. In addition, there exists a pollen sterility coupled with staminal indehiscence in the yellow cv. (Ngouo *et al.*, 1989). There is thus the need to identify a minimal descriptor list for Cameroon cocoyam in order to select an elite clone for cocoyam improvement.

According to several authors, morphological parameters have been widely used in the evaluation of various crops (Kaemer *et al.*, 1995). Effa *et al.* (2006) listed 17 morphological traits to establishe the list of minimum descriptors for characterization of one collection of *Cola acuminata* in Cameroon. However, the well utilisation of morphological descriptors involve the evaluation of agronomic performance in the farm (de Vicente *et al.*, 2005). Exploitation of such traits increases our knowledge of the genetic variability available and strongly facilities breeding for wider geographic adaptability, with respect to biotic and abiotic stress (Effa *et al.*, 2006).

Based on descriptors defined by IPGRI (1999) in *Colocassia esculenta*, morphological and agronomic characteristics were analyzed in order to evaluate differences among a Cameroon population of *X. sagittifolium* cvs. white and red and also to estimate their productive potential. The study of such a morphological complex can be achieved by multivariate analysis which enables the identification of minimal traits and the estimation of the relative importance of these traits in the available variability.

MATERIALS AND METHODS

Plant material: The plant material was made up of 63 accessions of white (41) and red (22) cocoyam cvs collected from 7 provinces of Cameroon corresponding to the Centre, East, Littoral, North-west, South-west, South and West (Fig. 1 and Table 1). Pre-sprouted corms were randomly planted in march-April 2000 and 2001 (6 plants from each accession with one replication) in an experimental farm in Yaounde I University (Latitude 3°50'-3°55'N, Longitude 11°28'-11°33'E, Guinea type equatorial climate, relative humidity 72.45%, average annual temperature 24.45°C, average annual rainfall 1730.57 mm). The planting distance was 1 m between rows and 0.75 m between plants in a row.

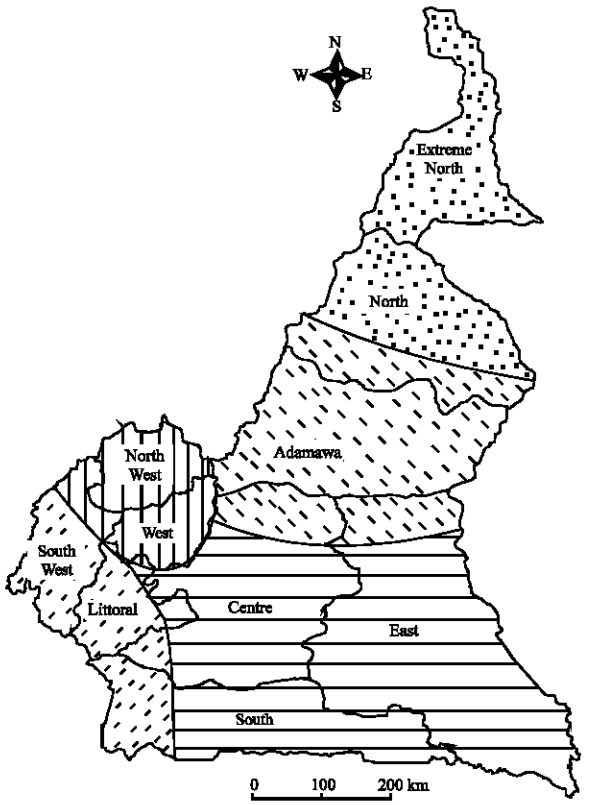

Fig. 1: Geographical locations of *X. sagittifolium* accessions analyzed in the present study (for details see Table 1)

Sahelian type, Tropical Climate: Rainfall 400-1500 mm; Thorn-shrub savannah/High Mandara savannah

Sudan type, Tropical Climate: Rainfall 1000-1500 mm; wood savannah and open dry forest/Grass and bush savannah (Adamawa)

Guinea type, Equatorial Climate: Rainfall 1500-2000 mm, Humid Forest/woodland savannah

Mountainous type, tropical Climate: Rainfall 1500-3000 mm; mountain savannah/mountain open dry forest

