UNIVERSITY OF CAPE COAST

THE STATE OF PESTICIDE USE AMONG COCOA FARMERS IN VOLTA REGION OF GHANA

RICHARD KODJO KOSIVI

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BY

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A Thesis submitted to the Department of Environmental Science of the School of Biological Sciences, College of Agriculture and Natural Sciences, University of Cape Coast, in partial fulfilment of the requirements for the award of a Master of Philosophy (M.Phil.) degree in Environmental Science

OCTOBER 2020

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this University or elsewhere.

Candidate's Signature………………………… Date…………………………

Name: ....

Supervisors' Declaration

I hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast, Cape Coast, Ghana.

Principal Supervisor's Signature……………………..........

Date…………………………………………………………

Name: ....

ABSTRACT

The main objective of this study was to assess knowledge, attitude and practices with respect to pesticide usage, alternative pest control methods and associated risks among cocoa farmers in the Volta region. A multi-stage sampling procedure which included purposive and simple random sampling was employed to choose a sample of 225 cocoa farmers. Mixed research design including field survey and experimental techniques (soil sampling) were employed in the study. A semi-structured questionnaire was used to collect data for the study. Univariate and multivariate analyses were conducted on the data using IBM SPSS version 21, STATA version 13 (Stata Corp, College Station, TX, USA) software. The study revealed that majority of the farmers were knowledgeable of the names of pests and diseases, pesticides used (88.0 %) and their health effects on humans (94.0 %). The farmers demonstrated positive attitude towards pesticides use, however, this did not translate in to safe pesticide use practices. Out of the 225 farmers, only 56 representing 25.0 % were aware and practiced some form of alternative pests and diseases control methods. Cultural method was the most (79.0 %) practiced alternative pest control method in the study area. The Generalized Linear Model result showed that farmers' knowledge of alternative pests control methods was influenced by agrochemical shops, degree of pest infestation and their community status. It was also discovered that the pesticides used posed risks to humans and the environment. Corn cob biochar was found more efficient for remediation of pesticide polluted soils in the study area. Famers should be trained and sensitized on regular bases on safe use of pesticides and alternative pests and diseases control methods.

KEYWORDS

Bifenthrin

Biochar

Pesticide

Integrated Pest Management / Alternative pests and diseases control

Cocoa farmer' knowledge, Attitude and practices

Human health and environment

Pesticide leachate and remediation

Volta Region

Ghana

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DEDICATION

I dedicate this work to my wife, Cynthia and all in the Kosivi family. I love all.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

RHBC	Rice Husk Biochar
CCBC	Corn Cob Biochar
SHW	Soil from Ho West
SAF	Soil from Afadjato South
ET	Economic Threshold
EIQ	Environmental Impact Quotient
IPM	Integrated Pest Management
MS	Mass Spectrometer
FAO	Food and Agriculture Organization
GSS	Ghana Statistical Service
PPE	Personal Protective Equipment
GC	Gas Chromatography
PVC	Polyvinyl Chloride Pipe
CEC	Cation Exchange Capacity

CHAPTER ONE

INTRODUCTION

Pesticides form very important component of modern agriculture and have been widely adopted to control pests and diseases all over the globe (Denkyirah *et al*., 2016). The use of pesticides to control pests and diseases of cocoa started back in 1950 in Ghana, and since then, various classes of pesticides have been recommended and used by farmers (Antwi-Agyakwa *et al.*, 2015). All over the world, a large number of people died every year due to pesticide exposure. In spite of the dangers associated with pesticides, their application, most especially in the cocoa sector is still in the ascendency (Denkyirah *et al*., 2016). Inadequate knowledge and negative attitude (Gesesew et al., 2016a; Ibitayo, 2006; Nalwanga and Ssempebwa, 2011) refusal to use or unsuitable PPE and improper storage at residence are causes of injury and death among farmers (Gesesew *et al*., 2016a; Mekonnen and Agonafir, 2002; Sivayoganathan et *al*., 1995). However, much has not been done to assess the risks the use of these pesticides poses to humans and the environment, and the remediation methods needed to clean the polluted soil.

Against this background, this study assesses knowledge, attitude, practices and experience of previous pesticide exposure and the associated risk pose among cocoa farmers and the environment in the Volta Region. Additionally, it seeks to use Environmental Impact Quotient (EIQ) and self-reported toxicological symptoms to evaluate the risks pose to humans and the environment by the pesticides, assess mobility of pesticides using column leaching experiment and finally to remediate the polluted soil using rice husk and corn cob biochars.

Background to the study

The major cash crop grown in the tropical regions of West Africa, South America, Asia and the Caribbean is cocoa. About 70 % of the world's cocoa is produced in West Africa with Ghana contributing about 21 % (Appiah, 2004). The cocoa sector generates about 70 –100 % of the annual income for about 800,000 smallholder farmers in Ghana. The sector provides, food, employment, tax revenue and foreign exchange earnings for the country (Anim-Kwapong and Frimpong, 2004; Appiah, 2004; Ayenor *et al*., 2007; Danso-Abbeam *et al*., 2014a; Denkyirah *et al*., 2016). Even though cocoa is economically important, its production in Ghana is threatened by insect pests and diseases, a situation which has resulted in the decline in cocoa production, with adverse impact on the Ghanaian economy (Denkyirah et *al*., 2016). Even though, non-chemical pests and diseases control methods are recommended in the industries due to health reasons, the use of some amount of pesticides is unavoidable in the effective management of cocoa farms globally (Adjinah & Opoku, 2014; Moy & Wessel, 2000; Opoku *et al*., 2007). The use of pesticides to control pest and diseases increases yearly. For example, in 2007 alone, about 2363 million kg of pesticides was used in the world. Out of this, herbicides contributed the highest of about 950.7 million kg followed by 404.6 million kg of insecticides and 262.17 million kg of fungicides (Sushma *et al*., 2015). The world's average pesticides use is 0.5 kg ai / ha, however, in some developed countries and industries, pesticide is used more than the world average. About 17 kg is used in Taiwan, 14 kg in Republic of Korea, 12 kg in Japan, 9.4 kg in Netherlands and 7 kg in the USA (Gyawali, 2018).

According to Owusu-Manu (2001), the main method recommended by the Cocoa Research Institute of Ghana (CRIG) for insect pests management has been the use of synthetic insecticides (Antwi-Agyakwa et *al*., 2015).The use of pesticide in the Ghanaian agriculture, though beneficial in reducing crop loss both before and after harvest, has been associated with threats to human health more often due to the misapplication of the chemicals (Clarke et *al*., 1997).

In view of their prospective effects on humans, countries have developed rules to regulate production, trade and encourage the safe use and control, production, import and exporting of these chemicals (Dzobo, 2016; Lorenz et *al*., 2012). In Ghana, the Environmental Protection Agency (EPA) and the Pesticides and Fertilizer Regulatory Division of the Ministry of Food and Agriculture (MoFA) are responsible for the registration and permit issuance of pesticide use (Dzobo, 2016). However, a study conducted in the Brong Ahafo, one of the cocoa growing regions in Ghana revealed that most of the farmers in the study area were found using Ghana COCOBOD approved and unapproved pesticides for cocoa production (Denkyirah *et al*., 2016).

Globally, a significant number of people die annually from pesticide exposure (Gesesew *et al*., 2016a; Konradsen *et al*., 2003; Sekiyama *et al*., 2007). Even though, there are no accurate statistics on adverse health effects of pesticides, it is estimated that every year, between 1 and 41 million people suffer from pesticide exposure globally (Gyawali, 2018). Short-term complications such as acute pesticide poisoning have been reported as a major consequence in the farming communities (Gesesew *et al*., 2016a; Ngowi, 2002). According to WHO (2009), a minimum of 300,000 people die from pesticide poisoning each year, with 99 % of them from low- and middle-income countries. World Bank in 2008, estimated the number of deaths at 355,000 while based on the recent data from Sri Lanka, FAO in 2005 reported that about 300,000 deaths per year may occur in the Asia Pacific alone due to pesticide poisoning (Gyawali, 2018). In most developing countries like Ghana, these consequences have often been severe because farmers do not use approved pesticides, and do not follow the recommended pesticide application schedules by government agencies for crops. They however misuse, overuse and apply pesticides indiscriminately (Denkyirah *et al*., 2016; Konradsen *et al*., 2003; Sam *et al*., 2008), disregarding safety measures and regulations on chemical use (Denkyirah *et al*., 2016). According to (Carvalho, 2006; Fianko *et al*., 2011), the movement of pesticide from areas of application and contamination of non-target sites such as surface and ground water represent a monetary loss to the farmer as well as a threat to the environment.

According to Fianko et al. (2011) and Osafo-Acquaah, (1997), water samples from rivers in the intensive cocoa growing areas in the Ashanti and Eastern Regions of Ghana have been found to contain lindane and endosul- fan. Hematological studies and an epidemiological survey conducted in Akomadan and Afrancho area of the Ashanti Region of Ghana to assess the probability of pesticidal effect on the health status of the farmers showed that majority of the farmers have experienced sneezing (56.0 %), skin irritation (65,9 %), headache (48.2 %), dizziness (40.0 %), abdominal pains (20.0 %) and (57.6 %) (Mensah *et al*., 2004). A collaborative study on possible pesticidal poisoning carried out by researchers of the Ghana Standards Board and the Department of Pathology of the University of Ghana between 1989 and 1997, revealed that out of the 1215 toxicological cases examined, 963 tested positive for chemical poisoning.

Misuse of pesticides accounted for the 30 % cases of chemical poisoning while the main causes for deaths were carbamates (126 cases), organophosphorus (66 cases) and organochlorines (74 cases) (Adetola et al., 1999). Additionally, in March 1999, three children died after consuming fruits containing high residue of carbamates (Fianko et al., 2011) in Ghana.

Damalas et al. (2006), reported that lack of education, knowledge, and unintentional application errors such as handling of pesticide carelessly can pose serious health risks to farmers (Öztaş et al., 2018). Another study also concluded that concerns about the adverse effects of pesticide on health are increasing in the developing countries, due to low educational level and unfavorable working conditions (Hashemi et al., 2012; Öztaş *et al*., 2018).

In order to curb pesticide exposure, farmers' knowledge level on potential hazards of pesticides is very essential (Damalas et al., 2006; Öztaş et al., 2018). According to Oluwole and Cheke, efforts for training farmers are required for proper use of pesticides (Oluwole & Cheke, 2009a). To buttress this, Perry and Layde in their study emphasized the need for training interventions aimed at increasing the awareness on pesticide safety and health risks (Öztaş *et al*., 2018; Perry &Layde, 2003). Pesticide loss to water bodies, could be minimized using soil amendments regimes such as the use of charcoal, metal oxides, biochar and activated carbon.

Due to high specific surface area and highly carbonaceous nature, biochar is considered a unique adsorbent (Khorram *et al*., 2016). Environmental behavior and biotoxicity of pesticides are the basis of studying sorption of pesticide in the soil. Soil leaching experiment using biochar is therefore, a tool that can be used to study the fate and contaminant transport of pesticides in soil

(Pérez-Lucas *et al*., 2018). Corn cob and rice husk biochars have been used in this study due to their cost effectiveness and local availability.

Based on efficacy or cost, pesticides are generally chosen by users rather than their potential impact on the environmental (Blessing, 2001; Muhammetoglu et *al*., 2010). Kovach et *al*. (1992a) reported that although, some growers and pest management practitioners did take into account the effect of pesticides on the applicator and beneficial natural enemies such as predatory mites when making pesticide recommendations, no formal method was available to assist them in making environmentally based pesticide choices. Individuals had to depend primarily on their own judgment to make decisions because there is no easy method to assess pesticide impacts (Kovach *et al*., 1992a). There is a wealth of toxicological and environmental impact data for most pesticides that are commonly used in agricultural systems due to EPA pesticide registration process. However, these data are not readily available or organized in a manner that is usable. The evaluation of secondary adverse effects of pesticides and tools, which summarize the complexity of environmental and human health hazards and associated risks have been developed (Kromann et *al*., 2011; Pittinger *et al*., 2003). To measure the impacts of pesticides on humans and the environment, risk indicators which combine several methods are used (Levitan, 1997). There exist methods which involved environmental simulation effects such as defined models, sampling, monitoring and identifying long term changes in species diversity. Assessment tools such as Environmental Yardstick of Pesticides (EYP), Pesticides Environmental Impact Indicator (Ipest), the GIS- based SYNPS and Environmental Impact Quotient (EIQ) have been developed. The selection of a good environmental assessment tool depends on the criteria it is supposed to meet. For example, it should be able to provide farmers with necessary information to make informed decision regarding pest management choices (Eklo et al., 2003), serve as ecological- labelling system which will influence market patterns and consumer behavior and research institutions which feed back into policy making frameworks at governmental level (Levitan, 2000, 1997).

The Environmental Impact Quotient (EIQ) meets the above-named criteria, hence has been used in this study. The Environmental Impact Quotient (EIQ) is of one the more widely used assessment tool to evaluate pesticide impacts on human health and the environment (Kovach et al., 1992a; Kromann et al., 2011). According to Kromann et al. (2011) and Levitan et al. (1995),the EIQ is a composite system, which permits the integration of several important environmental and human health impacts into one value. The EIQ is also used in this study because it is relatively easy to apply and has been documented in the scientific literature as useful for estimating potential environmental hazards associated with agricultural pesticide use in diverse environments (Hansson and Joelsson, 2013; Maud et *al*., 2001).

Statement of the Problem

Currently, restricted and banned pesticides such as dichlorodiphenyltrichloroethane (DDT) in industrialized countries have found their way in many third-world countries (Allsop et al., 2015; Gesesew et al., 2016a). A study conducted by Pesticide Action Network (PAN) reported the use of hazardous pesticides to control pests and diseases in cocoa production among farmers in Ghana (PAN, 2018). Human exposure to pesticides occurs primarily through dietary residues, outdoor pesticide exposures, indoor pesticide exposures, occupational exposures, and through unsafe use of pesticides on domestic animals (Allsop et al., 2015; Gesesew et al., 2016b).

The sprayers and the communities living around the farm fields have little knowledge about the health hazards connected with pesticide handling. However, extensive use of pesticides has negative effects on health (Mekonnen &Agonafir, 2002; WHO, 1993), and also contaminates water, soil and the immediate environment (Clarke et al., 1997; WHO, 1993). A study conducted in Ghana revealed that about 36% of the farmers had experienced negative side effects after applying pesticides (Fianko et al., 2011; Ntow, 2001). Such symptoms included headache, dizziness, fever, blurred vision, and nausea/vomiting (Fianko et al., 2011). The misapplication also impacts negatively on the environment and threatens future chances of agriculture (Steiro et al., 2020).

Farmers' awareness levels about pesticides effects on humans and the environment varied from region to region (Allahyari et al., 2017), yet, Ghanaian farmers knew a little about risks posed to them by pesticides (Denkyirah et al., 2016). A study conducted in Bodi District in the Western Region of Ghana indicated that cocoa farmers had low levels of education and poor attitude towards PPE use during pesticide handling and application. Besides, a study carried out in the Dormaa West District in the Brong Ahafo Region to assess pesticide exposure and the use of personal protective equipment by cocoa farmers in Ghana indicated that farmers were exposed to high risks of pesticide toxicity and hazards due to poor behavioral habits exhibited and mishandling of pesticides during application (Okoffo et al., 2016).

Little information is available in literature on farmers' knowledge, attitude, and practices with regards to pesticides use, alternative pests and diseases control methods and risks posed to humans and the environment among cocoa farmers in the Volta Region. This study therefore, seeks to assess farmers' knowledge, attitude and practices associated with pesticides use and alternative pests and diseases control methods employed by farmers. Additionally, it is aimed to evaluate the risk posed to the farmer, consumer and the environment and to determine the fate, transport of the pesticides and the appropriate remediation methods.

Objectives

General Objective

The main objective of the study is to evaluate farmers' knowledge, attitude, practices and health risks associated with pesticide use and its impacts on the environment.

Specific Objectives

Specifically, the study seeks to:

1. Establish the association between farmers' knowledge, attitude and pesticide use practices.
2. Examine alternative methods used by farmers to control pests and disease and the factors that influence their knowledge of alternative pest control.
3. Assess the risk posed to humans and the environment by pesticides, using the EIQ Model and the self-reported toxicological symptoms.
4. Predict mobility of pesticides in the soil of the study area using equilibrium model and determine the effective adsorbent for their remediation.

Research Questions

The research was guided by the following research questions in order to achieve the set objectives:

1. How do farmers' knowledge and attitude influence their pesticide use practices?
2. What are the alternative methods of pests and diseases control practiced by the cocoa farmers? and which factors influence their knowledge of alternative pests and diseases control methods?
3. What risks are posed to humans and the environment by pesticides?
4. Can the mobility of pesticides in the soil in the study area be predicted using the equilibrium model and is corn cob biochar or rice husk biochar a good adsorbent for pesticides in case of accidental spillage with respect to the soil type?

Hypotheses

The following include the hypotheses of the study:

i. Farmers' knowledge and attitude of pesticides is associated with the right use of pesticide.
ii. Cocoa farmers practice alternative pest control methods.
iii. Pesticides used by cocoa farmers pose humans health and environmental risks.
iv. Pesticides used by farmers can leach through the soil and corn cob biochar is an effective adsorbent of pesticide than rice husk.

