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The use of pesticides in agriculture in North-East Benin

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Abstract

In Benin, agriculture sector contributes to 26 % of the Gross Domestic Product in 2016. Intensification of agriculture has led to increase the use of new pesticides. This paper aims to asses practice attitudes of chemical pesticide use by farmers in North-East of Benin. Semi-structured interviews were conducted among 100 farmers chosen by the "snowball sampling" process in the communes of Banikoara, Kandi, Bembereke and Kalale. Survey was focused on farmer status, farming crops, pesticides and their use in agriculture. Descriptive statistics were performed with MS Excel while SAS software was used to perform chi-2 tests. Multiple correspondence analysis and hierarchical classification analysis were conducted to establish a farmer typology. Ninety-one percent of farmers were men and the predominant ethnic groups ($p<0.01$) were *Bariba* (31 %), *Gando* (29 %) and *Mokole* (23 %). Farmers were mostly uneducated (68 %) ($p<0.001$). The main activity of these farmers was agriculture (85 %) ($p<0.001$) before livestock (8 %) and trade (7 %).Surveyed farmers cultivated several crops of which maize (97.9±0.57 %), cotton (88.4±1.26 %) and sorghum (81.1±1.45 %) were predominant ($p<0.01$). Pesticides were mostly used to grow maize, cotton, sorghum and leguminous by 96, 94, 77 and 67 % of farmers, respectively. Thirteen herbicide active ingredients were found on labels of 21 chemical productswhile 14 active principles were found from 35 insecticide products. Seventy-eight percent of farmers purchased pesticides both in formal and illegal sectors while 17 % and 5 % of them shoped it from formal sector only and unauthorized market only, respectively. The modals of the pesticide use had sometimes known by 53 % of farmers. Farmers were classed in three groups: cluster 1 was high-risk class while clusters 2 and 3 were lower-risk classes able to cause contamination of environment and foods from animal bred in the study area by the pesticide residues. The use of pesticides as above described, suggests adverse health effects on farmers and on livestock animals.

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Introduction

In Benin, agriculture is the second sector (after services) that contributes to 26 % of the Gross Domestic Product in 2016 (The World Bank, 2016; *Unpublished*). Several vegetable crops as cotton are cultivated in this country. Cotton is the main ground-rent crop in the country (Lau *et al.*, 2015). There is a strong link between cotton prices and rural welfare in Benin (Minot and Daniels, 2005). So, cotton culture is very important for this country development. However, cotton plant is very sensitive to several diseases from arthropod ravagers, of which *Helicoverpa armigera* causes mostly nuisances (Alavo *et al.*, 2010). Among all the existing methods of fight, chemical control is the most dominant with spraying of very important annual quantities of various pesticides (Agbohessi *et al.*, 2011). In addition, in relation to rapid human population increase, intensification of agriculture to satisfy food needs and to contribute to global hunger reduction has led to increasing use of new pesticides (Pretty *et al.*, 2011; Tscharntke *et al.*, 2012; Sarwar and Salman, 2015).

Pesticides are very important for food crops production and for human health. These products are used to prevent and/or control undesirable organisms in agriculture or public health (Damalas *et al.*, 2011; Sarwar and Salman, 2015).

Several studies proved that pesticide use involves presence of their residues in environment and caused many nuisances living beings because of pesticide toxicity to animals and human health (Dawson *et al.*, 2010 ; Damalas *et al.*, 2011; Gbaguidi *et al.*, 2011; Mesnage *et al.*, 2014; Aïkpo *et al.*, 2016). Others authors found pesticide residues in foods from vegetables and animals (Krüger *et al.*, 2014; Shehata *et al.*, 2014; Ehling and Reddy, 2015; Ezemonye *et al.*, 2015).

Nevertheless, most of farmers living in some African rural areas used pesticides following bad attitude practices (Agbohessi *et al.*, 2011; Hinson *et al.*, 2015; Negatu *et al.*, 2016). Thus, it was necessary that this study assessed practice attitudes of chemical pesticides by agricultural farmers in North-East of Benin. Different pesticides used in the study area had been inventoried.

Materials and methods

Study area

In this study, data were collected in the departments of Borgou and Alibori in the North-East of Benin (Fig. 1).

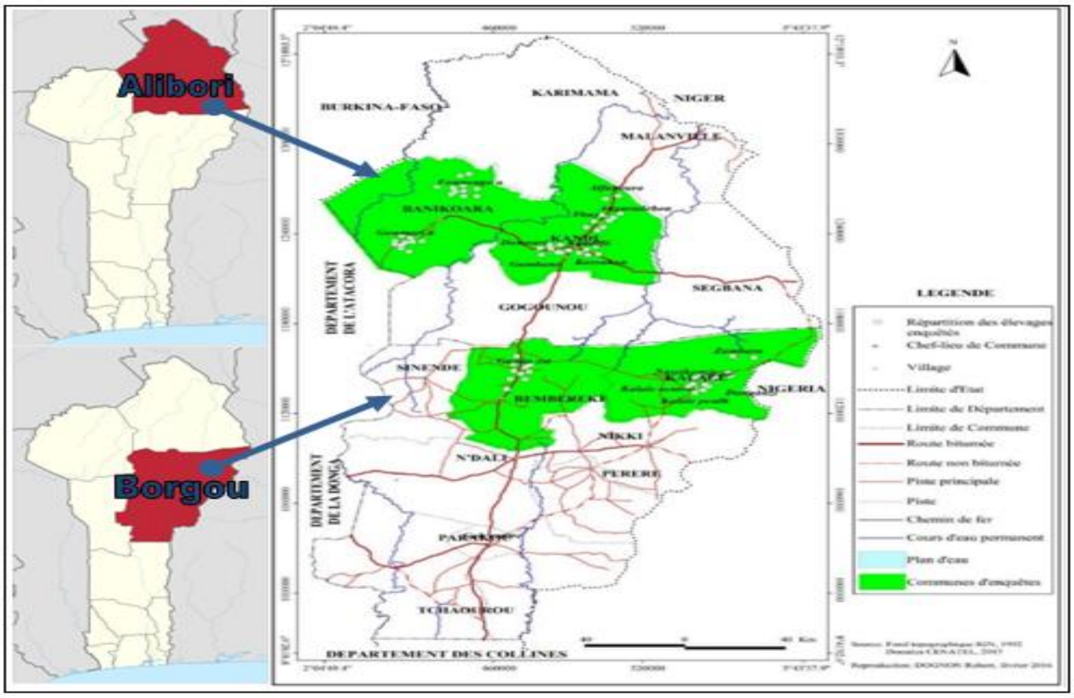

Fig. 1. Location of surveyed farmers in the departments of Borgou and Alibori.

The department of Alibori is located in the extreme North of Benin. It is bounded on the East by the Federal Republic of Nigeria, to the North by the republics of Burkina-Faso and Niger, to the South by the department of Borgou and to the West by the department of Atacora.

