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RESEARCH ARTICLE

ANALYSIS OF ASPECTS OF THE CONVENTIONAL AND ORGANIC COCOA PRODUCTION SYSTEM AND PRODUCERS' PERCEPTION OF THE USE OF BOTANICAL PESTICIDES FOR THE MANAGEMENT OF COCOA MIRIDS IN TOGO

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Abstract

Cocoa mirids are the main insect pests of the crop in Togo. In order to contribute to a sustainable management of these pests, the present study aimed at analyzing some aspects of the cocoa production system in conventional and organic farming and evaluating the perception of producers on the use of botanical pesticides as a means of control. Thus, a survey questionnaire was administered to 178 producers, including 96 conventional cocoa producers and 82 organic cocoa producers. The producers surveyed occured in 27 villages in the prefectures of Agou, Akébou, Kloto and Wawa. The results showed that about 98% of conventional cocoa farmers and 100% of organic cocoa farmers mentioned mirids as major pests of the crop. The average infestation rate of the plantations was estimated at 40.79 ± 25.72% in conventional cocoa production and 44.93 ± 26.92% in organic cocoa production. The related average losses are respectively 13.09 ± 8.58% and 17.39 ± 10.93% in conventional and organic cocoa production. As a means of control, 98.93% of producers in conventional cocoa production versus 65.06% in organic cocoa production use at least one insecticide. Three (3) classes of chemical insecticides are used in conventional cocoa production: Neonicotinoids (48.15%), pyrethrinoids (41.66%) and organophosphates (10.18%). In organic cocoa production, *Azadirachtaindica* is the plant most used for mirid control. 31.71% of producers use Neem oil against 17.05% and 15.85% who use its leaves and seeds respectively. Regarding producer adherence, 81.96% of conventional and 91.46% of organic cocoa farmers believe that local plant-based bioinsecticides can help to control cocoa mirids; 68.75% and 71.95% of these two respective groups are willing to use them if they are effective and affordable.

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Introduction:-

Cocoa production is a key subsector in the growth and economic development of several West African countries. In Togo, cocoa is an important source of income (DSID, 2018). It ranks third among agricultural exports after cotton and coffee (Koudjega and Tossah, 2009). However, cocoa farming is subject to many abiotic and biotic constraints. Among the biotic constraints are insect pests, the most dangerous of which are the cocoa mirids that cause enormous damage leading to the deformation of pods and beans, the drying of young branches and eventually the death of some plants (Kouakou et al., 2011).

Classically, farmers mainly use synthetic chemicals to protect their plantations (ITRA, 2016). However, the abusive use of these products induces genetic resistance in mirids as a result of mutations transmitted to their descendants, causing the loss of biodiversity with consequences for human, animal and environmental health (Hoyer et al., 2002). Being toxic and harmful to farmers, these chemical pesticides are not suitable for organic agriculture, they are the subject of much debate (Samuel and Saint Laurent, 2001). In view of the many adverse consequences of these chemicals, it is essential to find alternative methods for effective management of cocoa mirids. Plant-based bio-pesticides have the advantage of being environmentally friendly, biodegradable, and generally less hazardous to human health (Mboussi et al., 2018). The use of plant-based bioinsecticides could avoid health problems (headache, nausea, respiratory disorders and other forms of severe poisoning) in users, animals and also protect the environment (Mnif et al., 2011).

The objective of this study is to contribute to the sustainable management of cocoa mirids in Togo through (i) the analysis of the cocoa production system in conventional and organic farming and (ii) the evaluation of producers' perceptions of the use of botanical pesticides.

Materials And Methods:-

The study was conducted in the eco-floristic zone IV located in the southwest of Togo. ITRA (2009), in subdividing Togo into different agroecological zones, classified eco-floristic zone IV as an agroecological forest zone. This is the cocoa producing zone in Togo. It has a tropical Guinean climate, characterized by two rainy seasons (April-July and September-October) and two dry seasons (November-March and August) and annual rainfall varying between 900 and 1600 mm. The average monthly temperature varies from 25 to 29 °C during the year and average altitude varies from 300 to 900 m. This area is the most important potential forest environment in Togo (Oro, 2011).

The prefectures of Agou, Akébou, Kloto and Wawa were selected for the study (Figure 1). The choice of these four prefectures was guided by the fact that they represent the largest cocoa producing prefectures in Togo. The survey took place in 27 villages spread among the four prefectures (Figure 1). A total of 178 cocoa farmers, including 82 organic cocoa farmers and 96 conventional cocoa farmers were surveyed. The number of villages as well as the number of producers surveyed per prefecture were selected on the basis of the intensity of cocoa production in the different localities.

