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Constraints, and Implications of Organic Farming in Bananas and Plantains Production Sustainability in Benin

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Abstract

Bananas and plantains production is an important income source for millions of small farmers. The increased demand for bananas and plantains on national and international market would justify its value chain development. However, its value chain faces several constraints, of which production and marketing turn out to be the most important. This study aimed at determining and analyzing the constraints related to Bananas and Plantains value chain and showing the gaps between agroecological and agricultural practices used by farmers in southern Benin. Characterization was carried out on the seed production systems, agricultural practices, bananas and plantains production, fruit availability and commercialization constraints with farmers using individual and focus groups surveys. Bananas and plantains seedlings production and acquisition varied according to production areas. Their seedlings self-production was widespread in production areas and 26 cultivars have been identified as major. The availability of these cultivars varied across time and production areas. There were significant negative effects of agricultural practices on major banana pest's presence. Bananas and plantains production was limited by 12 factors, from which banana plants fall related to the wind, lack of financial support to irrigate banana fields, climate changes, no availability of cultivable

lands and low rainfall are revealed to be the most important. Regarding commercialization constraints, low sale prices and difficult access to markets were the most important. Better knowledge of bananas and plantains production systems would help to develop sustainable organic farming strategies to reduce the constraints identified.

Keywords

Bananas and Plantain, Seedling Production, Agricultural Practices, Constraints, Organic Farming

1. Introduction

In Benin, bananas and plantains' value chain is gradually developing as an important economic opportunity to stakeholders. Many food products derived from bananas and plantains are found in local and urban markets and are sold better than before [1]. However, these include improved plantain chips, banana cakes and banana wine. Currently products such as banana fruits are commonly found in people's diets. Despite the food and economic importance of this value chain, bananas and plantains are less available and scarce at given times of the year on the markets. This unavailability would undoubtedly be linked to the various production and marketing constraints.

Production and marketing are the main constraints undermining the development of banana and plantain value chain [2] [3]. Concerning production constraints, the most important is the premature fall of plants under violent wind, diseases and pests damages. These constraints considerably reduce more than half of production [4]. To solve these problems, research actions are essential to develop systems that are both inexpensive and effective to protect cultivated plants against climatic hazards. Natural repellents, made with local products such as neem seeds, have kept diseases and pests away from cultivated plants [5]. It is also fundamental to relay the results of previous studies, going beyond analysis in terms of returns. It is essential to adopt a more comprehensive approach to the economic and social benefits of agroecology with an increase in household income linked to savings achieved through the abandonment of chemical inputs and the diversification of production. Several agricultural practices are used by the farmers to reduce these constraints' effects [6].

Farmers use agricultural practices such as self-production of seeds, crop associations, crop rotation, irrigation, use of animal droppings to fertilize soils, and use of biopesticides to control pests and diseases. Irrigation is essential for the survival of bananas [7]. Irrigation combined with good soil fertilization greatly improves productivity and makes plants more vigorous and tolerant. In general, bananas are susceptible to diseases (*Fusarium* wilt, *Sigatoka*, Banana Bunchy Top Disease, etc.) and pests including the banana weevil and nematodes [8].

Many agricultural practices, in particular the increase in plant biodiversity such as cover plants [9] [10], associated crops [11] [12] [13] increase the abundance of predators which reduce damage to pests [14].

This study aimed at determining and analyzing the constraints related to the bananas and plantains value chain and showing the gaps between agroecological practices and agricultural practices used by farmers in southern Benin. Specifically, the study aimed at 1) determining and analyzing constraints related to seed management and production of bananas and plantains, 2) analyzing bananas and plantains seedling production systems, 3) identifying elite bananas and plantains cultivars and their availability across the time and markets, 4) identifying the gaps between agroecological practices and agricultural practices used by banana and plantains farmers, and 5) networking bananas and plantains farmers to improve their agricultural practices and to convert them in organic agriculture.

2. Material and Methods

2.1. Study Site

Data were collected from June to November 2019 in the large banana and plantain production area in southern Benin. The four most important bananas and plantains production districts were selected to carry out this study: Mono (Athiémé, Lokossa, Comè); Atlantique (Tori, Zè, Sèhouè, Ouègbo, Allada), Ouémé (Akpo-Missrété, Dangbo) and Plateau. There are 2 rainy seasons (a long season and a short season) and 2 dry seasons (a long dry season and a short dry season). The average annual rainfall was 1300 mm of water and the average annual temperature was 28˚C. The soils were mainly vertisols and clayey type, very rich in minerals and contribute to a better productivity of bananas and plantains in the region of Toffo. The regions of Mono and Ouémé have ferruginous and sandy soils and lowlands favorable to the production.

2.2. Selection of Bananas and Plantains Farmers

In each selected district, 10 villages with 6 farmers per village were selected for the survey. Within villages, firstly, a Key Informant Interview (KII) was granted to the village chief to explain the interest of the study to him and then he gives us the list of some bananas and plantains producers. Then, other bananas and plantains producers were identified asking farmers interviewed. Farmers included in the study owned at least 0.5 hectare of bananas and plantains fields in order to ensure the importance that this crop represents in their daily agricultural activities.

2.3. Socio-Demographic Parameters

Individual and focus group surveys were used to carry out this study. Focus group survey brought together a large number of farmers in each selected village. The first step of the study concerned the socio-demographic characteristics

of farmers (such as age, sex, marital status and number of experience years). Next, farmers were asked on their knowledge of organic farming and whether they are willing to pay the costs associated with the organic certification process.

