

Full Length Research Paper

Characterization of soil fertility management practices under greater nightshade cropping systems in South Benin

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Received 4 May, 2022; Accepted 15 August, 2022

This study aimed to characterize cropping systems of greater nightshade (*Solanum macrocarpon*) in the market garden areas located along the coastal zone in the South. Socio-economic profile of producers, soil fertility management practices, constraints and nuisances related to the use of organic fertilizers, as well as the endogenous solutions desired by producers were collected from 120 producers in the communes of Grand-Popo and Sèmè-Kpodji. The data collected were subjected to descriptive statistics and the quantitative data was subjected to the Student's *t*-test. Similarly, the typology of producers was carried out through a bottom-up numerical classification followed by a principal component analysis (PCA) and the determinants of fertilization practice through a binary logic regression. The results reveal that the main organic fertilizers used are poultry droppings (85%), cattle manure (45%), and household waste. The main associated mineral fertilizers are urea (95.8%) and NPK in order to improve soil fertility, and therefore yields. According to cultivation practices, there are five groups of market gardeners. The mode of application of mineral fertilizers, the number of farmworkers in the household, and the availability of poultry droppings ($p < 0.01$ to $p < 0.001$) are the main factors that determine the application of fertilizers by market gardeners.

Key words: Horticulture, greater nightshade, soil conservation, organic matter, mineral fertilizers.

INTRODUCTION

In recent years, vegetable production has developed in and around Beninese cities. This agriculture helps to

alleviate many socio-economic problems such as poverty, unemployment and food insecurity through the permanent

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supply of several types of nutrient-rich vegetables and fruits (Ouikoun et al., 2019; Ahouangninou et al., 2015; Assogba-Komlan et al., 2007). However, this activity is developed on sandy coastal soils or in swampy areas that are not well suited to this type of agricultural development (Bloukounon-Goubalan et al., 2018; Igué et al., 2013; Baco et al., 2007). The problem of poverty and the decline in the fertility of these soils arises because of their nature and cultivation practices that do not allow crop residues to be returned to the soil (Igué et al., 2013; Mamam et al., 2019). Indeed, the preparation of crop beds requires cleaning the soil so that it is free of all residues and facilitates the transplanting and emergence of plants (Bloukounon-Goubalan et al., 2018). This practice greatly reduces carbon stocks in the soil. The organic fertilizers used are applied in their raw state (Bloukounon-Goubalan et al., 2018), which accelerates their mineralization and the leaching of essential nutrients from the early stages of plant growth (Bloukounon-Goubalan et al., 2018; Assogba-Komlan et al., 2007; Assogba-Komlan et al., 2002). This situation limits the sustainability of the sector (Ouikoun et al., 2019; Ahouangninou et al., 2015; Adifon et al., 2015). Furthermore, a study by Ahouangninou (2013) revealed that in market gardening, mineral fertilizers are the most consumed compared to organic fertilizers. This practice also results in a decrease in the humus content of the soil and degradation of its structure (Bloukounon-Goubalan et al., 2018).

Solanum macrocarpon or large nightshade is the most widely grown and consumed traditional leafy vegetable in southern Benin (Assogba-Komlan et al., 2007). The area planted increased by 63.93% from the 2015-2016 season to the 2016-2017 season in Sèmè-Kpodji, and by 15% from 2015-2016 to 2016-2017 in Grand-Popo (DSA, 2017). The production obtained for these areas increased by 50.20% in Sèmè-Kpodji and by 31.07% in Grand-popo for these periods. The sustainability of its production is threatened by poverty and the declining fertility of the soils used. Moreover, its harvesting in successive cuts requires regular inputs of mineral and organic fertilizers in a fractional manner (Ouikoun et al., 2019). To remedy this, various soil fertilization strategies are used. These include the use of organic and mineral fertilizers (Turhan and Ozmen, 2021). The main objective of the present study was to characterize the cultivation systems of greater nightshade in southern Benin. This study complements existing studies on soil fertilization in market gardening in southern Benin (Ouikoun et al., 2019; Adifon et al., 2015; Assogba-Komlan et al., 2007). Specifically, the aim was to (i) determine the socio-economic profile of greater nightshade growers in southern Benin; (ii) establish a typology of greater nightshade growers according to their soil fertility management practices; (iii) identify the determinants of the adoption of soil fertility management practices in greater nightshade cropping systems; and (iv) identify the main constraints related to the use of organic fertilizers

as well as the endogenous solutions desired by greater nightshade growers on these sites.

MATERIALS AND METHODS

Study environment

The present study was conducted among market gardeners in two coastal areas (Figure 1) of southern Benin (Sèmè-Kpodji and Grand-Popo sites). The Sèmè-Kpodji market garden site is located in the commune of Sèmè-Kpodji on the Cotonou-Porto-Novo interstate road between latitudes 6°21 to 6°22 N and longitudes 2°34 E, while the Grand-Popo site is located in the southwest of Benin between latitudes 6°12 to 6°27 N and longitudes 1°37 to 1°55 E (Ouikoun et al., 2019).

The entire study area (Table 1) has a maritime sub-equatorial climate adjusted by four unevenly distributed seasons, two rainy seasons and two dry seasons. There is a long rainy season from mid-March to mid-July, a dry season from mid-July to mid-September, a short rainy season from mid-September to mid-November and a long dry season from mid-November to mid-March. The average monthly temperatures vary between 26 and 27°C. The highest daily maximum temperatures rarely exceed 34°C. They are recorded between February and March or even April (32.5°C), which turn out to be the hottest months of the year. The lowest temperatures (24°C on average) occur in August. Humidity is often high but drops slightly in December and January due to the harmattan. The maximum monthly relative humidity is 95%, which is a favorable factor for corrosion and biodegradation. The monthly averages vary between 74.27 and 81.18%. The monthly average rainfall varies between 13.04 mm in January and 309.44 mm in June. The annual average is 1195.62 mm (Adam and Boko, 1993; Adifon et al., 2015). The landform morphology of the study area is generally flat but may locally have interlocking aeolian ripples and knolls. The study area is also part of the geomorphological ensemble of the South Benin coastal zone, which is a very complex area due to the diversity and dynamism of the elements it combines: the sea, deltas, and lagoons, lakes, swamps and coastal strips. The various market garden sites studied are underlain by loose sediment and lie mostly on acidic sandy soils (white soils with podzolic tendencies) (Ouikoun et al., 2019). These soils, which are not very evolved in profile, are very poor in chemical and organic matter, are very permeable and dominated by well-drained sandy alluvium (Adifon et al., 2015; Igue et al. 2013; Assogba-Komlan et al., 2007; Azontonde et al., 1991).

