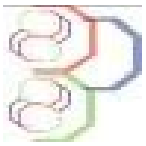

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Farmers'perceptions on the pineapple mealybug [*Dysmicoccus brevipes* (Cockerell) (Homoptera: Pseudococcidae)] and control methods in Benin

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ABSTRACT

Objectives: This study aimed at evaluating the perceptions of farmers on the pineapple mealybug, the different control methods adopted against the pest and the socio-cultural factors that influence these perceptions.

Methodology and Results: A survey was conducted among 180 pineapple producers using a semi-structured questionnaire in five main pineapple production areas in Benin. Binomial regression and Factorial Correspondence Analysis (FCA) were performed to determine the sociocultural factors that influence farmers' knowledge on the pineapple mealybug. Fifty eight percent of farmers perceived mealybug as pineapple insect pest while 22.22% reported the insect as the MWP disease vector. Experience in Pineapple production and participation in training determined the knowledge of farmers on the mealybug as important pineapple insect pest and as MWP disease vectors. Only trained farmers used to apply control methods.

Conclusions and application of findings: This study shows that it is the trained producers who have a better knowledge of the mealybug and adopt some control methods. It is therefore an emergency that training seminars be organized for a large number of producers followed by supervision in sight of making them qualified to better control the proliferation of mealybug and limit the spread of wilt disease.

Key words: Farmers 'perceptions, pineapple mealybug, control methods, Benin

INTRODUCTION

Agriculture is the predominant sector in Benin contributing to 39% of the gross domestic product (GDP) and 90% of the exports (Sossa, 2014). For several years, cotton was the main cash crop providing more than 70% of the country's export earnings. The cotton sector has experienced serious crisis due to the decline in production. This situation has led to an extension of national agricultural priorities to other crops including pineapple (*Ananas comosus* L. Merrill*)*, which became a product with high potential for export (Sossa, 2014). Pineapple production is primarily concentrated in the Atlantic department in the Southern part of Benin. Previous studies conducted in Benin showed that the pineapple industry contributes to 1.2% to the Gross Domestic Product (GDP) and to the reduction of unemployment. However, pineapple production is hindered by several constraints such as poor soil fertility, irregularity of rainfall and pest pressure. Mealybugs and the Mealybug Wilt of Pineapple (MWP) disease are the dominant pest and the most important disease of pineapple in Benin respectively (Fanou and Adikan, 2008). MWP disease can cause losses ranging from 30 to 35% of the production (Sether *et al*., 2001). The disease symptoms start by the reddening of the leaves which become red or pink, and the edge of the leaves curl down. Thereafter, the leaves lose their turgor and fall down from the plant (Carter, 1945). MWP disease is expressed by the concomitant action of the mealybug *Dysmicoccus* spp. and the Pineapple Mealybug Wilt Virus (PMWaV) which includes five forms (Gambley *et al*., 2008). Two mealybug species namely *D. brevipes* and *D. neobrevipes* are known to be the most important insect pests of pineapple in the world (Jahn *et al.,* 2003). Several control methods have been developed to control the mealybug. Cultural control method consists of limiting ants' population instead of a direct control against the mealybugs because the presence of scales is associated with ants which play a major role in the dissemination of mealybugs. (González-Hernández et *al*., 1999). Chemical control is applied through the use of insecticides and Biological control using parasitoids and predators has also been reported (González-Hernández *et al*., 1999). Socio-cultural factors may affect practices of farmers. Support from researchers, trainers and agricultural services, influences the decision of farmers to accept new technologies (Lowoga *et al*. 2011). Farmers are often responsive to the knowledge they receive from trainings and this can result in change of how they handle their cultural practices and/or adoption of new technologies (Nyantika and Aming'a, 2015). Fawole (2008) reported that in Nigeria, farmers use several sources of information to improve their knowledge and agricultural practices. The development of control programs against a pest requires the participatory involvement of farmers to take into account their socio-economic realities. In Benin, however knowledge of farmers on the pineapple mealybug and the associated control methods is less documented. In addition, little is known on the socio-cultural factors that influence farmers' knowledge about the insect at country level. It is therefore important to conduct surveys on this aspect in order to strengthen knowledge of Benin's farmers and guide them to implement effective pest management strategies to control pineapple mealybug. Therefore, this study aimed at (i): collecting farmers' perceptions on the pineapple mealybug; (ii) documenting the different control methods implemented by farmers in management of the pineapple mealybug and (iii): identifying the socio-cultural factors that determine their knowledge.

MATERIAL AND METHODS

Study area: The study was conducted in five municipalities (Allada, Abomey-Calavi, Toffo, Tori and Zè) located in the Atlantic department in Southern Benin (Figure 1). This area covers about 3 233 Km^2 and includes 500 villages and eight municipalities. The pedoclimatic conditions are suitable to the production of pineapple and most of pineapple producers are located in the five selected municipalities. The landscape is

composed of semi-deciduous, savannas, filled forests, meadows, fallow land and fields. The climate is of sub-equatorial type (Akoegninou *et al*., 2006). Annual rainfall ranges from 950 to 1400 mm and the soil is ferralitic. The mean annual temperature is 26 °C (± 2.5).

