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Research Article

Analysis of organic fertilizer management practices under onion (*Allium cepa* L.) cropping systems in Benin

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Abstract

Onion production in Benin is limited by the low fertility of the soils used to produce it. This study aimed to analyze soil fertility management practices under onion cropping systems to improve soil fertility and crop yields. A survey was carried out among 180 randomly selected producers, 60 in each urban and peri-urban site of Malanville (North), Grand-Popo and Sèmè-Kpodji (South). Descriptive statistics were used to analyze the data. The results showed that the organic fertilizers used are cattle and poultry droppings (according to their availability in the area) combined with urea (46 % N) or NPK. The results of the analysis of the variance (ANOVA) followed by the Student-Newman-Keuls test performed on the quantitative data collected showed that the producers in Malanville are more experienced in the use of organic fertilizers (14.53 ±1.12 years) than those in the south ($P<0.0001$). The farmers could be classified into seven main groups according to their soil fertility management practices. The type of service provided by the organization, the type of organic fertilizer and its mode of application are the main variables that determine the choice of fertilization practices of the market gardeners surveyed in the study area ($P < 0.05$). This study showed that organo-mineral fertilization is widely used in onion production and provides a basis for reflection for a better consideration of organic residues in vegetable fertilization.

1. Introduction

In Benin, market gardening plays a crucial socio-economic role, especially for the populations of urban and peri-urban areas who practice it [1-3]. It is also a source of essential nutrients for these populations [2]. This activity is widespread throughout the country [4]. The crops produced are exotic (cabbage, carrot, lettuce, celery, parsley, etc.) or local such as tomato, onion, okra, nightshade, amaranth, etc. [5]. Despite these assets, the sector is subject to many difficulties. These include the reduction of cultivable areas due to population growth, the development of areas unsuitable for agriculture such as lowlands and naturally poor coastal sandy soils [1, 6-8] and the depletion of these soils of nutrients due to their overexploitation to cover the needs of a growing urban population [5]. This situation affects the productivity of the main crops produced there. In addition, poor cultivation practices in market gardening that deprive the soil of all crop residues to facilitate transplanting and plant emergence aggravate this poverty of exploited soils [9,

10], which requires the use of several sources of fertilizer to keep productivity high.

Onions (*Allium Cepa* L.) are a highly prized vegetable in Benin [3]. Its production is mainly developed in the North in the department of Alibori [11] and represented 86.81% of national production in 2017 [12]. But in recent years, its cultivation has spread to the south (Littoral, Mono, Collines, Couffo and Ouémé departments) in order to satisfy national demand during periods of low availability of production from the North and imports, notably from Niger, Nigeria and Burkina-Faso [13, 14]. Thus, production in Malanville was estimated at 55 153 t during the 2022-2023 season for a sown area of 4 329 ha compared to 358 t for 37 ha in Sèmè-kpodji and 10 260 t for 594 ha in Grand-Popo during the same period [12]. However, all of this production is unable to meet national demand [13] due to, among other things, the problems of fertility of the soils used.

The present study aimed to analyze onion production systems in Benin. The data specifically focused on the characterization of different current soil fertility management practices under onion cultivation on some main market gardening sites in North and South Benin. The aim was to characterize the socio-economic profile of onion producers, to establish a typology of these producers according to their soil fertility management practices, to analyze the perception of producers in the study area on the importance of fertilizing their soils, and to identify the main determinants of the choice of these fertilization practices as well as the main constraints related to their use and the endogenous and exogenous solutions to remedy them. The main purpose is to encourage the use of quality organic fertilizers for sustainable production and to improve the living conditions of onion producers.

2. Materials and methods

2.1 Study area

The study was carried out among producers in the market gardening perimeters of North Benin (Malanville site) and the southern coastal zone (Grand-Popo and Sèmè-Kpodji sites) (Fig. 1). The commune of Malanville is located between 11° 52′ 0″ North, 3° 22′ 60″ East, in the Department of Alibori in the far North [15]. It is characterized by a Sudan-

