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Assessment of the Use and Application of Pesticides by Cocoa Farmers in Ghana

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Abstract Sustainability of cocoa farming is critical in the quest to improve the livelihood of Ghanaians. Though pesticides are needed in cocoa farming, their misuse can lead to health and environmental risks. The respondents' preference for specific pesticides, where they were obtained and how frequently they were used were assessed. Protection methods used during spraying, and the potential adverse impacts of the pesticides were determined. Data was obtained from 250 randomly selected respondents through pretested questionnaires, observations and discussions. The probit regression model, ordinary least square approach and total environmental impact quotient (EIQ) values were used to analyse the data. The respondents assessed pesticides from agrochemical stores and their colleagues. Data obtained from the respondents which included age, gender, educational status, years of farming, contact with extension workers, availability of agrochemical store, income from cocoa and membership of farmer-based organizations had varied influences on the choice of source of pesticides, frequency and the rate at which pesticides were applied. Chlorfenvinphos (60.03) and Glyphosate (13.85) had the highest and lowest total EIQ values respectively. Approved pesticides, Imidacloprid (Confidor) and Bifenthrin + Imidacloprid (Galil), and unapproved pesticides, Acetamiprid + Chlorfenvinphos (Buffalo-super) and Chlorfenvinphos (Buffalo) have the potential to adversely affect the environment. There was poor use of personal protective equipment among the farmers. The study suggests that Buffalo and Buffalo-super pesticides (highly hazardous) which were in the high impact category ought to be out-of-use. This study was carried out in the study region excluding other cocoa growing districts. Safe pesticide use should be enforced and monitored in the study area.

Keywords Cocoa Farmer, Pesticide Handling, Impact, Safety

1. Introduction

Commercial cultivation of cocoa in Ghana assumed bigger dimensions by the beginning of the nineteenth century [1]. Countries in the West African sub-region produce more than half of the world's cocoa [2]. Côte d'Ivoire and Ghana are the two top producers of cocoa in the world, with Côte d'Ivoire producing more than twice the volume produced by Ghana [1,3]. About 850,000 farm families are involved in cocoa farming in Ghana; and the sector contributes about 2 billion dollars to GDP annually [4]. However, the sector faces problems including unsustainable production system, poor management of soil fertility, the existence of old trees, pests and diseases, and variable weather conditions [1,5].

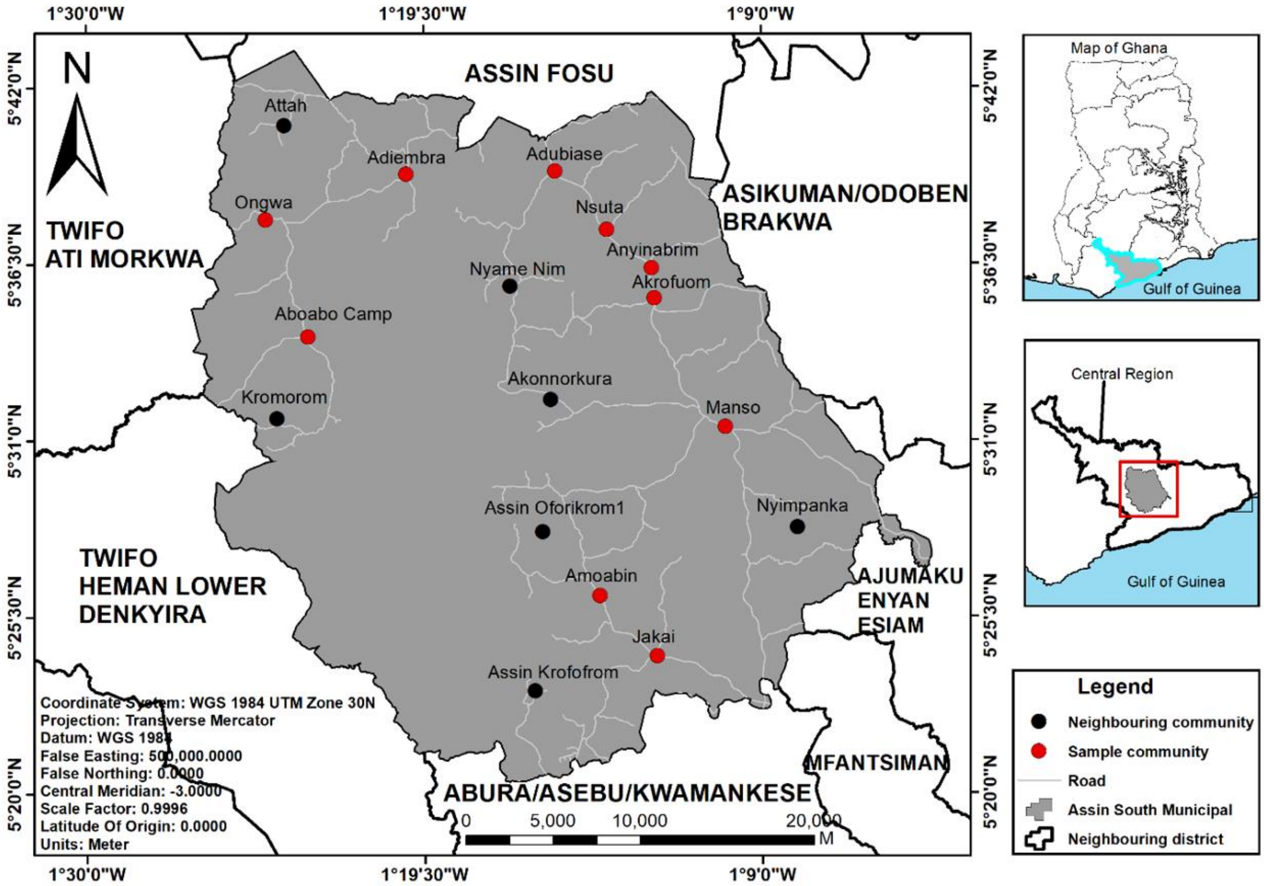
The control of pests and diseases is critical for crop production [6]. Cocoa farming in Ghana covers approximately 2.7 million hectares of land [7] and the quest to increase cocoa production has culminated in the Ghana government's policy of "mass cocoa spraying" in all the cocoa growing areas. In addition to the "mass cocoa spraying" policy, some farmers across Ghana use other unapproved pesticides hoping to obtain better yield and returns. Pesticides when applied appropriately do not pose significant risks; thus, the usage [8] can be minimized considerably if done in line with approved guidelines and categorization. The maintenance of environmental sustainability should be a priority in the attempt to use pesticides in agriculture for maximum yield returns. As noted by some authors [9], pesticide risk constraints the achievement of sustainable development goals. Pesticide use in agriculture is often associated with unseen consequences. These issues include habitat and water contamination, and ecosystem disruption [10,11]. The impact of a pesticide on the environment is influenced by the dosage, time of exposure, and prevailing climatic characteristics and conditions [8,12,13]; and there is a need to discuss the application methods, the routes of exposure and the health risks posed by pesticide application [13]. Indicator models which incorporate environmental and health risks assessment have been used to assess impacts of pesticides [13,14]. A typical indicator model, the EIQ model [15], is used to determine impacts of pesticides in agriculture. Moreover, its use is relatively economical and suitable for developing countries like Ghana as a major source of baseline studies for the sustainability of the environment and cocoa production.