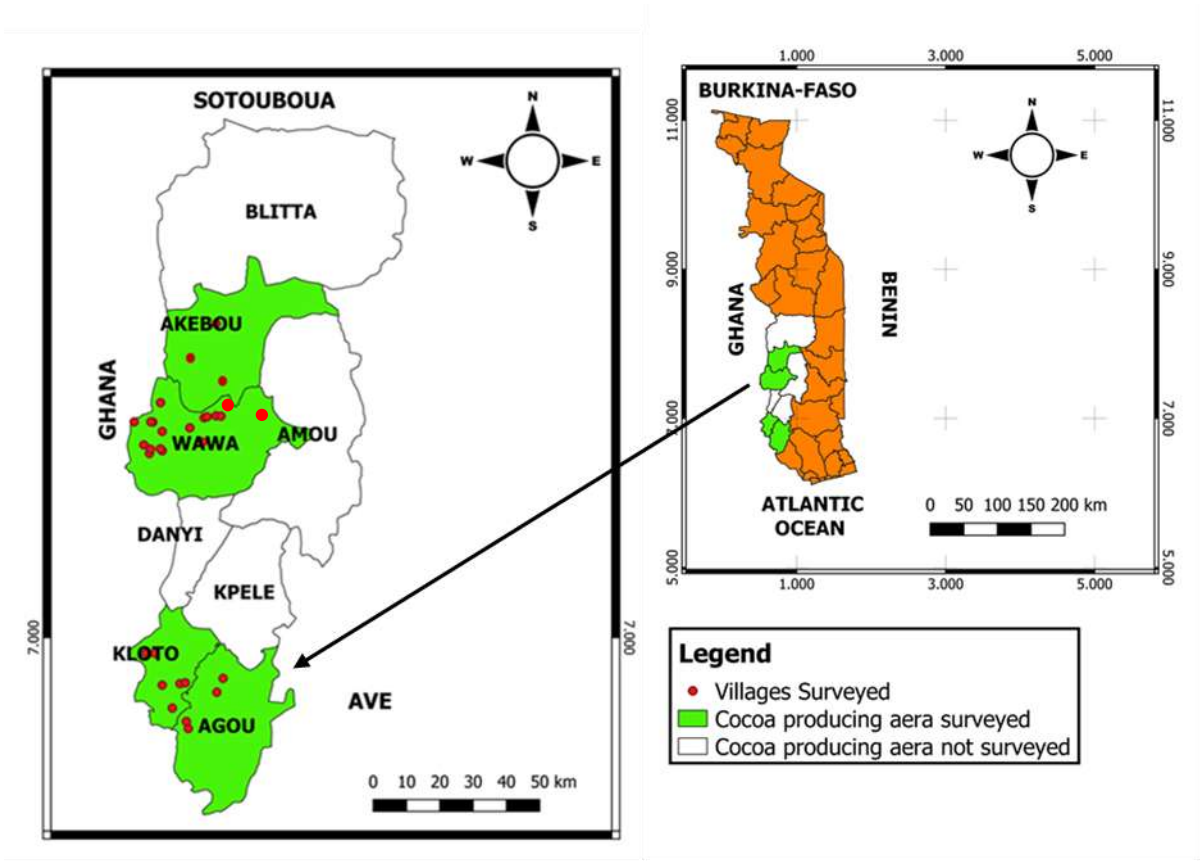

Figure 1:- Map of Togo showing the cocoa producing area and survey locations.

The geographic coordinates of the survey locations were recorded with GPS (Global Positioning System) during fieldwork. They were then projected on a base map using QGIS 2.18 software for map production (Figure 1).

Information on mirid damage (infestations and yield losses), pesticides used to control the pests, and producers' perceptions of the use of local plant-based biopesticides in conventional and organic cocoa production were collected from the producers surveyed.

Conduct of the survey

The survey was conducted from September to December 2021. The main data obtained during this survey took into account the overall socio-demographic characteristics of the producers, some aspects of cocoa production (area planted, perceptions of constraints, estimates of damage caused by cocoa mirids, pesticides used for the management of the pest) and the perception of producers on the use of botanical pesticides in order to determine whether or not to set up an alternative method for the integrated management of cocoa mirids

Processing of survey results

The data collected were entered into Excel and analyzed using IBM SPSS Statistics 20. The different parameters studied in conventional and organic cocoa production were compared using their averages. This comparison of means was done by an analysis of variance (ANOVA) at the 5% significance level. When significant differences were observed between the means, they were discriminated using the Student-Newman-Keul (SNK) test.

Results:-

Cocoa production system in conventional and organic farming

Socio-demographic characteristics of the cocoa farmers surveyed

Information was collected on age, gender, marital status, level of education and cocoa farming experience.

The distribution of cocoa farmers by age and gender is shown in Table 1a for conventional farmers and 1b for organic farmers.

In the sample of conventional cocoa farmers surveyed, about 74% are over 40 years old (Table 1a). Farmers between 51 and 60 years were predominant. They represented 30.21% of the sample. This age group was followed by that between 41 and 50 years, which made up 29.17% of the total. Producers between 31 and 40 years represented about 17% and those over 61 years, about 15%. Producers under 30 years constituting 9.37% of the sample were the least represented. Almost 90% of the sample was male (Table 1a).

