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Research Paper

Farming system and cultivation constraints in African yam *Dioscorea dumetorum* (Pax, Kunth) production in Benin

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Abstract. *Dioscorea dumetorum* is one of the important cultivated yams that significantly contribute to food security and poverty alleviation in Benin. However, the potential of this tuber crop is under-exploited and its production completely neglected by research and development policies. The objective of this study was then to document the indigenous knowledge related to its traditional farming system, agronomic practices and constraints that limit its production in Benin. Therefore, an ethnobotanical survey was conducted in seventy-eight (78) villages covering the major production areas in the country. The results revealed that *D. dumetorum* cultivation was mainly traditional and dominated by male, adults and old farmers while the participation of youth and women was found minimal. According to farmers, this yam was a less-demanding crop, requiring no specific input. Four main cropping systems practiced by farmers were identified. These were crop-association (50.53% of respondents), monoculture (20.47%), crop-rotation (18.86%) and home gardens planting (10.14%). Besides, seven approaches (use of basket, garret, straw hut, bag, shade, hole and pile) were practiced for postharvest storage of tubers. Finally, diverse range of constraints, including the susceptibility of tubers to termites and rodents in storage or in late harvesting, the frequent occurrence of drought during sprouting time, tubers' hardening in storage making them unsuitable for pounding, the presence of roots on tubers, were reported to impede *D. dumetorum* production. The important ethnobotanical data recorded here are useful for breeding programs but also in defining appropriate strategies for conservation and valorization of *D. dumetorum* in Benin.

Keywords: Benin, constraints, *D. dumetorum*, production system, storage, yam.

INTRODUCTION

In developing countries, efforts to achieve food security are nowadays often based on major food crops (maize, rice, cassava, groundnut, cowpea, etc.). However, many other minor but underutilized crops have played and continue to play such role in traditional agriculture in Africa (Adoukonou-Sagbadja *et al*., 2006). Yam is known as an important food security crop and has major economic and sociocultural importance in Sub-Saharan Africa, particularly in West-African yam belt (Coursey, 1967; Ayensu and Coursey 1972). More than 90% of the total world yam production is located in West Africa (FAO, 2014), primarily by smallholder farmers. Average

yam consumption per capita and per day is higher in Benin (364 kcal), followed by Ivory Cost (342 kcal), Ghana (296 kcal) and Nigeria (258 kcal) (IITA, 2009).

The yams belong to the major genus *Dioscorea* of the family *Dioscoreaceae* that includes six cultivated species of economic, medicinal and food importance (Adeigbe *et al.* 2015). Among these yam species, *Dioscorea dumetorum*, known as cluster yam (when the tubers are bunched), or bitter yam or three-leaved or trifoliate yam or yellow yam, is native to West Africa. In traditional agriculture, *D. dumetorum* is an important security crop for low income farmers. Besides, *D. dumetorum* has an important nutritional value with tubers rich in protein with a balanced composition in essential amino-acids (Mbome Lape and Treche, 1994; Sonibare *et al*., 2010). It is source of vitamins, glucids, nutrients and energy for the human consumption (Medoua *et al.*, 2005b; Alozie *et al.*, 2009; Ukpabi, 2015). According to Ferede *et al.* (2010), the flesh of yellow-dark *D. dumetorum* contains the provitamin and the carotenoids comparable with those in yellow corn lines selected to increase the concentration of provitamin A. Besides, *D. dumetorum* is mainly cultivated for self-consumption followed by market outlet. Except human consumption, the tubers can be used in industry. *D. dumetorum* is a promising source of starch because of its high content compared to cassava and cereals for diverse industrial applications (Ezeocha and Okafor, 2016). This may help relieving the pressure on popular starch sources like cassava and meeting at low cost the ravenous starch demand of the modern world (Oluwasina *et al.*, 2017).

In Benin; *D. dumetorum* is grown under a variety of agro-ecological conditions, ranging from favorable to marginal lands and only its tubers are used for food in boiled (Adigoun-Akotègnon *et al*., 2019), roosted and fried form (Laly *et al*., 2019). Likewise, *D. dumetorum* holds particular importance at nutritional, medicinal and magico-mystical level in many tribal areas of Benin (Adigoun-Akotègnon *et al.* 2019) and valued for its pharmaceutical purposes (Cornet, 2015; Essou *et al*., 2011). A study by Adigoun-Akotègnon *et al*. (2019) highlighted the importance of this yam in the traditional treatment (folk medicine) of 14 diseases in Benin. However, *D. dumetorum* remains a secondary crop in most producing countries in West-Africa, a neglected and underutilized crop (Dansi *et al.*, 2012).

Yam farming provides important incomes to farmers, particularly in the southern and central parts of Benin where it is produced for sale. Farmers had developed valuable knowledge and experiences on the management and use of this yam genetic resource in Benin (Adigoun-Akotègnon *et al*., 2019). Indeed, *D. dumetorum* is well appreciated and its food and market values are increasing, notably in urban centers in the southern Benin. However, the production of this yam is limited with drastically low yields due to a myriad of cultivation and post-harvest constraints. Besides, little is known on its agricultural practices as well these production constraints, limiting the promotion and valorization of this crop in Benin as well in West-Africa at whole.

Hence, this paper seeks to characterize the traditional farming system of *D. dumetorum* in Benin by (1) investigating agricultural practices and post-harvest conservation techniques in the production areas of *D. dumetorum*, (2) identifying constraints affecting *D. dumetorum* production and conservation in Benin, (3) describing gender role in *D. dumetorum* production in Benin. The information gathered from this ethnobotanical study will help to pave the way for improvement of *D. dumetorum* production and value this yam as an economical crop in Benin.

MATERIALS AND METHODS

Study area and sites selection

The present study was carried out in southern, central and northern parts of Benin Republic (Figure 1). Located in West Africa between the latitudes 6°10' N and 12°25' N and longitudes 0°45' E and 3°55' E, the Benin Republic covers several agro-ecologies characterized by contrasting climate and soils types differences (Adomou *et al*., 2011). The southern and central parts of the country covering the agro-ecologies V, VI, VII, VIII are characterized by a relatively humid climate with two rainy seasons and a mean annual rainfall varying from 1100 mm to 1400 mm/year (Yabi and Afouda, 2012). The mean annual temperature ranges from 26 to 28°C. This region is partitioned into eight administrative departments among which *D. dumetorum* is mainly produced in five including Collines, Couffo, Plateau, Ouémé and Zou. In these departments, we have different ethnic groups such as Adja, Fon, Holly, Idaasha, Mahi, Nago, Goun, Yoruba, etc. The northern Benin region is situated in arid and semi-arid agro-ecological zones (Zones I, II, III and IV), and characterized by unpredictable and irregular rainfalls oscillating between 800 and 950 mm/year with only one rainy season. Mean annual temperatures range from 26 to 28°C and may exceptionally reach 35 to 40°C in the far northern localities. The northern region is portioned into four administrative departments among which *D. dumetorum* is grown in three (Atacora, Donga and Borgou). In the country, the different types of vegetation encountered are semi-deciduous forest (south), woodland and savannah woodland (center-east and northeast), dry semi-deciduous forest (center-west and south of northwest) and tree and shrub savannahs (far north).

In total, seventy-eight (78) villages belonging to six producing agro-ecological zones (III, IV, V, VI, VII, VIII) and covering diverse sociolinguistic areas of *D. dumetorum* production were randomly selected after