It has an area of 26,242 km² (23 % of national territory) and a population estimated at 867,463 inhabitants (8.7 % of the national population) in 2013 (INSAE, 2015, *Unpublished*).

The climate is Sudano-Sahelian and the annual rainfall varies between 700 and 1200 mm (Adam et Boko, 1993).

The Department of Borgou covers 25,856 km². It is bounded to the North by the department of Alibori, South by the departments of Collines and Donga, to the East by the Federal Republic of Nigeria, and to the West by the department of Atacora.

Its population was estimated at 1,214,249 inhabitants (12.1% of the national population) in 2013 (INSAE, 2015; *Unpublished*). The climate is Sudanese type and the annual rainfall varies from 900 to 1300 mm (Adam et Boko, 1993).

In the two departments, the main activity of the populations is agriculture that is family-type. Livestock is very developed with large herds of cattle, sheep, goats, poultry, etc.

Interviews

Choice of the survey communes

Four communes were chosen following two steps. Firstly, according to data available in activity reports of the Regional Agricultural Centre for Rural Development of the departments of Borgou and Alibori, the first three communes of cotton production in 2014-2015 were pre-selected by department. Among these preselected communes, the first two,which had more bovine herd were chosen in each department. In fine, the communes of Banikoara and Kandi in the department of Alibori ; Bembereke and Kalale in Borgou were selected (Fig. 1).

Choice of the surveyed farmers

Farmers were selected according to the "snowball sampling " process. The first respondents were chosen with the help of the service of Communal Sector for Agricultural Development in each selected commune. Four Specialized Technicians of Vegetable Production (TSPV) wereinterviewed as key informants. The first respondents helpt to choose the followsurveyed farmers. The availability of respondents to provide the maximum of information was a key factor in their choice. A total of 100 farmers were interviewed (25 farmers by commune).

Data collection

From September to November 2015, semi-structured interviews were conducted in face to face with each of the selected farmers. With the help of a translator, interviews were conducted in local languages on the topics relating to the farmer status, growncrops, pesticides used and attitude practices of farmer to apply pesticides. Some informations such as cultivated superficie of each crop, pesticide used on vegetable andpesticide sources were systematically recorded to be analyzed quantitatively.

Data analysis

Data from semi-sructured survey were translated in a structured form in MS Excel 2013 to perform descriptive statistics. SAS software (version 9) was used to perform chi-2 test for the statistical comparisons between proportions of each modality.

In the data base, surveyed farmers were numbered from 1 to 100 following the interview rank. Banikoara farmers were numbered from 1 to 25, those of Kandi 26 to 50, those of Bembèrèkè 51 to 75 and those of Kalalé 76-100.

R software version 3.2.5 (package Facto Mine R, functions MCA and HCPC) was used as described by Husson *et al.* (2017) to perform multiple correspondence analysis (MCA) and hierarchical classification analysis (HCA) of variables related to risk practices in the use of pesticides by farmers. MCA is a statistical method to analyze the pattern of relationships between a set of qualitative variables.

This method projects the variable modalities on maps based on their correlations. As for the HCA, it based on the MCA results in order to project each of the farmers according to their modalities on an area map defined by virtual axis.

This algorithmic approach allowed defining hierarchically discrete groups (clusters) following the branches of a dendrogram. MCA and HCA results were interpreted as described by Dognon *et al.* (2018).

In this study, 9 variables with 26 modalities were used (Table 1) in order to establish a typology of the farmers according to their practices. Statistical comparisons were performed between farmer proportions (p) relative to different modalities of the clusters by determining confidence intervals (CIs) at 95 % using the formula $CI = 1.96 * \sqrt{p(100-p)/n}$ (n=total number in the sampled population). Each farmer cluster was then classified according to the risk-group using an assessment grid of practices able to cause contamination of environment and food products by pesticide residues (Table 2 adapted from Dognon *et al.* (2018)).

This assessment grid was based on modalities linked to good practices of pesticide use. In relation to each of these modalities, the risk was considered as high, medium and low if proportion of associate farmers was lower than 20 %, between 20 % and 50 %, and above 50 % of the total cluster farmers, respectively (Table 2). The risk level of each cluster was taken as the highest rate presented by the cluster across the grid.

Results

Farmer status

Table 3 shows the proportions of farmers in relation to their status modalities and the results of significance tests between the final proportions and between farmer percentages following sampled commune. Ninety-one percent of farmers were men. Seventy-four percent of the responding had age ranging from 30 to 59 old years.

Table 1. Codes of modalities used for the MCA and the HCA.

Variables	Modalities	Codes
Commune	Bembèrèkè	bke
	Kandi	kdi
	Banilkoara	bnk
	Kalalé	kal
Instruction level	No instruction	inst0
	Primary school	inst1
	Secondary school	inst2
Local language literate	No	lang0
	Yes	lang1
Knowledge of use modal of the pesticides	No	know0
	Yes	know1
	Yes sometimes	know2
Technician helping	No	tech0
	Yes	tech1
	Yes sometimes	tech2
Purchase site of the pesticides	Market	sourceM
	SCDA	sourceS
	SCDA and market	sourceT
Management of empty bottles	No disposal precaution	bottle0
	Burnt	bottle1
	Recycled for sell	bottle2
	Buried	bottle3
	Recycled for use	bottle4
Pasturing of crop residues by own bovines	No	past0
	Yes	past1
Pasturing of crop residues by other bovines	Yes	past

The predominant ethnic groups were *Bariba* (31 %), *Gando* (29 %) and *Mokole* (23 %).

Farmers were mostly uneducated (68 %) ($p<0.001$) with a rate of literacy in local languages of 35 %. Islam was the predominant religion (71 %) before Christianity (26 %). Proportion of farmers who practiced agriculture as the main activity (85 %) was significantly higher ($p<0.001$) than farmers whose livestock (8 %) and trade (7 %) were the main activities.

Table 2. Assess grid of the risk level of practices able to cause contamination of foods from animals bred in the area by pesticide residues (Adapted from Dognon et al. (2018).

Variable (good modality with low risk)	Percentages of farmers who respect the modality with low risk		
	Proportion lower than 20 % of farmers	Proportion between 20 and 50 % of farmers	Proportion higher than 50 % of farmers
Instruction level : primary or secondary school	High	Medium	Low
Local language literate : yes	High	Medium	Low
Knowledge of use modal : yes	High	Medium	Low
Technician helping : yes	High	Medium	Low
Purchase site : SCDA	High	Medium	Low
Management of empty bottles : buried or burnt	High	Medium	Low
Pasturing of crop residues by own bovines : no	High	Medium	Low
Pasturing of crop residues by other bovines : no	High	Medium	Low

High : high-risk able to cause contamination of foods from animal bred in the area by pesticide residues,
Medium : medium-risk able to cause contamination of foods from animal bred in the area by pesticide residues,
Low : low-risk able to cause contamination of foods from animal bred in the area by pesticide residues.

