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Agro morphological characterization of taro (*Colocasia esculenta*) and yautia (*Xanthosoma mafaffa*) in Togo, West Africa

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Taro and yautia are two edible aroids grown in the humid tropics of Asia, Africa and Latin America and used as staple food crops by millions of people in developing countries. They are mainly propagated vegetatively. Selection and improvement of these crops require characterization using desirable morphological traits for various end-uses. An agro morphological characterization study was conducted at the experimental site of Centre de Recherche Agronomique du Littoral (CRAL) of Institut Togolais de Recherche Agronomique (ITRA) in Togo. The aim of the study was to evaluate the morphological variation within taro and yautia accessions. A total of 127 accessions (26 accessions of taro and 101 accessions of yautia) were grown in a randomized complete block design with three replications from October 2016 to November 2017. Thirty-eight (38) characters were studied for taro and twenty-eight (28) for yautia. Data was analyzed using ANOVA, factorial and clustering analyses. Findings of ANOVA show high positive correlations between vegetative traits such as plant height, plant span with corm and cormels weight. The factorial analysis and dendrogram of the HCA, based on the agro morphological traits, showed four major groups for taro accessions and three groups for yautia accessions. The results demonstrated morphological variation among taro and yautia grown in Togo. Findings from this study are an important data base for conservation and use of these crops in Togo. However, the results suggest also the existence of duplicate in the collection. Ploidy analysis and molecular studies are required to complement and confirm the current agro morphological variation.

Key words: Colocasia, Xanthosoma, Araceae, morphology, diversity, Togo.

INTRODUCTION

Taro, *Colocasia esculenta* (L.) Schott, and yautia, *Xanthosoma sagittifolium* Schott, are perennial herbaceous aroids commonly grown in the humid tropics of Asia, Africa and Latin America. Most of the global production of these two crops is provided by smallholder production systems and mainly in developing

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countries (Singh et al., 2012).

Taro and yautia are the main crops of socio-economic importance in the family Araceae (Quero-Garcia et al., 2010). Globally, they rank fifth among the starchy root and tuber crops after cassava, potato, sweet potato and yam, have diverse traditional roles, and are prepared for eating in many different ways (Bamidele et al., 2014; Igbabul et al., 2014). Corms, cormels, and cut corm tops are generally used for propagation. The young leaves of taro (petioles and blades) are widely consumed (Matthews, 2014), and the young leaves of yautia are also consumed as a vegetable and they are an important source of proteins and vitamins (Garnier, 2004). The corms of yautia are eaten boiled, roasted and fried. Some varieties are used for the preparation of pounded fufu, a traditional dish often eaten in West Africa (Owuamanam et al., 2010).

Taro is an ancient crop of uncertain geographical and genetic origins in Southeast Asia (Matthews, 2014) and may have reached sub-Saharan Africa via the Nile or Madagascar (Quero-Garcia et al., 2010; Grimaldi 2016). Taro corms are an excellent source of carbohydrates (Rao et al., 2010; Darkwa and Darkwa, 2013). Young leaves are important source of protein, vitamins and minerals (Amagloh and Nyarko, 2012). The leaves and corms of *Colocasia esculenta* are very polymorphic. While many different morphologies are known, two botanical forms are commonly recognised and cultivated: *Colocasia esculenta* (L.) Schott var. esculenta or 'dasheen' form with large central corm, and *Colocasia esculenta* (L.) Schott var. antiquorum or the 'eddoe' form with a relatively small corm and many cormels (Quero-Garcia et al., 2010). The crop is known as aborbé in the South of Togo (designating dasheen type) and as kpèkèou in the North, designating the eddoe type.

The taxonomy of cultivated *Xanthosoma* species has only recently been reviewed. Three species of this South American genus are cultivated for their starchy corms: *X. maffafa*, *X. sagittifolium* and *X. violaceum* (Gonçalves, 2011, Croat and Delannay 2017; Croat et al., 2017). The presence of all three species in Africa has not been reported. Most agricultural writers in Africa and elsewhere have assumed that all cultivars of *Xanthosoma* sp. are *X. sagittifolium*, but *X. mafaffa* has been widely misidentified as *X. sagittifolium*, and the latter species may have a distribution that is limited to South America. In Togo, *X. mafaffa* is locally known as mancani (or bancani).

For crop selection and breeding programs, and the conservation of crop genetic resources, the morphological traits of existing cultivars need to be analysed in relation to taxonomy, agronomy (cultivation), storage and distribution, and end uses (e.g. culinary traits). Morphological analysis can also help to identify clones and reduce duplication in cultivar collections maintained for conservation and breeding purposes. Although several studies have reported diversity within taro and yautia (Lebot et al., 2010; Traore, 2013; Norman et al., 2015), the character sets recorded are generally not standardised, making comparison difficult across different reports. Here, we employ standard descriptor lists that have been recommended for *Colocasia esculenta* (IPGRI, 1999) and *Xanthosoma* (IBPGR, 1989).

In Togo, *C. esculenta* and *X. mafaffa* were described by Brunel et al. (1984) as introduced, cultivated, and more or less naturalized, and similar observations have been reported in neighbouring Benin (Hetterscheid and van der Maesen, 2006), where *X. mafaffa* is noted as having varied purplish pigmentation, as we have found in Togo. According to Akpavi et al. (2012) both are neglected and underutilized species that require promotion. Production records for *Xanthosoma* (20,165 tonnes, 20,407 tonnes and 11,337 tonnes respectively in 2011, 2012 and 2013) (DSID, 2014) show that the production is decreasing. This appears to be due to rainfall irregularity and soil poverty, and is the subject of ongoing research. Morphological characterization of both species is a prerequisite for the conservation, management and effective promotion and use of these species in Togo. Here, we describe the morphological diversity of *X. mafaffa* and *C. esculenta* in Togo, based on plants grown in a national collection.

MATERIALS AND METHODS

The plant material consists of 134 accessions collected from various locations of the country and implemented on farm.

Experimental site

The experiment/trial was implemented at the Centre de Recherche Agronomique du Littoral (CRAL) experimental station of Institut Togolais de Recherche Agronomique (ITRA) located at Davié and the following coordinates N 6° 23.355 'E 1° 12.255' with 88 m of altitude.

Experimental design and planting

The randomized complete block design (RCBD) with three replications, was used. Each block consisted of four (4) sub-blocks 11 m long and 2.25 m wide. Sub-blocks were spaced 2 m. The corms were planted in pockets 10 - 15 cm deep, following lines spaced 1 × 0.5 m (1 m between two lines and 0.5 m between two pockets). The area of the total experimental plot was 600 m^2 (25 × 24 m). The farm was implemented from the 29th October, 2016 to 10 November, 2017. No fertilizer was applied. As the experiment started at the end of the rainy season, to avoid rot of many propagules, a watering system was installed to water when needed. Regular weeding on the hoe was the main maintenance practice of the farm.

