Advances in Agricultural Science

Volume 7 (2019), Issue 02, 01-13

Journal homepage: www.aaasjournal.org

ISSN: 2588-3801

Research Article Open Access

Vegetable cropping systems in Southern Benin: cultivated plant diversity, agricultural practices and implications for better production

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ARTICLE INFO

Article history:

Received: September 08, 2018
Revised: October 28, 2018
Accepted: October 29, 2018
Available online: December 05, 2018

Keywords:
Fertilizers
Pest management
Urban agriculture
Vegetables

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ABSTRACT

In the context of urban agriculture, cropping vegetables constitute an important economic activity for farmers and food source for a population. Few studies have investigated in how these systems are organized. The objective of this study is to determine the diversity of vegetables cultivated in south of Benin and to assess the structure of the production systems in terms of soil fertilization and pest management. In the three most important vegetable producing zones (Cotonou, Seme, Grand-Popo), in southern Benin, we surveyed vegetable farmers. The results showed 26 vegetable species in producing systems. Vegetable producing sites, sociolinguistic groups and education of farmers didn't influence the vegetable diversity but influenced the density of vegetable species. The majority of vegetable farmers (45%) did not receive training on vegetable agricultural practices. Some farmers were trained by agricultural trainers (18%) and neighboring farmers on the sites of vegetable production by their colleagues (5% at Seme and 5% at Houeyiho). *Capsicum amum*, *Solanum macrocarpon*, *Allium cepa*, *Solanum licopersicum* were the main cultivated plants with the highest cropped surfaces. These cropped plants were followed by the *Lactuca sativa* and *Daucus carota*. The aromatic plants were lowest cropped in these vegetable cropping systems. Vegetable farmers used mainly organic fertilizers and few mineral fertilizers. Pest management remains a challenge and pesticides were used on 80% chemical products. It is necessary to train the vegetable farmers on innovate pest management using few chemical pesticides.

Introduction

In Africa, peri-urban agriculture is a very important source of income and food for disadvantaged urban dwellers (Moustier and Pagès, 1997). In Benin, vegetable cropping appears today as one of the main components of urban and peri-urban agriculture and plays an important social and economic role in the people life (Kakai *et al.*, 2010). It employs about 4% of the working population and produces about 15% of the national economic value (RNIB, 2008). According to Singbo et al. (2008), vegetable markets meet the food needs and preferences of urban populations. For this purpose, various plants are cultivated and their diversity depends on production area. The analysis of the distribution of producers by type of speculation produced by Houngue and Kindomihou, (2009) clearly shows a diversity of crops that they associate with differnces in consumer preferences, prices and seasonality of products.

Vegetable cropping is often an informal activity, generating income and employment, practiced by vulnerable sections of urban and peri-urban areas (Lachance 1999; Moustier and Pages, 1997). Vegetables and especially leafy vegetables have played an important role in this regime in southern Benin (Agossou et al. 2001). Indeed, in vegetable gardening, leafy vegetables rank second in southern Benin after tomatoes (Colin et Heyd, 1991). Among vegetable crops grown in Benin, leafy vegetables are the most widely consumed. Producers of these crops often face several challenges, including land management, pest management and soil fertilization. In this sector of activities, these constraints remain major despite multiple efforts by research institutions and the government to improve agricultural practices of farmers to increase yield and sustainability of fields.

Each producer defines a way of managing soil fertility and a policy to control crop pests according to his capacity. In southern Benin, Cotonou, Sèmè-Kpodji and Grand-Popo are the most prominent municipalities in which vegetable crops are produced. In these vegetable production zones, farmers us both chemical and organic fertilizers. As the fertilizer uses, the chemical and organic pesticides are also used for the pest management in the vegetable producing systems (James *et al.*, 2010). Many of these products are used for the integrated pest management in the vegetable producing systems. Both soil and pest management are important to improve the performance of vegetable producing systems.

Using pesticides by small farmers has become systematic in order to optimize the yield of vegetable crops. But unlike cotton farmers, vegetable producers do not benefit from supervision or continuous training. In southern Benin, they bought pesticides on local markets minimizing their toxicity or the way to use (Ahouangninou et al. 2011). In this case, some chemical products continue to be used by vegetable producers polluting the environment. It is important to know these products and see how to regulate them.

Studies on the diversity of cultivated plants in vegetable cropping systems are scarce, or limited to a production site or a locality. The objective of this study is to characterize the cultivated plant diversity, pest management and soil fertilization of vegetable cropping systems in southern Benin. Specifically, the present study aims to: i) determine the diversity of cultivated plants in vegetable producing systems in South Benin; ii) understand how farmer's sociodemographic characteristics influence the vegetable diversity and iii) determine the type of products (organic or chemical) used for soil fertilization and pest management in these producing systems.

Material and methods

Study sites

The study was carried out in Cotonou, Grand-Popo, and Seme, three big urban zones where vegetables are highly grown in southern Benin. A part of vegetable producing sites in Cotonou (Houeyiho, Fidjrossè, and airport) have acid sandy soils which are chemically poor. While these vegetable producing sites (Grand Popo and Seme) have salted alluvial soils which are too chemically poor. In the south of Benin, the climate is subequatorial type (ASECNA, 2002) with 4 seasons (2 rainy seasons and 2 dry seasons). The south of Benin is warm, humid agroecological zone with annual rainfall varying from 1100 to 1400 mm/year (ADAM and BOKO, 1993) andannual temperature ranges from 26 to 28°c (Adamou, 2005).