Choice of study villages

The choice of these two market garden sites, the subject of the study, is justified by the fact that they are among the most important peri-urban market garden sites in southern Benin. They provide the populations of the coastal region with nearly 64% of peri-urban market garden production (Adorgloh-Hessou, 2006; Adifon et al., 2015). Furthermore, the two sites are located in the southeast and southwest of Benin respectively.

Criteria relating to cultivation techniques (site maintenance, interest in nightshade, etc.), the practice of mineral, organic, and/or organo-mineral fertilization and access to a market were predominant in the selection of study sites. The availability of land, the accessibility of the area throughout the season and the openness of the market gardeners to collaborate with the research team and the gender aspect was the additional criteria used. As a prelude to the field survey, an exploratory study provided an overview of the market gardeners' cultivation techniques.

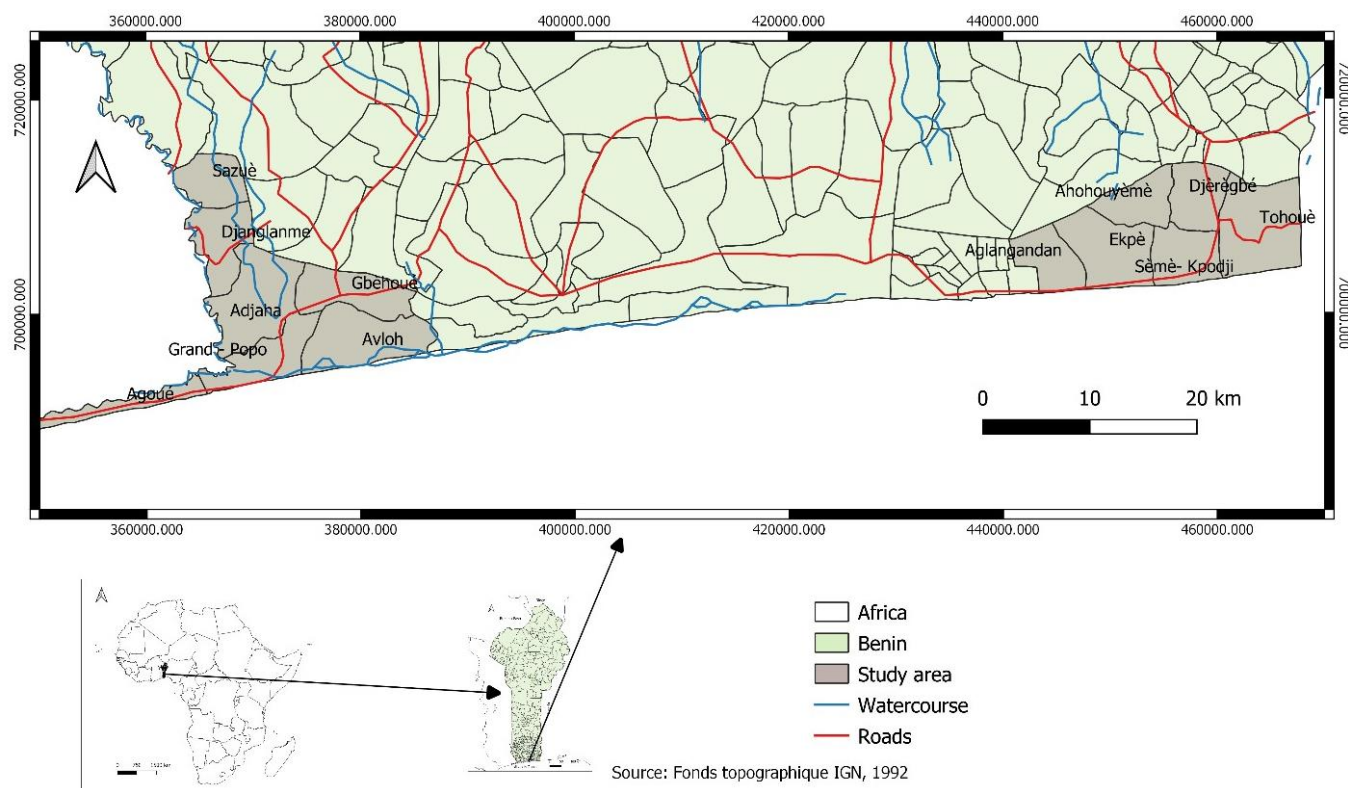


Figure 1. Map showing the study area.
Source: IGN topographic collection (1992); Kpanou et al. (2020).

Table 1. Study environment.