Measures / Variables of the Study

Response Variables

Four dependent variables were used in the study. The first three dependent variables considered were headache, fever, skin rashes and skin itching. For each disease symptom, respondents were asked if they had ever experienced any of the symptoms since they started using pesticides in their farms. The fourth dependent variable considered was knowledge in alternative pest control method. For this variable, respondents were asked if they had any knowledge of alternative pest control method. In all cases, the dichotomous response was coded as 0 (for no), 1 (for yes).

Key Predictor Variable

The key independent variable was selected based on literature, parsimony, practical significance, model fit, theoretical relevance and previous experience. The key explanatory variable for the toxicological symptoms (headache, fever and skin rashes) was wearing all required personal protective equipment (PPE). All PPE's usage includes wearing of nose mask, gloves, protective shoes and headcover, overall and google. For the alternative pest control, the key predictors were agrochemical shop services, farmers' years of experience and degree of pest infestation.

Compositional and Contextual Factors

Compositional factors refer to biosocial and socio-cultural characteristics of individuals. Biosocial factors include age, sex, race and ethnicity while socio-cultural factors include marital status, income, education, occupation, and religion, cooperative groups, extension service among others (Collins et al., 2017; Pol & Thomas, 2012). Contextual factors are location-specific opportunities in a region or a place (Ross & Mirowsky, 2008). The compositional factors considered in this study included gender (male, female) age (young adult: less than 35 years, middle-aged adult: 35–55 years), education (no formal education, secondary/higher), farm size (0.5-1.5 acres, 1.6-2 acres, 2.4-2.5 acres, 2.6-3.5 acres, 3.6-4.5 acres, 4.6-5.5 acres, 6.0-7.0 acres and more than 7 acres), pre-harvest interval (same day, 1-2 days, 3-6 days, 1 week, more than 1 week), pesticide container disposal (sell to others, throw on the farm, burry in ground on farm, burn on farm, keep in store room, gather them together on farm), cooperative group and extension service. The contextual factor was community of residence (Kpedze, Togorme, Kpoeta, Leklebi kame, Logba Alakpeti, Leklebi Agbesia, Bla, Gbledi Chebi and Fodome Woe).

Significance of the study

Pesticides are widely used to protect crops and to prevent disease. However, they can cause environmental pollution. Today, ecological policy and decision makers in many countries (i.e. EU) require sound scientific information on the environmental risk associated with pesticides in order to base and justify their decisions (Finizio & Villa, 2002). Farmers in different agroecological zones have different socio-economic backgrounds and resource endowments which might impact their resource use efficiency (Danso-Abbeam et al., 2012). Therefore, farmers knowledge, attitude and practices associated with pesticide use differ from community to community, district to district and region to region. A study conducted at Sefwi Wiaso in the Western Region indicated that majority of the farmers showed good knowledge in the dos and don’ts with pesticide usage. However, bad practices such as combination of different pesticides and higher doses of approved pesticides for spraying were identified

(Osei -Boadu, 2014). The understanding of farmers' behavior in pesticide use and the factors that affect such behavior is thus critical for the effective management, implementation, and dissemination of public policies (Fan et al., 2015). This study will show how farmers' knowledge, and attitude influence their pesticide use practices, alternative pest control methods practiced, the risks posed to cocoa farmers and the environment in the Volta Region. While it is envisaged that the findings of this study will augment the already existing academic knowledge on pesticides use, their effects on human and the environment, it will also help stakeholders such as Ghana COCOBOD and EPA in the effective monitoring formulation, management, implementation, and dissemination of public policies on pesticides. The EIQ model and EIQ field use rating system employ in this study can be applied by agricultural extension officers or pest management practitioners such as farmers to select the pesticides with least toxic effect and environmental impacts. It can also be used by EPA and COCOBOD to monitor the impacts of agriculture and pesticide policies, and in the evaluation of ongoing pest management programs among cocoa farmers in Volta the Region.

Delimitations

The research was delimited to only smallholder cocoa farmers who applied pesticides themselves on their farms. This was to enable the researcher to access the relevant information regarding pesticide use and its effects on the farmers. There are many cocoa growing districts in the Volta Region, but in this study, Ho West, Afadjato South and Hohoe Districts were chosen because of high cocoa production in these districts.

The study is also delimited to the collection of soil samples from only two districts out of the three districts studied due to the outbreak of covid 19 during the collection of the samples.

Limitations

The experimental work was faced with time constraints due to the Covid-19 pandemic restrictions, so the column leaching experiment was carried out for 4 weeks instead of 6 weeks. The above listed limitations, however, do not render the findings of the research non- reliable and application since the researcher carefully managed the limitations to achieve the objectives of the study.

Organization of the Study

This thesis is presented in five chapters. Chapter one considers the general introduction to the study and encompasses the background to the study, statement of the problem, main objective of the study, specific objectives, hypotheses, research questions, significance of the study, delimitation and limitations of the study and organization of the study.

Chapter two on the other hand, examined existing literature relating to the study under study, including concepts underpinning the study and many others. Chapter three explored the research methods. It included the study area, research design, sample size determination, sampling procedure and sample selection, questionnaire design and administration, EIQ Model, collection and preparation of leachates and determination of physico-chemical properties of leachates.

Chapter four presented results and discussion. Chapter five presents the summary of the findings, conclusions and recommendations.

CHAPTER TWO

LITERATURE REVIEW

Scope of the Review

This chapter gathers the existing theoretical and empirical studies that provide the background and necessary basis for the study. The chapter attempts to review relevant works done on farmers' knowledge, attitude and pesticide use practices, risks posed and remediation methods. Specifically, literature was reviewed on major topics such as cocoa production and its economic importance in Ghana, challenges of cocoa production, interventions to boost cocoa and its challenges, diseases and pests of cocoa, methods of pests and diseases control, pesticides and pesticides classification, pesticide use in Ghana, pesticide use in cocoa production in Ghana, knowledge, attitude and pesticide use practices, pesticide exposure, impacts of pesticides use, fate and behavior of pesticides in soil, farmers pesticide use practices, risk assessment, biochar as pesticide adsorbent in soil and alternative pests and diseases control method.

A conceptual framework which was to serve as a guide for the study, based on the review of relevant literature was finally developed.

Cocoa Production and its Economic Importance in Ghana

Among the most important cash crops grown in the Ghanaian agricultural sector is cocoa. Cocoa (*Theobroma cacao*) belongs to the family *Sterculiaceae*, and out of the over twenty (20) species of cocoa, it is only the *Theobroma cacao* which is economically important and grown in Ghana as a major cash crop (Naminse et al., 2011). Cocoa is the major agricultural export commodity and the main cash crop in Ghana with over one hundred years of history (Anim-Kwapong & Frimpong, 2005; Okoffo, 2015). Ghana is the world's second largest cocoa producer with a market share estimated as 20%. The cocoa sector accounts for about 9 % of Ghana's GDP and contributes about US$ 1.5 billion export revenues.

Additionally, the cocoa industry has reduced both the rural and the urban poverty rate in Ghana from 51.7 % in 1991/92 and 39.5 percent in 1998/1999 to 28.5 percent, a declined by 10 percentage points (Breisinger et al., 2008; Coulombe &Wodon, 2007).

Challenges of Cocoa Production

Before 1960, Ghana remained the world's largest cocoa producer (Bulíř et al., 2002; Mercy et al., 2015). However, between 1960s and the 1980s, there was a drastic decline in Ghana's cocoa output by 60 %. By the beginning of the 1980s, Ghana's production dropped significantly from an average of more than 400,000 tons per year to as low as 270,000 tons between 1988-1990 (Mercy et al., 2015; Opoku-Ameyaw et al., 2010). Some of the factors that accounted to this decline were the occurrences of pests and diseases, aging of cocoa trees, bad weather conditions, poor extension support, low producer prices and climate change. Paramount among these challenges was the incidence of insect pests and diseases which has been recognized as a major cause of declining yields in cocoa production. Consequently, Ghana lost her position as the world's leading cocoa producer (Anim-Kwapong & Frimpong, 2005).

Interventions to boost Cocoa Production and its Challenges

Recognizing the importance of cocoa to the Ghanaian economy, the Government of Ghana has relentlessly prioritized cocoa as a commodity crop and aims to increase its production. To achieve this goal, the government has over the years been implementing policy interventions aimed at reforming the cocoa sector in an attempt to boost production (Mercy et al., 2015).

Notable intervention was the 2001/2002 nationwide Cocoa Disease and Pest Control (CODAPEC) program dubbed 'mass spraying'. The program provided free spraying on all cocoa farms using recommended synthetic fungicides and insecticides against black pod disease and capsids respectively (Ayenor et al., 2007; Danso-Abbeam et al., 2014; Dormon, et al., 2007; Leeuwis, et al., 2007; Mercy et al., 2015; Ntiamoah & Afrane, 2008) The program was aimed at increasing cocoa production to 1,000,000 MT by 2012 (Adjinah & Opoku, 2010; Naminse et al., 2011). Besides, the program was to train farmers and technical personnel on the cultural methods of pest control (shade control through agroforestry), educate and train local sprayers on safe pesticide usage (Naminse et al., 2011).

Even though the initiative yielded some result, some of the cocoa farmers, however, wanted to take over the spraying themselves, complaining the government workers seemed to be too slow. In view of these challenges, the farmers took it upon themselves to do the spraying on their own despite lack of technical – know how. This has resulted in to the use of both CRIG approved and unapproved pesticides by the cocoa farmers (Danso-Abbeam & Baiyegunhi, 2017; Denkyirah et al., 2016).

Diseases and Pests of Cocoa

Cocoa Swollen shoot disease (CSSD)

The plant pathogenic virus, *Caulimo viridae* is the causative agent of *Cocoa* Swollen shoot disease (CSSD) and it is transmitted by a mealy bug. In 1936 CSSD was discovered in Ghana (Baah & Anchirinah, 2011). The single most economically important threat to the Ghanaian cocoa industry is the cocoa swollen shoot disease which largely led to Ghana losing her position as the world's leading cocoa producer (Baah & Anchirinah, 2011; Thresh & Owusu, 1986). The loss in terms of income to the farmer and revenue to the State is vast. The destructive effect of the CSSD on the cocoa tree may be felt within a short a period of three years (Baah & Anchirinah, 2011; Ollennu et al., 1989). Its presence is characterized by leaf discoloration, swelling of chupons and twigs, and die-back (Boakye, 2012; Dzahini-Obiatey et al., 2010). Boakye (2012) stated that cocoa yield losses caused by CSSVD within the first and the second years of infection is estimated at 25 % and 50 %, respectively.

A researcher also indicated that 70 % of the cocoa trees planted between 1904 and 1914 were killed by CSSV between 1939 and 1940 at Koransang in the Eastern Region of Ghana. Besides, crop yield reduced from 30 tons in 1926 – 1929 to 6 tons in 1943 – 1944 seasons. Out of the 400,000, 000 cocoa trees planted in Ghana in 1947, about 46,000,000 which were infested by CSSVD died within the year (Danquah, 2003). The long-term solution to the problem has been the recommendation on breeding for resistance to the virus

Cocoa black pod disease

Phytophthora palmivora and *P. megakarya* are the causative agents of black pod disease of cocoa in Ghana (Baah & Anchirinah, 2011; Thresh & Owusu, 1986). *Phytophthora palmivora* and *P. megakarya* belong to the large group of plant-damaging Oomycetes which can infect every living tissue of the cocoa plant. Wherever cocoa is grown phytophthora diseases, most notably black pod rot and stem canker, are prevalent (Despréaux, 2004; Surujdeo-Maharaj et al., 2016; Thorold, 1975). The symptoms associated with the disease include root rot, stem canker, leaf blight and pod rot. The most economic fungal disease of cocoa in Ghana currently is Black pod (Akrofi et al., 2013). Black pod disease is most especially severe in moist humid environments due to the reliance on free water and high humidity for spore production, germination, dissemination and infection. It is usually prevalent between the rainy months of June and October in Ghana (Akrofi et al., 2013; Vos et al., 2003). According to (Guest, 2007) annual losses from phytophthora diseases were estimated at 30 % of the cocoa which translates in to approximately 3.8 billion USD loss to the cocoa farmers worldwide. Though cultural control is recommended, it is suitable for *P. palmivora* only, hence cultural methods should be combined with chemical control for the more virulent *P. megakarya*. The reduction of the disease incidence in the absence of ants may be significantly established by ground cover or removal of pod husks and mummies (Padi & Owusu, 2015).

Mirids (capsids)

The most economically important insect pests of cocoa in West Africa is the mirids (Adu-Acheampong et al., 2014). Akesse-Ransford (2016) and Dungeon (1910) reported that since 1908 in Ghana, cocoa mirids have been known as serious pests. The local farmers called them "Sankonuabe" which literally means "go back and plant oil palm tree", indicating the situation they were associated with before the introduction of cocoa, because of their devastating effects (Akesse-Ransford, 2016; Wills, 1962). *Sahlbergella singularis* and *Distantiella theobroma* (Dist.) are the most widespread and generally economically important mirids in Ghana and West Africa (Adu-Acheampong et al., 2014; Owusu-Manu, 1985).

Insufficient records and the complexity of losses from other causes such as fungal and viral diseases as well as drought make losses caused by capsids always difficult to estimate. A study conducted by (Stapely & Hammond, 1959) revealed that crop loss in Ghana caused by capsid damage was estimated at 60,000 to 80,000 tons of dry cocoa beans. Yield loss may be as high as 75 % when cocoa farms attacked by capsids are left unattended for a period of over three years (Anikwe, 2010; Wahyudi, 2008).

Mealy bugs

Mealy bugs are vectors of cocoa swollen shoot virus disease (CSSVD). They belong to the family *Pseudoccidae* from the order Hemiptera. Currently, 18 species have been found to transmit the virus from one tree to the other during their feeding activities. Currently in Ghana, two species namely *Planococoides njalensis* and *Planococus citri* have been noticed (Akesse-Ransford, 2016; Dongo & Orisajo, 2007), and are known to be of economic importance as far as the production of cocoa is concerned (Akesse-Ransford, 2016; Belshaw & Bolton, 1993). There exist a strong mutual association between mealy bug and an ant. The ants depend on honey dew excreted by the mealy bug while the ant carry mealy bugs from one tree to the other and also protect them from natural enemies (Domfeh et al., 2011). They also build canopy to protect the mealy bugs. The vector takes up the virus into the circulatory system so it cannot replicate within them and therefore makes it semi- persistent. The virus can be transferred after acquisition within 20 minutes, and can last up to 48 hours after which the virus become dormant (Akesse-Ransford, 2016; Gibbs & Leston, 1970).

In order to control the outbreak of mealy bugs, favorable environmental conditions that enhance the survival and development of mealy bugs should be decreased to the minimum. Development of canopies coupled with interlocked branches, enhances mealy bug movement, which subsequently spread the virus quickly through the whole plantation (Cornwell, 1960; Strickland, 1951), therefore a little light in the farm will help to minimize the swellings of the shoots (Akesse-Ransford, 2016).

Stem borer

Stem borers are insect pests of cocoa and those associated with cocoa are *Phosphorus vicescens*, *Phosphorus gabonator* and *Apate monachus.* The alternative hosts for these pests included kola and coffee (Anikwe, 2010). However, currently, it has been discovered that the damage caused by cocoa stem borer, *Eulophonotus myrmeleon* Fldr. is economically great (Anikwe, 2010). The moth larvae bore in to stems, branches and create dark stain on the bark. This eventually weakens the tree leading to losses in yield and tree death (Asoma-Cheremeh & Ofori-Atta, 2019).

The percentage of damaged trees, as a result of the feeding activities of the stem borer is estimated at 4.6 to 5.8% per year, a proportion that is considered high for a tree crop like cocoa. Due to the nature of damage inflicted on the plant, recovery from E. *myrmeleon* damage is rarely possible (Adu-Acheampong et al., 2005; Anikwe, 2010). Spraying the adult moths twice with insecticide during their active reproductive phase coupled with the physical control, gave an effective control as pest damage was reduced to as low as 1.3 and 0.7% in 2004 and 2005, respectively. However, effective control depends on a detailed knowledge of the seasonal occurrence and spatial distribution (Adu-Acheampong et al., 2005; Padi & Adu-Acheampong, 2000).

Shield Bugs (Bathycoelia thalassina)

Bathycoelia thalassina, locally called Atee, is widely distributed in Central and Western tropical Africa (Akesse-Ransford, 2016). Currently, Shield Bug is becoming an economically important pest of cocoa in most of the cocoa growing countries in West Africa (Akesse-Ransford, 2016; Owusu-Manu, 1971; Wood, 1970), particularly Ghana (Akesse-Ransford, 2016; Gerard, 1964). Akesse-Ransford (2016) and Awudzi et al. (2009) confirmed that shield bugs existence came about as a result of regular application of synthetic insecticides or chemical insecticides for the control of capsids. Estimated loss due to the pest on cocoa production is estimated at 18 % (Owusu-Manu, 1975). *Bathycoelia thalassina* can be control by spraying with recommended insecticides (Owusu - Boateng, 2011).

Termites

Several species of termites are long known to be associated with cocoa but are now been found to cause economic damage to the seedling and mature plant. Those of most economic importance include; *Ancistrotermes sp, Amitermes sp, Macrotermes sp, Microtermes sp, and Nasuitrotermes sp.* (Akesse-Ransford, 2016; Awudzi et al., 2009). Termites can live in the canopy or in the underground. They attack seedlings or young trees at the base and without control, trees may wilt and die. They can also damage suckers of full-grown trees. Others chew the roots and tunnel up into the branch. Termites can also attack living cocoa wood making the cocoa tree susceptible to attack.

Severe attacks result in to sudden wilt of branches and the subsequent death of the plant (Owusu - Boateng, 2011).