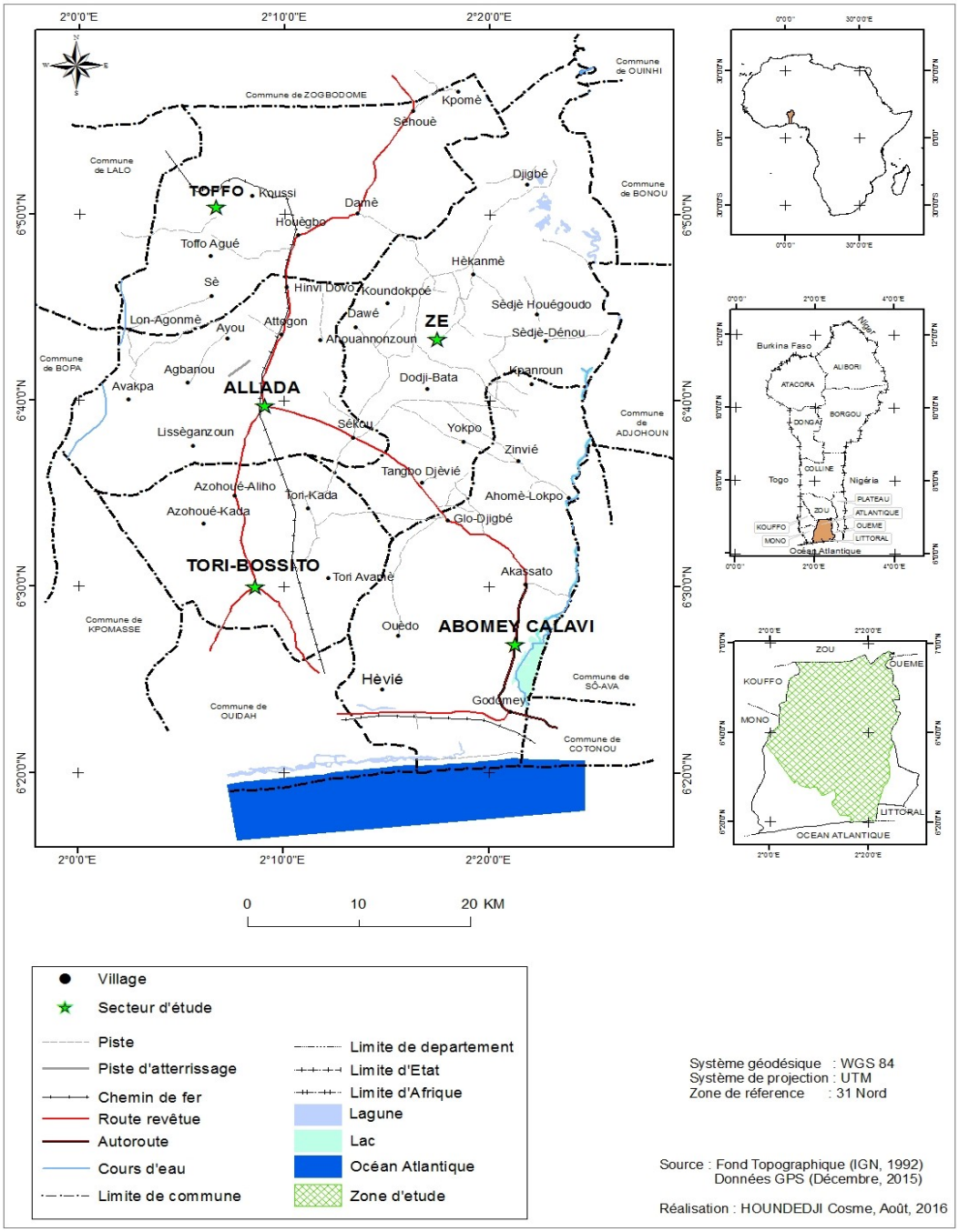

Figure 1: Map of Atlantic department showing the study area

Methods

Sampling and data collection: A survey was conducted across five municipalities (Allada, Abomey-Calavi, Toffo, Tori and Zè) between October and November 2015. Farmers were selected based on three main criteria: i) farmers having at least three years of experience in pineapple production, ii) farmers owning a pineapple field, iii) the size of field area ≥ 0. 5 ha. In each location, a focus group was conducted to identify pineapple producers and to collect information

about the different aspects under investigation. Afterwards, a list of specific semi-structured questions was individually addressed to farmers who were randomly selected. Data were collected on characteristics of the farmers (sex, level of education, experience (years) in pineapple production, the variety(ies) produced, participation in at least one training), knowledge on mealybug as insect pest, knowledge on mealybug as vector of the pineapple disease, causes of the presence and spread of mealybug in pineapple fields, the infested plant parts, susceptible varieties to the mealybug infestation, different control methods implemented against the pests and their effectiveness. To enable farmers to recognize the mealybug, we collected berries infested by mealybugs which were placed in bottles and showed during the interviews. Overall, 180 farmers from 57 villages in the municipalities were interviewed (40 in Allada, 30 in Abomey-Calavi, 31 in Toffo, 39 in Tori-Bossito, and 40 in Zè). The sample size (N) was obtained by using the normal approximation to the binomial distribution, as proposed by Dagnelie (1998):

$$N = [(U_1 - \alpha/2)^2 \times p(1-p)]/d^2$$

With: p (86.45%) determined from the exploratory survey as the proportion of persons who fit with the three criteria and the margin of error estimation, at 5% threshold in this study. U1 - α/2 = 1.96, represents the value of the normal random variable for a risk α equal to 0.05.