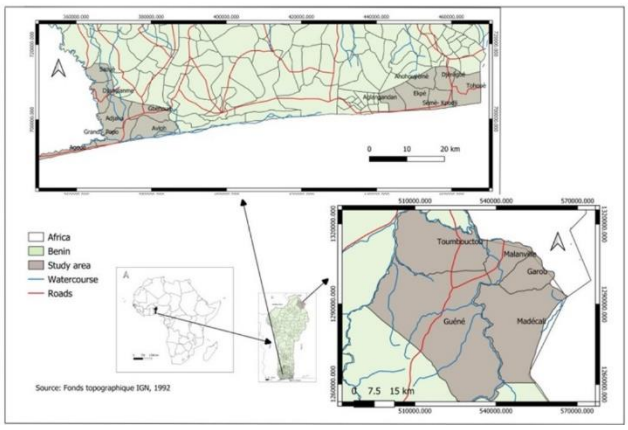

Figure 1. Map of the study area

Sahelian type climate marked by a dry season from November to April and a rainy season from May to October [14]. In the Niger valley and its tributaries, the soils are sandy-clay and ferruginous [16]. The district of Grand-Popo is located between 6° 22′ 00″ North and 2° 37′ 00″ East in the Cordon Littoral area of southern Benin [3]. There are three main types of soils, namely: littoral and dune cordon soils at the coast; ferruginous soils with a sandy-clay texture at the level of the plateau areas (the mainland) and finally alluvial and hydromorphic soils at the level of the swamps and plains [7]. The municipality of Sèmè-Kpodji is also located in the Cordon Littoral zone in southern Benin [3] between 6° 15′ 50″ North and 1° 44′ 30″ East. The soils, there are of the crude mineral type, consisting of fine sands, poor in organic matter, very permeable and well drained [17]. These two southern sites have a maritime sub- equatorial climate characterized by four unevenly distributed seasons, two rainy and two dry. 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 visited villages by the site are presented in Table 1.

2.2 Choice of study villages

The market garden sites selected were chosen because they are among the largest and most productive onion areas in Benin. In fact, in 2017, the production of these three sites represented 70.92% of national onion production [12]. 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

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Table 1. Study environment

Department	Commune	District	Villages
Ouémé	Sèmè-Kpodji	Kpodji-Agué	Edjedjié Pk14 Cica Kpodji-Agué
Mono	Grand-Popo	Grand-Popo	Ewecondji Yodocondji Hounssoukoè
Alibori	Malanville	Malanville	Monkassa Bodjécali

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 were the additional criteria used. As a prelude to the field survey, an exploratory study provided an overview of the market gardeners' cultivation techniques.

2.3 Sampling method

Socio-economic data were collected from randomly selected market gardeners in 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 [18]:

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

With p = the proportion of market gardeners producing greater nightshade; U1-α/2, value of the normal random variable for the probability value of 1-α/2, α being the risk of error. For α = 5%, the probability 1-α/2 = 0.975 and we have $U_{1-\alpha/2}$ = 1.96. d (1%≤d≤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 180 market gardeners were selected from the study area, with 60 producers per site.

2.4 Data collection methods and tools

Focus groups were used to identify experienced market gardeners to whom a questionnaire was administered individually using the method described by [19]. This survey was carried out with 60 people per site, i.e. 180 producers in total for the whole study area. Data were collected through questionnaires, group surveys, visits, observations and photography. The data collected related to the socio-demographic characteristics of the market gardeners surveyed; the methods of using organic fertilizers to date and their respective effects on onion yields; the farmers' assessment of the consequences of using 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 related to the use of fertilizers, etc. The actual areas considered are those corrected by the difference obtained between the values declared and measured with the GPS brand 'Garmin eTrex 20' from a sample of five farmers per village.

2.5 Data processing and analysis

The collected data were codified, entered and processed with SPSS (Statistical Package for Social Sciences) version 20.0 [20] for the determination of descriptive statistics in terms of percentage and mean. The quantitative data were then subjected to an analysis of the variance (ANOVA) using SAS (Statistical Analysis System) version 9.2 software. Comparisons of means were made using the Student-Newman-Keuls test at 5% [18].

A typology of all the market gardeners was carried out using a bottom-up numerical classification with SAS software version 9.2 and following the coefficient of determination R^2 =0.50 [21]. It allowed us to classify them according to some homogeneous criteria based on fertilization practices (Table 2). Then, the groups of market gardeners obtained were related to the different variables through a principal component analysis (PCA) according to [22] which 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 were related to women and men in the two sites through a simple Correspondence Factorial Analysis (CFA) according to [22]. Finally, to determine the factors that explain the market gardeners' fertilization practice, a binary logistic regression was performed according to the following model [23]:

$$yi = xi\,\beta + \varepsilon i$$

In this equation, yi represents the dichotomous dependent variable (the variable takes the value 1 if

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Table 2. Parameters used to perform the dendrogram and principal component analysis

Variables	Codes	Variables	Codes
Age of respondents	Age	Higher education level	NivSup
Hand weeding	lutAdvManual	Secondary education level	NivSecd
Use of the hoe for weeding	lutAdvBinette	Primary school level	NivPrim
Herbicide use	lutAdvHerbicid	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 dung	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

the producer uses a type of fertilizer to fertilize his soils and the value 0 otherwise), xi is the set of explanatory variables and εi is the standard error.

