Assessment of farmers' knowledge and pesticides management in cocoa production in Ghana

Benedicta Y. Fosu-Mensah [1, *], Elvis D. Okoffo [1], Michael Mensah [2]

[1]Institute for Environment and Sanitation Studies, College of Basic and Applied Sciences, University of Ghana, Accra, Ghana
[2]Department of Business Administration, University of Professional Studies, Accra (UPSA), Accra, Ghana

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ABSTRACT

The use of pesticides to control pests and diseases has been a measure to increase cocoa productivity in Ghana. However, regular use and indiscriminate application of pesticides have unintended environmental and health risks. This study assesses the types of pesticides used by cocoa farmers in Ghana, sources and knowledge on application rate, frequency of application and factors that could influence farmers' choice of source of pesticides, knowledge on application rate, and frequency of application. Two hundred and forty cocoa farmers from the Dormaa West District of Ghana were interviewed from December 2014 to February 2015 using a pre-tested questionnaire. The results showed that farmers sourced pesticides from agrochemical shops and fellow farmers, with some benefiting from the government of Ghana's ''free mass cocoa spraying'' program. A majority (51.2%) of the farmers sprayed more than three times per cocoa season. In addition, 35% of the farmers dangerously mixed two or more different pesticides together when spraying. Gender, age, educational level, and income from cocoa farming significantly influenced the choice of source of pesticide while knowledge on pesticides application rate was significantly influenced by educational level of farmers, access to extension services, presence of agrochemical shop, membership of a farm-based organization, and age of a farmer. Frequency of pesticides application was significantly influenced by educational level of farmers, access to extension services, presence of agrochemical shop, membership of the farmer-based organization, knowledge of Ghana COCOBOD recommendation on pesticides application rate, income from cocoa farming, and age of farmers. The majority of the farmers mixed two or more pesticides together during spraying. The limitation of this research is the inability to carry out the survey in other cocoa-growing districts within the study region. There is a need for the training of farmers on the safe use of pesticides by the Ghana COCOBOD to effectively manage pests and diseases and reduce environmental pollution.

1. Introduction

Cocoa (*Theobroma cacao* L) is an important cash crop for several developing countries and a key import commodity for some developed countries. In the agricultural sectors of the top ten producing countries, (Côte d'Ivoire, Ghana, Indonesia, Nigeria, Cameroon, Brazil, Ecuador, Mexico, Dominican Republic, and Peru) (FAOSTAT, 2016; Aminu et al., 2019), cocoa is of regional importance, providing employment and foreign earnings. Globally, the worth of the cocoa industry is estimated at the US $73 billion dollars with global cocoa production of about 3.8 million metric tons per annum (Lanaud et al., 2009). According to Orisajo (2009), West Africa currently accounts for about 70% of the world's cocoa and nearly one million people, mostly smallholder farmers derive their livelihood from the crop. Côte d'Ivoire and Ghana produce approximately 41% and 17% of the world output, respectively, with Cameroon and Nigeria, each contributing approximately 5% of world cocoa production (Binam et al., 2008).

In Ghana, cocoa has been the major agricultural export and the main cash crop with over one

hundred (100) years of history. The crop contributes substantially to the national economy in terms of foreign revenue earnings, employment, and domestic incomes (Ayenor et al., 2007; Anang, 2011). In 2013, earnings from cocoa constituted approximately 16.48% (US$ 2,267.3 million) of total agriculture export (ISSER 2014). The cocoa sector in Ghana employs over eight hundred thousand (800,000) smallholder farm families and about 1.5 million hectares of land is used in the cultivation (Danso-Abbeam et al., 2014). In addition, cocoa is known to contribute about 70–100% of the household income of cocoa farmers annually (Appiah, 2004; Abankwah et al., 2010).

Unfortunately, the production of cocoa in Ghana is constrained by several factors. Among these factors is the incidence of pests and diseases which has been recognized as a major cause of declining yields in cocoa production (Ayenor et al., 2007; Ntiamoah and Afrane, 2008) with adverse consequences on the country's economy. According to (Lass, 2004; Lanaud et al., 2009), 30% -40% of cocoa produced globally is lost due to insect pests and diseases infestation. Although the use of non-chemical means of managing pests and diseases are widely recommended for health and other reasons, the use of pesticides to manage cocoa pests and diseases has become an unavoidable necessity to increase cocoa production in Ghana (Afrane and Ntiamoah, 2011).

