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Agro-morphological characterization of yams (*Dioscorea sp*) of Passoré in Burkina Faso

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ABSTRACT

Yams are monocotyledonous plants adapted to areas where the rainfall is high (≥ 800 mm/year). However the northern part of Burkina Faso where the rainfall is low (400 to 600 per year) produces a particular group of yams adapted to the arid conditions of the province of Passoré. This group commonly called Passoré yams or "*yùyà*" in the national language "*mooré*", has three morphotypes respectively called "*waogo*", "*boussa*" and "*nyù*". On the farming area of the "*yùyà*" in Mia (Arbollé) province of Passoré, 66 accessions were collected. Measured characteristics were focused on the size, the shape and the colors of the leaves, the stems and the tubers. The results of morphological characteristics helped to link the morphotype "*waogo*" to the Asian crop *Dioscorea alata*; the morphotype "*boussa*" to the complex species of African yams *Dioscorea cayenensis-D. rotundata* and the morphotype "*nyù*" to the wild African species *Dioscorea abyssinica/ D. lecardii/D. sagittifolia*. The multivariate analyses (PCA and HAC) associate the "*nyù*" to long stems and tubers; the "*boussa*" to heavy short tubers and the "*waogo*" to long wide leaves. Differences in yield have been observed within all the three groups: 15 to 25 t/ha for the "*nyù*"; 35.75 to 40 t/ha for the "*boussa*" and 10 to 19 t/ha for the "*waogo*".
KEYWORDS: yam, characterization, *yùyà, nyù, boussa, waogo*, Passoré, Burkina Faso

INTRODUCTION

Diet plays a vital role in all living organism life. No sustainable progress is expected in whatever field it is in human societies if food is not sufficient in quantity and quality to satisfy the nutritional requirement of these societies [1]. In addition, the management of natural genetic resources used in diet by producers allowed combining food sovereignty with good nutritional status. The government of Burkina Faso has focused on the promotion of irrigation; on making tools and agricultural machinery, fertilizers and improved seed varieties available to producers. Furthermore the government has turned its actions to the training of farmers' communities in order to improve their technical level for a better implementation of technical recommendations disseminated or on the way of dissemination while respecting its international commitments [2].Despite these initiatives, Burkina Faso is experiencing frequent periods of deficit in food production. The sahelian zone, the driest part, is primarily affected by these deficits. The vulnerability of this area is marked more by the disruption in rainfall patterns making impossible the growth of certain crop species that have higher demanding in water. However the main alternative is to promote the neglected crop species in order to resolve the problem of food insecurity [3]. Some of these neglected crop species are grown by small scale farmer communities. No attention has been given to these species when collecting agricultural statistical data and therefore no benefit from any promotional activities. Fortunately, some conservative farmers know the socio-economic interest of these crop species and are still growing them. Therefore, in Burkina Faso, some of the species especially the yams of Passoré commonly called "*yùyà*" can be found in local market. The name "*yùyà*" refers in "*mooré*" the national language, to three morphotypes of yams (*boussa, nyù and waogo*) grown for their tubers. Highly adopted in traditional societies of "*Mossi*" of Passoré, the "*yùyà*" represents the main food used during certain ceremonies such as: social meetings, celebrations, births, weddings etc.

In West Africa, tubers such as yams can be used to make several meals like couscous, chips, steamed yam, "*gnon*" stew etc. In Burkina Faso, the production of "*yùyà*" helps in improving farmers' income. The "*yùyà"* has nutritional and therapeutic benefits. They are source of starch. They are used in therapy to treat diarrhea, pre and

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post menopausal illness, to control blood pressure and is even used as an aphrodisiac or male sexual stimulant. Despite the socio-economic and cultural importance of the "*yùyà",* they have not being of interest for research in Burkina Faso. Any agro-morphologic diversity analysis, development and promotion of the production of this biological material, has not yet been carried out. Any comprehensive inventory of the taxonomic groups of "*yùyà*", found in the province of Passoré in Burkina Faso, does not yet exist in literature. In report researches, little description of these plants" *nyù"* is not always concordant [4]; [5]. A common name locally used to call the "yùyà" often refers to size, the shape and the color of stems and the consistency of tubers. Therefore one name is often used for several varieties or even several species since the criteria of classification that are used, are strongly influenced by the environment. In 1994 and 1995, [4], [6] named the "*yùyà*", "yams of Pilimpikou" and classified them in the complex of *Dioscorea cayenensis-D. rotundata*. In 1988 and 2005, successively [7] and [5] classified the "*nyù*" in the complex *Dioscorea cayenensis-D. rotundata.*