Data collection and analysis

The agro morphological characterization consisted of description of morphological and agronomic characters of accessions. It was carried out 6 months after planting for the aboveground traits and at harvest for the underground traits (corms and cormel). Both qualitative and quantitative characters were described. Thirty-eight characters selected in the descriptor of International Plant Genetic Resources Institute (IPGRI) (1999) were studied for *C. esculenta* and 28 characters selected in the descriptor of International Board for Plant Genetic Resources (IBPGR) (1989) were studied for *X. mafaffa* (Table 1).

i) Qualitative characters: twenty-one (21) qualitative characters were described for *C. esculenta*, including eleven (11) on the aboveground part and ten (10) on the underground part. For *X. mafaffa*, sixteen (16) characters were described including eleven (11) on the aboveground part and five on the underground part.

ii) Quantitative characters: Seventeen (17) characters were described for *C. esculenta*, including 13 for the aboveground part and 4 for the underground part. Twelve (12) quantitative characters were noted for *X. mafaffa*, nine (9) on the aboveground part and three on the underground part.

For all data, accessions with no data on at least three of the five plants per replicate were discarded from the analysis. Thereafter, the quantitative data were subjected to a normality test before the one-way analysis of variance. Characters that did not have a normal distribution (Plant span (PS), plant height (PH), Number of stolon (NSt), distance of stolon (DSt), petiole length (LP), were transformed by the square root (PS_sqr; PH_sqr; NSt_sqr). Transformed values were used for multivariate analyses using IBM SPSS statistics 20 software.

Qualitative variables were recorded in presence (1) absences (0) matrix. For the petiole basal-ring colour (PBRC) for example, the modalities were coded as follows: PBRC1: White; PBRC2: Yellow; PBRC3: Orange; PBRC4: Pink; PBRC5: Violet. For an accession, if the petiole basal ring colour is pink, the score 1 is recorded for the PBRC4 and the score 0 for the others. Some quantitative variables related to yield were recoded into qualitative variables for hierarchical clustering. The structuring of variability was evaluated with a hierarchical ascending classification (HCA) using UPGMA (Unweighted pair group method with arithmetic mean). The distribution of the variability of the constituted groups was characterized by the discriminant factor analysis (FA). The DARwin6 Software was used for these analyses.

RESULTS

Variation of qualitative characteristics

All *C. esculenta* accessions had peltate leaves, undulate leaf blade margin, white petiole basal-ring, purple colour for basal third of petiole and white buds. Accessions of *X. mafaffa* showed unpelted leaves, undulate leaf blade margin, cup-shaped leaf blade and green colour for upper third of petiole. Flowering was not observed (*C. esculenta* and *X. mafaffa*) under the conditions of our trial.

Most accessions of *C. esculenta* had drooping leaves (PPLLS5 72.73%), green colour for leaf sheath and main vein (LSC3 77.23% and LMVC4 72.73% respectively), a light green to violet green colour for the middle third of the petiole (PCMT4 50% and PCMT7 18.18%) and a light green colour for the basal third of petiole (PCBT4 81.82%). Petiole junction for nearly 50% of the accessions had a yellow or purple colour (PJC1 45.45%, PJC4 50%). Few accessions showed purple for the middle and lower third of the petiole (PCBT3 31.82 and PCBT7 18.2%). For qualitative characteristics observed on the underground part, the accessions presented a brown cortex and a very fibrous character. The main corm shapes were cylindrical, elliptical and dumb-bell (CS3 31.82%, CS5 31.82% and CS4 36.36%), while for cormels, the elongated form was predominant (SC5 40.91%). The corm and cormels showed mostly uniform white flesh.

Relative to *X. mafaffa*, most of the accessions showed hasted leaves (FF2 85.86%), a purple-red leaf blade margin (LBMC 85.86%), a dark green upper leaf surface (CULS3 85.86%) and a pink petiole ring base (PBRC4 71.72%). For the underground traits most of accessions had pink buds (BC 70.72%) and cormels flesh (FCC4 70.72%). Most of cormels were elliptical (SC4 64%).

Variation in quantitative characteristics

C. esculenta accessions had a mean span (transformed values) of 7.69 ± 1.04 cm and a coefficient of variation of 13.55%. Plant height (transformed values) ranged from 4.58 to 8.43 cm with an average of 06.75 ± 0.95 cm, a coefficient of variation of 14.08%. Mean value of leaf length (LL) was 27 ± 6.72 cm and 19 ± 4.66 cm for leaf width (LW) with a coefficient of variation of about 25%. Mean leaf sheath (SL) and petiole (PL_sqr) lengths were 22.6 ± 6.72 cm and 06.18 ± 0.89 cm, respectively. Their coefficients of variation were 29.75 and 14.40%. The calculated ratios presented the lowest coefficients of variation. The mean value of leaf lamina length/width ratio (LLLWR) was 1.45 ± 0.18 with a coefficient of variation of 12.19%. The average ratio of sheath length /total petiole length (RSLTPL) was 0.6 ± 0.09 with a coefficient of variation of 14.92%.

For *X. mafaffa*, leaf lamina length/width ratio had the lowest coefficient of variation (12.55%). Plant height (PHT_sqr) ranged from 4.69 to 10.10 with an average of 7.41 ± 1.11 cm and a coefficient of variation of 14.91%. The circumference of the cormels ranged from 5 to 34 cm with an average of 15.33 ± 5.62 and a coefficient of variation of 36.67%. The dimensions of the lamina were in average 26.64 ± 7.48 cm for the length and 19.09 ± 5.35 cm width and coefficients of variation respectively 25.24 and 28%. Each accession had about 10 tubers with an average weight of 20.08 ± 5.98 g (transformed values per square root). Their respective coefficients of variation are 46.94 and 29.78%.