Crops cultivated by farmers from 2006 to 2015

Surveyed farmers cultivated several crops from 2006 to 2015 in order to satisfy food needs and get necessary income for other want. Fig. 2 shows proportions of farmers following grown crops during last decade. From 2006 to 2015, maize, cotton and sorghum were cultivated by 97.9±0.57, 88.4±1.26 and 81.1±1.45 % of the farmers, respectively. Other grown crops were leguminous (59.4±7.46 %), roots and tubers (41.6±0.97 %), rice (20.9±2.96 %) gardening (16.5±1.51 %), etc. These percentages were significantly different ($p<0.01$) from the one crop to the other.

Use of pesticides following different grown crops

Table 4 shows the use of pesticides by farmers following grown crops and sampled communes. It results that the use of pesticide was not the same for all crops. Farmers on all crop fields used herbicides while insecticides were used only in three grown crops such as cotton, leguminous and gardening. Generally, pesticides were mostly used for growing maize (herbicide), cotton (herbicide and insecticide), sorghum (herbicide) and leguminous (herbicide and insecticide) by 96, 94, 77 and 67 % of the farmers, respectively.

In the cotton fields, both non-selective and pre-emergent herbicides were used while only non-selective weedkillers containing glyphosate as active ingredient were mostly used in others crop fields. Then, non-selective herbicides are sprayed on weeds before ploughing.

Pesticides used by farmers in 2015

Herbicides and insecticides were the two pesticide types registered among farmers during the survey in 2015. Table 5 shows herbicide products used in agriculture by the responding farmers.

According to the label informations, 12/21 herbicide products were single compounds while the nine others weedkillers were mixtures of at least two active elements. Cottonex PG 560SC and nicomaïs were the mostly herbicide products used by 55±9.75 % and 47±9.78 % of the farmers, respectively.

Table 3. Status of farmers.

Variables and modalities	Proportion of farmers (%)	Distribution in communes (%)			
		Bnk	Kdi	Bke	Kal
Sex					
Male	91[a]	24.18[e]	27.47[e]	23.08[e]	25.27[e]
Female	9[b]	33.33[e]	0.00[f]	44.44[e]	22.22[ef]
Ages (years)					
Age < 30	9[b]	22.22[e]	33.33[e]	22.22[e]	22.22[e]
30 ≤ Age ≤ 59	74[a]	24.32[e]	28.38[e]	25.68[e]	21.62[e]
Age ≥ 60	17[b]	29.41[ef]	5.88[f]	23.53[ef]	41.18[e]
Ethnic groups					
Bariba	31[a]	61.29[e]	3.23[h]	35.48[f]	0.00[h]
Gando	29[a]	0.00[h]	0.00[h]	24.14[f]	75.86[e]
Mokole	23[a]	0.00[f]	100.00[e]	0.00[f]	0.00[f]
Fulani	8[b]	75.00[e]	0.00[f]	12.50[f]	12.50[f]
Djerma	7[bc]	0.00[f]	14.29[f]	71.43[e]	14.29[f]
Boo	1[c]	0.00[e]	0.00[e]	0.00[e]	100.00[e]
Nago	1[c]	0.00[e]	0.00[e]	100.00[e]	0.00[e]
Instruction level					
Uneducated	68[a]	32.35[e]	17.65[f]	22.06[ef]	27.94[ef]
Primary school	15[b]	13.33[f]	46.67[e]	33.33[ef]	6.67[f]
Secondary school	17[b]	5.88[f]	35.29[e]	29.41[ef]	29.41[ef]
Local language literate					
No	65[a]	29.23[e]	29.23[e]	27.69[e]	13.85[f]
Yes	35[b]	17.14[f]	17.14[f]	20.00[f]	45.71[e]
Religion					
Islam	71[a]	23.94[e]	29.58[e]	25.35[e]	21.13[e]
Christianity	26[b]	23.08[e]	15.38[e]	23.08[e]	38.46[e]
Non-religious	3[c]	66.67[e]	0.00[e]	33.33[e]	0.00[e]
Principal activities					
Agriculture	85[a]	21.18[e]	24.71[e]	25.88[e]	28.24[e]
Breeding	8[b]	75.00[e]	0.00[f]	12.50[f]	12.50[f]
Trade	7[b]	14.29[ef]	57.14[e]	28.57[ef]	0.00[f]
Secondary activities					
Breeding	65[a]	20.00[e]	26.15[e]	30.77[e]	23.08[e]
Agriculture	15[b]	46.67[e]	26.67[ef]	20.00[ef]	6.67[f]
Trade	20[b]	25.00[ef]	20.00[ef]	10.00[f]	45.00[e]

Bnk : Banikoara ; Kdi : Kandi ; Bke : Bembereke ; Kal : Kalale ; Letters a, b and c were used to notify significant difference between proportions of modalities for the same variable; Letters e, f and h were used to notify significant difference between proportions of the same modality in different communes.

These last proportions were significantly different to the percentages of farmers using others weedkillers ($p<0.05$). A total of 13 active ingredients were registered from these herbicide products. Glyphosate, prometrin and fluometuron were the most represented active agents present in 11, 6 and 5 different products, respectively. Eighty-six percent of herbicide products had their active agent on the list of authorized pesticide by the National Comity of Consent and Control of Phytopharmaceutical Products in Benin (CNAC, 2014; unpublished).

As for the insecticides, 14 active agents were registered from the 35 trade products which 40 % were single compound (Table 6).

Twenty-one products of them were mixtures of two or three active ingredients.

Ema star 112 EC was the insecticide mostly used by the farmers (89±6.13 %) before Acer 35EC (78±8.12 % of farmers) and Cutter 112EC (47±9.78 % of farmers) ($p<0.05$) (Table 6).

Acetamipride and λ-Cyhalothrin were the most ($p<0.05$) active ingredients in 37 and 25.7 % of the insecticide products. Cypermethrin, profenofos, and emamectine were present in 22.8, 20 and 20 % of insecticide products with no significant difference ($p>0.05$).

All active agents were found on the list of authorized pesticide by the National Comity of Consent and Control of Phytopharmaceutical Products in Benin (CNAC, 2014; unpublished), but only 15 products of them had their trade name on that list.

Table 4. Proportions of farmers using pesticides following crops in the sampled communes.