Prior to theses studies, in 1987, the same authors [8] had linked the "*nyù*" to the savannah complex *Dioscorea abyssinica/D. lecardii/D. sagittifolia.* In considering the divergences a new classification of "*nyù*" is necessary. The works of [7]; [5] hypothesizing that this yam (the "*nyù"*) is a wild species likely the *Dioscorea abyssinica/D. lecardii/D. sagittifolia* domesticated in the Passoré for its tubers is plausible. The study was conducted to determinate agro-morphologic characteristic of morphotypes of "yùyà", the level diversity of agro-morphologic and proposes the botanic classification of the morphotypes.

Knowledge of agro-morphologic diversity of yams of Passoré could be exploited in yams improvement programs of Burkina Faso.

For a better classification of yams of Passoré, a collection and agro morphological characterization of the morphotypes has been carried out.

MATERIAL AND METHODS

A total of 66 accessions have been collected in 13 villages from five departments of the province of Passoré (Figure 1). This plant material consisted of 41 accessions of the morphotype of "*nyù*", 10 accessions of the morphotype of "*waogo*" and 15 accessions of the morphotype of "*boussa*" was characterized. Each sample of the collected morphotypes from a farmer is an accession.

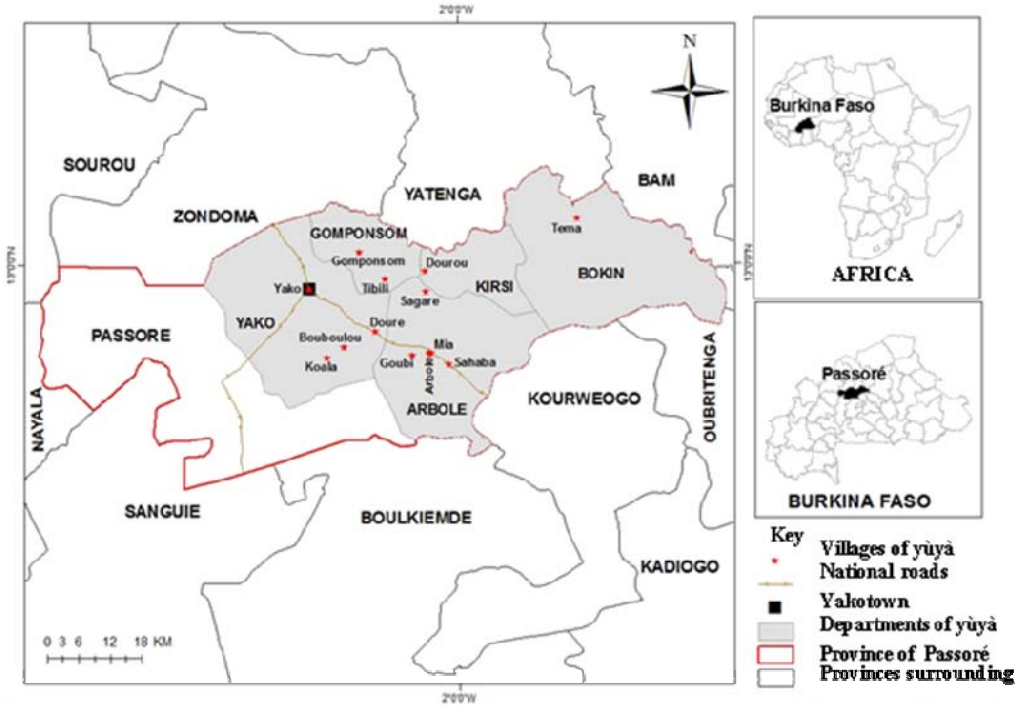


Figure 1: Localization of collection sites of the yams "yùyà" in the province of Passoré

METHODS

Experimental site

In order to minimize the effects of environmental factors on the expression of agromorphological characteristics, the tests have been carried out in the province of Passoré specifically in the village of Mia (12°50'29 North; 02°03'48.1 West, 377 m of altitude) located in the department of Arbollé (12°50'56 North;

02°02'49.4 West 345 m of altitude). Mia is one of the producers' villages where the "yùyà" is well promoted through the feasts of yams. The annual rainfall is less than 700 mm.