Various researchers have raised environmental and health safety concerns when pesticides are used on crops [8,16,17,18]. Following pesticide application in cocoa plots, some studies show that residues have been left in cocoa beans, soil and water resources in cocoa farms in West African countries including Ghana [19,20]. To help regulate pesticide use and distribution, Ghana Cocoa Board (COCOBOD) insists on the registration of pesticides [21]. What is lacking is effective monitoring to check pesticide misuse, misapplication and human exposure levels. The three main forms of pesticides (insecticide, fungicide and herbicide) used in cocoa farming in Ghana were assessed to determine their potential adverse impacts. The study also assessed the types, sources, knowledge on load limits of pesticides on a site (application rate) and factors that tend to influence the choice of pesticides used by the farmers.

2. Materials and Methods

2.1. Study Area

Assin South District is situated at 5º 3" degrees north (latitude) and 1º 2" degrees west (longitude). The district is bounded on the west, south, east and north by the following districts; Twifo Hemang Lower Denkyira, Abura Asebu Kwamangkese, Asikuma Odoben-Brakwa and Ajumako Enyan-Essiam, and Assin North Municipality respectively (Figure 1). The total land mass is 1100,89650 km^2 and the vegetation cover is mainly forest (evergreen and semi-deciduous). There are five forest reserves namely, Ayensua, Krotoa, Apeminim, Attendansu and Kakum. The annual mean temperature falls between 20 ℃ and 30 ℃, rainfall is between 1250 mm to 2000 mm and humidity ranges between 60 percent and 70 percent. The topography has a shape like a wave with frequent changes in elevation at different points with a mean height of 200 m. The Assin South District is drained by rivers including Kakum, Wanko, Ochi and Kyina [22].



Source: Geography and Regional Planning Department, University of Cape Coast

Figure 1. Map of Assin South District showing the sampled communities

2.2. Data Collection

The study was done between October, 2021 and September, 2022 covering the 2022 cocoa growing season. Ten out of the twenty major cocoa growing communities in the district were randomly selected for the study. The communities were Adiembra, Ongwa, Aboabo camp, Adubiase, Nsuta, Akrofuom, Anyinabrim, Jakai, Amoaben and Manso. A simple random technique was used to select 25 farmers in each community, making a total of 250 farmers. The communities for this study were selected in consultation with the district cocoa farmers association and the COCOBOD office.