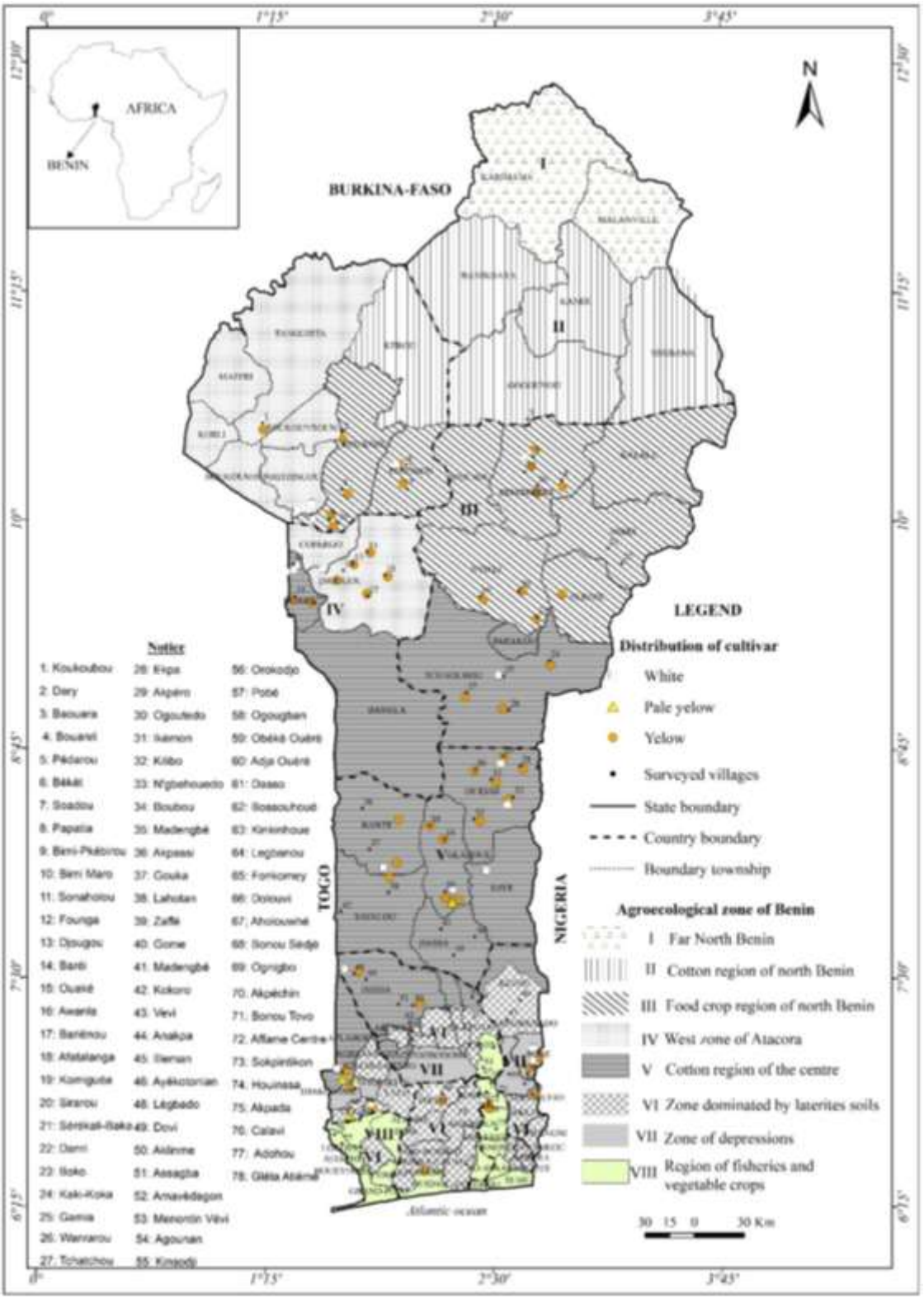

Figure 1. Surveyed villages and agro-ecological localization in Benin.

literature and exploratory surveys in agricultural research centers, agricultural extension services rural and urban markets through informal discussions with diverse actors such as resources persons, farmers and sellers. This

methodological selection procedure followed that recently applied by Adigoun-Akotègnon *et al.* (2019).

Ethnobotanical surveys and data collection

The ethnobotanical surveys on bitter yam production were conducted during two consecutive growing seasons (2016-2017 and 2017-2018) and took place from November to March when *D. dumetorum* was planted, harvested and sold by farmers. These surveys were conducted using participatory rural appraisal techniques and tools recommended by Adoukonou-Sagbadja *et al*. (2006) and recently applied by Zavinon *et al.* (2019) and Adigoun-Akotègnon *et al.* (2019). *D. dumetorum* farmers were selected using snow ball method described by N'danikou *et al.* (2015) and a total of 555 respondents were finally surveyed. In each selected village, traditional chiefs and local authorities were involved in the study to facilitate the meetings and data collection.

For data collection, a structured questionnaire was administered to the participating farmers to collect general information on their socio-demographic characteristics (sex, age, education, etc.), the land use systems, the agricultural practices, the perceived constraints in *D. dumetorum* production, post-harvest management and storage tools used as well the gender role in the production. Interviews were conducted with the help of translators when needed.

Data analysis

The survey data were achieved in Microsoft Excel spread sheet and analyzed through descriptive statistics (frequencies, percentages, means, etc.) to generate summaries and tables at different (zone, villages, individuals, etc.) levels. Specifically, radar diagram and frequency tables were used to establish the importance of the different cropping systems in *D. dumetorum* in the agro-ecological zones surveyed. The importance of *D. dumetorum* cultivars among these agro-ecological production zones was assessed according to the average area of farm allocated to each category of *D. dumetorum* cultivars. A Kruskal-Wallis test was later performed to compare the amount of areas allocated to each category of cultivar among agro-ecological zones. Based on the quotation frequency, a principal component analysis was conducted to characterize the production constraints and to map the distribution of storage approaches of *D. dumetorum* tubers used by farmers following the agro-ecological zones surveyed. Finally, a factorial analysis of correspondence was used to investigate the relationships of the variation of gender roles in *D. dumetorum* farming system according to agro-ecological zones of production in Benin. All the data analysis was executed using R software package vs. 3.3.2.

RESULTS

Socio-demographic profile of *D. dumetorum* growers

A total of 555 producers have been interviewed during the study. They belonged to eighteen (18) ethnic groups among which traditionally 6 living the south, 3 the center and 9 the north of the country. Figure 2 presents some socio-demographic characteristics of *D. dumetorum* farmers.

The study indicated male dominance in *D. dumetorum* production in Benin. Among these 555 farmers, 84% of respondents were male while 16% were female. Gender differences were observed in years of experience in *D. dumetorum* production. The average is 16 years for men, but 9 years for women. Hence, compared to men, women were relatively new in *D. dumetorum* production. Besides, 12% of the farmers surveyed were young people, 66 % were adults (40 to 50 years) and 22% (over 50 years) were old people. The main occupation for most of the respondents was crop farming (95.7 % of respondents). The educational level was very low. Only 15.67% of respondents had completed primary school and 7.43% have reached secondary school. Most of them (76.9%) have never been to school.

D. dumetorum cultivar diversity and its importance in traditional farming system

A total of 25 different farmer-named cultivars folk-classified into three major morphotypes (yellow, white and pale-yellow) were identified in the study area (cf. detail in Adigoun-Akotègnon *et al.*, 2019). The importance of these cultivars in production was assessed by the surface of land devoted to their cultivation. Land allocation to these cultivars was compared across agro-ecological production zones. The results of Kruskal-Wallis test conducted on the mean land areas showed highly significant differences among agro-ecological zones (Table 1), highlighting the differences in importance of trifoliate yam in each zone. Yellow landraces were largely and quantitatively the most produced variety group than the white and pale yellow ones through all the agro-ecological zones of production. These landraces of this morphotype were mainly produced in the agro-ecological zones VIII, VII, VI and V with the average of cultivated lands of 3.55, 3.41, 2.92 and 2.49 ha, respectively. After the yellow landraces, the white landraces are the most produced in importance with their cultivation observed in all agro-ecologies but in reduced areas (0.03 ha to 0.19 ha in average). Pale-yellow cultivars were less important in production with its cultivation observed only in three zones (that is, VI, VIII and V) with an average devoted land ranging from 0.02 ha to 0.07 ha. Finally, it is important to note here that 67.9% of the *D. dumetorum* farmers gained access to