2.4. Management of Banana and Plantain Seed Production Systems

A characterization was carried out on the seed production systems of bananas and plantains in order to offer farmers the seed sustainable management. First, information was gathered on bananas and plantains seeds acquiring methods such as seed donation, seed sharing, seed loan and seed self-production. Next, types of bananas and plantains seed production systems, especially technology based on seedlings from banana stem fragments commonly referred to as PIF [15] [16], were identified. Seed production systems using insecticides and those using biopesticides have been identified.

2.5. Constraints and Problems Related to Production and Marketing

During the individual survey, farmers identified all production and marketing constraints linked to bananas and plantains value chain. These constraints were ranked according to their importance and then updated in relation to previous studies [2]. During the focus group survey (on average 10 farmers per village) carried out in each selected village, producers listed in order of importance the problems that undermine the production and marketing of bananas and plantains.

2.6. Identification of Elite Bananas and Plantains Cultivars and Their Availability across Districts and Time

Based on the fact that a diversity of bananas and plantains cultivars existed in the study areas [2], farmers were asked to list the highly economical and productive elite cultivars in their districts. Then, the time and district availability of bunches of these cultivars were determined using scores. A score of 1 was attributed to cultivars with low bunch availability, score 2 for cultivars with moderate bunch availability and finally a score 3 for cultivars with high bunch availability.

2.7. Identification of Agricultural Practices Used by Banana and Plantain Farmers and Diseases and Pests Presence in Plantations

During the survey, farmers were asked to list the agricultural practices they use on their plantations. The agricultural practices listed were ranked in order of importance according to their quote frequency by farmers. The presence of the main diseases and pests of bananas and plantains has been determined in 45 farmers' fields. In each field, a field visit was organized in the morning of the day of the visit to identify diseases and pests. For the banana weevil, 20 pseudostem

traps were used and placed randomly over the entire field for sampling [11] [12]. These traps were recorded 48 hours after installation to note the presence or absence of the pest in the field. Next, a few roots were taken from 20 randomly selected banana and plantain plants to observe galls and nematode damage spots in the laboratory in order to note the presence or absence of nematodes [17] [18]. The presence of symptoms (yellowing of the margins of the oldest leaves, wilting of the leaves with the constitution of a crown of dead leaves) of *Fusarium* sp. was sought and noted in each farmer's field. The presence of symptoms of Bunchy Top Banana Disease (BBTD) including plants that have turned into flowers.

2.8. Gaps between Agricultural Practices Used by Farmers and Organic Farming Practices

During focus group discussions, each agricultural practice was analyzed in a participatory manner with the farmers. Application modes of the practices have been detailed and then its deviation from organic farming practices is assessed using scores. A score of 1 (low level) means a small difference between the agricultural practice used and the practice of organic farming. The score 2 (mean level) means an average difference while the score 3 (high level) means a high difference between the agricultural practice used and the practice of organic farming.

2.9. Data Analyses

The Generalized Linear Model (GLM) distribution and logit link with the binomial family were carried out to determine the effects of agricultural practices and types of crop associations on the presence of the major pests and diseases of bananas and plantains. The Generalized Linear Model (GLM) distribution and logit link with the binomial family were also used to determine the relationship between the modes of production and acquisition of banana and plantain seedlings, the availability of different cultivars, means of farmer's communication and localities. Dendrograms were used to categorize the groups of banana production constraints. All the analyses were carried out in R [19] at the significant level of 5%.

3. Results

3.1. Socio-Economic and Demographic Characteristics of Farmers

A total of 210 banana and plantains farmers were surveyed in the 4 zones of high production. Farmer's surveyed age varied from 39 to 47 years old with a mean age of 42 years. The majority of farmers were men especially in the Plateau district where no female banana/plantain farmers were surveyed. The most important presence of women (22.7% of farmers) in bananas and plantains production was found in the Ouémé district. Bananas and plantains farmers were generally monogamous with 31% as the highest rate of polygamy observed in the Atlanti-

que district. The ethnic groups represented were Goun (100% of farmers of Ouémé and 81.8% for Plateau), Kotafon (72.50% of farmers of Mono), Aizo (54% of farmers of Atlantique) and Fon (21.7% of farmers of Atlantique). The majority of the farmers surveyed were Christians (71.77% of farmers), anemists (27.85% of farmers) and very few Muslims (0.62% of farmers). The Mono district followed by the Atlantique had lands available for agriculture especially for the production of bananas and plantains. However, farmers of the Ouémé and Plateau have more professional experiences. The latter were less associated in cooperatives or groups of farmers for the bananas and plantains production. The majority of farmers in Mono (80% of farmers), Ouémé (100% of farmers) and Plateau (100% of farmers) have a good knowledge of organic banana production systems. Additionally, very few Atlantique farmers (10.9% of farmers) knew the organic banana production. All the farmers surveyed were motivated to convert their production systems into organic production systems and the majority of them were ready to pay the costs of the certification process for their organic products. The main activities of surveyed farmers were agriculture (91.25% of farmers) followed by animal breeding (47.05% of farmers) and food processing (29.47% of farmers) (Table 1).