Data collection was done using a pre-tested semi-structured questionnaire, focus group discussions (FGDs) with farmers in each community; and observations made during the study. Data on pesticides commonly applied, where they were obtained from, and what convinced the respondents to use these pesticides were obtained. In addition, records on the frequency and rate of pesticide application, and safety measures used during spraying of the pesticides were also obtained. The active ingredients, formulation, composition, quantity and application rates of the pesticides were obtained from the pesticide labels.

2.3. Data Analysis

EIQ Equation

The formula for estimating the EIQ value of each pesticide was based on the equation developed by [23]. The values in the EIQ equation were derived by searching through databases including NPIRS (National Pesticide Information Retrieval System), PHED (Pesticide Handlers Exposure Databases), TOXNET (Toxicological Data Network), IRIS (Integrated Risk Information System), ECOTOX (Ecotoxicological Database), Toxicological Profiles, use of toxicological data from United State of America's Environmental Protection Agency, and pesticides EIQ website (http://nysipm.cornell.edu/publications/eiq/) at Cornell University [23,24]. Chemically similar products belonging to the same WHO hazard class [25] were used to obtain some active ingredients of pesticides in this study. According to the classification of impacts by [24,26] EIQ values in the ranges 0 - 20, 21-40, and ≥ 40 are assigned as low, medium and high impact respectively. The use of EIQ field rating is more beneficial in comparing environmental impacts of different pesticides [27]. However, the information needed to calculate this value could not be provided by the farmers. Thus, total EIQ was employed to investigate the impacts.

The regression analysis and determination of mean responses were done using STATA version 13. The frequency of pesticide application was determined using the Ordinary Least Square (OLS) approach. What informed the source and the rate at which the pesticides were applied were determined using the probit regression model [28]. The model has a dichotomous dependent variable (outcome) which is categorical and can only take on one of the two values, such as 'yes'(1) or 'no'(0). The predictor variables are the continuous variables. Consequently, the probability of any outcome will be known [28]. Also, the difficulty associated with heteroscedasticity is eliminated [29,30]. Thus, the continuous (predictor) variable (Y_i^*) determines the value of the dependent (outcome) variable (Y_i) [31,32]. The probit regression model has been used to measure how individual farmer's subjective feeling influences how the farmer applies pesticides in tea farms [33], as well as measuring rice farmers' pesticide overuse practice [34] in China.

In this model:

$$Y_i^* = \check{I}_0 + \check{I}_1 X_{1i} + \check{I}_2 X_{2i} + \ldots + \check{I}_n X_{ni} + Ui \qquad (1)$$

Outcome variable (Y_i) = 1 if the predictor variable (Y_i^*) > 0

Where:

Yi = vector of explanatory variables

Ǐ = vector of unknown parameters

U = random disturbance term

The probit regression model used is specified below:

$$Y = \check{I}_0 + \check{I}_1 X_1 + \check{I}_2 X_2 + \check{I}_3 X_3 + \check{I}_4 X_4 + \check{I}_5 X_5 + \check{I}_6 X_6 + \check{I}_7 X_7 + \check{I}_8 X_8 + \check{I}_9 X_9 + U \qquad (2)$$

Where:

Y = dependent variable representing choice of pesticide source;

knowledge on application rate;

Ǐ0 = coefficient of the constant term;

Ǐ1- Ǐ9 = coefficient of the independent variables;

β1-β9 = explanatory variables;

U = error term

Definitions of Explanatory variables used in this study are:

β_1 = gender (1= male, 0 = female);

β_2 = age (in years; continuous variable);

β_3 = educational status (1 = no formal education, 2 = basic, 3 = Secondary, 4 = Tertiary)

β_4 = years in farming (in years; continuous variable);

β_5 = contact with extension officer (1 = contact, 0= no contact);

β_6 = associate of FBO (1 = associate, 0 = otherwise);

β_7 = proximity to agrochemical store (1 = near, 0 = otherwise);

β_8 = farm size (acres; continuous variable);

$\beta_{9\,=}$ income from cocoa (in cedis; continuous variable)

3. Results

3.1. Demographic Profile of the Respondents

The demographic profile of the respondents showed that 80.8 % were males while 19.2 % were females (Table 1). Cocoa farming in the area is dominated by people in the age bracket of 39-59 years (61.2 %). Farmers above 60 years formed 21.6 % while farmers in the age bracket (28-38 years) constituted 7.2 % of the farmer's population. The age of the oldest respondent was 80, and the mean age of the respondents at the time of this study was 53 years. The distribution in terms of formal education was 4.0 % educated to the tertiary level, 28.8 % up to secondary and 44.8 % at the basic level. Illiteracy among the farmers was relatively moderate as 22.8 % had no formal education. Two hundred and forty-one farmers (96.4 %) had 11 or more years- experience in cocoa farming.