Relationships between the studied characters

Analysis of the relationships between the studied quantitative characteristics shows significant correlations between several quantitative characters. In fact, for *C. esculenta*, there is a positive and significant correlation between plant span, the height of the plant, lamina length and width, petiole length and sheath length. A positive

Table 1. Morphological traits measured in 127 taro and yautia accessions. The traits and measurement methods were based on the IBPGR (1989) and IPGRI (1999)

Character	Species	Trait acronym	Score code
Growth habit	*Xanthosoma*	PH	1= Acaulescent; 2=Erect aboveground stem; 3=Reclining aboveground stem
Plant span	*Colocasia*	PS	1=narrow (<50 cm); 2=medium (50-100 cm); 3=wide (>100 cm)
Circumference	*Xanthosoma*	CIR	
Plant height	Both	PHT	1=dwarf (<50 cm); 2=medium (50-100 cm); 3=tall (>100 cm)
Number of stolons (side shoots)	*Colocasia*	NSS	0=none; 1=1 to 5; 2= 6 to 10; 3=11 to 20; 4= >20
Stolon length	*Colocasia*	SL	1= Short (<15 cm); 2= Long (≥15 cm)
Number of suckers (direct shoots)	Both	NDS	0=none; 1=1 to 5; 2= 6 to 10; 3=11 to 20; 4= >20
Leaf base shape	Both	LBS	1–peltate; 99 Other (e.g. sagittate; hastate)
Predominant position (shape) of leaf lamina surface	Both	PPLLS	1=drooping; 2=horizontal; 3=cup-shaped; 4=erect - apex up; 5=erect - apex down
Leaf blade margin	Both	LBM	1-entire; 2-undulate; 3-sinuate
Colour upper leaf surface	Both	CULS	1–light green; 2–medium green; 3-dark green; 4–reddish/purplish green; 5–other (specify)
Colour lower leaf surface	Both	CLLS	1–light green; 2–medium green; 3-dark green; 4–reddish/purplish green; 5–other (specify)
Leaf blade colour	Both	LBC	1-whitish; 2-yellow or yellow green; 3-green; 4-dark green; 5-pink; 6- red; 7-purple; 8-blackish (violet-blue)
Leaf blade colour variegation	Both	LBCV	0–absent; 1=present
Leaf blade margin colour	Both	LBMC	1 = Whitish; 2= Yellow; 3 = Orange; 4 = Green; 5 = Pink; 6 = Red; 7= Purple
Leaf lamina length/width ratio	Both	LLLWR	Recorded at maximum length and width of leaf excluding petiole
Petiole junction pattern	*Colocasia*	PJP	0=absent; 1=small; 2=medium; 3=large
Petiole junction colour	*Colocasia*	PJC	0–absent; 1–light green; 2–dark green; 3–purple; 4–purple green
Leaf main vein colour	Both	LMVC	1=whitish; 2=yellow; 3=orange; 4=green; 5=pink; 6=red; 7=brownish; 8=purple
Vein pattern	Both	VP	1=V pattern ('V' space); 2=I pattern ('I' space); 3=Y pattern ('Y' space); 4=Y pattern and extending to secondary veins
Petiole/lamina length ratio	*Colocasia*	PLLR	Ratio of direct measurements
Petiole colour of top third	Both	PCTT	1=whitish; 2=yellow; 3=orange; 4=light green; 5=green; 6=red; 7=brown; 8=purple
Petiole colour of middle third	Both	PCMT	1=whitish; 2=yellow; 3=orange; 4=light green; 5=green; 6=red; 7=brown; 8=purple
Petiole colour of basal third	Both	PCBT	1=whitish; 2=yellow; 3=orange; 4=light green; 5=green; 6=red; 7=brown; 8=purple
Petiole basal-ring colour	Both	PBRC	1 = White; 2 = Green (yellow green); 3= Pink; 4 = Red; 5 = Purple
Leaf sheath length	Both	LSL	
Ratio of sheath length /total petiole length	*Colocasia*	RSLTPL	
Leaf sheath colour	*Colocasia*	LSC	1=whitish; 2=yellow; 3=light green; 4=red purple; 5=brownish
Leaf sheath edge colour	Both	LSEC	1=dark brown (continuous); 2=dark brown (not continuous)
Flower formation	Both	FLOWER	0=no flower; 1=rarely flowering (< 10% of plants flowering); 2=flowering (> 10% of plants flowering)
Corm length (measured on fully mature plants)	*Xanthosoma*	CLEN	3=short (8 cm); 5=intermediate (12 cm); 7=long (18 cm)
Corm shape	*Colocasia*	CS	1=conical; 2=round; 3=cylindrical; 4=elliptical; 5=dumb-bell; 6=elongated; 7=flat and multi-faced; 8=clustered; 9=hammer shaped
Corm weight	Both	CW	1=<0.25 kg; 2=0.25-0.50 kg; 3=0.51-1.0 kg; 4=1.1-1.5; 5=1.6-2.0 kg; 6=2.1-2.5 kg; 7=>2.5 kg
Cormel circumference	*Xanthosoma*	CCIR	
Corm cortex colour	*Colocasia*	CCC	1=white; 2=yellow or yellow-orange; 3=red; 4=pink; 5=brown; 6=purple; 7=blackish; 8=purple-yellow; 9=cream

Table 1. Contd.

Corm flesh colour of central part	*Colocasia*	CFCCP	1=white; 2=light yellow; 3=yellow-orange; 4=pink; 5=red; 6=red-purple; 7=purple; 8=purple-yellow; 9=cream
Corm flesh fibre colour of central part	*Colocasia*	CFFCCP	1=white; 2=light yellow; 3=yellow-orange; 4=red, 5=brown; 6=purple; 99=others (specify)
Bud colour	Both	BC	1=white; 2=yellow-green; 3=pink or red; 4=purple; 99=others (specify)
Number of cormels	Both	NC	1=less than 5; 2=5-10; 3=>10
Weight of cormels	Both	WCL	1=<100 g; 2=100-200 g; 3=201-300 g; 4=301-400 g; 5=401-500; 6=501-600; 7=>600
Shape of cormels	Both	SC	1=conical; 2=round; 3=cylindrical; 4=elliptical; 5=elongated; 6= elongated and curved; 99=others (specify)
Flesh colour of cormels	Both	FCC	1=white; 2=yellow; 3=orange; 4=pink; 5=red; 6=red-purple; 7=purple; 8=colour not uniform (lighter blotches or darker pigmentation)

Table 2. Pearson's correlation coefficients obtained among taro accessions.