Department	Town	Municipality	Villages
Ouémé	Sèmè-kpodji	Kpodji-Agué	Edjedjié
			Pk14
			Cica
			Kpodji-Agué
Mono	Grand-Popo	Grand-Popo	Ewecondji
			Yodocondji
			Hounssoukoè

Source: Field Survey, 2021

Sampling method

Socio-economic data were collected from randomly selected market gardeners at each site. The sample size N of market gardeners interviewed during the data collection was determined using the normal approximation of the binomial distribution proposed by Dagnélie (1986):

$$N = \left[\left(U_{1-\frac{\alpha}{2}} \right)^2 \times p(1-p) \right] / d^2$$

where p = the proportion of market gardeners producing the greater nightshade; $U_{1-\alpha/2} = 1.96$, the value of the normal random variable

for the probability value of $1-\alpha/2$, α being the risk of error. For $\alpha = 5\%$, the probability $1-\alpha/2 = 0.975$ and we have $U_{1-\alpha/2} = 1.96$. d ($1\% \leq d \leq 15\%$), the margin of estimation error, retained at 5% in this study. Thus, based on the p -values from the results of the exploratory phase of the study, a total of 120 market gardeners were selected in the study area, with 60 producers per site.

Data collection methods and tools

By market garden site, the market gardeners were identified following the focus groups. The individual survey was carried out

Table 2. Parameters used to perform the dendrogram and PCA.

Variable	Code	Variable	Code
Age of respondents	Age	Higher education level	NivSup
Hand weeding	IutAdvManual	Secondary education level	NivSecd
Use of the hoe for weeding	IutAdvBinette	Primary school level	NivPrim
Herbicide use	IutAdvHerbicid	No level of education	No levelNo
Highly profitable production	TreRentabl	Membership in a farmers' organization	ApartOrgYes
Cost-effective production	Cost-effective	Non-membership in a farmers' organization	ApartOrgNon
Fertigation practice	MdAplEMFertig	Year of experience	AneExper
Application of bulk mineral fertilizers	MdAplEMVrac	Household size	TailMeng
Quantity of mineral fertilizers	QteEM	Number of agricultural workers	AssetsTotal
Date of commencement of use of mineral fertilizers	DebUtilisEM	Area planted	SupCult
Use of SuperGro as a mineral fertilizer	Supergro	Area of a board	SupPlanch
NPK cotton fertilizer	NPK	Number of boards	NbrPlanch
Urea	Uree	Type of organic fertilizer used_ Bovine manure	TypOMBouse
How to apply organic fertilizers online	MdAplEOLigne	Type of organic fertilizer used_ Poultry manure combined with animal waste	TypOMBousF
Quantity of organic fertilizers	QutiteEO	Type of organic fertilizer used_ Poultry manure	TypOMFient
Application of bulk organic fertilizers	MdAplEOVrac	Date of commencement of use of organic fertilizers	DebUtilEO

Source: Field Survey, 2021

according to the method described by Balogoun et al. (2016) and Bello et al. (2017) and involved 120 market gardeners with some experience in the production of greater nightshade. In each of the selected sites, data were collected using questionnaires, individual and group surveys, and garden visits (Kombo et al., 2012). The data collected relate to the socio-demographic characteristics of the market gardeners surveyed; the modes of use of organic fertilizers used to date and their respective effects on yields of greater nightshade; the farmers' assessment of the consequences of the use of these organic fertilizers on soil fertility, the prevalence of weeds and pests; and the prospects, according to the market gardeners, for continuing to use these organic fertilizer-based technologies, the constraints linked to the use of fertilizers, etc. Other methods such as observations and photography were used during this data collection phase. The actual areas considered are those corrected by the difference between the values declared and measured with the GPS brand 'Garmin etrex 20' from a sample of five planters per village (Balogoun et al., 2014).

Data processing and analysis

The collected data were coded, entered, and processed with SPSS (Statistical Package for Social Sciences) version 20.0 (Norusis, 2002) for the determination of descriptive statistics in terms of percentage and mean. The quantitative data were then subjected to a Student's t-test with SAS (Statistical Analysis System) version 9.2.

To subdivide the set of market gardeners into a smaller number of classes or groups made up of fairly homogeneous elements according to fertilization practices (Table 2), a bottom-up numerical classification was carried out with the SAS software version 9.2 and following the coefficient of determination $R^2 = 0.50$ (Sossa et al., 2014). Then, the obtained groups of greater nightshade growers were related to the different variables through a principal component analysis (PCA) according to Bello et al. (2017) to facilitate the interpretation of the results and better characterize each of these groups.

Similarly, the types of fertilizers used, the fertilization practices and reasons for using these fertilizers as well as

the constraints of use were related to women and men in the two sites through a simple Factorial Correspondence Analysis (FCA) following Bello et al. (2017). Finally, to determine the factors that explain the market gardeners' fertilization practice, a binary logistic regression was performed according to the following model (Nabikolo et al., 2012):

$$y_i = x_i \beta + \epsilon_i$$

In this equation, y_i represents the dichotomous dependent variable (the variable takes the value 1 if the producer uses a type of fertilizer to fertilize his soils and the value 0 otherwise), x_i is the set of explanatory variables and ϵ_i is the standard error.

The explanatory variables considered are among those reported by different authors (Oyekale and Oladele, 2012; Loko et al., 2013) as affecting awareness by producers. The results of the different analyses are presented in tables and figures according to Kisauzi et al. (2012).

Table 3. Socio-economic characteristics of surveyed nightshade growers.

Variable	Modality	Percentage of respondents		
		Grand-Popo (n=60) ¹	Sèmè-Kpodji (n=60) ¹	Total (n=120) ¹
Gender	Female	28.3	15	22
	Male	71.7	85	78
Age (years)	≤ 40	56.7	53.4	55.1
	≤ 70	43.3	46.6	44.9
Level of education	Not educated	16.7	13.3	15.3
	Primary	31.7	35	33.9
	Secondary	36.7	41.7	39.8
	Superior	15	6.7	11
Membership of an organization	Yes	61.7	93.3	78.9
	No	36.7	3.3	20.3
Main activity	Farmer	96.7	85	92.4
	Agri-farmer	3.3	5	4.2
	Artisan	0	3.3	1.7
	Caregiver	0	3.3	1.7
Experience in the production of large nightshade (years)	<10	60	84.5	72
	10 - 20	30	13.8	22.1
	> 20 s	10	1.7	5.9
Household size	≤ 5	56.7	27.6	42.4
	≤ 10	41.6	56.9	49.1
	> 10	1.7	15.5	8.5
Agricultural assets	A ≤ 5	85	91.4	88.1
	A > 5	15	8.6	11.9
Total area available (ha)	≤ 0.5	60	31	45.8
	≤ 1	17.7	34.5	25.4
	S ≥ 1	22.3	34.5	28.8
Allocated area (ha)	≤ 0.5	95	98.3	96.6
	≤ 1	3.3	1.7	2.6
	≥ 1	1.7	0	0.8
Area of land (ha)	≤ 0.02	18.3	100	58.5
	≤ 0.05	56.7	0	28.8
	≥ 0.05	25	0	12.7

Source: Field Survey (2021).