The explanatory variables considered are among those reported by different authors [24, 25] as affecting awareness by producers. The results of the different analyses are presented in tables and Fig.s according to [26].

3. Results

3.1 Socio-economic characteristics of greater nightshade growers

Table 3 presents the results of the descriptive analysis of the socio-economic variables of onion producers in the three production zones surveyed in Benin. In general, men produce more onions (86.7%), are young with an average age of 38±2,0 years (52.2%) and are educated (66.7%). The commune of Malanville stands out from the other sites because this activity is carried out exclusively by men (100%), most of whom are not educated (71.7%). These producers are united within organizations (61.1%), especially in Sèmè-Kpodji (91%). Throughout the study area, the main activity of the people surveyed is agriculture (95%). However, there were also civil servants (2.8%) and artisans (1.7%). Most producers have an average experience of 11.4 years. The households of these producers range from 5 to 10 people (40.6%), of whom less than five are actively involved in agricultural production (80%). 47.3% of these producers have an agricultural area of between 1ha and 5 ha (78.3% of respondents in Malanville). The area allocated to onion cultivation in the entire study area is less than 0.5 ha (72.8%). However, in Malanville, 40% of respondents allocate between 0.5 and 1 ha to this crop. Furthermore, in Malanville and Sèmè-Kpodji, the planks made are less than 15 m² long (100%), whereas they are between 30 and 60 m² long in Grand-Popo (68.3%).

Furthermore, the analysis of variance presented in Tables 4a and 4b showed no significant difference ($P>0.05$) between all the study sites (Malanville, Grand-Popo and Sèmè-Kpodji) for the age of market gardeners. However, the differences are highly significant ($P< 0.01$ to $P< 0.001$) for the number of total

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Table 3. Socio-economic characteristics of surveyed nightshade growers

Variables	Modalities	Percentage of respondents (%)			
		Malanville (n=60)[1]	Grand-Popo (n=60)[2]	Sèmè-Kpodji (n=60)[3]	Total (n=180)[4]
Gender	Female	0	28.3	11.7	13.3
	Male	100	71.7	88.3	86.7
Age	Age ≤ 36 years	60	58.3	38.3	52.2
	36≤Age≤ 60 years	40	41.7	61.7	47.2
	Age ≥ 60 years	0	1.7	0	0.6
Level of education	Not educated	71.7	15	13.3	33.3
	Primary	10	31.7	30	23.9
	Secondary	16.7	38.7	48.3	34.4
	Superior	1.7	15	8.3	8.3
Membership of an organization	Yes	43.3	48.3	91.7	61.1
	No	56.7	51.7	8.3	38.9
Main activity	Farmer	93.3	100	91.7	95
	Artisan	3.3	0	1.7	1.7
	Civil servant	3.3	0	5	2.8
Experience in onion production	Under 10 years	36.7	48.3	98.3	61.1
	Between 10 and 20 years	36.6	40	1.7	26.1
	More than 20 years	26.7	11.7	0	12.8
Household size	Less than 5	26.7	68.3	3.3	39.4
	Between 5 and 10	31.6	30	60	40.6
	More than 10	41.7	1.7	16.7	20
Agricultural assets	Less than 5	71.7	78.3	90	80
	More than 5	28.3	21.7	10	20
Total area available (ha)	S ≤ 0.5	1.7	63.3	21.7	28.9
	0.5 ≤ S ≤ 1	10	18.4	33.3	20.5
	1 ≤ S ≤ 5	78.3	18.3	45	47.3
	5 ≤ S ≤ 20	10	0	0	3.3
Allocated area (ha)	S ≤ 0.5	38.3	80	100	72.8
	0.5 ≤ S ≤ 1	40	10	0	16.6
	S ≥ 1	21.7	10	0	10.6
Board area (m^2)	S ≤ 15	100	3.3	100	67.8
	15 ≤ S ≤ 30	0	26.7	0	8.9
	30 ≤ S ≤ 60	0	68.3	0	22.7
	S ≥ 60	0	1.7	0	0.6

[1]Number of respondents in Malanville, [2]Number of respondents in Grand-Popo, [3]Number of respondents in Sèmè-kpodji, [4]Number of respondents from the whole study area.

assets between Malanville and Grand-Popo on the one hand compared to Sèmè-Kpodji, as well as for the quantity of mineral fertilizer applied per unit area and on the other hand, differences are highly significant (P< 0.001) between all these sites for variables such as (experience in onion production, household size, area allocated to cultivation, area of a bed, amount of organic fertilizer applied per unit area, experience in the use of organic and mineral fertilizers, price of mineral fertilizers in times of scarcity, profitability with mineral fertilizers, and selling prices of the crop in times of fertilizers scarcity and abundance (Table 4a and Table 4b).