	PS	PHT	NSS	SL	NDS	LL	LW	LLLWR	PL	PLLR	LSL	RSLTPL	CLEN	NC	CW	WCL
PS	1															
PHT	0.869**	1														
NSS	0.585**	0.665**	1													
SL	0.624**	0.517**	0.683**	1												
NDS	0.305*	0.196	0.073	0.058	1											
LL	0.805**	0.929**	0.564**	0.460**	0.069	1										
LW	0.748**	0.927**	0.563**	0.383**	0.092	0.945**	1									
LLLWR	0.303*	0.125	0.111	0.335**	-0.102	0.259*	-0.043	1								
PL	0.908**	0.969**	0.607**	0.553**	0.266*	0.906**	0.887**	0.177	1							
PLLR	0.474**	0.351**	0.201	0.318**	0.436**	0.083	0.125	-0.019	0.477**	1						
LSL	0.870**	0.920**	.668**	0.550**	0.161	.886**	.844**	0.222	0.926**	0.332**	1					
RSLTPL	0.000	0.043	0.293*	0.095	-0.159	0.063	0.047	0.000	-0.062	-0.375**	0.265*	1				
CLEN	0.037	0.041	-0.145	-0.139	-0.045	0.133	0.131	-0.086	0.080	-0.136	0.155	0.116	1			
NC	-0.011	-0.101	0.089	0.100	-0.047	-0.111	-0.118	-0.068	-0.092	-0.112	0.082	0.451**	.151	1		
CW	0.206	0.281*	0.035	-0.014	0.041	0.376**	0.392**	-0.107	0.290*	-0.154	0.333**	0.099	0.828**	0.091	1	
WCL	0.174	0.256*	0.182	0.106	-0.056	0.244*	0.250*	-0.098	0.265*	0.015	0.303*	0.158	0.221	0.628**	0.241	1

**. The correlation is significant at the 0.01 level (bilateral).
*. The correlation is significant at the 0.05 level (bilateral).

and significant correlation was observed between plant height and corm and cormels weight (Table 2).

For *X. mafaffa*, significant positive correlations are observed in plant height and cormels circumference (CCIR), lamina dimensions (LL and LW), petiole length, sheath length, corm length (CLEN), number of cormels and weight of cormels (Table 3).

The factorial analysis of *C. esculenta* qualitative traits distinguish four groups according to axes 1 and 2 with total inertia of 61.38%. Axis 1 (40.47% of inertia) separate eddoe-type accessions in the upper part. These accessions are grouped into two subgroups: a subgroup characterized by the presence of a small petiole junction pattern and violet petiole at middle third (PCMT8), the second subgroup is characterized by the absence petiole

Table 3. Pearson's correlation coefficients obtained among yautia accessions.

	PTH	CIR	NDS	LL	LW	LLLWR	PL	LSL	CLEN	NC	WCL
PTH	1										
CIR	0.930**	1									
NDS	0.121	0.130	1								
LL	0.914**	0.923**	0.211*	1							
LW	0.926**	0.909**	0.081	0.933**	1						
LLLWR	-0.378**	-0.321**	0.170	-0.228*	-0.533**	1					
PL	0.984**	0.921**	0.086	0.910**	0.935**	-0.399**	1				
LSL	0.971**	0.939**	0.130	0.928**	0.905**	-0.295**	0.969**	1			
CLEN	0.432**	0.455**	0.037	0.464**	0.496**	-0.279**	0.441**	0.443**	1		
NC	.517**	0.525**	0.142	0.547**	0.512**	-0.108	0.528**	0.548**	0.292**	1	
WCL	0.649**	0.666**	0.022	0.642**	0.644**	-0.228*	0.669**	0.674**	0.523**	0.817**	1

**. The correlation is significant at the 0.01 level (bilateral).
*. The correlation is significant at the 0.05 level (bilateral).

junction pattern and the light green petiole at middle third.

Axis 2 (20.91% inertia) associates accessions according to the purple colour for the main vein, the leaf margin, the petiole junction pattern and middle third of petiole (PCMT8), cup shaped leaf lamina surface, dark green leaf blade (LBC4), the presence of petiole junction pattern, and corm or cormels slice uniformity (CFCCP99 and FCC99) (Figure 1).

For *X. mafaffa*, axis 1 of inertia 51.17% groups the accessions into two, according to the petiole basal ring colour, the bud colour and flesh colour of cormels. Between the two extreme groups is an intermediate group having above-ground trait of the first group (CULS3, PCBT4) and underground traits of the second group (PBRC1, BC1, FCC1) (Figure 2).

Clustering analysis

The radial dendrogram cluster *C. esculenta* accessions into four groups of morphotypes (Figure 3) and *X. mafaffa* accessions into three (Figure 4). For both species, the accessions are not grouped following ecological zones except for eddoe-type accessions of *C. esculenta* accessions that were almost collected in ecological zone II. For *C. esculenta* accessions, Group 1 consists of six dasheen-type accessions from ecological zones III and IV; Group 2 also six dasheen-type accessions collected in ecological zones I (one accession), III (one accession) and IV (four accessions); Group 3 of five eddoe-type accessions and Group 4 of 4 eddoe-type accessions. For accessions of *X. mafaffa*, Group 1 consists of 14 accessions; Group 2 of 15 accessions and Group 3 of 70 accessions.

Agro morphological characteristics of morphotypes

For *C. esculenta* accessions (Figures 3 and 5), Group 1 consists of dasheen-type accessions that were collected in swampy or flooded environment. These morphotypes are founded wild along the rivers. As specific morphological features, these accessions have cup-shaped leaf surface, violet main vein and very often produce a large number of stolons.

Group 2, also consisting of dasheen-type accessions, collected in wet to flooded environment. As characteristics, they have drooping leaves, a green main vein, a large main corm with white uniform flesh or not uniform flesh.

Group 3 has eddoe-type accessions characterized by a few number of suckers, a green petiole, a yellow petiole junction pattern, and droopy leaves.

Group 4 is composed of eddoe-type accessions with many suckers, a small and purple petiole junction pattern, a purple petiole at the upper third and brown in the middle and basal third.

Groups of *X. mafaffa* accessions are characterized as follows (Figures 4 and 6):