In recent years, there has been a significant increase in the use of pesticides in Ghana, particularly in cocoa production (Dankyi et al., 2014; Denkyirah et al., 2016) to increase cocoa productivity. According to Dankyi et al. (2014), the high use of pesticides has been mainly due to the government policy of free pesticide spraying of cocoa farms. This is an effort to control pests and diseases to increase cocoa productivity and also prevent the use of unapproved or banned pesticides on cocoa farms. However, pesticides have been misused, overused, and improperly applied by cocoa farmers due to the scale of cocoa farming (Dankyi et al., 2014). The frequency, intensity, and the indiscriminate use of banned/unapproved or approved/recommended pesticides by farmers in the cocoa industry in Ghana may result in large volumes of pesticide residues in the environment (water, soil, plants, air, etc.) with its associated human health consequences (Dankyi et al., 2014; Okoffo et al., 2016). Pesticides pollutants that get into the soil may persist for a significant time due to their inability to degrade into non-toxic forms (Bempah et al., 2011; Agbeve et al., 2014), possibly in impacting soil organisms such as earthworms, microbes and the natural enemies which act as decomposers (Ntiamoah and Afrane, 2008). In the same way, the increased accumulation of these chemicals in the food chain may pose serious health hazards when they are not metabolized by the body and accumulate in the soft tissues (Akan et al., 2013; Tanner et al., 2011). Examples of such health hazards include testicular cancer, reproductive and immune

malfunction, endocrine disruptions, cancers, immunotoxicity, neurobehavioral and developmental disorders (Tanner et al., 2011; Cocco et al., 2013; Gill and Garg, 2014).

The Brong Ahafo Region is one of the major cocoa-producing regions in Ghana. Farmers in this region use pesticides extensively to control pests and diseases in cocoa production in order to increase yield (Fosu-Mensah et al., 2016; Denkyirah et al., 2016). However, these chemicals are used improperly or in dangerous combinations with disregard for the recommended frequency, mode of application as well as the use of unapproved pesticides (Denkyirah et al., 2016). There is, however, little information on pesticides management by cocoa farmers in the Region. This paper aims at assessing the (i) types of pesticides used by cocoa farmers in the region, (ii) the sources of these pesticides, (iii) the knowledge of farmers on the frequency of pesticide application (iv) factors that may influence cocoa farmers' decisions on choice of sources of pesticides, and frequency of pesticides application on cocoa farms in Brong Ahafo Region of Ghana.

2. Materials and methods

2.1. Description of the study area

The study was carried out in the Dormaa West District located at the western part of the Brong Ahafo (now Bono) Region of Ghana with slightly hilly terrain (240–300m above sea level). It is bounded in the north by the Dormaa Central Municipality, in the east by Asunafo North Municipality, in the south by Bia East District and in the west by Côte d'Ivoire. The District has a population of 47, 678 comprising of 24, 681 (51.8%) males and 22, 997 (48.2%) females (GSS, 2014). The highest mean temperature of the District is about 30 ºC which occurs between March and April and the lowest is about 26.1ºC which occurs in August. The district lies in the sub-humid zone (with annual total rainfall of 800mm to 1200mm) and has a bimodal rainfall regime. The climatic condition of the district is suitable for the cultivation of various cash crops such as cocoa and coffee, as well as food crops such as plantain, cocoyam, and cassava. The land size of farmers varied from small (0.5ha) and spatially dispersed parcels to larger plots (10ha) due to land fragmentation of the arable land.

2.2. Sample selection and data collection

A household survey was conducted in December 2014–February 2015 where 240 cocoa farmers were randomly sampled from four (4) cocoa-growing communities (Nkrankwanta, Diabaa, Krakrom, and Kwakuanya) using the multi-stage sampling technique. The Brong Ahafo (now Bono) Region of Ghana was purposively selected due to the predominance of cocoa production in the region. The

Dormaa West district, known to be one of the major cocoa growing districts in the Brong-Ahafo region was randomly selected out of the several cocoas producing districts in the region after which four (4) cocoa-growing communities, namely, Nkrankwanta, Diabaa, Krakrom, and Kwakuanya in the district were randomly sampled. Sixty cocoa farmers were selected from each of the four cocoa-growing communities. A pre-tested semi-structured questionnaire was used to investigate the common pesticides used in the study area, the sources of pesticides, the source of knowledge on the application rate of pesticides, and the frequency of application of pesticides. All participants agreed to participate in the research study by signing informed consent forms.

2.3. Data analysis

The STATA version 13 was used to determine mean responses and for regression analysis. The probit regression model (Khan et al., 2015) was used to determine the factors that influence cocoa farmers' choice of pesticide source and knowledge on pesticide application rate. The dichotomous dependent variable of this model takes the form of a dummy where 1 is 'yes' and 0 is 'no'. The purpose of the model is to estimate the probability that observation with particular characteristics will fall into one of the specific proposed categories; thus, the probit model can be used to predict the probability that an outcome will occur (Khan et al., 2015). The model has the ability to resolve the problem of heteroscedasticity, and its ability to constrain the utility value of a decision to lie within 0 and 1 (Asante et al., 2011). The probit model makes the assumption that while we only observe the values of 0 and 1 for the dependent variable Z_i, there is a latent, unobserved continuous variable Z_i^* that determines the value of Z_i (Sebopetji and Belete, 2009). This model has been used to identify determinants of health effects and determinants of pesticide overuse among farmers in Bangladesh (Dasgupta and Meisner, 2005), as well as determinants of pesticide poisoning among farmworkers in Vietnam (Dasgupta et al., 2005).