3.2 Typology of onion producers

The dendrogram shown in Fig. 2 classifies onion farmers into eight groups according to their fertilization practices. In the first Group (Group 1), there are 41 market garden producers (22.78%). The second and third groups (Group 2 and 3) contain each 42 market garden producers (23.33%). In Group 4, they are 11 market garden producers (6.11%). Concerning Group 5, there are 4 market garden

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Table 4a. Quantitative data (mean values ± standard errors) of onion producers in the three study areas

Municipalities	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)
Malanville	36.92± 1.14a	17.27± 1.18 a	10.12± 0.72a	4.55± 0.37 a	3.58± 0.38 a	0.98± 0.088 a	2.95± 0.026b	14.53± 1.12 a
Grand-Popo	38.02± 1.49a	12.22± 0.95b	4.42± 0.28b	4.15± 0.22a	0.76± 0.11b	0.43± 0.06b	38.35± 1.51a	9.7± 0.76b
Sèmè-Kpodji	40.62± 1.28a	4.72± 0.35c	7.2± 0.43c	2.85± 0.26 b	1.3± 0.10b	0.14± 0.016c	4.92± 0.05b	5.87± 0.39c
F value	2.11	49.6	28.07	9.49	40.83	44.26	519.59	28.68
Probability	0.1243	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Table 4b. Continuation of quantitative data (mean values ± standard errors) of onion producers in the three study areas

Municipalities	Quantity of organic fertilizer (kg) per hectare	Experience in using mineral fertilizer (years)	Price of mineral fertilizer in times of shortage (FCFA)	Quantity of mineral fertilizer (kg) per hectare	Profitability with mineral fertilizer (FCFA)	Selling price of crop during the fertilizer shortage (FCFA)	Selling price of the crop in times of fertilizer abundance (FCFA)
Malanville	27242 ± 3465.13a	17.18 ± 1.16a	13523.33 ± 53.33b	249.17 ± 16.79a	15184.67 ± 653.24c	19400 ± 1045.22b	8233.33 ± 43819 b
Grand-Popo	16516.67 ± 1561.79b	11.08 ± 0.83b	14783.33 ± 136.22a	115.87 ± 41.88b	34322.11 ± 1641.82a	31275 ± 1525.83a	11400 ± 891.41a
Sèmè-Kpodji	8035.51± 554.66c	5.82 ± 0.39c	12840 ± 46.71c	234.03 ± 21.06a	18829.62 ± 626.73b	3615 ± 50.73c	2036.67 ± 49.52c
F value	18.84	44.14	123.64	6.45	88.12	168.74	68.8
Probability	<0.0001	<0.0001	<0.0001	0.002	<0.0001	<0.0001	<0.0001

producers (2.22%) while Group 6 regrouped 9 market garden producers (5%). Group 7 regroups 30 market garden producers (17.22%) and Group 8 includes 1 market gardener (Fig. 2).

The results of Principal component analysis (PCA) performed on the different classes identified and the variables related to soil fertility management practices described the relationships between them and to better characterize each class. These results indicate that the first two axes accounted for 56.4% of the total information (Table 5).

The projection of the different variables into the system of axes defined by the groups of market gardeners (Fig. 3) revealed that ***Group 1*** composed of primary school market gardeners belonging to an organization provides them with training. The organic fertilizer used is poultry droppings applied in rows. Pests appear during the dry season. ***Group 2*** producers are educated market gardeners (university level). They belong to organizations that provide them with micro-credit and assistance. They use large quantities of inputs, especially mineral fertilizer, which they bring in bulk. Their crops are attacked by pests but they find their activity profitable. ***Group 3*** clustered market gardeners with a small household size and education (secondary level). They have small areas and apply mineral fertilizers by fertigation. They observed the appearance of pests one to two weeks after transplanting. ***Group 4*** included primary school market gardeners who belong to an organiza-

Table 5. Eigenvalues of the first seven principal components

Axis of PC	Eigenvalue	Proportion	Cumulative Proportion
Axis 1	10,966	0,313	0,313
Axis 2	8,757	0,250	0,564
Axis 3	6,035	0,172	0,736