The experimental site is characterized by shallow sandy and clayey soil [9]. The test was set up in January 2012 in optimal soil humidity condition for the conservation of tuber seeds.

Experimental design and data collection

Each test was conducted in a randomized completed block design (RCBD) in two replications. Each replication contained 66 entries (accessions): 41 from "*nyu*", 10 from "*waogo*" and 15 from "*boussa*". Each entry is a row-plot prepared in ridge of 0.5 m of height. The two replications were separated by a space of 2 m. Each ridge was planted with five cuttings per accession spaced out of 50 cm. Fertilizers were applied during planting (120g/plant).

Using the descriptors for yams, twenty eight variables were selected of which 16 quantitative and 12 qualitative have been used in the description of the collection.

The qualitative variables consist of: the color of seedling (CSL), The color of young leaves (CYL), The color of mature thorns (CMT), the color of the veins (CMV), the color of mature stems (CMS), the color of mature leaves (CML), the curves of leaves (CLF), the type of inflorescence (TIN), the shape of tubers (STU), the consistence of tubers (CnTU), The color of tubers skin (CTS) and the color of tubers flesh (CTF).

As for quantitative variables, they were: the number of days at growing (NDG), the number of stems (NST), the length of stems (LST), the diameter of stems (DST), the length of internodes (LIN), the length of petiole (LPE), the length of limb (LLI), the width on limb (WLI), the number of the main veins (NMV), the number of inflorescence per node (NIN), the number of flowers per inflorescence (NFL), the length of inflorescence (LIN), the number of tubers per plant (NTU), the length of tubers (LTU), the average diameter of tubers (DTU) and the weight of tubers (WTU).

The flower characteristics were observed only on the morphotypes of "*nyù*".

Data analysis

The processing of the collected data was performed using Excel and Statistica version 6. The average analysis between morphotypes was done using Excel. An analysis of variance was performed for the studied variables, firstly between accessions of the same morphotype and secondly for all the accessions. The overall organization of diversity has been studied through a Principal Component Analysis (PCA) with qualitative variables. The relations between the accessions have been clarified according to Ward's aggregation method using Statistica version 6 from the Ascending Hierarchical Clustering (AHC).

RESULTS

Description of morphotypes using qualitative characteristics

The morphotype "nyù"

The morphotype "*nyù*" presents seedlings with purple or crimson horny leaves t at their emergence. At the mature stage, the stem is mostly characterized by purple sometimes bluish at certain part; by yellow adult thorns (Figure 2A); by very hard dark green wavy leaves (Figure 2B) and by many male flowers.

At harvest, the tuber is unique, hairy or smooth (depending on whether the planting is carried out on swampy or sandy soil), thin and long (threadlike) with little thorny roots and with white flesh sometimes yellow at the top (proximal part) and white at the base. The tubers with high hairiness whose proximal part is thin and the base is wide can be also observed (Figure 3). Compared to the other morphotypes, the accessions of "nyù" have a very thin skin that can be easily peeled from the flesh. This morphotype which represents 62.12% of the accessions could either be the *Dioscorea abyssinica* or *Dioscorea sagittifolia* or *Dioscorea lecardii* (Figure 2 and 3)

A: Mature purple stem with yellow thorns

B: Very undulating dark-green leaves

Figure 2: Different shapes and colors of leaves, stems and thorns of "*nyù*"

A: Threadlike hairy tuber (left) and thornless (right)

B: tubers with thin proximal part and large hairy base

Figure 3: Different shapes of the tubers of "*nyù*"

The morphotype "waogo"

The morphotype "*waogo*" is characterized by quadrangular stems, colorful (purple) wings or not, leaves wholly green and heart shaped with wide long petiole, black large stocky and hairy tubers. Two sub-morphotypes have been identified.

