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Diversity in agricultural practices among smallholder plantain-based farms across the Guineo-Gongolean zone of Benin Republic

Euloge Codjo Togbé [a], Fanou Alain Ahohouendo [a,*], Alphonsine Agbalè Badou [a], Sylvain Kpènavoun Chogou [b], Bonaventure Cohovi Ahohuendo [a]

[a] *Laboratory of Plant Biology, School of Crop Sciences, Faculty of Agronomic Sciences, University of Abomey-Calavi, Benin*
[b] *Laboratory of Poverty and Performance Studies of Agriculture, Faculty of Agronomic Sciences, University of Abomey-Calavi, Benin*

Abstract

Understanding diversity in agricultural practices of plantain (*Musa* AAB) cultivation is crucial for recommendations to increase yield and food security. Whereas in Benin, the diversity of agricultural practices among smallholder plantain-based farms in banana production areas is tittle characterised and information on the subject is less available and little disseminated. The purpose of this study was to identify existing diversity in plantain cultivation among smallholder farms. The study was carried out in five municipalities (Adja-Ouèrè, Athiémé, Tori-Bossito, Ouinhi and Zè) in the Benin Republic. Data were collected from 432 farmers through interviews targeting characteristics that evidenced differences in agricultural practices. The majority of farmers (96 %) grew native varieties while the remaining used imported ones. Suckers were supplied from their own plantations (36 %) or from neighbours for free (60 %) or purchase from fellow farmers (4 %). Intercropping was practiced by 66 % of the farmers with plantain-taro being the dominant practice (26 %). De-leafing, de-suckering and staking practices were respectively applied by 7 %, 6 % and 62 % of the respondents. Watering during dry weather was not a common practice in the study areas, while manure and/or mineral fertiliser was applied by 19 % of the farmers. Almost half of the respondents (45.8 %) were aware of the physical changes and damages on plantain tree, but did not relate those changes to the symptoms of pests and diseases. Strategies for controlling those pests and diseases were applied by only 4 % of the respondents, and entailed application of synthetic pesticides or following local practices such as spreading ash. The poor rate of good agricultural practices by the surveyed farmers is an indicator that justifies the low productivity in plantain based systems in Benin. This also makes it possible to design strategies including production of healthy planting materials and the scaling of agroforestry based on fast growing species in order to proper address pest constraints in plantain production.

Keywords: cropping system, farm maintenance, native varieties, *Musa* AAB

1 Introduction

Plantain (*Musa* spp. AAB) is a major food crop grown worldwide in tropical and subtropical regions, mainly by smallholder farmers (Swennen *et al.*, 2013; Quain *et al.*, 2018). The pulp of the fruit is highly nutritious and serves the dual purpose of dietary/nutritional and therapeutic, locally consumed as an important component of the daily diet (Oyeyinka & Afolayan, 2019). Apart from the pulp, the peel, both ripe and unripe, which represents approximately 38 % of the fruit in weight (Agama-Acevedo *et al.*, 2016) similarly, is a phytochemical and nutrient repository (Behiry *et al.*, 2019) with further application as livestock feed and compost (Agama-Acevedo *et al.*, 2016), and in biorefinery for the biogas production (Martínez-Ruano *et al.*, 2018). Other parts of the plant, such as leaf, shoot, root, fruit, seed, inflorescence, and flower, are also receiving scientific attention (Lavanya *et al.*, 2016). The crop has become a significant source of income in rural areas because it can be harvested year round (Dassou *et al.*, 2015). Also, the fruit has been introduced gradually in the daily diet of people countrywide and the intake will increase in the coming years. But, un-

* Corresponding author: a.f.ahohouendo@gmail.com

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like in Ghana, Cameroon and Nigeria (Cauthen *et al.*, 2013; Quain *et al.*, 2018), little research has been conducted on this crop in Benin and most results of research activities are not made public (Chabi *et al.*, 2018). In addition, there is also a lack of political will to support plantain production compared to cotton and maize production (Togbe, 2013). Indeed, plantain is not enlisted among the thirteen flagship crops in Benin's agricultural policy document known as "Plan Stratégique de Relance du Secteur Agricole" (PSRSA, 2011).

The average plantain yield in West and Central African countries is between 5 and 15 $t\,ha^{-1}\,cycle^{-1}$ (Dzomeku *et al.*, 2011). This productivity is far below the attainable yield, which can range between 20 and 30 $t\,ha^{-1}$ on stations under controlled and non-limiting growing conditions (Dépigny *et al.*, 2019). This poor performance is observed in different production systems and is influenced by different agricultural practices, such as the non-application of high quality planting material, the non-renewal of old plants after some years of harvesting, as well as the use of unsuitable landraces or improved cultivars. Some abiotic factors, such as fertiliser, mulching and irrigation; and biotic factors, such as sucker sanitation, diseases and pests, are also identified as undermining the potential of cultivars. Analysing the relevance of those factors for yield formation, Norgrove & Hauser (2014) pointed out the intercropping of having no influence on yield, while others referred to intercropping systems as leading to higher productivity (Martin-Guay *et al.*, 2018). In fact, from an agro-biodiversity agenda point of view intercropping is better than sole cropping, even if sometimes it can lead to a lower yield per unit area production due to poor relative densities. In such a context, a proper, balanced and comprehensive analysis of agro-biodiversity characteristics and productivity is worth investigating.