Methodology

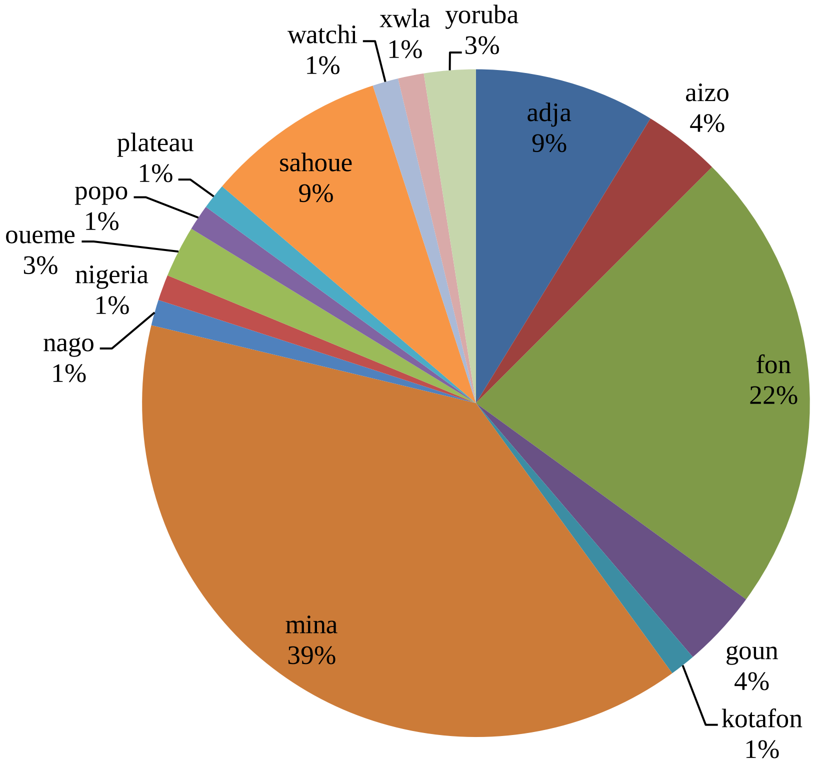

Figure 1. Diagram of vegetable farmer ethnic groups in Southern Benin.

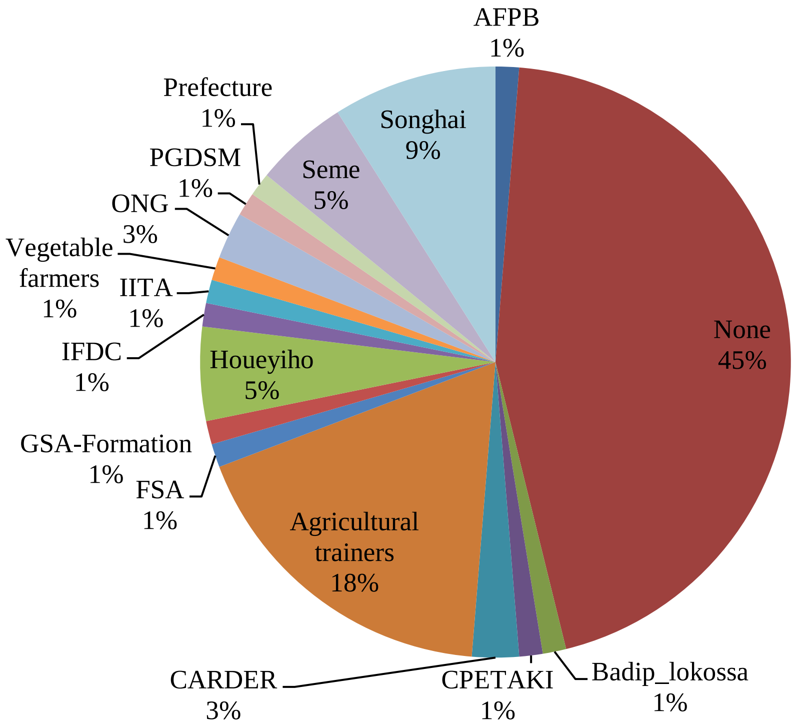

Figure 2. Diagram of vegetable farmers trained by different organizations; Regional Action Centers for Rural Development (CARDER), Songhai center, Faculty of agronomic sciences of University of Abomey-calavi (FSA-UAC), University GASA-Formation, International Institute of Tropical Agriculture (IITA), Prefecture, Non-Government Organization NGOs, Support project for professional training in Benin (AFPB), Household Solid Waste Management Project (PGDSM), International fertilizer development center (IFDC), International Koberside Technical Agricultural Private College (CPETAKI), Bangladesh Agricultural and Disaster Insurance Programme (BADIP-Lokossa).