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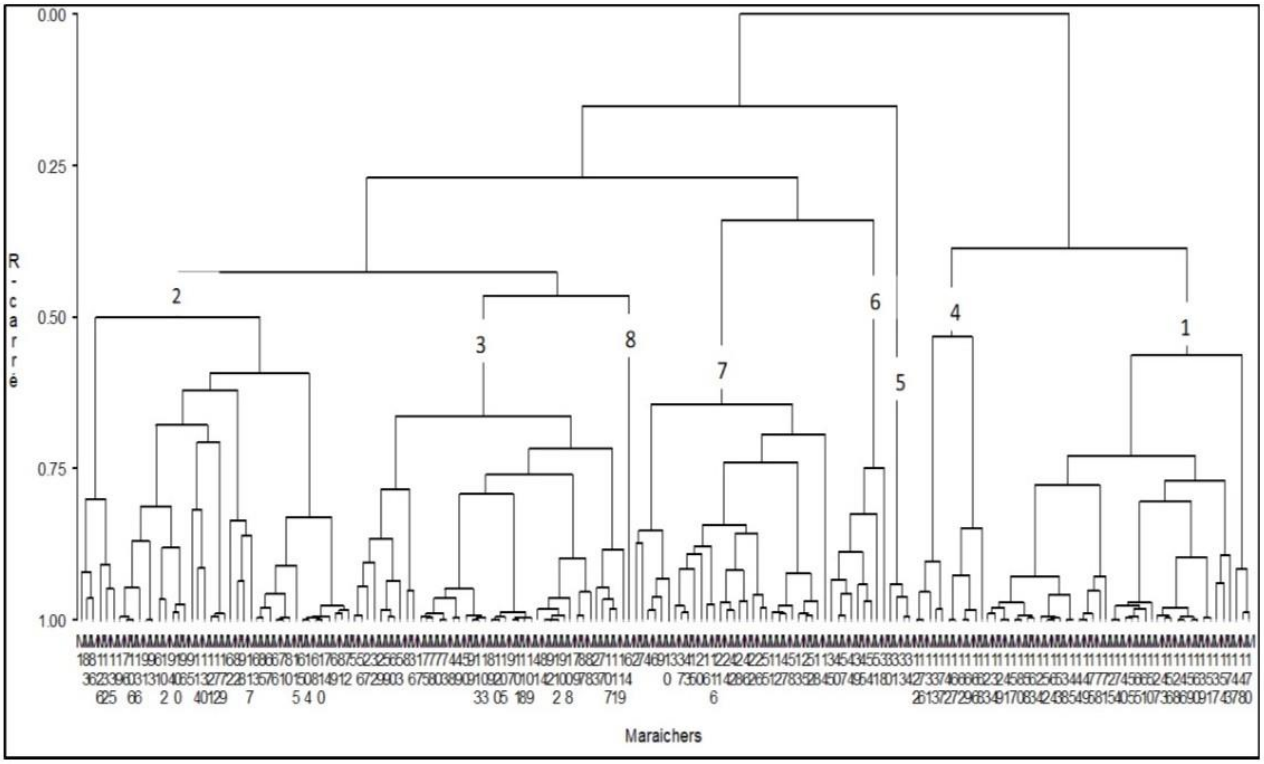

Figure 2. Typology of onion producers according to their soil fertility management practices

tion that trains them. These farmers use poultry droppings as organic fertilizer, which they bring in rows. Pests appear between November and March. ***Group 5*** consists of market gardeners who use cattle dung and droppings to fertilize their crops. They bring them in bulk or rows. They don't remark any pest attacks and find their activity very profitable.

The market gardeners in ***Group 6*** have an average total number of assets and area, and no formal education. They apply mineral fertilizer by fertigation. These market gardeners note the appearance of pests throughout the development stage of the crop but nevertheless consider onion production to be profitable. ***Group 7*** includes market gardeners who do not belong to any organization, who apply organic fertilizer in bulk, and who have more experience in onion production and the use of mineral and organic fertilizers. They use exclusively cattle manure as organic fertilizer. ***Group 8*** includes producers who do not belong to any organization and have extensive experience in the use of organic fertilizers, especially cattle manure. They use large quantities of organic fertilizers, have large cultivable areas. The results demonstrate in general that the education level, the membership or non- membership in an organization