RESULTS

Socio-economic characteristics of greater nightshade growers

The results of the descriptive analysis carried out on the

socio-economic characteristics of the greater nightshade growers surveyed in Grand-Popo and Sèmè-Kpodji are presented in Table 3. The analysis of the table shows that the majority of market gardeners are men (78% against 22% of women). Their age varies from 22 to 70 years, with an average of 40.05 ± 10.96 years in the

Table 4. Quantitative data (mean values $\pm$ standard errors) on greater nightshade producers in the two study areas.

Municipality	Age (years)	Experience (years)	Household size	Total assets	Total area available (ha)	Allocated area (ha)	Area of a board (ha)	Experience in using organic fertilizer (years)	Experience in using mineral fertilizer (years)
Grand-popo	40.23 $\pm$ 1.51 ^a	11.17 $\pm$ 0.98 ^a	5.35 $\pm$ 0.31 ^b	4.02 $\pm$ 0.27 ^a	0.91 $\pm$ 0.14 ^a	0.16 $\pm$ 0.03 ^a	0.04 $\pm$ 0.002 ^a	9.68 $\pm$ 0.86 ^a	10.5 $\pm$ 0.92 ^a
Sèmè-kpodji	39.86 $\pm$ 1.34 ^a	7.62 $\pm$ 0.65 ^b	7 $\pm$ 0.41 ^a	2.81 $\pm$ 0.26 ^b	1.34 $\pm$ 0.2 ^a	0.13 $\pm$ 0.01 ^a	0.03 $\pm$ 0.00 ^b	8.38 $\pm$ 0.55 ^a	8.43 $\pm$ 0.60 ^a
Probability	0.85	0.003	0.002	0.002	0.08	0.38	0.0001	0.21	0.06

Means followed by the same alphabetical letters are not significantly different ($P > 0.05$) according to Student's t-test*
Source: Field Survey, 2021

whole study area. They are mostly educated (85%) and belong to an organization (78.9%), especially in Sèmè-kpodji (93%). The main services provided by these organizations are training (50%), granting of microcredits (17%) and, to a lesser extent, the supply of agricultural inputs (4.2%) and assistance (3.4%). The main activity of these producers is agriculture (92.4%). The Student's t-test (Table 4) showed no significant difference ($p > 0.05$) between the two sites (Grand-Popo and Sèmè-Kpodji) in terms of the age of the market gardeners, the total area available, the area allocated to nightshade, and experience in using organic and mineral fertilizers. However, the experience of market gardeners in producing nightshade, the size of the household and the number of total agricultural assets, and the area allocated to beds varied very significantly ($p < 0.01$ to $p < 0.001$) from one site to another, and the market gardeners in Grand-Popo were the most experienced.

Typology of nightshade producers

The result of the market gardeners' typology is presented in the form of a dendrogram (Figure 2). Based on the results of the dendrogram, the initial information allows us to classify these market gardeners into five types of market gardeners

according to their fertilization practices (Figure 2). Group 1 contains 58 farmers (48.33%), group 2 contains 37 farmers (30.83%), group 3 contains seven farmers (5.83%), group 4 contains 17 farmers (14.17%) and one farmer (0.83%) forms group 5.

The results of the principal component analysis (PCA) carried out on the different groups of vegetable farmers and the variables related to soil fertility management practices made it possible to describe the relationships between them and refine their analysis. These results indicate that the first two axes explain 74% of the total information (Table 5).

The projection of the different variables into the system of axes defined by the groups of market gardeners (Figure 3) reveals that the market gardeners in Group 1 are educated producers (secondary school level), belonging to an organization with high household size and area allocated to the cultivation of greater nightshade and using household waste and poultry droppings as organic fertilizer. They apply mineral fertilizer in bulk and use weeding or hoeing for weed control. Group 2 consists of market gardeners with secondary education. These producers use cattle droppings, poultry droppings, and household waste only as organic fertilizer. Those in Groups 3 and 4 are uneducated market gardeners with large areas. They make large beds and have no

particular preference for the use of organic fertilizers. However, they make a very good return on their large nightshade production compared to the other groups. Group 5 consists of the only primary-level farmer who does not belong to an organization. He is very experienced, with high total assets, and has been using household waste and cattle dung for a long time, combined with mineral fertilizer applied by fertigation. He uses herbicide for weed control and finds nightshade production profitable.

Reasons and constraints for using organic fertilizers according to men and women market gardeners in the two sites

The results of the correspondence factorial analysis (CFA) performed on the data related to the reasons and constraints mentioned by women and men's market gardeners showed that the first two explain 97.83% of the total information (Table 6).