Statistical analysis: Data collected were submitted to descriptive statistics analysis (mean, frequency) in order to categorize farmers.

Socio-cultural characteristics determining knowledge of mealybug as pest and vector of the Pineapple Mealybug Wilt disease: Binary logistic regression analysis (Crawley, 2007) was performed in R software version 3.2.4 considering knowledge of mealybug as insect pest pineapple and knowledge of mealybug as vector of the Mealybug Wilt of Pineapple (MWP) disease as dependent variables, and municipality, sex, level of education, number of years of experience in pineapple production, and participation in training as independent variables. Effect of farmers' sociocultural characteristics on identification of the mealybug as insect pest and mealybug as vector of the Mealybug Wilt of Pineapple (MWP) disease was assessed. The probabilities to predict farmers' knowledge about mealybug as insect pest of pineapple and knowledge of mealybug as a vector of the Mealybug Wilt of Pineapple (MWP) disease were estimated and the trend lines scalable and illustrative bar graphs were drawn.

Sociocultural characteristics influencing control methods used by farmers against the pineapple mealybug: Factors that influence the implementation of control methods developed by farmers against mealybug were analyzed. Local perceptions and practices are generally dependent upon the socio-cultural groups that differed from one area to another one). Hence, farmers were grouped based on two sociocultural characteristics i.e. the municipality and participation in training on the recognition of the pineapple mealybug as insect pest to the crop and mealybug as vector of the Mealybug Wilt of Pineapple (MWP) disease. Ten socio-cultural groups were identified, and for each of them, the frequency of farmers who have adopted each of the identified control method was computed. Thereafter, a contingency table was drawn with the ten socio-cultural groups placed in the rows and the control methods in the columns. The output was submitted to simple correspondence factorial analysis (FCA) in R software version 3.2.4 to describe the relationships between the socio-cultural groups and the pineapple mealybug control methods.

RESULTS

Socio-cultural characteristics of farmers: The sociocultural characteristics of the interviewed farmers across the different municipalities are presented in Table 1. It revealed that pineapple production is mostly practiced by men. Farmers were in majority illiterate (57.6%) whilst 28.9% and 18.3% of them have attended primary school and secondary school education level respectively. Regarding experience in pineapple production, farmers from the municipality of Toffo were the most experienced with an average of 12.5 years while farmers with the lowest years of experience were observed in the municipality of Tori. Two varieties of pineapple, Smooth Cayenne and Sugarloaf were cultivated by most of farmers across the surveyed areas with Sugarloaf grown by all surveyed farmers. However, in the municipality of Toffo, all respondent farmers produced the Smooth Cayenne though 77.4% of them produced also Sugarloaf. Most of the farmers interviewed did not participate in training on the pineapple pest (78.3%), except at Toffo where 51.61% of farmers participated in trainings.

Table 1: Socio-cultural characteristics of the farmers across municipalities Provide informative table captions

Farmers profile	Frequency of farmers (%)					
Variables	Abomey-Calavi	Allada	Toffo	Tori	Zè	Five Municipalities
Level of education						
Not educated	43.3	55	25.8	66.7	87.5	57.8
Primary	33.3	32.5	38.7	15.4	5	28.9
Secondary	23.3	12.5	35.5	17.9	7.5	18.3
Sex						
Male	100	97.5	100	100	97.5	98.9
Female	0	2.5	0	0	2.5	1.1
Varieties produced						
Sugarloaf	100	100	77.4	100	97.5	95.6
Smooth Cayenne	40	55	100	12.5	62.5	52.8
Participation in training						
Participants	13.3	12.5	51.6	12.8	22.5	21.7
Non-participants	86.7	87.5	48.4	87.2	77.5	78.3
Experience in culture						
Number of years	10.3 ± 7.1	11.0 ± 5.5	12.3 ± 6.9	8.7 ± 4.6	11.2 ± 6.5	10.7 ± 6.1

Farmers' perceptions on the pineapple mealybug: Most of the farmers in the surveyed municipalities recognized mealybug as pineapple's insect pest (Table 2). But not all of them really appreciated the detrimental effect of the pest in pineapple production. About 83.3% considered mealybug as insect pest for pineapple in the municipality of Abomey-Calavi, which is the highest proportion compared to the other municipalities (Table 2). Only 22.2% of farmers know the role of this insect in the transmission of the virus responsible for the pineapple disease. Thirty eight percent of farmers from the municipality of Toffo have a better understanding of the role of mealybug in the dissemination of the disease (Table 2). Indeed, damages of the mealybug differed among the plant parts and were greater on the pineapple fruit than on the leaves, stem and roots. Farmers do not have the same application about the most infested pineapple variety. About 44.44% of farmers perceived sugarloaf as the most susceptible variety to mealybug while some of them have pointed out the variety smooth cayenne as the most infested. The remaining proportion indicated that either the infestation rate of the two varieties was the same or had no idea on the infestation rate of the two varieties. Perceptions on this aspect varied between municipalities with 66.7%, 45% and 79.5% of farmers in the municipalities of Abomey-Calavi, Allada and Tori, respectively, who have reported Sugarloaf as the most attacked variety by the pest while smooth cayenne variety has been pointed out as susceptible variety in Toffo and Zè, (Table 2).