To assess vegetable diversity, data were collected from the vegetable producing sites across 3 selected areas in south of Benin. Interviews were carried out on 14 vegetable farmers in Seme, 28 vegetable farmers in Cotonou and 40 vegetable farmers in Grand-Popo. Data were collected in spring 2016 through the use of tools and methods of the participatory research approach, such as direct observation, individual interviews and field visits (Dansi et al., 2013). Information on farm location and farmer ethnicity was documented withdiversity and density of cultivated vegetables, performance of the vegetable producing, soil fertilization, pest management and their use frequencies. Pest management and soil fertilization methods were also documented using the spontaneous reaction evaluation method. Responses were on the all types of products used by farmers to control pests and manage the soil fertilization. They described also how to use the products and their use frequencies. For each parameter studied, responses are also evaluated by each farmer using 2 scores: 0 and 1. Score 1 is assigned when the product (organic or chemical) is used to control pests or to fertilize the soils. If not, the score is 0 (Gbedolo et al., 2018).

Data analysis

The vegetable density per subplot was determined and the vegetable diversity was assessed with the Shannon index (Shannon, 1948), which was calculated with the diversity function of the Vegan package version (Oksanen and O'Hara, 2013). We analyzed the effects of sociodemographic (age, gender, matrimonial situation…) characteristics, education (received trainings) and vegetable producing sites on the vegetable diversity and the density of each vegetable species using Poisson Generalized Linear Models (GLMs). Vegetable diversity and density were evaluated by count of plants of cultivated species allowing us to use Poisson Generalized Linear Models for analyses. All the analyses were calculated in the R software (R Development Core Team, 2014).

Results

Sociodemographic characteristics of vegetable farmers in South Benin

Women were poorly represented among the vegetable farmers in the three areas surveyed but more commonly participated in vegetation cropping at Grand-Popo and Seme. Amongst vegetable farmers in the three vegetable producing zones, there were more married farmers than single farmers (Table 1). The majority vegetable farmers in Southern Benin were Mina (39%) and Fon (22%) followed by Adja (9%) and Sahoue (9%) ethnic groups (Figure 1). The majority of vegetable farmers (45%) did not have training on the cultural practices of vegetable production systems. Some were trained by the agricultural trainers (18%) and others farmers on the sites of vegetable production (5% at Seme and 5% at Houeyiho). Others farmers were trained through national and international institutions such as Regional Action Centers for Rural Development (CARDER), Songhai center, Faculty of agronomic sciences of University of Abomey-calavi (FSA-UAC), University GASA-Formation, International Institute of Tropical Agriculture (IITA), Prefecture, Non-Government Organization NGOs, Support project for professional training in Benin (AFPB), Household Solid Waste Management Project (PGDSM), International fertilizer development center (IFDC), International Koberside Technical Agricultural Private College (CPETAKI), Bangladesh Agricultural and Disaster Insurance Programme (BADIP-Lokossa) (Figure 2).

Influence of sociodemographic parameters on the cultivated plant diversity in vegetable producing systems

We identified 26 cultivated plants in vegetable producing systems. *Capsicum annum* (18.07% of cultivated surfaces), *Allium cepa* (18.95% of cultivated surfaces), *Solanum lycopersicum* (15.95% of cultivated surfaces) and *Solanum macrocarpon* (12.66% of cultivated surfaces) were