We assume Z_i^* can be specified as:

$$Z_i^* = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_n X_{ni} + \varepsilon_i \qquad (1)$$
$$Z_i = 1 \text{ if } Z_i^* > 0$$
$$Z_i = 0, \text{ otherwise.}$$

where X_i represents a vector of explanatory variables, β is a vector of unknown parameters and ε_i is a random disturbance term.

The probit model is specified for this study as:

$$Z = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \varepsilon \qquad (2)$$

Z is the dependent variable representing, choice of pesticide source and also knowledge on pesticide application rate, β_0=coefficient of the constant term, β_1 –β_9 =coefficient of the independent variables, X_1–X_9 =explanatory variables, ε=error term.

The explanatory variables are defined as follows; X_1 denotes gender (1=male, 0=female), X_2 denotes the age of farmer (measured in years), X_3 denotes educational level (measured as 1=no formal education, 2=primary/JHS, 3=middle/SHS, 4=tertiary), X_4 denotes years of farming experience (measured in years), X_5 denotes access to extension service (1=access, 0=no access), X_6 denotes member of Farmer Based Organization (FBO) (1=member, 0, otherwise), X_7 presence or nearness to agrochemical shop (1=near, 0=otherwise), X_8 denotes farm size (measured in acres) and X_9 denotes income from cocoa (measured in Ghana cedi).

Ordinary Least Squares regression (OLS) approach was used for estimating the frequency of pesticides application by farmers.

3. Results

3.1. Demographic characteristics of farmers

The demographic characteristics of the farmers indicate that 87.5% of respondents were males while 12.5% were females (Table 1). Most (63.8%) of the respondents were between 40 and 59 years old, with 25.8% above 60 years. Only 10.4% of the farmers were between the ages of 20-39 years. The average age of the cocoa farmers is 52 years and the maximum age is 83 years. About 81.2% of the respondents had formal education, mainly middle/senior high school (43.3%), primary/junior high school education (34.6%) and tertiary education (3.3%), with 18.8% of the farmers with no formal education. Concerning the number of years of farming, 94.2% of the farmers had 11 or more years of farming experience in cocoa production. The average number of years of farming cocoa in the study area was 21.8 years.

3.2. Major insect pests and diseases of cocoa in the study area

Cocoa farmers in the study area complained that the crop is severely hampered by several insect pests and diseases, with mirids (capsid) (*Distantiella theobroma* and *Sahlbergella singularis*), locally known as '*akate*' identified as the major insect pest. Other insect pests mentioned included stemborers (*Eulophonotus myrmeleon*), pod borers *(Conopomorpha crammerella)*, shield bugs (*Bathycoelia thalassina*), mealy bugs (*planococcus and stictococcus species*), termites, grasshoppers, ants, and mites. The major diseases of cocoa identified by the farmers are the black pod disease (*Phythophthora* pod rot) and the cocoa swollen shoot virus (locally as '*cocoa sasabro*'). Mistletoe, a parasitic plant, and rodents were also mentioned by some farmers to be a major cause of a decline in cocoa production.

3.3. Types and sources of pesticides used by cocoa farmers in the study area

All cocoa farmers interviewed in this study used chemical pesticides to control insect pests and diseases on cocoa farms. A majority (60.4%) of the farmers used the Ghana Cocoa Board (COCOBOD) approved insecticides and fungicides for the control of cocoa insect pests and diseases in the study area while 38.6 used other unapproved pesticides. Among the approved insecticides used were Confidor (Imidacloprid), Akatemaster (Bifenthrin) and Actara (Thiamethoxam) while the approved fungicides used were, Nordox (Cuprous oxide), Kocide (Cupric Hyroxide), Champion (Cuprous Hydroxide), Funguran (Cuprous Hydroxide), Metalm (cuprous Oxide+Metalaxyl) and Ridomil (Metalaxyl cuprous oxide).