In West and Central Africa, five common plantain systems have been identified: (i) food intercropping systems, (ii) home garden systems, (iii) mono cropping systems, (iv) plantain-cocoa systems and (v) other agroforestry systems (Akinyemi *et al.*, 2010). These systems differ from each other in the agricultural practices adopted by farmers. Although cocoa is not mostly grown in Benin Republic, similar typology could be found in the Benin context (ECOWAS-SWAC/OECD, 2007). The current study will come up with data that will allow understanding to what extent this typology is applicable to the context of plantain production in Benin Republic. In fact, at the onset of any strategy targeting productivity improvement and in the face of the low performance of plantain production system, it is worthwhile to evaluate how the crop is grown nationwide. To date, no data exist to describe the current agronomic practices in place including fertiliser management, water management, suckers supply and distribution. Those data are crucial to better design interventions in order to improve plantain productivity and enhance food security and livelihoods of farmers involved in its production. This study aims at identifying the existing agricultural practices of plantain in smallholder farms in southern Benin. This location was selected due to the contribution of this area in the total production of plantain in Benin. In fact, plantain production is limited to the southern region of Benin. Overall, this work will conclude on the typology of existing plantain systems in smallholder farms and will draw on possible alignment with the available typology validated at the level of west and central Africa (Sivirihauma *et al.*, 2017).

2 Materials and methods

2.1 Study area

This study was carried out from June to October 2019 in Guineo-Congolean climatic zone located between 1°–2°45' E and 6°30–7°30' N. In the Guineo-Congolean climatic, rainfall is bimodal, with two rainy seasons (April to July and September to November) and two dry seasons (November to March and July to September). The mean annual rainfall varying between 900 mm (west) and 1300 mm (east), with mean annual temperature of 27 °C, and mean relative humidity estimated at 80 % (Houinato & Sinsin, 2002). For this study, five municipalities: Adja-Ouèrè, Athiémé, Ouinhi, Tori-Bossito and Zê were surveyed (Fig. 1). Those municipalities were identified within Avlanto-Benin project as a great plantain production area in Benin.

2.2 Sampling method

Data were collected from a stratified sample of 432 plantain farmers selected within a target population of 2277 farmers (Table 1) identified in five municipalities (Adja-Ouèrè, Athiémé, Ouinhi, Tori-Bossito and Zê). This target population represented all plantain growing farmers living in the surveyed area. Each municipality is composed of many sub-municipalities. A sub-municipality is a location that has a number of plantain growers higher than the average number of farmers per sub-municipality. The spatial distribution showed that there were at least two sub-municipalities that met this condition in each municipality. Thus, two sub-municipalities were chosen at random in each municipality except in the municipality of Ouinhi in which only one sub-municipality met the criterion. Not all growers had the same probability of belonging to this sample. Thus, in order to avoid distortions in the estimates resulting from the survey, exact weighting was used to compensate for the difference

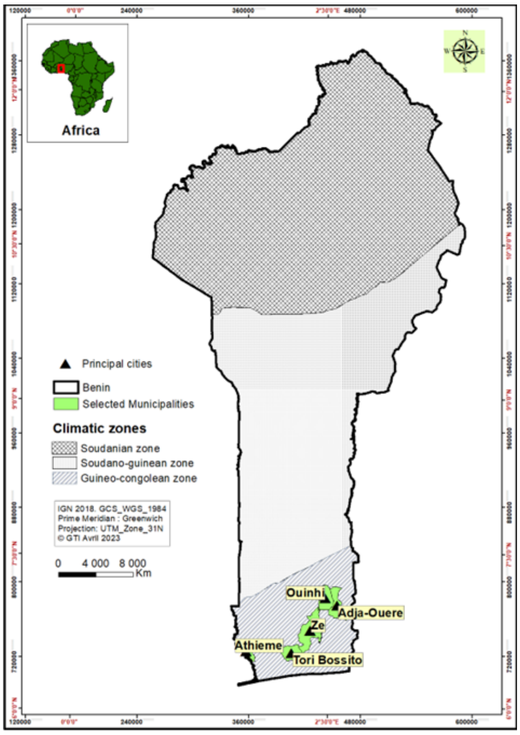

Fig. 1: *Location of study in the Guineo-Gongolean zone of Benin Republic.*

between the sizes of sample identified in the survey. The weight of a selected unit is the inverse of the probability of that unit belonging to the sample (Cochran, 1977). The probability of each selected farmer (Pi) was therefore calculated as:

$$P_i = \left(\frac{2}{NAE_i}\right)\left(\frac{4}{NV_i}\right)\left(\frac{m}{NPV_i}\right)$$

Where i indicates the observation made at the level of the ith farmer, $i = 1, 2, ...,$ n (with n the size of the sample); NAE_i is number of eligible sub-municipalities in the municipality in which farmer i lives; NV_i is the number of villages in the sub-municipality in which farmer i lives; NPV_i is the number of farmers identified in the village where farmer i lives; and m is the number of farmers really surveyed in the village of farmer i. The weight w_i of a selected farmer is the inverse of the probability of this farmer belonging to the sample. Thus, the weighting of farmer i, is given by:

$$w_i = \frac{1}{P_i}$$

For the sum of the weightings to be equal to the sample size, the sample weighting was "normalized". In other words, the weightings were multiplied by the ratio r:

$$r = \frac{NP}{\sum WP}$$

Where NP is the number of farmers surveyed and $\sum WP$ the weightings of all surveyed farmers.

Table 1: *Number of plantain growers interviewed in each municipality.*

Municipality	*Target population (n=2277)**	*Sample (n=432)**
Tori-Bossito	335 (14.7)	96 (22.2)
Zê	486 (21.3)	96 (22.2)
Athiémé	1029 (45.2)	96 (22.2)
Adja-Ouèrè	315 (13.8)	96 (22.2)
Ouinhi	112 (5.0)	48 (11.2)

*% in parentheses.

2.3 Data collection and analysis

Quantitative and qualitative data were collected using mobile phones with a structured open questionnaire using CsPro software. Those data collected included:

1. Cultivar characteristics (type of planting material, origin of planting materials, cultivars grown). Three kinds of cultivars were distinguished: landrace, imported and improved cultivars. Those varieties that were introduced in farming systems and cultivated by farmers since 50 years or more were considered landraces. In contrast, imported varieties were those recently introduced from neighboring countries and disseminated through farmer-to-farmer diffusion mechanisms; improved varieties were those under experimentation in research institutes and farmers' fields.