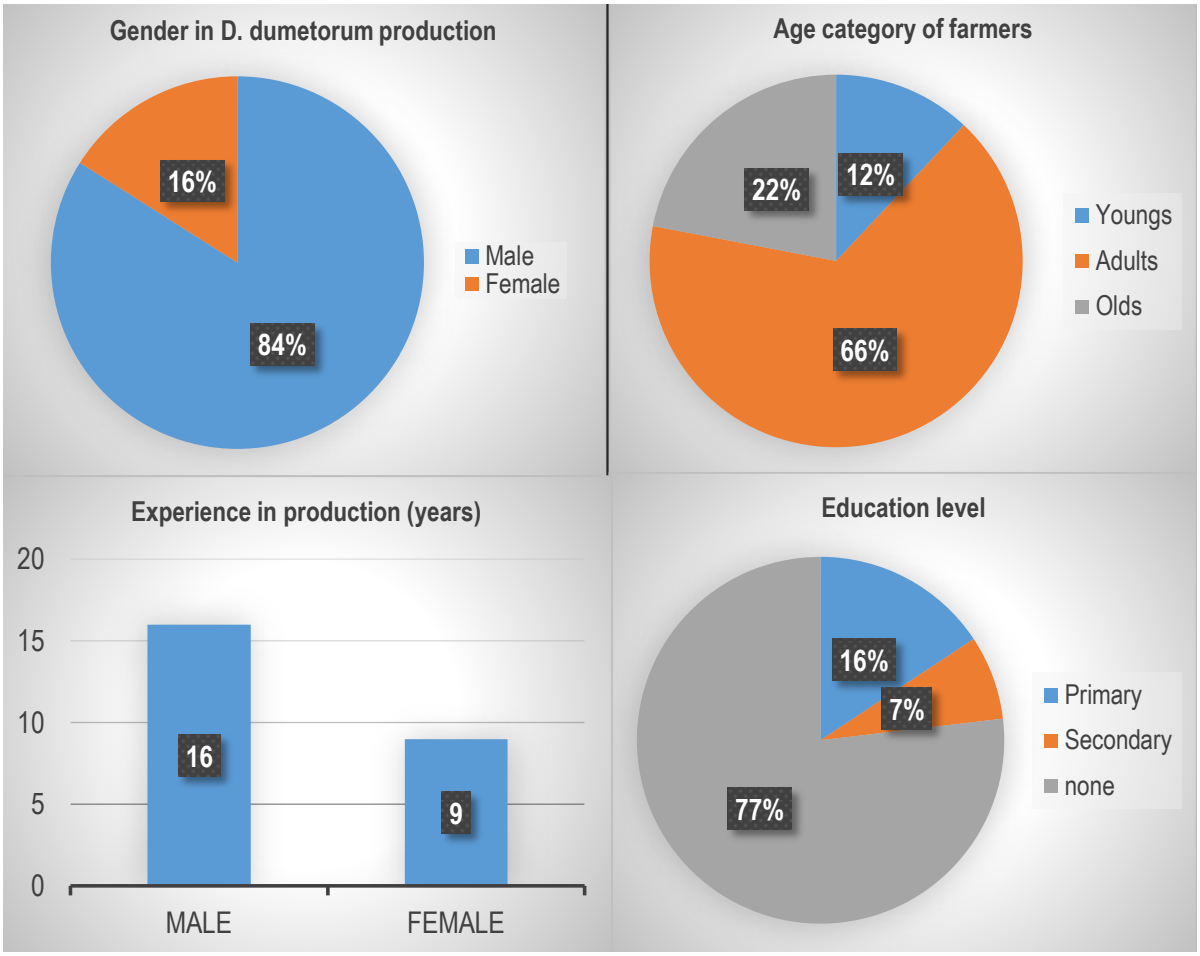

Figure 2. Socio-demographic characteristics of *D. dumetorum* farmers in Benin.

Table 1. The average area of farm land allocated to *D. Dumetorum* cultivars production through agro-ecological zones in Benin.

Agro-ecological zones	Yellow morphotypes		White morphotypes		Pale yellow morphotypes	
	Mean (ha)	cv (%)	Mean (ha)	cv (%)	Mean (ha)	cv (%)
Zone V	2.49	114.19	0.06	299.63	0.02	747.30
Zone VI	2.92	98.91	0.14	188.39	0.07	381.51
Zone VII	3.41	109.68	0.15	171.55	0.00	*
Zone VIII	3.55	70.59	0.19	171.02	0.04	556.28
Zone III	0.06	322.00	0.03	519.46	0.00	*
Zone IV	0.17	347.46	0.07	310.30	0.00	*
Probability	0.000	-	0.000	-	0.000	-

* Not available in the agro-ecological zone

their land through family inheritance, 22% through leasing, 10.1% through purchase.

Cultivation practices of *D. dumetorum*

Like other cultivated yams, diverse farming activities were observed during *D. dumetorum* cultivation and were reported by farmers to be labor intensive. These were bush cleaning, mounding, planting tuber seed selection, planting, weeding, harvesting; marketing. In order to reduce labor cost, many households practically conducted all the production activities themselves. All the yam farmers interviewed still used traditional farming

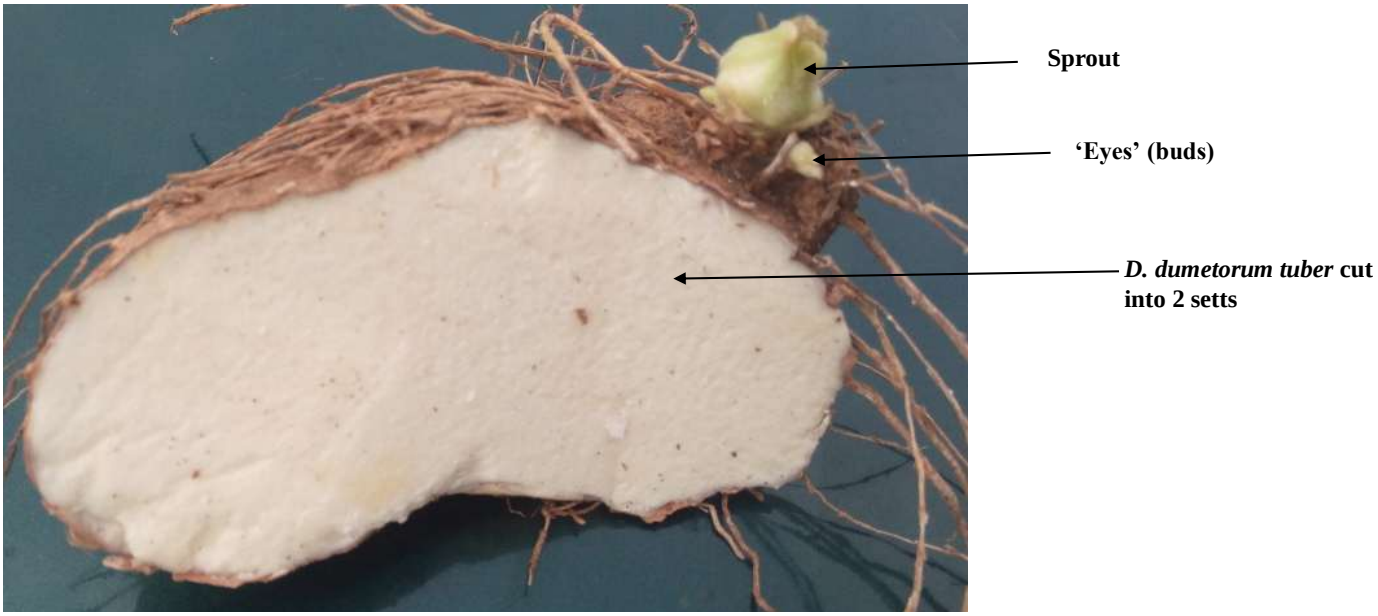

Figure 3. Large tuber cut into two pieces (setts) with 2 'eyes' (buds) to ensure good sprouting.

tools and methods such as hand hoes, axes, woods and cutlasses for most farm related activities mostly.

Tuber planting and field management

In the whole growing area, land preparation included two major activities: bush cleaning and mounding. Mounds are prepared after clearing from early December to about mid-March. These operations were completed before the major rains. Farmers depended largely on hoe-cutlass labor.

Planting was done manually on medium hills (87%) by soiling tuber seeds with the hoe in the South and the daba in the Center and North. Traditional method of seed production included the harvesting of small tubers and cutting large tubers into small sett. The tuber seeds were selected usually after the dormancy was broken (that is 2-3 months after harvest).

At the end of dormancy period the tubers produce eyes' (buds) where sprouts emerge at the proximal region of the tubers. But some tuber seeds have tendency to develop multiple sprouts (Figure 3) and the farmers cut them into pieces (setts) if they are large, ensuring that each sett has 'eyes' (buds) that can produce good sprouts. The small tubers are not marketable, hence these are used as direct planting material.

Planting methods

Trifoliate yam is an under-demanding plant, requiring no specific input, mainly grown in the field (92%) on sandy soil, clay soil and sandy loamy soils. Farmers preferred soft, non-stony soils because stones cause deformation on the tubers. Slightly above 72% of the farmers interviewed obtained the land for *D. dumetorum* by inheritance while 28 % of respondents leased or rented the land. In the whole study area, no fertilizers or pesticides were used specifically for the yam crop cultivation, although the yam crop profited from the pesticides and fertilizers applied in the other mixed associated crops. Only 12% of the respondents indicated that they applied herbicide for weed control in the whole farm. One day before planting, some producers of center and northern region, (10.2%) treated the seed with wood ash to avoid mouse's and rat attack. The setts were planted with the cut face facing up at an interval of 90 cm to 1.5 m.

Planting is done at flat (Figure 4D) in southern region, at the bottom of charred trees or at the bottom of other large mound of yam in the north (Figure 4A) or in small to middle sized mounds in southern and central part (Figure 4B). After planting, a cushion of harsh grass is put at the top of the mound to avoid its drying out when sprout emerges.

For the majority of farmers interviewed, the first rains signaled the start of planting season. However, late planting after raining season established was done by some farmers. In this case, sprouts give already stem before planting (Figure 4C).