Table 1: Demographic characteristics of farmers in the study area

Variable	Description	Mean	Percentage (%)
Sex of farmers	Male		87.5
	Female		12.5
Age of farmers	20-29		2.1
	30-39		8.3
	40-49		32.5
	50-59		31.3
	Above 60		25.8
	Mean		52
Educational level	No Education		18.8
	Primary/JHS		34.6
	Middle/SHS		43.3
	Tertiary		3.3
Farmers years of experience in cocoa cultivation	5-10		5.8
	11-15		15.7
	16-20		17.8
	Above 20		60.7
	Mean		21.8

Most of the farmers (87.9%) purchased pesticides from agrochemical shops with 12.1% purchasing from other cocoa farmers. It should be noted however that, cultural practices such as weeding, pruning and fertilizer application in combination with pesticides application were not measured in this study. The most important criteria for the selection of pesticides by farmers were pesticides effectiveness in cocoa pest and disease control (42.1%), availability in the market (27.1%), affordability (16.3%) and recommendations by fellow farmers and extension agents (14.5%). Results showed that 60.4% of the respondents benefited from the Government of Ghana 'Cocoa Diseases and Pests Control (CODAPEC) or "free mass cocoa spraying" program, where cocoa farms were sprayed for free with Ghana COCOBOD approved pesticides (insecticides and fungicides), while the remaining 39.6% did not benefit. A total of 51.7% out of 60.4% farmers who benefited from the "free mass cocoa spraying" program in the year under review had their farms sprayed only once while only 6.9% of farmers had their farms sprayed four times. Thus, farmers had to augment spraying by purchasing chemicals from the market. A total of

65% of the farmers (including some of the farmers who used the Ghana Cocoa Board (COCOBOD) approved pesticides and those who did not use the recommended pesticides), indicating the use of other pesticides that are not approved by Ghana COCOBOD. Table 2 presents unapproved pesticides used by farmers. From Table 2, 70.8% of the types of unapproved pesticides used by the farmers fall within the moderately hazardous class of classification of pesticides according to WHO classification. A total of 12.5% of the unapproved falls within "slightly hazardous", 12.5% extremely hazardous with 4.2% of the pesticides with unidentified active ingredients.

3.4. Farmer's knowledge on pesticide application rates

Most of the farmers (85%) had knowledge on pesticides application rates, with 50% indicating their source of knowledge was from chemical sellers, whereas 10% stated extension officers, 15% indicated they read instructions on the pesticides label themselves, while the remaining 25% of the farmers obtained this information from fellow cocoa farmers and farm-based organizations (FBOs).

3.5. Factors influencing farmers' choice of source of pesticides

Table 3 presents the results of probit regression on the factors influencing the choice of source of pesticides by cocoa farmers in the study area. From the result, gender, educational level, and income from cocoa farming significantly and positively ($p<0.01$) influence the choice of source of pesticides. Also, farmers' age negatively influences ($p<0.05$) choice of source of pesticides. On the contrary, farming experience, access to extension services, presence or nearness to agrochemical shop, membership of FBO and farm size did not influence the choice of source of pesticide.

3.6. Factors influencing farmers' knowledge on pesticides application rate

Results of probit regression indicate that educational level of farmers, access to extension services, presence of agrochemical shop, membership of FBO and age of farmer significantly ($p<0.05$) influence knowledge on pesticides application rate (Table 4). However, farming experience did not influence farmers' knowledge of pesticides application rates.

3.7. Frequency of pesticide applications in the year under review

The survey revealed that 51.2% of the farmers sprayed pesticides more than three times in the year under review (2014/2015) whilst 24.6%, 14.2% and 10% sprayed pesticides thrice, twice and once,

respectively (Fig. 1) in addition to what some farmers (60.4%) benefited from the Government of Ghana "free cocoa mass spraying" program. Most (50.8%) of the farmers spray any time they see pests and diseases on cocoa trees. However, 16.7% did spray on a calendar basis, 15.8% based on a received recommendation from agrochemical dealers, extension officers advise (8.8%) and fellow farmers (7.9%). The survey revealed most farmers (67.5%) did not consider the direction of wind before spraying, with only 32.5% indicating in the affirmative.

Table 2: Commonly used unapproved pesticides by cocoa farmers in the study area

Trade name	Active ingredient	Main use	Chemical Hazardous class
Akatesuro	Diazinon	Insecticide	II
Argine	Aldrin		I
Buffalo-Super	Acetamiprid/Chlorfenvinphos	Broad spectrum	I
Controller-super	Lambda-Cyhalothrin	Broad Spectrum	II
Sunpyrifos	Chlorpyrifos-Ethyl	Broad Spectrum	II
Lamtox	Lambda-Cyhalothrin	Insecticide	II
Dursban	Chlorpyrifos	Broad Spectrum	II
Okumakete	Thiamethoxam	Insecticide	III
Pyrethroids-Decis	Deltamethrin	Insecticide	II
Thiodan	Endosulfan	Insecticide	II
Sumitox	Fenvalerate	Insecticide	II
Lambda-M	Lambda-Cyhalothrin	Insecticide	II
Condifor	Imidacloprid	Insecticide	II
Kombat	Lambda-Cyhalothrin	Insecticide	II
Aceta-star	Methyl-thiophanate	Pesticide/fungicide	III
Topsin-M	Methyl-thiophanate	fungicide	III
Fastrack	Alpha-Cypermethrin	Insecticide	II
Polythrine	Cypermethrin	Insecticide	II
DDT	DDT	Insecticide	I
Clement powder			
Sumico 200 EC	Fenvalerate	Broad Spectrum	II
Confidence	Chlopyrifos/Lamda-cyhalothrin	Insecticide/fertilizer	II
Super 10	Permethrin	Broad Spectrum	II
Consider Supa	Imidacloprid	Broad Spectrum	II