These sub-morphotypes differ from each other by the size of stems, the color of the wings and the shape of the leaves (Figure 4). One of the two sub-morphotypes (20% of accessions of "waogo") has a small stem with green-light wings, erected heart shaped leaves (Figure 4A) and tubers generally short and little round (Figure 5A). The over sub-morphotype (80% of the morphotype "*waogo*") has very thick stems with purple wings, heart-shaped and droopy leaves (Figure 4B) and long tubers (Figure 5B). Within this sub-morphotype, 15.15% of accessions have quadrangular stems and could be classified as *Dioscorea alata.*

A: *waogo* with quadrangular uncolored and winged stem and triangular erect leaves

B: *waogo* with quadrangular colorful and winged stem and wide droopy leaves

Figure 4: Different forms of leaves and stems of "*waogo*"

A: Short and globular tubers of the sub- morphotype with uncolored and winged stem

B: Elongated tubers of the sub-morphotype with colored winged stem

Figure 5: Different forms of tubers of morphotype "*waogo*"

The morphotype "*boussa*"

Polymorphism (stem and tuber) is more important within this group defined by farmers (Figure 6 and 7). Several sub morphotypes have been distinguished but they are not based on the color of the stem:

-Sub-morphotype with big blue thorns (13.33%),

- Sub-morphotype with thick thorn less stems and small internodes (33.33%);

-thorn less sub-morphotype with long internodes (20%);

-Sub-morphotype with thick, squat and grooved stems whose base in thorny (26.66%);

-Sub-morphotype with several stems and small leaves (2%).

At harvest, an important variations have been noticed from the tubers. A real relationship between the shapes of tubers and the different characteristics above can be established. However, two forms of stems have produced specific tubers. Plants with several stems have substantially produced the same number of tubers as the number of stems and plants with thick, grooved and chunky stems produced tubers whose proximal part is wide and base is narrowed with small lateral tubers. The morphotype "boussa" which represents 22.73% of the collected accessions (Figure 6) is a set of cultivars that obviously belong to the complex *Dioscorea cayenensis-D. rotundata*. The phenotypic characteristics of tubers (Figure 7) are highly influenced by the soil texture (Figure 6 and 7).

A: Thorn less stem with long internode

B: Thorny stem spotted at the base

C: Less thorny stem, with three branches and long internodes

D: Plant in several thin stems

E: Thick, stocky and ridged stem

Figure 6: Morphological variations of the stems of" *boussa*"

A: fusiforme tuber

B :cylindrical tuber

C: Tuber with large proximal part and narrowed base

D : Obconical tuber

E: Cylindrical and hairy tuber

F: Conical tuber

Figure 7: Morphological variations of tubers of morphotype "*boussa*"

Description of morphotypes using quantitative variables

Agronomic characteristics of morphotypes

After planting, the morphotypes "*nyù*" "*boussa*" and "*waogo*" got harvested respectively after an average of 178, 209 and 215 days (table 1). Regarding the growing cycle, the morphotypes "*boussa* and "*waogo*" was harvested one month after "*nyù*". At the development of the stem, the "nyù" spent a maximum of one week to wrap around the stake, while the groups "boussa" and "waogo", spent three weeks. A difference of more than 75 cm in length of the stem was noticed between the"nyu" and the other two morphotypes (*boussa* and *waogo*). Furthermore, there was homogeneity of growth within the same group. Regarding the length of internodes, the "*boussa*" has the highest length. In this study of the yams of Passoré, the stem number appeared very discriminating among morphotypes. It clearly separates the "*nyù*" from the "*boussa*". The stem was unique for the "*nyù*" while varying from 1 to 4 or more for the "*boussa*" and the "*waogo*". The main veins of the "*nyù*" are 7 and those of the "*boussa*" and the "*waogo*" are 5. "*Waogo*" is the morphotype which has the widest and the longest leaves. "*Nyù*" with a maximum length of 78.36 cm and an average diameter of 50.83 mm, has the most remarkable length. The "*boussa*" and the "*waogo*", they have large shorter tubers. However the two latter are distinguished by the color of their tubers (grey for "*boussa*" and white for the "*waogo*"). The "*nyù*" which has the thinnest tubers of low weight, gave a yield of about 25t/ha. The "*boussa*" gave the largest tubers with a yield of about 35.75t/ha. The "*waogo*" with a yield estimated of 19t/ha, has not produced any large tubers on our test site for a potential of more than 40t/ha. The inflorescence of an average length of 16.39 cm observed in the "nyù" was a male. The number of flowers per inflorescence varied from 1 to 79 with an average of 59.57. The type of inflorescences, the most frequently observed on the same plant was the one in cob. Flowering occurs between mid august and September and indicates the period of strong tuber formation. At this stage, a pre-harvest is possible but a lack of rain will prevent a new tuber formation, then, pre-harvest is unadvisable.