2. Cropping systems (food intercropping systems, mono cropping systems or other systems).

3. Food crops associated with plantain (taro, maize, cassava...).

4. Plantain farm maintenance (de-suckering, de-leafing, watering, staking).

5. Fertilisation (types of fertiliser applied, number of applications, moment of applying).

6. Farmers' perceptions on pests and diseases management.

Data were analysed using descriptive statistics (percentages and means) related to various agricultural practices across study areas. They were generated using R 3.6.3. All graphs were generated using ggplot2 packages in R.

3 Results

3.1 Cultivars identified in farmers' fields

Sixteen different plantain cultivars were grown by farmers (Table 2). Landraces were produced by nearly all farmers (97.3 %), while imported and improved cultivars were cultivated by 0.8 and 1.9 % of the farmers, respectively. Farmers contended that they have a preference for local cultivars because these are widely known and easily marketable. These landraces had two characteristics in common: yellowish colour of the flesh and high level of sugar. Among improved

Table 2: *Plantain cultivars grown by farmers and percentage of farmers growing each of them in the study area (n=432).*

Cultivar origin	'Fon'*	Farmers cultivating in %†
Landraces	Aloga Alowé	22.5
	Aloga Kowé	23.4
	Aloga Wéwé	2.8
	Aloga Kokolodjo	79.6
	Gnivlan	30.1
	Kpahissi Wéwé	0.5
	Kpahissi Kokolodjo	36.1
	Kpahissi Kowé	0.5
Imported	Orishélé	0.5
	Agbagba	0.5
	Big Ebanga	0.2
	Batard	0.5
	Pélipita	0.2
Improved and imported	FHIA 21	3.2
	L5449	0.2
	Pita 3	0.5

*Socio-linguistic vernacular name of cultivars.
†One farmer can grow more than one cultivar.

and imported cultivars, FHIA 21 appeared to be the most important (3.2 %). Farmers who adopted this cultivar considered that it is very similar to "Aloga Kokolodjo", except that the flesh is not as firm. One to six cultivars were identified in each field, grown either in monoculture or in multi-species systems with other crops. Some farmers (40.7 %) focused only on growing one cultivar, especially "Aloga Kokolodjo" which comes first as cultivated by 92.6 % of this group of farmers, followed by "Kpahissi Kokolodjo" and "Aloga Kowé". Other farmers adopted two cultivars in which "Aloga Kokolodjo" comes always first in terms of number of farmers.

3.2 Planting materials and plantain cropping systems

All interviewed farmers used suckers as planting material (Table 3). These suckers were mainly collected for free from fellow farmers' plantations (59.9 %) or from their own fields (35.8 %). A small amount of planting materials (4.2 %) was purchased by farmers from their peers.

Table 3: *Distribution of type of plantain planting amongst the farmers in the study area (n=432).*

Variable	Material	Farmers applying in %
Type of planting material	Suckers	100
	Macro-propagation plantlets	0
	in-vitro plantlets	0
Origin of planting material	Fellows' farmers gift	59.9
	Own plantation	35.9
	Purchased from fellow farmers	4.2

Three main cropping systems were identified in the plantain fields of the study area: intercropping of plantain with another food crop (65.5 % of interviewed farmers), home gardens system (23.6 %) and mono cropping (10.8 %). Intercropping of plantain with other food crops was practiced in various ways. One practice was that suckers were scattered between the lines of annual food crops where they stood for a second income generating means. Another practice consisted of associating plantain with perennial plants such as oil palm (Elaeis guineensis Jacq.) or annual plants such as taro [Colocasia esculenta (L.) Schott]. In the latter case, plantain density was higher and was used as the main income generating means. Those intercropping systems can integrate a wide diversity of species with limited risk of competition. Densities and modalities of those intercropping systems varied, as well as their functions ranging from technical complementarity in cropping systems (fertility or shade management) to simple plot boundaries. Home garden systems were present around almost every compound, and typically maintained by women. It is one of the oldest production systems, reflecting the traditions and cultural heritage of the communities. It consists of an opportunistic planting of a few suckers in open spaces around the houses where plants benefit from the large amount of nutrients available through small livestock and poultry manure; however, those plants are present in clumps which does not optimise per plant yield, due to competition over space, nutrients and light. In monoculture system, only plantain is grown in rows or scattered on a small plot with sometimes up to four varieties.

3.3 Multi-species systems in plantain production

Plantain is grown under various production systems including intercropping, home garden and monoculture. With regard to intercropping, plantain is associated with many food crops in the same field without no respect to rows and lines. These practices led to small densities sometimes less than 400 plants of plantain per hectare. The number of intercrops associated on the same field varied between one to four. Overall, seven cases (25.9 %) of plantain intercrops with one food crop, twelve cases of plantain intercrops involving two food crops (44.4 %), seven cases of plantain intercrops with three food crops (25.9 %), and only one case (3.8 %) of plantain intercrops with four food crops such as maize, beans, cassava and taro (Fig. 2). The dominant intercropping systems included the association of plantain with one or several annual crops such as taro [*Colocasia esculenta* (L.) Schott], maize (Zea mays L.), cassava (*Manihot esculenta* Crantz), chili pepper (*Capsicum annuum* L.), and common bean (*Phaseolus vulgaris* L.).