I=extremely hazardous; II=moderately hazardous; III=slightly hazardous; (WHO, 2005)

Table 3: Probit results on factors influencing farmers' choice of source of pesticides

Variable	Coefficient	P values	Marginal effect
Gender	2.765	$p \leq 0.001$	0.811
Education level	1.758	0.002**	0.228
Farming experience	-0.015	0.281	-0.004
Cocoa income	0.001	0.007**	0.002
Extension visit	0.612	0.073	0.158
Chemical shop	0.459	0.101	0.115
FBO	0.184	0.580	0.043
Age	-0.029	0.048*	-0.007
Farm size	0.016	0.345	-0.004
Constant	-1.662	0.028*	
Regression Diagnostics			
Log likelihood	-65.633		
Pseudo R^2	0.5249		
LR chi^2 (9)	145.05		
Prob > chi^2	0.0000		

*, ** indicate 5% and 1% significance levels

Table 4: Probit results on factors influencing farmers' knowledge on pesticides application rates

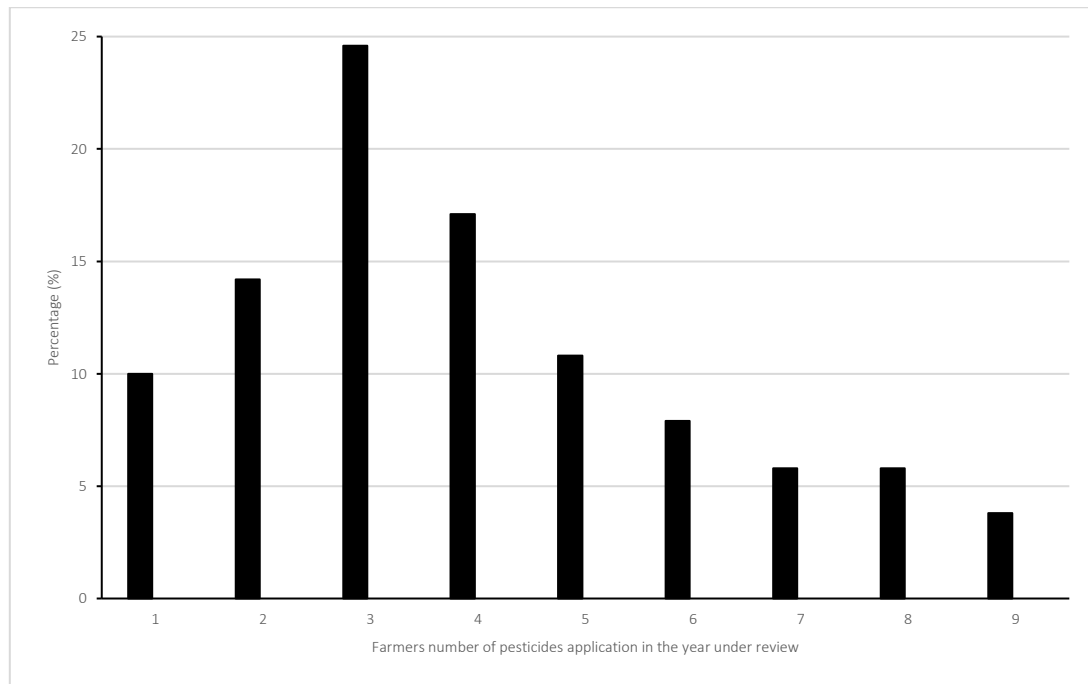| Variable	Coefficient	P values	Marginal effect
Education level	0.448	0.019*	0.177
Farming experience	0.012	0.060	0.005
Extension service	0.660	0.001**	0.255
Chemical shop	0.431	0.020*	0.171
FBO	0.399	0.028*	0.158
Age	-0.025	$p \leq 0.001$	-0.010
Constant	-1.247	0.008**	
Regression Diagnostics			
Log likelihood	-141.236		
Pseudo R2	0.1495		
LR chi2 (6)	49.64		
Prob> chi2	0.0000		

*, ** 5% and 1% significance level

Fig. 1: Frequency of pesticides applications by farmers in the year under review (2014/2015 season)

3.8. Factors influencing frequency of pesticides application

Table 5 presents the summary results of the ordinary least Square (OLS) Regression analysis of factors influencing frequency of pesticides application. Results showed that gender, farming experience, and farm size did not influence the frequency of pesticides application. However, age of farmer, access to extension service, presence of chemical shop, membership of FBO, knowledge of Ghana COCOBOD recommendation on pesticides application, income from cocoa farming and the level of education significantly influence ($p<0.05$) the frequency of pesticides application. From these results, multicollinearity is not a problem as VIF is less than 10.