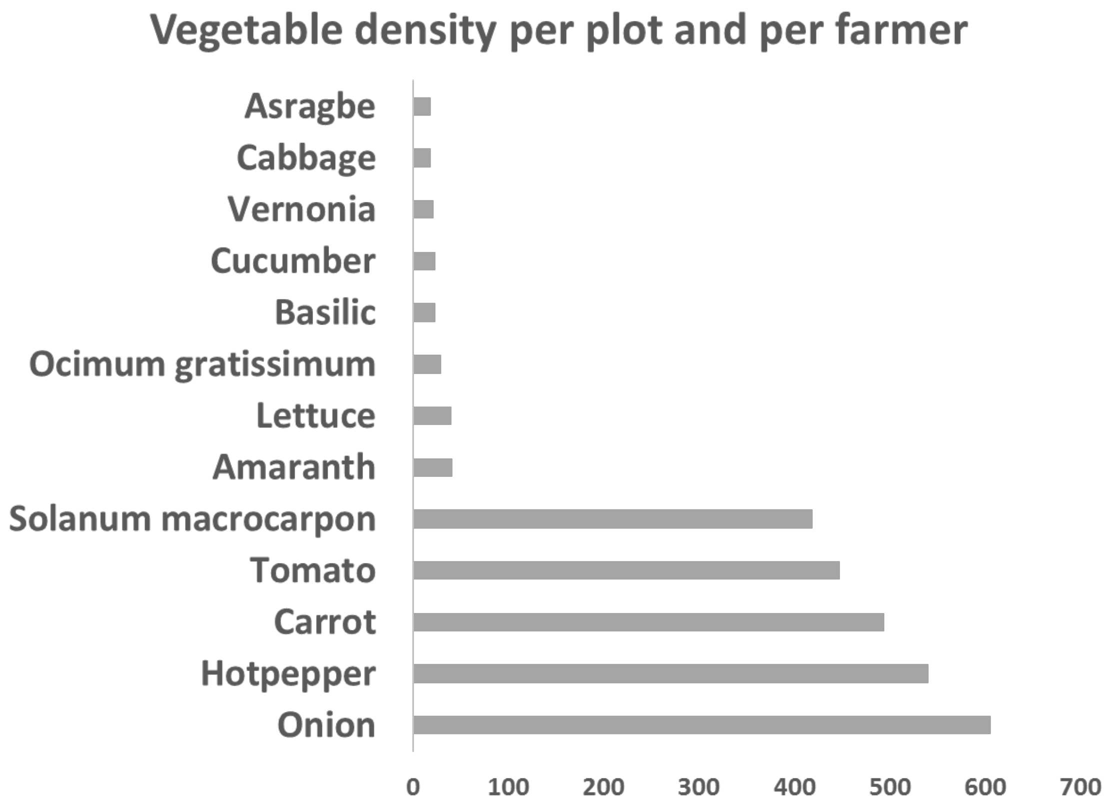

Figure 3. Mean density of major vegetable cultivated per plot and per farmer. Y-axis: major cultivated plant species. X-axis: Average of cultivated plant density per subplot (density > 10 cultivated plants per subplot).

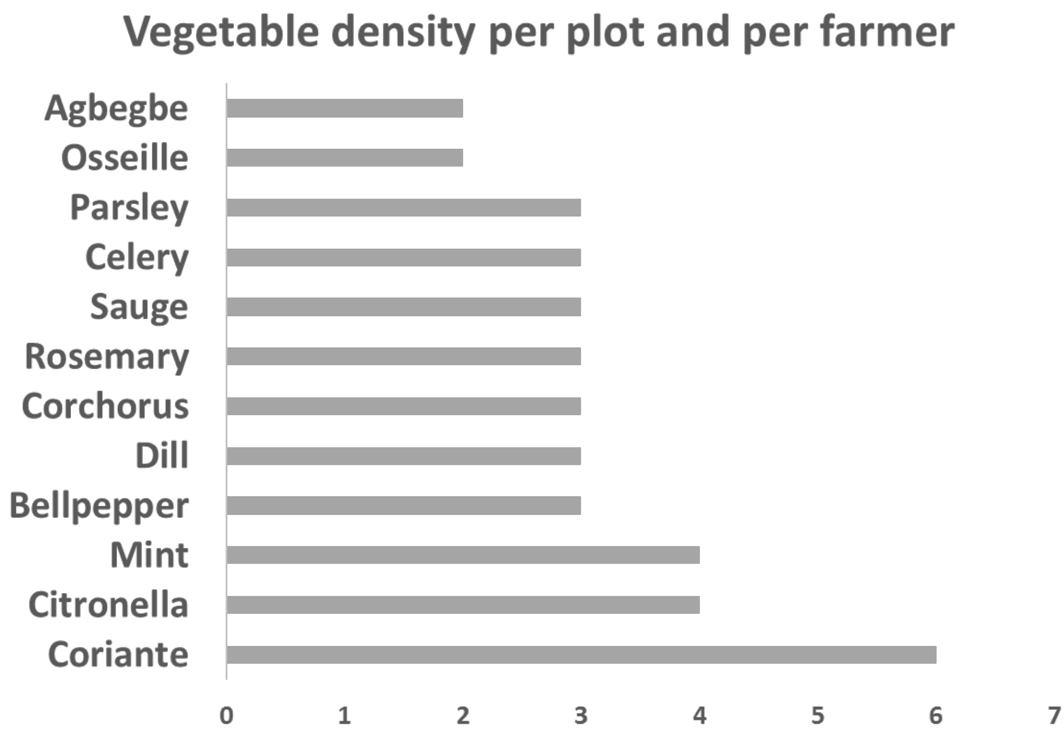

Figure 4. Mean density of minor vegetable cultivated per plot and per farmer. Y-axis: minor cultivated plant species. X-axis: Average of cultivated plant density per subplot (density < 10 cultivated plants per subplot).

Table 1. Sociodemographic parameters of vegetable farmers at South Benin

Sociodemograghic parameters		Grand-Popo	Cotonou	Seme
Sex	Male	34	26	6
	Female	7	1	6
Matrimonial situation	Divorced	1	0	0
	Single	7	9	1
	Married	33	18	11

Table 2. Cultivated plant diversity and their mean cropped surfaces by farmer

N°	Vegetables	Varieties	Scientific names	Mean cropped surfaces (m2)
1	lettuce	Madrilène, Batavia, Hybride, bon jardinier	*Lactuca sativa*	146.525
2	cuncumber	Hybride, Corncette, Nadinie, Sadina, Cornicha	*Cucumis sativus*	139.4375
3	hotpepper	Hybride, long	*Capsicum annum*	759.5125
4	celery	Hybride	*Apium graveolens*	2.5
5	parsley	Salvago frisé	*Petroselinum crispum*	7.675
6	coriander	Hybride	*Coriandrum sativum*	8.6875
7	rosemary	-	*Rosmarinus officinalis*	2.5
8	sauge	-	*Salvia officinalis*	1.3125
9	amaranth	Hybride	*Amaranthus* sp	95.7875
10	solanum macrocarpon	Hybride	*Solanum macrocarpon*	532.375
11	vernonia	Hybride	*Verninia* sp	32.275
12	cabbage	Hybride	*Brassica oleracea*	40.55
13	bellpepper	Hybride	*Brassica oleracea*	27.1875
14	carott	Hybride, Sezan cross, Touchon hybride, America	*Daucus carota*	763.7125
15	beet	-	*Beta vulgaris*	10.75
16	onion	Hybride, Vert, Simple, Echalotte, Prema	*Allium cepa*	796.7875
17	chiayo	-	*Ocimum gratissimum*	137.9125
18	tomato	Hybride	*Solanum lycopersicum*	669.6
19	citronella	Hybride	*Cymbopogon* sp	7.125
20	mint	Vert poivré	*Mentha* sp	2.0625
21	oseille	-	*Rumex* sp	9
22	agbegbe	-	No identified	3
23	basil	Hybride	*Ocimum basilicum*	0.55
24	dill	-	*Anethum graveolens*	0.45
25	corchorus	-	*Corchorus* spp.	3
26	asrangbe	-	No identified	2.25