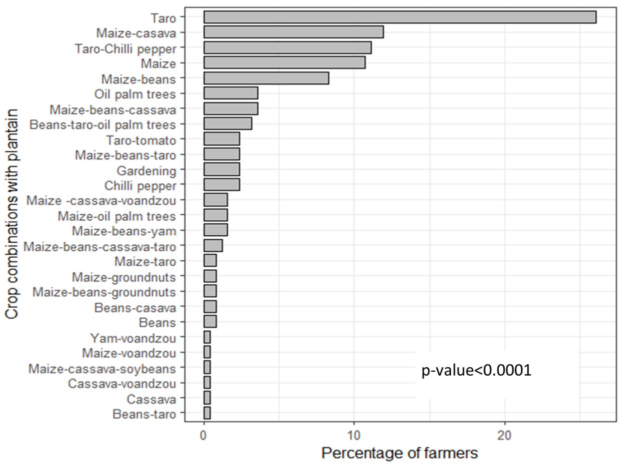

Fig. 2: *Percentage of farmers growing different crop associations with plantain, systems ordered by frequency of occurrence.*

Plantain-taro systems represent 26.1 % of the total number of farmers investigated, followed by plantain-maize-cassava (11.9 %), plantain-taro-chili pepper (11.1 %) plantain-maize (10.7 %) and plantain-maize-beans (8.3 %) (Fig. 2). Each combination emanated from the optimisation of available factors (land, availability of suckers, labor), food security objectives, risk perception, knowledge and skills to properly managing the crops. Farmers gave a try to whatever could bring additional income to them apart from plantain. In fact, fields were considered primarily for plantain production, but then other crops were added along the production cycle according the purposed outcomes the field expected by farmers. Thus, new crops were gradually introduced in the field as long as they could generate new income or contribute to food security.

3.4 Plantation maintenance

Plantation maintenance included de-leafing, de-suckering, staking, soil fertility management, watering during dry weather and staking. De-leafing entails reducing the leaf load of plantain, and was practiced by 69.9 % of the farmers in the study area (Fig 3). Most farmers adopting this technique considered this practice obvious in the multi-species systems to avoid shading of the companion crop by the plantain.

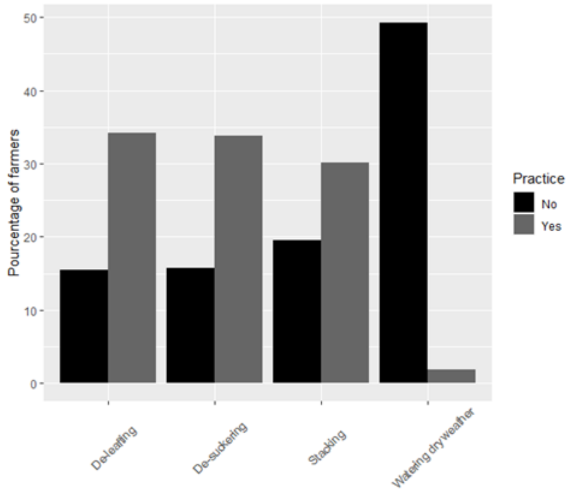

Fig. 3: *Distribution of farmers according to the methods used to maintain plantain plantations.*

Some other farmers (10.02 %) traded the leaves to food processors as packaging materials. Few of them (1.2 %) indicated that this practice was used for sanitation purpose in order to limit the occurrence of diseases. De-suckering (removal of the newly emerging suckers that compete with the mother plant) was common in the study area (69 % of farmers). Almost half of the farmers (45.5 %) left three suckers with the mother plant; others (45.8 %) left four or more than four suckers with the mother plant; the remaining left only one or two with the mother tree. All farmers that adopted this practice used suckers to either extend their fields, or establish a new plantation, or provide their peers with planting materials. To sustain the pseudo stem, 61.8 % of the farmers practiced staking after the emergence of flowers or fruits on trees that were prone to lodging. Farmers considered that lodging is one of the greatest threats to plantain production. Most farmers (96 %) relied on rain only to cover the demand in water of their fields. However, few of them (4 %) had established irrigation infrastructure and watered their plantations at least twice a week during dry spells. The watering consists of spreading water on the ground using pipelines in order to keep the floor wet. This irrigation system was adopted by few farmers using mono cropping system (Fig. 3).

Fertiliser application was not common in plantain production in the study area. Most farmers did not apply any nutrients to their plantain crops, while 19 % applied fertilisers (organic or synthetic). Among farmers applying nutrients, only organic fertilisers were used by the majority (67 %), followed by only synthetic fertilisers (27 %) or a mix of both organic and synthetic fertilisers (6 %). Synthetic fertilisers NPK-14-23-14+5S+1B recommended in cotton production was used by 13.6 % of the farmers applying synthetic fertilisers; while the one recommended for food crops NPK-15-15-15 was used by 36.4 %, urea by 18.2 % and the mix food crops NPK and urea by 31.8 %. Organic fertilisers included poultry droppings (applied by 27.3 % of the total number of farmers using organic fertilisers), in situ compost produced by farmers (21.8 %) and other organic fertilisers such as household waste and cassava peels (50.9 %). Those organic fertilisers were applied mainly as maintenance fertilisers once or twice a year, and sometimes as basal dressing.

3.5 *Farmers' awareness and knowledge on pests, diseases and their management*

The investigation of farmers' awareness and knowledge on pests and diseases revealed the existence of a big gap with 45.8 % of farmers having no knowledge about these biotic constraints (Table 4). This result also revealed the ability of farmers to recognize predominantly the presence of Black Sigatoka and the weevils in the fields, and to the lesser extent the symptoms of the nematodes. None of the farmers had a clue regarding the cause, origin and impact of pests on the productivity of plantain. As far as pest management is concerned, synthetic pesticides, ash and aqueous extracts based on neem leaves were used either alone or in integrated manner.