Group 1: consists of accessions with a green

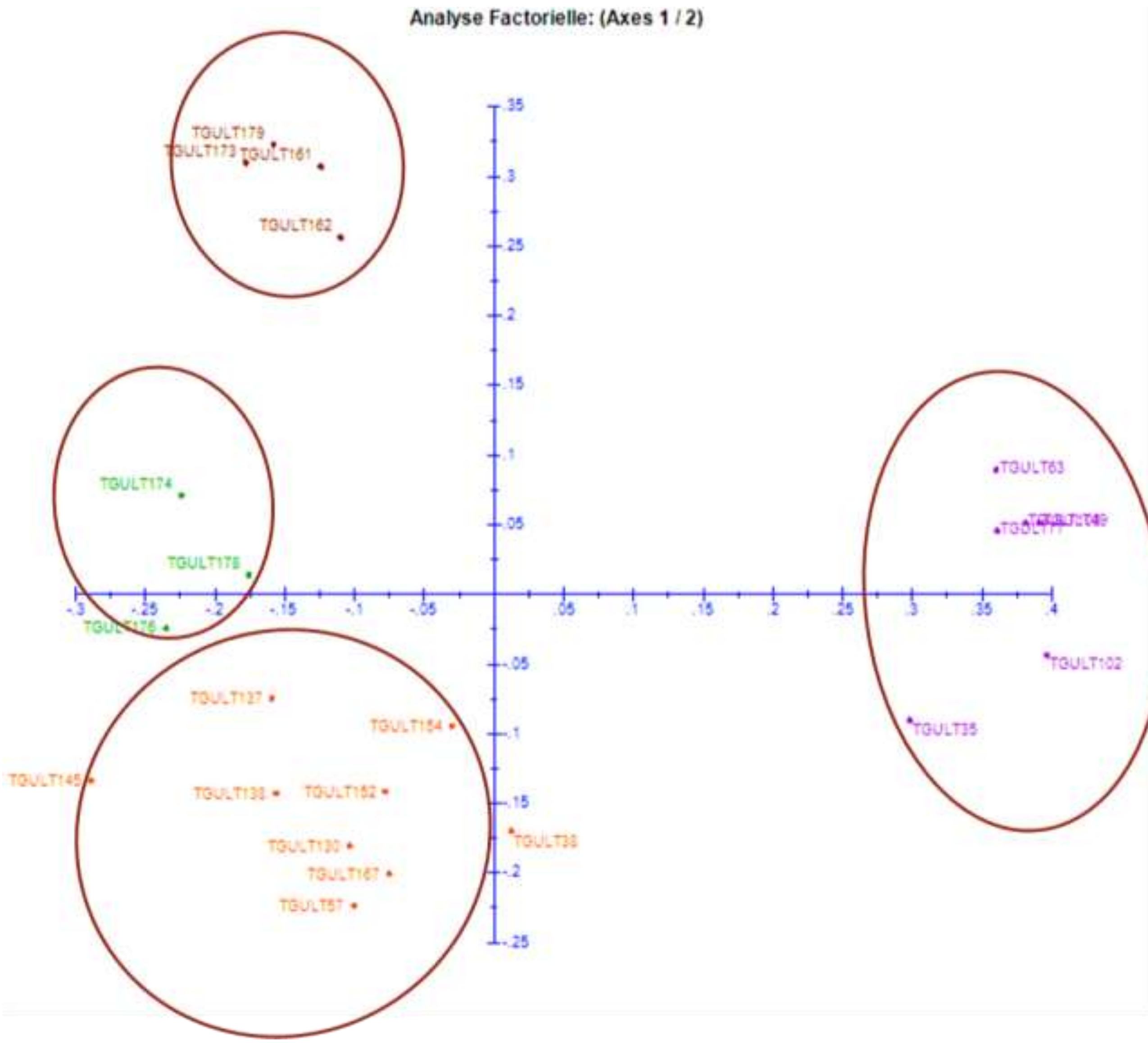

Figure 1. Factorial analysis of the qualitative characteristics of *C. esculenta*

vegetative system. The petiole basal ring is white as well as the bud and the flesh of cormels.

Group 2: an intermediate group between group 1 and group 3. It includes accessions with a dark green blade, a green petiole at the upper third and green striped violet to the lower third but a petiole basal ring the bud and the flesh of cormels are white.

Group 3: These accessions are the most abundant in the collection and the most cultivated. They are characterized by a dark green blade, a green petiole at the upper third and green striped with violet at the lower third, a petiole basal ring pink as well as the bud and the flesh of cormels.

DISCUSSION

Agro morphological variability is based on the colour of the leaf, the corms and cormels flesh colour and the shape of corms and cormels. Several authors have reported similar results for both *C. esculenta* and *X. mafaffa*. According to Lebot et al. (2004), the leaf lamina colour of taro is variable according to the genotype from yellowish to dark purple. In this study, the accessions showed yellow-green to dark green leaves. Similar results on taro were reported by Traore (2013) in Burkina Faso and by Norman et al. (2015) on yautia in Sierra Leone.

Findings of correlation analysis revealed, for both species, strong positive correlation between plant height,