Perception on planting and harvesting time of *D. dumetorum*

The perception of the farmers in the studied area revealed that most of farmers grow *D. dumetorum* in April

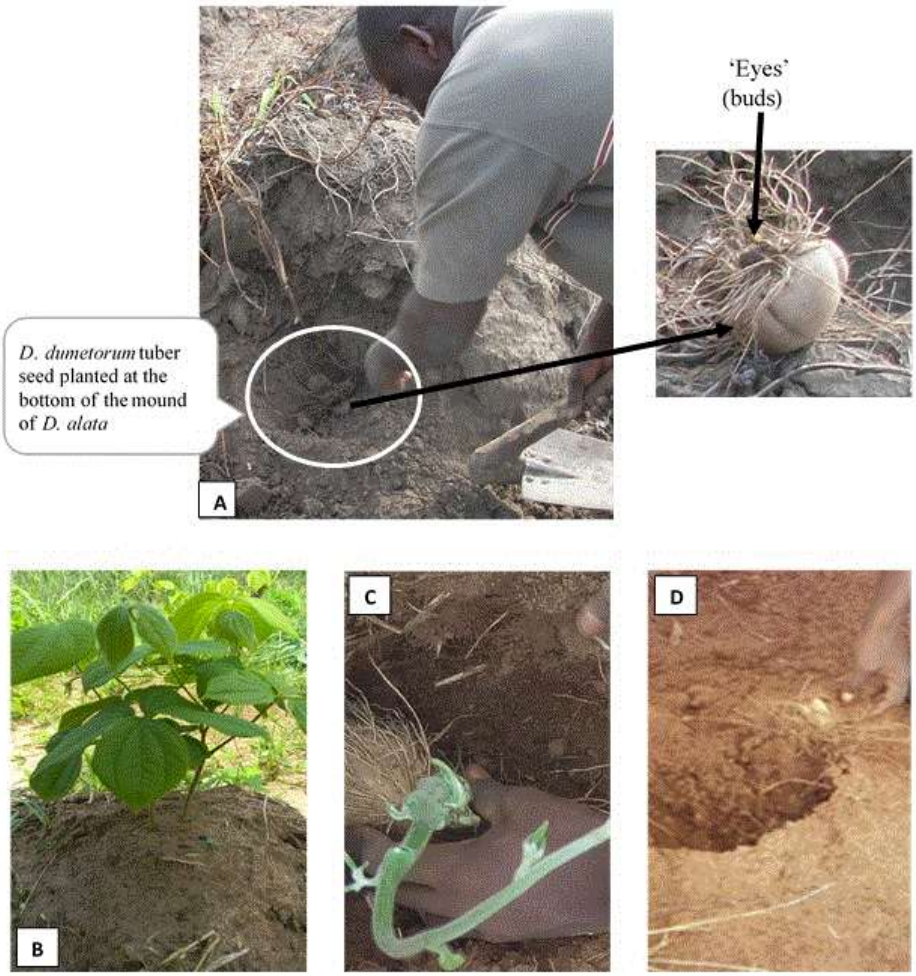

Figure 4: Planting system of *D. dumetorum*. **A:** Planting at the bottom of *D. alata* mound in Northern region; **B***:* Planting in small mound in central region; **C:** Late planting after end of dormancy; **D:** Planting in flat in southern region.

(41.98%) and May (49.91%). Majority of farmers harvest fresh tubers in December (38.55%) and January (30.27%), while 12.07 and 10.09% of the farmers harvest in November and February respectively (Figure 5). Priming/selective (i.e. early) harvesting is done in October (4.5 %) and latest harvesting is done in March. We notice that the white cultivar which is planted at the beginning of the rainy season is harvested first in August (1.1%) or September (1.44%).

Cropping system

The results reveal that 89.86% of farmers cultivated their trifoliate yam in farms far away from the place of residence while 10.14% cultivated around their residence (home gardens) through four main cropping systems. Monoculture, crop-rotation, crop-association or direct planting in home gardens are the main system practiced by farmers in the diverse agro-ecological areas surveyed. Their importance varied across the agro-ecological zones (Figure 6). Indeed, crop association was the main cropping systems identified across all the agro-ecological zones and the only one used in the Zones III and IV. This was followed by crop rotation detected in the Zones V, VI, VII and VIII, and the monoculture present in these areas but more in the Zone V. Finally, the home gardens production of yam was found less practiced, only in the agro-ecological Zones VIII and VI. It was also found to be less costly by farmers. Farm production, practiced nonetheless by the majority of producers far away from their home, incurred considerable production costs because of transportation expenses, seeds and other agricultural inputs, as well as marketing costs. This could also lead to poor management of the farm in terms of timely and proper execution of routine activities like weeding, pests and diseases control in the farm.

Among the producers surveyed, crop association with other crops was practiced by 50.53% and monoculture of *D. dumetorum* was practiced by 20.47% of producers.

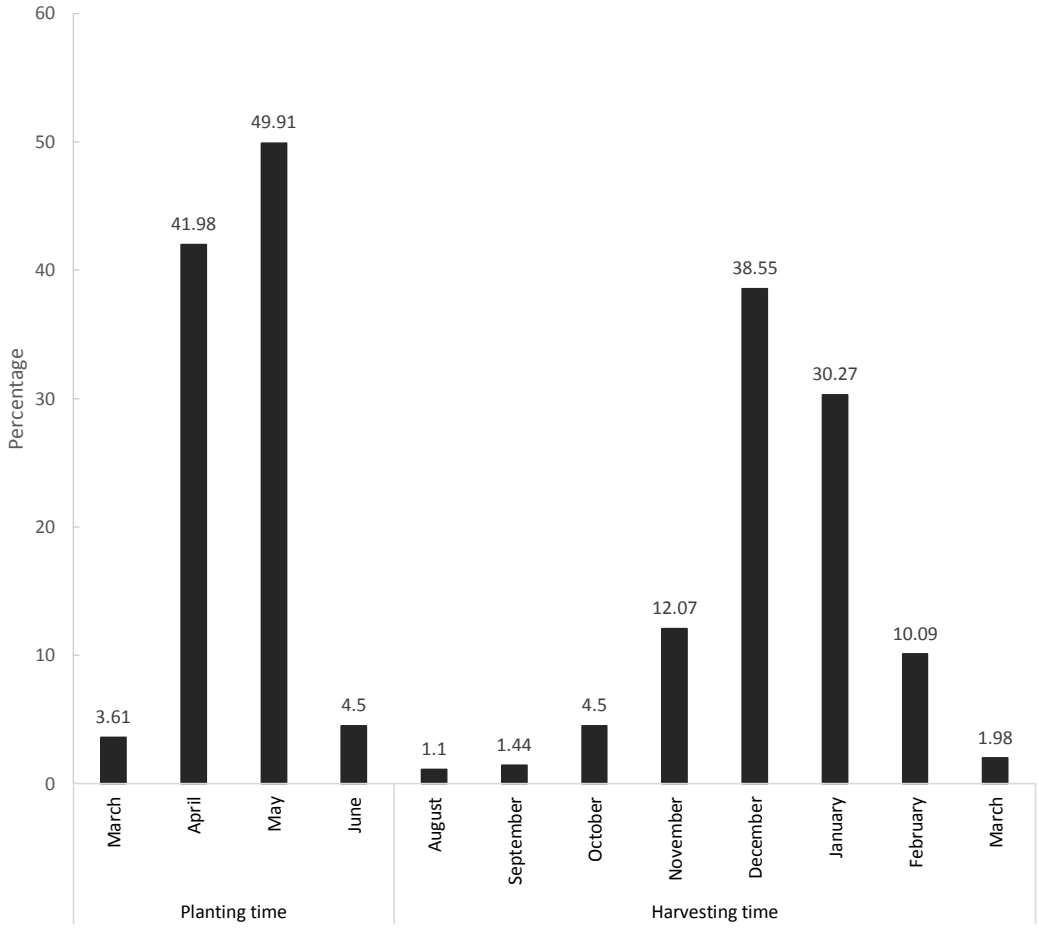

Figure 5. Distribution of 555 respondents interviewed based on time of planting and harvesting of *D. dumetorum.*

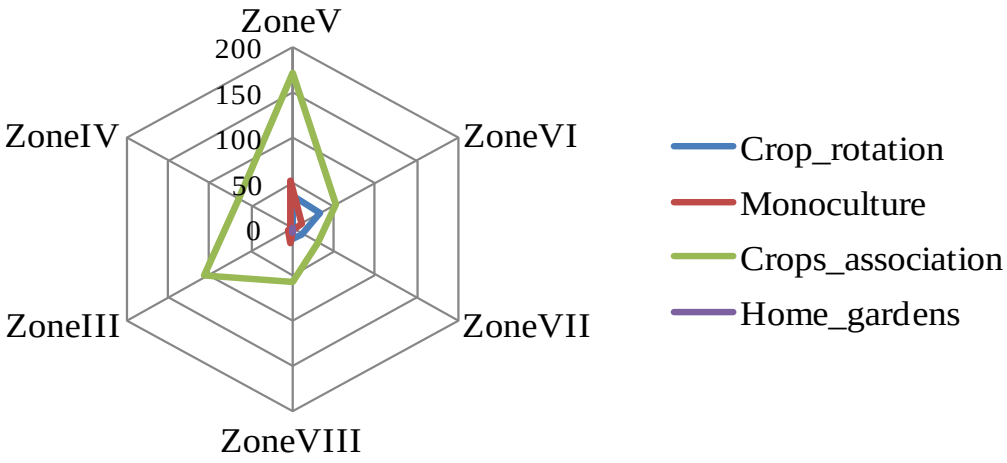

Figure 6. Importance of cropping systems of D. dumetorum in the agro-ecological zones surveyed in Benin.