Table 1a:- Distribution of conventional cocoa producers by age and gender.

Age group (years)	Men	Women	Total	Percentage (%)
21-30	8	1	9	9.37
31-40	15	1	16	16.67
41-50	22	6	28	29.17
51-60	27	2	29	30.21
61 and over	14	0	14	14.58
Total	**86**	**10**	**96**	**100**
(%)	**89.58**	**10.42**	**100**	

Of the organic cocoa farmers surveyed, more than 78% were over 40 years old (Table 1b). Producers in the 41-50 age group predominated. They represented about 33% of the sample. Those over 60 years constituted 23.17% and those from 51 to 60 years constituted about 22%. Producers under 40 years made up about 22% of the total. About 88% of the organic cocoa producers surveyed were male (Table 1b).

Table 1b:- Distribution of organic cocoa producers by age and gender.

Age group (years)	Men	Women	Total	Percentage (%)
21-30	2	0	2	2.44
31-40	15	1	16	19.51
41-50	21	6	27	32.93
51-60	17	1	18	21.95
61 and over	17	2	19	23.17
Total	**72**	**10**	**82**	**100**
(%)	**87.80**	**12.20**	**100**	

The distribution of farmers according to gender and education level showed that the cocoa farmers surveyed have an average level of education (Tables 2a and 2b).

In conventional cocoa farming, 26.04% and 56.25% of farmers have primary and secondary education respectively (Table 2a). Illiterate farmers represent 7.29% and literate farmers represent 4.17%. Moreover, producers with a university degree make up 6.25% of the total number of conventional cocoa producers. In the sample of producers surveyed, 60% of women have a level of education lower than or equal to primary school, while 65% of their male colleagues have a level higher than or equal to secondary school (Table 2b).

Table 2a:- Distribution of conventional cocoa producers by gender and level of education.

	Level of education					Total
	Illiterate	Literate	Primary	Secondary	University	
	Number (%)	Number (%)	Number (%)	Number (%)	Number (%)	Number (%)
Male	6 (6.98)	4 (4.65)	20 (23.26)	50 (58.14)	6 (6.98)	**86 (100)**
Female	1 (10)	0 (0)	5 (50)	4 (40)	0 (0)	**10 (100)**
Total	**7 (7.29)**	**4 (4.17)**	**25 (26.04)**	**54 (56.25)**	**6 (6.25)**	**96 (100)**

The level of education of the organic cocoa producers surveyed (Table 2b) showed that 31.71% had primary education and 48.78% had secondary education. Illiterate and literate producers represented 7.32% and 3.66% of the sample respectively. People with a university degree made up 8.54% of the total number of organic cocoa producers

surveyed. In this sample, 70% of women had a level of education lower than or equal to primary school, while 61% of men had a level of education higher than or equal to secondary school (Table 2b).

Table 2b:- Distribution of organic cocoa farmers according to gender and level of education.

	Level of education					Total
	Illiterate	Literate	Primary	Secondary	University	
	Number (%)	Number (%)	Number (%)	Number (%)	Number (%)	Number (%)
Men	5 (6.94)	3 (4.17)	20 (27.78)	37 (51.39)	7 (9.72)	**72 (100)**
Women	1 (10)	0 (0)	6 (60)	3 (30)	0 (0)	**10 (100)**
Total	**6 (7.32)**	**3 (3.66)**	**26 (31.71)**	**40 (48.78)**	**7 (8.54)**	**82 (100)**

The distribution of cocoa farmers according to marital status shows that the majority of farmers (90.63% in conventional cocoa farming and 90.24% in organic farming) are married (Table 3). Single farmers represent 2% in conventional cocoa production and 3.66% in organic production. Widows or widowers make up 7% of the sample of conventional cocoa farmers and 6% of organic cocoa farmers (Table 3).

Table 3:- Distribution of cocoa farmers surveyed according to marital status.

Marital status of farmers surveyed	Conventional cocoa farming		Organic cocoa farming	
	Number	%	Number	%
Unmarried	2	2.08	3	3.66
Married	87	90.63	74	90.24
Widowed	7	7.29	5	6.09
Total	**96**	**100**	**82**	**100**

Regarding experience in cocoa farming, conventional cocoa farmers are more experienced than organic farmers (Table 4). The average number of years of experience is 17.76 ± 9.95 for conventional cocoa farmers and 6.12 ± 4.55 for organic cocoa farmers.

Table 4:- Experience of producers according to type of cocoa production.

	Number of producers surveyed	Average number of years of experience
Conventional cocoa farming	96	17.76 ± 9.95
Organic cocoa farming	82	6.12 ± 4.55
F		92.46
P (5%)		< 0.001*

*Significant values at the 5% threshold ($P \leq 0.05$)

Cocoa production

The average area of cocoa farm planted by the producers surveyed was 1.96 ± 2.98 hectares for conventional cocoa plantations and 1.39 ± 0.97 hectares for organic cocoa field (Table 5). There is no significant difference between these types of cocoa farms.