Farmers' perceptions on the causes of mealybug spreading: Farmers' perceptions on the causes of spreading of mealybug in the pineapple fields are diverse. Seven factors were identified to be involved in this mechanism (Table 2). About thirty six percent (36.1%) of farmers identified the abundance of weeds in the fields as the most important cause that facilitates the infestation and spreading of mealybug in pineapple fields. With decreasing percentage, propagules of pineapple, ants, and dry season are others factors which influence more the infestation rate. Among municipalities, farmers' perceptions on the contribution of these factors to the proliferation of the mealybug differed. The presence of weeds is thought to be the main cause observed of mealybug' dissemination at Toffo as well as at Tori and Allada. However, the dry season is perceived as a main cause that increases the proliferation of mealybug in Abomey-Calavi and Toffo fields whereas the presence of weeds and ants are main causes of the disease spread at Zè.

Table 2: Farmers perceptions in the different municipalities

Variables	Frequencies of farmers (%)					
	Abomey-Calavi	Allada	Toffo	Tori	Zè	All five municipalities
Knowledge of the mealybug						
Insect pest	83.3	52.5	58.6	61.5	37.5	58.3
Vector MWP disease	16.7	15	38.7	17.9	25	22.2
Parts of the plant						
Leaves	16.7	32.5	25.8	10.3	30	23.3
Stem	10	12.5	3.2	17.9	12.5	16.7
Fruit	100	90	90.3	94.9	92.5	93.3
Root	3.3	2.5	22.1	2.6	2.5	6.1
Susceptible variety to mealybug						
No knowledge	3.3	17.5	3.2	7.7	15	6.7
Smooth Cayenne	30	32.5	74.2	12.8	65	42.2
Sugarloaf	66.7	45	16.1	79.5	15	44.4
Two varieties	0	5	6.6	0	5	3.3
Causes						
No knowledge	70	47.5	19.4	35.9	80	36.1
Weeds	10	27.5	70.9	61.5	12.5	36.1
Pineapple rejections	3.3	10	16.1	15.4	2.5	9.4
Ants	0	7.5	9.7	0	12.5	6.1
Dry season	16.6	10	16.1	0	5	8.3
Rainy season	0	2.5	6.6	0	0	1.6
Association papaya	6.6	0	0	0	0	1.1
Association cassava	3.3	0	3.2	0	0	1.1
Control methods						
No knowledge	96.7	85	61.3	89.7	92.5	85.9
HabillRj	0	2.5	6.5	0	5	2.7
SolutionIn	0	5	9.7	0	0	2.7
Luttchimi	0	2.5	19.4	0	5	5
SarclgEspR	3.3	7.5	12.9	12.8	0	7.2
Assoc	0	0	9.7	0	0	1.7

Effectiveness of the different methods used by farmers in the management of pineapple mealybug disease: Five different control methods are used by the farmers against the pineapple mealybug disease. These include dressing of pineapple's propagules, chemical control by the disinfection of pineapple's propagules, chemical control of pineapple fields, regular weeding, spacing of plants, and intercropping system. About 80% of the farmers reported that the dressing of pineapple's propagules is an effective method in controlling the disease (Figure 2). Regular weeding and spacing of the pineapple plants were practiced by farmers among which 53.8% believed that it is effective.

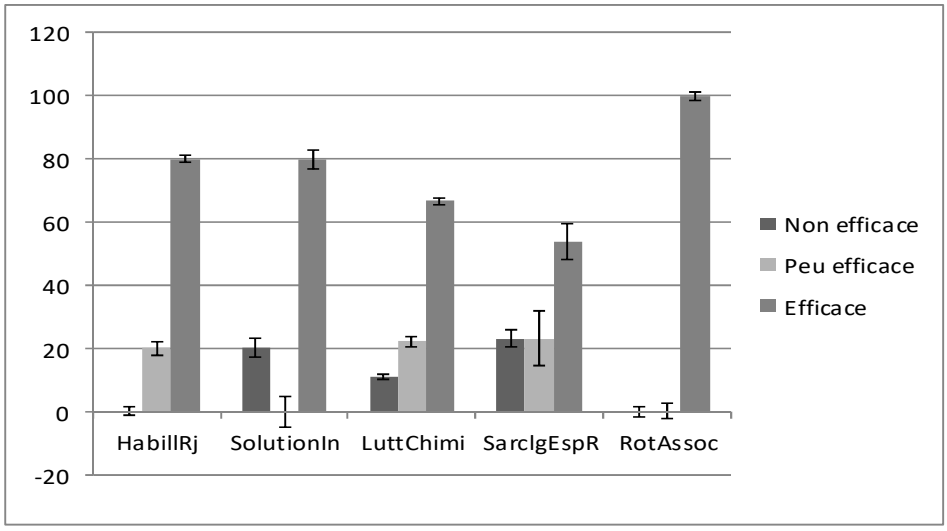

Figure 2: Farmers perceptions on the effectiveness of different control methods used against pineapple mealybugs.
Legend. ***HabillRj*** = dressing of pineapple's propagules; ***SolutionIn*** = disinfection of pineapple's propagules by insecticide-based solutions; ***LuttChimi*** = chemical control in the fields; ***SarclgEspR*** = regular weeding and plant spacing; ***Assoc***= crops association

Intercropping has been identified by only 9.7% of farmers in Toffo. According to these farmers intercropping pineapple with other crops including cowpea, or soybean could reduce the population of mealybug. Though chemical treatment of pineapple seedlings with insecticides before planting is not a common practice used by farmers, 80% of those who applied this perceived it as an effective method. This method is mostly practiced in Allada and Toffo. Five percent of the surveyed farmers used chemical control in field. This practice is most commonly used in Toffo than Allada and Zè. The insecticide used is dimethoate. In fact, it is used not only against mealybugs, but also against ants. Among the products used, 66.7% of farmers reported that the dimethoathe is effective.