Variables and modalities	Proportion of farmers (%)	Distribution in communes (%)			
		Bnk	Kdi	Bke	Kal
Maize					
Herbicide	96^{a}	26.04^{e}	26.04^{e}	22.92^{e}	25.00^{e}
No use of pesticide	4^{b}	0.00^{f}	0.00^{f}	75.00^{e}	25.00^{f}
Cotton					
Herbicide and Insecticide	94^{a}	26.60^{e}	26.60^{e}	21.28^{e}	25.53^{e}
No use of pesticide	6^{b}	0.00^{f}	0.00^{f}	83.33^{e}	16.67^{f}
Sorghum					
Herbicide	77^{a}	27.27^{e}	25.97^{e}	20.78^{e}	25.97^{e}
No use of pesticide	23^{b}	17.39^{e}	21.74^{e}	39.13^{e}	21.74^{e}
Leguminous					
Herbicide and Insecticide	26^{b}	53.85^{e}	15.38^{fh}	3.85^{h}	26.92^{f}
Insecticide	41^{a}	0.00^{h}	46.34^{e}	34.15^{ef}	19.51^{f}
No use of pesticide	33^{ab}	33.33^{e}	6.06^{f}	30.30^{e}	30.30^{e}
Gardening					
Herbicide and Insecticide	15^{b}	20.00^{ef}	33.33^{e}	0.00^{f}	46.67^{e}
Insecticide	14^{b}	7.14^{f}	21.43^{ef}	28.57^{ef}	42.86^{e}
No use of pesticide	71^{a}	29.58^{e}	23.94^{e}	29.58^{e}	16.90^{e}
Rice					
Herbicide	22^{b}	22.73^{e}	31.82^{e}	18.18^{e}	27.27^{e}
No use of pesticide	78^{a}	25.64^{e}	23.08^{e}	26.92^{e}	24.36^{e}
Roots and tubers					
Herbicide	17^{b}	23.53^{e}	0.00^{f}	47.06^{e}	29.41^{e}
No use of pesticide	83^{a}	25.30^{e}	30.12^{e}	20.48^{e}	24.10^{e}

Bnk : Banikoara ; Kdi : Kandi ; Bke : Bembereke ; Kal : Kalale ; Letters a and b were used to notify significant difference between modality proportions for the same variable; Letters e, f and h were used to notify significant difference between proportions of the same modality in different communes.

Table 5. Herbicides used by responding farmers in 2015.

N°	Trade names	Active ingredients	Farmer frequency±CI(%)
1	Cottonex PG 560SC	Fluometuron+ Prometrin+ Glyphosate	55±9.75^{a}
2	Nicomaïs	Nicosulfuron	47±9.78^{a}
3	Spring PFG 560SC**	Fluometuron+ Prometrin+ Glyphosate	29±8.89^{b}
4	Kalach 360SL	Glyphosate	28±8.80^{b}
5	Spider**	Fluometuron+ Prometrin+ Glyphosate	28±8.80^{b}
6	Glyphos 360 SL	Glyphosate	26±8.60^{b}
7	Glyphospring 410SL**	Glyphosate	26±8.60^{b}
8	Glycel 41%	Glyphosate	18±7.53^{bc}
9	JAF PFG**	Fluometuron+ Prometrin+ Glyphosate	13±6.59^{c}
10	Atra force*	Atrazine#	8±5.32^{c}
11	Buster*	Butachlor	1±1.95^{d}
12	Buta force*	Butachlor	1±1.95^{d}
13	Callifor G	Fluometuron+ Prometrin+ Glyphosate	1±1.95^{d}
14	Force Up**	Glyphosate	1±1.95^{d}
15	GALLANT Super	Haloxyfop methyl ester	1±1.95^{d}
16	Garill	Triclopyr+ Propanil	1±1.95^{d}
17	Glyphogan 360SL	Glyphosate	1±1.95^{d}
18	Lagon 380 SC	Isoxaflutole+ Aclonifene	1±1.95^{d}
19	ITABARKA**	Prometrin	1±1.95^{d}
20	Terbulor	Metolachlor+ Terburnin	1±1.95^{d}
21	TRIPRO	Triclopyr+ Propanil	1±1.95^{d}

Farmer frequency (%): proportion of farmer using product. CI: Confident interval at 95 %. Letters from a to d were used to notify significant difference between the percentages. *: Product thattrade name and actives ingredients were not found on the list of authorized pesticide by the National Comity of Consent and Control of Phytopharmaceutical Products (CNAC) in Benin (CNAC, 2014; unpublished). **: Product that trade name was not found on the list of authorized pesticide of CNAC (2014; unpublished) while actives agents were found on that list.

Practices of use of pesticides in the area study

All surveyed farmers used pesticides for control and prevention of harmful organisms.

Table 7 shows practices of use of pesticides. Seventy-eight percent of farmers purchased pesticides in both authorized shop of communal sector for agricultural developpment (SCDA) and illegal market while 17 % and 5 % of them shoped from SCDA only and illegal market only, respectively.

Table 6. Insecticides used by the responding farmers in 2015.

N°	Trade names	Active ingredients	Farmer frequency ± CI (%)
1	Ema star 112 EC	Emamectine+ Acetamipride	89±6.13[a]
2	Acer 35EC**	λ-Cyhalothrin+Acetamipride	78±8.12[b]
3	Cutter 112EC	Emamectine+ Acetamipride	47±9.78[c]
4	Napeco Metafos**	Emamectine+ Acetamipride	33±9.22[cd]
5	LAMENET 46EC**	λ-Cyhalothrin+Acetamipride	25±8.49[d]
6	Caïman B**	Emamectine	10±5.88[e]
7	Lamber**	λ-Cyhalothrin+Acetamipride	10±5.88[e]
8	Sharp Shoster**	Cypermethrin+Profenofos	10±5.88[e]
9	Conquest 88	Cypermethrin+ Acetamipride	7±5.00[ef]
10	Chemaprid**	Cypermethrin+ Acetamipride	3±3.34[f]
11	Karto Super 2.5 EC**	λ-Cyhalothrin	3±3.34[f]
12	Aceta star**	Bifenthrin+ Acetamipride	2±2.74[f]
13	Conquest plus 388EC	Cypermethrin+ Acetamipride+ Triazophos	2±2.74[f]
14	Cyperkill 10EC**	Cypermethrin	2±2.74[f]
15	EMA SUPER 56 DC	Emamectine+ Acetamipride	2±2.74[f]
16	Fanga 500EC	Profenofos	2±2.74[f]
17	KD+**	λ-Cyhalothrin+ Chlorpyriphos	2±2.74[f]
18	Lampride**	λ-Cyhalothrin+ Acetamipride	2±2.74[f]
19	Moacartarine**	λ-Cyhalothrin+ Acetamipride	2±2.74[f]
20	Nurelle D 35/300	Cypermethrin+ Chlorpyriphos ethyl	2±2.74[f]
21	Profenet 500 EC**	Profenofos	2±2.74[f]
22	Steward 150 EC	Indoxacarbe	2±2.74[f]
23	Tenor 500 EC**	Profenofos	2±2.74[f]
24	Thunder 145 o-teq	Imidaclopride+ Beta-cyfluthrin	2±2.74[f]
25	Tihan 175 o-teq	Spirotetramate+ Flubendiamide	2±2.74[f]
26	CALIF 500EC	Profenofos	1±1.95[f]
27	Champion Cyhalon 2.5 EC**	λ-Cyhalothrin	1±1.95[f]
28	D-BAN Super 480EC**	Chlorpyrifos-ethyl	1±1.95[f]
29	Emacot 019EC	Emamectine	1±1.95[f]
30	Emectine 19.2EC**	Emamectine	1±1.95[f]
31	EMIR 88EC	Cypermethrin+ Acetamipride	1±1.95[f]
32	FAIZER**	Indoxacarbe	1±1.95[f]
33	Lamdacal P 315 EC	λ-Cyhalothrin+ Profenofos	1±1.95[f]
34	Nurelle D 36/200	Cypermethrin+ Chlorpyriphos ethyl	1±1.95[f]
35	Profenofos**	Profenofos	1±1.95[f]

Farmer frequency (%): proportion of farmer using product; CI: Confident interval at 95 %; Letters from a to f were used to notify significant difference between percentages. **: Product that trade name was not found on the list of authorized pesticide by the CNAC (2014, unpublished) in Benin while actives ingredients were found on that list.