Table 5:- Average area of cocoa plantations according to type of cocoa farming.

	Number of producers surveyed	Average area of plantations (ha)
Conventional cocoa farming	96	1.96 ± 2.98
Organic cocoa farming	82	1.39 ± 0.97
F		2.8
P (5%)		0.096 (NS)

NS = Not Significant

All organic and almost all (98%) conventional farmers reported that cocoa mirids are a major problem on their farms (Table 6). The proportion of plots infested by the pest was estimated by producers surveyed to be 40.79 ± 25.72% in conventional cocoa and 44.93 ± 26.92% in organic cocoa farms. The average loss of marketable cocoa yields was

estimated at 13.09 ± 8.58% on average by conventional cocoa farmers, compared to 17.39 ± 10.93% by organic farmers (Table 6).

Table 6:- Producers' statements on the constraints imposed by cocoa mirids, infestation of plantations and yield losses caused.

	Number of producers surveyed	% of producers who reported mirids as a major constraint	Average proportion of plantations infested (%)	Average yield loss (%) in marketable cocoa
Conventional cocoa farming	96	98	40.79 ± 25.72	13.09 ± 8.58
Organic cocoa farming	82	100	44.93 ± 26.92	17.39 ± 10.93
F		-	0.97	6.19
P (5%)		-	0.32 (NS)	0.014*

***Significant values at the 5% level (P ≤ 0.05); NS = Not Significant**

Producers often use pesticides to limit pest damage. Almost all farmers in conventional cocoa production (98.93%) and 65% in organic cocoa production use at least one insecticide to eliminate mirids from the cocoa tree or reduce damage in the plantations (Figure 2).

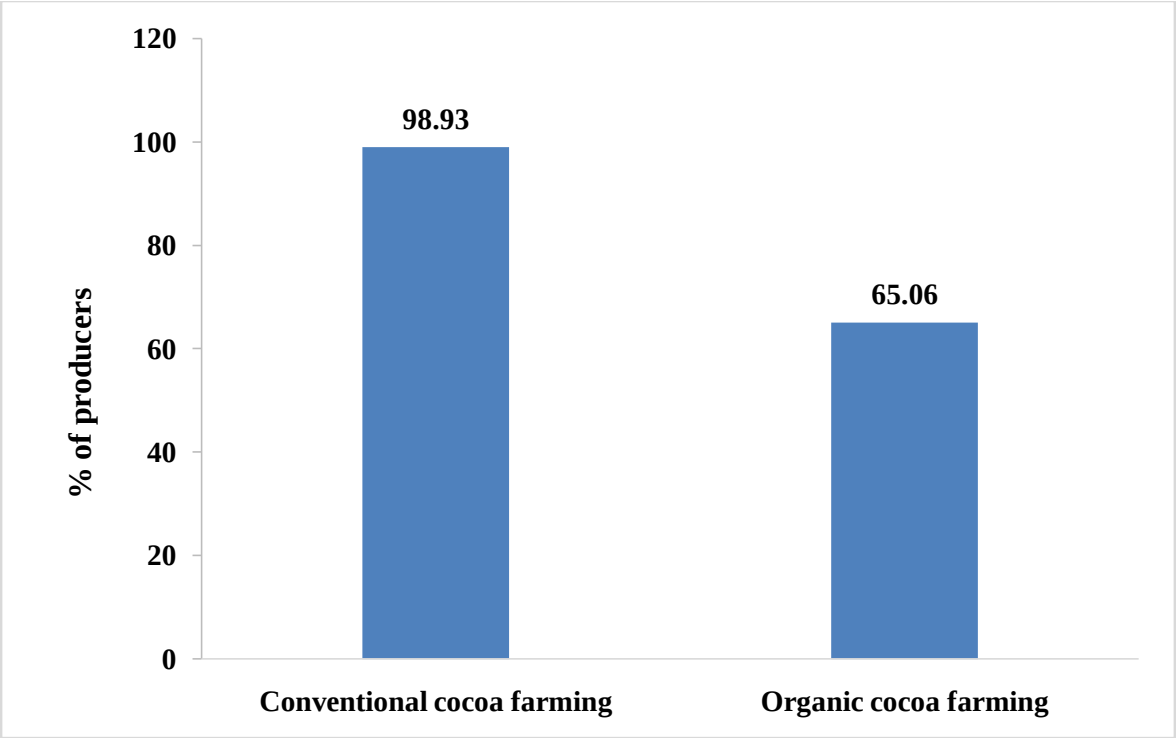

Figure 2:- Proportion (%) of farmers using at least one insecticide for mirid control.