Termites can be controlled by preventing trees damage to make them less attractive to termite attack. Botanical pesticides such as neem rather than chemical pesticides can be used to control the natural enemies of termites (Owusu - Boateng, 2011).

Grasshoppers

Grasshoppers are mostly common at the beginning of the rains (April) and persist till July. Out of the numerous species that affect cocoa, the variegated grasshoppers (*Zonocerus variegatus*) are found to be the most economically important species. They cause damage to cocoa plants but may normally not result in yield loss. Grasshoppers also bite off the growing tips of newly germinated seedlings (Akesse-Ransford, 2016; Awudzi et al., 2009). They are normally not controlled except when an outbreak occurs. The use of a formulated myco-pesticide based on *Metarhizium anisoplea* under the trade name Green muscle for biological control of locust has been proven to be highly effective on grasshoppers (Akesse-Ransford, 2016).

Mistletoes

A common parasitic plant found on cocoa tress is the mistletoe (*Tapinanthus bangwensis*). They bring about reduction in yield due to extraction of water and nutrients from the cocoa plant (Dormon, Huis, et al., 2007; Wilson, 1999). According to Dormon et al. (2004), a major problem in the farms of Ghanaian cocoa farmers is mistletoe.

Methods of Diseases and Pests Control

Biological Method

The biological control method which involves the use of living organisms that serves as predators to control pests, proves to be a more environmentally friendly control method (Alalade et al., 2017; Kwasiborski et al., 2012). Bueno et al. (2011) stated that biological control is the management and regular release of beneficial arthropods or microorganisms in crops in order to boost naturally occurring levels of these natural enemies (Alalade et al., 2017). Worldwide, it is estimated to be applied to 0.16 million km^2 commercially. The application of biological control by conversion is in the ascendency (Alalade et al., 2017; Bueno et al., 2011).

Collier and Van Steenwyk (2004) concluded that the potential for using “augmentative” biological control to suppress arthropod pests has been recognized for many years. Predators and parasites of the pests can also be used to control pests. Using biological control method does not eradicate the parasite but controls it, so it is manageable and natural. Ideally, the parasite and pests should be in balance with each other, where the pest has little effect (Alalade et al., 2017)

Cultural Method

Cultural control is one of the major and oldest pest and disease control methods adopted by man, which predated the appearance of synthetic pesticides. It involves the use of farming practices associated with the crop production to make the environment less favorable for survival, growth or reproduction of pest species. Besides, cultural practices are commonly known as simplest, cheapest and safest approaches for combating pests and diseases of agricultural crops. It entails the modification of the environment governing the relationships between phytophagous fauna and their host plants (Satti, 2012).

Shade management is very vital in pest and weed control at various stages in cocoa production. A break in canopy increases light penetration. Subsequently, there is emergence of young succulent chupons which become spots of attraction to insect pests of cocoa. These spots later become foci for local population build-up. Hence the shade must be control in order to manage the insect pests. At the early stage of cocoa production, various types of crops such as plantain, cocoyam, cassava, rubs and trees like *Gliricidia sepium* are grown with the cocoa to provide the shade needed for weed suppression and soil structure development (Dzobo, 2016; Padi et al., 1996). According to Collingwood and Marchart (1969) and Dzobo (2016), well developed canopies provide cocoa trees self-protection against serious capsid damage due to the shade and high humidity within the canopy and also restricts the development of large population of capsids compared with more exposed cocoa with breakages in canopy.

Disease losses can be reduced through practices that include pruning and shade management, leaf mulching, regular and complete harvesting, sanitation and appropriate pod case disposal (Guest, 2007).

Host Resistance

Host plant resistance has been used successfully for several years , as a single pest management factor that has achieved outstanding record (Maxwell, 1985). The use of host-plant resistance is the most economic and ecologically sound option for the control of the most important insect pest of cocoa such as *Sahlbergella singularis* to the poor resource farmers while leaving no deleterious side effects on the produce and the environment (Anikwe et al., 2009).

Hallman et al. (1984) stated that one importance of growing a resistant variety is that the reduced rate of pest increase may greatly prolong the time required by the pests to reach the economic threshold for crop damage (Maxwell, 1985). This is true because resistant plants do change the economic threshold of the pests. The use of host resistant is not only the most effective and practical means of pest and diseases control but also helps to avoid and reduce chemical pesticides usage. Besides, it is believed that local varieties have high resistance to local pests and diseases than the exotic varieties. Therefore, farmers must be knowledgeable in the characteristics of traditional and local varieties to be able to select resistant crop varieties. Identifying the pests that are most damaging and finding suitable and resistant varieties are important steps in pest control, since agricultural plant varieties are rarely resistant to all pests and diseases in a specific area (Caldwell, 2005; Obiri et al., 2017)

Mechanical Control

Obiri et al. (2017) stated that it is often difficult to distinguish mechanical control methods from cultural methods. Mechanical control is the reduction of pest populations by means of devices that affect them directly or alter their physical environment radically. Mechanical control involves special physical measures rather than normal agricultural practices. It includes hand picking of pests or their larvae by the hand, removing the part or whole plant that is affected, using traps or catching them with the help of nets (Dzobo, 2016). Screens, barriers, sticky bands, and shading devices are also mechanical methods or devices. Hopper- dozers and drags are types of specialized control equipment for collecting or smashing insects. Hand picking and trapping are familiar mechanical methods of insect control. One of the drawbacks of the method is that it is time consuming and laborious; hence impractical on a large scale (Obiri et al., 2017).

Chemical Method

Chemical methods involve the use of chemicals (pesticides) on a large scale to mitigate pests. It is effective and faster compared to other methods but it is also the most hazardous to humans and the environment. Improper use chemical pesticides can result in resistance among various pests, which could lead to extensive outbreaks resulting in cost increase of cultivation and losses (Dzobo, 2016).

Pesticides and Pesticides Classification

A pesticide can be defined as "any substance, or mixture of substances of chemical or biological ingredients intended for repelling, destroying or controlling any pest, or regulating plant growth" (FAO, 2014).

Classification of Pesticides

Pesticides can be classified based on different factors. They may be classified according to the type of pests they destroy, how hazardous they are and their mode of action or chemical properties (Kaur et al., 2019a).

Classification Based on the Types of Pests they Kill

Based on the type of pests pesticides kill, they can be classified as; Insecticides – insects, Herbicides – plants, Rodenticides – rodents (rats & mice), Bactericides – bacteria, Fungicides – fungi and Larvicides – larvae (Kaur et al., 2019a).

WHO Classification of Pesticides by Hazards

The WHO Recommended Classification of Pesticides by Hazard was approved by the 28th World Health Assembly in 1975 and has since gained wide acceptance. The classification distinguishes between the more and the less hazardous forms of each pesticide in that it is based on the toxicity of the active ingredient and its formulations. This classification includes; Extremely Hazardous (Class 1a), Highly Hazardous (Class 1b), Moderately Hazardous (Class II) and Slightly Hazardous (Class III) (Dzobo, 2016; Kaur et al., 2019a; WHO, 2005).

Classification of Pesticides Based on Chemical Properties

The most common and useful method of classifying pesticide is based on their chemical composition and nature of active ingredients. This kind of classification gives the clue about the efficacy, physical and chemical properties of the pesticides. The information on chemical and physical characteristics of pesticides is very useful in determining the mode of application, precautions that need to be taken during application and the application rates. Based on chemical composition, pesticides are classified into four main groups namely; organochlorines, organophosphorus, carbamates and pyrethroids (Kaur et al., 2019b).

Organochlorines

Organochlorine pesticides are considered to be one of the broad-spectrum pesticides which control wide range of pests due to their multiple functions. These pesticides are also considered as biodegradable, cause minimum environmental pollution and are slow pest resistance (Kaur et al., 2019a). Dichlorodiphenyltrichloroethane (DDT), is the most widely known organochlorine pesticide (Eskenazi et al., 2006; Islam et al., 2019; Kaur et al., 2019a; van den Berg, 2009). According to Nicolopoulou-Stamati et al. (2016), other organochlorines pesticides used include dieldrin, endosulfan, heptachlor, dicofol, and methoxychlor. Though forbidden in Ghana due to their health and environmental consequences and perseverance in the environment, some farmers illegally use Organochlorines such as DDT (Dzobo, 2016).

Organochlorines cause symptoms such as stomach poison, contact poison and fumigant poison leading to nerve poisons (Kaur et al., 2019a). It is believed that every living organism on earth has a DDT body burden, mainly stored in the fat because DDT is a pervasive chemical substance (Eskenazi et al., 2006; Nicolopoulou-Stamati et al., 2016). DDT and its metabolite p,p-dichloro diphenyl dichloroethylene (DDE) are associated with endocrine-disrupting potential and carcinogenic action (Nicolopoulou-Stamati et al., 2016; Turusov et al., 2002).

Organophosphates (OP)

Organophosphates are considered more ecological alternative to organochlorines (Eskenazi et al., 2006; Nicolopoulou-Stamati et al., 2016), is made up of different pesticides and the most common is the glyphosate. Other class of known pesticides which belong to this class include malathion, parathion, and dimethoate. (Gasnier et al., 2009; McKinlay et al., 2008; Mnif et al., 2011; Nicolopoulou-Stamati et al., 2016). The route of entry of organophosphates in to the body include the gastrointestinal tract (GIT), lungs and skin. Associated acute symptoms of OP exposure include wheezing and hypoxia, bradycardia and hypotension (Dzobo, 2016; Lu, 2009).

Carbamate Pesticides

Carbamates and organophosphates are similar but differ in their origin. Carbamates are derived from carbamic acid while Organophosphates are derivatives of phosphoric acid. The carbamate pesticides work the same way as that of organophosphate pesticides in that they affect the transmission of nerve signals resulting in the death of the pest by poisoning (Kaur et al., 2019b).

According to Mnif et al. (2011), another class of carbamate pesticides that have been associated with endocrine-disrupting activity and possible reproductive disorders included aldicarb, carbofuran, and ziram (Goad et al., 2004; Jamal et al., 2016; Nicolopoulou-Stamati et al., 2016) and effects on the cellular metabolic mechanisms and mitochondrial function (Karami-Mohajeri & Abdollahi, 2011; Nicolopoulou-Stamati et al., 2016).

Pyrethroids

Among the safer insecticides currently available for agricultural and public health purposes are synthetic pyrethroids, such as fenvalerate, bifenthrin, permethrin, and sumithrin (Kolaczinski & Curtis, 2004; Nicolopoulou-Stamati et al., 2016; Ray & Fry, 2006). Sunlight and atmospheric air can degrade them. A study conducted on them has shown that pyrenoids do not contaminate ground water or water bodies but are eventually degraded in the soil because they are not easily taken up by plant roots since they are bound to the soil. Pyrenoids were discovered alongside the identification of the problems related to DDT use (Neghab et al., 2014).

Notwithstanding, there is indications of their ability to display endocrine-disrupting activity (Garey & Wolff, 1998; Mnif et al., 2011; Nicolopoulou-Stamati et al., 2016; Pandey & Mohanty, 2015). They can also affect reproductive parameters in experimental animals including reproductive behavior (Jaensson et al., 2007; Moore & Waring, 2001; Nicolopoulou-Stamati et al., 2016). Additionally, other researchers related more than one pyrethroid metabolite to DNA damages in human sperm, raising concerns about possible negative effects on human reproductive health (Jurewicz et al., 2015; Nicolopoulou-Stamati et al., 2016) .

Bifenthrin

Bifenthrin belongs to the class of pesticides known as pyrethroids (Briggs, 1992; Keith & Walker, 1992; Seyler, 1994) and falls under the Toxicity Class II – moderately toxic (WHO, 2005; Yang et al., 2018). Liu et al. (2011) reported that bifenthrin is characterized by low water solubility, high organic matter coefficient and a good stability at 5 – 9.5 pH. It serves as both acaricide and an insecticide that affect the nervous system of insects (Briggs, 1992; Keith & Walker, 1992; Seyler, 1994). As a pesticide, bifenthrin exists as emulsifiable concentrate (Holmes et al., 2008; Werner & Moran, 2008),

Even though, bifenthrin is less toxic to mammals (Hill, 1989; Liu et al., 2005), it can be very highly toxic to fish (Keith & Walker, 1992; Meister, 1992; Seyler, 1994) and other aquatic organisms (Hill, 1989; Hintzen et al., 2009; Keith & Walker, 1992; Meister, 1992; Weston et al., 2011). Bifenthrin has raised a lot of health concerns due to its most detection in urban sediments among the pyrethroids (Chen et al., 2012; Hintzen et al., 2009; Holmes et al., 2008; Weston et al., 2011).

When bifenthrin is ingested on large doses, it may cause incoordination, tremor, diarrhea, salivation, vomiting, irritability to sound and touch, though it is moderately toxic to mammals. In a female rat, the LD_{50} is about 54 mg / kg and that of the male is about 74 mg / kg US EPA, 1988 (Seyler, 1994). Notwithstanding the fact that bifenthrin does not cause inflammation or irritation on the human skin, it can cause a tingling sensation which may last for 12 hours. Bifenthrin when applied topically, it is absorbed via intact skin (Health & Services, 1993). It then undergoes similar modes of breakdown within animal systems as other pyrethroid insecticides.

Bifenthrin is static in soils with large amounts of organic matter, clay and silt. It also has a low mobility in sandy soils that are low in organic matter. Since bifenthrin is relatively insoluble in water, there are no concerns about groundwater contamination through leaching. It has half-life of 7 days to 8 months in soil, depending on the soil type and the amount of air in the soil (Keith & Walker, 1992; Meister, 1992; Seyler, 1994).

Chen et al. (2012) and Laskowski (2002), stated that when bifenthrin is released to surface waters or sediments, it is subjected to hydrolysis, photodecomposition, volatilization, and aerobic degradation by microorganisms. The most significant process determining the fate of bifenthrin and other pyrethroids in nature among all the processes is the microbial degradation (Chen et al., 2012; Fenlon et al., 2011). Microbial degradation has received increasing attention as, cheap, effective and safe approach for cleaning up contaminated environments (Chen et al., 2012; Singh & Walker, 2006).

Pesticide Use in Ghana

As a developing and agro-based country, Ghana continues to experience economic growth and subsequently uses pesticides for national development (meeting the demand for food supply and health needs), regardless of their effects on humans and the environment. Pesticide use in Ghana has increased tremendously in both type and quantities due to increase in crop yield to meet the need for increase in demand (Dzobo, 2016; Ntow et al., 2009). On the contrary, other studies show that the situation with pesticide in Ghana is similar to those in many other African countries and that the overall level of pesticide use is low but, in the areas, where they are used, the situation is similar to those countries where pesticides are heavily used.

Some scholars are with the view that , pesticide use in Ghana is concentrated on cocoa, vegetables and fruits, cereals (Dzobo, 2016; Gerken et al., 2001; Ntow et al., 2009) and oil palm sectors (Dzobo, 2016; Ntow et al., 2009). More often than not, pesticides are misused with the unknown negative effects on productivity, human health and environment (Gerken et al., 2001).

Apart from the physical inputs in crop production, which form less than 30%, the use of pesticides is now widespread. Ntow and co – authors , confirmed that 21 different kinds of pesticides were imported in to Ghana between 1995 and 2000 (Dzobo, 2016; Ntow et al., 2009). Pesticides officially imported between 1995 and 2000 were on the average of 814 tons. Out of these, insecticides make up 70% followed by fungicides with 14%, herbicides (13%) and nematicides (2.6%). Due to lack of official reports until 1995, earlier data on pesticide imports is not available Gerken et al., 2001). The amount of pesticides imported into the country from 2002 to 2006 increased. “Agrochemicals and the Ghanaian Environment”, an updated register of pesticides from the Environmental Protection Agency in Ghana in 2008 indicated that about 141 different types of pesticide products have been registered in the country under the Part II of the Environmental Protection Agency Act, 1994 (Act 490) (Dzobo, 2016; Ntow et al., 2006a).

In Ghana, about 87% of the farmers use one or a combination of more than one pesticide on a crop, due to their cost effectiveness. (Dzobo, 2016). Pesticides mostly used to control foliar pests of pineapple in Ghana include chlorpyrifos, dimethoate, diazinon, cymethoate and fenitrothion while the fungicides maneb, carbendazim, imazil, copper hydroxide are used for post-harvest treatment. Lambdacyhalothrin cypermethrin, dimethoate and endosulfan are mostly used by farmers who grow vegetables. Among the pesticides used to clear vegetation include Glyphosate, fluazifopbutyl, ametryne, diuron or bromacil (Dzobo, 2016; Ntow et al., 2006a).

A substantial number of people died yearly from the consequences of pesticide exposure globally (Gesesew et al., 2016b; Konradsen et al., 2003; Sekiyama et al., 2007). Though pesticide application is beneficial in reducing crop loss both before and after harvest in Ghanaian agriculture, it has been associated with threats to human health due to its misapplication (Clarke et al., 1997). Even though farmers demonstrated knowledge of some health risks associated with pesticides, the use of personal protective equipment (PPE) was minimal which they attributed primarily to financial constraints (Clarke et al., 1997).

Pesticides Use in Cocoa Industry in Ghana

According to Owusu-Manu (2001), the main method recommended by the Cocoa Research Institute of Ghana (CRIG) for insect pests management has been the use of synthetic insecticides. Chemical control of mirids was first attempted in 1910 (Antwi-Agyakwa et al., 2015; Dudgeon, 1910) when kerosene-soap emulsion was employed.