Socio-cultural factors determining farmer knowledge on pineapple mealybug as insect pest and vector of the Mealybug Wilt of Pineapple (MWP) disease: Municipality, number of years of experience in pineapple production and participation in training significantly influenced ($P < 0.05$) knowledge of farmers on mealybug as pineapple insect pest and vector for the MWP disease. Furthermore, farmers in the municipalities of Allada, Tori, Zè and Toffo identified more frequently mealybug as pineapple insect and vector of the disease than farmers in Abomey-Calavi (Table 3). In regard to farmers experience in pineapple production, an increase in year multiplied by 1.037 enhance the chance of identifying mealybug as insect pest of pineapple while an increase in the year multiplied by 0.974 enhance farmers' ability to identify mealybug as the MWP disease vector. Trained farmers were able to identify the mealybug as insect pest of pineapple and vector of the MWP. The predictive probability that a producer identifies the mealybug as insect pest of pineapple or vector for the Mealybug Wilt of Pineapple (MWP) disease based on the number of years of experience in pineapple production is presented in Figure 3. Results showed that the locality of a particular producer, the number of years of experience in pineapple production are positively correlated ($P < 0.05$) with the identification of the mealybug of pineapple, except farmers from Abomey-Calavi and Allada (Figure 3.a). Regarding the identification of mealybug as a vector of the MWP disease, it is positively correlated with the number of years of experience in pineapple production, mainly in Toffo and Tori (Figure 3.b). It appears from Figure 4 that farmers who benefited from training, even once, are more able to identify mealybug as pest and vector of the MWP disease. In addition, participation in training was found to influence the ability of famers to identify mealybug as insect pest of pineapple and vector of the MWP disease.

Table 3: Effect of socio-cultural characteristics on farmers knowledge about pineapple mealybug as insect pest and vector of the Mealybug Wilt of Pineapple (MWP) disease: overall result of binary logistic regression

Sources of variation	Df	Insect pest		Vector of MWP	
		Deviance	Pr (Chi)	Deviance	Pr (>Chi)
Municipality	4	16.319	0.003	11.735	0.019
Experience in production	1	8.521	0.004	7.229	0.007
Training	1	59.358	0.000	111.643	0.000

Only significant value have been presented (P<0.05)

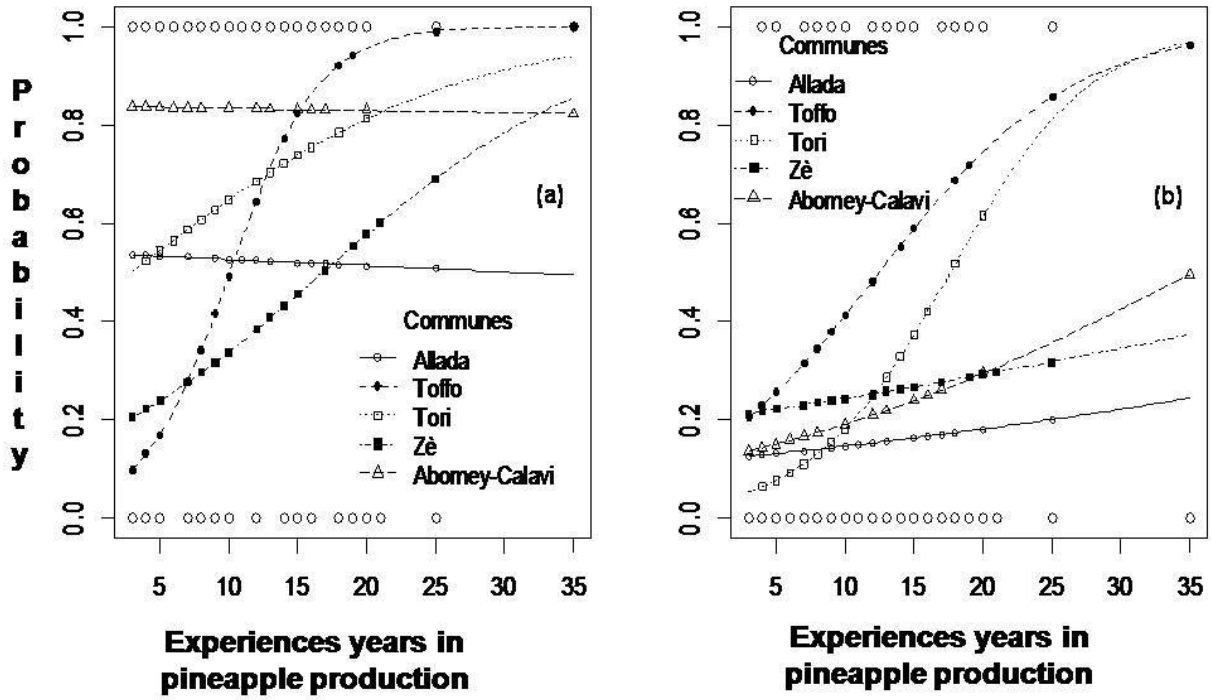

Figure 3: Predictive probability of identification of (a) mealybug as insect pest of pineapple; and (b) vector of the Mealybug Wilt of Pineapple (MWP) disease in relation to experience in pineapple production at each municipality