Table 1. Demography of respondents used for the study

Variable	Category	Frequency (%)
Gender	Male	202 (80.8)
	Female	48 (19.2)
Age (years)	28-38	18 (7.2)
(mean= 53 years)	39-49	80 (32.0)
	50-59	98 (39.2)
	Above 60	54 (21.6)
Educational status	Lack of formal education	57 (22.8)
	Basic	112 (44.8)
	Secondary	71 (28.4)
	Tertiary	10 (4.0)
Number of Years in farming	6-10	9 (3.6)
(mean= 20.3 years)	11-15	31 (12.4)
	16-20	68 (27.2)
	21-25	65 (36.0)
	Above 25	77(30.8)

3.2. Types and Sources of Pesticides

The respondents applied 25 types of chemical pesticides, consisting of 6 approved and 19 unapproved, on their farms. The insecticides were 15 (60.0 %), 4 (16.0%) were fungicides, 3 (12.0 %) were herbicides and 3 (12.0 %) were broad spectrum pesticides (Table 2). Imidacloprid (Confidor) 68.8 %, Bifenthrin (Akate master) 64.8 %, Imidacloprid + Bifenthrin (Galil) 51.6 %, and Acetamiprid + Chlorfenvinphos (Galil) 50.4 % were mostly used by the farmers (Table 2). From the data, pesticides were mainly sourced from agrochemical stores (75.45 %) and from other cocoa farmers (14.63 %). The dominant factors influencing the selection of pesticides by the farmers were pesticide effectiveness in controlling cocoa pests and diseases (46.1 %), availability in the market (25.2 %), recommendation from extension officers and colleague farmers (16.9 %) and affordability (11.8 %). In the year under review (2021/2022), some farmers benefited from Ghana COCOBOB's "free mass cocoa spraying programme" where COCOBOB-approved pesticides were used. Farmers whose farms were not sprayed four times during the exercise, and those whose farms were not visited during the exercise, had to purchase pesticides from the market to augment the spraying of their farms. A total of 70 % of the farmers invariably used unapproved pesticides.

3.3. Factors Controlling Farmer's Decision to Choose Pesticide from a Source

From the results (Table 3), the number of years in farming and belonging to FBO significantly ($p<0.5$) influenced the decision by farmers to align to a source for pesticides. However, the effect occurred in the negative direction. Though contact with extension officers, educational status, income from cocoa and presence of agrochemical stores had positive effects on the decision by farmers to adopt a source for pesticides, they occurred at different significant levels. Income from cocoa occurred at ($p<0.01$), educational status, contact with extension officers and presence of agrochemical store at ($p<0.05$). Age, gender and farm size of the respondents did not influence the choice of source of pesticide.

Table 2. Types of pesticides applied by respondents

Active ingredient	Common name	Usage	Chemical family	Respondents (%)
Acetamiprid + Chlorfenvinphos	Buffalo-super	B	Neonicotinoids+ Organophosphate	126 (50.4)
Aldrin	Argine	B	Organochlorine	36 (14.4)
Alpha-Cypermethrin	Fastrack	I	Pyrethroid	19 (7.6)
Bifenthrin	Akate master*	I	Pyrethroid	162 (64.8)
Chlorfenvinphos	Buffalo	I	Organophosphate	113 (45.2)
Copper Hydroxide	Fungikill	F	Inorganic	52 (20.8)
Copper Hydroxide	Funguran*	F	Inorganic	58 (23.2)
Deltamethrin	Butox	I	Pyrethroid	46 (18.4)
Diazinon	Akate suro	I	Organophosphate	46(18.4)
Endosulfan	Thiodan	I	Organochlorine	39 (15.6)
Fenvalerate	Sumitox	I	Pyrethroid	26 (10.4)
Glyphosate	Adwuma-wura	H	Organophosphate	39 (15.6)
Glyphosate	Condemn	H	Organophosphate	12(4.8)
Imidacloprid	Confidor*	I	Neonicotinoids	172 (68.8)
Imidacloprid	Consider Supa	I	Neonicotinoids	17(6.8)
Imidacloprid	Consider	I	Organophosphate	43 (17.2)
Imidacloprid + Bifenthrin	Galil*	I	Neonicotinoids +Pyrethroid	129 (51.6)
Lamda-Cyhalothrin	Lamtex	I	Pyrethroid	55 (22.0)
Lamda-Cyhalothrin	Kombat	I	Pyrethroid	57 (22.8)
Lamda-Cyhalothrin	Lamda	I	Pyrethroid	51 (20.4)
Metalaxyl	Ridomil*	F	Acylamines	75 (30.0)
Paraquat	Weed-off	H	Bipyridyl	25 (10.0)
Permethrin	Super 10	B	Pyrethroid	67 (26.8)
Thiamethoxam	Akate power*	I	Neonicotinoids	101 (40.4)
Thiophanate-Methyl	Topsin-M	F	Benzimidazole	19 (7.6)

H= Herbicide, F=Fungicide, I= Insecticide, B= Broad spectrum, * Approved pesticide