Table 5 Ordinary least Square regression of the factors influencing farmers' frequency of pesticide application

Variable	Coefficient	Standard	t	P values	VIF	1/VIF
Gender	0.429	0.233	1.84	0.066	1.53	0.654011
Farming experience	0.004	0.005	0.70	0.484	1.48	0.675080
Age	0.047	0.007	6.85	$p \leq 0.001$	1.47	0.680801
Extension visit	-0.509	0..155	-3.29	0.001**	1.41	0.710623
Chemical shop	-0.384	0.192	-1.99	0.047*	1.40	0.716221
FBO	-1.378	0.211	-6.53	$p \leq 0.001$	1.36	0.732836
Farm size	0.003	0.066	0.44	0.658	1.31	0.762871
Knowledge of COCOBOD recommendation	0.977	0.256	3.82	$p \leq 0.001$	1.16	0.864633
Cocoa income	0.000	0.000	2.39	0.018*	1.13	0.884505
Educational level Regression Diagnostics	0.447	0.165	2.71	0.007**	1.61	0.621118
Cons	2.718	0.4880	5.57	$p \leq 0.001$		
R-squared	0.8658					
Adj R-squared	0.8599					
Prob> F	0.0000					
Mean VIF					1.37	

*, ** indicate 5%, and 1% significance levels

3.9. Mixing pesticides and methods of application (spraying) by farmers in the study area

The survey revealed that 35% of the farmers mixed different pesticides together when spraying while 65% responded otherwise. Most of the farmers (82.1%) who mixed pesticides together during spraying indicated they mixed two different pesticides while the remaining 17.9% mixed three pesticides. A total of 75% of the farmers who mixed pesticides during spraying perceived it was the most effective way to control pests and diseases while the remaining 25% did that to save time and labor. On the other hand, most (56.4 %) of the farmers who did not mix pesticides during spraying indicated they did not do so because of safety reasons since they do not know the chemical constituents. However, 27.6% indicated that not mixing was effective in controlling pests and diseases while the remaining 16% perceived the formulation was effective to control pests and diseases. It was observed that majority of the farmers who mixed pesticides, mixed Confidor (Imidacloprid) and Akatemaster (Bifenthrin) or other pesticides from the open market. The survey revealed that 72.9% of the farmers used blanket-spraying methods on cocoa farms, while the remaining 27.1% used the spot spraying methods.

4. Discussion

It was evident from the results that males dominated cocoa farming in the study area. This could be attributed to the fact that males, mostly household heads traditionally control assets such as land and tree crops than females as reported by (Anang et al., 2013). The labor-intensive nature of cocoa farming might have made it unattractive to females. This finding is in line with the findings of Anang et al. (2013) and Boateng et al. (2014) in Wassa-Amenfi West and Atiwa Districts of Ghana. It was revealed that the cocoa farmers in the study area are old and aging. This has implications for cocoa production in the future as ones' health normally declines with age. The finding also has a negative impact on new technology adoption as older farmers are more likely to stick to their old ways of doing things compared to younger ones. The result is in line with those reported by Anang et al. (2013) and Boateng et al. (2014) which indicated that most cocoa farmers (Wassa-Amenfi West and Atiwa Districts of Ghana) aged 40 years and above.

Byrness and Byrness (1969) have indicated that education enhances one's ability to receive, decode and understand information. Since a greater proportion of the farmers (81.2%) had some form of formal education, it was possible to understand the components of pesticides used to some extent. However, the lower level of education of the farmers probably affected their ability to perform some technical tasks (e.g. calibration of sprayers and measurement) that required some degree of higher education. Anang et al. (2013) and Boateng et al. (2014) reported a similar trend in the educational level of cocoa farmers in Ghana. The results suggest that the literacy rate has improved over the years among cocoa farmers as Dankwa (2001) and Kumi (2003) reported a 50-55% illiteracy rate of cocoa farmers in Ashanti and Eastern Regions of Ghana. The improvement in the educational levels of farmers could be attributed to educational reforms in Ghana.

Most cocoa farmers in the study area had adequate experience in cocoa production. This is in line with the report by Anang et al. (2013) from the Wassa-Amenfi West Districts of Ghana, respectively.

Lass (2004) estimated losses by insect pests and diseases to be 30% of global yields of cocoa annually. Farmers identified mirids insect pests, the black pod disease, and the cocoa swollen shoot virus as the major pest and diseases affecting cocoa yield in the area. This confirms the fact that mirids remain one of the most important economic insect pests in Ghana (Antwi-Agyakwa, 2013). In addition, some respondents reported that rodents were among the pests of cocoa causing pre-harvest losses and this could be attributed to poor maintenance of farms.