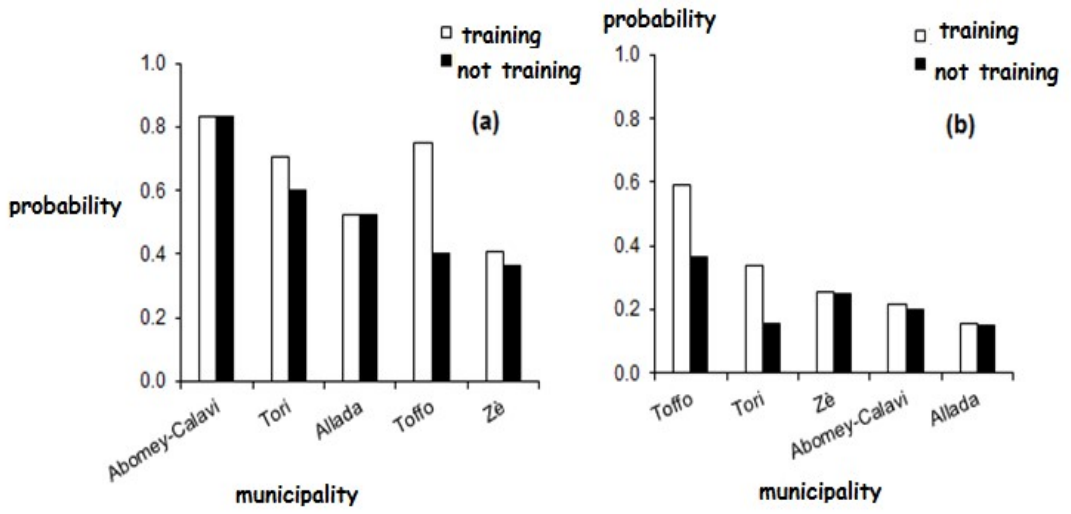

Figure 4: Predictive probability of identifying (a) the mealybug as insect pest of pineapple; and (b) as vector of the Mealybug Wilt of Pineapple (MWP) disease on the basis of participation in a previous training on pineapple production

Socio-cultural characteristics influencing control methods developed by farmers against mealybug: Results from the simple Factorial Correspondence Analysis (AFC) indicated that the first two axes concentrated 92.6% of the decisional information, which is sufficient to ensure an accuracy of interpretation. The categories of farmers and the control methods were projected in factorial axes system (Figure 5). The biplot shows that on axis 1, farmers of the municipality of Toffo who were trained on pineapple production techniques, adopted crops association, chemical control and disinfection of pineapple's propagules against the mealybug. They are opposed to the untrained farmers who did not adopt any control method, and the trained farmers of Zè and Allada. In regard to the axis 2, it opposed farmers of Zè who have been trained and adopted the wrapping of discharges and the trained farmers of Allada who adopted weeding and plants spacing as techniques to control the mealybug.