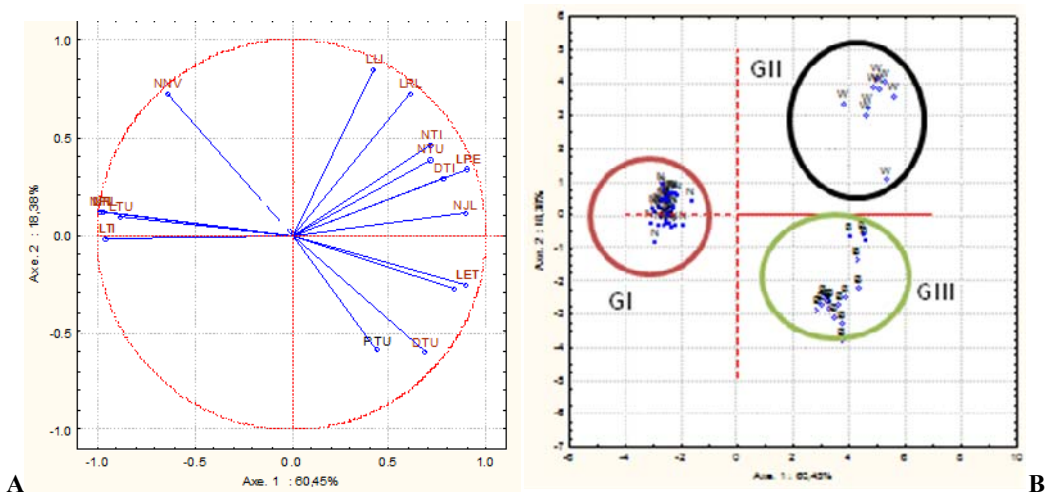
Table 1: Performance of the three morphotypes of the "*yùyà*"

	Morphotypes									
	« Nyù »			*« Boussa »*			*« Waogo »*			
Caractè	**Mini**	**Aver**	**Max**	**Mini**	**Aver**	**Max**	**Mini**	**Aver**	**Max**	**F**
NDL	134	178	202	198	209	231	199	215.8	234	5,47*
LST	1.43	1.90	2.189	0.67	0.86	0.99	0.56	0.68	0.92	8,24**
LIT	6	7.73	8.3	12	12.48	13	10	10.76	12	0,04 ns
NST	1	1	1	1	3.01	5	2	2.57	4	22,67**
DST	2.88	3.17	3.45	1.15	4.43	6.67	2.58	5.30	8.56	0,08 ns
LPE	4	4.86	6.2	6	6.26	7	8	8	8	0,76 ns
LLI	11.20	12.33	13	11	12.57	13	14	16.18	17	8,87**
WLI	7.9	8.38	9	7	8.98	10	11	12.53	13	3,15 ns
NMV	7	7	7	5	5	5	7	7	7	18,86**
NTU	1	1.01	1.20	1	1.26	4	1	2.35	4	62,06**
LTU	31	42.5	78.36	6	23.20	35	18	24.29	35	1,26 ns
DTU	38.77	50.83	63.16	41.65	71.89	105.5	42.40	71.36	102.8	4,73*
WTU	343.2	524.12	706.9	321	713	977	200.1	384	723.2	56,97**
NIN	1	2	4	-	-	-	-	-	-	
LIN	7.8	16.39	18.10	-	-	-	-	-	-	
NFL	1,00	59.57	79,00	-	-	-	-	-	-	

Key *: Mini : minimum; Aver : average; Max : maximum***;** *NDL : number of days at lifting ; NST : number of stems ; LSTI: length of stems (cm) ; LIT : length of internodes (cm) ; DST : diameter of stem (mm) ; LPE : length of petiole (cm) ; LLI : length of limb(cm) ; WLI : l width of limb(cm) ; NMV : number of the main vein ; NIN : number of inflorescence per knot; LIN : length of inflorescence (cm) ; NFL : number of flowers ; NTU : number of tubers ; LTU : length of tubers; DTU* **:** *diameter of tubers (mm) ;WTU :weight of tuber*
*ns: not significantly at 5%, *: significantly at 5%, **: significantly at 1%,*