In the late 1990's imidacloprid (Confidor ® 200SL) was introduced to gradually replace lindane and propoxur as evidence began to emerge that resistance was being built against them. Even though these pesticides were used to control pest and diseases, cocoa yield continued to decline (Antwi-Agyakwa et al., 2015). This decline was attributed to unavailability and high cost of pesticides coupled with technical problems regarding the application of the pesticides.

The Ghana COCOBOD introduced a technology package which included cocoa diseases and pests' control program (CODAPEC) or mass spraying of cocoa farms and Cocoa High Technology programs, which provides free inputs, training and labour for the control of capsids and black pod as well as fertilizer to cocoa farmers on credit. This is because the spraying frequency of the "mass spraying exercise" was not adequate and cocoa farmers were expected to do additional spraying.

For effective and sustainable control of pest and diseases, one of the components of the technology is the requirement that cocoa farmers spray their farms with insecticides four times per cocoa year. Spraying is done from the month of August to December, leaving out November for harvesting and to ensure that treatment coincides with the main period of capsid or mirid population increase which usually occurs between August and November (Adu-Acheampong et al., 2006; Danso-Abbeam et al., 2014b).

Currently, Imidacloprid (Confidor), Bifenthrin (Akatemaster) and Thiamethoxam (Actara) are recommended by Ghana Cocoa Board (COCOBOD) for insect pest management (Antwi-Agyakwa et al., 2015).

A survey conducted in four regions of Ghana, Ashanti, Eastern, Volta and Western involving 147 cocoa farmers showed that the farmers used mostly Imidacloprid and Bifenthrin insecticides and the frequency of application was more than that recommended by COCOBOD. Moreover, among the three recommended insecticides, 43 % each of the farmers across the three regions used either Confidor® or Akatemaster® whilst the remaining 14 % used Actara®. Some farmers do as many as 11 applications in a year while some do not apply insecticides to their farms at all (Antwi-Agyakwa et al., 2015).

Most of the insecticides used are classified as class II under WHO Hazard. Moderate to severe damage levels on eye health of Ghanaian cocoa farmers has been reported, following pesticide spraying. About 10-19% of farmers reported pesticide-related eye damage. Out of the COCOBOD approved pesticides, 12 are known to cause eye irritation and several are classified as serious eye irritants (PAN, 2018).

The result of a study carried out in cocoa growing region of Ghana revealed that most of the farmers were aware of the negative effects of pesticides on their health and the environment if not well handled. However, most farmers did not handle pesticides with care and do not adhere to the use of PPE, therefore, increasing their risks to danger of exposure to pesticides (Okoffo et al., 2016).

Knowledge, Attitude and Pesticide Use

Knowledge, attitude, and practices (KAP) studies have been conducted to identify knowledge gaps, commonly held beliefs and behavioral patterns in order to increase understanding of issues and clarify targets and subjects for intervention (Lorenz et al., 2012). KAP studies on the use of pesticide have been carried out in countries such as Egypt, Brazil, South Africa and Ghana (Dzobo, 2016)

Zyoud et al. (2010) reported in a KAP study of farmers in the Palestine West Bank that 97 % of the farmers were aware of the names of the pesticides they used. They also discovered that the factors influencing good knowledge were secondary education ($p < 0.001$), college education ($p < 0.01$), working experience over 10 years, and using pesticide more than 10 years ($p = 0.03$) while poor knowledge was not associated with primary education. They hypothesized earlier that good knowledge was associated with safe use of pesticides and that reported symptoms were associated with unsafe pesticide use.

A KAP study in Uganda also disclosed that farmers who underwent small scale farming had no knowledge of proper use of pesticides. However, those with high knowledge level regarding health effects of pesticides, did not practice based on the knowledge they had (Oesterlund et al., 2014). Remoundou et al. (2014) reported that high illiteracy rate was a contributing factor to farmers inability to understand and follow instructions and safety advice on pesticide use. When the differences in gender in knowledge on pesticide use was examined in Nepal, it was found that female farmers have lower levels of knowledge than the male farmers which hampered their ability to read and understand labels on pesticides (Atreya, 2007).

According to Ntow et al. (2006), Ghanaian farmers have high risk perception with regards to pesticide hazards, however, only 30 % wear full PPE during pesticide use and handling.

In Brazil, Knowledge was not found to influence pesticide use practices because even though, majority of farmers admitted receiving training from the government and had read pesticide labels instructions and warning yet, they do not take adequate protective measures. This could be attributed to low levels of education of farmers (Remoundou et al., 2014). This therefore, indicates that farmers' education is vital in the increase in knowledge in safety practices (Dey, 2010) and that high levels of knowledge and perception of risk are not enough to influence workers' and operators' self-protective behavior (Remoundou et al., 2014).

Pesticides Exposure

Humans get exposed to pesticides through different ways. Besides, exposures also differ in their intensities, hence add up to their differential effects. Pesticide concentration exposure also differs from individual to individual. Workers at the pesticide industries, transporters of these hazardous chemicals, farmers, fruit and vegetable sellers and consumers get exposed to different concentrations of pesticides. Because majority of human population gets exposed either actively or passively to pesticides, human health is always at risk (Sabarwal et al., 2018). According to (Baker JR et al., 1978), the non-occupational exposure populations are mainly at the consumer level (through fruits, vegetables, grains).

Other exposure media include air, water, and dust. Exposure pathways may include eating of contaminated food, touching of contaminated surfaces and breathing of contaminated air while the route of exposure include nasal (inhalation), mouth (ingestion), skin (dermal) or multiple routes (Dzobo, 2016).

Pesticide residues which are absorbed by inhalation, ingestion, and dermal contact have the potential to cause acute and chronic toxicity (Sabarwal et al., 2018; Wesseling et al., 2002). The types of toxicity depend on the types of pesticides, point of entry, dose, metabolism and accumulation. Acute toxicity is brought about by short-term exposure and happens within a relatively short period of time, whereas chronic toxicity is due to repeated or long-term exposure, and occurs over a longer period of time (Sabarwal et al., 2018; Wesseling et al., 2002).

Impacts of Pesticides Use:

Effects on Humans Health (self- reported symptoms)

Pesticides are designed to kill pests, but some pesticides can also cause negative health effects in people (Gyawali, 2018; Wesseling et al., 1997). Bunggush and Anwar (2000) and Chowdhury et al. (2012), stated that diseases such as headache and nausea are known to be acute symptoms to pesticide exposure. On the other hand, cancer, reproductive defects (Bassil et al., 2007; Bunggush & Anwar, 2000), developmental impairment, immunotoxicity (Berrada et al., 2010; Bunggush & Anwar, 2000) , birth defects and endocrine disruption are associated symptoms (Bunggush & Anwar, 2000; Longnecker et al., 1997). In 2002, WHO announced that pesticide toxicity had resulted in about 849,000 death of people globally in 2001 (Hossain et al., 2015), but most of them occurred in the developing countries.

Another study conducted at Densu Basin of Ghana revealed that majority of the farmers and the farm workers ones in their life time experienced clinicopathological conditions such as blurred vision, vomiting, headache, dizziness, nausea, abdominal cramps and diarrhea due to the application and handling of pesticides without appropriate PPEs (Delon, 2019; Fosu-Mensah et al., 2016).

Paudyal (2008) revealed that studies have shown the association of organochlorine and organophosphate with diabetes mellitus (Gyawali, 2018). Organophosphate inhibits the neurotransmitter acetyl cholinesterase and can affect the central and autonomic nervous system and few leading symptoms related to the autonomic nervous system are abdominal cramps; nausea, diarrhea, salivation, miosis and symptoms related to the central nervous system are dizziness, tremor, anxiety, and confusion (Aryal et al., 2016; Gyawali, 2018).

In order to determining the degree of pesticide contamination in the food stuffs in the European Union, a program entitled 'Monitoring of Pesticide Residues in Products of Plant Origin was established in 1996. In 1996, seven pesticides (acephate, chlorpyriphos, chlopyriphos-methyl, methamidophos, iprodione, procymidone and chlorothalonil) and two groups of pesticides (benomyl group and maneb group, i.e. dithiocarbonates) were analyzed in apples, tomatoes, lettuce, strawberries and grapes. For each pesticide or pesticide group, 5.2% of the samples were found to contain residues and 0.31% had residues higher than the respective minimal residual level (MRL) for that specific pesticide (Aktar et al., 2009).

Six out of eight samples of waakye (rice and beans) and one out of eight samples of fufu (cassava and plantain dough) collected for test showed the presence of the pesticide chlorpyriphos. Additionally, vegetables on the Ghanaian market collected for test were also found to contain detectable levels of chlorpyriphos, lindane, endosulfan, lambda-cyhalothrin, and DDT residues in lettuce, cabbage, tomato and onion (Fianko et al., 2011; Ntow, 1998, 2001).

Impact on Environment

Soil, water, turf, and other vegetation can be contaminated by pesticides. Apart from killing of insects or weeds, pesticides can be toxic to a host of other organisms including birds, fish, beneficial insects, and non-target plants. Among pesticides, insecticides are generally the most acutely toxic class of pesticides even though herbicides can also pose risks to non-target organisms (Aktar et al., 2009).

Groundwater and Surface Water Contamination

Groundwater pollution due to pesticides is a worldwide problem. According to Carvalho(2006), intensive use of pesticides has caused serious contamination of aquifers and surface water bodies, decreasing the quality of water for human consumption (Fianko et al., 2011). Pesticide residues in water sources have been a great concern to environmental and consumer group associations since the mid-1960's. This came to light when Rachel Carson drew the public's attention to the deleterious ecological effects of organochlorine pesticides especially 1,1,1-trichloro-2,2-bis-(4'-chlorophenyl) ethane (DDT) (Camargo & Alonso, 2006; Fianko et al., 2011). According to the USGS, at least 143 different pesticides and 21 transformation products have been found in ground water, including pesticides from every major chemical class (Aktar et al., 2009; Waskom, 1994). A survey conducted in India showed that, about 58% of drinking water samples drawn from various hand pumps and wells around Bhopal were contaminated with Organochlorine pesticides above the EPA standards (Aktar et al., 2009; Kole & Bagchi, 1995).

According to Osafo-Acquaah (1997), water samples drawn from rivers in the intensive cocoa growing areas in the Ashanti and Eastern Regions of Ghana have been found to contain lindane and endosulfan (Fianko et al., 2011). Additionally, water samples from Akumadan, a vegetable farming community in the Ashanti Region and different areas of Ghana revealed the presence of significant levels of pesticide residues. The Volta Lake was also found to be mildly contaminated with lindane, DDT, DDE and endosulfan (Fianko et al., 2011; Ntow, 2005).

Contamination of Air, Soil, Non-target vegetation and Animals

When pesticides are applied, they can directly hit non-target vegetation, or can drift from the treated area and contaminate air, soil, and non-target plants. According to Aktar et al. (2009) and Glotfelty and Schomburg, (1989), some pesticide drift occurs during every application, even from ground equipment. Drift can account for a loss of 2 to 25% of the chemical being applied, which can spread over a distance of a few yards to several hundred miles.

About 80–90 % of applied pesticides can be volatilized within a few days of application (Aktar et al., 2009; Majewski, 2019). Despite the fact that only limited research has been done on the topic, studies consistently find pesticide residues in air (Aktar et al., 2009; Savonen, 1997). A study carried out by USGS revealed the detection of pesticides in the atmosphere in all sampled areas of the USA (Aktar et al., 2009; Savonen, 1997). (Aktar et al., 2009) reported that nearly all the pesticides of concern which were investigated have been detected in rain, air, fog, or snow across the nation at different times of the years by US Geological Survey in 1999.

Since herbicides are designed to kill plants, it is not surprising that they can injure or kill desirable species if they are applied directly to such plants, or if they drift or volatilize onto them. According to (Aktar et al., 2009; Straathof, 1986), many ester-formulation herbicides have been identified to volatilize off treated plants with vapors sufficient to cause severe damage to other plants. In addition to killing non-target plants outright, pesticide exposure can cause sublethal effects on plants. Phenoxy herbicides such as 2,4-D, have been found to be injurious to nearby trees and shrubs if they drift or volatilize onto leaves (Dreistadt, 2012). Locke et al. (1995) stated that exposure to the herbicide glyphosate can severely reduce seed quality and can also increase the susceptibility of certain plants to disease (Brammall & Higgins, 1988).

The herbicide oxadiazon has been found to be toxic to bees, which are pollinators (Washington State Department of Transportation, 1993). They may also hurt insects or spiders indirectly when they destroy the foliage that these animals need for food and shelter (Aktar et al., 2009; Asteraki et al., 1992).

Two major groups of organisms, natural enemies and pollinators, have received the most attention due to their value in integrated pest management (IPM) (Desneux et al., 2007; Schmuck, 2004) and pollination processes (Desneux et al., 2007; Richards, 1993). Economic gains due to beekeeping and agricultural pollination might be reduced by exposure of colonies to pesticides. A long-term study conducted in eastern Canada in blueberry production, which depended largely on pollination by as many as 70 species of native insects, failed in 1970 and subsequent years as a result of aerial spraying of fenitrothion (Desneux et al., 2007; Kevan, 1990).

Fate and Behavior of Pesticides in Soil

Apart from accidental or intentional discharges, pesticides may also enter agricultural soils through treatments applied to the aerial part of crops to combat pests, when approximately 50% of the pesticide may reach the soil and the direct treatment of the soil itself with insecticides, nematicides, disinfectants, and mainly herbicides), which will obviously lead to higher concentrations of pesticide load in the soil (Navarro et al., 2007; Pérez-Lucas et al., 2018). Appropriate analytical tools capable of determining residual concentrations in different media (plant, soil, and water) and the knowledge of the main metabolites that appear are needed to understand the behavior of a pesticide. Analytical procedures such as sampling, sample preparation, isolation of the target compounds, identification, and quantification mainly by Gas Chromatography Mass Spectrometer (GC-MS) and Liquid Chromatography Mass Spectrometer (LC-MS) can be employed to determine the residual concentration in different media (Pérez-Lucas et al., 2018; Semen et al., 2016; Tadeo et al., 2012).

The fate and behavior of pesticide residues in soil is determined by the following key processes: leaching, adsorption and degradation (Pérez-Lucas et al., 2018). Pesticides can be moved in the soil through leaching, diffusion, volatilization, erosion and run-off, assimilation by microorganisms, and plant uptake. Pesticides are frequently leached through the soil by the effect of rain or irrigation water (Pérez-Lucas et al., 2018).Pesticide leaching is highest for weakly sorbing and/or persistent compounds, climates with high precipitation and low temperatures, and soils with low organic matter and sandy texture. On the contrary, for pesticides with a low persistence that disappear quickly, the risk of groundwater pollution considerably decreases.

Different and varied factors such as physicochemical properties of the pesticide, a permeability of the soil, texture and organic matter content of the soil, volatilization, crop-root uptake, method and dose of pesticide application are responsible for the leaching rate of the pesticides. Soils that are high in clays and organic matter will slow the movement of water, attach easily to many pesticides, and generally have a higher diversity and population of soil organisms that can metabolize the pesticides (Pérez-Lucas et al., 2018).

Pesticide degradation is a gradual process that involves the formation of one or more metabolites and takes place through photochemical, chemical, and/or microbiological processes. Photodegradation refers to the decomposition induced by radiant energy (ultraviolet/visible light range) on pollutants and is only relevant at the soil surface (Pérez-Lucas et al., 2018; Weiner & Goldberg, 1985). The chemical process (hydrolysis, oxidation, aromatic hydroxylation, etc.) and biological processes of pesticide degradation are collectively known as biochemical degradation because they are closely linked and it is difficult to distinguish between them. Besides the pesticide's properties, other factors such as the colloidal composition, texture and moisture content of the soil and the number of microorganisms present (including bacteria and fungi) play a key role in the transformation of pesticides (Das, 2014; Pérez-Lucas et al., 2018). Whereas biodegradable pesticides are broken down within days or weeks by soil microorganisms, non-biodegradable pesticides remain for long periods (years or even decades) in the soil. A total degradation of a pesticide (mineralization) results in to the formation of CO_2, salts, water and parts of the chemical are built into new molecular structures in the soil humus or in biomass (bound residues) (Gevao et al., 2000; Pérez-Lucas et al., 2018).

Pesticide Adsorption

Adsorption of pesticides may be chemical (electrostatic interactions) or physical (van der Waals forces). It involves the electrical attraction between charged particles, pesticide molecules (sorbate), and soil particles (adsorbent). Pesticide molecules that are positively charged are attracted to negatively charged particles on clays and organic matter. Chemical reactions between unaltered pesticides or their metabolites often lead to the formation of strong bonds (chemisorption) resulting in an increase in the persistence of the residues in the soil, while causing it to lose its chemical identity (Pérez-Lucas et al., 2018; Weiner & Goldberg, 1985).

The partitioning of a pesticide molecule between solid and aqueous phases is controlled by a number of factors. These include physico-chemical properties of soil and pesticides as well as environmental conditions. The soil factors are organic matter content, minerals and microorganisms (Khan, 2016).

The important role played by soil organic matter in controlling the sorption of non-ionic pesticides in soil is well established (Benoit et al., 2008; Fernández-Bayo et al., 2009; Gondar et al., 2013; Karickhoff, 1984; Khan, 2016; Spark & Swift, 2002). Even though organic matter only constitutes a small proportion of the total dried material in most soils, it has been considered as a major sorbent for pesticides in soil (Calvet, 1989; Khan, 2016). This is attributed to its high chemical reactivity towards organic molecules, allowing various types of interactions with pesticides (Chaplain et al., 2011; Khan, 2016).