the main cultivated plants with the highest cropped surfaces (> 500 m^2; Figure 3). The aromatic plants were lowest cropped in these vegetable cropping systems (Table 2; Figure 4 and 5). The cultivated plant diversity was highest on Fidjrossè sites followed respectively by Grand-Popo, Cocotiers,

Table 3. Effect of sites, sociolinguistic groups and education on the densities of cultivated plants in vegetable cropping systems

	Sites		Sociolinguistic groups		Education	
Vegetables	**Df**	**Pr**	**Df**	**Pr**	**Df**	**Pr**
lettuce	14	<0.0001	14	<0.0001	20	0.2401
cucumber	14	<0.0001	14	0.1059	20	0.3191
hotpepper	14	<0.0001	14	<0.0001	20	0.01166
celery	14	<0.0001	14	0.6538	20	1
parsley	14	<0.0001	14	<0.0001	20	0.4167
coriander	14	0.02027	14	0.7432	20	0.5152
rosemary	14	1	14	1	20	1
sauge	14	1	14	1	20	1
amaranth	14	<0.0001	14	0.00054	20	0.2472
solanum macrocarpon	14	0.8394	14	0.5555	20	<0.0001
vernonia	14	<0.0001	14	0.2378	20	0.6019
cabbage	14	<0.0001	14	0.5171	20	0.2673
bellpepper	14	<0.0001	14	0.01005	20	0.8328
carott	14	0.8079	14	0.7036	20	0.01851
beet	14	0.3112	14	0.7867	20	0.1227
onion	14	<0.0001	14	0.7455	20	0.01308
ocimum	14	<0.0001	14	0.01256	20	0.00011
tomato	14	<0.0001	14	0.09162	20	0.06725
citronella	14	<0.0001	14	0.00046	20	0.01502
mint	14	0.2289	14	0.00292	20	0.9316
oseille	14	<0.0001	14	0.9993	20	0.9983
agbegbe	14	<0.0001	14	0.8677	20	0.0001
basilic	14	0.5896	14	0.0573	20	0.9933
dill	14	0.01792	14	0.04286	20	0.8657
corchorus	14	0.6833	14	0.9727	20	<0.0001
asrangbe	14	0.007544	14	0.9948	20	<0.0001

Table 4. Utilities of the fertilizers

Fertlizers	**Use**	**Utilities**
Urea	15 small square per kg	Growth of the vegetables, increases the leaves green color
Superglo	15 small square per kg	Growth of the vegetables, increases the leaves green color
NPK	15 small square per kg	Facilitate the growth and development of the vegetables, facilitate the development of the flowers
Dungs	15 small square per kg	Facilitate the growth and development of the vegetables
Compost	1 small square per 50kg	Facilitate the growth and development of the vegetables
Cow pie	1 small square per 50kg	Facilitate the growth and development of the vegetables
Ammoniac	15 small square per kg	Increase the nitrogen dose in the soil for the growth and development of the vegetables