Structuring agro morphological diversity

The Principal Component Analysis (PCA) (Figure 8) and the Ascending Hierarchical Clustering (AHC) (Figure 9) have been used to structure the 66 accessions of "*yùyà"*. Axes 1 and 2 of the PCA from the 16 quantitative variables show the most discriminating variables (78.38% of total diversity) within the "*yùyà*" (Figure 8A). Axis 1 which explains 60.45% of the variability is negatively correlated to the length of the stems (LST), the length of inflorescence (LIN) and the length of tuber (LTU) and positively correlated to the number of days of growth (NDG), the length of petiole (LPE), the number of tuber (NTU) and the length of internodes (LIN). It is this axis which defines the size of the organs. Axis 2 which has in total 18.38% of the complete inertia, is positively associates to the number of the main veins (NMV), the width of the limb (WLI) and the length of limb (LLI) and negatively associates to the diameter and to the weight of the tuber (DTU), (WTU). The projections of accessions on the axes using previous variables show the distribution of accessions in to 3 groups. Axis 2 separates the accessions of the morphotypes "*nyù*" from the other accessions whereas the axis 1 separates the other two morphotypes (*boussa* and *waogo*).



A B

Figure 8 (A, B): overall grouping of variables and accessions of "yùyà" on the axes (1x2) of the PCA

From the Ascending Hierarchical Clustering (AHC) of the 66 accessions 3 groups were formed base on the most discriminating variables: the length of the stem, the length of the petiole, the length of limb, the length of tuber, the number of main veins and the length of the internodes. The first group (GI) mainly consists of the accessions of "nyù" coming from thirteen villages. It is characterized by long stems, long tubers and the main veins. The second group (GII) consists of all the accessions of "*waogo*". It is different from other groups by its long and wide leaves with long petioles. The third group (GIII), essentially consist of the accessions of "*boussa*". It is characterized by short stems with long internodes and short tubers.

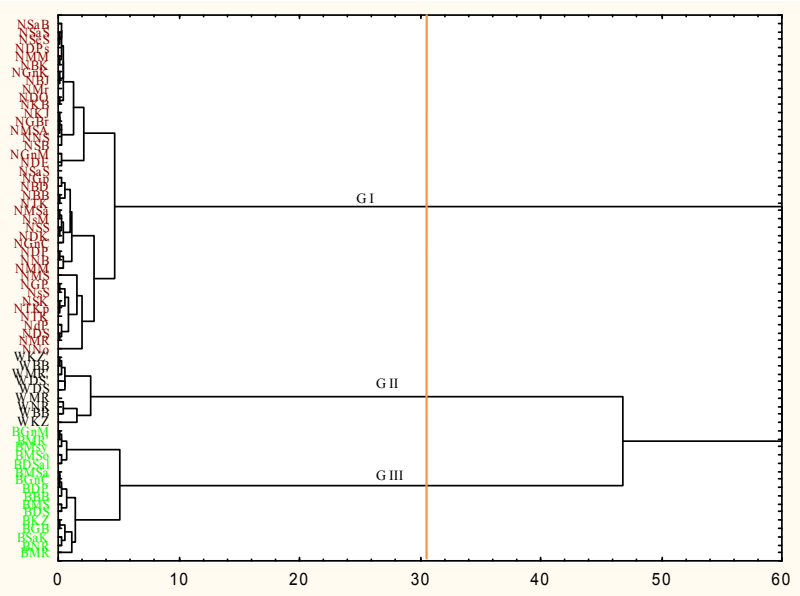


Figure 9: Dendrogram of hierarchical clustering (HAC) of the 66 accessions of "*yùyà*"

DISCUSSION AND CONCLUSION

DISCUSSION

The characteristics used in this study enable to discriminate the three morphotypes (*nyù, boussa* and *waogo).* These same agromorphological characteristics have also been used by [7]; [10]; [11]; [12]; [13] for the classification of West African and Asian yams. This agro morphological classification coincides with farmers' nomenclature. This could be explained by the use of certain phenotypic caractors mainly the qualitative ones in the farmers' description.

However, the sub-morphotypes have been identified within the "*boussa*" and "*waogo*". The "*boussa*" is less cultivated in Passoré than the "*nyù*". In fact, the yams of "*boussa*" group (complex *D. Cayenensis- Dioscorea rotundata*) are preferentially grown in areas where the annual rainfall is high, between 1200 and 1500 mm [14]; [15].

These rainfall conditions would explain why the "*boussa*" is less cultivated in the Passoré than the "*nyù*" which is very suited to the rainfall of that area (less than 700 mm per year). The important size of stem of "*nyù*" could be due of a genetic nature or could be represented a better adaptation of the area. The high heterogeneity of the "*boussa"* certainly explains the difficulties observed in the classification of yams of this group. According to [7] Zoundjihékpon (pers. Com), these difficulties observed in the systematic of these yams in 1978, led to the grouping of all the domesticated yams originated from West Africa, in the complex *Dioscorea cayenensis-D .rotundata*.