Costal type, Equatorial Climate: 2000-10000 mm; mountain forest, rain forest and mangrove

Table 1: Localities and agro ecological zones of the sites where *X. sagittifolium* were sampled

Site	Locality	Accessions	Province
1	Akonolonga (AKL B)	White-flesh	
2	Akonolonga (AKL R)	Red-flesh	
3	Bafia (BFI B)	White-flesh	
4	Bafia (BFI R)	Red-flesh	
5	Bangasina (SIN B)	White-flesh	
6	Bangasina (SIN R)	Red-flesh	
7	Bouraka (BOU B)	White-flesh	Centre

Table 1: Continued

Site	Locality	Accessions	Province
8	Bouraka (BOU R)	Red-flesh	
9	Bape (BAP B)	White-flesh	
10	Bape (BAP R)	Red-flesh	
11	Yaoundé (YDE B)	White-flesh	
12	Yaoundé (YDE R)	Red-flesh	
13	Makenene (MKN B)	White-flesh	
14	Ngoke (NGK B)	White-flesh	
15	Mbankomo (MKM B)	White-flesh	
16	Mbankomo (MKM R)	Red-flesh	
17	Ombessa (OMB B)	White-flesh	
18	Mfou (MFO B)	White-flesh	
19	Mfou (MFO R)	Red-flesh	
20	Ngo'o (NGO B)	White-flesh	
21	Talba (TAL B)	White-flesh	
22	Talba (TAL R)	Red-flesh	
23	Okola (OKL B)	White-flesh	
24	Botmakak (BMK B)	White-flesh	
25	Botmakak (BMK R)	Red-flesh	
26	Yambeta (YAM B)	White-flesh	Centre
27	Denk (DEU B)	White-flesh	
28	Abong-Mbang (ABB B)	White-flesh	
29	Abong-Mbang (ABB R)	Red-flesh	East
30	Bertoua (BET B)	White-flesh	
31	Nkongsamba (NKG B)	White-flesh	Littoral
32	Bamenda (BDA B)	White-flesh	North-west
33	Santa (SAN B)	Red-flesh	
34	Buéa (BUA B)	White-flesh	
35	Bova (BOV B)	White-flesh	
36	Libon (LIB B)	White-flesh	
37	Mile 26 (MIL B)	White-flesh	
38	Mile 26 (MIL R)	Red-flesh	South-west
39	Matango (MAT B)	White-flesh	
40	Matango (MAT R)	Red-flesh	
41	Mountain (MOU B)	White-flesh	
42	Mountain (MOU R)	Red-flesh	
43	Muyuka (MUY B)	White-flesh	
44	Muyuka (MUY R)	Red-flesh	
45	Lissoka (LIS B)	White-flesh	
46	Bussuma (BUS B)	White-flesh	
47	Busuma (BUS R)	Red-flesh	
48	Masuma (MAS B)	White-flesh	
49	Ebolowa (EBW B)	White-flesh	
50	Bipindi (BIP B)	White-flesh	South
51	Bipindi (BIP R)	Red-flesh	
52	Baleng (BAL R)	Red-flesh	
53	Baham (BAH B)	White-flesh	
54	Baham (BAH R)	Red-flesh	
55	Bamendjou (BAJ B)	White-flesh	
56	Bandjoun (BJN B)	White-flesh	West
57	Bamougoum (BGM B)	White-flesh	
58	Mbouda (MDA)	White-flesh	
59	Bafoussam (BFS B)	White-flesh	
60	Bafoussam$_2$ (BFS$_2$ B)	White-flesh	
61	Bafoussam$_3$ (BFS$_3$ B)	White-flesh	
62	Foto (FOT B)	White-flesh	
63	Foumbot (FBT B)	White-flesh	

Morphological and agronomic traits: The morphological parameters (Table 2) were evaluated 3 months after planting. From this, a minimum descriptor list comprising descriptors that remained constant or invariable during two years of the development of plants was established. Agronomic parameters (number of cormels, weight of cormels and corms) were evaluated after 9 months.