Figure 4 presents the results of the CFA. The analysis of this figure shows that in Grand-Popo, men and women market gardeners use household waste, cattle droppings, and poultry droppings as organic fertilizers and combine them with the foliar liquid fertilizer 'Super Gro'. The mineral fertilizers used by them are NPK (NPK 15-15-15, NPK 13-

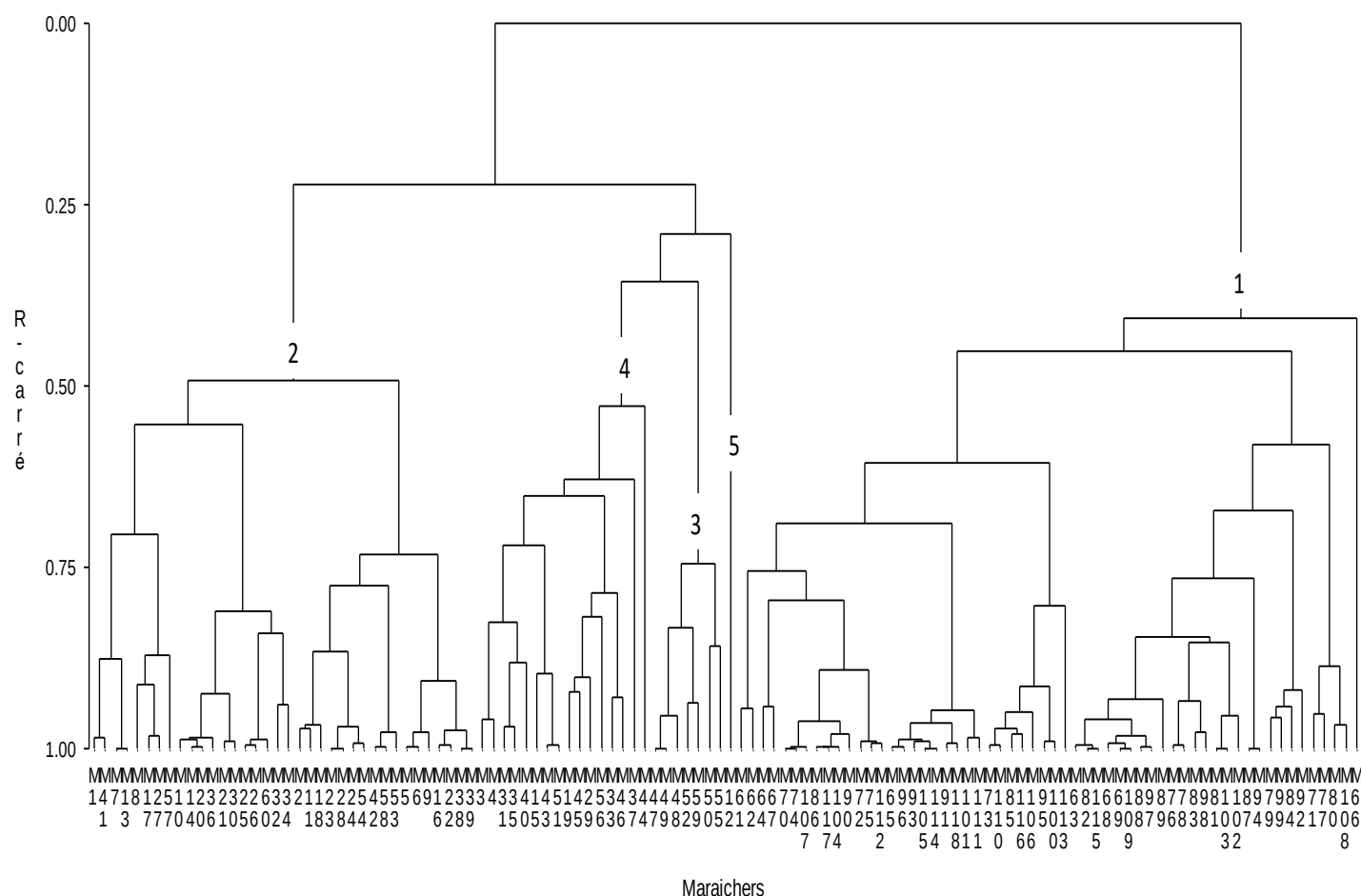


Figure 2. Typology of greater nightshade growers according to their soil fertility management practices.
Source: Field Survey, 2021

Table 5. Eigenvalue of the first four principal components.

Axis of PC	Eigen value	Proportion	Cumulative proportion
Axis 1	11.646	0.485	0.485
Axis 2	6.002	0.250	0.735
Axis 3	3.594	0.150	0.885
Axis 4	2.758	0.115	1

Means followed by the same alphabetical letters are not significantly different ($P > 0.05$) according to Student's t-test*.

Source: Field Survey (2021).

17-17, NPK 20-10-10) and urea. They use these fertilizers to improve the growth and development of the crop. These market gardeners benefit from micro-credits. The main constraint noted by these market gardeners is the prevalence of weeds, difficulties in obtaining raw materials and the rapid development of weeds linked to the use of organic fertilizers.

In Sèmè-kpodji, men use household waste and poultry

droppings much more for organic fertilization of the greater nightshade. They use these organic fertilizers to improve the fertility of their soils. The main constraints in using these organic fertilizers are the availability of manpower for transport and application and the burning of the leaves. In addition, they receive assistance from the farmers' organizations to which they belong. As for the women of the said commune, they have the same