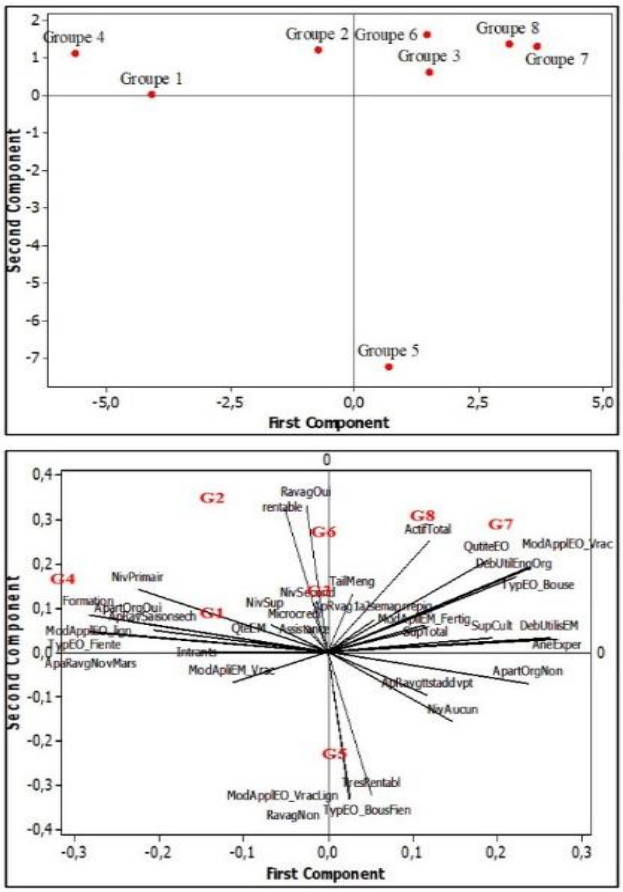

Figure 3. Projection of the different onion producer groups identified and their characteristics after principal component analysis (PCA).

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and onion experience production are the main factors or reasons defining the nature of fertilizer used.

3.3 Use of organic fertilizers by market gardeners

The results of the Correspondence Factorial Analysis (CFA) carried out on the data related to the reasons and constraints mentioned by women and men market gardeners showed that the first two components explain 95.54% of the total information (Table 6).

Table 6. Inertia and percentage of information on the axes

Axes	Inertia	Proportion	Cumulated proportion
1	0,4602	0,6308	0,6308
2	0,2368	0,3246	0,9554
3	0,0260	0,0357	0,9911
4	0,0065	0,0089	1,0000

The results of the Correspondence Factorial Analysis (CFA) performed on the data related to reasons for using organic fertilizers and constraints (Fig. 4) showed that in Malanville (North Benin), men who produce onions mainly use cattle dung, which they bring in bulk or in rows. They combine this with the mineral fertilizer NPKSBZn (14-23-14-5-1).

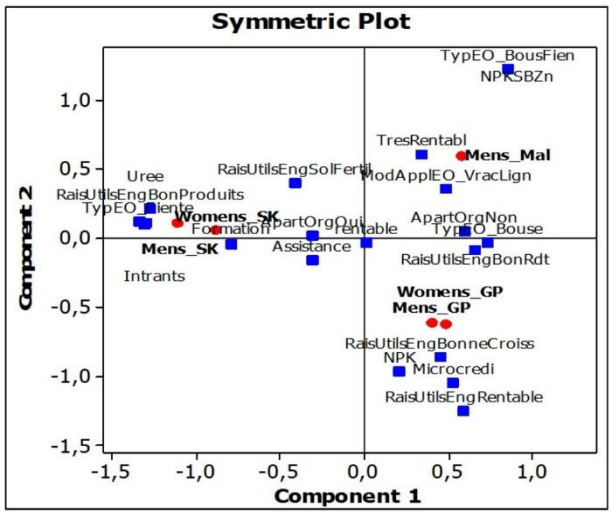

Figure 4. Reasons for using organic fertilizers and constraints: Result of the Correspondence Factorial Analysis (CFA). Legend: Mal= Malanville SK= Sèmè-Kpodji; GP= Grand Popo.

These practices enable them to improve their yields and thus make their activity more profitable. Moreover, these market gardeners do not belong to any organization. In Grand-Popo, the men and women belong to organizations that provide them with micro-credit. They use organic fertilizers combined with NPK (20-10-10) or NPKSBZn (13-17-17-6-0,5-1,5) and Urea (46% of N) to improve crop growth and the profitability of their business. In Sèmè-Kpodji, the men and women belong to organizations that mainly provide training and assistance. They mainly use poultry droppings combined with urea to have good products and improve the fertility of their soils.

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

The results of the binary logic regression (Table 7) showed that among the thirty or so Independent variables considered, the type of service provided by the organization, the type of organic fertilizers and its method of application ($P<0.05$) are the main variables determining the choice of fertilization practices of the market gardeners surveyed in the study area. Thus, market gardeners receiving training are the most likely to use good onion fertilization practices on their site.

4. Discussion

4.1 Socio-economic characteristics of onion producers

Onion production in Benin is carried out mainly by men in southern Benin and exclusively by them in the north (Malanville site). They are on average 36 years old and mostly educated except in Malanville. These results corroborate those of [2, 4], [14] and [11]. Field observations during the socio-economic data collection phase revealed that women and children are only involved at harvest time where they collect the onion leaves to make a highly prized spice in the area called 'Gabou' as mentioned by [11]. This low involvement of women in onion production, especially in the north, is due to the fact that soils are cultivated in the dry season. As a result, these very clayey soils, which are still waterlogged, require great physical strength to work. The strong membership of an organization of these onion producers in the study area is proof that the sector is highly organized, as shown by [14]. Indeed, according to these authors, there is an Onion Reception and Sales Committee (CORVO) based in Malanville and Cotonou in charge of the exclusive marketing of onions from Malanville, but also, the Association of Onion Importers of Benin(AIOB) in charge of importing onions from Niger and marketing them on the Cotonou markets.