Table 3. Results of probit analysis on decision to source pesticides

Category	Coefficient	Significance	Instantaneous rate of change
Age	0.0351	0.1610	0.0082
Chemical store	0.3132	0.0450*	0.1303
Income from cocoa	0.1124	0.0031**	0.0320
Educational status	0.0582	0.0422*	0.3611
Extension access	0.5303	0.0373*	0.1476
Farm size	0.2187	0.4625	-0.1152
Years in farming	-0.1169	0.0491*	-0.2251
FBO	-0.2860	0.0402*	-0.0085
Gender	0.4131	0.1274	0.2360
Constant	-1.7142	0.0420*	
Model Diagnostics			
LR Chi square	76.94		
Prob > Chi square	0.1121		
Pseudo R square	0.2440		
Log Likelihood	-125.38		

*= 5% significance level; ** = 1% significance level

3.4. Farmers' Knowledge on Loading Limits of Pesticides on a Site

From the probit regression results (Table 4), the presence of agrochemical stores and the educational status of respondents had a strong ($p<0.05$) influence on farmers' knowledge of the loading limit of pesticide on a site and hence farmer's decision, while contact with extension officer had very strong ($p<0.01$) influence on farmers understanding of loading limits of pesticides on a site. Belonging to FBOs also had a strong ($p<0.05$) influence on knowing the application rate of pesticides but in the negative direction. However, age and number of years in farming did not sway the farmers on knowing the loading limit of pesticides on their farms.

Table 4. Factors affecting how farmers decide on loading limits of the pesticides on a site

Category	Coefficient	Significance	Instantaneous rate of change
Age	0.0653	0.2120	0.2125
Chemical store	0.5205	0.0312*	0.2820
Contact with extension officer	0.1596	0.0023**	0.1478
Educational status	0.1231	0.0481*	0.3201
FBO	-0.2920	0.0320*	-0.1674
Years in farming	0.3167	0.1216	0.2449
Constant	-0.1462	0.0173*	
Model Diagnostics			
LR Chi Square	67.13		
Prob > Chi square	0.1014		
Pseudo R square	0.2159		
Log Likelihood	-121.15		

*= 5% significance level; **= 1% significance level

3.5. Factors Influencing How Often Pesticides were Applied

The presence of agrochemical stores, contact with extension officers and the number of years in cocoa farming strongly ($p<0.05$) affected how often pesticides were used, while a farmer's membership of FBO very strongly ($p<0.01$) influenced how frequently pesticides were applied (Table 5). On the other hand, age, gender, farm size, income from cocoa and educational status did not affect the decision of farmers on how often to use pesticides.

Table 5. Ordinary least square regression on how often pesticides were used in the study area

Category	Coefficient of determination	Regression standard	Matrix transpose (t)	p-value	VIF	1/ VIF
Age	0.2049	0.387	6.77	0.166	2.43	0.4115
Chemical store	0.4906	0.0927	2.6325	0.0381*	1.98	0.505
Income from cocoa	1.102	0.3224	4.8133	0.2796	2.19	0.4566
Educational status regression diagnostics	0.4503	0.2611	3.1687	0.4873	1.63	0.6134
Extension officer contact	-0.459	0.2925	-4.3752	0.0028*	1.77	0.5649
Farm size	1.0001	0.1599	1.2266	0.5614	2.54	0.3937
Years in farming	0.6018	0.1048	3.5304	0.0382*	1.87	0.5347
FBO	0.9016	0.426	5.4123	0.0061**	1.6	0.625
Gender	0.3337	0.3124	1.8291	0.0782	2.65	0.3773
Cons	3.0022	0.569	4.998	0.0045**		
Prob > F	0.1143					
R-squared	1.0022					
Adjusted R-squared	0.9979					
Mean VIF					2.07	

Table 6. Pesticides and their total EIQ values in the study area

Category	Active ingredient	EIQ total	WHO hazardous class	Impact category
Lamda	Lamda-Cyhalothrin	19.8	II	Low
Funguran*	Copper Hydroxide	19.45	II	ii
Fungikill	Copper Hydroxide	18.33	II	ii
Butox	Deltamethrin	15.93	II	ii
Fastrack	Alpha-Cypermethrin	15.85	II	ii
Ridomil*	Metalaxyl	15.33	II	ii
Adwuma-wura	Glyphosate	17.47	III	ii
Condemn	Glyphosate	13.85	III	Low
Sumitox	Fenvalerate	39.85	II	Medium
Akate suro	Diazinon	38.4	II	ii
Lamtex	Lamda-Cyhalothrin	33.6	II	ii
Consider	Imidacloprid	33.2	II	ii
Akate master*	Bifenthrin	32.58	II	ii
Combat	Lamda-Cyhalothrin	29.2	II	ii
Weed-off	Paraquat	26.85	II	ii
Super 10	Permethrin	26.33	II	ii
Akate power*	Thiamethoxam	37.33	III	ii
Topsin-M	Thiophanate-Methyl	36.45	III	ii
Argine	Aldrin	24.66	III	ii
Consider supa	Imidacloprid	22.15	III	Medium
Buffalo	Chlorfenvinphos	60.03	Ib	High
Buffalo-supa	Acetamiprid-Chlorfenvinphos	48.06	Ib	ii
Confidor*	Imidacloprid	49.63	II	ii
Galil*	Imidacloprid+ Bifenthrin	50.12	II	ii
Thiodan	Endosulfan	44.2	II	High

1b= highly hazardous; II= moderately hazardous; III= slightly hazardous; * Approved pesticides; [59,60].