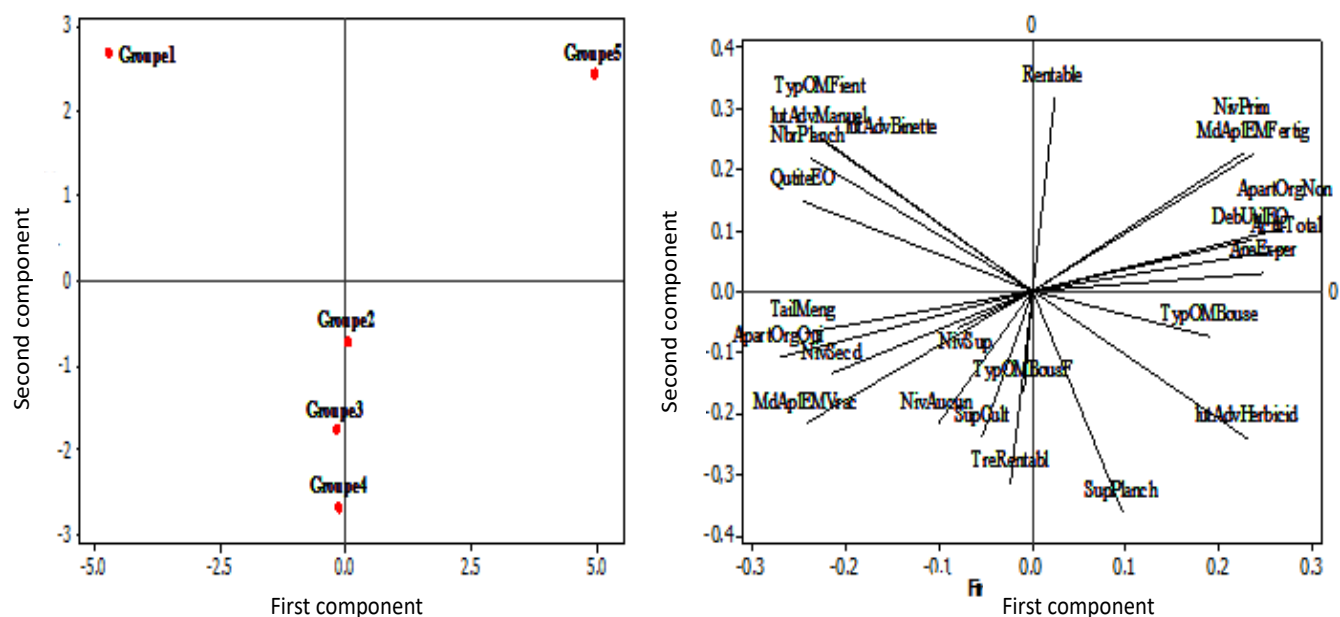


Figure 3. Projection of the different groups of identified nightshade producers and their characteristics according to the principal component analysis (PCA).
Source: Field Survey (2021).

Table 6. Inertia and percentage of information on the axes.

Axes	Inertia	Proportion	Cumulative
1	0.4156	0.9215	0.9215
2	0.0256	0.0568	0.9783
3	0.0098	0.0217	1

Source: Field Survey (2021).

characteristics, except that they use organic fertilizers to have quality vegetables and to improve profitability. In the site of Sèmè-kpodji, the constraints listed are the lack of financial means, the difficulties in supplying organic fertilizers, the scarcity of manpower and the burning of leaves after applying organic fertilizers.

Determinants of the choice of fertilization practices despite the constraints linked to their use

The binary logic regression analysis (Table 7) revealed that among the thirty or so explanatory variables considered, the sale price of crops in periods of abundance, the mode of application of mineral fertilizer; plank area, the type of organic fertilizer, the number of agricultural assets in the household, the area cultivated, experience in using organic fertilizer and its price in periods of abundance ($p < 0.05$ to $p < 0.001$) are the factors that determine the fertilization practice of the market gardeners surveyed. The results indicate that market gardeners with very good experience in the use of

organic fertilizers and with large areas of land and a large number of farmworkers in the household, combined with easy access to organic fertilizers, especially during periods of abundance, and combine with mineral fertilizers to obtain good profits at the end of the sale, are the most likely to define a good fertilization practice for greater nightshade on their site (Table 6).

DISCUSSION

Socio-economic characteristics of greater nightshade growers

The production of large nightshade in South Benin is a male activity. Indeed, it is carried out by adult men under the age of 40 years. These results corroborate those of Ouikoun et al. (2019) who, after a socio-economic study of market gardeners in this area, found that the majority were men under 50 years. The experience of these market gardeners in the production of greater nightshade is a major asset in that they have mastered production

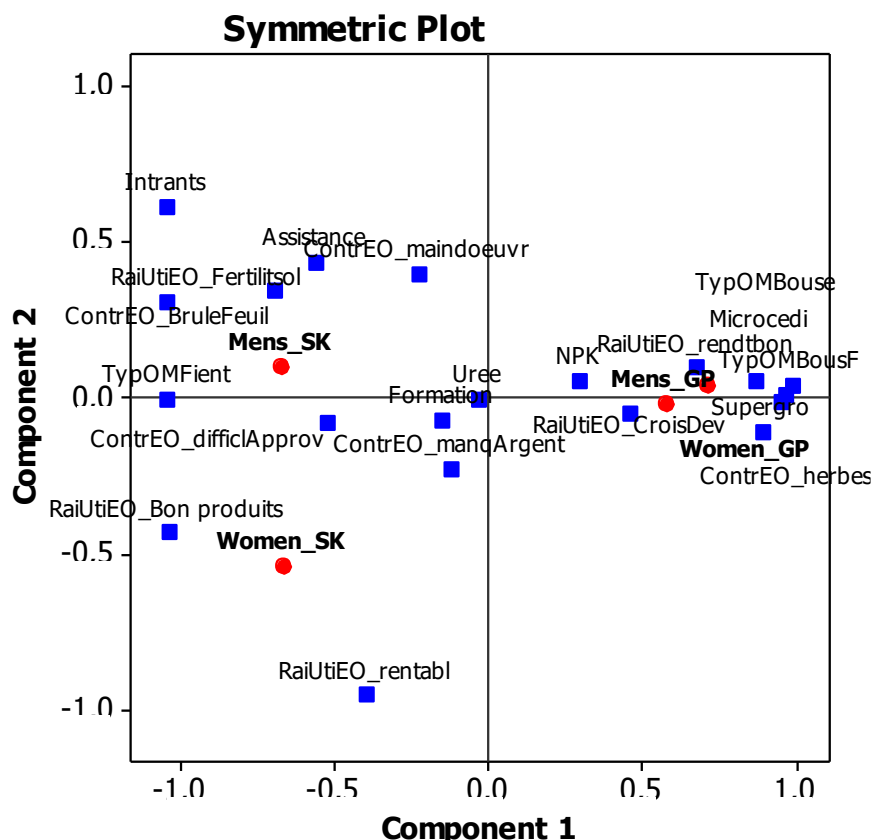


Figure 4. Reasons for using organic fertilizers and constraints: Result of the Correspondence Factorial Analysis (CFA). Legend: SK= Sèmè-kpodji; GP= Grand Popo. Source: Field Survey (2021).