Table 2: Morphological parameters studied after three and nine months of culture

Morphological parameters	Descriptors
After 3 months of culture	
Leaf margin colour	Light-green (lmlg), purple-green (lmpg), dark green (lmdg), very dark-green (lmvg).
Petiole colour	Light-green (plg), purple-green (ppg), yellow-green (pyg), purple (pp), dark-green (pdg)
Main vein colour	Light-green (mvlg), purple-green (mvpg), yellow-green (mvyg), purple (mvp), brown-green (mvbg)
Lower leaf surface colour	Light-green (lsvlg), yellow-green (lsyg)
Colour of petiole to corm insertion point	Light-green (pilg), purple-green (pipg), brown-green (pibg)
Open foliate sheath colour	Light-green (oflg), purple (ofp), purple-green (ofpg), yellow-green (ofyg), green with brown strip (ofgb)
Closed foliate sheath colour	Light-green (cflg), purple (cfp), purple-green (cfpg), yellow-green (cfyg), green with brown strip (cfgb), very dark-green (cfvg)
Plant vigour	Weak (w), average (a), strong (s)
Plant height (cm)	
Circumference of petiole to corm insertion point (cm)	
Number of leaves per plant	NL_3
After 9 months of culture	
Number of cormels per plant	NCP
Weight of cormels per plant (g)	WCP
Weight of corm (g)	WC
Number of shoots per plant	NSP
Number of leaves per plant	NL_9

Data analysis: To present data structure and relationship among individual accessions, Multiple Component Analysis (MCA), Principal Component Analysis (PCA) and cluster analysis were done. MCA and PCA consist in representing the dispersion of objects in a multivariable graph containing as many axes as descriptors. MCA was carried out over all qualitative data while PCA was carried out over all quantitative data. Characteristics that contributed most to the variability were determined on the basis of those original variables with greater influence to the component. The aim of both methods was to obtain an aggregation of variables exhibiting a pattern of joint contribution to the total variation. Cluster analysis puts together varieties according to thier morphological similarities and visual phylogenetic relations existing between them. For this, a matrix of Euclidian's similarity coefficients was generated from all the qualitative morphological data using SPAD.4 software package programme.

RESULTS AND DISCUSSION

Qualitative parameters: The number of leaves per plant was not shown any significant variation between the white and red cvs studied. However, an intra-varietal variability was noted within the white and the red cvs. A slight variation in the colour of the leaf margin was also

observed. Most of the accessions of the red cv. (72.20%) had a dark green leaf margin while 27.8% had a very dark green leaf margin. In the white cv., 81.81% of the accessions had a dark green leaf margin, while 11.36% were light green and 6.81% were purple green. From these morphological parameters, the major descriptors controlling 70.72% of the total variability was observed in the white cv when the first five axes are selected. Out of all qualitative parameters studied, 9 contributed to the formation of the first three axes. The parameters colour of the main vein, colour of petiole, colour of lower leaf surface and colour of closed leaf sheath contributed in the formation of the first axis. The colour of the petiole, main vein, leaf margin and petiole to corm insertion point contribute in the formation of the second axis while the colour of petiole and main vein contributed in the formation of the third axis.

In the red cv., the first five axes influencing 46.70% of the total variability were selected. Seven parameters contributed highly in the formation of the first three axes. The parameters colour of lower leaf surface and colour of petiole to corm insertion point contributed to the formation of the first axis. The colour of the leaf margin, main vein and closed leaf sheath contributed in the formation of the second axis while the third axis was greatly influenced by the colour of the petiole to corm insertion point.

Out of the morphological parameters studied, a list of minimum descriptors for the proper characterization and evaluation of cocoyam was established comprising 5 descriptors for both the white cv. and the red cv. (leaf margin, lower leaf surface, petiole, petiole to corm insertion, closed foliate sheath). These minimum descriptors, besides being genotype-dependent, are probably dependent on the climatic and edaphic conditions. Indeed, although cultivated under the same microclimate, these plants conserved the characteristics acquired previously and provided vital information on the morphological diversity. The possible influence of the Yaounde microclimate probably explains the presence of certain plants in some sub-groups even when they are geographically separated from them. Tinamoto and Matsumoto (1986) did not obtain any significant correlation between the characteristics of the different organs of *Colocassia esculenta* (taro) studied in Japan. On the contrary, by increasing the number of parameters studied, Manzano *et al.* (2001) revealed a list of 15 minimum descriptors while evaluating the morphological and isoenzymatic variability of taro in Cuba.