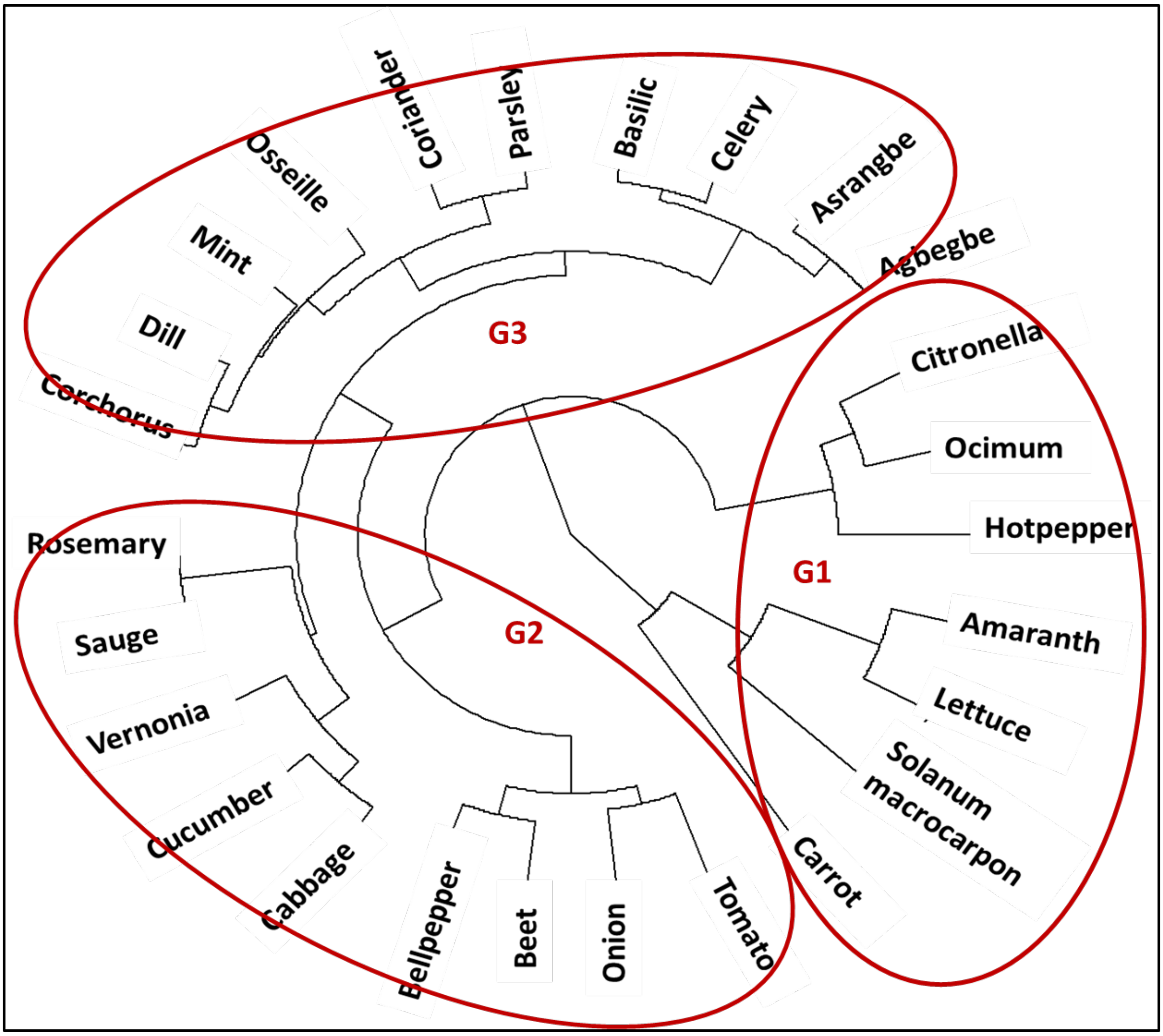

Figure 5. Dendrogram grouping cultivated plants according to their densities. Group G1: cultivated plant species with high densities, Group G2: cultivated plant species with mean densities, Group G3: cultivated plant species with low densities.

Aeroport, Atingangomey, Houeyiho, Sèmè, Zevilitidji and Nicouecondji 5 (Figure 6). Farmer's age (Df=1; P=0.796), gender (Df=1; P=0.26), matrimonial status (Df=1; P=0.26), education (Df=20; P=0.41) and vegetable producing sites (Df=14; P=0.22) did not have effect on cultivated plant diversity. But vegetable producing sites, farmer sociolinguistic groups and farmer education had significant effects on the density of many cultivated plants species (Table 3).

Importance of fertilizers in the growth and development of plants and pest management in vegetable producing systems

Vegetable farmers used fertilizers including urea, dung, compost and superglo to facilitate growth and development of the leaves. Although, these fertilizers facilitate the growth and development of vegetables, farmers also used synthetic Nitrogen-Phosphorus-Potassium (NPK) mixtures. . Others vegetable farmers used the cow-pie and ammoniac