Cocoa farmers in the study area purchased pesticides from agrochemical shops/sellers within their communities or nearby communities and fellow cocoa farmers. The finding confirmed the results by Adeogun and Agbongiarhuoyi (2009) in Ondo State, Nigeria, where most cocoa farmers purchased their chemicals from the open market with few obtaining it from cocoa buyers and the Ministry of Agriculture. However, the types of chemicals sold at these sources were not approved by Ghana COCOBOD for cocoa production. In the cocoa industry in Ghana, approved COCOBOD pesticides are not sold in the open market. Farmers can only have access to or benefit from the ''free mass cocoa spraying'' program.

Cocoa farms in the study area were to be sprayed four times in a year, between July and November under the ''free mass cocoa spraying'' program, however, most of the farmers who benefited from the program in the year under review had their farms sprayed only once (Abankwah et al., 2010). It was, therefore, not surprising when farmers who benefited from the program indicted the use of unapproved pesticides as they had to argue the number of spraying. Interestingly, some farmers who benefited from the program believed pesticides in the open market which were not approved for cocoa production by Ghana COCOBOD were more effective than the approved ones. The result of this study is in line with the finding of Anang et al. (2013) who reported that most of the cocoa farmers in the Wassa Amenfi West District of Ghana had their farms sprayed only once under the ''free cocoa mass spraying'' program. In addition, the result support claims that the spraying frequency of the ''free cocoa mass spraying'' program was not adequate and cocoa farmers were expected to do additional spraying (Aneani et al., 2012; Danso-Abbeam et al., 2014). Cocoa farmers in the study area stated they are forced to use unapproved pesticides because the approved pesticides by Ghana COCOBOD are not for sale, hence, are not available in the open market. The high use of moderately hazardous unapproved pesticides poses a health risk to cocoa farmers. According to Tiwari et al. (2011), the intensive use of broad-spectrum pesticides to deal with pest outbreaks may have direct consequences for pest control through the appearance of insecticide-resistant strains, pest resurgence, and secondary pest outbreaks.

The gender of respondents significantly influenced the choice of source of pesticide. This means the probability of male farmers sourcing pesticides from chemical shops is higher than their female counterparts by 0.81%. Thus, female cocoa farmers may prefer to source pesticides from other farmers rather than buying from a chemical shop. The significant influence of the educational level of the farmers on the choice of source of pesticides means farmers with a higher level of education are more likely to source pesticides from chemical shops than those with less or no formal education. Many studies show a positive relationship between the educational level of the household head and the adoption of improved technologies (Lin, 1991; Deressa et al., 2009; Fosu-Mensah et al., 2012). Thus, a year increase in education of farmers will result in

a 0.228 increase in the purchase of pesticides from a chemical shop.

The positive and significant influence of income from the cocoa farm on the choice of source of pesticides implies that the probability of sourcing pesticides from a chemical shop increases with an increase in income from cocoa farming. This means that the farmers who gain more income from the sale of cocoa are more likely to purchase pesticides from a chemical shop. Similarly, an increase in a farmer's age reduces the probability of the farmer to source pesticide from chemical shops. This probably means as farmers age, they lose interest and zeal for updated information on pesticides and are not interested in sourcing pesticides from chemical shops where new information is gained.

Most of the respondents had knowledge of pesticides application rates. Although a majority of the farmers had some form of formal education only a few could read the instructions on pesticides labels due to the technical nature of the instructions on the chemicals. Extension officers were not readily available to farmers and, hence, very few respondents contacted them for help regarding instructions and application rates of pesticides. The observations in this study are, however, contrary to the report by Tijani (2006) where 46% of cocoa farmers and 44% of farmworkers using pesticides obtained knowledge of pesticide application rates from extension agents. Educational level significantly ($p<0.05$) influences knowledge on pesticide application rate. Thus, farmers with higher educational levels are more likely to have knowledge of the pesticide application rate. Maddison (2006), reported that an increase in the educational level of farmers increases their access to information. Similarly, access to extension service significantly ($p<0.01$) and positively influence knowledge on pesticide application rate with the marginal effect of 0.255. A 1% increase in the number of extension services received by farmers increases the probability of farmers' knowledge acquisition on pesticides application rate by 0.225.

Availability of chemical shop significantly ($p<0.05$) influence knowledge on pesticide application rate with a marginal effect of 0.171. This means a 1% increase in the availability of chemical shops in a farming community increased farmers' knowledge acquisition on pesticides application rate by 0.171 as chemical sellers educate farmers on application rates. The probability of a farmer gaining knowledge on pesticide application rate increased with a membership of FBO as members of FBOs are educated on new methods and proper ways of farming. Age was statistically significant ($p<0.01$) but negatively influenced pesticides application rate. Thus, as the age of the farmer increases, they are less likely to adopt new knowledge.