3.2. Acquisition and Production of Banana and Plantain Seedlings

Production and acquisition of banana and plantain seedlings varied according to the production zones ($P < 0.00001$). Self-production of banana and plantain seedlings was widespread in production areas (96% of farmers). The purchase (51.83% of farmers) and donation (48.35% of farmers) of banana and plantain seedlings were also developed by some farmers. The production of bananas and plantains seedlings by the technology of plants resulting from stem fragments (named as PIF in French) were moderately used in the production area. Very few farmers inherited, collected and lent seeds of bananas. Few farmers have a good knowledge of organic banana seedling production using biopesticides (Figure 1).

3.3. Banana and Plantain Cultivars Produced and Their Availability across the Time

In total, the availability of 26 cultivars of bananas and plantains has been identified as major cultivars in the production areas (Figure 2). The availability of these cultivars varied across time and production areas ($P < 0.00001$, $Df = 27$). In the Atlantique district, cultivars were highly available towards the end of the year. In Mono district, several cultivars were moderately available at the year starting and had become highly available throughout the year. In Ouémé district, all cultivars were poorly available in the first half of the year and had become highly available in the second half of the year. Finally, in the Plateau district, a few cultivars that were poorly available at the year starting became highly available from April to May (Figure 3).

Table 1. Socio-economic and demographic characteristics of farmers.

Parameters		Atlantique	Mono	Ouémé	Plateau
Mean age		41	39	47	42
Sex (%)	Female	4.3	17.5	22.7	-
	Male	95.7	82.5	77.3	100
Farmer's household situation (%)	Monogam	68.5	72.5	79.6	81.8
	Polygam	31.5	27.5	20.4	18.2
Ethnic groups (%)	Fon	21.7	7.5	-	18.2
	Adja	2.2	2.5	-	-
	Goun	17.4	-	100	81.8
	Aizo (Ayizo)	54.3	-	-	-
	Kotafon	4.3	72.5	-	-
	Mina	-	17.5	-	-
Religion (%)	Christian	69.6	57.5	95.5	63.6
	Animist	30.50	40	4.5	36.4
	Muslim	-	2.5	-	-
Agricultural area available (hectare)		3.59	9.05	1.84	2.91
Agricultural area used (hectare)		2.63	8.63	1.77	2.64
Area occupied by bananas and plantains (hectare)		0.90	1.22	0.70	1.32
Seniority in banana and plantain production (years)		8	10	17	12
Banana farmers group/Cooperative (%)	Membership	100	87.5	18.2	27.3
	No Membership	-	12.5	81.8	72.7
Organic production system (%)	No knowledge	89.1	20	-	-
	Knowledge	10.9	80	100	100
Organic production of bananas and plantains	Not motivated	-	-	-	-
	Motivated	100	100	100	100
Be ready to follow training on the organic production process (%)		100	100	100	100
Pay the costs of the certification of organic products (%)	Not agree	23.5	2.7	4.5	9.1
	Agree	76.5	97.3	95.5	90.9
Agriculture		100	65	100	100
Animal breeding		8.7	25	81.8	72.7
Fishing/fish farming		2.2	-	13.66	-
Food processing		10.9	2.5	40.9	63.6
Small business/sales		8.7	27.5	59.1	27.3
Crafts (sewing, hairdressing, mechanics, etc.)		52.2	20	40.9	9.1
Government employee/private employee		6.5	12.5	4.5	9.1

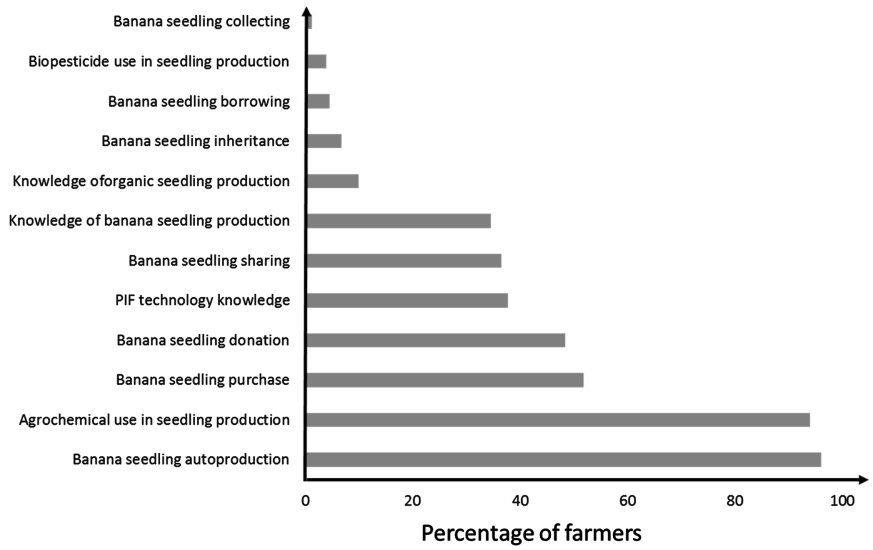

Figure 1. Modes of acquisition of banana seedlings.

Figure 2. Banana cultivar Doheze on the left and Plantain cultivar Gnivlan on the right.