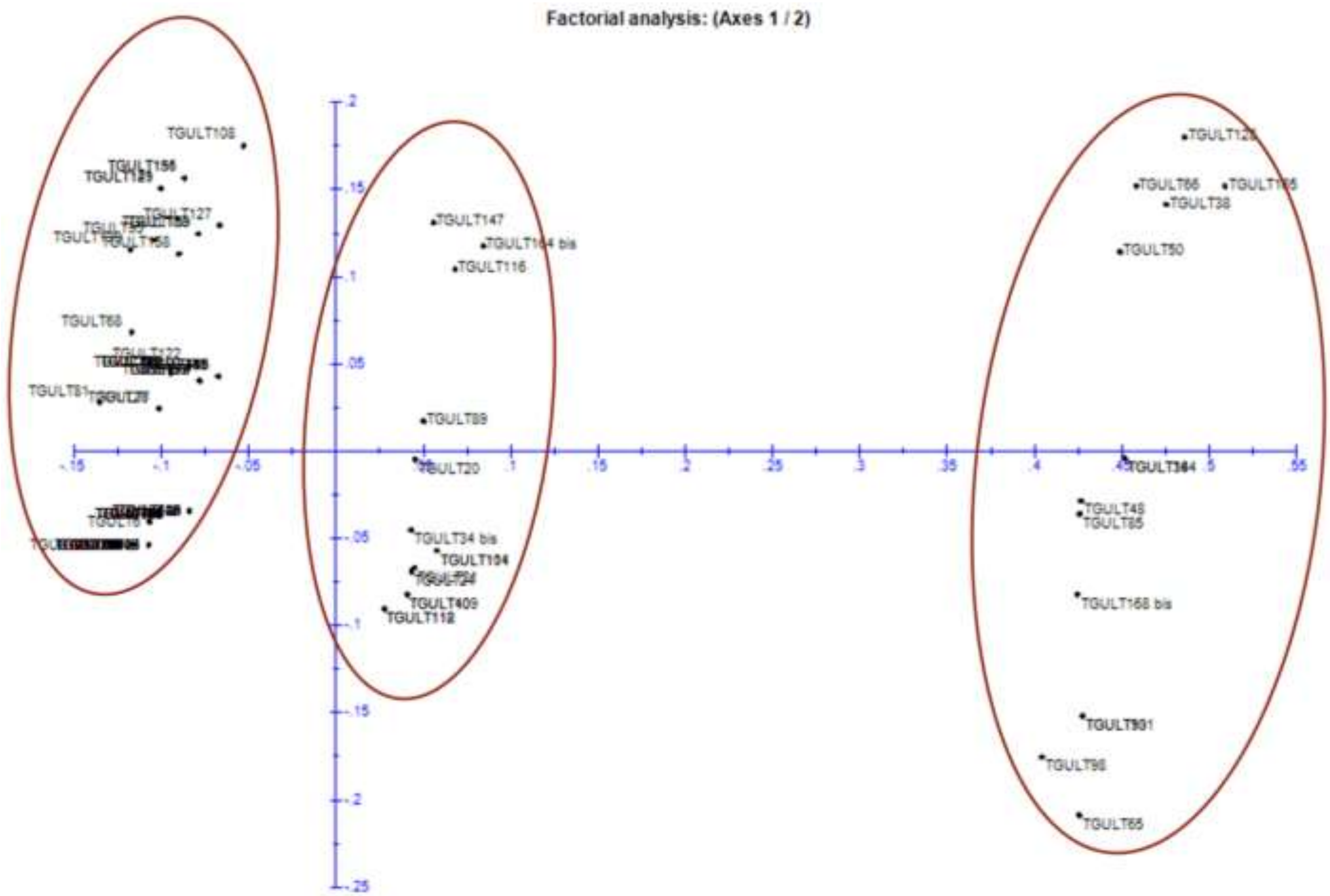

Figure 2. Factorial analysis of the qualitative characteristics of *X. mafaffa*

lamina length and width, petiole length, cormel and cormel weight. This indicates that increasing plant height increases weight of corms and cormels. The strong positive correlations observed between the quantitative traits shows a great agronomic potential of these accessions. Based on similar characters, other authors reported the interdependence between genetic variables and yield. Paul and Bari (2012), Fantaw et al. (2014) and Norman et al. (2015) reported that the number of suckers per plant, the number of cormels per plant, the weight of the cormels, the corm weight and the total yield per plant have a high heritability. According to Quero-Garcia et al. (2004), these characters can be used in the breeding program and production of these species.

The clustering analysis grouped *C. esculenta* accessions into four groups: two groups of dasheen-type accessions and two eddoe-type. The accessions were grouped based on morphological characters such as: blade colour, leaf blade margin colour, petiole junction pattern, petiole colour, leaf main vein colour. These morphological groups are similar to those described by Traore (2013) in Burkina Faso. Accessions of group 1, dasheen type, were collected in a flooded environment, most often along the rivers. This morphotype is locally named *aborbed* or *mancani kokoo*. The second group, also consisting of dasheen type accession, were also collected in wetlands. However, the two groups of eddoe morphotypes were all collected in ecological zone II, which has less annual rainfall than Ecological III and IV. This corroborates the results of Traore (2013) and Lebot et al. (2004) who report that most of the taro morphotypes adapted to flooded or irrigated conditions generally belong to the dasheen varieties and morphotypes adapted to rainfed conditions most often belonging to the eddoe varieties.

For *X. mafaffa*, three groups were identified as distinctive traits: the petiole basal ring colour, the colour of basal third of the petiole, and the colour cormels flesh and bud. According to Opoku-Agyeman et al. (2004), bud colour is the main distinguishing trait of *X. mafaffa* accessions collected in Ghana. In our study, in addition to these traits, the colour of the cormels flesh, the petiole basal ring colour and the colour of basal third of the petiole significantly contribute to the discrimination of

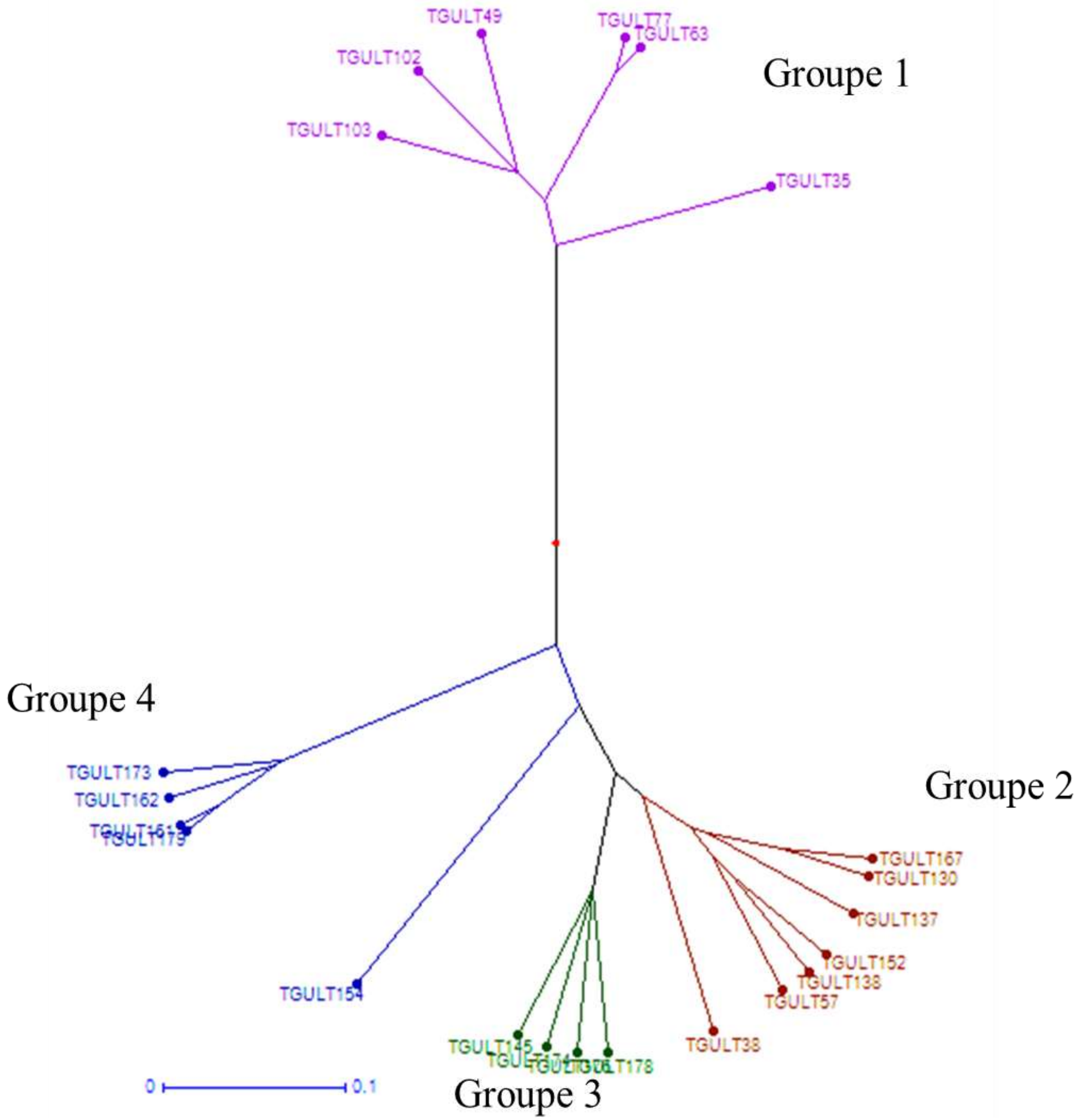

Figure 3. Dendrogram based on UPGMA analysis generated using the Euclidean coefficient representing the morphological relationships among taro accession of Togo