techniques, which enables them to make their activity profitable despite the existing constraints. The fact that the vast majority of them belong to organizations is proof that the sector is organized, which facilitates the dissemination of new technologies and information by the services in charge of agricultural development, as mentioned by Biaoou et al. (2016). Such a level of organization also facilitates collaboration between these producers and private organizations in the agricultural sector such as NGOs, projects and programs, the Ministry of Agriculture, etc. The high literacy rate (85%) among the surveyed population is also a major asset for understanding the training provided to them and thus facilitates the dissemination of technologies. The area allocated to the cultivation of greater nightshade in the entire study area is less than 0.5 ha (96.6% of respondents). The studies by Ahouangninou (2013) and Assogba-Komlan et al. (2007) also revealed that market gardeners in southern Benin cultivated small areas often smaller than 0.25 ha in peri-urban areas and 0.05 ha in urban areas in Cotonou. The difficulty of land availability in these areas limits investment in heavy equipment and the latest technologies to modernize the sector. This also

encourages reductions in the length of fallow periods and a preference for crop rotations with short-cycle crops in these areas.

Typology of nightshade producers

The typology of producers revealed that market gardeners who produce greater nightshade can be grouped into five classes. Groups 3 and 4 have the same characteristics, with the only difference being that the educational level of the producers is secondary for some and university for others, so these two classes could be combined into one, which would reduce the typology to 4 main groups distributed as follows. Group I (48.33%): Educated market gardeners (secondary school level), belonging to an organization, with a high household size and area allocated to cultivation and using household waste and poultry droppings as organic fertilizer, who apply mineral fertilizer in bulk and have as a means of weed control weeding or the use of the hoe; Group II(30.83%): Educated market gardeners (secondary school or university level) who use exclusively one or other of the

Table 7. Probability of variables for the determination of factors influencing the choice of fertilization practices despite the constraints linked to their use.

Explanatory variable	Chi- ²	Pr > Khi- ²
Level of education	0.7453 ^{ns}	0.3880
Membership in an organization	2.0586 ^{ns}	0.1513
No membership in an organization	2.0586 ^{ns}	0.1513
Number of years of experience	3.2098 ^{ns}	0.0732
Household size	1.3644 ^{ns}	0.2428
Total assets	4.0285*	0.0447
Cultivated area	7.7885*	0.0053
Area of the Planche	4.2812**	0.0385
Number of boards	2.2683 ^{ns}	0.1320
Cattle manure	5.0778**	0.0242
Cattle manure and dung	0.2611 ^{ns}	0.6094
Manure	4.0023*	0.0454
Experience in the use of organic fertilizer	5.1010*	0.0239
Quantity of organic fertilizer	1.4784 ^{ns}	0.2240
Application of bulk organic fertilizer	3.3760 ^{ns}	0.0662
Application of organic fertilizer inline	3.3760 ^{ns}	0.0662
Experience in the use of mineral fertilizer	3.8200 ^{ns}	0.0506
Quantity of mineral fertilizer	0.0183 ^{ns}	0.8923
Application of bulk mineral fertilizer	28.7436	<0.0001
Application of mineral fertilizer by fertigation	28.7436	<0.0001
Cost-effective production	2.9350 ^{ns}	0.0867
Highly profitable production	2.9350 ^{ns}	0.0867
Price of organic fertilizer in times of shortage	2.8559 ^{ns}	0.0910
Price of organic fertilizer in times of planting	3.8559	0.0496
Selling prices of crops in times of planting	11.0219	0.0009
Access to Microcredit	3.2130 ^{ns}	0.0731
Access to training	1.4437 ^{ns}	0.2295
Support	0.1453 ^{ns}	0.7031
Inputs	0.1832 ^{ns}	0.6686

*P < 0.05; **P < 0.01; ***P < 0.001; ns: p>0.05.

Source: Field Survey (2021).

following organic fertilizers: cattle or poultry droppings or household waste; Group III (19.99%): Uneducated market gardeners with the largest areas and who use any available organic fertilizer. Group IV (0.83%): Primary level market gardeners, not belonging to any organization, very experienced, with high total assets. They have rich experience in using household waste and cattle dung in combination with mineral fertilizer applied by fertigation. This category of producers uses herbicide for weed control and finds the production of greater nightshade profitable.

This approach was used by Anago et al. (2020) to determine groups of rice producers according to endogenous cropping systems in Benin. Another typology was carried out by Ahouangninou et al. (2015) to categorize vegetable farms in southern Benin according to the scores obtained for different sustainability

indicators. Seven types of vegetable farms were identified by this study.

The typological analysis of the cultivation systems for greater nightshade on the two sites showed that there is diversity. The systems are distinguished in particular by the length of time the land is used under nightshade cultivation, the quantities and types of organic and mineral fertilizers used, and how these manures are used.

The socio-professional characteristics that determine a farmer's choice of cropping system are the size of the farmer's household, age, seniority, and education level. The most dominant systems are systems 1 and 2, which account for 48.33 and 30.83% of the producers surveyed respectively. Similar results were obtained with pineapple producers on the Allada plateau in Benin (Sossa et al., 2014).