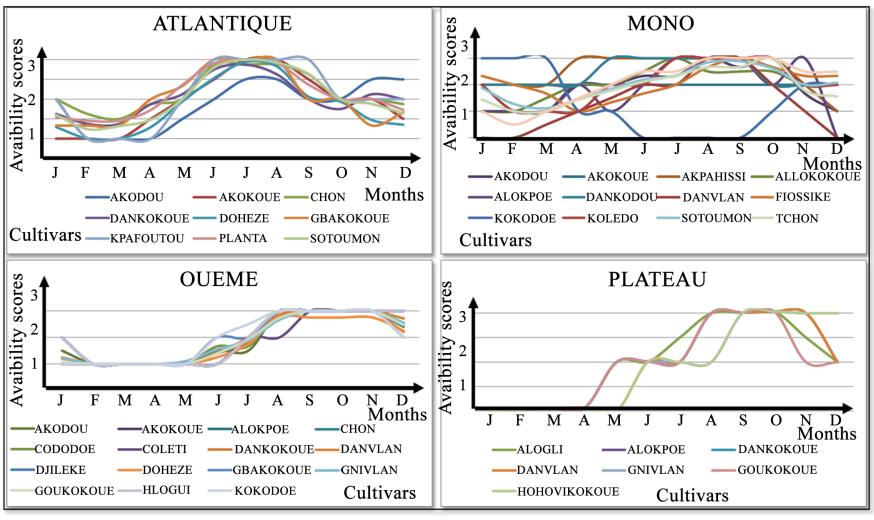

Figure 3. Banana and plantain varieties produced by district and their avaibility.

3.4. Agricultural Practices Used by Farmers in Bananas and Plantains Cropping Systems and Their Influence on Major Banana Pests

Statistical analyzes revealed significant negative effects of agricultural practices on the presence of the major banana pests (Table 2). The most frequent agricultural practices used to face this issue were crop association (89.30% of farmers, Table 3), mechanical destruction of diseased plants (51.07% of farmers), banana plantations in shallows (30.10% of farmers), crop rotation (16.85% of farmers), compost use (9.65% of farmers), poultry manure use (7.92% of farmers) and herbicide use (6.82% of farmers). Other agricultural practices were less frequently used by farmers (<5% of farmers) (Figure 4). The use of biopesticides, trap plants, composts, crop rotation and crop association have significant negative effects on the presence of the banana weevil. The use of manures and crop associations have significant negative effects on the presence of *Fusarium* sp while the use of biopesticides, irrigation and trap plants have significant negative effects on its presence. The use of biopesticides, agrochemicals, trap plants, crop rotation and crop association have significant negative effects on the presence of nematodes while cultivar resistance, irrigation, repellent plants, manure and shallow have significant positive effects. The use of trap plants, herbicides, shallows and the destruction of disease plants have significant negative effects on the presence of BBTV while the use of biopesticides and repellent plants have significant positive effects (Table 4).

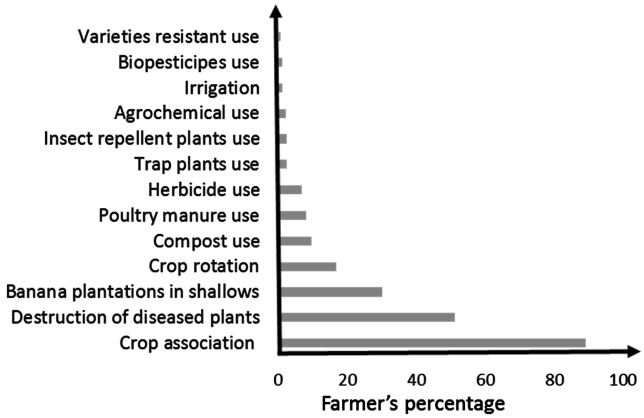

Figure 4. Agricultural practices used by banana and plantain farmer's.

Table 2. Effect of agricultural practices on the presence of major banana pests in the production zones.

Major banana pests	Estimates	Df	Deviance Resid	P (>|Chi|)
Banana weevil	−18.38	12	61.56	<0.00001
Nematodes	−0.51	12	25.76	0.0116
Fusarium sp	−0.18	12	28.17	0.005217
Banana Bunchy Top Virus	−0.91	12	31.52	0.001638

Table 3. Farmer percentage cultivating crops associated to bananas and plantains in rainy season and in dry season.

Associated crops	Scientific names	Farmer percentage cultivating in rainy season	Farmer percentage cultivating in dry season
Plantains	*Musa paradisiaca*	15.91	38.55
Bananas	*Musa spp.*	6.51	30.12
Basilic (Tchiayo)	*Ocimum gratissimum*	0.48	2.41
Pepper	*Capsicum annuum*	3.86	2.41
Tomato	*Solanum lycopersicum*	8.92	7.23
Okra	*Abelmoschus esculentus*	0.72	1.20
Crin-crin	*Corchorus olitorius*	0.48	1.20
African eggplant	*Solanum macrocarpon*	0.96	3.61
Amaranth	*Amaranthus spp.*	0.24	9.64
Pineapple	*Ananas comosus*	1.69	0
Maize	*Zea mays*	21.2	0
Cowpea	*Vigna unguiculata*	8.92	0
Peanut	*Arachis hypogaea*	5.54	0
Yam	*Disocorea spp.*	1.69	0
Cassava	*Manihot esculenta*	13.01	1.20
Palm	*Elaeis guineensis*	3.61	1.20
Egussi	*Citrullus lanatus*	0.24	0
Taro	*Colocasia esculenta*	4.34	0
Sweet potato	*Ipomoea batatas*	1.2	0
Lettuce	*Lactuca sativa*	0.48	1.23

Table 4. Effect of agricultural practices on the presence of major diseases and pests of banana and plantain. Values in the table are the probabilities of effects of agricultural practices on the presence of major pests and diseases. $P < 0.05$ means significant effects showing an influence of the agricultural practice on the presence of the pest or the disease and $P > 0.05$ means no significant effects showing no relation between the agricultural practice and the presence of the disease or the pest.