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

Independent variables	Chi-Square	Pr >Chi- Square
Membership of an organization	1.2870ns	0.2566
No Membership in an Organization	1.2870ns	0.2566
Support	0.0697ns	0.7917
Training	**4.2542***	**0.0392**
Microcredit	0.2247ns	0.6355
Inputs	0.0343ns	0.8531
Experience in onion production	1.7053ns	0.1916
Household size	0.0430ns	0.8358
Total number of assets	0.1571ns	0.6918
Cultivated area	1.0346ns	0.3661
Use of cattle manure	3.934ns	0.0616
Use of droppings	**4.0449***	**0.0443**
Use of cattle manure and droppings	0.0460ns	0.8302
Experience in the use of organic fertilizers	0.9267ns	0.3357
Amount of organic fertilizer applied	0.4313	0.5114
Bulk application of organic fertilizer	**3.849***	**0.0498**
Application of organic fertilizer in line	**4.5965***	**0.0320**
Application of organic fertilizer in bulk and in-line	0.0818ns	0.7748
Experience in the use of mineral fertilizer	1.4688ns	0.2255
Amount of mineral fertilizer applied	1.1883ns	0.2757
Application of bulk mineral fertilizer	0.0578ns	0.8100
Application of mineral fertilizer by fertigation	0.0113ns	0.9153
Cost-effective	0.2387ns	0.6252
Very profitable	0.2387ns	0.6252
Presence of pests	0.0460ns	0.8302
Absence of pests	0.0460ns	0.8302
Profitability with mineral fertilizers	0.7945ns	0.3727
Selling prices in times of fertilizer shortage	2.2399ns	0.1345
Selling prices in times of fertilizer abundance	1.7787ns	0.1823
Area of the board	0.7369ns	0.3907

** : P < 0.05 ; ns : P>0.05*

On the other hand, [11] showed that onion cultivation in Malanville was a family activity, with mutual aid during field preparation and harvesting. During this period, the authors did not note the presence of any specific organization of onion producers in the Malanville basin, excepted Bodjécali village committee, which at the time was mainly concerned with marketing. Belonging to a farmers' organization facilitates collaboration with decentralized agricultural development services and other agricultural partners and promoters regarding the introduction and extension of technology packages [4]. These results for the southern region would explain the great experience of southern producers in conducting trial work in the framework of research projects and studies.

The average experience of 11.4 years is proof that onion production in Benin is relatively recent, as pointed out by [14], and even more so in southern Benin where most of the market gardeners surveyed have less than 10 years' experience (48.3% in Grand-Popo and 98.3% in Sèmè- Kpodji), whereas in the north there are producers with 20 years' experience in the activity. This experience is an asset in the sense that these producers master the production techniques, which allows them to bypass existing constraints and make their activity profitable.

The areas allocated to onion cultivation in the South (Grand-Popo and Sèmè-Kpodji) are mostly less than 0.5 ha, whereas in the North (Malanville) where the areas easily reach 5 ha. These results demonstrate the problem of land availability that hinders the

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development of market gardening in southern Benin as mentioned by [8] and [3]. This does not allow market gardeners in urban and peri-urban areas in South Benin to invest more intensive in market gardening with more modern means of production. On the other hand, in the North, despite the size of the areas planted, the means of production used are still very primitive, as [2] have pointed out. The low education rate of market gardeners in this zone (71.7%) could explain this observation.

4.2 Typology of onion producers

The typology of onion producers in Benin showed that they can be grouped into 8 classes. These groups are in order of importance: group2 (23.33%), group3 (23.33%), group 1 (22.78%), group 7 (16.67%), group 4 (6.11%), group 6 (5%), group 5 (2.22%) and group 8 (0.55%). The closest groups in the axis projection, such as groups 7 and 8, mean that they have the same characteristics in general with some differences. These could therefore be merged into one group according to their degree of closeness, which would reduce the typology to group 7. Other typologies of onion producers in Benin have been carried out by some authors. [11]and [14] carried out a typology of onion producers in Malanville based on the area under onion and the importance of early onion production. According only to the cultivated area available for the producers, market gardeners would be divided into three classes: small producers with an area of 0.25 ha to 0.5 ha, medium producers with an area of 0.5 ha to 1.5 ha, and large producers with an area of over 1.75 ha for this study.