Proportion of farmers who purshased pesticides in SCDA shop exclusivelly was more in Banikoara (47.06 %) and Kalale (47.06 %) than Kandi (5.88 %) and Bembereke (0 %). This last commune had the highest proportion (80 %) of farmers who solely got pesticides from illegal market.

The modals of the pesticide use had sometimes been known by 53 % of farmers and regulary known by 45 % of them. Sixteen percent of the farmers were not ever assisted by the technicians of vegetable production.

As for the management of pesticide empty bottles, “no disposal precaution” (60 %) was the dominant modality ($p<0.001$). Others pesticide empty bottles were burnt (17 %), recycled for sell (12 %), buried (6 %) and recycled for other use (5 %).

Table 7. Practice of use of pesticides.

Variables and modalities	Proportion of farmers (%)	Distribution in communes (%)			
		Bnk	Kdi	Bke	Kal
Purchase site					
SCDA and Market	78[a]	21.79[e]	29.49[e]	26.92[e]	21.79[e]
SCDA	17[b]	47.06[e]	5.88[f]	0.00[f]	47.06[e]
Market	5[c]	0.00[f]	20.00[f]	80.00[e]	0.00[f]
Knowledge of use modal					
Yes sometimes	53[a]	43.40[e]	43.40[e]	9.43[f]	3.77[f]
Yes	45[a]	4.44[f]	4.44[f]	44.44[e]	46.67[e]
No	2[b]	0.00[f]	0.00[f]	0.00[f]	100.00[e]
Technician helping					
Yes sometimes	52[a]	46.15[e]	44.23[e]	9.62[f]	0.00[h]
Yes	32[b]	3.13[f]	6.25[f]	43.75[e]	46.88[e]
No	16[c]	0.00[f]	0.00[f]	37.50[e]	62.50[e]
Management of empty bottles					
No disposal precaution	60[a]	36.67[e]	15.00[f]	28.33[ef]	20.00[f]
Burnt	17[b]	0.00[f]	17.65[f]	29.41[e]	52.94[e]
Recycled for sell	12[bc]	0.00[f]	83.33[e]	16.67[f]	0.00[f]
Buried	6[c]	0.00[f]	16.67[f]	16.67[f]	66.67[e]
Recycled for use	5[c]	60.00[e]	40.00[ef]	0.00[f]	0.00[f]
Knowledge of adverse effect of pesticides					
No effect	42[a]	45.24[e]	23.81[f]	23.81[f]	7.14[h]
Human diseases	24[b]	25.00[f]	0.00[h]	0.00[h]	75.00[e]
Animal diseases	18[b]	0.00[f]	44.44[e]	55.56[e]	0.00[f]
Animal and human diseases	16[b]	0.00[f]	43.75[e]	31.25[e]	25.00[e]
Bovine herd holder					
Yes	85[a]	29.41[e]	27.06[e]	14.12[f]	29.41[e]
No	15[b]	0.00[f]	13.33[f]	86.67[e]	0.00[e]
Pasturing of crop residues by own bovines					
Yes	84[a]	29.76[e]	27.38[e]	13.10[f]	29.76[e]
No	16[b]	0.00[f]	12.50[f]	87.50[e]	0.00[f]
Pasturing of crop residues by other bovines					
Yes	100	25.00[e]	25.00[e]	25.00[e]	25.00[e]

Bnk : Banikoara ; Kdi : Kandi ; Bke : Bembereke ; Kal : Kalale ; Letters a, b and c were used to notify significant difference between proportions of modalities for the same variable; Letters e, f and h were used to notify significant difference between proportions of the same modality in different communes.

Many farmers (42 %) declared that they did not know any adverse effect caused by pesticides on animal and human beings.

This proportion is significantly upper ($p<0.01$) than that of others farmer categories who recognized that pesticides use could cause human diseases (24 %), animal diseases (18 %) and, both animal and human diseases (16 %).

According to the farmers, animal illnesses could be respiratory diseases and swellen stomach which caused sometimes animal death.

As for the human diseases, farmers declared that pesticides made themself fell dizzy. Eighty-five percent of farmers were bovine herd holders.

These cattle pastured crop residues in 84 % of their older fields; but all surveyed farmers declared that others bovines got pasture in their fields.

Typology of farmers according to risky practices

Multiple correspondence analysis

Three axes were retained for interpreting the results of the multiple correspondence analyses (MCA).

Table 8. Distribution of farmers in the three classes according to the whole modalities.