Practices	Df	Banana weevil		Fusarium sp		Nematodes		BBTV	
		Estimates	Pr (>Chi)	Estimates	Pr (>Chi)	Estimates	Pr (>Chi)	Estimates	Pr (>Chi)
Resistance plant	79	−16.45	0.222	−0.14	0.892	1.35	0.020*	−1.46	0.120
Biopesticides	79	−15.42	0.020*	2.29	0.019*	−17.35	0.017*	18.16	0.001**
Irrigation	79	−15.39	0.425	14.95	0.005**	16.98	0.021*	1.16	0.350
Agrochemical	79	−15.41	0.355	1.79	0.103	−16.33	0.033*	0.44	0.662
Repellent plants	79	−15.42	0.290	2.29	0.019*	0.08	0.001**	18.16	0.001**
Trap plants	79	−0.90	0.048*	1.37	0.150	−17.35	0.017*	−17.24	0.022*
Herbicides	79	−0.13	0.410	0.78	0.327	1.51	0.107	−0.67	0.008**

Continued

Manure	79	0.14	0.896	−17.05	0.044*	1.76	0.020*	0.91	0.244
Compost	79	−1.62	0.044*	−1.22	0.192	−0.23	0.680	−0.81	0.174
Rotation	79	−15.41	0.005**	0.59	0.621	−0.23	0.033*	0.44	0.662
Shallow	79	−15.42	0.29	−15.98	0.178	18.0489	0.002**	−17.24	0.022*
Crop association	79	−16.48	0.001**	−17.05	0.044*	−1.029	0.007**	−0.29	0.689
Diseased plant destruction	79	−14.38	0.51	−14.94	0.039*	−16.28	0.135	−17.05	0.0005***

3.5. Soil Fertility and Pest Management in Banana and Plantain Systems

Bananas and plantains farmers surveyed used chemical fertilizers and organic. In the Atlantique district, none of farmers surveyed used chemical fertilizers, but they used composts and poultry manure. In the other 3 districts, the majority of farmers used chemical fertilizers and a few used composts, poultry manure and cow dung (Table 5). Regarding the management of diseases and pests in banana and plantain cropping systems, farmers provided information on the knowledge and management of Banana Bunchy Top Disease (BBTD), phytophagous nematodes and banana weevil. Almost all farmers in Ouémé and Plateau and a few farmers in Atlantic and Mono have a good knowledge of the manifestations of BBTD and its symptoms. No farmer in the Atlantique and Mono districts knew about BBTD management methods. Very few farmers in the Ouémé and Plateau districts used Glyphosate (1% of farmers in the Plateau), Sharp 480 (2.33% of farmers of Ouémé) and Le Lagon (2.75% of farmers of Ouémé) to fight BBTD. No organic product were used to fight BBTD. In the 4 districts, a few farmers knew how to identify the damage caused by the banana weevil. Farmers in the Atlantique (15.4%) observed banana weevil damage in production systems up to 25% while the majority of farmers in all districts observed minor damage of up to 5%. The majority of farmers in the 4 districts had a good knowledge of the symptoms and damage of phytophagous nematodes. The majority of Atlantique farmers used ashes (130 kg/hectare), ashes associated to motor oil (4 kg/hectare), ashes associated to oil neem (500 kg/hectare) and neem oil associated with neem leaf extracts (50 kg/hectare) (Table 6).

3.6. Major Constraints Related to Banana and Plantain Production and Others Problems of the Value Chain

Banana and plantain production was limited by 12 factors, the most important of which were banana plants fall related to the wind (88.65% of farmers), the lack of financial support to irrigate banana fields (71.85% of farmers), climate changes (66.55% of farmers), no availability of cultivable lands (60.32% of farmers) and low rainfall (50.72% of farmers). Low quality of banana seedlings (0.55% of farmers) was the least cited factor (Table 7). After production constraints, farmers

Table 5. Conventional and organic products used in banana and plantain systems.

Parameters	Atlantique	Mono	Ouémé	Plateau
Chemical fertilizer use (Farmer's percentage)				
NPK	-	100	87.5	100
Urea	-	100	87.5	100
Potassium sulphate	-	0	50	100
Organic fertilizer use (Farmer's percentage)				
Compost	50	0	100	0
Poultry manure	50	-	14.3	50
Cow dung	-	100	-	-

Table 6. Pests and diseases management in banana and plantain systems.