The "*nyù*", the main morphotype peculiar to the Passoré, is classified in the complex *Dioscorea cayenensis-D. rotundata* [7]; [5]. However, according to Hamon [7];[8] this variety of *D. cayenensis-D. rotundata*, regarding its morphological characteristics, is close to the savanna species *D. abyssinica / lecardii D. / D. sagittifolia.* The "*nyù*" could therefore be a wild species being domesticated. For [5], the "*nyù*" could therefore correspond to other group of yams found in Benin, Guinea and northern Togo. Besides, the characteristics such as: number of the leaves' veins, shape fragility, length and weight of tubers, bring the "*nyù*" closer to the wild west African species *Dioscorea abyssinica* described by [18]; [5] and to the wild species of Aka and Baka pigmies of central Africa in Cameroon, the *Dioscorea semperflorens*. This latter species is the most abundant in Aka's area. It has a spindly and watery tuber so fragile that is can only develop on light soils dominated by sand [19]. The average mass of stored tubers per plant does not exceed 2 kg [18]; [19]. The presence of thorns on the stem and at the base of the petiole makes the "*nyù*" different from the wild yams (*Dioscorea abyssinica*). According to [18];[19]; [5] the wild species have not thorns. In 2014 using morphological characteristics (color of seedlings, the number of the main veins, the curves of leaves) and characteristics of tubers (fragility and spindly shape) of the "nyù", Millogo (pers. Com.) suggested a new classification of this yam within the wild yams. Similarly, [20] classified the"*nyù*" (yam of *Pilimpikou*) within the group of the variety '*Baniakpa* "described by [16]. This variety is originally from Benin or Nigeria, or from Burkina Faso [7]. However with

regard to the characteristics of tubers, stems and leaves, the morphotype "*boussa*" belongs to the complex *Dioscorea cayenensis-D.rotundata* described by [16].

The characteristics such as quadrangular stems, colored wings or not, wide, droopy leaves allowed to distinguish the morphotype "*waogo*" from the others and to identify it as a species *Dioscorea alata*. These results are in agreement with those of [14]; [21]; [11]; [12]; and Guinko (pers. Comm), who, base on the quadrangular stems, had classified these yams within the Asian species *Dioscorea alata*. The identified morphotypes correspond to the three farmers' groups essentially characterized by qualitative and quantitative traits of tubers. The yields from the morphotypes of Passoré (*waogo*: 19t/ha, *nyù*: 25t/ha and *boussa*: 35t/ha) are comparable to those from the countries producing these yams: 20 t/ha for *alata* C18 [12]; [22], 10t/ha in Baoulé's countries and 15 t/ha in northern Benin for *Dioscorea cayenensis-D. rotundata* [23]; [24]. The high yield of the morphotypes of "*yùyà*" is due to the significant number of tubers harvested from the ridges. The cropping system using ridges produces light weight tubers but on contrary to cropping using mound. The use of ridges enables to harvest a large number of plants and tubers by reducing the distance between plants.

CONCLUSION

This study has allowed us to identify the discriminant characteristics (color of seedlings, shape of stems, shape and length of leaves, shape and length of tuber, color of tubers flesh) of the three morphotypes of the yams of Passoré in Burkina Faso. It has also showed a agreement between farmers' nomenclature and botanical nomenclature of the three morphotypes of yams. So:

- The "*boussa*" is characterized by the size and consistency of its tubers, belongs to the complex *Dioscorea cayenensis-D. rotundata*;
- The "*waogo*" plant with quadrangular stem and large black tuber belongs to the species *Dioscorea alata*;
- The "*nyù*", the morphotype peculiar to the Passoré, is characterized by long fragile tubers.

The results of the study show that this morphotype, previously classified in the complex *Dioscorea cayenensis-D. rotundata* is actually a wild species which could belong to the complex *Dioscorea abyssinica / D.lecardii / D. sagitifolia* or *Dioscorea semperflorens* domesticated since centuries. Earlier taxonomic errors observed in the classification of the"*nyù*" could have been affected by studies carried outside its ecological environment and to the characteristics used. Molecular characterization using microsatellite markers of wild species cultivated in Burkina Faso could better deepen the results of this study.

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