groups. On this basis, groups 1 and 3 are completely distinct while group 2 is an intermediate group between the two main groups. In fact, this group has morphological traits of group 3 for the above-ground part (leaf, petiole) and morphological trait of group 1 in the underground part (petiole basal ring, bud and cormels flesh). The diversity among each species is narrow compared to the diversity reported for Pacific, India or China (Mandal et al., 2013; Chaïr et al., 2016). Other studies in West Africa (Traoré, 2013; Norman et al.,

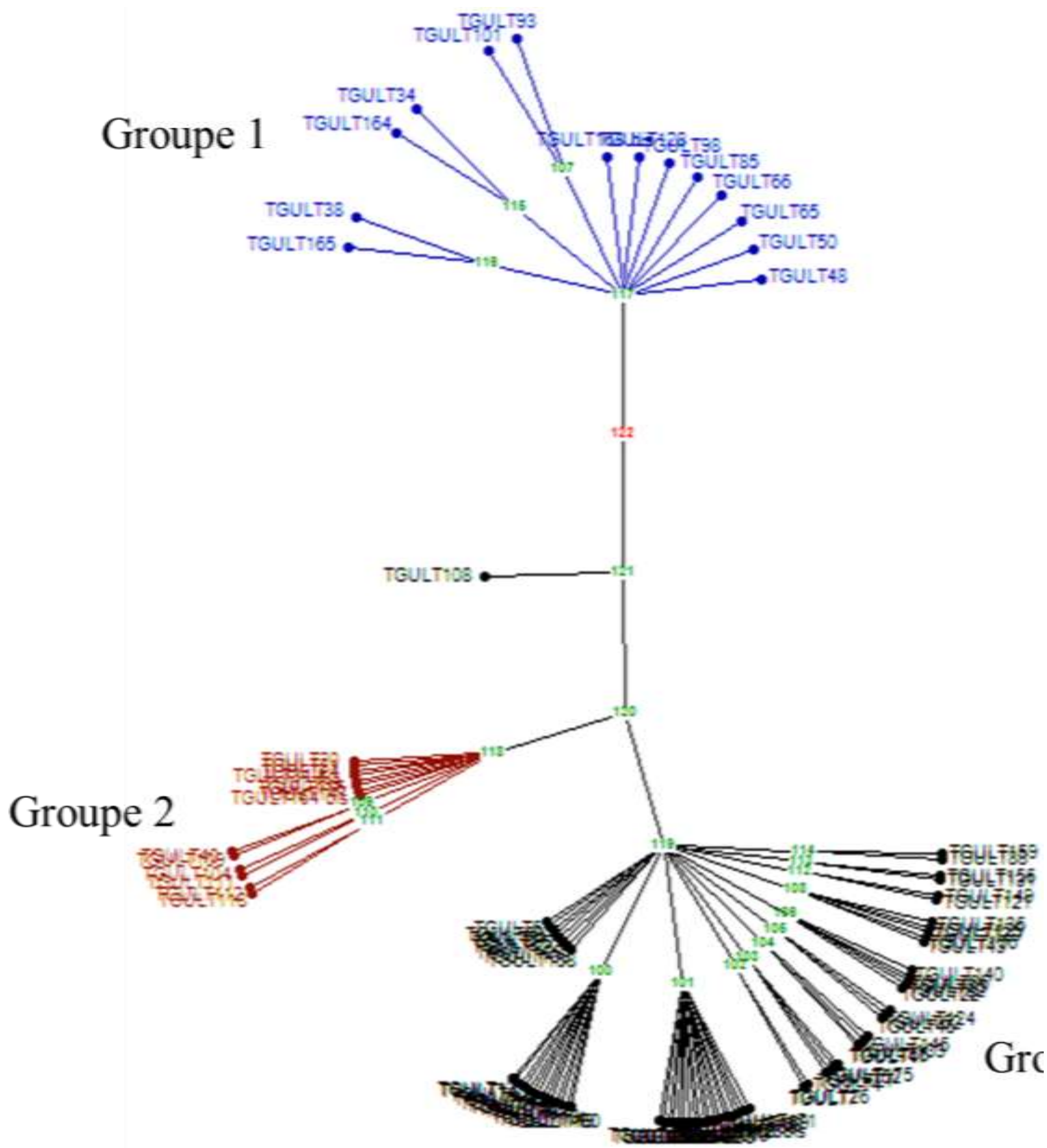

Figure 4. Dendrogram based on UPGMA analysis generated using the Euclidean coefficient representing the morphological relationships among yautia accession of Togo

2015) report a narrow genetic diversity based on morphological and/or molecular tools. The low diversity is explained by the low sexual propagation since these crops are clonally propagated.