Parameters		Atlantique	Mono	Ouémé	Plateau
Knowledge of manifestations of BBTD (Banana Bunchy Top Disease)		4.3	5	100	72.7
Identification of BBTD symptoms (%)					
Banana plants that are sterile or produce inedible fruit		50	0	31.8	0
Bushy leaf top		50	0	0	0
Leaf edges turn yellow and curl upward		0	100	18.2	62.5
Narrow, erect and more or less short leaves		0	0	50	37.5
Quantity of agrochemicals used per hectare to manage BBTD (kg/hectare)					
Griphosat		-	-	-	1
sharp 480		-	-	2.33	-
Lagon		-	-	2.75	-
Use of organic products for the management of BBTD (%)		0	0	0	0
Knowledge of banana weevil damage		28.3	2.5	45.5	27.3
Average percentage of plant attacked	25%	15.4	0	0	0
	5%	76.9	100	60	66.7
	0%	7.7	0	40	33.3
Knowledge of the manifestations of phytophagous banana nematodes		54.3	2.5	9.1	9.1
Manifestations of banana plant-feeding nematodes					
Damage on banana roots		88	100	0	100
Premature fall of banana plants		64	100	100	0
Root nodules		60	0	0	

Continued

Quantity of biological products used per hectare for the management of banana nematodes (kg/hectare)				
Ashes	130	-	119	-
Ashes and motor oil	4	-	-	-
Ashes and neem oil	500	-	-	-
Neem oil and neem leaves extracts	50	-	-	-

Table 7. Constraints related to banana and plantain production in the localities.

Constraints	Atlantique (%)	Mono (%)	Ouémé (%)	Plateau (%)	Mean (%)
Banana plants fall related to the wind	69.6	85	100	100	88.65
Lack of financial support to irrigate banana fields	67.4	20	100	100	71.85
Climate Changes	58.7	7.5	100	100	66.55
Non availability of cultivable land	56.5	7.5	95.5	81.8	60.32
Low rainfall	0	57.5	81.8	63.6	50.72
Soil poverty	0	12.5	81.8	72.7	41.75
Low production linked to BBTD (Banana Bunchy Top Disease)	0	0	100	63.6	40.9
Damage of other pests (banana weevil, nematodes…)	13	25	36.4	45.5	29.97
Non availability of performing varieties	34.8	0	13.6	36.4	21.20
Damage by monkeys	0	0	18.2	36.4	13.65
Difficult access to banana seedlings	10.9	2.5	4.5	9.1	6.27
Low quality of banana seedlings	2.2	0	0	0	0.55
Others	2.2	0	0	0	0.55

frequently cited 15 major problems that hamper the development of bananas and plantains value chain (Table 8). The dendrogram realized made it possible to categorize the problems into 5 groups according to their importance. The first 3 groups were the most important. The first group was made up of problems such as difficult access to biofertilizers and biopesticides, difficult access to plant materials, high price of seedlings, and problems of plant fall. The 2nd group consisted only of climatic hazards. The third group was made up of low financial resources and difficult weed management. Regarding commercialization constraints (Table 9), low sale price (50.72% of farmers) and difficult access to sales markets (37.02% of farmers) were the most important. The short storage period (3.40% of farmers), difficulty in accessing market information (3.90% of farmers) were the least important constraints (Figure 5). The dendrogram produced made it possible to categorize the marketing constraints into 2 groups according to their importance (Figure 6).

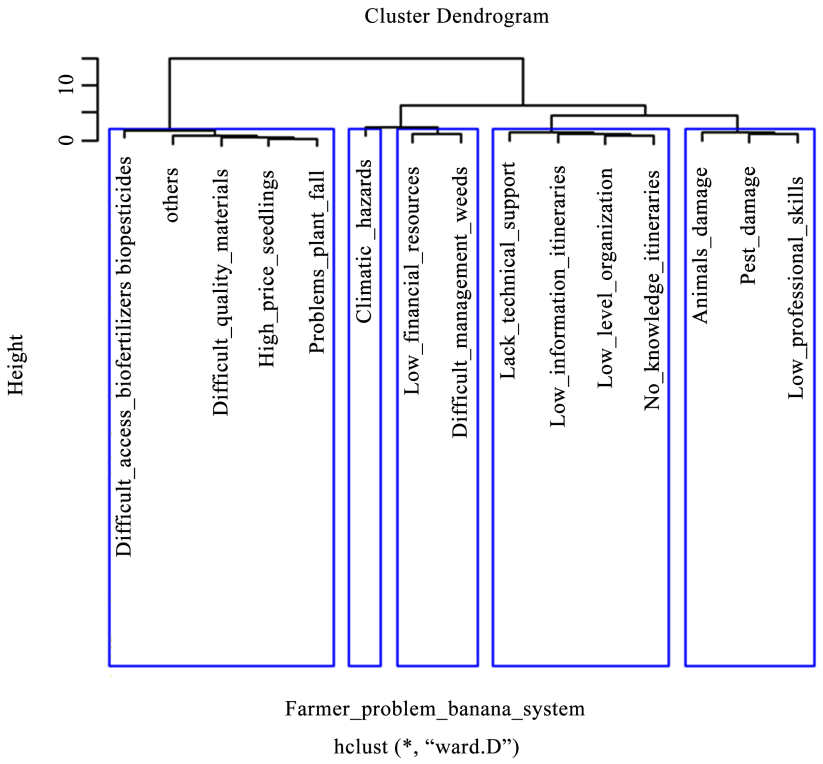

Figure 5. Hierarchization and categorization of banana and plantain production problems.