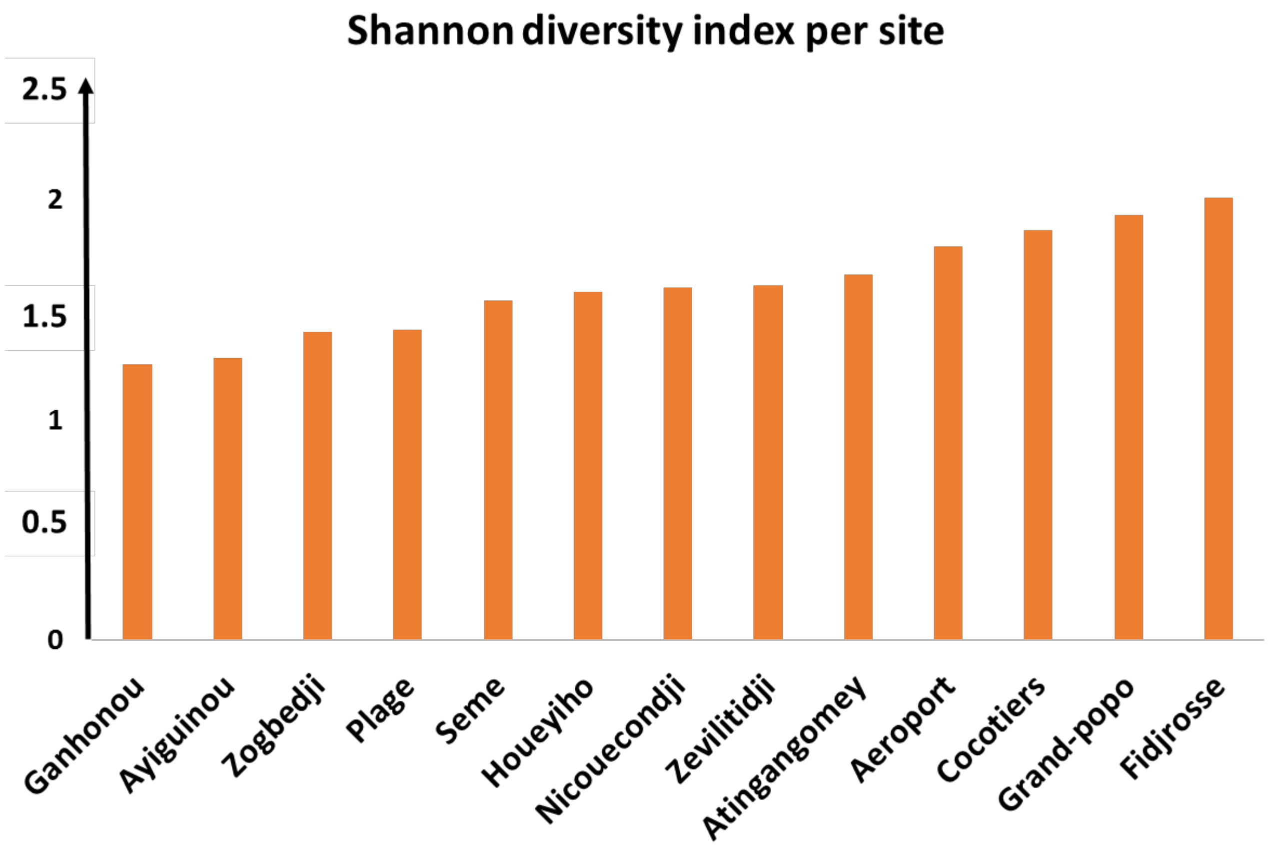

Figure 6. Cultivated plant diversity of each site of vegetable production

Table 5. Efficiency of pesticides

Pesticides	Target pests	Nature of the pesticides	Efficiency
Lambda	borers, mites, locusts, nematodes, catapillars	Chemical	High
Topxine	rots, rusts, caterpillars, cabbage butterflies	Chemical	High
Neem	mites, termites, caterpillars	Biopesticide	Mean
Lamdacal	nematodes, locusts, worms	Chemical	High
Lazer	caterpillars	Chemical	High
Acarus	mites	Chemical	High
Ashes	mites	Biopesticide	Mean
Simplifox	locusts	Chemical	High
Cypercal	caterpillars	Chemical	High
Pyrifox	locusts, mites, caterpillars	Chemical	High
Caterpillar	caterpillars, locusts	Chemical	High
Enacide	nematodes	Chemical	High
Pacha	mites, worms	Chemical	High
Sintex	worms	Chemical	High
Potach	locusts, mites, caterpillars	Biopesticide	Mean
Durban	Worms, locusts	Chemical	High
Montaz	Worms	Chemical	High
Madazine	Worms, locusts	Chemical	High
Megazine	Worms, locusts	Chemical	High
Bendazine	Worms	Chemical	High
Coldazine	Worms	Chemical	High

to improve soil structure and nitrogen levels (Table 4). Concerning the plant protection, the vegetable farmers used 22 pesticides from which 2 alone are biological pesticides. Amongst the pesticides used, 90% were chemical pesticides (Table 5).

Discussion

Men and woman participated in vegetable farming, however, their roles were often separated. Women were more likely responsible for shipping sale of goods while men grew the vegetables and maintained the fields. (Adetonah *et al.*, 2010). Ours results showed that 45% of the vegetable farmers were not trained on the vegetable cultural practices. Few vegetable farmers were trained by agricultural trainers from national and international institutions even though trainings improve farmer’s knowledge and skills on agricultural practices including pest management (Adekambi *et al.*, 2010). There are a positive significant correlation between trainings received by the vegetable farmers and vegetable species such as *Solanum macrocarpon*, Ocimum gratissimum, *Cymbopogon* sp., *Capsicum annum*, *Allium cepa* and *Daucus carota* (Table 3). The farmers trained on the agricultural practices managed well their producing systems. Inversely, the regular lack of trainings of vegetable farmers can lead to low vegetable production (Williamson *et al.*, 2008).

In this study**,** we determined a high vegetable diversity on different sites of production. This diversity was dominated by exotic crops and few local crops were cultivated on the sites of vegetable producing. We found that the sites had significant effects on vegetable species density showing the farmer’s preference for the high production of vegetable species such as the lettuce which in Cotonou and tomatoes and onion in Grand-Popo. Cotonou was representative of vegetatble diversity across Benin (Lund *et al.*, 2010; Sathe *et al.*, 2007). Farmer’s sociolinguistic groups had significant effects on vegetable species showing that Fon, Mina and Sahoue sociolinguistic groups were more frequently farming vegetables than other sociolinguistic groups.

Many fertilizers were used by the vegetable farmers to grow and develop the plants. Over the 7 fertilizers identified in the vegetable producing systems in Southern Benin, 6 organic fertilizers were used. Organic fertilizers were the most used by the vegetable farmers because they are less expensive, readily available and efficient. The proper use of organic fertilizer can reduce soil and water pollution in vegetable producing systems and improve vegetable production (Pretty *et al.*, 2011). In the vegetable producing, we identified 21 pesticides that were used for pest control. The majority of pesticides used were chemical products which could pollute the environment.