The direct hierarchical classification of the germplasm (Fig. 2) showed a similarity between groups. On the basis

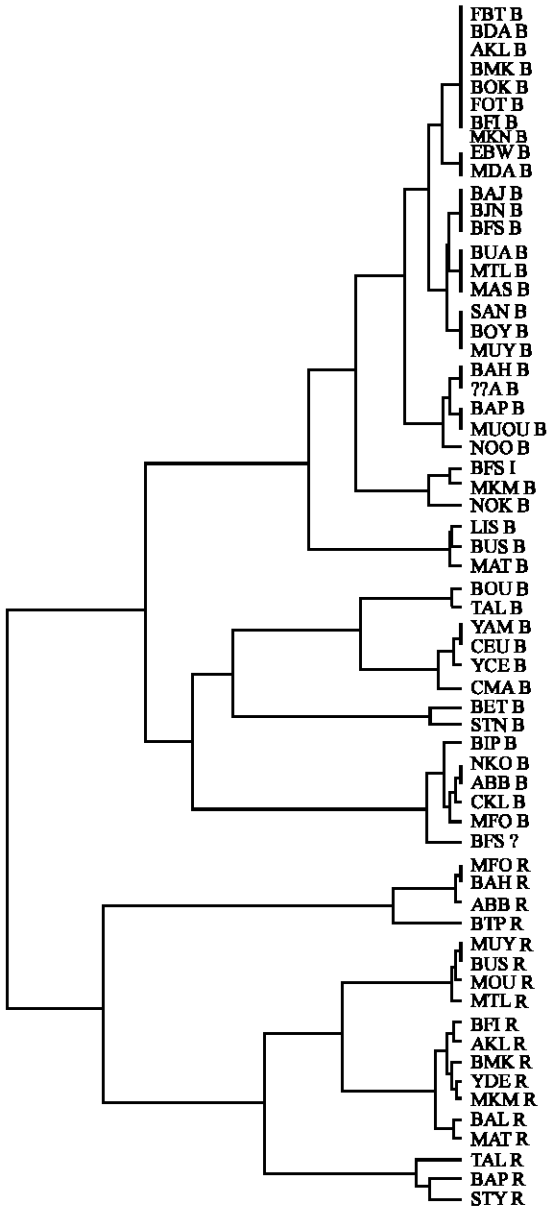

Fig. 2: Dendogram that illustrates genetic similarities among 63 accessions of *X. sagittifolium*. The dendogram was generated by cluster analysis based on morphological traits

of the traits studied and particularly the colour of the tuber flesh, 2 main groups were defined: the white group and the red group. The white group can be further divided into 4 sub-groups. The sub-group W1 comprises plants from the Western highlands of Cameroon, Bamougoum (BGM B), Mbouda (MDA B), Foumbot (FBT B), Foto (FOT B), Bamendjou (BAJ B), Bandjoun (BJN B), Bafoussam$_1$ (BFS$_1$ B), Bamenda (BDA B) extending towards the Centre Province with plant accessions

from Bafia$_1$ (BFI$_1$ B), Makénéné (MKN B), Mbankomo (MKM B), Botmakak (BMK B), Akonolinga (AKL B) and Ebolowa (EBW B). These plants were of average vigour and were characterized by a light-green or dark-green leaf margin, light-green petiole to corm insertion point, light-green open leaf sheath and green closed leaf sheath with purple strip. Plant accessions from the south west of Cameroon showed characteristics that were closely related to the above. They were characterized by a purple open leaf sheath, light-green closed leaf sheath and a light-green lower leaf surface and comprised plant accessions from Buea (BUA B), Mile 26 (MIL B), Bova (BOV B), Muyuka (MUY B) and Massuma (MAS B). This sub-group comprising plant accessions from the west and south-west where the microclimate is of the mountain savannah type, contains plants characterized by a light-green petiole and leaf sheath.