Conclusion

Agro morphological variability is observed in taro and yautia accessions in Togo. Taro accessions are distinguished by the colour of the petiole, the leaf main vein colour, the leaf blade colour and the corm and cormels flesh colour. Based on these characters, four groups or morphotypes are distinguished. Two morphotypes of the dasheen type, most found in wet and swampy areas and two eddoe morphotypes more cultivated in the north and adapted to relatively low rainfall conditions. Although flowering was observed during the collecting survey, no accession flourished under the conditions of the trial. For yautia, three morphotypes are distinguished mainly by the colour of the petiole, leaf blade colour, petiole basal ring colour, bud and cormels flesh colour. The disproportionality of groups in accession numbers suggests a selection by

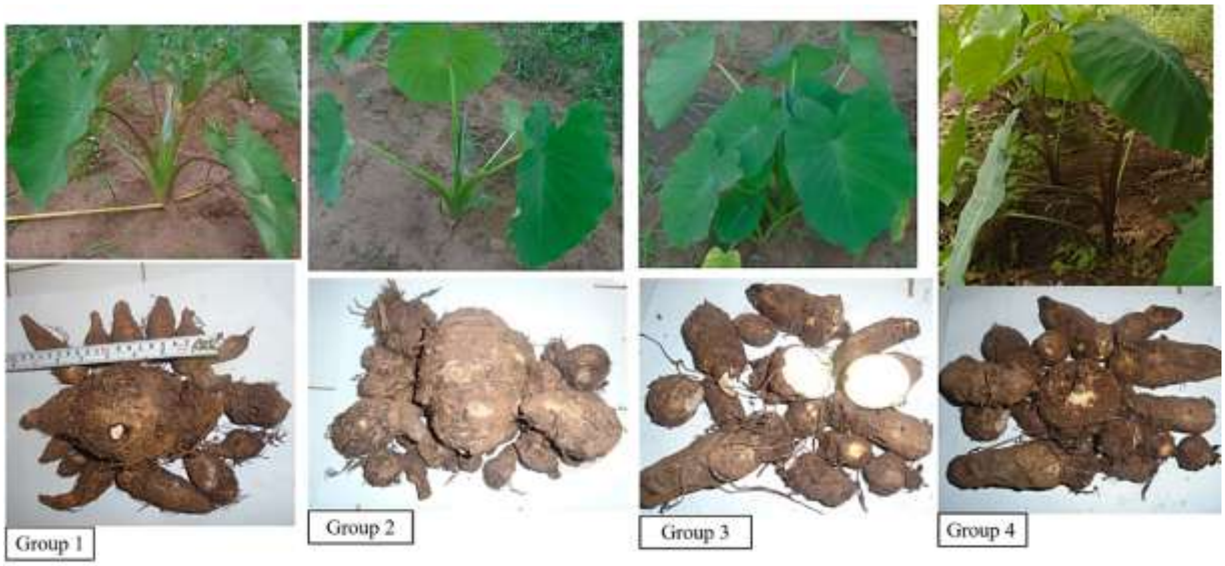

Figure 5. Accessions groups of *Colocasia esculenta*

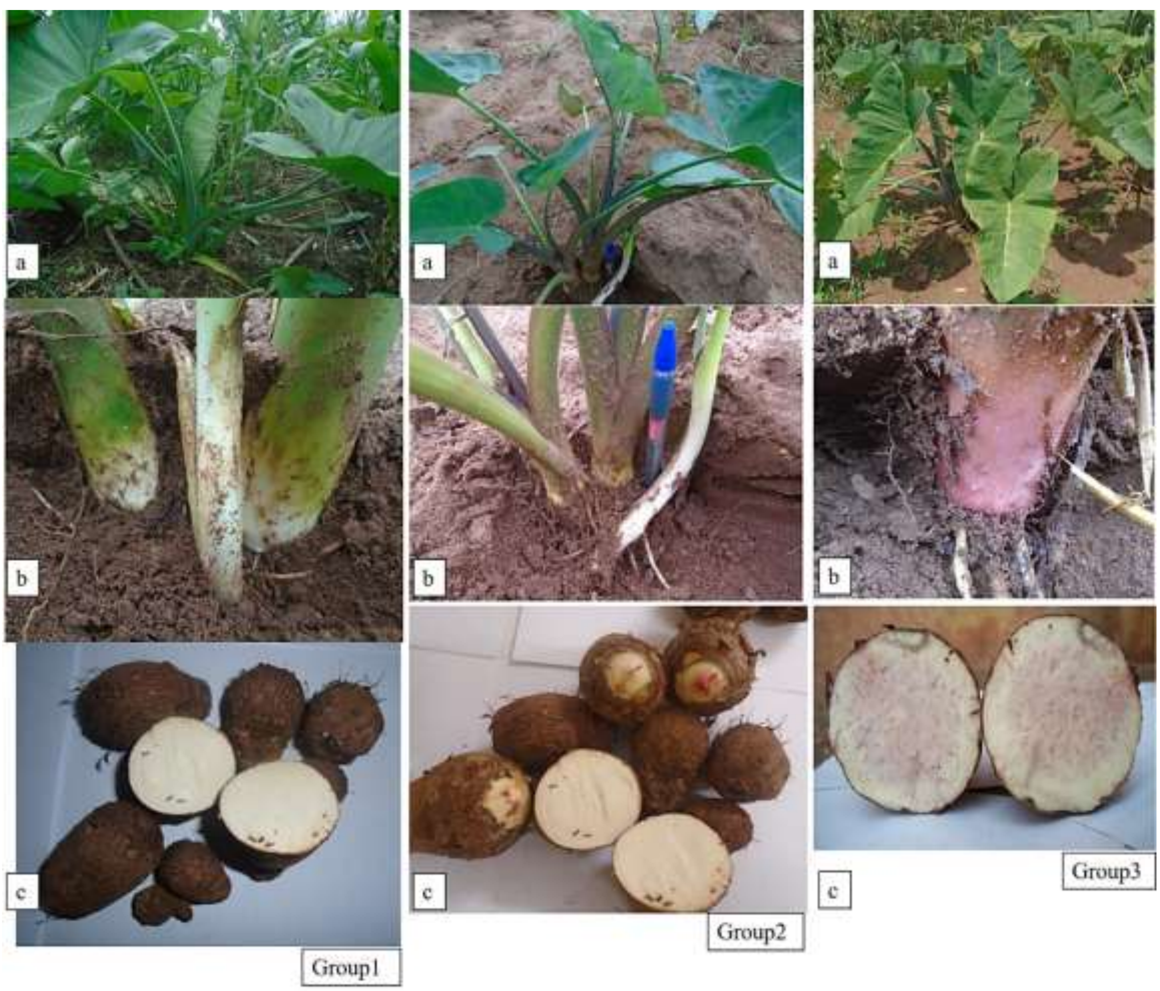

Figure 6. Accession groups of *X. mafaffa*; aboveground part (a); petiole basal ring color (b) and cormel flesh color (c)

farmers or the effect of biotic and abiotic constraints such as soil poverty, rainfall irregularity, diseases and pests. The vegetative propagation which constitutes the main way of propagation of these species suggests the existence of duplicates in the collection. In addition, the observed agro morphological variability is not always synonymous to genetic diversity. A ploidy analysis will clearly identify diploid accessions and triploid accessions for improvement. A characterization by molecular markers such as SSR is required for the identification of clones and establishment of a breeding program of these species in Togo.

CONFLICT OF INTERESTS

The authors have not declared any conflicts of interests.

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