Table 4: *Farmers' awareness of pests and diseases and related methods of control.*

Variable	*Awareness*	*Percentage of farmers*
Pest knowledge (n=432)	No knowledge	45.8
	Knowledge	54.2
Type of pest or disease known by farmers (n=234)	Black Sigatoka	66.2
	Weevil	26.1
	Nematodes symptoms	3.8
	Others diseases	3.8
Pest management (n=234)	Applied	6.8
	Not applied	93.7
Control methods (n=16)	Pesticides	56.2
	Traditional methods*	43.7

*e.g. ash and aqueous extracts of neem leaves.

4 Discussion

4.1 *Varieties adopted by producers*

Local varieties, including Aloga Kokolodjo, Kpahissi Kokolodjo and Gnivlan, were widely adopted despite the high diversity of varieties identified in the survey. Farmers' preferences were in line with the findings of several studies, which showed that communities in Africa are strongly attached to their local varieties at the expense of new, improved, disease-resistant and high-yielding varieties. In fact, consumer acceptance and adoption of new varieties is based on a combination of several important traits (Karamura *et al.*, 2016). These traits are specific to plantain and include taste, flesh colour, texture and cooking properties (Honfo *et al.*, 2020). The fact that the above three varieties have yellowish flesh showed the importance of this trait in the selection of plantain varieties. According to Kikulwe *et al.* (2011), farmers select cultivars based on some observable characteristics that each cultivar embodies and produces. Yellow flesh was by far the most preferred. This behaviour is stimulated by the attempt to maintain local varieties through a dynamic process where farmers often select varieties on the basis of a particular trait (Thijssen *et al.*, 2008). This could be the reason for the reluctance of farmers to adopt Pita 3 and FHIA 21, which were introduced in Benin and are widely distributed in the West African sub-region (Tenkouano *et al.*, 2019), despite their high yield performance and resistance to several major pests and diseases affecting plantain production (Karamura *et al.*, 2016). In fact, Pita 3 and FHIA 21 did not have the same organoleptic characteristics as local cultivars and therefore did not meet consumer preferences (Angbo-Kouakou *et al.*, 2016). Madalla (20-21) found that in Tanzania and Uganda (East Africa), most banana hybrids were highly rated by farmers in terms of desired production traits such as good agronomic performance and yield, and resistance to pathogens, but very poorly rated in terms of consumption traits such as taste, flavour and colour of local food. To address the problem that limits the adoption of improved or imported varieties, Madalla (2021) proposed a participatory approach to selection involving farmers to simultaneously balance desired production and consumption traits.

4.2 *Diversity of plantain cropping systems*

This study identified the diversity of agricultural practices, as well as emphasized the various intercropping systems in place in plantain production in Benin. Food intercropping system is by far the dominant system adopted by farmers, followed by monoculture system and home garden system. These cropping systems are common among farmers in West and Central Africa (Sivirihauma *et al*., 2017). The rationale behind these systems is crop which leads to optimising the use of a small area of land available to farmers. This diversification provides farmers with the means to have many sources of income; this is a secure way of sustaining livelihoods and avoiding the risks associated with monoculture (Adjimoti, 2018). Although banana monoculture contributes to increased yields, this practice is dependent on synthetic fertilisers and pesticides, which are costly and can have adverse effects on human health and the environment (Bellamy, 2013). The choice of species to associate with plantains is supported by the objectives pursued by the farmers. Plantain-taro association was the dominant intercropping practice in the study area because the root system of taro is shallow, and the above-ground canopy of taro is less than one metre high, which does not adversely affect the growth of plantain. In addition, the moisture content of the soil under the plantain canopy is suitable for taro growth (Hartemink *et al*., 2000). The high acceptance of intercropping taro with plantain was also due to the high market value of taro, especially when processed into chips (Woldekiros, 2022). Technically, intercropping plantain with other food crops involves ploughing within the plantations, which damages the surface roots of plantain and exposes the plants to disease. However, apart from the economic benefits (Bellamy, 2013), intercropping plantain with other crops has some additional benefits in terms of yield stability, water and nutrient use, and reducing the impact of pathogens (Zhang *et al*., 2013). This leads to improvements in crop and soil quality as a result of optimised use of limited resources and reduced dependence on external inputs. Intercropping systems also enhance various soil-microbe-bound mechanisms, such as nitrogen fixation and phosphorus mobilisation in the rhizosphere (Eisenhauer *et al*., 2018). These empirical results make it possible to promote plantain-based intercropping systems when land sizes are decreasing, as is the case in southern Benin. Three main cropping systems were recorded: intercropping of plantain with another food crop (65.5 % of farmers surveyed), home garden system (23.6 %) and monocropping (10.8 %). Unlike in Côte d'Ivoire, Cameroon and Ghana (Norgrove & Hauser, 2014), agroforestry systems like the intercropping of plantain with cocoa were not adopted by farmers, probably because cocoa has not been among the prioritised crops promoted by extension agents and farmer's advisory system established by the government of Benin. For this reason, this production system is very marginal in Benin, and restricted to remote locations close to the borders with Nigeria, which was not part of the study area.

4.3 Planting materials, maintenance and sanitation measures

Suckers were used as planting materials by all surveyed farmers. These suckers come from fellow farmers' plantations and farmers' own fields. In sub-Saharan Africa, most farmers depend on natural regeneration of existing banana mats to obtain suckers (Ocimati *et al*., 2013) but these often harbour pests and diseases which are spread within and between farms leading to a decline in productivity and a shortened lifespan of new plantations (Robooni *et al*., 2016). According to Ocimati *et al*. (2013), this reliance on suckers from farmers' own and fellow farmers' farms is due to the lack of capacity for producing propagating materials through other methods, or limited financial resources to purchase these plantlets from nurseries. Many initiatives are being taken to promote planting material from macro- and micropropagation in the country, which would enable the supply of healthy planting material in sufficient numbers to avoid the spread of diseases. This provides the guarantee to ensure the sustainability and productivity of the newly established plantations (Tumuhimbise & Talengera, 2018).