The mineral fractions, predominantly the clay-sized particles in soils which have low organic matter contents influence retention and mobility of pesticides in the soil (Spark & Swift, 2002). The mineral fractions that are mainly involved in the sorption of organic pesticides are clays (as silicate minerals), oxides and hydroxides (Calvet, 1989; Khan, 2016). According to (Khan, 2016; Spark & Swift, 2002), increased proportion of clay minerals in soil has been reported to increase the retention and reduce the mobility of pesticides in soils.

Gilani et al. (2016) and Khan (2016) stated that soil microorganisms play a key role in biodegradation of pesticides, hence may influence pesticide sorption behavior within the soil environment. The metabolism of pesticides in soil is highly dependent on microbial activities (Burauel & Führ, 2000). Chaplain et al. (2011) and Khan (2016) explained that soil microbes are able to metabolize pesticides through numerous enzymatic reactions. In addition to the soil properties, the following chemical properties of pesticides also influence their behavior in soils: electronic structure, water solubility (or hydrophilicity) and lipophilicity (or hydrophobicity).

Adsorption Distribution Coefficient and Organic Carbon Water Partition Coefficient

The relation between the concentrations of the compound (pesticide) in the solid and liquid phases is known as the distribution coefficient and is directly proportional to the solubility of the pesticide in water and inversely proportional to the organic matter (OM) and clay content of the soil.

Mathematically, Kd = $\frac{Ca}{Cs}$ (Khan, 2016) where Kd = coefficient of partition between soil and water (V/M); Ca = amount of pesticide adsorbed per unit of adsorbent mass (M/M); and Cs = concentration of pesticide dissolved (M/V)

According to Karickhoff (1984), there exist a linear correlation between the coefficient of partition and the soil's organic carbon content and this is given as: Koc = $\left(\frac{Kd}{OC}\right) x\ 100$

where Koc = soil organic partition coefficient and OC is the organic carbon content (%) (Pérez-Lucas et al., 2018)

Pérez-Lucas et al. (2018) and Sadegh-Zadeh et al. (2017a) explained in a study that the content of organic carbon (OC) is considered as the single largest factor having maximum influence on pesticide degradation, adsorption, and mobility in soil. Therefore, the soil organic adsorption coefficient (Koc) is generally used as a measure of the relative potential mobility of pesticides in soils to describe the partitioning of pesticides in the water/soil/air compartment.

Pesticide Risk Assessment

It has been estimated that global food production could fall by as much as 35–40% without pesticides (Lewis et al., 2016; Oerke, 2006). This could lead to increasing cost of food and threatening food security. In spite of their importance, pesticides pose potential risks to human health (Fantke et al., 2012; Lewis et al., 2016; Mostafalou & Abdollahi, 2013) and the environment (Skinner et al., 1997; Tilman, 1999; Van der Werf et al., 2007). Therefore, pesticide policies, particularly those of the developed world, advocate the sustainable use of these chemicals to minimize the risks and maximize the benefits (Lewis et al., 2016).

In light of these hazards, an evidence-based risk assessment is fundamental to protecting human health and ecosystems from the possible adverse effects arising from exposure to pesticides. Establishing that any potential risks to humans and the environment are acceptable requires a suite of complex risk assessments of the regulatory context of most developed countries. This takes in to consideration the potential of that substance to pollute the environment; harm biodiversity; and endanger consumers, the general public, or agricultural workers (Lewis et al., 2016).

According to Haas et al. (1999), risk assessment is a process that involves the quantitative, qualitative characterization and estimation of potential adverse effects associated with exposure of individuals or populations to hazard (material or situation, physical, chemical or microbial agents). Risk assessment is a crucial tool which predicts the likelihood of adverse effects of pesticides to man and the environment and to identify the need of preventive actions. It determines the magnitude of the hazard posed by the pesticide product, the dose-response assessment, the extent of exposure and the characterization of risk (which determines the relative need for control actions and contents of preventive strategy) (Lotti, 1995; Maroni et al., 2006).

Due to pesticides' intrinsic toxicity, most countries have a specific and complex legislation prescribing a thorough risk assessment process for pesticides prior to their entrance to the market (pre-marketing risk assessment). The post-marketing risk assessment is conducted during the use of pesticides. The post – market risk assessment aims at assessing the risk exposed to the operators. The results of the risk assessment are the base for the health surveillance of exposed workers. In addition, occupational exposure to pesticides in agriculture includes product distributors, mixers and loaders, applicators, bystanders, and rural workers re-entering the fields shortly after treatment. A proper risk assessment and management of pesticide use is an essential component of this preventative strategy (Maroni et al., 2006).

Apart from undertaking pesticide risk assessments for regulatory purposes, risk is also being used extensively by national and local governments to help define national, regional, catchment pollution mitigation and management plans, as well as to develop and monitor policies and interventions. Additionally, this method serves as a tool for water companies to help establish risks associated with drinking water supplies. It is also used by multinational grocery retailers to reduce risk to consumers and drive forward the sustainable farming agenda (Feola et al., 2011; Lewis et al., 2016).

Hence, pesticide risk assessment of the soil and the use of environmentally friendly remediation procedures to minimize these negative effects need to be adopted. In order to analyze the hazard and exposure characteristics of pesticides for various potential human health and environmental impacts, a wide variety of tools have been developed. These tools are collectively called ‘‘Pesticide Risk Indicators’’ (PRI). PRI consider impacts, such as toxicity to humans, birds, fish or beneficial insects and pollution of surface waters, groundwater and air due to PRI variation in scope and format. In some instances, multiple impacts may be considered and an overall rating developed (Surgan et al., 2010)

Some of the pesticide-risk indicators employed by researchers to evaluate the environmental impacts of active ingredients in pesticides include the Environmental Impact Quotient (EIQ), the Toxicity, Human Health, and

Persistency Hazard Rating System (THP) and the Pesticide Environmental Risk Indicator (PERI) (Surgan et al., 2010).

Biochar as Pesticide Adsorbent in Soil

soil quality is now seriously being threatened by anthropogenic contamination, which may pose unacceptable ecological risks to biota and human beings (Kong et al., 2014). A wide range of remediation techniques, such as soil washing, soil flushing, soil vapor extraction and bioremediation, have been proposed to remediate contaminated soil previously. However, due to the characteristic deficiencies or new problems that emerged after their application, such as high costs of maintenance, fertility loss, nutrient leaching and soil erosion, such methods are usually not applicable in field operation (Khorram et al., 2016; Kong et al., 2014; Kumpiene et al., 2008; Powlson et al., 2011).

Therefore, biochar, an amendment for contaminated soil been introduced as a new alternative to meet remediation needs. Biochar is cost effective (Khorram et al., 2016; Lehmann & Joseph, 2009) with less disruptive effects and can be used to remediate pesticide-contaminated soil by binding pesticides to reduce their potential mobility into water resources and living organisms. . Additionally, it provides nutrients to promote plant growth and stimulates ecological restoration (Bernal et al., 2007; Khorram et al., 2016; Vangronsveld et al., 2009).

Biochar is a product of the pyrolysis of carbon-rich plant- and animal residues under low oxygen and high temperature conditions. It is increasingly being used for its positive role in soil compartmentalization through activities such as carbon sequestration and improving soil quality. One of the properties of biochar which makes it a unique adsorbent is its high specific surface area coupled with its highly carbonaceous nature. Soil amendments with small amounts of biochar could result in higher adsorption and, consequently, decrease the bioavailability of contaminants to microbial communities, plants, earthworms, and other organisms in the soil (Khorram et al., 2016). The feedstock of biochar can be obtained from any carbonaceous materials (Kavitha et al., 2018; Suliman et al., 2016; Wang et al., 2018) including agricultural, municipal, animal, or industrial sources (Kavitha et al., 2018; Kwapinski et al., 2010).

Besides, the elemental composition of biochar which comprises carbon, nitrogen, hydrogen, potassium, and magnesium, can all serve as major nutrients in plant growth. The addition of biochar increases the amount of organic matter in the soil (e.g, organic carbon), thereby improving soil physicochemical and biological properties. Biochar can positively or negatively affect the soil microbial growth to alter the agricultural environment (Kavitha et al., 2018).

Biochar could be considered as environment friendly and carbon-neutral material because the biomass releases the same quantity of CO_2 into the atmosphere during the conversion and utilization as that absorbed by the photosynthesis during plants' growth (Yi et al., 2018; Yuan et al., 2017, 2019). In addition, the physicochemical properties of biochar, such as three-dimensional reticulated and porous structure (Hu et al., 2018), could contribute to a long-term storage of carbon (Shackley et al., 2012; Yuan et al., 2019) and the adsorption and degradation of pollutants (Sneath et al., 2013; Yuan et al., 2019).

Environmental Impact Quotient (EIQ) Model

According to Kovach et al. (1992), the EIQ was developed to measure the environmental impacts of pesticide active ingredients used in vegetable and fruit production. According to the model, the potential impact of a specific pesticide is equal to the product of the toxicity of the pesticide and the potential for exposure. Kovach et al. (1992) and Levitan (1997) described the detailed information on the variables and the rating system in EIQ.

The EIQ model equation involves three main principal components. These include: i. the farm worker-based on applicators and pickers; ii. the consumer-based on chronic toxicity, soil half-life, plant surface residue half-life, ability to be absorbed by plants and groundwater leaching potential, and iii. non-human biota—based on aquatic organisms, birds, bees and beneficial arthropods. In the model, equal weight is given to each component but individual factors within components are weighted differently (Kovach et al., 1992a).

According to Muhammetoglu and Uslu (2007), the equation for determination of the EIQ for individual pesticides, is the average of the farm worker, consumer, and ecological components. The application of the model has been evaluated by (Levitan, 1997; Stenrød et al., 2008). Once an EIQ value has been established for the active ingredient of a pesticide, the EIQ score can be turned into a field-use rating to compare environmental impacts of different pesticides and pest management strategies (Muhammetoglu & Uslu, 2007).

Integrated Pest Management

A study has revealed that majority of farmers in Ghana do not adopt research recommendations due to economic and technical reasons (Dormon et al., 2007). Integrated Pest Management had been tried with farmers in Ghana. These technologies yielded good results, however, adoption was constrained by social, technical and economic factors (Dormon & Leeuwis, et al., 2007).

Service and Service (1987) defines Integrated pest management as ‘‘a systematic approach to pest regulation that emphasizes increased sampling to assess pest infestation levels and promote improved decision-making so that control costs can be reduced, and social, economic, and environmental benefits can be maximized’’. IPM does not completely avoid the use of chemical pesticides but integrate non-chemical control strategies (Stern et al., 1959) such as cultural, biological and structural strategies to control multitude of pest problems .

IPM works under certain principles. The elements of the principle: Correct taxonomic identification of the pest, Characterization of population dynamics and mortality factors, pest sampling plan, Characterization of economic injury levels and development of economic thresholds, and finally the development of alternative options such as biological control, cultural control, mechanical, breeding host-plant resistance; chemical tactics (judicious application of selective pesticides) and mating disruption using pheromones.

Economic Injury Level (EIL)

Population density or degree of infestation is very crucial in determining the economic injury level (EIL) of the pests and diseases. Economic Injury Level is the smallest number of insect pests that will cause yield losses equal to the insect management costs. The EILs are usually expressed as a pest density and are developed from yield-loss relationships derived from field research studies. The EIL has been described as the break -even point, and the level of pest a plant can tolerate, among other things. It is aimed at managing the pest population before it reaches the EIL and that is where the economic threshold (ET) comes in (Leon, 1997; Sarwar et al., 2011).

Economic Threshold (ET)

It is the pest density at which management action should be taken to prevent an increasing pest population from reaching the economic injury level. The ET is the practical rule which calls for management action to be taken. Since ET is essentially a prediction of when a pest population is going to reach the EIL, some researchers called it action threshold (Sarwar et al., 2011). It is assumed that once the ET is reached, there is a high probability that the pest population can reach the EIL if no management action is taken (Leon, 1997; Sarwar et al., 2011).

Conceptual Framework of Farmers' Knowledge, Attitude, Practices and Risks Associated with Pesticide Use

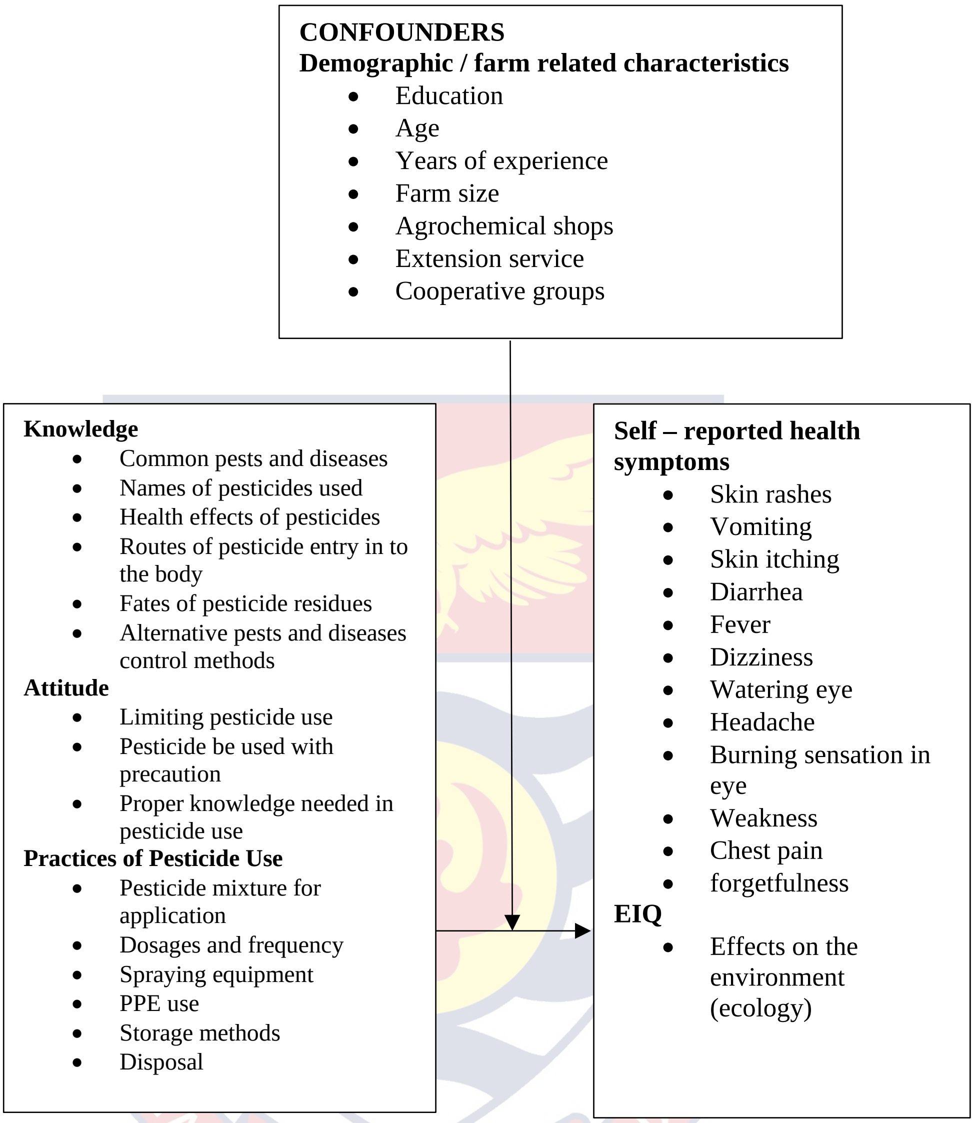

Figure 1: Conceptual Framework of Farmers' Knowledge, Attitude, Practices and Risks Associated with Pesticide Usage.

According to Rogers (1995) , knowledge development is the first phase in decision- making process in terms of adoption of innovation. The knowledge of farmers consists of existence of a new technology and how to apply it, out comes in terms of products, yield, costs, potential environmental benefits and risks. The perceptions and the attitudes an individual develop towards the innovation or the technology is the information the individual has about the new technology. Knowledge refers to factual information and understanding of how the new technology works and what it can achieve (Mubushar et al., 2019).

The conceptual framework in fig. 1 was used for the study. It is based on linear relationship between knowledge, attitude, practices and health outcomes. With regards to this study, knowledge assessed the extent to which a farmer is aware of types of pests and diseases of cocoa, name of pesticide, public health concepts of pesticide usage and alternative pests and disease control methods.

The attitude attribute characterizes an individual's feelings, inclinations and indeed those of other household members with regards to pesticide usage (Muleme et al., 2017). These were characterized as negative (bad) or positive (good) in relation to the scientifically documented risks of pesticide poisoning and environmental contamination (Muleme et al., 2017).

The practice on the other hand considers the actions related to pesticide usage, right from purchasing, usage, to disposal of the pesticide receptacles (Muleme et al., 2017). These were also characterized as proper or improper in relation to the scientifically documented risks of pesticide poisoning and environmental contamination (Muleme et al., 2017).

According to Santaweesuk et al. (2020), there is a mutual relationship between Knowledge and attitude and linked to pesticide use practices and that improper use of pesticides was a risk factor for health issues. However, Yuantari et al. (2015) reported no significant relationship between knowledge and attitude on good pesticides practices on the one hand and the use of personal protective equipment in practice on the other hand. This indicates that improved knowledge and attitudes are not enough to change the behavior of farmers to work in a healthy and safe way. To bridge the gap between knowledge and practice, more interactive and participatory training models are required (Yuantari et al., 2015).