The frequency of pesticides application per season varied widely with an average frequency of application of five (5) times per season. This exceeds the Ghana COCOBOD recommended frequency of pesticide application (i.e. four times per season)

(Adu-Acheampong et al., 2006; Danso-Abbeam et al., 2014) as reported by Denkyirah et al. (2016). The under or over application frequency of pesticides indicates that farmers are not guided by the peak of pest and disease population but rather when they deem appropriate. Some farmers indicated that they spray when they notice pests and diseases on the farm. This is in line with the finding of Denkyirah et al. (2016) and Ntow et al. (2006) in Berekum municipality of Ghana. According to Ntow et al. (2006), increased wash-off by rainfall might have necessitated the further application of pesticides. The results of the study confirm the report by Padi et al. (2000) which stated that field surveys done by COCOBOD in 1997/98 and 1998/99 revealed that out of 1,750 farmers interviewed, only 3.5% of the farmers used the recommended pesticides Under 20 and Gamma BHC at the recommended dosage, time and frequency. This finding is contrary to the report by Aneani et al. (2012) who stated that cocoa farmers in Ondo State, Nigeria sprayed based on recommendations.

The age of a farmer had a positive and significant influence on the frequency of pesticide application. This is in line with Sharifzadeh et al. (2018) but contrary to the finding of Adejumo et al. (2014) who reported that younger farmers are likely to apply pesticides than older farmers. Extension visits decreased the frequency of pesticide application probably due to knowledge gained on the effect of indiscriminate application of pesticide which is in line with the finding of Denkyirah et al. (2016). Similarly, the availability of chemical shops reduced the frequency of pesticide application probably due to education received from agrochemical sellers. In addition, membership of FBO reduced the frequency of pesticide applications due to the education of members on the recommended number of applications per season. This is in line with the report by Denkyirah et al. (2016). Knowledge of COCOBOD recommended pesticide application rates increased frequency of pesticide application. This contradicted the a-priori expectation which indicates that knowledge of COCOBOD recommended pesticide application rate decreased frequency of pesticide application. This might be due to the high incidence of insect infestation due to climate change. Income from cocoa farming increased the frequency of pesticide application as farmers could afford to purchase pesticides. Similarly, the educational level of farmers significantly increased the frequency of pesticide application which is contrary to the a-priori expectation that the educational level of farmers would decrease frequency of pesticide application as they would have gained knowledge on the recommended frequency. This observation might also be due to proliferation of insect pests and diseases on cocoa farms.

It was evident from the study that most of the farmers had in-depth knowledge of the Ghana COCOBOD approved pesticides than the recommended frequency of pesticide application. This result is consistent with the findings of Antwi-

Agyakwa (2013) who reported that cocoa farmers in some cocoa-producing regions in Ghana have adequate knowledge on the Ghana COCOBOD approved pesticides. Farmers who were members of FBOs in the study area were aware of the approved pesticides through their organizations. This is in line with the finding of Tijani (2010) who reported that membership to a cooperate organization by cocoa farmers in Ondo State, Nigeria increased the adoption of a particular pesticide. The non-adherence to the recommended number or frequency of pesticides application per growing season can result in increased chemical residues in harvested cocoa beans as well as pesticide resistance and pest resurgence (Antwi-Agyakwa et al., 2015).

Most of the farmers mixed two or more different pesticides together to control insect pests and disease regardless of their side effects. It was a common practice for farmers to mix pesticides with the same active ingredients but different trade names. A typical example was lambda-cyhalothrin groups, and this was a clear misuse of pesticides that could affect the health of farmers and the environment. The practice defies some of the basic principles of insecticides management (Ntow et al., 2006). The mixing of insecticides generally results in simultaneous development of resistance. These results, however, contradict the report by Georghiou (1980) which indicated that such practice helps to manage pesticides resistance.

5. Conclusion

Cocoa farmers in the study area used unapproved pesticides for the control of insect pests and diseases on cocoa farms. Farmers sourced pesticides from agrochemicals shops and fellow farmers, with some benefiting from the Government of Ghana's "free mass cocoa spraying'' program. Most farmers had knowledge on pesticides application rates, with the main source of knowledge or information coming from chemical sellers. The limitation of this research is the inability to carry out the survey in other cocoa-growing districts within the study region. Based on the findings of this study, the Ghana COCOBOD should make the approved pesticides readily available and affordable in agrochemical shops across Ghana for easy access by farmers. Regular training of farmers on the safe use of pesticides by Ghana COCOBOD is also recommended. Similarly, the recommended frequency of pesticides application should be enforced and monitored to reduce over or under spraying to prevent environmental pollution.

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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