De-leafing was widely practiced mainly to maintain the field and reduce shading at the onset of the rainfall. This practice has also been recommended in controlling leaf disease severity due to black Sigatoka (Engwali *et al*., 2013), and Xanthomonas wilt (Blomme *et al*., 2017). But its application must follow certain rules (Ocimati *et al*., 2013). In fact, de Lapeyre de Bellaire *et al*. (2010) have recommended that this practice be limited to a simple mechanical removal of necrotic leaf parts and not in a systematic cut of the leaf blade or whole leaves. Besides, the use of clean cutting materials to prevent the transmission of diseases from one plantation to another should be promoted.

De-suckering is common in the study area, practiced widely by 69.2 % of farmers in the surveyed area. The core reason for this practice adopted by farmers was the establishment of new plantations. But, according to Mahdi *et al*. 2014), this practice has a significant effect on yield parameters, since many suckers around the mother plant contribute to greater competition for photosynthesis and nutrients between the mother plant and suckers. In addition, farmers of southern Benin who practice de-suckering kept two or more suckers with the mother plant. Ademiluyi (2013) indicated the effectiveness of sucker removal by claiming that a higher number of suckers with the parent plant resulted in reduced yield with taller, thinner plants being produced. Zero suckers or only one sucker, however, resulted in increased yield and yield components with shorter, thicker plants. It is therefore recommended to limit the number of suckers in plantain production to achieve optimal yield.

Although the study area is characterised by relatively high temperature and variation in rainfall throughout the year with alternating rainy and dry seasons (Akande *et al.*, 2017), very few farmers (3.9 %) practised irrigation in plantain plantation. However, good irrigation management of plantain will lead to improved productivity and continuous fruit yield, especially in tropical regions where rainfall and its distribution are erratic (Akinro *et al.*, 2012). Even though the soils are characterised by very low cation exchange capacity (Igue *et al.*, 2013) and low stable organic matter content, farmers did not use synthetic fertilisers, while organic manure was applied. In fact, access to fertiliser was a major challenge in Benin, especially for households not involved in cotton production (Adjimoti, 2018).

5 Conclusion

This study identified the existing agricultural practices in plantain-based production areas in southern Benin. The absence of plantain-based agroforestry systems provides an opportunity to promote this system in Benin's plantain development policy, with the strong involvement of extension agents and farmer advisory councils established in the various production areas. Once this phase has been successfully completed, the constraints of lodging and pressure on trees for staking will be limited. In addition to the environmental benefits of this practice, the associated crop will become another source of income, providing greater resilience to poverty. The low rate of adoption of good agricultural practices to control pests and diseases is evidence of the low productivity of plantain-based systems in Benin, making it possible to put in place strategies, including mass production of healthy planting material, to sustain large-scale production of plantain in the Republic of Benin. In addition, the study of the genetic profile of local varieties widely used by farmers could also be relevant in the sense that the result could provide useful information to identify genotypes with potential to be used in breeding disease resistant varieties.

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Authors' contributions

The conceptualisation, methodology and investigation were performed by CET and FAA with CET, the major contributor in writing the manuscript. AAB contributed for writing review; SKC contributed for software and data curation. Acquisition of financing was provided by CET, BCA and FAA. Supervision was done by BCA. All authors read and approved the final manuscript.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Ademiluyi, B. O. (2013). Influence of number of sucker per plant on the growth, yield and yield components of Plantain (*Musa* sp) in Ado-Ekiti, Nigeria. *Agricultural Science Research Journal*, 3(2), 45–49.

Adjimoti, G. O. (2018). Analysis of cropland allocation in rural areas Benin: A fractional multinomial approach. *Cogent Food & Agriculture*, 4(1). https://doi.org/10.1080/23311932.2018.1488339.

Agama-Acevedo, E., Sañudo-Barajas, J. A., Vélez De La Rocha, R., González- Aguilar, G. A., & Bello-Peréz, L. A. (2016). Potential of plantain peels flour (*Musa* paradisiaca L .) as a source of dietary fiber and antioxidant compound. *CyTA - Journal of Food*, 14(1), 117–123. https://doi.org/10.1080/19476337.2015.1055306.

Akande, A., Costa, A. C., Mateu, J., & Henriques, R. (2017). Geospatial Analysis of Extreme Weather Events in Nigeria (1985-2015) Using Self-Organizing Maps. *Advances in Meteorology*, 2017, 1–11. https://doi.org/10.1155/2017/8576150.

Akinro, A. O., Olufayo, A. A., & Oguntunde, P. G. (2012). Crop Water Productivity of Plantain (*Musa* Sp) in a Humid Tropical Environment. *Journal of Engineering Science and Technology Review*, 5(1), 19–25. https://doi.org/10.25103/jestr.051.04.

Akinyemi, S. O. S., Aiyelaagbe, I. O. O., & Akyeampong, E. (2010). Plantain (*Musa* spp.) cultivation in Nigeria: A review of its production, marketing and research in the last two decades. *Acta Horticulturae,* 879, 211–218. https://doi.org/10.17660/ActaHortic.2010.879.19.

Angbo-Kouakou, E., Temple, L., Mathé, S., & Assemien, A. (2016). Plateformes d'innovation comme dispositif d'orientation des trajectoires technologiques des filières agricoles. Cas de la filière banane plantain en Côte d'Ivoire. *OpenScience*, 17(2), 1–18. https://doi.org/10.21494/iste.op.2017.0107.

Behiry, S., Okla, M., Alamri, S., EL-Hefny, M., Salem, M., Alaraidh, I., Ali, H., Al-Ghtani, S., Monroy, J., & Salem, A. (2019). Antifungal and Antibacterial Activities of *Musa paradisiaca* L. Peel Extract: HPLC Analysis of Phenolic and Flavonoid Contents. *Processes*, 7(215), 1–11.