Most of the health effects experience by farmers could be attributed to a lack of knowledge regarding the dangers of pesticide exposure and a negative attitude toward safety, in particular, improper handling of pesticides (Santaweesuk et al., 2020). Agricultural workers faced challenges such as knowledge, attitude and good practice regarding health hazard of pesticides. However, these have not been well assessed (Shan, 2017). Current researches have showed a moderate to low awareness among farm workers towards the fate of pesticide residues in plants and groundwater, soil and air. Besides, farm workers could be at risk when handle pesticide residue on plants, soil, and dust particles after spraying due to moderate or low level of knowledge (Tijani & Nurudeen, 2012).

Socio - demographic and farm related characteristics impact farmers' knowledge, attitude and practices either positively or negatively (Bosompem, 2015). Farming experience has been found to have impacted positively on farmers' adaptation and can lead to better knowledge and understating in field and operational efficiency since farmers can learn by doing (Bosompem, 2015).

Most pesticides are toxic to humans and animals and can bring about negative health effects which may be short term or long term (Remoundou et al., 2014). Occupational exposure may occur acutely as a result of mixing, loading, application or contact with sprayed crops. The risk of exposure increases when farmers ignore safety instructions on the proper use of pesticides, PPE use, storage and disposal (Damalas et al., 2008) and not following pre- harvest intervals.

Delon (2019) reported that farmers suffer from health problems such as headache, diarrhea, vomiting, nausea, blurred vision, dizziness and abdominal cramps due to poor safety practices during pesticide handling.

CHAPTER THREE

MATERIALS AND METHODS

Study Area

The study was carried out in one municipality (Hohoe) and two districts (Afadjato South and Ho West) in the Volta Region of Ghana. Volta Region is located between latitudes 5^0 45' N and 8^0 45' N and sharing boundary with the Republic of Togo to the East, Greater Accra to the West, to the North with Oti and has the Gulf of Guinea to the south. Its total land area is 20,570 square kilometres, representing 8.7 percent of the total land area of Ghana (GSS, 2013). The regional population was 2,118,252 in 2010 with annual average growth rate of 2.5%. The region has a tropical climate, characterized by rainy and dry seasons. It has moderate temperatures, 21-32° Celsius (70 – 90° F) for most of the year. Rainy seasons are from April to July and September to November (GSS, 2013)

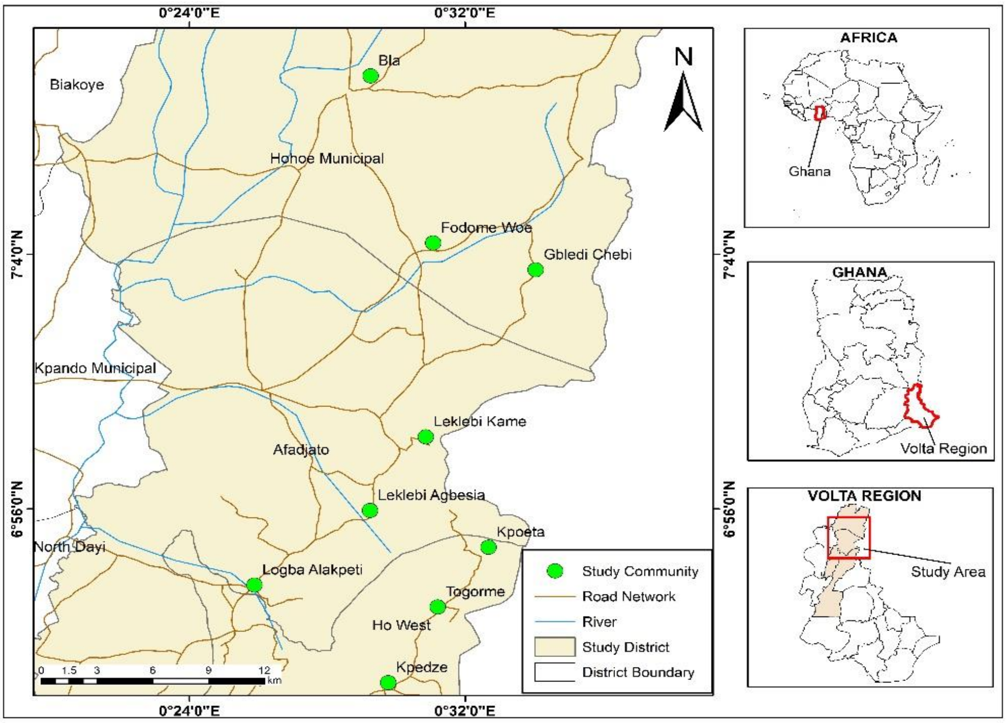

Figure 2: Map of study area and selected communities in Hohoe, Afadjato South and Ho West Districts

Geographic Description of the Study Sites

Hohoe Municipality

The Hohoe Municipality has a total land cover of 1,172 square kilometre, which is 5.6 percent of the land area of the region. It is located in longitude 0^{o} 15' E and 0^{o} 45' E and latitude 6^{o} 45' N and 7^{o} 15' N (GSS, 2014c). The Municipality is one of the four main cocoa growing areas in Volta region. The Municipality lies in the wet semi-equatorial climatic zone. Annual rainfall is between 1,016 mm- 1,210 mm. There is 4 -5 months dry season between November and April. The rains start in late April and ends in October. Temperatures are high throughout the year and range from 26 ºC in the coldest months to about 32 ºC in the hottest months. The Municipality falls within the forest-savannah transitional ecological zone (GSS, 2014b).

The population of the Municipality was167,016 in 2014. Males constituted 47.9 percent and 52.1 percent are females. The Municipality has 52.6 percent of the population in urban locality and the remaining 47.4 percent in rural locality. The age dependency population was 77.6 percent. Children below five years in the population were 12.4 percent, the population below 15 years (0-14 years) is 34.6 percent and below 20 years was 45.6 percent. As at 2014, the labour force (15-64 years) was 56.3 percent of the total population. This implies that a pool of working population is available to be harnessed for productive work. The age dependency ratio for the Municipality was about 73 dependents (child and old age). Out of this, the age dependency ratio of the males was 76 and that of the females was 71 (GSS, 2014b). The main economic activities of the municipality apart from cocoa farming are pretty trading, crop farming and poultry keeping. Some tourist attraction sites of the municipality include Wli Waterfall, Tsatsadu Waterfall and Wadzakli Waterfall.

Afadjato South District

The Afadjato South District is one of the 46 administrative districts created in 2012 with its capital at Ve -Golokuati. The total land area of the District is 553.0 square kilometres. The District lies in the wet semi-equatorial climatic zone. Annual rainfall is between 1,016 mm-1,210 mm with an average of four to five (4-5) months dry season experienced through November to April. The usual rainfall pattern of double maxima regime has gradually changed giving a long stretch of rainy season starting from late April and ends in October. Temperatures are high throughout the year and range from 26 ^{o}C in the coolest months to about 32 ^{o}C in the hottest month usually just before the rainy season. Mean monthly temperature is about 29 ^{o}C. The District is located in the forest-savannah transitional ecological zone of Ghana. The predominant vegetation found in the District is Semi-Deciduous Forest and Guinea Savannah Woodlands. The main soil groups in the district are ochrosols and oxysols. The forest ochrosol is fertile and supports oil-palm, cocoa and para-rubber (GSS, 2014c). Some tourist sites of attraction in the district include Afadja Mountain and Tafi Atome Monkey Sanctuary.

The population of Afadzato South District was about 95,030 representing 4.5 percent of the region's total population and 0.4 percent of the country's population. Males constituted 48.7 percent and females represented 51.3 percent. The Urban –Rural division was 18.7 and 81.3 respectively and has a sex ratio of 94.9. The age group 0-14 forms 38.5 percent of the Districts population; this implies that the District's population is youthful. About 72.8%

of the households in the District are engaged in agriculture. In the rural localities, more than eight out of ten households (85.3%) are agricultural households while in the urban localities, 14.7 percent of households are into agriculture. The total age dependency ratio for the District was 84.7, with males having a higher dependency ratio of 89.4 as against 80.4 for females (GSS, 2014c).

Ho West District

Ho West District is located between latitudes 6.33° 32'' N and 6.93° 63" N and longitudes 0.17° 45" E and 0.53° 39" E. It has a total land area of 1,002.79 square kilometres. Mean temperature in the District range between 22 °C and 32 °C while annual mean temperature ranges from 16.5 °C to 37.8 °C. In effect, temperatures are generally high throughout the year which is good for plants and food crop farming. The rainfall pattern is characterized by two rainy seasons referred to as the major and the minor seasons. The major season is from March to June while the minor one is from July to November. The rest of the year is the dry season. Mean annual rainfall figures are between 120.1 mm and 192 mm. The highest rainfall occurs in June and has mean value of 192 mm while the lowest rainfall is in November recording about 120.1mm. Ho West District falls into two main types of vegetation zones; these are the moist semideciduous forest which mostly covers the hills in the District and savannah woodland. The forest soil type includes ochrosols, lethosols and intergrades soil found in the mountainous and wetter areas in the District. The forest soils support perennial crops such as cocoa, oil palm, coffee, avocado, plantain and banana (GSS, 2014a). Togorme Waterfalls forms a tourist site of the district.

The population of Ho West according to the 2010 Population and Housing Census was 94600. As of 2010, males constituted 48 percent and females represent 52 percent. The Urban –Rural division was 10.9 and 89.1 percent respectively and had a sex ratio of 92.1. The age group 0-14 forms 36.5 percent of the Districts population, implying the District's population is youthful. This is shown in the broad base population pyramid which narrowed off with a small number of elderly persons. The total age dependency ratio for the District was 81.9, with males having a higher dependency ratio of 86.2 as against 78 for females. The dependency ratio for the rural as compared to the urban was 82.6 and 76.3 respectively (GSS, 2014a).

Research Design

In this study, an attempt was made to investigate and describe knowledge, attitude, pesticide use practices and associated risks among smallholder cocoa farmers in the Volta Region. The study therefore, followed a mixed method design using both survey and experimental techniques.

The design was made up of two stages in which mixed methods, qualitative and quantitative were used to collect data. A survey method was used in the first stage by administering questionnaire to cocoa farmers to seek their views on their knowledge, attitude and practices regarding pesticide usage. The second stage on the other hand, involved the use of part of the data generated from the first stage in an experimental set up to assess the risks posed to humans and the environment by pesticides.

A study that uses mixed methods, enables the researcher to get in depth understanding of the issues related to the study under investigation (Buabeng, 2015; Cohen et al., 2000). The mixed method was used for this study because it helped to simultaneously answer confirmatory and explanatory questions. Besides, the qualitative method could be used to generate theory, and the quantitative method to test the theory (Pole, 2007).

One of the advantages of using the mixed method is that a researcher can confirm an effect on a phenomenon by statistical analysis of quantitative data, and then employ the reasons behind the observed effect by using surveys.

Sample Size Determination

The sample size of the study was determine using single population proportion formular (Gizaw et al., 2018) with the following assumption: p = 85.1 % (percentage of farmers who applied pesticides themselves on their farm) (Denkyirah et al., 2016), 95% confidence interval, and a 5% margin of error (d)

$$n = \frac{(Z\alpha/2)^2 P\ (1-P)}{d^2} = \frac{(1.96)^2 0.851\ (1-0.851)}{0.05^2} = 195$$

By taking 15 % non- response rate, n = 225. Thus, to ensure that the 95 % confident interval estimate of the proportion of cocoa farmers who applied pesticides in the Volta Region is within the 5 % of the true proportion, a minimum sample size of 225 was needed for the study.

Sampling Technique and Sample Selection

A multi-stage sampling procedure which included purposive and simple random sampling techniques at various stages was employed for the study. Green and co - authors (as cited by Okoffo et al., 2016) reported that multi-stage sampling creates a more representative sample of the population than a single sampling technique and this can help reduce costs of large-scale survey research. Multi-stage is often preferred for reasons of precision and economy (Okoffo et al., 2016). In this study, the Volta Region was purposively selected as one of the cocoa growing regions in Ghana. Purposive sampling was used because it is less expensive and does not need all the elements of the population (Acharya et al., 2013). A group of individuals, persons, objects, or units from which samples are taken for measurement is referred to as population (Saunders et al., 2009). Smallholder cocoa farmers from Ho West District, Afadjato South District and Hohoe Municipality constituted the study population. With regards to this study, Ho West District, Afadjato District and the Hohoe Municipality were randomly selected as some of the cocoa growing districts in the Volta Region. The selection of the districts was done based on the available literature and in collaboration with the Cocoa Health Extension Division (CHED) of Ghana Cocoa Board (COCOBOD) in the Volta Region. Information regarding the most cocoa growing communities in the districts was also obtained.

The next stage involved the random selection of three cocoa growing communities from each of the three districts. To circumvent bias and to ensure that every member of the population has the probability of being selected (Alvi, 2016) for the study, the simple random sampling technique was used to select twenty- five (25) farm households from each of the three selected farming communities. The farm households were those who used and assumed to have knowledge in pesticides application in each of the three study sites districts. This gave a total sample size of 225 cocoa farmers. (Total sample size (225) = (3 Districts x 3 Communities x 25 farmers).

Data Collection Instruments

Questionnaire Design

A structured questionnaire modified after (Paintsil, 2017) pretested in a study in the Bodi district in the Western Region of Ghana was used as an instrument to collect data. The questionnaire consisted of both closed and open-ended questions. The closed-ended questions were used to obtain the exact information being sought to be collected for quantitative and qualitative analysis, whilst the open-ended questions gave the respondents more room to clarify certain responses provided. The first part covered the socio - demographic characteristics of the respondents. The survey focused on four main sections ; (I) Farmers' knowledge (names of pesticides used, including forbidden ones, common pests and diseases of cocoa, health effects of pesticides, routes of exposure and fate in the environment); (II) Pesticide use practices (years of experience, reason of using pesticides, source of pesticides amount per application per area, application interval and application equipment, common crops, mixing of pesticides, source of knowledge of the application and factors that influence application times); (III) Farmers' attitudes towards pesticide (IV) finally, the questionnaire sought to find out the protective measures adopted during pesticide application by the respondents, self – reported health symptoms and the alternative methods of pest control.

Items in sections I, II and IV were measured using close – ended, open – ended and partially close – ended items. Items in section III on the other hand were measured using a five – point likert – type scale ranging from 1 to 5 with 1 representing the lowest level of agreement while 5 representing the highest measurement.

Questionnaire Administration

The questionnaire was self- administered to all the 225 farmers in English, but few of the farmers who had difficulty with the English language, the researcher translated to the local language of the area (Ewe), Selection of farmers for interview was not biased towards any gender, religious or political affiliation. Village chief farmers and other appropriate opinion leaders in each selected community were briefed on the purpose of the study before any farmer was interviewed. This ensured that farmers received the interviewers through the proper chain of command in each community to enhance the accuracy of information given. The questionnaire was administered in September, 2019.

Pesticide Impact Analysis

The Environmental Impact Quotient Model (EIQ)

The Environmental Impact Quotient (EIQ) described by (Kovach et al., 1992b) was employed to assess the environmental impacts of pesticides used by cocoa farmers in the study area. The impacts encompass effects of the pesticides on the farmer worker, the consumer and the ecological component. The information gathered from the individual farmers on their pesticide application from the questionnaires administered was used in the calculations. Displayed below are the formular of the components:

A. Applicator Exposure + Picker Exposure

The risk of farm worker is determined as the sum of applicator exposure (DT*5) and picker exposure (DT*P) times chronic toxicity. The long-term effect of pesticide is Chronic toxicity (C). Applicator exposure is calculated as dermal toxicity (DT) times five. The picker exposure is calculated by, multiply DT with plant surface half-life potential (P). The time required for one half of the pesticide chemical to break down on plant surfaces is known as Plant surface half-life potential (Ayano-Negawo, 2016; Kovach et al., 1992a)EI farmworker = C [(DT ∗ 5) + (DT ∗ P) ……………………...… (eqn. 1)

B. Consumer Exposure Potential

Consumers' exposure potential is determined by, multiply chronic toxicity (C) by average residue potential in soil (S) and plant surfaces (P) with systemic potential rating of pesticide (SY) plus the potential ground water effect (L). The ability of pesticide to be absorbed by plant system is referred to as Systemic potential rating of pesticide. Potential ground water effect (L) was considered under consumers' exposure potential since it has a relationship with human health. Consumers have a possibility to drink contaminated water from wells, rivers and lakes. The health effects of pesticide were calculated based on the result obtained from tests conducted on small mammals such as rats, mice, rabbits and dogs. Farm workers and consumers in EIQ model represented mammals' exposure to pesticide (Ayano-Negawo, 2016; Kovach et al., 1992a)

$EI\ consumer = (C * ((S + P)/2 * SY) + (L)$ ……………….………… (eqn.2)

C. Ecological Components Exposure

Ecological components of EIQ model consisted of fish (F), birds (D), bees (Z) and beneficial arthropods (B). The model calculates effects on both aquatic and terrestrial. Impacts of pesticides on aquatic system is calculated by multiply chemical toxicity to fish rate (F) with surface runoff potential (R) of specific pesticide. Surface run potential takes represents the half-life of the pesticide on surface water. To determine the impacts of pesticides on birds, multiply toxicity rate to birds (D) with average half-life on plant and soil surfaces times three. The impacts of pesticides on bees calculated as toxicity rating to bee (Z) multiply by half-life on plant surfaces (P) times three. The effect of pesticides on beneficial arthropods (B) is determined by pesticide rating to beneficial natural enemies multiply by the half-life on plant surfaces times five.