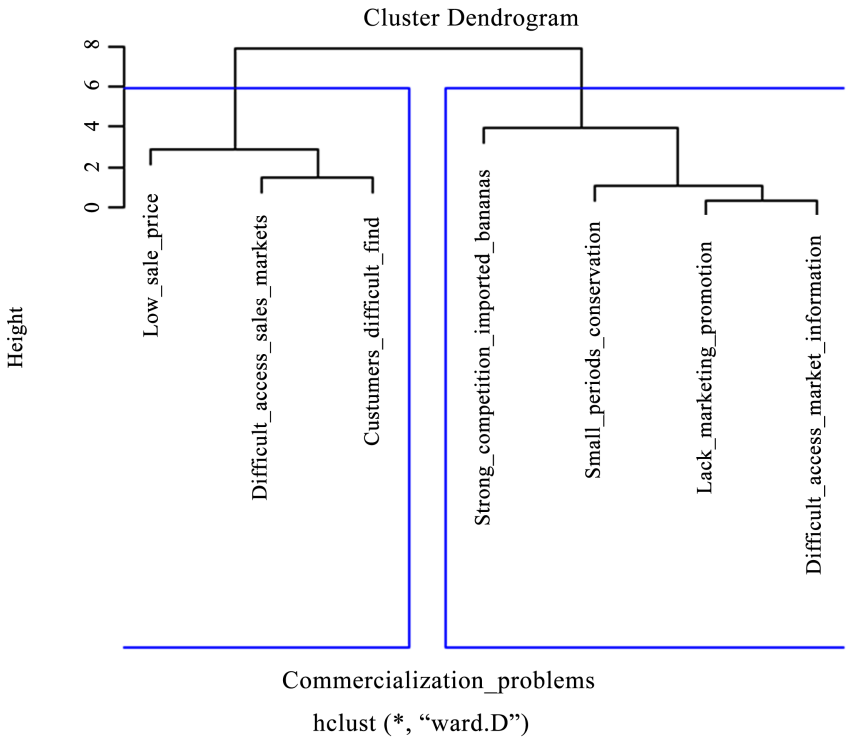

Figure 6. Hierarchization and categorization of banana and plantain commercialization problems.

Table 8. Problems of banana and plantain production systems.

Constraints	Atlantique (%)	Mono (%)	Ouémé (%)	Plateau (%)
Banana tree fall related to the wind	69.6	85	100	100
Lack of financial support to irrigate banana fields	67.4	20	100	100
Climate Changes	58.7	7.5	100	100
Non availability of cultivable land	56.5	7.5	95.5	81.8
Low rainfall	0	57.5	81.8	63.6
Soil poverty	0	12.5	81.8	72.7
Low production linked to BBTD (Banana Bunchy Top Disease)	0	0	100	63.6
Damage of other pests (banana weevil, nematodes…)	13	25	36.4	45.5
Non availability of performing varieties	34.8	0	13.6	36.4
Damage by monkeys	0	0	18.2	36.4
Difficult access to banana seedlings	10.9	2.5	4.5	9.1
Low quality of banana seedlings	2.2	0	0	0
Others	2.2	0	0	0

3.7. Gaps between Organic Agriculture Practices and Agricultural Practices Used by Farmers and Networking of Banana Farmers to Improve Their Agricultural Practices

The farmers have a good knowledge of some organic farming practices such as organic fertilizers use, mulch use, biopesticides use, seed organic treatment and low knowledge for others practices (**Table 10**). The majority of farmers (100%) could attend meetings and training while some farmers (80%) could follow information on the agroecological practices on local radios. Regarding the use of phones and smartphones, 90% of the farmers surveyed had mobile phones while 65% of them could exchange SMS messages on innovate agroecological practices. Few farmers (10%) with smartphones could exchange wathsapp messages on organic banana field management (**Figure 7**). There was a significant variation in the means of communication of farmers across the localities ($P < 0.00001$; $Df = 12$).

4. Discussion

The present study has shown various modes of bananas and plantains seeds acquisition which are loan, donation and sharing. The most widely used procurement method was self-production, which could be explained by the regeneration of banana plants from the main plant. This method of acquiring seeds has been improved by farmers who use the banana stalk to produce ten to twenty seedlings by a technology called plants from stem fragments (PIF) [16] [20]. The PIF technology requires the use of agrochemicals to disinfect seed production systems.

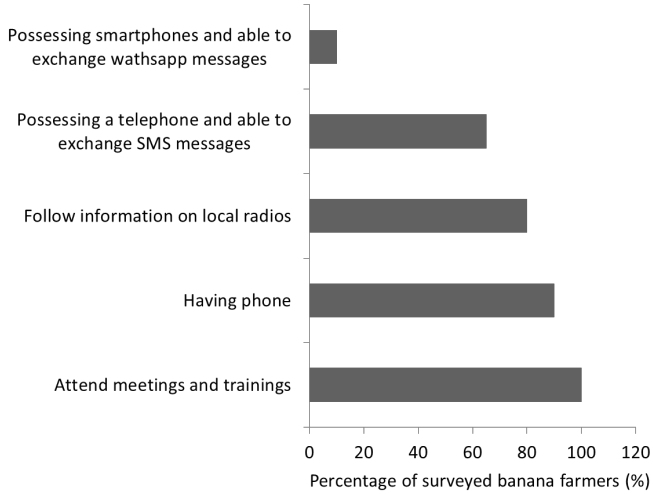

Figure 7. Means of communication of banana farmers on agroecological practices.

Table 9. Constraints related to the banana and plantain commercialization.