Three classes of insecticides are reported to be used in conventional cocoa production by the producers surveyed (Figure 3). These are an organophosphate, Pyriforce 480 EC (chlorpyrifos ethyl 480 g/l), two (2) synthetic pyrethroids including Akate Master (Bifenthine 27 g/l) and Attack (Tefluthrin), one (1) neonicotinoid, Iron 30 SC (imidacloprid 30 g/l) and three binaries: Thodan super 35 SC (acetamiprid 20 g/l + lambda-cyhalothrin 15 g/l), Pasha 25 EC (acetamiprid 10 g/l + lambda-cyhalothrin 15 g/l) and K-optimal (acetamiprid 20 g/l + lambda-cyhalothrin 15 g/l).

The Neonicotinoid class (48.15%), represented by acetamiprid (36.75% of total active ingredients) and imidacloprid (15.39% of active ingredients) was more frequent (Figure 3). Pyrethroids (41.66%) were represented by lambda-cyhalothrin (36.75%), Bifenthrin (0.85%) and Tefluthrin (0.85%). The least frequent class of insecticides was the Organophosphates (10.18%), represented by the single active ingredient chlorpyrifos ethyl (9.4%) (Figure 3).

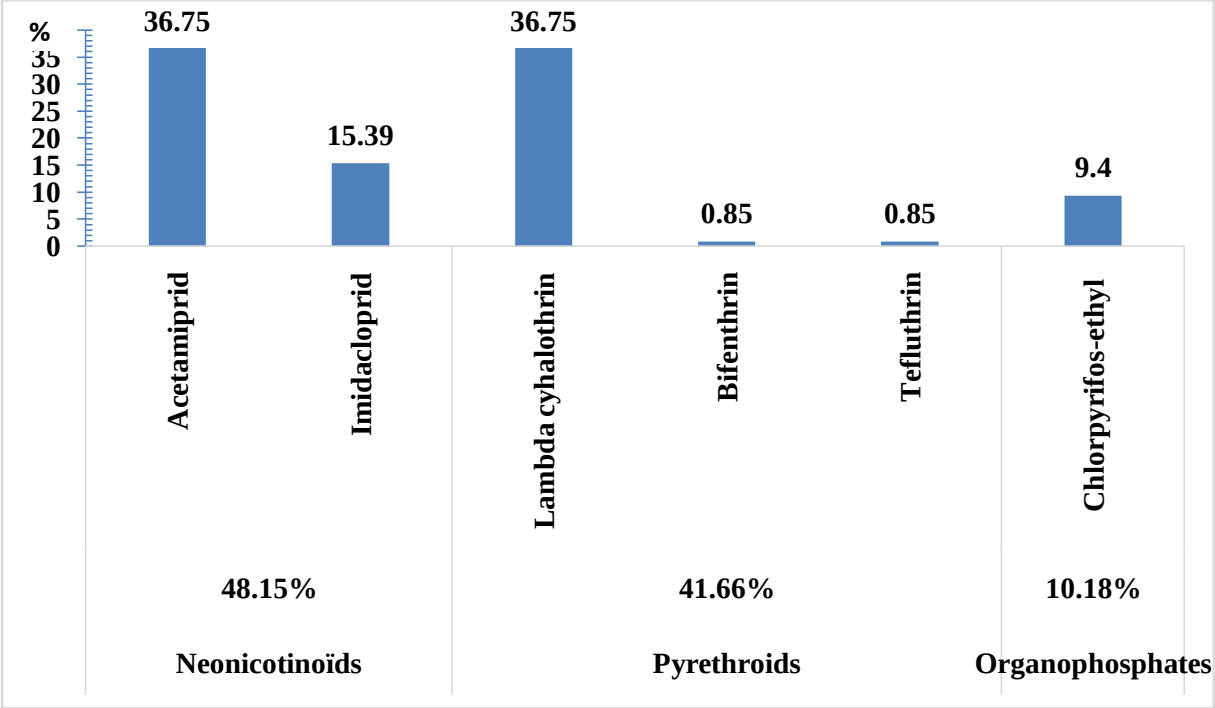

Figure 3:- Prevalence (%) of classes and active ingredients of chemical insecticides used in conventional cocoa production.