As implications, two aspects can be addressed in this study. First, the vegetables cultivated in southern Benin are mostly exotic. This great diversity of cultivated plants has very few local crops including local traditional vegetables. It is important to promote local vegetables and urge farmers to produce them in order to increase the diversity of crops to guard against disease and pest outbreaks. Local traditional vegetables are very rich in nutritional and dietary compositions and their production on vegetable producing sites would improve the food security of populations. Native species are also suited to the local climate and soil conditions, thus requiring less fertilizer. The use of chemicals in vegetable producing systems is pervasive with potential environmental harm to soil and water resources. Adverse effects on human health have been documented worldwide and should be a call to local farmers and the government to train farmers on new techniques for pest management and soil fertilization and regulate potential harmful products.

Acknowledgments

We thank vegetable farmers in Southern Benin who unconditionally accepted to respond to interviews and to make available their fields for observations.

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Appendices/Appendix1

Table 1. Density per small square of cultivated plants on the vegetable sites in south of Benin

Vegetables	aeroport	atingangomey	ayiguinnou	cocotiers	fidjrosse	ganhonou	gpopo	houeyiho	nicouecondji	plage	seme	zevilitidji	zogbedji
lettuce	105	40	28	200	120	0	105	118	0	73	110	0	0
cucumber	21	15	15	40	25	0	105	26	0	10	37	0	0
hotpepper	0	67	401	0	0	860	0	44	684	140	8	684	566
celery	0	0	0	0	23	0	0	0	0	0	0	0	0
parsley	0	0	0	0	25	0	0	29	0	131	0	0	0
coriander	0	0	0	0	21	0	0	18	0	134	8	0	0
rosemary	0	0	0	0	0	0	0	140	0	0	0	0	0
sage	0	0	0	0	0	0	0	150	0	0	0	0	0
amaranth	105	33	0	100	120	0	105	85	0	68	68	0	0
solanum macrocarpon	105	133	570	200	120	248	105	145	684	208	56	684	547
vernonia	0	33	0	0	60	0	55	44	0	0	26	0	0
cabbage	22	33	0	60	12	0	50	26	0	28	14	0	0
bellpepper	25	0	0	32	60	0	0	4	0	0	10	0	573
carott	250	390	412	250	0	840	55	270	0	462	242	684	0
beet	105	33	30	0	60	0	0	7	684	13	13	0	244
onion	0	120	275	0	60	270	50	113	0	19	33	0	560
chiayo	0	93	473	80	0	0	55	22	0	108	46	684	87
tomato	0	67	92	0	0	270	0	43	684	0	3	0	376
citronella	0	0	473	0	0	770	0	0	0	140	27	684	0
mint	0	0	0	0	30	106	0	5	0	11	6	0	0
oseille	0	50	0	0	0	0	0	0	0	0	0	0	115
agbegbe	0	0	0	0	0	27	0	0	0	0	0	0	0
basil	0	0	0	0	25	116	0	5	0	0	6	0	0
dill	0	0	0	0	0	0	0	7	0	0	0	0	0
corchorus	0	0	0	0	0	0	0	9	0	13	7	0	0
Ceni agu	0	0	81	0	0	0	0	0	0	0	0	0	0
asorangbe	0	0	20	0	0	0	0	0	0	0	0	0	0

Appendices/Appendix2

Table2. Number of farmers per sociolinguistic group cropping the vegetables in south of Benin

Vegetables	Adja	Aizo	Fon	Goun	Kotafon	Mina	Nago	Nigeria	Oueme	Plateau	Popo	Sahoue	Watchi	Xwla	Yoruba
lettuce	4	2	16	3	0	4	1	0	2	0	0	6	0	0	2
cucumber	2	1	12	0	0	4	1	0	2	0	0	5	0	0	1
hotpepper	3	1	3	0	1	23	0	1	1	0	1	1	1	1	0
celery	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0
parsley	0	1	3	0	0	0	0	0	1	0	0	2	0	0	0
coriander	0	0	3	0	0	0	0	0	0	0	0	4	0	0	0
rosemary	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
sage	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0
amaranth	4	2	13	3	0	2	1	0	2	0	0	5	0	0	1
solanum macrocarpon	6	3	12	1	0	22	0	0	2	0	1	1	0	0	1
vernonia	3	1	9	0	0	10	1	0	1	0	0	0	1	0	1
cabbage	1	2	4	2	0	1	0	0	0	0	0	0	0	0	0
bellpepper	2	1	3	1	0	1	0	0	1	0	0	7	0	0	0
carott	6	3	13	3	1	0	0	1	1	1	1	6	0	0	2
beet	1	0	0	2	0	21	0	0	0	0	0	2	1	1	0
onion	2	1	8	2	1	2	0	1	2	1	1	6	0	0	1
chiayo	0	0	4	2	0	29	1	0	2	0	0	2	1	1	0
tomato	2	1	1	1	1	1	0	1	1	1	1	1	0	0	1
citronella	0	0	0	2	0	1	0	0	2	0	0	2	1	0	0
mint	0	1	2	1	0	0	0	0	1	0	0	1	0	0	0
oseille	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
agbegbe	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
basil	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
dill	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
corchorus	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceni agu	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
asorangbe	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Siboul	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0