Constraints	Atlantique (%)	Mono (%)	Ouémé (%)	Plateau (%)
Low sale price	91.30	52.50	31.80	27.30
Difficult access to sales markets	28.30	42.50	31.80	45.50
Lack of marketing and promotion of local bananas and plantains	13	2.50	4.50	9.10
Custumers difficult to find	8.70	37.50	18.20	27.30
Difficult access to market information	6.50	5	0	9.10
Strong competition with imported bananas and plantains	4.30	5	63.60	9.10
Short periods of banana and plantain conservation	0	0	13.60	0

This agricultural practice does not respect organic farming principles and needs to be improved by the use of biopesticides such as neem oils.

Our results also showed the availability of 26 elite bananas and plantain cultivars in the production areas. This study focused on the most important cultivars unlike other studies which revealed a high diversity of cultivated bananas and plantains [2] [21]. Many cultivars of bananas and plantains are available during the rainy seasons thus showing that these production systems depend on the rains. Irrigation technics are very poorly developed in banana and plantain production systems. These agricultural practices combined with good soil fertilization could improve production systems and make bananas and plantains available all year round [22]. Unfortunately, few farmers invest in improving bananas and plantains production systems through innovative technologies. This result could be explained by the fact that in study area bananas and plantains have been neglected. Farmers produced them mainly for family consumption. But since market demand increased for these products they got more importance between farmer's crop choices.

Table 10. Gaps between organic agriculture practices and agricultural practices used by farmers.

Organic agriculture practices	Methods of application and Contribution to the system in organic and ecological agriculture	Level of involvement/knowledge by farmers	Response percentage of farmers
Water management	Microbiological, chemical and physical studies should be performed to ensure that the water used is clean, whether it comes from a river or an uncontaminated source	Low	2%
	Keep tanks or water reservoirs clean, avoiding contamination	Low	2%
	The use of chlorine is the most common method of ensuring the bacteriological quality of water	Low	2%
Soil management	Choose for planting soils free from pests (nematodes, banana weevil, *Cercospriosis*, *Fusarium*, banana bunchy top disease) that affect bananas	Mean	52%
	Soils for bananas should be loose, deep and well-drained, with good organic matter content and good moisture retention	Low	16%
	Adequate drainage to allow the evacuation of surface and underground water	Low	5%
	Special treatment is required for soils with high pH due to high salt concentrations from excessive chemical fertilization in previous crops	Low	6%
	Use of dead covers (mulch) to avoid losing soil through runoff	High	80%
Soil fertilization with organic products	Banana farmers use organic fertilizers such as chicken manure, growing worms, compost, manure, or green manures such as legumes	High	95%
	Increase the time between organic fertilizer application and harvest to reduce the risk of contaminating the fruit	Low	10%
Choice of plant material	The origin of the plant material should be taken into account when selecting seeds, choosing the characteristics of growth and vigorous young plants	Low	38%

Continued

	The presence of pests and diseases will decrease dramatically with these preparation practices. However, their total elimination is not guaranteed so it is advisable to soak the plants in hot water for a while and apply fungicides and organic insecticides.	High	75%
Pest management	Use biological and mechanical pest management	Mean	50%
	Trap use	Low	15%
	Biopesticides use	High	80%

The study showed that the most used agricultural practices were crop associations, the mechanical destruction of diseased plants, the installation of banana and plantain plantations in lowlands, crop rotation, the use of composts and manures to fertilize the soil. The majority of these agricultural practices are agroecological practices with very little use of chemicals. Many banana and plantain farmers use organic farming practices and their cropping systems are likely to be converted to organic production systems. These good organic farming practices contribute to the sustainability of banana production systems and improve the productivity and profitability of the value chain [23]. This is very relevant and shows the potential of bananas and plantains value chain potential to be converted into organic production with many ecological and social economic opportunities.

Results also showed that almost all of the farmers surveyed knew the symptoms of Banana Bunchy Top Disease (BBTD). Only farmers in the Atlantic and Mono do not know the methods of managing this disease showing that they have not received training on best practices for managing BBTD. In this study, the identification of symptoms of BBTD is based on direct observations and not modern technologies using aerial images and machine learning methods [24]. Farmers in Ouémé and Plateau have received several pieces of training on the management of this disease and some producers still use glyphosate, Sharp 480 and Lagon to control it. Raising awareness and training farmers on agroecological methods such as roguing developed in previous studies [25] are essential to better control this disease in bananas. Banana weevil and nematodes are also identified as the major pests of bananas in the study area, but farmers use many agroecological practices (neem oils, trap plants, etc.) for their sustainable management. Other studies showed that the incorporation around the plant base of powdered neem (*Azadirachta indica* A. Juss.) seed or cake at 60 - 100 g/mat at 4-month intervals, gave better control of the banana weevil, *Cosmopolites sordidus* (Germar), and parasitic nematodes, than that achieved with soil application of Furadan 5G (carbofuran) at 60 g/mat at 6-month intervals [26] [27].

Several constraints limit the production of bananas and plantains. The majority of these stresses were the effects of climate change, the premature fall of banana plants due to lack of water and damage from diseases and pests. Climate change, diseases and pests weaken the production systems of bananas and plantains [28]. These constraints have been identified in other studies as the main constraints in banana and plantain production [29]. Other constraints such as those of commercialization have been identified. It's about the low selling price and access to markets. This study allowed us to understand the banana and plantain production systems and the challenges to be met for an improvement of their value chain.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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