Bellamy, A. S. (2013). Banana production systems: Identification of alternative systems for more sustainable production. *Ambio*, 42(3), 334–343. https://doi.org/10.1007/s13280-012-0341-y.

Blomme, G., Ocimati, W., Sivirihauma, C., Vutseme, L., Mariamu, B., Kamira, M., van Schagen, B., Ekboir, J., & Ntamwira, J. (2017). A control package revolving around the removal of single diseased banana stems is effective for the restoration of Xanthomonas wilt infected fields. *European Journal of Plant Pathology*, 149(2), 385–400. https://doi.org/10.1007/s10658-017-1189-6.

Cauthen, J., Jones, D., Gugerty, M. K., & Anderson, C. L. (2013). Banana and Plantain Value Chain: West Africa. EPAR Brief No. 239, 1–25.

Chabi, M. C., Dassou, A. G., Dossou-Aminon, I., Ogouchoro, D., Aman, B. O., & Dansi, A. (2018). Banana and plantain production systems in Benin: Ethnobotanical investigation, varietal diversity, pests, and implications for better production. *Journal of Ethnobiology and Ethnomedicine*, 14(1), 78. https://doi.org/10.1186/s13002-018-0280-1.

Cochran, W. G. (1977). Sampling Techniques. 3rd Edition, John Wiley & Sons, New York.

Dassou, A. G., Carval, D., Dépigny, S., Fansi, G., & Tixier, P. (2015). Ant abundance and Cosmopolites sordidus damage in plantain fields as affected by intercropping. *Biological Control*, 81, 51–57. https://doi.org/10.1016/j.biocontrol.2014.11.008.

de Lapeyre de Bellaire, L., Abadie, C., Carlier, J., Ngando, J. E., & Kema, G. H. J. (2010). Les cercosporioses des bananiers (*Mycosphaerella* spp): vers une lutte intégrée. Available at:http://www.endurenetwork.eu/content/download/6385/47114/file/Banana\,\%20Case\,\%20Study_2_French.pdf.

Dépigny, S., Delrieu Wils, E., Tixier, P., Ndoumbé Keng, M., Cilas, C., Lescot, T., & Jagoret, P. (2019). Plantain productivity: Insights from Cameroonian cropping systems. *Agricultural Systems*, 168(April 2018), 1–10. https://doi.org/10.1016/j.agsy.2018.10.001.

Dzomeku, B. M., Dankyi, A. A., & Darkey, S. K. (2011). Socioeconomic importance of plantain cultivation in Ghana. *The Journal of Animal & Plant Sciences*, 21(2), 269–273.

ECOWAS-SWAC/OECD. (2007). *Cocoa*. The Atlas on Regional Integration. Economy Series.

Eisenhauer, N., Hines, J., Isbell, F., van der Plas, F., Hobbie, S. E., Kazanski, C. E., Lehmann, A., Liu, M., Lochner, A., Rillig, M. C., Vogel, A., Worm, K., & Reich, P. B. (2018). Plant diversity maintains multiple soil functions in future environments. *ELife*, 7, 1–20. https://doi.org/10.7554/eLife.41228.

Engwali, F. D., Nfor, T. D., & Kong, A. (2013). On-Farm Evaluation of Deleafing Frequency on the Severity of Black Sigatoka Disease (*Mycosphaerella fijiensis* Morelet) and Yield of Banana (*Musa* spp). *Journal of Experimental Agriculture International*, 3(3), 595–605.

Hartemink, A. E., Johnston, M., O'sullivan, J. N., & Poloma, S. (2000). Nitrogen use efficiency of taro and sweet potato in the humid lowlands of Papua New Guinea. *Agriculture, Ecosystems & Environment*, 79(2–3), 271–280.

Honfo, F. G., Togbe, E. C., Ahohouendo, A. F., & Ahohuendo, B. C. (2020). Physical characteristics of some banana plantain cultivars (*Musa* spp .) consumed in Benin. Ann. UP, *Série Sciences Naturelles et Agronomie*, 10(2), 17–22.

Houinato, M., Sinsin, B. (2002). Analyse phytogéographique de la région des Monts Kouffè au Bénin. *Systematics and Geography of Plants*, 71(1), 889–910.

Igue, A. M., Saidou, A., Adjanohoun, A., Ezui, G., Attiogbe, P., Kpagbin, G., Gotoechan-Hodonou, H., Youl, S., Pare, T., Balogoun, I., Ouedraogo, J., Dossa, E., Mando, A., & Sogbedji, J. M. (2013). Evaluation de la fertilité des sols au sud et centre du Bénin. *Bulletin de La Recherche Agronomique du Bénin*, 1, 12–23.

Karamura, D., Tumuhimbise, R., Muhangi, S., Nyine, M., Pillay, M., Tendo, R. S., Talengera, D., Namanya, P., Kubiriba, J., & Karamura, E. (2016). Ploidy level of the banana (*Musa* spp.) accessions at the germplasm collection centre for the East and Central Africa. *African Journal of Biotechnology*, 15(31), 1692–1698. https://doi.org/10.5897/ajb2016.15442.

Kikulwe, E. M., Birol, E., Wesseler, J., & Falck-Zepeda, J. (2011). A latent class approach to investigating demand for genetically modified banana in Uganda. *Agricultural Economics*, 42(5), 547–560. https://doi.org/10.1111/j.1574-0862.2010.00529.x.

Lavanya, K., Abi Beaulah, G., & Vani, G. (2016). *Musa* Paradisiaca: A review on phytochemistry and pharmacology. *World Journal of Pharmaceutical and Medical Research*, 2(6), 163–173.

Madalla, N. A. (2021). Farmers ' traits preferences for improved banana cultivars in Tanzania and Uganda.