3.6. Total EIQ values and Impact Categories of Pesticides Used by the Farmers

Out of the 25 pesticides used by the farmers, 6 (24.0 %) were approved by the Ghana COCOBOD and 19 (76.0 %) were unapproved. A total of 60.0 % of the pesticides used are moderately hazardous, 24.0 % fall in the slightly hazardous and 8.0 % into the highly hazardous category (Table 6). Pesticides with relatively higher EIO values included Buffalo (Chlorfenvinphos) 60.03, Galil (Imidacloprid + Bifenthrin), 50.12, Confidor (Imidacloprid) 49.63, and Buffalo-super (Acetamiprid + Chlorfenvinphos) 48.06. The pesticides with relatively low EIQ values included Condem (Glyphosate) 13.85, Ridomil (Metalaxly) 15.33, and Fastrack (Alpha-Cypermethrin) 15.85 and Butox (Deltamethrin) 15.93. Results on the impacts of pesticides revealed that the majority were in the medium category (48.0 %) followed by the low impact (32.0 %) and high impact (20.0 %) respectively. Three of the unapproved pesticides, Buffalo (Chlorfenvinphos), Buffalo-super (Acetamiprid + Chlorfenvinphos) and Thiodan (Endosulfan) were in the high impact categories. Galil (Imidacloprid + Bifenthrin) and Confidor (Imidacloprid) are approved pesticides and in the high impact category (Table 6).

3.7. Farmer's Handling and Application of Pesticides

The majority (57.6 %) of the respondents failed to use appropriate measures (googles, rubber gloves, wellington boots, nose masks, overall, hats etc.) to protect themselves during pesticide handling and application while 42.4 % adhered to safety measures by using PPEs (Table 7). The study showed that 60 % of the farmers had their meals before spraying, 27.2 % after application and 12.8 % ate their meals in the middle of the application. The data revealed that some of the farmers (52 %) cleaned their hands while others (48 %) did not, before eating. The majority of the respondents (58.8%) applied their pesticides before harvest, 39.6 % applied after harvest and only 1.6 % applied their pesticides close to the time of harvest. A relatively smaller number of farmers (32.4 %) had information on their pesticides from the labels while 67.7 % did not read the labels.

4. Discussion

4.1. Demographic Profile of Studied Area

The profile of the respondents (Table 1) indicates the dominance of males since they are traditionally in charge of households and are required to hold in trust all assets of the family. Moreover, females are less attracted to cocoa farming because it is labour intensive. This observation is in line with works done by some researchers in Ghana [20,35,36,37] and in other African countries [38]. Data from the study reveals an ageing farmer population which is not conducive for the sustenance of cocoa farming in the area. This showed that the youth were not much involved in cocoa farming, and the adoption of new technologies for farming would be adversely affected. This finding confirms earlier works done in Ghana [35,39,40] which showed that most cocoa farmers were aged 43 years and above. However, there is a possibility that this trend in the study area may change in the next few years. As a result of the introduction of the government of Ghana's new and attractive programme, "Planting for Food and Jobs", the youth may go into cocoa farming.

Table 7. Safety measures employed by the cocoa farmers during pesticide application

Variable	Category	Frequency (%)
Equipment for protection	Used	106 (42.4)
	Not used	144 (57.6)
Cleaned hands before meals	Yes	130 (52.0)
	No	120 (48.0)
	Preceding application	150 (60.0)
Period farmers took meals	At time of application	32 (12.8)
	Post application	68 (27.2)
	Preceding harvest	147 (58.8)
Time of application of pesticides	Near to harvest	4 (1.6)
	Post harvest	99 (39.6)
Information on pesticides from labels	Yes	81 (32.4)
	No	169 (67.6)

Generally, educating an individual tends to improve the person's knowledge, skills and reasoning effectiveness [41], and this probably influenced the adaptive capacity of the respondents [42] since 77.2 % of them were educated. About 67.6 % of the respondents had only basic education or no formal education which adversely affected their ability to perform certain activities such as reading and understanding pesticide labels. However, the relatively good educational status of respondents confirms studies conducted by other researchers indicating improvement in the literacy rate among some cocoa farmers in Ghana [20,43]. The majority of the respondents had an appreciable number of years in cocoa farming (Table 1), corroborating the work done by [44] in Wassa-Amenfi West District of Ghana. However, in a study in Ghana, the majority of the respondents had spent less than 20 years in cocoa farming [36]. Agrochemical stores and colleague respondents being the main sources for the acquisition of pesticides confirmed works done in Ghana [45] and Nigeria [46].

The implication is, younger people who are comparatively educated are not attracted to cocoa farming in the study area. Measures should be put in place to recruit and retain young people in cocoa farming. COCOBOD should encourage young people to join the Tree Crops section of the Government's flagship programme, Planting for Food and Jobs.