Reasons and constraints for using organic fertilizers according to men and women market gardeners in the two sites

The sustainability of production in South Benin is limited by, among other things, the small area under cultivation and the decline in soil fertility (Ahouangninou et al., 2015). The results of the present study are in line with this. Indeed, the poor nature of coastal soils and urban and peri-urban areas implies systematic organo-mineral fertilization before any agricultural valorization compared to the soils of floodplain areas (Ouikoun et al., 2019; Assogba-Komlan et al., 2007). Thus, the organic fertilizers used to raise the fertility of these soils are household waste, cattle droppings, and poultry droppings as reported by Assogba-Komlan et al. (2007) and Ahouangninou (2013). These fertilizers are generally brought in raw form without prior sorting or composting. Such practices present risks for the environment and health in the sense that due to the sandy texture of the exploited soils, especially on the coastal strip, risks of percolation of chemical substances towards water sources are inevitable as well as their bioaccumulation in consumed vegetables as reported by Ouikoun et al. (2019) and Pazou Yehouenou et al. (2010). In addition, it should be noted that nightshade is more fertilized than other leafy vegetables because of its harvesting in several successive cuts (Assogba-Komlan et al., 2007). Also, the doses of organic fertilizer applied are much higher than those recommended by research (20 t/ha) for leafy vegetables (Ouikoun et al., 2019; Assogba-Komlan et al., 2007). The highest doses are applied in coastal areas, inland and on the outskirts of cities (Assogba-Komlan et al., 2007). They average about 50 kg for an area of 35 to 60 m² per application (Ouikoun et al., 2019).

Concerning the mineral fertilizers used, the analysis of the data revealed that these were urea 46%N and NKP formulations (15-15-15, 13-17-17 and 20-10-10). The work of Ouikoun et al. (2019) and Assogba-Komlan et al. (2007) also showed that in addition to 46%N urea and NKP (15-15-15 and 20-10-10), NPK 14-23-14 was also used. Furthermore, this work revealed that these mineral fertilizers were applied twice on average in a fractional manner, unlike organic fertilizer, which is applied once at the beginning of the cycle, regardless of the zone. The doses applied were much higher (5 times) than the doses of urea (75 kg/ha) and 3 times higher than the doses of NPK (150 kg/ha) accepted and recommended by research for leafy vegetables in Benin (Ouikoun et al., 2019). It is recommended that the use of mineral fertilizers be reduced in favor of organic fertilizers to make vegetable production in these areas more sustainable (Akpo et al., 2016; Ahouangninou et al., 2015; Assogba-Komlan et al., 2007). The constraints related to the use of organic fertilizers noted by producers in Su-Benin are the prevalence of weeds, difficulties in supplying raw materials, the lack of manpower for

transporting and applying organic fertilizers, the burning of leaves, and the lack of financial means. Numerous studies have pointed out the importance of treating these organic fertilizers, particularly through the composting process, to improve their quality, stability and effectiveness and to limit environmental and health risks (Ahouangninou et al., 2015; Agbossou et al., 2003). This would also allow for better and sustainable conservation of these organic fertilizers and make them available to producers at any time of the year. The problem of financing was also identified and corroborated by the work of Ahouangninou (2013) due to the small size of the areas farmed, which does not allow these producers to increase their land and equipment capital for more efficient and profitable production. Access to agricultural credit would be a very good alternative to facilitate the acquisition of inputs needed to improve their activity. These technologies are used to improve soil fertility, yield and the quality of nightshade leaves.

Determinants of the choice of fertilization practices despite the constraints linked to their use

Our results revealed that the main determinants of the choice of organic fertilizers to improve the productivity of greater nightshade in southern Benin are experienced in the use of these organic fertilizers, the area allocated to the crop, the availability of manpower to carry out the cultivation operations, the availability of these fertilizers, especially in periods of abundance as well as the profitability of the activity when these fertilizers are used in combination with mineral fertilizers. Gender, age of the producer, education, marital status of the producer, origin, number of active women in the household, area allocated to cashew and source of funding for cashew cultivation did not influence whether or not a fertilization plan was adopted. Bello et al. (2017) had also obtained similar results from cashew farmers in Benin. However, these results are contrary to those obtained by Tazeze et al. (2012) in Ethiopia, Oyekale and Oladele (2012) in Nigeria and Loko et al. (2013) in Benin. However, these authors obtained the same results about the experience of producers as a determinant of the choice of an adaptation strategy. These results corroborate those obtained by Hassan and Nhemachena (2008), who showed that age and gender are not necessarily determinants of adaptive strategies developed at the local level, but rather it is the experience of farmers in agriculture and the capacity of households to access credit and the market. According to Falola et al. (2012), the fact that vegetable farmers in the production areas visited acquire and develop more skills over time allows them to take adaptive measures to acquire organic fertilizers. However, the study by Deressa et al. (2011) in Ethiopia, found similar results and revealed that the education level of the producer also increases the

probability of adopting a good crop fertilization plan.

Conclusion

This study made it possible to characterize soil fertility management practices in the peri-urban market gardens of southern Benin. It was found that nightshade production in this area is mainly carried out by educated men, adults and young people, belonging to organizations that mainly provide them with training. These market gardeners use organic fertilizers (poultry droppings, cattle droppings and household waste) combined with mineral fertilizers (urea and NPK) to improve the fertility of the naturally poor sandy soils they use, but also to increase yields, improve the quality of the nightshade leaves and the profitability of the activity. The main constraints to the use of these organic fertilizers are the prevalence of weeds, the availability of these organic fertilizers at all times, as well as the availability of manpower to carry out all the cultivation operations including the transport and application of these organic fertilizers. Other constraints to the development of the sector include the difficulty of accessing land and the lack of financial resources to modernize and develop this crop. Thus, prior treatment of these organic fertilizers (sorting and composting) would make it possible to improve their quality, long-term conservation, availability and effectiveness for more sustainable fertilization and productivity. In addition, support such as agricultural credits would enable greater nightshade producers to strengthen their land, equipment and technical capital to better develop this activity and to largely cover the needs of the urban population for this commodity.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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