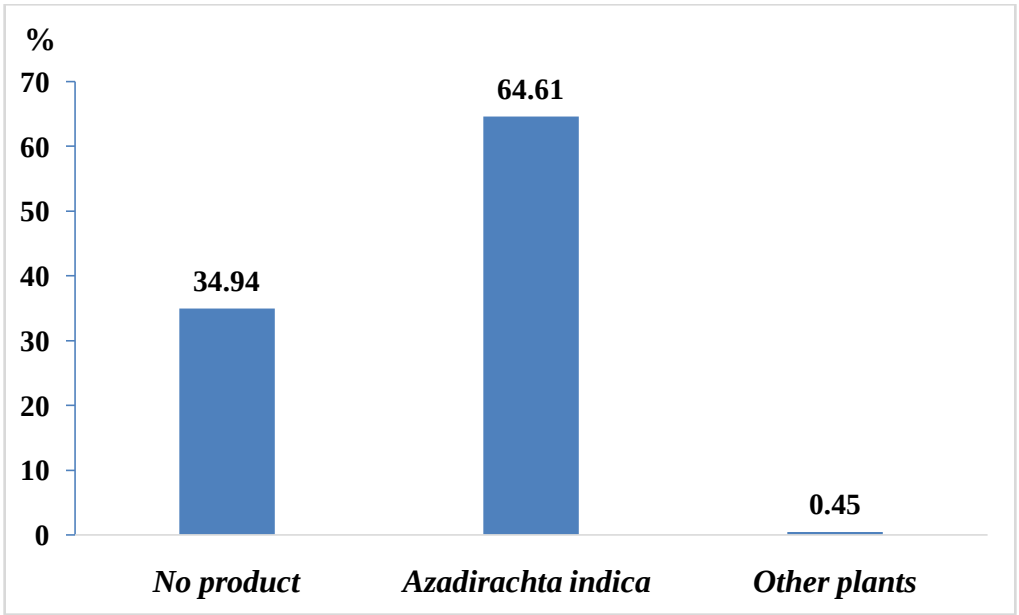

Figure 4:- Frequency (%) of use or non use of botanical products against mirids in organic cocoa production.

In organic cocoa, about 35% of producers do not use any products against cocoa mirids (Figure 4). The other producers use bioinsecticides mainly based on the plant *A. indica* (64.61%) and other plants (0.45%) such as *Nicotianatabacum* and *Momordicacharantia*.

A. indica products used are in the form of neem oil (31.71%) and aqueous extracts of leaves (17.05%) or seeds (15.85%) for the treatment of cocoa trees against mirid attacks (Figure 5).

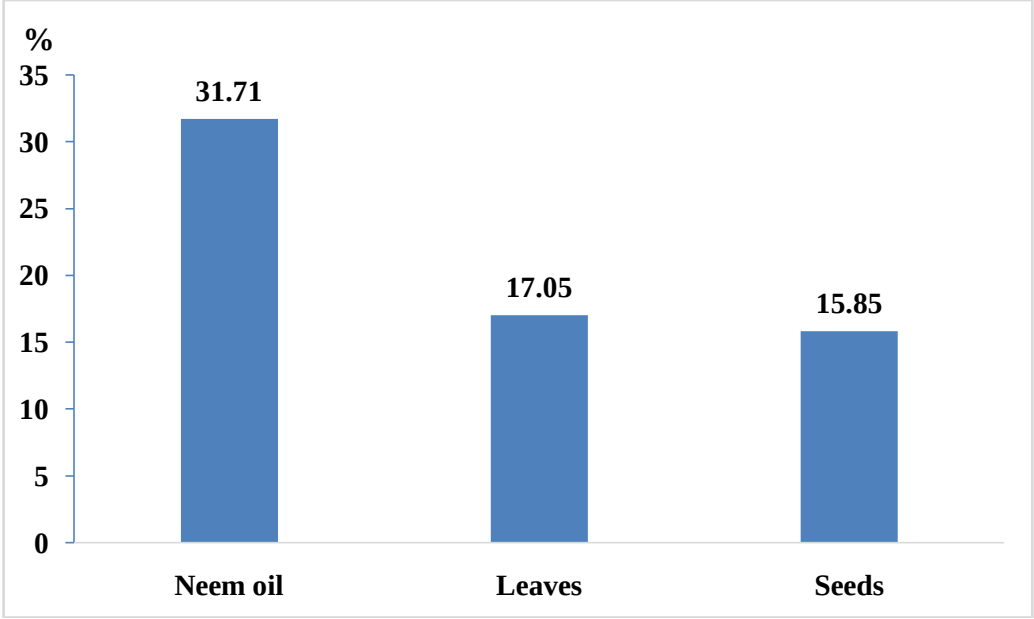

Figure 5:- Frequency (%) of the different forms of bioinsecticides based on *Azadirachtaindica* used.

Products based on neem are often used in combination with Allium sativum pods (12.19% of producers), Capsicum annuum (9.76% of producers) and/or Marseille soap, traditional black soap and oil by a few producers.

Farmers' perceptions of the use of botanical pesticides for the management of cocoa mirids

In order to determine whether local plant-based biopesticides could be part of future integrated management programs for cocoa mirid control in Togo, farmers' opinions were asked for. Information was collected on the potential of biopesticides to control pests as well as on the adherence of farmers to the use of biological products. Regarding the potential of biopesticides for pest control, 81.96% of conventional cocoa farmers and 91.46% of organic farmers believe that bioinsecticides can contribute to a better management of cocoa mirids (Figure 6).