Arthropods are not transient like birds and bees; hence their exposure potential is greater. This accounted to multiply the risks by scale of five (Ayano-Negawo, 2016; Kovach et al., 1992a)

EI ecology = (F ∗ R) + (D ∗ ((S + P/2) ∗ 3 + (B ∗ P ∗ 5) …………… (eqn.3)

Below are the symbols for variables used in the formular:

DT = dermal toxicity	D = bird toxicity
C = chronic toxicity	S = soil half-life
SY = Mode of action	Z = bee toxicity
F = fish toxicity	B = beneficial arthropod toxicity
L = leaching potential	P = plant surface half-life
R = surface loss potential	

The average of the farm worker, consumer, and ecological components constitute the Environmental Impact Quotient value. This is represented by the combination of the three equations above and shown as below:

EIQ = {[C (DT ∗ 5) + (DT ∗ P)] + [(C ∗ ((S + P)/2 ∗ SY) + (L)] + [(F ∗ R) + (D ∗ ((S + P/2) ∗ 3 + (B ∗ P ∗ 5)]}/3

For an accurate comparison of pesticides and pest management strategies, EIQ Field use rating was used. In order to obtain this, information, the dose, formulation or percentage of active ingredient and the frequency of application need to be shown clearly. One of the drawbacks of the rating system is seen when dealing with pesticides of the same active ingredients but different formulations. An EIQ Field use rating which accounted for these differences was developed. To calculate Field Use Rating EIQ, multiply reference EIQ for a specific pesticide with percent active ingredient and with rate per acre (Ayano-Negawo, 2016; Kovach et al., 1992a).

EIQ F. U. = EIQ ∗ % active ingredient (AI) ∗ application rate (R) kg/ha.

The Cornell University's online EIQ calculator (Eshenaur et al., 2015) was employed for all the calculations involving the Environmental Impact Quotient model for the study. In order to run the calculator: % AI, application rate and application intervals were imputed.

Laboratory Experiment

Collection of Leaching Samples

Soil sampling

The soil samples used for the study were collected from three communities each in two districts. These districts included Afadjato South and Ho West Districts. Three samples were collected in each farm. In all, 75 soil samples were collected. In order to ensure uniformity, all the soil samples were randomly collected from the upper 20 cm of the surface horizon following the removal of the surface vegetation and litter. The geographical coordinates of each sampling site were also taken.

Biochar Sampling

Two biochar types, corn cob and rice husk biochars were obtained from Soil Research Institute, Centre for Scientific and Industrial Research (CSIR) in Kumasi, Ashanti Region of Ghana for the study. The two adsorbent, Rice husk and Corn cob biochars were used for the remediation of the chemically polluted soil. The choice of these adsorbents was based on their local availability, cost-effectiveness, prevalence and literature on their effectiveness as amendments for pesticide polluted soils. Temperature greatly influences the physicochemical characteristics of biochar. Tang et al. (2013) and Yuan et al. (2019)

demonstrated that higher pyrolysis temperature usually resulted in an increase of surface area and carbonized fraction of biochar and that both of them would lead to higher sorption capability for pollutants in contaminated soil. Based on this the two biochars were prepared at the same pyrolysis temperature of 450 ^{o}C to ensure uniformity and easy comparison of their adsorptive capacities.

Characterization of Biochar and Soil Samples

The biochar samples were crushed in a mortar and sieved through a 2 mm sieve for uniform samples to be obtained. The soil sample were air dried by spreading them on a polythene rubber under room temperature for 48 hours. The lumpy particles were then broken in to smaller particles and then sieved through a 2 mm sieve to obtain a uniform size fraction. The sieved soil samples were stored under room temperature conditions in loosely closed black plastic bags for further analysis. Both the soil and the biochar samples were characterized by testing for the following physico – chemical properties: pH, moisture content, cation exchange capacity, organic carbon and textual class for only the soil samples using the procedures below.

Physico-chemical Properties Analysis

Determination of pH

Soil pH is a measure of hydronium ion (H_3O^+, or more commonly the H^+) activity in the soil solution. Soil pH influences many facets of crop production and soil chemistry, including availabilities of nutrients and toxic substances, activities and nature of microbial populations as well as activities of certain pesticides (Eckert & Sims, 1995). About 10 g of the previously air-dried soil sample was weighed in to a plastic test tube with a screw cap. Using a measuring cylinder, about 25 ml of distilled water was measured and poured on to the soil sample in the plastic test tube and shaken for 15 minutes on a mechanical shaker. Having calibrated the pH meter at pH of 4.00, 7.00 and 10.00, the pH was measured by inserting the electrode in to the soil suspension and the readings were taken (Clark, 1928). The pH of each of the soil samples was replicated three times and the average of pH values determined. The same procedure was employed to determine the pH of the biochar samples.

Determination of Percentage Moisture Content

About 5 g of the fresh soil sample was weighed in to a dry, weighed evaporating basin and placed in an air-circulating oven at 105 ^{o}C and dried to constant weight. The soil samples were cooled in a desiccator and weighed. The % fresh moisture was determined from loss in weight. The % moisture content was duplicated twice and the average of each calculated. The same procedure was used to determine the percentage moisture content of the biochar samples.

Calculation:

$$\%\text{ Moisture content} = \frac{\text{loss in wt. of on drying (g)} \times 100}{\text{Initial sample wt. (g)}}$$

Organic Carbon Content determination

In duplicate, 0.5g of soil sample was weighed out and transfer in to 500 mL Erlenmeyer flask and the weight recorded. By means of a pipette, 10 mL of $K_2Cr_2O_7$ solution was added to the soil sample and swirled gently. 20 mL of conc. H_2SO_4 was then added and content swirled gently for a minute. The flask was then allowed to stand for 30 minutes. Addition of conc. H_2SO_4 caused heat to be evolved. This heat was necessary to drive the reaction to completion. After 30 minutes of standing, the content of the flask was diluted with 200 mL of distilled water and swirled again to ensure thorough mixing. About 10 mL of

H_3P0_4, 0.2g NaF and 1mL of diphenylamine indicator were added to the sample. The excess $Cr_2O_7^{2-}$ with 0.5 M ferrous solution was back titrated to a green end point. A blank titration in an identical way using the same reagents was carried out, but omitting the soil and the biochar.

Calculation:

$$\%\ \text{organic carbon} = \frac{(B-S) \times \text{Molarity of } Fe^{2+} \times 0.003 \times 100 \times 100}{\text{Weight of soil} \times 77}$$

Where,

B = Blank titre value S = Sample titre value

0.003 = 12 / 4000 = milliequivalent weight of carbon

100/77 = the factor converting the carbon actually oxidized to total carbon

100 = the factor to change from decimal to per cent.

Determination of Cation Exchange Capacity

The cation exchange capacity (CEC) of a soil is a measure of the quantity of negatively charged sites on soil surfaces that can retain positively charged ions (cations) such as calcium (Ca^{2+} magnesium (Mg^{2+} and potassium (K^{+}), by electrostatic forces. Cations retained electrostatically are easily exchangeable with cations in the soil solution. Therefore, soil with a higher CEC has a greater capacity to maintain adequate quantities of $Ca^{2+,}$ Mg^{2+} and K^{+} than a soil with a low CEC. A soil with a higher CEC may not necessarily be more fertile because soil's CEC can also be occupied by acid cations such as hydrogen (H^{+}) and aluminum (Al^{3+})$^{.}$ However, when combined with other measures of soil fertility, CEC is a good indicator of soil quality and productivity (Ross & Ketterings, 1995).

About 6 g of previously air – dry soil sample was weighed and transferred in to a 50-mL narrow-neck centrifuge tube. An amount of 33 mL of 1.0 M sodium acetate solution was added and the tube was closed with a stopper. The mixture was then shaken in a mechanical shaker for 5 minutes and centrifuged at 2000 rmp until the supernatant liquid was clear. The liquid was decanted and the procedure above was repeated three more times. Then 33 mL of 95 % isopropyl alcohol was added to the mixture, closed with a stopper and shaken in a mechanical shaker for 5 min, and centrifuged again until the supernatant liquid was clear. The step above was repeated until the electrical conductivity (EC) of the decant reads less than 40 mS/cm. Then 33 mL of ammonium acetate (NH_4OAc) solution was added, the tube was covered with a stopper and shaken in a mechanical shaker for 5 min and centrifuged until the supernatant liquid was clear. The washing was decanted into a 100-mL volumetric flask and the above step was repeated two more times. The combined washing was diluted to the 100-mL mark with ammonium acetate solution and the sodium concentration was determined by flame photometry. Series of Na standard solutions ranging from 0 – 10 me/liter of Na were prepared. A standard curve was then created by plotting Na concentration on the X – axis and the flame photometry readings on the Y- axis. The samples extracted from the Na standards were incorporated in to the flame photometry and the readings taken, representing the concentration of Na read from the standard curve. In order to achieve a better result, Lithium chloride (LiCl) was then added in each standard to yield a final concentration of about 5 me/litre of LiCl. The cation exchange capacity (CEC) of the soil was calculated as follows:

The exchangeable Na in me/100 g soil:

$$= \frac{\text{Na conc of extract in meq /litre(Y) x 100}}{\text{Wt. of soil in g}} \times \frac{\text{vol. of extract in mL (100)}}{1000}$$

$$= \frac{y \quad + \quad 10}{\text{Wt. of soil}}$$

Where; y = Na conc, wt. = weight of soil

The displaced Na actually measured the CEC of the soil. Hence the Na/ 100 g is me exchangeable cations (K, Mg, Ca and Na)/ 100 g soil (Motsara & Roy, 2008).

Column Leaching Experiment and Experimental Design

The column was made from a polyvinyl chloride pipes (PVC) with a 5 cm inside diameter and 17 cm in height. The bottom of the column was equipped with a 2 cm drainage holes fitted with drilled end caps and screwed to accept 13 mm x 102 mm male – to male adaptor as drainage pipes. To prevent the loss of soil samples from the column, screen fibers of garden mulch were glued over the holes with silicon caulk. The columns were then supported on a wooden rack by two 28 cable ties per column (Silveira et al., 2006).

A randomized complete block design was employed in the study. A total of 30 columns were used. The columns were arranged in a randomized complete block design to experience the same environmentally relevant conditions (Kernan et al., 1999).

Treatment and Total Number of Columns from the Experiment

Soil 1: 2 amendments (corn cob biochar and rice husk biochar) at 2 rates (0.5 % and 1 %) plus 3 controls with 3 replicates [number = 15]

Soil 2: 2 amendments (corn cob biochar and rice husk biochar) at 2 rates (0.5 % and 1 %) plus 3 controls with 3 replicates [number = 15]

Thus, 2 soil types [2 amendments x 2 rates x 3 replicates] + 6 controls = 30 columns

Test Chemical

According to the result obtained from the qualitative responses from the farmers about the type of pesticides used, bifenthrin commonly known as Akate Master was found to be the most common pesticide used by the farmers in the study area. Akate Master (Bifenthrin) was therefore used in the adsorption experiment

Procedure for column Leaching Experiment.

About 250 mL of the Bifenthrin was dissolved in distilled water and applied to previously homogenized and characterized soil samples. The resulted soil sample was air dried for 24 hours. This is to assume the state of accidental pesticide spillage in soil. About 260 g of each of the soil samples were treated with three rates of rice husk and corn cob biochar (0 %, 0.5 % and 1 % by weight) and transferred in to zip lock bags. The soil mixtures in the zip lock were mixed thoroughly with gloved hands to ensure uniform distribution. The bagged samples were incubated at room temperature for 7 days and were subjected to kneading every morning and exposed to air for about 10 – 15 minutes to reduce the occurrence of anaerobic conditions (Miyittah et al., 2011).

The incubated soil mixture samples were poured in to the columns in small portions with spoon and pressed with plunger under simultaneous gentle column vibration until the top of the column did not sink in further since uniform packing was required to obtain reproducible results (OECD, 1994). After packing, the columns were pre- wetted (OECD, 1994) with the artificial rain in order to displace the air in the soil pores by the water. Thereafter, the columns were allowed to equilibrate and the excess water drained by gravity and the pore volume (90 ml) was determined. Each leaching event is considered to be corresponded to 1 pore volume. The leaching involved the application of 90 ml of artificial water to each column weekly for four weeks. In order to ensure the evenly distribution of the artificial rain over the entire surface to prevent disturbance of soil surface by rain drops, the surfaces of the columns were covered by glass fibers (OECD, 1994). With the aid of a dropping funnel, the columns were irrigated with 90 ml of Voltic water which has a pH (acidic) of the rainwater of the study site. In order to minimize evaporation and to maintain field capacity, a transparent polythene sheet was used to cover wetted columns after irrigation. The leachates were collected weekly and analyzed using Gas Chromatography- Mass Spectrometer (GC – MS).

Batch Adsorption Experiment

The standard batch equilibrium method for the sorption–desorption experiments based on the OECD guideline 106 (OECD, 1994) was used for the batch adsorption experiment. Three different concentrations of the pesticide (Akate Master, Bifenthrin) with concentrations ranging from 10, 15 and 20 l/ g pesticide per gram of each of the biochars (corn cob biochar and rice husk biochar) were used. Triplicates were prepared for each concentration for each biochar. Blank samples were also used in order to check for artefacts in the analytical method. All experiments were performed at room temperature, 21 ± 2 C. To measure sorption of the pesticide samples, 5 g of each biochar were placed in polypropylene centrifuge tubes (45 ml maximum capacity) with 0.01 M $CaCl_2$ solution (23 ml) in deionized water and shaken for 6 hours using an orbital shaker at 150 rpm. After the biochar was pre-equilibrated with the 0.01 M $CaCl_2$, appropriate volumes from aqueous pesticide solutions were added in order to obtain the appropriate concentrations. No pesticides were used for the blank samples. It was ensured that the volume of the stock solution that was added did not exceed 10% of the final volume of the aqueous phase so as to limit any change of the pre-equilibration solution (OECD, 1994). The final volume of 25 ml aqueous phase was obtained by addition of 0.01 M $CaCl_2$ solution giving a biochar: solution ratio of 0.2 g/ml. Tubes were then returned to the orbital shaker for 24 hr. After the shaking of the mixture, the biochar suspensions were separated by centrifugation at 4500 rpm for 10 min. An aliquot (1 ml) from the supernatant was pipetted into a HPLC for analysis. The amount of pesticide in the solution was calculated by using the equation obtained from the calibration curve of each pesticide. The amount of sorbed pesticide in the soil sample was determined as the difference between the amount of test substance, which was initially present in solution and amount of pesticide that existed after equilibration in the aqueous phase.

The biochar sorption distribution coefficient or partition coefficient K_d, conventionally written with a subscript d (for 'distribution'), can be defined as a ratio of the pesticide concentration in the solid phase to that in the solution phase at equilibrium (Kah & Brown, 2007; Khan, 2016; Wauchope et al., 2002).

Sorption distribution coefficients (K_d) $cm^3\ g^{-1}$ were obtained by plotting the mean equilibrium concentration of the pesticide in the aqueous phase, C_{aq} ($\mu g\ g^{-1}$) versus the mean concentration of pesticide sorbed on the biochar samples, C_s ($\mu g\ g^{-1}$) for each equilibrium concentration.

$K_d = C_s / C_{aq}$

The organic carbon (OC) of soil sample is the single largest factor that have maximum influence on pesticide degradation, adsorption, and mobility in the soil. Hence the soil organic carbon adsorption distribution coefficient (K_{OC}) is generally used as a measure of the relative potential mobility of pesticides in soils to describe the partitioning of them in the water/soil/air compartments (Pérez-Lucas et al., 2018).

The organic carbon sorption distribution coefficient, K_{oc} (cm^3 g^{-1}) was calculated for each soil as:

$K_{oc} = K_d \times 100 / o.c$

where o.c is the content of organic carbon in the soil samples expressed as % (Khan, 2016; Yazgan et al., 2005). Large values of K_d (of the order of ≥ 100 mL g-1) indicate that a pesticide is strongly sorbed to the soil particles and will be relatively immobile in soil; it may also be relatively resistant to microbial degradation (Khan, 2016; Wauchope et al., 2002).

Quality Assurance / Quality Control (QA/QC)

To take care of the matrix effect on the analyte in order to check the efficiency of the extraction process, recovery test was conducted by spiking 20 % of the samples with 50 µl of 0.1 ppm standard before extraction. Solvent blank analysis was performed using methanol, purity > 99.99 followed by the analysis of the control. Continued calibration Verifications (CCVs) standard was analyzed for every 10 samples run to verify the reliability of the method calibration curve and the instrument (US EPA, 1998). The result of the quality control is shown in figure 3 below.

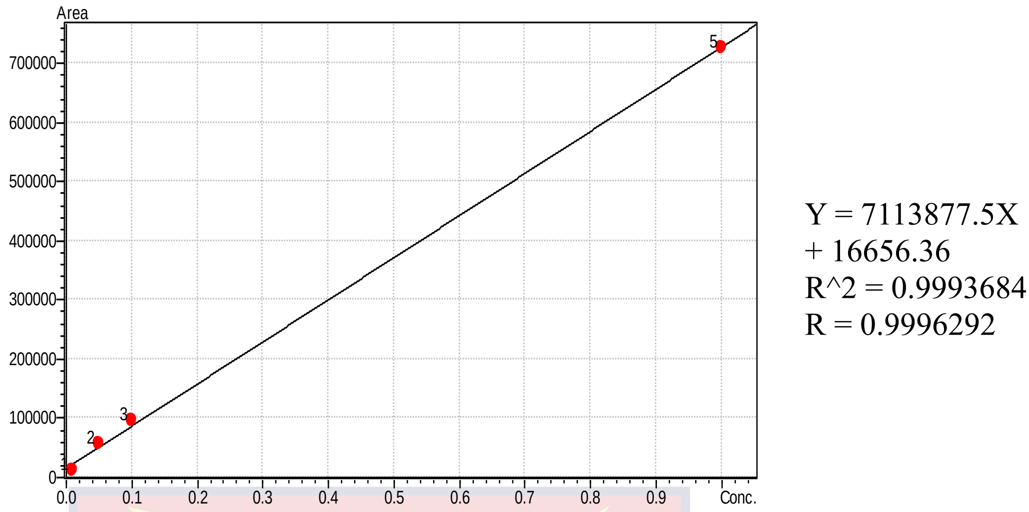

Figure 3: Calibration curve for bifenthrin

The recovery of spikes ranged from 80 to 110 %. The result show that the extraction process was about 99 % efficient.