Some people adopted only crop rotation (18.86); the minority (elders and some women's) practices either home garden cultivation (10.14%). Crop rotation consisted to an alternation of crops in the field one year to another. Crop association or mixed/multiple cropping involves growing two or more crops on the same piece of

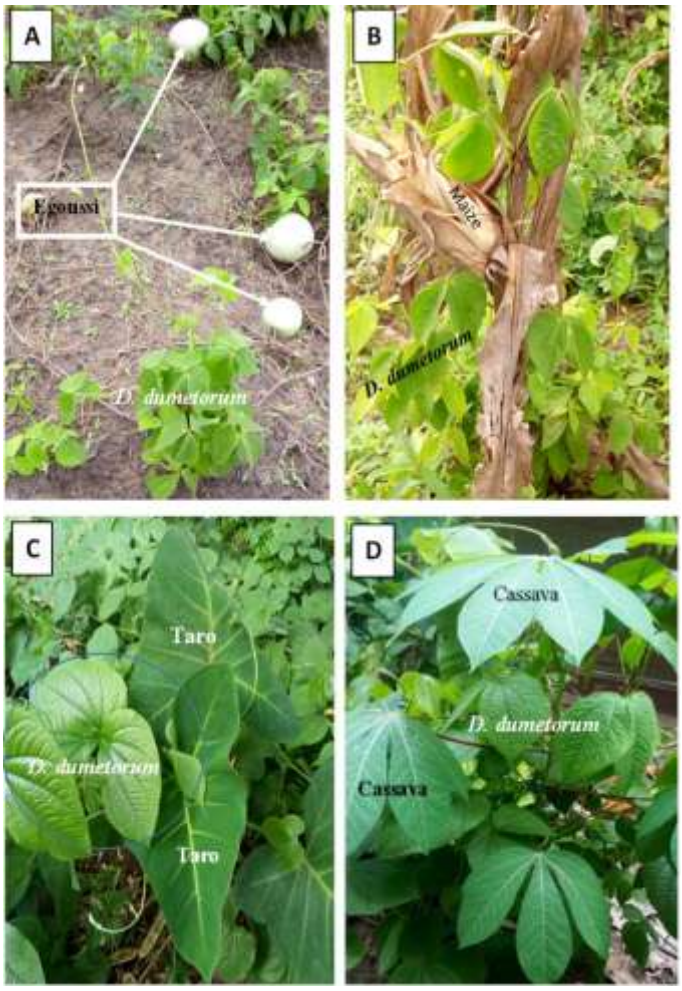

Figure 7. *D. dumetorum* cropping system in Benin showing different associations with (A) Egoussi, (B) maize, (C) Taro and (D) cassava.

land and at the same time.

In northern region, crop association was commonly practiced with *D. dumetorum* grown with cereals like *Zea mays* (Figure 7B), *Sorghum bicolor* (sorghum), *Pennisetum glaucum* (millet). The results of the survey also pointed out that the advantage of association with cereals was that they acted as stake for *D. dumetorum* plants. This avoids destroying farm trees used as stake. Besides, *D. dumetorum* was also intercropped with legumes (pepper, okra, cowpea, tomato, pigeon pea, peanut, etc) in home gardens (Figure 7A) or with other tubers and root crops such as *Manihot esculentus,* yams (*Dioscorea.* spp) and taro (Figure 7C, D). In humid zones like Ouémé valley, *D. dumetorum* was planted in intercropping systems with banana, plantain (*Musa* spp.), vegetables and maize (*Zea Mays*).

It is important to note here that despites the fact that producers need stakes for *D. dumetorum* tubers, they leave these trees in their fields mainly because of their cultural and economic importance. The trees found in the *D. dumetorum* fields are: *Parkia biglobosa* (21.14%), *Vitellaria paradoxa* (20.30%), *Pterocarpus erinaceus* (5.20%), *Anogessus leiocarpa* (3.90%), *Anacardium occidentale* (2.67%), *Khaya senegalensis* (2.37%), *Borassus aethiopum* (1.55%) in center and northern regions. In southern, we found essentially *Eleais guineensis*, *manguifera indica and Tectona grandis*. In monoculture, the density of *D. dumetorum* was on average 10,175 plants per hectare according to the measurements taken in some fields.

Field maintenance and harvesting

In order to facilitate the good growth of plants, field maintenance is done and consists of weeding at varying frequencies according to the producers. The majority of the producers (43%) weeded their fields as needed, on the other hand, 31% weeded their fields at least twice a year, 14% 3 to 4 times and only 12% clean it 4 to 6 times. After weeding, crop residues are often removed from the fields or burned. According to producers, late weeding promoted weed growth and induced yield reduction. During the wet season, the first stage of vegetative growth of vine extension and flowering takes place. During the dry season, most aerial growth stops and the nutrients are moved to the tuber, which grows before entering into a dormant state.

Yellowing and drying of leaves, petioles and stems announce the maturity of the tubers in the plant. The harvest was carried out by farmers during the dry season often during the months of December and January for yellow cultivars. For white cultivars, however, sown in March just after the first rains, the harvest is usually during August and September. However, the market price of yam tuber is the lowest in this period. Most of farmers (87%) recognize pests and diseases on *D. dumetorum* in cultivation. However, few producers (13%) reported that these attacks did not have any great effect on the yield of the crop. Decrease of yield can be attributed to harvesting and postharvest management. Harvesting should be done on time not late to avoid termites and rats attacks on tubers (Figure 8). Damage occurs in tubers in form of internal injury and lesions that permit entrance of pathogens and other pest. According to the farmers, late harvest also promoted tubers' sprouts causing tuber hardening and rendering them unfit for consumption.

Postharvest management of *D. dumetorum* tubers in the agro-ecological zones

Producers used several indigenous methods or strategies planned to protect tubers from sunshine, heat, humidity, and destructive animals (termites and rodents in particular). The principal component analysis based on the quotation frequency of storage approaches or strategies (Figure 10) revealed 80.97 % variability among the agro-ecological zones. Traditional storage approaches of tubers included the use of basket, garret,

Figure 8. Termites' damages on *D. dumetorum* tubers caused by late harvesting.

Figure 9. Post harvest storage approaches at home and in field: (a) Tubers in dig in the field and covered with branch and (b) Storage at home.

straw hut, bag, shade, hole and pile. Storage in pile consisted to gather the harvested tubers in mound, in shady place to protect them from sun and flooding. The mound had middle size to favor ventilation and airing (Figure 9). Other producers assembled the tubers in a ditch dug in the fields and covered them with fallen branches and soil.

The farmers in agro-ecological Zone III used mostly garret, straw hut, bag and pile for storing harvested *D. dumetorum* tubers. In addition to these latter, farmers in the agro-ecological Zone V used two other approaches such as shade and hole to conserve tubers.