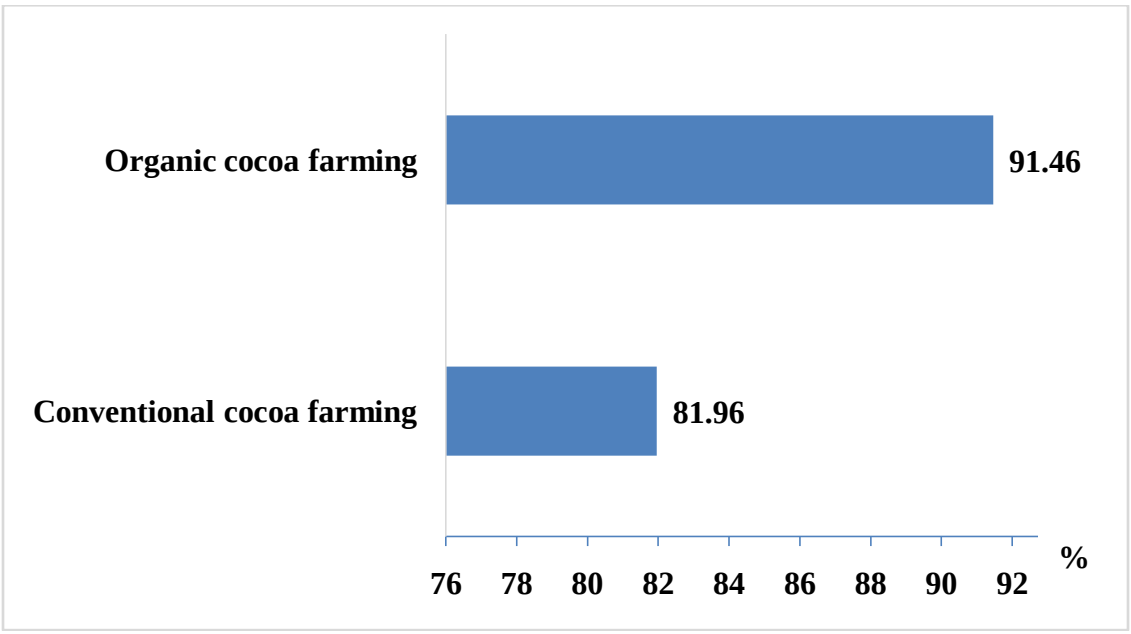

Figure 6:- Proportion (%) of farmers who think that it is possible to control cocoa mirids with biological insecticides made from local plants in Togo.

With regard to producer support for the use of locally made bioinsecticides to control cocoa mirids, 68.75% of conventional and 71.95% of organic cocoa farmers are willing to use these products provided that they are effective and affordable (Figure 7).

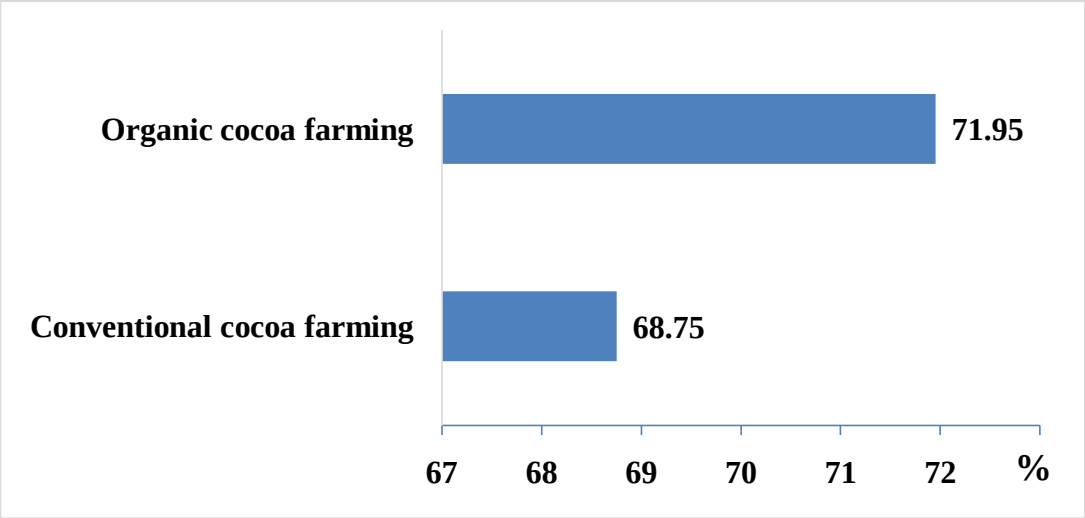

Figure 7:-Proportion (%) of farmers willing to use organic insecticides made from local plants to control cocoa mirids in Togo.

Discussion:-

Surveys of cocoa farmers in the major cocoa-producing areas of Togo have shown that the population engaged in this activity is relatively old. Indeed, DSID (2018) has shown that the population of cocoa farmers is aging. Young people in the villages are nowadays more preoccupied with remunerative activities that generate daily income to the detriment of activities with non-immediate income. In addition, the rural exodus is causing an aging of the rural population, including cocoa farmers.

Furthermore, this survey population is made up mainly of men, probably because cocoa farming requires significant physical effort, making it a very difficult activity for women. This was also revealed during the 2017 cocoa farmer census in Togo (DSID, 2018).