Variables/Modalities	Farmer number (n=100)	Proportions of farmer distribution in the clusters (% ± CI)		
		Cluster 1	Cluster 2	Cluster 3
Commune				
Bembèrèkè	25	0.0 ± 0.0^{b}	100.0 ± 0.0^{a}	6.9 ± 9.2^{b}
Kandi	25	50.0 ± 14.1^{a}	0.0 ± 0.0^{b}	3.4 ± 6.6^{b}
Banikoara	25	50.0 ± 14.1^{a}	0.0 ± 0.0^{b}	3.4 ± 6.6^{b}
Kalalé	25	0.0 ± 0.0^{b}	0.0 ± 0.0^{b}	86.2 ± 12.6^{a}
Instruction level				
No instruction	68	70.8 ± 12.9^{a}	56.5 ± 20.3^{a}	72.4 ± 16.3^{a}
Primary school	15	16.7 ± 10.5^{a}	21.7 ± 16.9^{a}	6.9 ± 9.2^{a}
Secondary school	17	12.5 ± 9.4^{a}	21.7 ± 16.9^{a}	20.7 ± 14.7^{a}
Local language literate				
No	65	79.2 ± 11.5^{a}	78.3 ± 16.9^{a}	31.0 ± 16.8^{b}
Yes	35	20.8 ± 11.5^{b}	21.7 ± 16.9^{b}	69.0 ± 16.8^{a}
Knowledge of use modal				
No	2	0.0 ± 0.0^{a}	0.0 ± 0.0^{a}	6.9 ± 9.2^{a}
Yes	45	4.2 ± 5.7^{b}	78.3 ± 16.9^{a}	86.2 ± 12.6^{a}
Yes sometimes	53	95.8 ± 5.7^{a}	21.7 ± 16.9^{b}	6.9 ± 9.2^{b}
Technician helping				
No	16	0.0 ± 0.0^{b}	21.7 ± 16.9^{a}	37.9 ± 17.7^{a}
Yes	32	4.2 ± 5.7^{b}	56.5 ± 20.3^{a}	58.6 ± 17.9^{a}
Yes sometimes	52	95.8 ± 5.7^{a}	21.7 ± 16.9^{b}	3.4 ± 6.6^{c}
Purchase site				
Market	5	2.1 ± 4.0^{ab}	17.4 ± 15.5^{a}	0.0 ± 0.0^{b}
SCDA	17	18.8 ± 11.0^{a}	0.0 ± 0.0^{b}	27.6 ± 16.3^{a}
SCDA and market	78	79.2 ± 11.5^{a}	82.6 ± 15.5^{a}	72.4 ± 16.3
Management of empty bottles				
No disposal precaution	60	62.5 ± 13.7^{ab}	69.6 ± 18.8^{a}	48.3 ± 18.2^{b}
Burnt	17	4.2 ± 5.7^{b}	17.4 ± 15.5^{b}	37.9 ± 17.7^{a}
Recycled for sell	12	20.8 ± 11.5^{a}	8.7 ± 11.5^{b}	0.0 ± 0.0^{b}
Buried	6	2.1 ± 4.0^{a}	4.3 ± 8.3^{a}	13.8 ± 12.6^{a}
Recycled for use	5	10.4 ± 8.6^{a}	0.0 ± 0.0^{b}	0.0 ± 0.0^{b}
Pasturing of crop residues by own bovines				
No	16	4.2 ± 5.7^{b}	60.9 ± 19.9^{a}	0.0 ± 0.0^{b}
Yes	84	95.8 ± 5.7^{a}	39.1 ± 19.9^{b}	100.0 ± 0.0^{a}
Pasturing of crop residues by other bovines				
Yes	100	100.0 ± 0.0^{a}	100.0 ± 0.0^{a}	100.0 ± 0.0^{a}

CI: Confidence interval at 95 %; Letters a, b and c were used to notify significant difference between proportions of modalities about in clusters.

The analysis of the indicator matrix shown respectively for the axes 1, 2 and 3 a value of 18.69 %, 13.06 % and 9.77 % of the total inertia (Fig. 3 and 4).

The component 1 opposes the districts of Banikoara and Kandi, associated to modalities of farmers who did not follow local language literate, who sometimes know the use modal of the pesticides and get agricultural technician helps for the pesticide use (negative coordinates, Fig. 3), to the district of Kalalé, where some farmers received local language lecture and were not helped by the agricultural technicians (positive coordinates, Fig. 3).

The component 2 discriminates the group of modalities related to farmers in the district of Bembèrèkè (positive coordinates, Fig. 3) to other groups of farmers in Banikoara on the one hand and Kalalé on the other hand (negative coordinates, Fig. 3).

As for the component 3, it opposes farmers who purchase pesticides from legal shop (SCDA) to those who use local market as sources of supply of pesticides.

Hierarchical classification analysis and description of classes

Fig. 4 shows the projection of individual farmers on the plane defined by the factorial axes 1 and 2, which allowed observing the affinity groups in three clusters, holding 48 % of the total variability between groups. Table 8 shows the distribution of farmers in the three classes according to all modalities of which the most relevant by farmer class are presented in Table 9.

Table 9. Distribution of farmers in the three classes according to the most relevant modalities (percentage of modalities compared to the farmer number in each cluster).

Variables/Modalities	Proportions of farmer distribution in the clusters (% ± CI)		
	Cluster 1	Cluster 2	Cluster 3
Specific modalities to cluster 1			
Commune : Kandi	50.0 ± 14.1^{a}	0.0 ± 0.0^{b}	3.4 ± 6.6^{b}
Commune : Banikoara	50.0 ± 14.1^{a}	0.0 ± 0.0^{b}	3.4 ± 6.6^{b}
Knowledge of use modal : yes sometimes	95.8 ± 5.7^{a}	21.7 ± 16.9^{b}	6.9 ± 9.2^{b}
Technician helping : yes sometimes	95.8 ± 5.7^{a}	21.7 ± 16.9^{b}	3.4 ± 6.6^{c}
Management of empty bottles : recycled for sell	20.8 ± 11.5^{a}	8.7 ± 11.5^{b}	0.0 ± 0.0^{b}
Management of empty bottles : recycled for use	10.4 ± 8.6^{a}	0.0 ± 0.0^{b}	0.0 ± 0.0^{b}
Specific modalities to cluster 2			
Commune : Bembèrèkè	0.0 ± 0.0^{b}	100.0 ± 0.0^{a}	6.9 ± 9.2^{b}
Pasturing of crop residues by own bovines : no	4.2 ± 5.7^{b}	60.9 ± 19.9^{a}	0.0 ± 0.0^{b}
Specific modalities to cluster 3			
Commune : Kalalé	0.0 ± 0.0^{b}	0.0 ± 0.0^{b}	86.2 ± 12.6^{a}
Local language literate : yes	20.8 ± 11.5^{b}	21.7 ± 16.9^{b}	69.0 ± 16.8^{a}
Management of empty bottles : burnt	4.2 ± 5.7^{b}	17.4 ± 15.5^{b}	37.9 ± 17.7^{a}
Common modalities to at least two clusters			
Pasturing of crop residues by other bovines : yes	100.0 ± 0.0^{a}	100.0 ± 0.0^{a}	100.0 ± 0.0^{a}
Purchase site : SCDA and market	79.2 ± 11.5^{a}	82.6 ± 15.5^{a}	72.4 ± 16.3^{a}
Instruction level : no instruction	70.8 ± 12.9^{a}	56.5 ± 20.3^{a}	72.4 ± 16.3^{a}
Local language literate : no	79.2 ± 11.5^{a}	78.3 ± 16.9^{a}	31.0 ± 16.8^{b}
Management of empty bottles : no disposal precaution	62.5 ± 13.7^{ab}	69.6 ± 18.8^{a}	48.3 ± 18.2^{b}
Pasturing of crop residues by own bovines : yes	95.8 ± 5.7^{a}	39.1 ± 19.9^{b}	100.0 ± 0.0^{a}
Knowledge of use modal : yes	4.2 ± 5.7^{b}	78.3 ± 16.9^{a}	86.2 ± 12.6^{a}
Technician helping : yes	4.2 ± 5.7^{b}	56.5 ± 20.3^{a}	58.6 ± 17.9^{a}

CI: Confidence interval at 95 %; Letters a, b and c were used to notify significant difference between proportions of modalities about in clusters.

Cluster 1 counted 48 farmers (48 ± 14.1 % of total farmers) from Banikoara and Kandi districts. They sometimes get helps of agricultural technician and sometimes know the use modal of pesticides (Table 9).

Cluster 2 was composed of 23 ± 17.2 % of the farmers (all from Bembèrèkè) (Table 8). Several farmers of this group (60.9 ± 19.9 %) were characterized by the modality of "pasturing of crop residues by own bovines (no)" (Table 9).