Farmers living in agro-ecological Zone VIII conserved more *D. dumetorum* tubers in garret and straw hut. Storage strategies such as the use of shade, hole and pile tools were highly practiced in agro-ecological Zone IV (Figure 10) while the basket was mainly used in the agro-ecological Zone VI. In the agro-ecological Zone VII, garret and straw hut were slightly used by farmers. *D. dumetorum* tubers storage strategies aim to maintain food security by the storage of tubers for self-consumption, tuber sale and use as seed. Despites these diverse strategies developed, farmers reported that they still faced insects (termites, ants) and vermin (rats; mole)

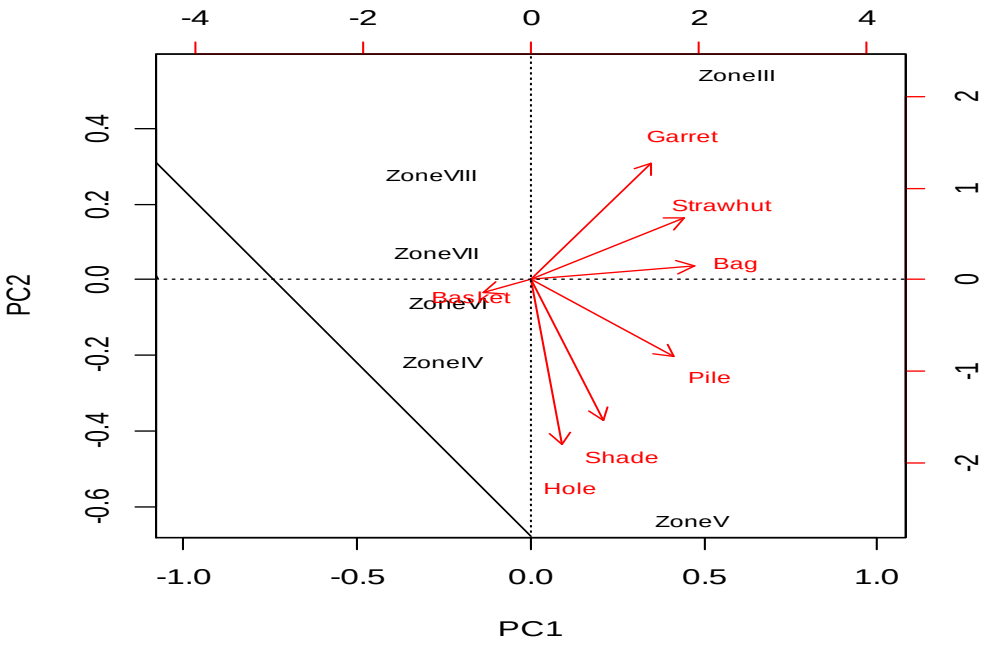

Figure 10. Biplot diagram from principal component analysis showing the distribution of storage approaches of *D. Dumetorum* tubers used by farmers following agro-ecological zones in Benin.

Figure 11. Rats damage on tubers by eating the flesh (affect germination).

damage on the tubers in storage (Figure 11).

Insects and rats were said to damage tubers by eating the flesh that could adversely affect germination. To control pest damages, producers used natural ash or traded rat poison. Fresh tubers storage was for one day to one week for white cultivar and one week to three months for yellow cultivars, depending on the harvest time, the maturity status and the way the harvesting avoid the wounding of the tubers. At the start of rain, dormancy of the tubers is broken and begins to germinate. By systematically removing sprouts when they appear, producers extend storage of tubers for home consumption. But with this method, the skin of the tubers becomes hard and wrinkled and they gradually lose their culinary value. Producers were aware of post-harvest hardening phenomenon on tubers (Figure 12).

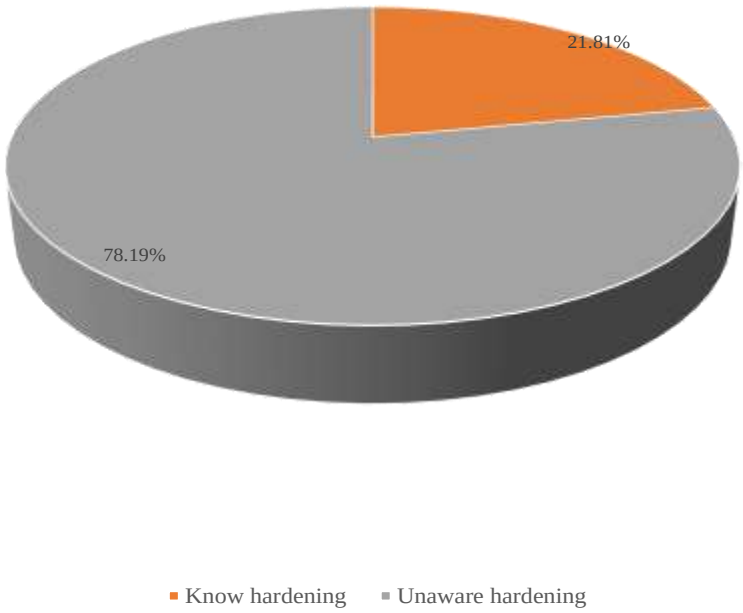

Figure 12. Awareness on tubers hardening after harvest.

In the study area, 21.81% producers knew the hardening phenomenon. In this proportion, 7% were aware on the hardening phenomenon without having specific knowledge on it. According to 34% of producers, early harvest, damage and wounded the tubers during harvest (20%) induced hardening of tubers. Sprouting of tubers (14%), long duration of storage (10%), storage without soil (9%) were the principal reasons advocated by the farmers for the hardening phenomenon. Only 5% of producers claimed that color of cultivar determined hardening as the white cultivars become hard earlier than the yellow ones (Figure 13).

Gender role in *Dioscorea dumetorum* production in Benin

In total, eleven activities were performed in *D. dumetorum* production throughout the agro-ecological zones surveyed in Benin. These were field cleaning, threshing, ploughing, mounds making, tuber seed preparation, planting, weeding, harvesting, transport, storage, marketing and sale. *D. dumetorum* like other yam is labor intensive and in order to cut labor cost, most family members practically did all the production activities themselves. Men, women and a few children performed production activities.

The results of factorial correspondence analysis on diverse activities related to *D. dumetorum* in relation to gender in the agro-ecological areas revealed that the trees principal components must be used to cover a full view of distribution pattern of gender activities among the agro-ecological zones (Tables 2 and 3).

The criteria that contributions Ci are C≥10% on an axis are those which contributed to the formation of this axis and are represented on the axis only if their Cosinus^2 is ≥0.30 (all values in bold in the table)

The simultaneous analysis of the distribution pattern of activities (Figures 14 and 15) based on the contribution and representativeness of activities and gender (Tables 2 and 3) revealed gender activities gradient with the first axis. The criteria that contributions Ci are C≥10% on an axis are those which contributed to the formation of this axis and are represented on the axis only if their Cosinus^2 is ≥0.30 (all values in bold in the table). The females are characterized by low intensity of activities and separated by the males more and diverse hand workers (Figures 1 and 2). Female are not or are low involved in clearing, mount and threshing. All of the activities are practiced by the male in the communities at diverse degrees (Figures 14 and 15).

Major constraints on *D. dumetorum* production in Benin

A diverse range of constraints impede *D. dumetorum* production and productivity (Figure 16). Based on farmer's responses and perceptions, seven (7) biotic and abiotic constraints hampering *D. dumetorum* production in agro-ecological zones of Benin were identified. These were the susceptibility to insect attacked (termites) in storage or in late harvesting, the frequent occurrence of drought in sprouting time, the inability of *D. dumetorum* tubers to be pounded, the rodent attack in storage, the presence of roots on tubers, the poor organization of market, hardening in storage. Their importance varied among agro-ecologies.

Analysis of the barplot (Figure 16) showed that all of the constraints recorded occurred in the agro-ecological

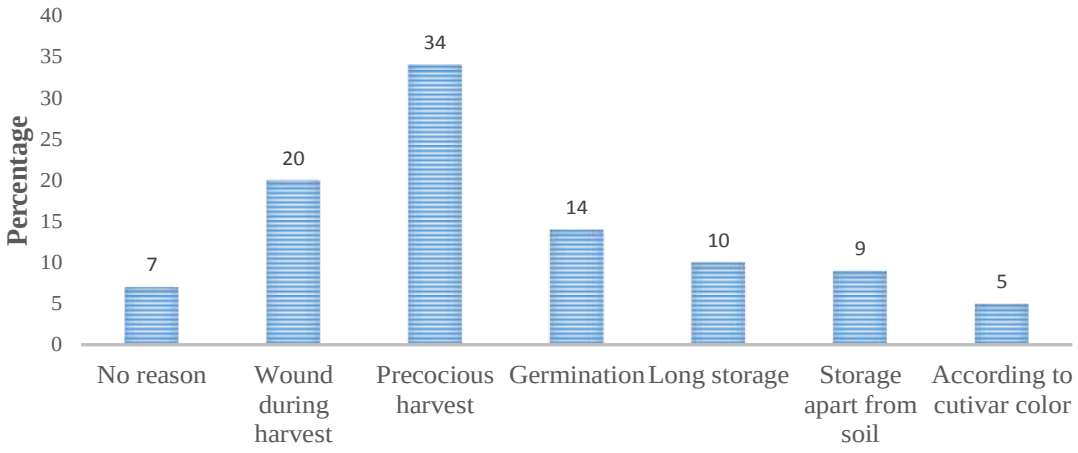

Figure 13. Famers' perceptions on hardening after harvest.