4.2. Factors Influencing Where Farmers Obtain Pesticides

The number of years spent in farming and association with FBOs strongly ($p< 0.05$) influenced where farmers obtain their pesticides but in the negative direction (Table 3). This probably means as farmers acquire more years in farming and establish longer associations with FBOs, they are not inclined to source pesticides from agrochemical stores, with its accompanying loss of information on pesticides often provided by these chemical vendors. Earlier, researchers who worked on better ways of controlling the distribution and use of pesticides through registration in Ghana, indicated that the number of years spent in cocoa farming significantly influenced the attitude of the respondents [21]. Income from cocoa farming influenced very strongly ($p<0.01$) and in the positive direction where farmers obtain their pesticides. This probably indicates that enhancement of income of farmers corresponds to higher patronage of agrochemical stores for pesticides. The educational status of respondents affects strongly ($p<0.05$) where they source for pesticides. The more educated ones will probably visit agrochemical stores when in need of pesticides. A study on factors affecting technology adoption by operators in the agriculture sector revealed that the educational status of users (eg. Farmers) is critical [47]. From this study, if the educational status of a farmer is increased by one year, it will lead to a 0.361 increase in the sourcing of pesticides from agrochemical stores. Farmers' contact with extension officers and the presence of agrochemical stores strongly ($p<0.05$) swayed the farmers to obtain pesticides mainly from agrochemical stores, confirming earlier findings on cocoa [16,54]. The variation in the number of times cocoa farms that were sprayed by COCOBOD in the study area, greatly influenced the purchase of unapproved pesticides. Thus, the farmers sprayed their farms three to four times using unapproved pesticides. This observation confirmed the findings in earlier studies in Ghana and elsewhere [45,46].

Cocoa farming in the study area is currently dominated by older people and these experienced farmers are presently not purchasing pesticides from agrochemical stores, Thus, COCOBOD should find suitable ways to engage and transmit appropriate information to influence experienced farmers to obtain pesticides from agrochemical stores.

4.3. Factors Influencing How Farmers Decide on Loading Limits of Pesticides

The study revealed that most of the farmers had an appreciable understanding of the rate at which pesticides should be applied, and a relatively good educational status. The fact that the appreciable educational status of the farmers did not reflect in the reading of pesticide labels was probably due to the technical nature of the instructions on the labels. Belonging to FBOs had a strong ($p<0.05$) influence on farmers' understanding of the rate of application of pesticides but in the negative direction. This probably indicates longer period of association with FBOs does not inure to the benefit of farmers, as they assume they know enough and would make their own decisions.

The presence and availability of agrochemical stores strongly ($p< 0.05$) influenced farmers' understanding of the rate at which pesticides are applied, with the instantaneous rate of change (marginal effect) of 0.382 (Table 4). Thus, a 1 % improvement in the availability and access to agrochemical stores, increases farmer's knowledge on acquiring pesticides application rates by 0.382, since agrochemical vendors often educate farmers on application rates. The educational status of respondents had a strong ($p< 0.05$) effect on the understanding of the rate at which pesticides are applied, confirming work done earlier in cocoa farms [36,45]. The study showed that access to extension service positively and very strongly ($p< 0.01$) affected farmer's understanding of the rate at which pesticides are applied. In this study, a 1 % improvement in the services provided by these officials enhances the probability of farmers' acquiring knowledge on pesticide application rates by 0.447. Studies conducted earlier in Ghana indicated that extension agents greatly enhanced cocoa farmers' knowledge of pesticide application rates [36,45,48].

These observations imply that farmer's accessibility to agrochemical stores and extension officers should be strengthened further however, FBOs and other farming groups need training to provide effective and desired information to influence farmer's decisions on the application rate of pesticides.

4.4. Pesticide Used and their Potential Environmental and Health Impacts

The most common pesticides used were the insecticides, Imidacloprid (Confidor) 68.8 %, Bifenthrin (Akate master) 64.8 %, and Imidacloprid + Bifenthrin (Galil) 51.6 % (Table 2). This could be due to their effectiveness in controlling insects especially mirids; and are also approved by Ghana Cocoa Board (COCOBOD). This observation confirms studies done in Ghana and Nigeria [36,46,48,49]. There was high use of unapproved pesticides (Table 6) with the farmers citing reasons including; unapproved pesticides being readily available, affordable, and effective. Moreover, the approved ones are generally not available in the chemical stores. This finding is in line with works done earlier [45,50]. However, the use of unapproved pesticides can lead to increased and unintended negative environmental impacts [36]. Two unapproved pesticides which are in the highly hazardous class were used by a lot of the farmers. Acetamiprid + Chlorfenvinphos (Buffalo-super) and Chlorfenvinphos (Buffalo) were used by 50.4 % and 45.2 % of the farmers respectively (Tables 2 and 6). Moreover, these pesticides fall in the high impact category in the present study and could pose environmental risks in the study area if not effectively monitored and probably banned. EIQ helps with the selection of safer pesticides which are not likely to cause environmental and health risks [52,53]. The use of herbicides and fungicides (Table 2) was relatively low in the study area probably due to cultural practices employed by the farmers to control weeds and fungi. Nigerian cocoa farms traditionally use insecticides, fungicides and herbicides as the main forms of pesticides [51]. Though only 12.0 % of the farmers used broad spectrum pesticides, their continuous use may facilitate secondary pests' outbreaks. Confidor (Imidacloprid) and Galil (Bifenthrin + Imidacloprid) are approved pesticides however, their current status in the study area (Table 6) indicates they may pose environmental and health risks if they are not monitored.