In this survey, men are in the majority. This high proportion of men would be explained by the fact that field work in general requires a lot of physical effort that men are more able to deploy (Mondedji et al., 2015).

The greater experience of conventional cocoa farmers compared to organic cocoa farmers could be explained by the fact that conventional cocoa farming is older and more developed in Togo. The same is true for the surface area planted, with conventional cocoa plantations being slightly bigger than organic cocoa plantations.

Regarding constraints, almost all the producers surveyed mentioned mirids as a major problem in their farms. These pests cause significant damage leading to a drop in yields and a big drop in production income (Lavabre, 1977; Badegana et al., 2005; Babin, 2009; Kouakou et al., 2011). Mirid attacks on cocoa trees are characterized by stinging spots on pods and twigs, cankers on trunks, stems and twigs, deformation and premature yellowing of pods, fall of attacked flowers and cherries, desiccation and even death of severely attacked plants (Williams, 1953; Entwistle, 1972; Youdeowei, 1977; Wheeler, 2000; Babin, 2009). Indeed, Lavabre (1977) stated that production losses in case of heavy attack are estimated to be between 25 and 30%. In Malaysia, research has estimated yield losses as high as 50% (Tong-Kwee et al., 1989). In Ghana, Padi in 1997 estimated mirid related losses at 75% in an area attacked and left untreated for three years. Also in Ghana, surveys estimated losses of 30-40% in national production (Awudzi et al., 2016). In Togo, although figures are not yet available on the impact of mirids, Wegbe and Agbodzavu (2013) stated that "if it is known that these insects can lead to the death of severely attacked plants, one realizes that the losses they cause must not be negligible."

Regarding the means of control of these pests, the significant use of chemicals in conventional cocoa production compared to smaller use of biopesticides could be explained by the fact that the best known and most popularized control method is still treatment with synthetic chemicals (Hoyer et al., 2002; ITRA, 2016). In addition, knowledge of the methods of manufacturing or use of biopesticides is almost absent or lacking, as are new technologies or biological methods that are not widely used in cocoa production in Togo (ITRA, 2016). There are also no registered anti cocoa miridbiopesticides in Togo (DPV, 2022). Only synthetic chemical pesticides are available. For these, the presence of Neonicotinoids, Pyrethrinoids and Organophosphates testifies to the use of active ingredients from these families for the formulation of synthetic chemical insecticides. The notable absence of Organochlorines among the insecticide products used is due to the prohibition of several active ingredients from this family including DDT, lindane, aldrin and dieldrin (Babin, 2009). In Togo, Article 1 of Order No. 0078/18/MAEP/Cab/SG/DPV directive of the Ministry of Agriculture, Livestock and Fisheries prohibits the importation, sale and use of certain products because of their toxic effects on the environment and the lives of the Togolese population (MAEP, 2018). The abundance of Neonicotinoids and Pyrethrinoids can be explained by the extensive use of Acetamiprid, Imidacloprid and lambda-Cyhalothrin in the formulation of chemical pesticides used against cocoa mirids.

The significant use of neem as a biopesticide is due to the strong insecticidal effect of this plant (Mondedji, 2010; Anjarwalla et al., 2016; Yarou et al., 2017). Indeed, Neem is a wonderful 100% effective natural insecticide, harmless to humans and animals, active against more than 200 insects. Its active ingredients (mainly azadirachtin) act by producing disturbances in the insect's feeding habit and intervening in its hormonal cycle, causing malformations in the molting process, preventing its normal development and growth (Vallet, 2006).

The strong adhesion of producers to the use of local plant extracts against cocoa mirids is due to the advantages linked to these products, notably the availability of the raw material, and ecosystemic, environmental and human health preservation. Thus, Mnif et al. (2011) asserted that the use of plant-based bio-insecticides could avoid health problems (headaches, nausea, respiratory disorders and other forms of serious poisoning) in farmers and animals and also protect the environment.

Because of the negative health and environmental impacts of synthetic chemical pesticides, the conventional and organic cocoa farmers surveyed prefer the use of non-toxic organic products to improve their yields. However, the higher proportion of organic cocoa farmers adhering to the use of biopesticides compared to conventional cocoa farmers may be explained by the fact that they are the first actors concerned by mirid losses and do not have organic products.

Conclusion:-

The present survey of conventional and organic cocoa farmers in Togo found that cocoa farmers are predominantly male and aging. The study also showed that men are more educated than women in the producers surveyed. In terms of work experience, conventional cocoa farmers were more experienced than organic cocoa farmers. In addition, cocoa mirids are a major constraint on cocoa production, causing significant yield losses. The use of insecticides is the main means used by farmers to control the pest. Synthetic chemical insecticides are more widely used than bioinsecticides. Alternative control measures using products extracted from local plants are approved by both groups of cocoa farmers. Thus, the present study provides a basis for further research on local plant-based biopesticides for cocoa mirid control.

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