Table 2. Contributions of activities to the formation of the axes and their representativeness.

Activities	Contributions			Representativeness		
	Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3
Clearing	**49.40**	4.63	1.76	**0.96**	0.02	0.00
Threshing	0.30	**24.70**	28.85	0.03	0.65	0.25
Ploughing	0.94	**14.15**	15.64	0.14	0.49	0.18
Mounds	**27.67**	**22.97**	6.63	0.81	0.16	0.02
Seeds	3.69	0.97	9.88	0.71	0.05	0.15
Planting	2.95	2.51	4.96	0.62	0.13	0.08
Weeding	2.74	1.33	1.73	0.78	0.09	0.04
Harvesting	3.38	4.19	0.01	0.72	0.22	0.00
Transport	0.51	0.03	4.80	0.41	0.01	0.31
Conservation	0.84	0.49	8.60	0.39	0.05	0.32
Sale	7.58	**24.04**	17.14	0.48	0.37	0.09

Table 3. Contributions of gender and agro-ecological zones to the formation of the axes and their representativeness.

Gender	Contributions			Representativeness		
	Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3
FIV	2.55	0.08	5.05	0.76	0.01	0.12
FV	**48.25**	6.05	2.88	0.96	0.03	0.00
FVI	**13.82**	0.21	9.30	0.91	0.00	0.05
FVIII	**15.84**	2.14	3.64	0.90	0.03	0.02
MIII	0.01	**17.85**	36.26	0.00	0.58	0.39
MIV	0.01	**11.13**	0.04	0.00	0.83	0.00
MV	3.31	2.90	31.64	0.48	0.10	0.37
MVI	5.42	**44.47**	1.91	0.32	0.64	0.01
MVII	6.83	**12.23**	6.98	0.55	0.24	0.05
MVIII	3.98	2.93	2.30	0.66	0.12	0.03

production areas V followed by the agro-ecological production areas III (85.71% of the constraints), the agro-ecological production areas IV (85.71% of the constraints) and the agro-ecological production areas VII (57.14% of the constraints). *D. dumetorum* production was less threatened in the agro-ecological production areas VI. The

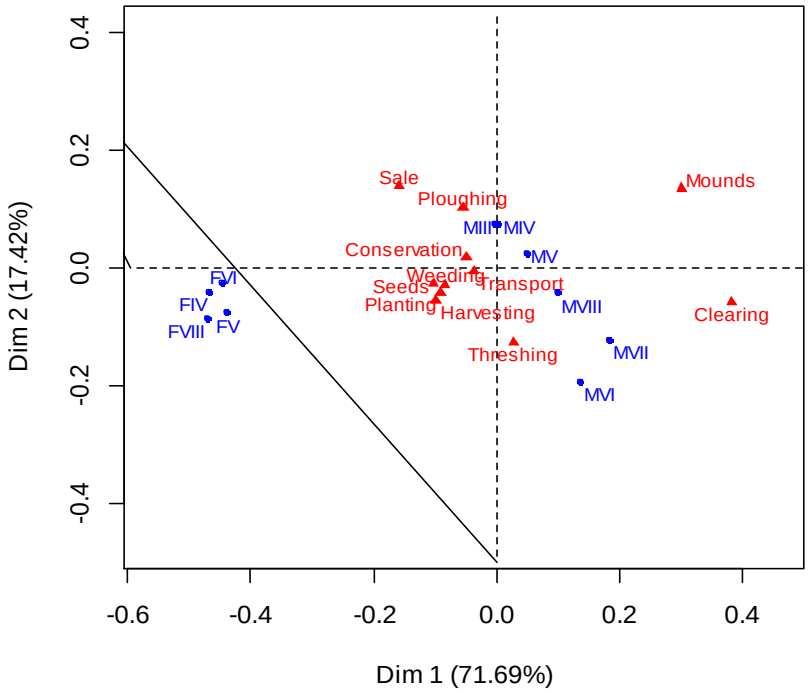

Figure 14. Simultaneous representation of gender role and agro-ecological zones using the first two factorial axes.

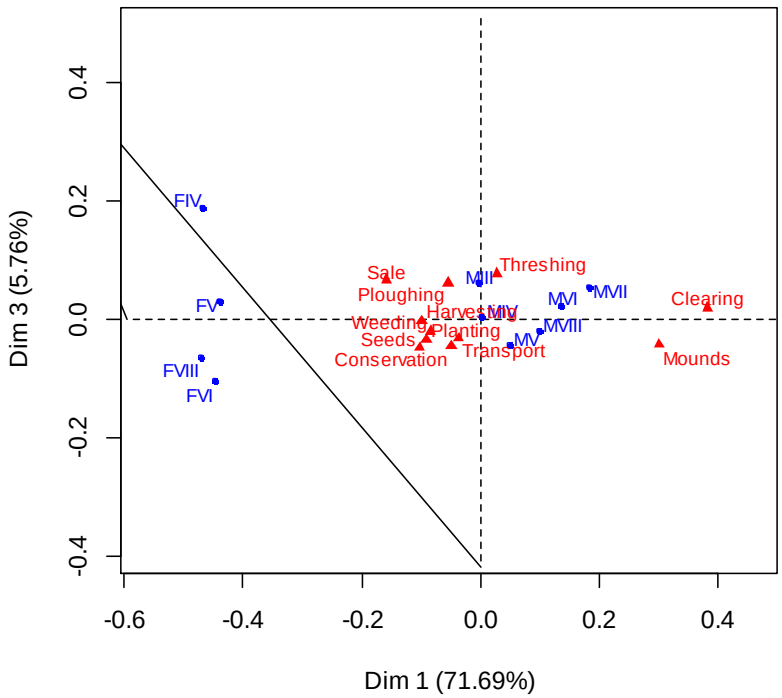

Figure 15. Simultaneous representation of gender role and agro-ecological zones using the first and the third factorial axes.

constraints most recognized in the agro-ecological production areas V were inability of the tuber to be pound, hardening in storage, poor organization of the markets and rot on tubers. Inadaptability to pound, poor organization of the markets, hardening in storage, rodent attack, drought and insect damages were the main

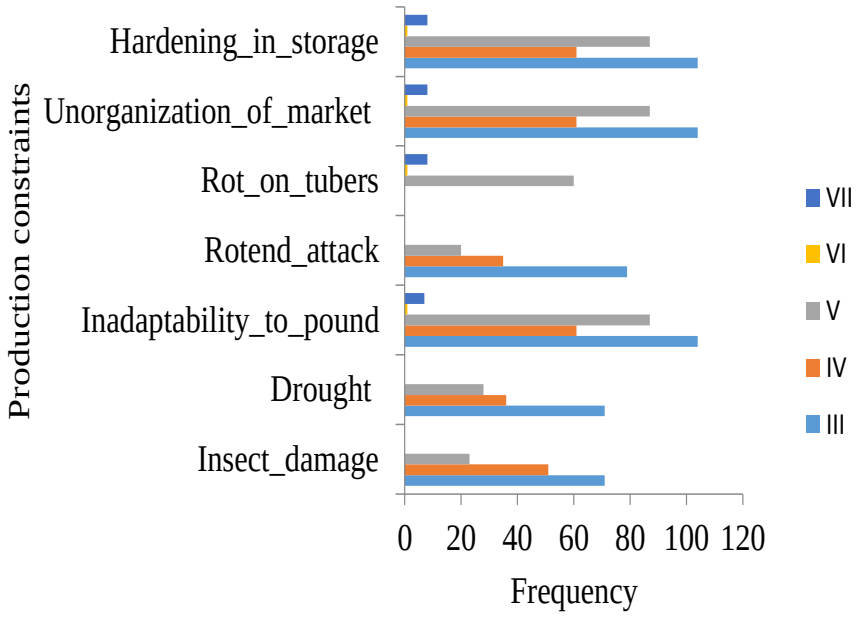

Figure 16. Distribution pattern of constraints linked to the production of *D. dumetorum* throughout agro-ecological zones.

constraints in the agro-ecological production areas III while it was Inadaptability to pound, hardening in storage, poor organization of the markets, insect damages, rodent attack and drought the main constraints in the agro-ecological production areas IV.

DISCUSSION

In this study, we investigated the cultivation and post-harvest practices, constraints affecting the production and described gender role in *D. dumetorum* production in Benin. The results of the assessment of its production system revealed that it remained traditional and we have specified activities according to gender. The species was globally produced in southern, central and northern parts of Benin.

The results imply that most of the *D. dumetorum* farmers in Benin are ageing (88%) while the young people were less involved in *D. dumetorum* cultivation. As explained previously in Adigoun-Akotègnon *et al*. (2019), the majority of farmers involved in *D. dumetorum* cultivation was aged people. This finding confirms previous observation by Ukpabi (2015) in Nigeria who showed that young Nigerian farmers, especially in the northern states, regarded *D. dumetorum* crop as a source of food only for their aged parents or grand-parents.