The sub-group W2 comprises plant accessions from Libon (LIB B), Mountain (MOU B), Busuma (BUS B), Matango (Mat B), Lissoka (LIS B), Ngo'o (NGO B), Ngoke (NGK B), Baham (BAH B) and Bafoussam$_3$ (BAF$_3$ B). These plants were characterized by a purple-green leaf margin and petiole and were of average vigour.

The sub-group W3 is made up of plants from Bouraka (BOU B), Talba (TAL B) and Ombessa (OMB B), which were characterized by a yellow-green petiole and main vein. Besides, plant accessions from Deuk (DEU B), Yambeta (YAM B), Bertoua (BET B) and Yaoundé (YDE B) were characterized by a yellow-green lower leaf surface and closed leaf sheath in addition to the preceding variables. All these regions are found in the Great Mbam (Center province) with a microclimate of woodland savannah and the plant accessions were characterized by a yellow-green coloration of the minimum variables (petiole, main vein, leaf sheath).

The sub-group W4 comprises plant accessions from Okola (OKL B), Bipindi (BIP B), Abong Mbang (ABB B), Mfou (MFO B), Nkongsamba (NKG B), Bangasina (SIN B) and Bafoussam$_2$ (BFS$_2$ B). Apart from Nkongsamba and Bafoussam$_2$ these localities are of the equatorial forest climate. The shady microclimate is likely to have influenced the plant accessions of this sub-group over the years, hence the purple green colour of the main vein and petiole that characterizes them. The presence of plant accessions from Bafoussam and Nkongsamba in this sub-group is probably due to human influence and their characteristics were perhaps not yet evolved.

The red group reveals 4 sub-groups irrespective of the geographical distribution. The sub-group R1 comprises plants from Mfou (MFO R), AbongMbang (ABB R), Baham (BAH R) and Bipindi (BIP R). They were characterized by a purple-green petiole and leaf-sheath and a light-green petiole to corm insertion point.

The sub-group R2 comprises plants from Bussuma (BUS R), Muyuka (MUY R) Matango (MAT R) and Mountain (MOU R). They were characterized by a purple petiole colour, purple-green petiole to corm insertion point and a purple closed leaf sheath.

The sub-group R3 comprises plant accessions from Yaoundé (YDE R), Bafia (BFI R), Akonolinga (AKL R), Mbankomo (MKM R), Botmakak (BMK R), Matango (MAT R) and Baleng (BAL R). These plants were characterized by a light-green lower leaf surface and a green closed leaf sheath with a purple strip.

The sub-group R4 is made up of plant accessions from Bape (BAP R), Talba (TAL R) and Bangasina (SIN R). They were characterized by a very dark-green leaf margin and a green petiole to corm insertion point with a brown strip.

Unlike the white cv, the sub-groups of the red cv did not show characteristics that were specific to a zone and so they cannot be classified in relation to their origin. This could be explained by its high diversity. Indeed, Tambong *et al.* (1997) revealed a high variability (13.40-96%) of intra-specific productivity in cultivated cocoyams, this intra-specific variability being more pronounced in the red cv.

Quantitative parameters: Table 3 shows that the number of leaves was the most diversified parameter (2.232 and 2.478 after 3 and 9 months respectively) whereas the number of shoots per plant showed the lowest variability (0.194 after 9 months).