4.3 Reasons and constraints for using organic fertilizers according to market gardeners

From this study, the reasons and constraints were taken into account in the typology realized. Some of them are the low fertility of soil, the low availability of organic fertilizer, the distance to be done for obtain the organic fertilizer and the most important quantity of organic fertilizer to applied for market gardens. Poor soils used in onion production in Benin makes systematic fertilizers use in order to achieve production objectives. These fertilization practices are used on all sites by both men and women. It is mainly the use of cattle dung (especially in the North) and poultry droppings (in the South), with or without urea or NPK depending on the area. This can be explained by the high prevalence of poultry farms in the South and cattle herds in the North [3, 27, 28]. However, in the North, [14] and [11] reported that mineral fertilizers such as NPKSBZn and urea are the most commonly used. Their studies revealed that onion farmers in Malanville did not use organic fertilizers unlike Nigerian farmers, leading to an overdose of mineral fertilizer of up to eight bags of NPK cotton and 100 kg of urea [11, 15]. They obtain mineral fertilizer on credit ([26]). The average application rate of mineral fertilizer is 800 kg of NPKSB (14-23-14-5-1) and 100 kg of urea. According to [15]; market gardeners in the North use very little organic fertilizer (4t/ha) and of poor quality (yard dust, badly decomposed manure). In Sèmè- Kpodji, poultry droppings are the most commonly used source of organic matter. They combine it with urea to improve their soil fertility and product quality.

The results of the present study have shown that throughout the study area, the soil fertilization practices identified improve soil fertility, yields, and onion quality. These market gardeners consider onion production to be profitable, as mentioned by [11]. According to these authors, this profitability can vary from simple to quadruple depending on the season in Malanville.

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

The type of service provided by the Organizations, the type of organic fertilizer and its method of application are the main variables that determine the choice of fertilization practices of market gardeners surveyed in the study area. Indeed, through training and assistance, farmers' organizations contribute to the dissemination of organic fertilizer processing techniques such as composting. This process of processing organic fertilizers enables it to obtain more stable products, which degrade gradually over time and thus maintain soil fertility for longer than raw inputs of the organic matter source. Furthermore, the benefits on soil physico-chemical properties and yields associated with the use of compost are widely reported in the literature and recommended [8, 29-30]. Furthermore, the type of organic fertilizer is linked to its ability to be easily transported to the fields and its mode of application. This reveals the constraint of manpower availability for these operations and

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determines the choice of organic fertilizer sources.

In the literature, many constraints have been raised that hinder the development of the sector in Benin [18, 31]. These include the high cost of imported seeds, which are more efficient than local ones, especially Galmi violet. There are also the difficulties in self-production of improved seeds by Beninese market gardeners; and difficulties in preserving crops, which pushes them to sell them entirely. Then, the difficulties in accessing financing, especially input credits, and the high seasonality of production. Finally, the low level of interest in agricultural research. In response to these constraints, [31] and [11] recommended, among other things, facilitating access to input credits for producers and creating supervisory and guidance bodies to support them in the use of these credits; the introduction of high-performance seeds adapted to local conditions and the determination of economically profitable combinations of mineral and organic fertilizers for sustainable production; and the development of technologies for long-term product conservation.

5. Conclusions

This study aimed to analyze soil fertilization practices under onion cultivation in Benin. The results of this study showed that in Benin, onion production is carried out by both men and women in the South but exclusively by men in the North. These market gardeners are mostly educated young adults and belong to organizations. The main sources of organic fertilizer used are cattle droppings (exclusively in the North) and poultry droppings in the South. These organic fertilizers are applied without preliminary treatment. The mineral fertilizers used are NPK formulations and urea. These technologies are used to improve farmed soil fertility, yields and product quality. The choice of these types of fertilizer depends on the type of services provided by the organizations to which they belong, but also on the type of organic fertilizer and the constraints associated with its application. Despite the difficulties encountered, producers surveyed consider the activity to be profitable to very profitable depending on the area. However, support to overcome bottlenecks in the sector will make it possible to make this production more profitable. Particular emphasis is placed on research intervention on the development and availability of improved seeds adapted to local conditions, the determination of economically profitable combinations of organic (better quality) and mineral fertilizers, and the facilitation of access to input credits and structures to support producers in the judicious use of credits.

Authors' contributions

Wrote the proposal questionnaire and conducted the surveys, G.K.L. and F.C.; Validated the proposal and questionnaire, supervised the surveys and reviewed the final version of the article, G.D., A.S. and F.C.; O.D.B. and G.K.L.; Contributed data analyses and drafting of the article.

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Availability of data and materials

All data will be made available on request according to the journal policy

Conflicts of interest

The authors declare no conflict of interest

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