As for the cluster 3, it contained 29 farmers (29 ± 16.5 % of the total farmers which of 25 from Kalalé, 2 from Bembèrèkè, 1 in Kandi and 1 in Banikoara). Most of these farmers followed local language literate and burned the empty bottles of pesticides (Table 9).

The specific modalities of each cluster (Table 9) crossed with the assessment grid of the risk level of practices (Table 2), allowed identifying clusters 2 and 3 as the lower-risk classes while cluster 1 was high-risk class able to cause contamination of environment and foods from animal bred in the study area by the pesticide residues.

Discussion

Status of the farmers

Surveyed farmers were dominated by men (91 %). The same observation was done by Hinson *et al.* (2015) in Banikoara where responding farmer sample contained 94.8 % of men. These last authors showed that farmers were majoritary uneducated (80.3 %). That seemed to be similar to the whole of instruction level in this study (68 % of farmers were unaducated). So, few farmers attended primary and secondary school. In addition, only 35 % of them were done local language literate. Thus, informations on pesticide labels would not be understood by majoritary of the farmers. This situation could favour the bad use of pesticides.

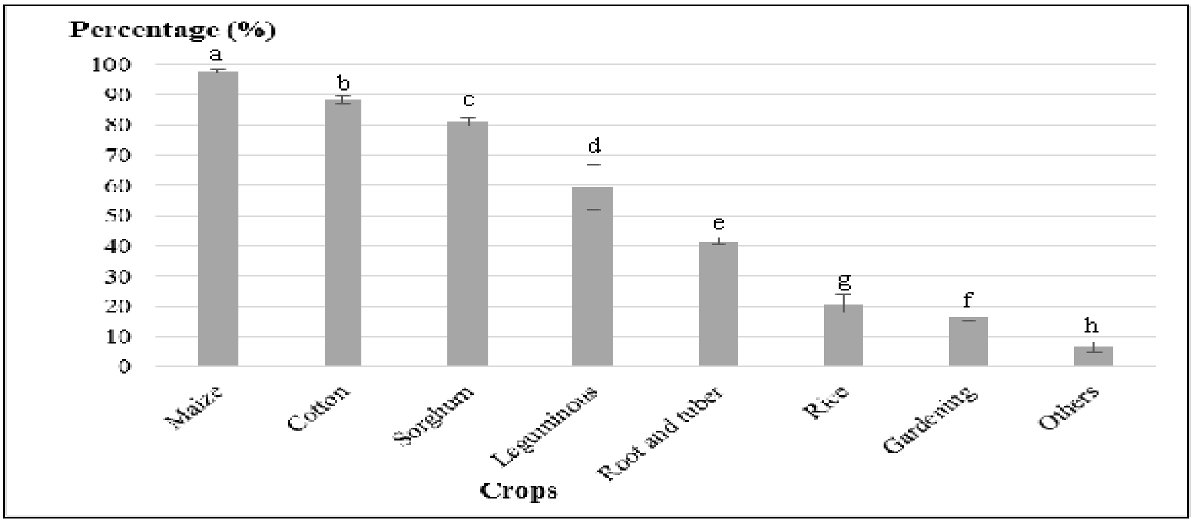

Fig. 2. Average proportions of farmers following crops cultivated from 2006 to 2015. Error bars represent standard deviations (SD) while letters from a to h were used to notify significant difference between percentages (p<0.01).

Crops cultivated and pesticides used by the farmers

From 2006 to 2015, the three crops mostly cultivated by the farmers were maize, cotton and sorghum. These results did not surprise. In fact, maize is the first cereal in main foods of the whole of the Benin population for the breakfast, lunch and dinner. In fact, the average of maize consummation was estimated to 69 kg per capita in Benin (ONS, 2011; *Unpublished*). Thus, surveyed farmers produce maize not only for their own food, but also for economic purpose.

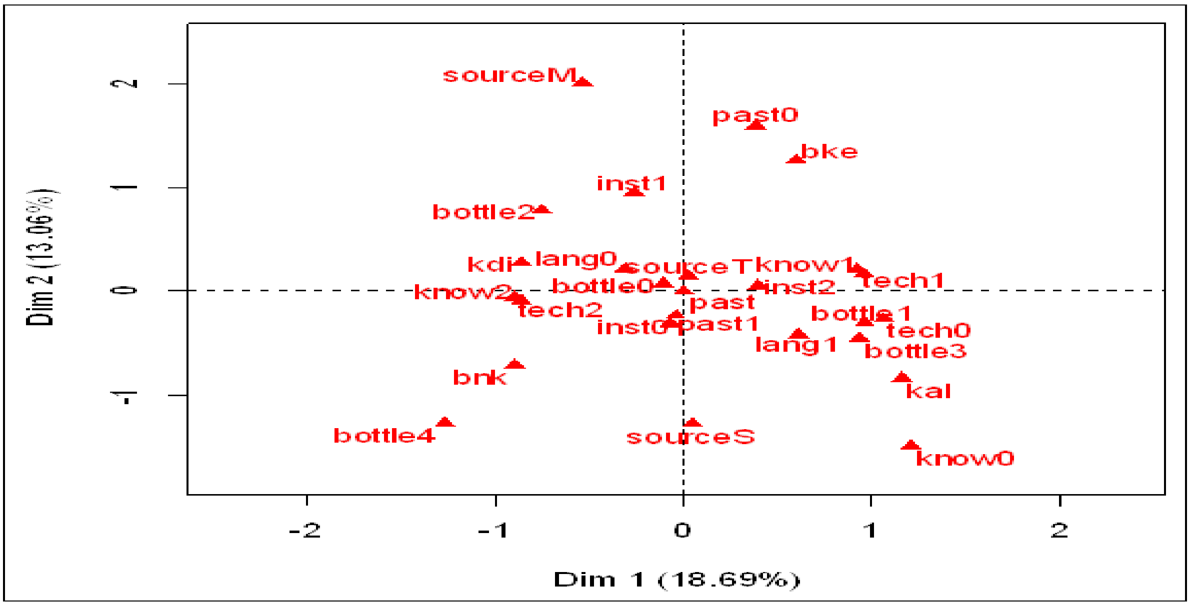

Fig. 3. Graphic representation of modalities on the factorial axes 1 and 2.

The same reasons justify the production of sorghum in the area study where this cereal is mostly used for their own foods. As for the cotton, this plant is the main ground-rent crop which contributes strongly to the country economy (Minot and Daniels, 2005; Lau *et al.*, 2015). So, cotton crop is not only very important for the study area economy but also for the development of the whole of the country.

According to Alavo *et al.* (2010), cotton plant is very sensitive to several diseases from arthropod ravagers as *H. armigera*. That justifies the use of many insecticide products on cotton plant by almost of the farmers (94 %). This level is very upper than the 69 % of chemical pesticide users surveyed in Banikoara in 2011 (Agbohessi *et al.*, 2011).