Pearson's correlation matrix reveals some levels of correlation between the quantitative descriptors studied. After 3 months of culture, there was a significant positive correlation ($p<0.01$) (Table 4) between the circumference

Table 3: Variability of some growth parameters of cocoyam: number of leaves per plant (NL_3) after three months of culture, plant height (PH), circumference of petiole to corm insertion point (CP), Number of leaves per plant after nine months (NL_9), Number of cormels per plant (NCP), Weight of cormels per plant (WCP), Weight of corm (WC), Number of shoots per plant (NSP)

	Mean	Standard-deviation	Minimum	Maximum
NL_3	3.81	0.89900	2	6
PH (cm)	60.90	15.08457	23	101
C P (cm)	11.36	3.43600	4	24
NL_9	4.48	1.04700	2	7
NCP	3.24	1.66800	0	7
WCP (g)	189.59	132.26700	0	844
WC (g)	335.66	144.68200	140	756
NSP	0.33	0.73500	0	3

Table 4: Pearson correlation matrix between the number of leaves (NL_3) after 3 months of culture. Plant Height (PH) and circumference of petiole to corm insertion point (CP)

	NL_3	PH	CB
NL_3	1.000		
PH	0.408**	1.000	
CP	0.737**	0.766**	1.000

** Significant at 0.01 (bilateral)

Table 5: Pearson correlation matrix between different variables after 9 months of culture: number of leaves (NL_9). number of cormels per plant (NCP), weight of cormels per plant (WCP), weight of corm (WC) and number of shoots per plant (NSP)

	NL_9	NCP	WCP	WC	NSP
NL_9	1.000				
NCP	0.691**	1.000			
WCP	0.676**	0.824**	1.000		
WC	0.500**	0.433**	0.613**	1.000	
NSP	0.073	0.131	0.250	0.030	1.000

**Significant at 0.01 (bilatéral)

of the petiole to corm insertion point and the number of leaves on the one hand (r_p= 0.737) and between the circumference of the petiole to corm insertion point and the weight of the plant on the other hand (r_p = 0.766). After 9 months of culture, positive correlations ($p<0.01$) were observed between some of the parameters evaluated (Table 5). A positive correlation ($p<0.01$) also existed between the number of leaves and the number of cormels per plant (r_p = 0.691) on the one hand and between the number of leaves and the weight of cormels on the other hand (r_p = 0.676). This finding could be useful to predict the productivity of this crop from the number of leaves. The highest positive correlation was found between the number of cormels per plant and their weight (r_p = 0.824). In addition, a significant correlation ($p<0.01$) was noted between the weight of corm and the weight of cormels (r_p = 0.613) on the one hand and between the weight of corm and the number of cormels (r_p = 0.433) on the other hand. Pandey *et al.* (1996) while studying the correlation between 8 parameters controlling productivity in taro showed that the high correlation between the weight of corm and that of cormels could serve as a criterion for selection of productivity. In our findings, the correlations between the number of shoots and the number of cormels per plant, the number of shoots per plant and the average weight of cormels as well as the number of shoots per plant and the number of corms were not significant at 0.05%. Thus the number of shoots per plant would not be reliable as an index of selection to predict productivity in *X. sagittifolium*. This result contradicts that obtained by Manzano *et al.* (1999) in taro. These authors observed a positive correlation between the number of shoots and the number of cormels and retained the number of shoots per plant as criterion for predicting productivity.

CONCLUSION

In conclusion, the analysis of the morphological variability and the agronomic evaluation of 63 cocoyam accessions grown in Cameroon indicate that (1): the colour of the corm differentiates the white and red cvs., although it did not enable an intra specific discrimination; (2): light colour of variables (leaf margin, petiole to corm insertion point, open leaf sheath) and yellow green colour of variables (petiole, main vein, closed foliate sheath) enabled the differentiation of four sub-groups within the white cv.; (3) purple-green colour of variables (petiole, foliate sheath, petiole to corm insertion point, green closed leaf sheath with purple strip) and very dark leaf margin colour enabled the differentiation of four sub-groups within the red cv.; (4): there was no correlation between the hierarchical classification and the agro-ecologic distribution of the accessions of the red cv although a correlation was found with the white cv.

The diversity of all the accessions was no doubt indicative of an important genetic potential for a better agronomic exploitation of Cameroon cocoyam germplasm. It is hence imperative to establish a biological database in order to develop a strategy for the conservation and the valorisation of the existing diversity. On-going work in our laboratory is aimed at using molecular markers to better appreciate the diversity of this species for the improvement of the crop.

ACKNOWLEDGEMENTS

This study was partially supported by a grant (N°: C3792-1) of International Fondation of Science (IFS).

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