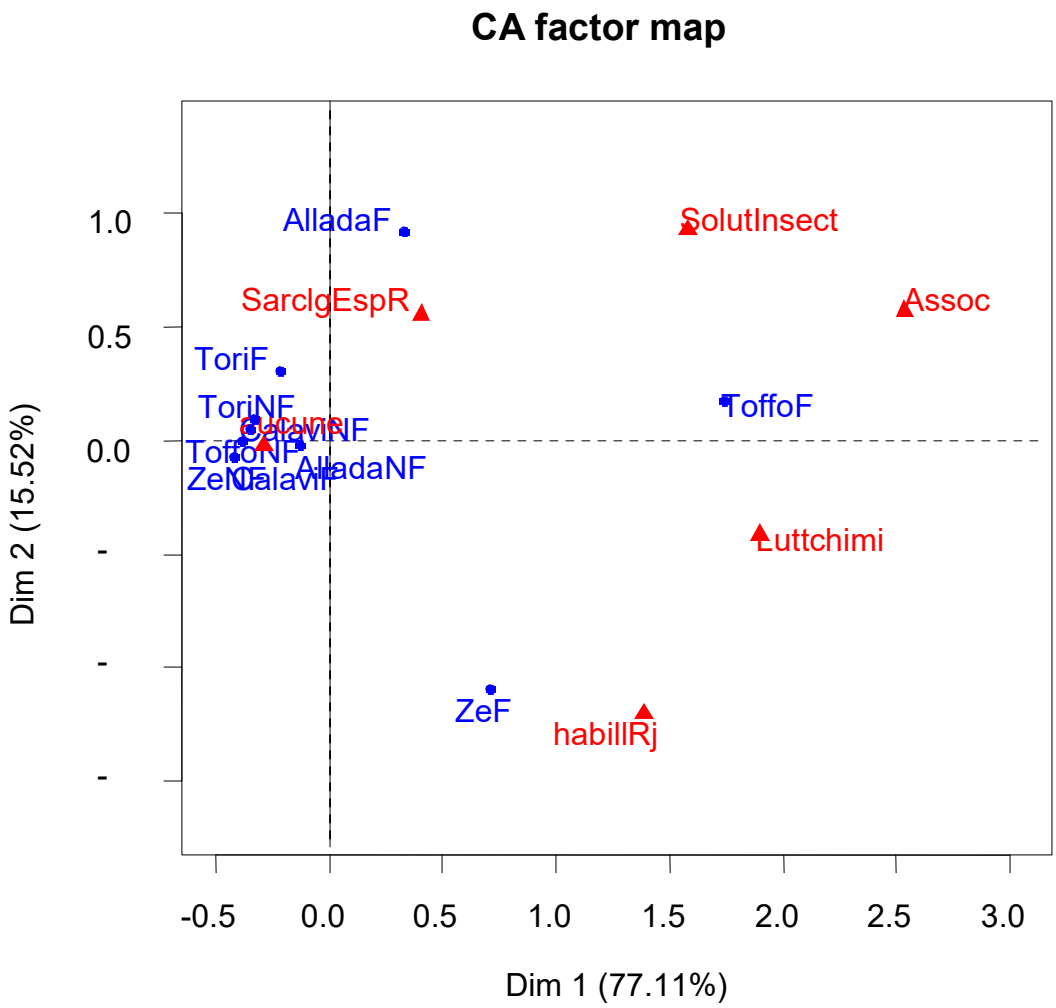

Figure 5: Biplot showing relationship between famers' characteristics and the methods they use in controlling the mealybug across five municipalities in Benin. **Legend**. ***F***: Farmers trained; ***NF***: Farmers not trained; ***HabilIRj*** =dressing of pineapple's propagules; ***SolutionIn*** = disinfection of pineapple's propagules by insecticide-based solutions; ***LuttChimi*** = chemical control in the fields; ***SarclgEspR*** = regular weeding and plant spacing; ***Assoc*** = crops association

DISCUSSION

The current study analyzed the perceptions of farmers on the pineapple's mealybug, as pest or vector of the Mealybug Wilt of Pineapple (MWP) disease. The results revealed that farmers' perceptions on the pineapple mealybug are influenced by three socio-cultural factors namely municipality, number of years of experience in pineapple production and participation of farmers in a training on pineapple production. Indeed, farmers' perceptions considering the mealybug as detrimental for pineapple and vectors of the wilt disease within the same municipality is homogeneous but varies from one municipality to another. This could be explained by the fact that the training of groups of pineapple producers and sharing information is in line with local but deferred other. These results are consistent with the findings of Brandt *et al*. (2013) who reported that the geographic position influence the ethnobotanical knowledge. Furthermore, farmers were able to recognize the mealybug as insect pest of pineapple and vector of the MWP disease. Fanou and Adikan (2008) also reported the mealybug as the most important pest of pineapple in Benin. Meanwhile, farmers attributed the vulnerability of pineapple production to mealybug to the high susceptibility of pineapple variety "Smooth cayenne", the most widely grown variety across the surveyed areas. However, Fanou and Adikan (2008) found that

the mealybug is more subservient to the smooth cayenne variety. Farmers in the surveyed municipalities perceived the abundance of weeds in the fields, and ants as factors that can increase the infestation of pineapples by mealybug. This can be explained by the fact that mealybug's presence is associated with the presence of ants which are determinant in the dissemination of the mealybug. Thus, ants protect mealybugs from their natural enemies (predators and parasites) and facilitate their dissemination by transporting them from plant to plant, which in return benefit from honeydew produced by the mealybugs (González-Hernández *et al*., 1999). Dry season is also one of the factors reported by farmers as cause of mealybug proliferation (Jurie *et al*., 2001, Akintola *et al.,* 2013; Fanou *et al.,* 2014). Weeds are also host plants for mealybug and therefore contribute to the survival and spread of the MWP disease (Pandey and Johnson, 2006). This study revealed that farmers developed some methods to control mealybug, including the chemical sanitation of the pineapple's propagules, chemical control in fields, regular weeding and the spacing of plants. This was particularly observed in the municipality of Toffo where farmers adopt almost all control measures identified. This could be due to the long period of cultivation of smooth cayenne, a high susceptible variety, which has somehow constrained Toffo's farmers to try all possible control measures to address this challenge. Furthermore, participation in training strengthens the knowledge of farmers on the pineapple mealybug. It was recorded that only farmers who were trained applied control methods against the pineapple mealybug. This corroborates the results of Lowoga *et al.* (2011) who highlighted that support from researchers, trainers and agricultural services influence the farmers' decision to accept new knowledge in relation to their specific needs. This conception is in line with the conclusions of several authors according to which farmers are motivated to apply new technologies or advices received from agricultural trainers to improve their practice (Nyantika and Aming'a, 2015; Lowoga *et al*., 2011; Fawole, 2008) Chemical control in the fields and disinfection of pineapple propagules are control methods practiced by farmers in Benin, using dimethoate which is effective against the mealybug and ants. In line with this, Jahn *et al*. (2003) found that farmers use Malathion and diazinon to control mealybugs, vector of MWP disease in the Hawaiian Islands. However, chemical control alone may not help to completely eliminate the population of mealybugs, and regular weeding was revealed as the current control method applied in all municipalities. The adoption of this method is justified by the fact that weeds are a source of proliferation of mealybug and therefore their elimination may significantly reduce the population of mealybugs. Overall, this study shows that farmers perceive the mealybug as insect pest of pineapple and vector of the wilt disease affecting pineapple production in Benin. These perceptions and knowledge on the mealybug, its resulting disease, and the control methods developed by farmers during their daily pineapple production activity are determined by the sociocultural characteristics, the number of years of experience in pineapple production and participation in a previous training. This underlines thus the need of multiplying outreach actions to inform and train farmers on the effective management strategies to control the mealybug population and limit the losses induced by the wilt disease in pineapple production in Benin.