Indications from this section show that both approved and unapproved pesticides are being abused. The COCOBOD should educate the farmers to move away from the notion that applying more of the approved pesticides ensures better yield. The routes for acquisition of unapproved pesticides, especially highly hazardous ones, should be curtailed; and replaced with a timely provision of enough approved pesticides in the area.

4.5. Measures Used by Farmers during Handling and Spraying of Pesticides

Cocoa farmers in Ghana have been encouraged to wear protective personal equipment (PPE) as a safety measure. The majority of the farmers (57.6 %) did not use PPEs, mishandled the application process or exhibited poor habits during pesticide application. This observation could be due to a poor understanding of the possible negative effects of pesticides. This finding corroborated other studies done on cocoa farms [54,55]. In this study, 57.6 % used PPEs and 42.4 % did not. This observation agrees with the findings of researchers who indicated that 58 % of cocoa farmers did not use PPEs; and in the other study, 45 % of the cocoa farmers used partial PPEs while 20 % did not wear PPEs [20,54]. Some of the farmers complained about blurring of googles with moisture during spraying which impaired their vision, and the difficulty of using PPE like noise masks and rather preferred use of a rag and scarf as a nose cover. Some hardly wore hand gloves and argued that the protection from the use of PPEs was not sufficient, and that not using them was far better. These findings confirm studies done earlier [56,57,58]. Moreover, some of the farmers break from spraying to eat their food or eat immediately after spraying (Table 7), sometimes without washing their hands; corroborating studies done on cocoa farms [20,36]. The farmers were not aware that pesticide application could leave residues on their food. From the study, knowledge gained by the farmers on the need to use PPEs from extension officers and by virtue of their membership of FBOs, did not translate into practice confirming findings from other studies on cocoa farms [58].

There is poor use of PPEs in the study area. The COCOBOD should educate the farmers on the dangers of not using PPEs and as much as possible avoid direct contact with pesticides during spraying and eating.

4.6. Minimizing Risks from Chemical Pesticide Use in the Study Area

The Government of Ghana through COCOBOD should build the capacity of farmers and encourage them to join Farm Based Organizations (FBOs) and other approved farm groups where the farmers can be trained as a group in the handling and use of chemical pesticides. The contact period between cocoa extension officers and farmers should be enhanced to allow the officers to impact more knowledge on current issues concerning the use of pesticides on cocoa farms and monitor the cultivation practices adopted by the cocoa farmers. The Government's “mass cocoa spraying exercise” should cover all the farmers; and complete application (four times in a cocoa season) would help reduce the use of unapproved pesticides in the study area. Farmers who adhere to the use of only approved pesticides from COCOBOD should be rewarded at organized durbars to encourage other colleague farmers. The use of indigenous cultural control methods which is already being practiced by a section of the farmers, must be intensified and supported to form part of integrated pest management in the area. Challenges identified by the farmers including, lack of farm implements, labour cost and notably the unavailability of *Azadiractha indica* A. Juss. (most often employed for cultural control of pests in the area) should be addressed by the Government to help reduce risks from chemical pesticide use. Monitoring by COCOBOD officials should be regular and intensified.

5. Conclusions

This study revealed that the respondents applied 25 pesticides of which only 6 were approved. There was poor use of personal protective equipment among farmers in the study area during the handling and spraying of pesticides. The farmers obtained their pesticides from COCOBOD free spraying, colleagues and agrochemical stores. The respondents had information on the loading limits of pesticides on a site (application rate) mainly from extension officers and agrochemical vendors. Approved pesticides, Imidacloprid (Confidor) and Bifenthrin + Imidacloprid (Galil), and unapproved pesticides Acetamiprid + Chlorfenvinphos (Buffalo-super) and Chlorfenvinphos (Buffalo) have the potential to adversely affect the environment. The use of the above unapproved pesticides which are highly hazardous and in the high impact category should probably be banned from the study area. Although a lot of the farmers claimed enough knowledge on pesticides, it did not reflect in the handling and spraying of pesticides. Ghana COCOBOD should educate and explain current issues about pesticides to stakeholders, enforce safe pesticide use and implement effective monitoring of pesticides in the study area.

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Conflict of Interest

The author declares that there is no competing interest either financially or by personal association regarding the publication of this paper

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