In addition, this can be an indication of a rural-urban migration of the young people as evidence elsewhere in many rural areas of sub-Sahara Africa (Winrock, 1992). This migration of youths from rural to urban zone negatively affects farming labor. The findings are partly consistent with those obtained by Luka and Yahaya (2012), who noted the 31 to 40 years' age bracket are actively involved in agriculture.

The result that 84% of producers were male is consistent with Adigoun-Akotègnon *et al.* (2019), Laly *et al.* (2019) and Dansi *et al.* (2012) which stated that the production of *D. dumetorum* is essentially done by male. Male dominance in *D. dumetorum* production could be attributed to the fact that this yam was considered mainly as a man's crop because of the need for strong labor, in addition to women having limited access to farming resources. These findings are in agreement with the results observed by Dansi *et al.* (2003) in the complex *D. cayenensis* to *D. rotoundata.*

The production of *D. dumetorum* cultivars is of varying importance depending on the agro-ecological zones. The results of Kruskal-Wallis test showed highly significant differences among the importance of *D. dumetorum* cultivars in cultivation within the agro-ecological zones, highlighting its importance in each zone. Yellow cultivar was largely the most quantitatively produced variety than white and pale yellow cultivars through all the agro-ecological zones, mainly in the agro-ecological zones VIII, VII, VI and V with an average of cultivated land of 3.55, 3.41, 2.92 and 2.49 ha, respectively. The study revealed that pale yellow cultivar is produced mainly in the zone VI, VIII and V on relatively small areas with an average land of 0.07 ha, 0.04 ha and 0.02 ha, respectively. According to Laly *et al.* (2019), *D. dumetorum* was found in association with other crops and on very small areas ranging from 0.0035 to 0.1159 ha with an average of 0.0514 ha in central and northern region of Benin.

Concerning planting methods, the results indicate that

most farmers grow *D. dumetorum* in April/May and harvest in December/January. The information obtained will help probable development program which want to involved in seed supply systems for the timely distribution of planting materials. Also, finding on time of harvesting will serve as a guide for research activities such as germplasm collection and market studies. According to Mayong *et al.* (1998), in western Nigeria, planting of yam by most of the farmer's begin in March and April after the first rain.

D. dumetorum production like other yam (bush clearing, mounding; staking, weeding, harvesting; marketing) is labor intensive and in order to cut labor cost, most family members practically do all the production activities themselves. This finding is also observed in Nigeria where over 65% of smallholder farmers used family labor in yam plantation (Ike and Inoni, 2006; Okeoghene *et al.*, 2013). All the smallholder yam farmers interviewed still used traditional farming methods such as hand hoes, axes, woods and cutlasses for farm related activities mostly like other yam producers in developing countries like Nigeria, Ghana, Cote d'Ivoire, Benin and Togo (Verter and Bečvařova, 2015).

In *D. dumetorum* production activity, four main cropping systems like monoculture, crop-rotation, crop-association or direct planting in home gardens are the main system practiced by farmers in the diverse agro-ecological areas surveyed. The types of association observed are numerous and varied according to the number of species in association with *D. dumetorum*. According to farmers, resorting to multiple cropping system guards against crop failure in such a manner that when a crop fails another one may not fail. Referring to Fu *et al.* (2011), most of farmers of central Nigeria adopted intercropping and mixed cropping for yam cultivation. According to Iwuchukwu and Okwor (2017), when the right crop combination is made in mixed/multiple cropping, it leads to an improvement in the fertility of the soil and increase in crop yield because the products and waste from one crop help in the growth of the other crop and vice-versa.

Producers surveyed pointed out that the advantage of association with cereals, cassava, okra as these crops act as stake for *D. dumetorum,* thus avoiding cutting of trees. These findings are in agreement with the results obtained by Oyolu (1982) and Baco (2007). According to these authors, the direct advantage farmers have by using productive stake is augmentation of profit margins. On the one hand, according to (Trèche, 1989; Agbor-Egbe and Trèche, 1995), staking is necessary for *D. dumetorum* but is not obligatory. From point of view of farmers, presence or absence of stake didn't affect the yield. Staking has been considered to increase cost of yam production and reduces the profit margins of farmers engaged in yam production (Bassey 2017). Staking is also time consuming and labor intensive (Tomothy and Bassey, 2009). Promotion of *D. dumetorum* like non-stake yam could encourage more farmers to produced *D. dumetorum* (Timothy and Bassey, 2009), thereby increasing total tuber yield.

On the other hand, although the fact that some producers used stakes for *D. dumetorum* tubers, they leave some trees in their fields because of their cultural and economic importance. This system of production using cover plant and trees is a way to install durable agriculture and agroforestry for better production like Baco (2007) observed it in yam production area in Northern Benin. According to this author, this kind of association gives to women's especially cash for family daily economy.

In the field management, a good maintenance is essential. Field maintenance is done by weeding. After the weeding, majority of producers collect crop residues. They are often removed from the fields or burned, contributing to negative nutrient balances (Stoorvogel *et al.* 1993). These practices expose the soil to erosion, nutrient and organic matter leaching, natural resource degradations and decreasing soil microbial diversity (Cardoso and Kuyper, 2006), leading to soil degradation (Salako *et al*. 2007). With increasing demographic pressure, land use intensity and reducing forest cover areas, suitable land for yam cultivation becomes gradually scarcer (Carsky *et al.*, 2001). Furthermore, fallow periods become shorter and most farmers increasingly cultivate yam without any fallow. It is scientifically known that yams in general require rich; fertile soils with high organic matter content (Carsky *et al*., 2001; O'Sulllivan and Jenner, 2006; Loko *et al.*, 2013) but *D. dumetorum* tolerate better poor soils and producers use yam to grow in marginal soils. But this can affect the general production because one major constraint highlighted for its contribution to declining yam productivity is soil fertility degradation, due to nutrient depletion by leaching, erosion and the loss of organic matter from most soils in West Africa (Schlecht *et al.*, 2006).

Some studies (Ayanwuyi *et al*., 2011; Kleih *et al*., 2012), stressed that low soil fertility, high cost of labor and lack of finance to carry out necessary farming activities were some constraints to yam productivity in Nigeria. Yam is prone to infection by various diseases from the seedling stage to harvest (field diseases) and during storage (storage diseases) (Amusa *et al*., 2003). According to farmers survey and based on our individual observation, during the growth period, many pathogenic diseases have been found associated with *D. dumetorum*. One of biological issue we found in this survey is the susceptibility to insect attacked (termites) in late harvesting and rat and mouse in storage period.

In addition to be largely neglected, yellow yam production was also subjected to many constraints in southern central and northern Benin. Based on farmer's responses and perceptions, seven (7) biotic and abiotic constraints hampering *D. dumetorum* production in agro-ecological zones of Benin were identified. These were susceptibility to insect attacked (termites) in storage or in late harvesting, the frequent occurrence of drought in

sprouting time, the inability to be pounded, the rodent attack in storage, the presence of roots on *D. dumetorum* tubers, the poor organization of market and hardening in storage.

According to Laly *et al.* (2019), in northern and central part of Benin, *D. dumetorum* production is faced with many constraints divided into two categories: biological constraints (termite tuber attack was the most important followed by those as centipedes and rodents) and non-biological constraints (the slump in sales, lack of the flow markets, long cycle of production and the maladjustment of any landraces listed to crushed yam, chop and stew.
These findings are in agreement with the results of observed by Dansi *et al.* (2003) in the complex *D. cayenensis - D. rotoundata*.

According to Albert and Emodi (2015), lack of capital, insect's infection and flooding were the major constraints to bitter yam production on Rivers State in Nigeria. In Nigeria, some of the constraints to yam production are unavailability of planting materials, soil degradation, poor handling and storability, pest and disease and other environmental factors (Ibitoye and Attah, 2012). Laly *et al.* (2019) found eleven (11) storage methods in parts of central and southern regions.

CONCLUSION

This study presents the current practices and has contributed to a better understanding of cultivation techniques, the different constraints the producers face in the cultivation of *D. dumetorum* in Benin. The result revealed that *D. dumetorum* production is facing various constraints. It was found that the two major constraint limiting yam production in the region was poor organization of market and the hardening phenomenon in storage. According to the producers, of *D. dumetorum*, cultivars in Benin present many undesirable characteristics such as the roots on tubers and the inadaptability to pound. The species cultivation practice remains traditional and is mainly cultivated in association with other crops. Appropriate strategies and policies need to be urgently developed to improve *D. dumetorum* farming system and organize its production.

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