Mahdi, E. F., Bakhiet, S. B., & Gasim, S. (2014). Growth and yield responses of banana plant to desuckering practice. *International Journal of Science, Environment and Technology*, 3(1), 279–285.

Martin-Guay, M. O., Paquette, A., Dupras, J., & Rivest, D. (2018). The new Green Revolution: Sustainable intensification of agriculture by intercropping. *Science of the Total Environment*, 615, 767–772. https://doi.org/10.1016/j.scitotenv.2017.10.024.

Martínez-Ruano, J. A., Caballero-galván, A. S., Restrepo-serna, D. L., & Cardona, C. A. (2018). Techno-economic and environmental assessment of biogas production from banana peel (*Musa* paradisiaca) in a biorefinery concept. *Environmental Science and Pollution Research*, 25, 35971–35980. https://doi.org/org/10.1007/s11356-018-1848-y.

Norgrove, L., & Hauser, S. (2014). Improving plantain (*Musa* spp. AAB) yields on smallholder farms in West and Central Africa. *Food Security*, 6(4), 501–514. https://doi.org/10.1007/s12571-014-0365-1.

Ocimati, W., Karamura, D., Rutikanga, A., Sivirihauma, C., Ndungo, V., Ntamwira, J., Kamira, M., Kanyaruguru, J. P., & Blomme, G. (2013). Agronomic practices used by farmers in the management of *Musa* across different agroecological zones in Burundi, eastern Democratic Republic of Congo and Rwanda. In: Blomme,G., van Asten, P., & Vanlauwe, B. (eds). *Banana Systems in the Humid Highlands of sub-Saharan Africa: Enhancing Resilience and Productivity*. CABI. https://doi.org/10.1079/9781780642314.0175.

Oyeyinka, B. O., & Afolayan, A. J. (2019). Comparative Evaluation of the Nutritive, Mineral, and Antinutritive Composition of *Musa* sinensis L. (Banana) and *Musa* paradisiaca L. (Plantain) Fruit Compartments. *Plants*, 8, 598. https://doi.org/doi.org/10.3390/plants8120598.

PSRSA. (2011). *Plan Stratégique de Relance du Secteur Agricole.* http://www.inter-reseaux.org/IMG/pdf/PSRSA_version_finale.pdf.

Quain, M. D., Agyeman, A., & Dzomeku, B. M. (2018). Assessment of plantain (*Musa* sapientum L.) accessions genotypic groups relatedness using simple sequence repeats markers. *African Journal of Biotechnology*, 17(16), 541–551. https://doi.org/10.5897/ajb2017.16363.

Robooni, T., Henry, B., Alex, B., Reuben, T. S., David, T., Jerome, K., Sedrach, M., Betty, N., Priver, N., & Geofrey, A. (2016). Selection of cooking banana genotypes for yield and black Sigatoka resistance in different locations in Uganda. *Journal of Plant Breeding and Crop Science*, 8(5), 60–71. https://doi.org/10.5897/JPBCS2016.0559.

Sivirihauma, C., Ocimati, W., Valimuzigha, K., Kamira, M., Vutseme, L., Ntamwira, J., Bumba, M., & Blomme, G. (2017). Diversity of cultural practices used in banana plantations and possibilities for fine-tuning: Case of North Kivu and Ituri provinces, eastern Democratic Republic of Congo. *African Journal of Agricultural Research*, 12(25), 2163–2177. https://doi.org/10.5897/AJAR2016.11861.

Swennen, R., Blomme, G., Van Asten, P., Lepoint, P., Karamura, E., Njukwe, E., Tinzaara, W., Viljoen, A., Karangwa, P., Coyne, D., & Lorenzen, J. (2013). Mitigating the impact of biotic constraints to build resilient banana systems in Central and Eastern Africa. In: Vanlauwe, B., van Asten, P., & Blomme, G. (eds) *Agro-ecological intensification of agricultural systems in the African Highlands*, Abingdon: Routledge, pp. 85–104.

Tenkouano, A., Niéyidouba, L., Agogbua, J., Amah, D., Swennen, R., Traoré, S., Thiemele, D., Aby, N., Kobenan, K., Gnonhouri, G., Yao, N., Astin, G., Sawadogo-Kabore, S., Tarpaga, V., Issa, W., Lokossou, B., Adjanohoun, A., Amadji, G. L., Adangnitode, S., Igue, K. A. D., & Ortiz, R. (2019). Promising High-Yielding Tetraploid Plantain-Bred Hybrids in West Africa. *International Journal of Agronomy*, 2019(1). https://doi.org/10.1155/2019/3873198.

Thijssen, M. H., Bishaw, A., Beshir, A., & de Boef, W. S. (2008). *Farmers, seeds and varieties: supporting informal seed supply in Ethiopia*. Wageningen, Wageningen International.

Togbe, C. E. (2013). *Cotton in Benin: Governance and pest*. Ph.D. Thesis; Wageningen University, Wageningen, The Netherlands, 201 p.

Tumuhimbise, R., & Talengera, D. (2018). Improved propagation techniques to enhance the productivity of Banana (*Musa* spp.). *Open Agriculture*, 3(1), 138–145. https://doi.org/10.1515/opag-2018-0014.

Woldekiros, B. (2022). Evaluating Intercropping Taro (*Colocasia esculenta* L.) with Common Bean (*Phaseolus vulgaris* L.) in Cheha and Silti Municipalities, Southern Ethiopia. *Journal of Horticulture*, 9(4), 3–5. https://doi.org/10.35248/2376-0354.22.9.003.

Zhang, H., Mallik, A., & Zeng, R. S. (2013). Control of Panama Disease of Banana by Rotating and Intercropping with Chinese Chive (*Allium tuberosum* Rottler): Role of Plant Volatiles. *Journal of Chemical Ecology*, 39(2), 243–252. https://doi.org/10.1007/s10886-013-0243-x.