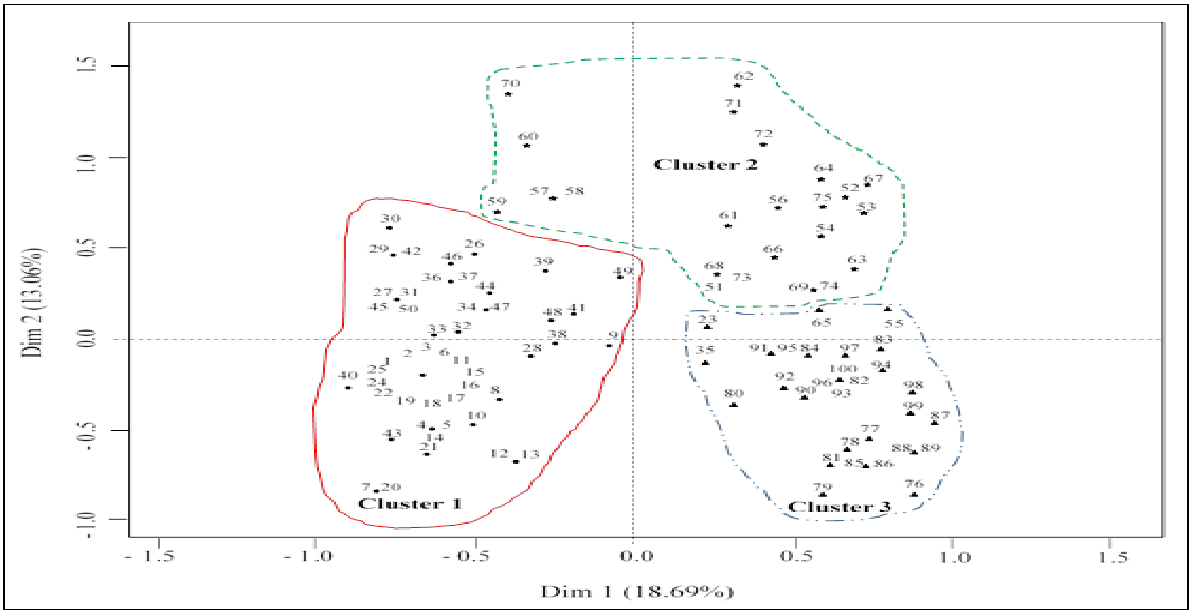

Fig. 4. Graphic representation of farmer clusters on the factorial axes 1 and 2. *The numbers correspond to the farmers who are represented on the map by "•", "★" and "▲" in the clusters 1, 2 and 3, respectively.*

Banikoara is the first commune of cotton production in Benin. Thus, several of cotton harmful insects attack also leguminous during growing. This situation justifies the proportion of the pesticide users on leguminous crops in Banikoara (53.85 %) which was significantly higher ($p<0.05$) than the percentages in the other communes.

In addition to insecticide products that were also used against leguminous and gardening devastators, weedicides were important pesticides used for the all crops growing. According to Chauhan *et al.* (2012) and Bajwa (2014), herbicides are more used in agriculture to gain time and decrease manpower. During this study, 13 active chemicals were found on 21 label herbicides. On the contrary, Hinson *et al.* (2015) survey in Banikoara showed only four herbicide products used by farmers in agriculture. But before, Agbohessi *et al.* (2011) registered three active ingredients in two herbicide products used for the cotton production in Banikoara. So, works of Hinson *et al.* (2015) seemed to be about of only cotton herbicides.

Moreover, glyphosate was the most represented active compounds present in 11 of the 22 herbicide products. It was also the more active ingredient on the labels of herbicide products documented by Agbohessi *et al.* (2011). Indeed, glyphosate is a broad spectrum, nonselective, post-emergence herbicide extensively used worldwide in various applications for weed control (Duke and Powles, 2008).

As for the insecticides, results showed 14 active substances in 35 products. This product number is lightly higher than the 11 active ingredients on labels of 27 insecticide products in Banikoara (Hinson *et al.*, 2015).

But in 2011, Banikoara's farmers used nine active chemicls from seven products to kill cotton harmful insects (Agbohessi *et al.*, 2011). According to Hinson *et al.* (2015), acetamipride was present in 13/27 of the insecticide products, this chemical was also the most active compounds in 37 % of the insecticide products documented during this survey.

Practices of pesticide use by the farmers

Contrary to Agbohessi *et al.* (2011) results, which showed that 67 % of farmers purchased pesticides from formal sector in Banikoara, this study revealed that only 17 % of surveyed farmers got pesticide from authorized shop. Thus, 83 % of the farmers purchased pesticides in both illegal markets and/or in authorized shop. According to Agbohessi *et al.* (2011), any control was performed about pesticides sold in informal sector from cross-border trading (Togo, Nigeria, Ghana, etc.). These products could be store in bad conditions and are more cheaper than official pesticides. Thus, farmers accessed easily to these prohibited and smuggled products. This situation justify the presence of some pesticides that active ingredient was not authorized. For example, Atra force, Buster and Buta force contained Atrazine and Butachlor that were not authorized to be used in Benin (CNAC, 2014, *Unpublished*). This Beninese situation is similar to that of Ethiopia where direct import of pesticides outside of legal chain was observed (Negatu *et al.,* 2016).

Despite of the banning of endosulfan use in Benin since 2007 (Badarou and Coppieters, 2009), this pesticide was using in Banikoara three years after the deadline (December 2008) (Agbohessi *et al.*, 2011). Fortunately, this study did not show any endosulfan product. This happy situation was not similar to that of Ethiopia where illegitimate usages of DDT and endosulfan on food crops continued until 2016 (Negatu *et al.*, 2016).

Moreover, the difference between percentages of farmers helped by the technician from the different communes could be justified by an unequal distribution of the technicians in these municipalities.

Farmer group according to risky practices

The typology of the farmers in North-East Benin as established in this study allowed characterizing two categories of farmers. Cluster 1 was the high-risk class and mostly composed of farmers from Banikoara and Kandi districts in the Department of Alibori, while the lower-risk classes (clusters 2 and 3) were mostly composed of farmers from Bembèrèkè and Kalalé districts in the Department of Borgou. Thus, the Departments were strongly liked to the risky practices of the use of the pesticide products. In fact, Alibori is the first Department of cotton production in Benin. The limited number of the agricultural technician in this locality did not allow covering the most of these cotton farmers who largely used pesticides from several illegal sources. However, concerning the common modalities (Table 9), it is important to recall that none of the three farmer classes displays the minimum conditions for ensuring a healthy environment for food safety.

All these observations support the hypothesis that the pesticide sector in Benin should be reorganized with enhanced measures of control and follow recommended practices. Based on these observations, it is necessary to study the prevalence of pesticide residues in foods in generally and particularly in foods from livestock animals. Finally, the reinforcement of the legislation on pesticide practices is essential for the well-being of animals and animal food consumers.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing of this article.

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