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REFERENCES

Akintola AJ, Oyegoke OO, Ikusebiala IM, 2013. Morphometry and preffered feeding site of Egyptian mealybug (*Icerya aegyptiaca* Douglas) on croton *Codiaeu variegatum* plant. International Journal of Applied Agricultural Research 9: 189-195.

Akoegninou A, Van Derburg WJ, Van Der Maesen LJG, 2006. Flore Analytique du Bénin. Backhuys Publishers, Wageningen; 1034 p.

Brandt R, Mathez-Stiefel SL, Lachmuth S, Hensen I, Rist S, 2013. Journal of Ethnobiology and Ethnomedicine, 9), 14 p.

Carter W, 1945. Some etiological aspects of mealybug wilt. Phytopathology 35: 305–315.

Carter W, 1967. Insects and related pests of pineapple in Hawaii: a manual for field men. Pineapple Research Institute of Hawaii. Honolulu, Hawaii

Crawley MJ, 2007. The R Book. Chichester, U.K.: John Wiley and Sons, Ltd.

Dagnelie P, 1998. Statistique théorique et appliquée, Tome 2: Inférences statistiques à une et à deux dimensions. De Boeck et Larcier, Paris-Bruxelles, , 659 p.

Fanou A, Adikan B, 2008. Etude de l'importance et de la distribution des ravageurs et maladies d'ananas dans le département de l'Atlantique dans la perspective d'élaborer des méthodes de la lutte intégrée. In Promotion des Filières Agricoles Porteuses, Adjanohoun A, Igue K (eds). Actes de l'Atelier Scientifique National. Tenu à Abomey-Calavi, 19-22 Décembre 2006.1: 146-158.

Fanou A, Baïmey H, Zandjanakou-Tachin M, Lawouin L, 2014. Efficacité d'extraits botaniques et de Cydim Super dans la lutte contre la cochenille (*Dysmicoccus brevipes*) associée à la maladie du wilt chez l'ananas. International Journal of Biological and Chemical Sciences 8: 2007-2014.

Fawole OP, 2008. "Pineapple farmers' information sources and usage in Nigeria", Bulgarian Journal of Agricultural Science14: 381-389.

Gambley CF, Steele V, Geering ADW, Thomas JE, 2008. The genetic diversity of ampeloviruses in Australian pineapples and their association with mealybug wilt disease. Australasian Plant Pathology 37:95-105.

González-Hernández H, Reimer NJ, Johnson MW, 1999. Survey of the natural enemies of *Dysmicoccus mealybugs* on pineapple in Hawaii. BioControl 44: 47–58.

Illingworth JF, 1931. Preliminary report on evidence that mealybugs are an important factor in pineapple wilt. Journal of Economic Entomology, 24: 877-889.

Jahn GC, Beardsley JW, Gonzalez- Hermandez H, 2003. A Review of the Association of Ants with Mealybug Wilt Disease of Pineapple. Proceedings of Hawaiian Entomological Society 36: 9-28.

Jahn GC, 1995. Gray pineapple mealybugs, *Dysmicoccus neobrevipes* Beardsley (Homoptera: Pseudococcidae), inside closed pineapple blossom cups. Proceedingsof Hawaiin Entomological. Society 32: 147–148.

Jurie I, Jeremy DH, Harry M, 2001. Effects of weather and phenology on the abundance and diversity of geometroid moths in a natural Malaysian tropical rainforest. Journal of Tropical Ecology 17:411- 429.

Lwoga ET, Stilwell C, Ngulube P, 2011. Access and use of agricultural information and knowledge in Tanzania. Library Review 60: 383-39.

Nyantika MM, Aming'a NN, 2015. Effect of education attainment and previous training on farm practices among pineapple farmer in tree Barangays in Philippines. Asian journal of agricultural extension, economics and Sociology 5: 192-201.

Pandey RR, Johnson MW, 2006. Weeds Adjacent to Hawaiian Pineapple Plantings Harboring Pink Pineapple Mealybugs. Environmental Entomology 35: 68-74.

Sether DM, Karasev AV, Okumura C, Arakawa C, Zee F, Kislan MM, Busto, JL, Hu JS, 2001. Differentiation, distribution, and elimination of two different Pineapple mealybug wilt-associated viruses Found in Pineapple. Plant Disease. 85: 856-864.

Sossa EL, Amadji GL, Vissoh PV, Hounsou BM, Agbossou KE, Hounhouigan DJ, 2014. Caractérisation des systèmes de culture d'ananas (*Ananas comosus* (L.) Merrill) sur le plateau d'Allada au Sud-Bénin. International Journal of Biological and Chemical Sciences. 8: 1030-1038.

Togbe CE, Zannou ET, Vodouhê SD, Haagsma R, Gbèhounou G, Kossou DK, Vanhuis A, 2012. Technical and institutional constraints of a cotton pest management strategy in Benin. NJAS-Wageningen Journal of Life Sciences 60-63: 67-78.