Solid Phase Extraction of Bifenthrin

A 500 mg C – 18 bonded silica cartridges were used to separate the analyte from the matrices of the pesticide leachate. Before the loading of the cartridges, the cartridges were conditioned with 10 ml of methanol followed by 6 ml of deionized water while ensuring that they cartridges were kept wet. About 200 ml of the sample was loaded on to the pre-conditioned cartridge and washed with 6 ml of deionized water to remove the matrices. The content in the cartridge was allow to dry for 5 minutes. The content was then eluded with 3 ml of methanol three successive times.

Standard Solution Preparation

A serial dilution of a concentrated standard was performed with methanol to prepare concentrations of 0.01 ppm, 0.10 ppm and 1 ppm each in to labelled 1.5 ml vials. The analyzed standard was used to obtained a calibration curve.

Quantitative Analysis of Bifenthrin Using GC-MS

Gas Chromatography (GC) Conditions

The temperature programming was employed for the GC. The initial temperature, 50 ^{o}C was held for 1 minute and then ramped at a rate of 20 ^{o}C and held for 3 minutes making a total run of 25.25 mins. The injection port temperature was held at 250 ^{o}C. A column rate flow of 1.69 mL / min was used with the linear velocity control mode. The used column was 30 m (leigh) x 0.25 micro (thickness) x 0.25 mm (Internal Diameter), RTX- 5 ms Restack column (US EPA, 1998).

Data Analysis

Data were analyzed using the IBM Statistical Product and Service Solution (SPSS) version 20.0 and Stata version 13 software. Data analyses included univariate and multivariate statistics. Frequencies and percentages were used to describe the knowledge level and attitude of farmers towards pesticides. For the pesticide use practices, frequencies and percentages were employed to assess the types of pests and diseases control methods used by farmers, types of pesticides and their sources, reasons for application, source of knowledge for application, dosages and frequency of application, pre- harvest intervals, pesticide mixtures for application, pesticide storage and disposal methods, PPEs used, the types of spraying equipment used by farmers and farmers opinions about the trend of pesticide use. The Pearson Chi – square statistics was used to compare significance differences between factors associated with farmers' pesticide storage and empty container and remnants of spray disposal methods. Additionally, the significance differences between factors influencing the use of just the presence of pests and diseases as timing for pesticide application was also determine using Pearson Chi- square. The Pearson Chi- square is used to estimate the association between categorical variables (Armah et al., 2018). The Chi-square test of independence is a nonparametric statistical test that is used to determine if two or more group of samples are independent or not (Armah et al., 2018). The Cramer's V statistics was used to measure the magnitude or effect size of the significance. To predict the factors influencing the use of just the presence of pests and diseases and the likelihood that a farmer will experience fever, headache or skin rashes were determined using generalized linear models (GLMs) (objective 1).

Frequencies and percentages were used to describe farmers' knowledge and awareness levels of alternative pest and diseases control methods, alternative pests and diseases control methods practiced and their components and sources of information about them. The Pearson Chi – square statistics was used to compare significance differences between factors associated with farmers' knowledge of alternative pests and diseases control methods. However, the Cramer's V statistics was used to measure the magnitude or effect size of the significance. The generalized linear models was used to predict factors that influence farmers' knowledge of alternative pests and diseases control (objective 2).

The EIQ model and the self – reported toxicological symptoms of pesticide use were used to assess the risks posed to humans and the environment. The risks posed to the farmer, consumer and the ecology were determined using the Cornell University online EIQ calculator. Frequencies and percentages were used to describe the self – reported pesticide toxicological symptoms experienced by farmers. The Pearson Chi – square statistics was used to compare significance differences between factors associated with the reporting of fever, headache and skin rashes while the Cramer's V statistics was used to measure the magnitude or effect size of the significance (objective 3). The supernatant of the Batch adsorption equilibrium experiment and the leachate of the soil column leaching experiment were analyzed using Gas Chromatography Mass Spectrometer (GC–MS) (US EPA, 1998). The generalized linear models was used to determine the significance differences within treatments, weeks and within treatment weeks at $p< 0.05$ (objective 4).

Model specification of the binary regression

For the analysis, the likelihood of farmers using just the presence of pests and diseases as timing for pesticide application, reporting of pesticide toxicological symptom (fever, headache and skin rashes) and the likelihood of farmers being knowledgeable of alternative pests and diseases control methods were estimated using exponentiated coefficients—odds ratios (ORs). An OR of 1 means that predictor does not affect odds of influencing; farmers to apply pesticides due to just presence of pests and diseases or farmers' being knowledgeable of alternative methods of pest control or a farmer reporting pesticide toxicological symptom (fever, headache or skin rashes) ; OR > 1 means that predictor is associated with higher odds of influencing; farmers to apply pesticides due to just the presence of pests and diseases or farmers' being knowledgeable of alternative methods of pest control or a farmer reporting pesticide toxicological symptom (fever, headache or skin rashes); and OR < 1 means that predictor is associated with lower odds influencing farmers to apply pesticides due to just the presence of pests and diseases or farmers' being knowledge of alternative methods of pest and diseases control or a farmer reporting pesticide toxicological symptom (fever, headache or skin rashes). The study employed 95 % confidence interval (Cl) and the level of statistical significance was set at 0.05. Under the assumption of a binary response (no = 0, yes = 1) to each of the variables, there are a number of probable options: the logit model, probit model, complementary log-log model, and negative log-log model depending on the link function of the GLM (Armah et al., 2019a). Both logit and probit link functions have the same property, which is link [π (x)] = log [- log (1 – π (x))]. This means that the response curve for (x) has a symmetric appearance about the point $\pi(x)$ = 0.5, and so $\pi(x)$ has the same rate for approaching 0, as well as for approaching 1 (Aitkin et al., 2005; Armah et al., 2019a). This implies that 50% of participants responded in the affirmative, and the other 50% did not (Armah et al., 2019a). In this study, none of the outcome variable satisfied this property of symmetry so it was not used. When the number of affirmative and negative responses is asymmetric in the [0, 1] interval, as in the case of five outcome variables in this study, a complementary log-log link function or negative log-log link is therefore, appropriate depending on the distribution (Armah, 2014; Armah et al., 2019a; Fahrmeir et al., 1994). Seventy- one percent of respondents reported using just the presence of pests and diseases as timing for pesticide application while the rest did not. Besides, sixty-two percent reported fever, fifty-nine percent, headache and fifty –two percent reported skin rashes. The complementary log-log model, which takes into account the fact that affirmative responses are more probable, gives a better representation and was therefore used for the analysis of the relationship between the odds of reporting, using just the presence of pests and diseases as timing for pesticide application, fever, headache, skin rashes and theoretically relevant variables. Knowledge of alternative pests and diseases control methods (25% yes, 75 % no) signify asymmetry in the distribution of reported knowledge of alternative pests and diseases control methods, with no as more probable responses. Therefore, knowledge of alternative pests and diseases control methods parameter estimates was determined by binary negative log-log regression (a GLM), which was adjusted for the remaining independent variables included in the regression models.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

This chapter presents and discusses the results of the study in relation to the specific objectives, the hypotheses and the relevant literature of the study.

To establish the association between farmers' knowledge, attitude and pesticide use practices

Socio- demographic Characteristics of the Respondents

Table 1 presents the demographic characteristics of the respondents in the study area. The demographic characteristics of the respondents considered in this study included gender, age, education, household size, ethnic group, farmers' years of experience and farm size.

It was evident from the study that male dominated cocoa farming in the Volta Region of Ghana, 212 (94.0 %) were males while females were13 (6.0 %). This may be attributed to the laborious nature of the occupation coupled with long years it takes for the cocoa to mature hence less attractive to most females. The male to female ratio in this study corroborates earlier report by (Denkyirah et al., 2016; Okoffo et al., 2016; Paintsil, 2017) who reported that cocoa farming in Ghana was dominated by males.

The mean age of the farmers was 51 years, with the minimum being 20 years and the maximum 84 years. About 50.0 % were within the 34 – 55 years group with only 10.0 % being below 35 years. About 40.0 % were 55 and above years old. The findings of this study is in line with (Okoffo et al., 2016) and at variance with the findings of (Denkyirah et al., 2016; Paintsil, 2017) who reported that the average of the farmers were 44 and 38 years respectively. The mean age is an indication of poor quality of labour in cocoa production in the study area which would lead to low productivity since the older farmers are less energetic than the younger ones. This is a worrisome situation since the industry lies in the hands of the middle adult and the old adult groups. Kwadzo (2015) reported that younger farmers are more likely to undertake a new venture than older farmers nearing retirement age. With the current crop of cocoa farmers fast aging, it is feared that without involvement of the youth in cocoa farming, many people whose livelihoods depend on a sustainable cocoa supply chain, risk losing their jobs.

The educational levels of the farmers were very low as majority 137 (61.0 %) had basic education, secondary 66 (29.0 %), tertiary 12(6.0 %) and no form of formal education 10 (4.0 %) (Table 1). The farmer's educational level affects the decisions they take in terms of adoption of new technology and the engagement of activities that will not have adverse effects on the environment and human health. According to Adejumo et al.(2014), Falusi(1974), Kebede et al. (1990), Mariyono (2007), Norris and Batie (1987), farmers who are educated seem to be easily adopted to new technologies and are more likely to be earlier adopters (Table 1).

The average household size was 7; minimum being 1 and maximum 19. The medium household group, 6 – 10 had the highest 130 (58.0 %) household members while the small group,1 – 5 and large group, ≥ 10 had 52 (23.0%) and 43 (19.0 %) respectively (Table 1).

With regards to ethnicity in the study area, most 197 (87.0 %) were Ewe while the rest 16 (7.0 %), 8 (4.0 %), 4 (2.0 %) were Bassari, Hausa and Dagbani and others respectively. This implies that most of the farmers in the study area were natives. Majority 82 (36.0 %) of the farmers had more than 10 years' experience, with 69 (31.0 %) having 7 – 10 years of experience. Those with 4 – 6 years of farming experience were 62 (28.0 %) while those with 1 – 2 years were 12 (5.0 %). The results show that most of the farmers in the study area have quite adequate farming experience. This findings agree with Adesuyi et al. (2018) and Denkyirah et al. (2016) and Okoffo et al. (2016) who reported that majority of the farmers in Nigeria and Ghana had adequate farming experience respectively. It is obvious from the result that the likelihood of farmers in the study area adopting technologies on how use pesticides would be high.

Table 1: Socio- demographic Characteristics of the Respondents

Variable	Frequency	Percentage (%)
Gender		
Male	212	94
Female	13	6
Age group (years)		
Below 35 years	22	10
35 - 55 years	113	50
55 and above years	90	40
Education level		
No formal education)	10	4
Primary education	137	61
Secondary Education	66	29
Tertiary education	12	6
Farmer's experience		
1 - 3 years	12.0	5
4- 6 years	62.0	28
7 - 10 years	69.0	31
Above 10 years	82.0	36
Ethnic group		
Ewe	197.0	87
Bassari	16.0	7
Hausa	8.0	4
Dagbani & others	4.0	2
House hold size		
small (1-5)	52.0	23
medium (6-10)	130.0	58
large (above 10)	42.0	19
Farm size (acres)		
Mean	4.2	
Mode	2.0	
Minimum	0.5	
Maximum	20.0	

Farmers' Knowledge of Common Pests and Diseases of Cocoa

Table 2 shows the commonly reported diseases and pests of cocoa in the study area. The results also show that majority 163 (72.4 %) of the farmers identified mirids as the most important economic insect pest in the area (Table 2). Similar observations were made by (Antwi-Agyakwa, 2013; Osei-Boadu, 2014; Paintsil, 2017). Similarly, a study conducted by Antwi-Agyakwa et al. (2015) to assess insecticide use practices in four cocoa growing regions in Ghana revealed that mirids were the major insect pest in the study areas. This buttresses the fact that mirids remain the insect pests of economic importance in Ghana. Wessel and Quist-Wessel (2015) concluded in a similar study that Mirids (*Distantiella theobroma* and *Sahlbergella singularis*) are the most important insect pest of cocoa in West Africa and cause annual crop losses about 25 percent in Ghana. Identifying Mirids as the most prevalent insect pest in the area may be attributed to the misapplication of Akate Master by majority of the farmers (Table 15), a pesticide commonly used (Table 11) by the farmers to control mirids, which has led to development of resistance by the insect. Other pests identified by the farmers in the study area included 20 (8.9 %) termites, 18 (8.0 %) caterpillars, 11(4.5 %) mistletoes, 9 (4.0 %) mealy bugs and 4 (2.0%) stem borers (Table 2).

Table 2: Farmers' Knowledge of common Pests and Diseases of Cocoa (n =225)

Pests and Diseases	Frequency	Percentage (%)
Pests		
Mirids	163	72.4
Termites	20	8.9
Caterpillar	18	8
Mistletoe	11	4.9
Stem borers	4	1.8
Mealy bugs	9	4
Diseases		
Black pod	168	74.7
Swollen shoot	41	18.2
Cherelle wilt	11	4.9
Canker	5	2.2

When it came to the most common diseases in the area, majority 168 (74.7 %) of the farmers mentioned black pod disease. This finding is in agreement with (Opoku et al. (2007). Dormon (2006) reported that black pod, caused by *phytophthora* spp is the most common disease of cocoa in Ghana. According to (Dakwa, 1976), a black pod survey conducted in 1970s revealed that Volta Region consistently had the highest black pod incidence. This confirms the fact that black pod is the major cocoa disease in the Volta Region. This could be attributed to the fact that Volta Region shares a border with Togo where P. *megakarya* was the dominant species (Dakwa, 1976). Other diseases mentioned were 41 (18.2 %) swollen shoot, 5 (2.0 %) *Phytophthora* canker and Cherelle wilt 11 (4.9 %) (Table 2).

Farmers' Knowledge of names of Used and Forbidden Pesticides and their Health Effects

Farmers' Knowledge of Pesticides

Table 3 illustrates the knowledge of famers (n = 225) regarding the names of pesticides and their health effects. Farmers' knowledge of the names of pesticides is very crucial when it comes to the assessment of pesticide toxicology. In the last three decades due to ecotoxicities and long half-lives of pesticides, there has been a banned on several pesticides (Yang et al., 2014). The result showed that a total of 215 (96.0) farmers knew the names of the pesticides they were using. This means that all (100.0 %) of the nine communities under studied, had more than 50.0 % of the farmers knew the names of the pesticides they were using. This could be linked to the fact that majority of the famers had primary (61.0 %) and secondary (29.0 %) education, and this could help them at least to read and keep the names of the pesticide they used in mind. This finding is consistent with a study in Gaza Strip where majority of the farmers were found to have relatively accurate knowledge of the names of the pesticides they used (Yassin et al., 2002). A similar study conducted in Palestine also showed that about 97.9 % of the participants knew the names of the pesticides they were using (Zyoud et al., 2010). However, in this study, only 71(32.0) farmers knew the names of some of the pesticides banned by COCOBOD and EPA (Table 3). This is worrisome and can be traced to the low level of education and extension services in the community. The poor knowledge of farmers in the banned pesticides may lead to the application of these pesticides which may increase the issues of chemical residues in harvested cocoa beans and other crops grown among the cocoa, resistance and pest resurgence as well as human health problems. Contrary to this finding, other researchers concluded in a study carried out in China that majority of the respondents knew the names of the banned pesticides (Yang et al., 2014).

Table 3: Farmers' Knowledge of Pesticides and Health Effects (n = 225)

Variable	Frequency	Percentage (%)
Name of pesticides used		
Do you Know the name of any pesticides used?		
No	10	4.0
Yes	215	96.0
Do you Know the name of any banned pesticides?		
No	154	68.0
Yes	71	32.0
Health effects of pesticides		
Do you Know pesticides can cause negative health effects?		
No	14	6.0
Yes	211	94.0
Do you Know all pesticide have same health effects?		
No	94	42.0
Yes	131	58.0
Do you Know pesticides are dangerous to use?		
No	14	6.0
Yes	211	94.0

Farmers' Knowledge of Health Effects of Pesticides

Other studies revealed that factors contributing to the morbidity and mortality of pesticide exposure included inadequate knowledge (Gesesew et al., 2016a; Ibitayo, 2006; Nalwanga & Ssempebwa, 2011). When the distribution of the farmers based on their knowledge of the health effects of pesticides was evaluated, a total of 221 (94.0 %) farmers who took part in the study indicated that pesticides could cause negative health effects to humans. When the farmers were asked further whether all pesticides have the same health effects, a total of 131 farmers, representing (58.0 %) knew that all pesticides do not have the same health effects. About 211 (94.0 %) of the farmers claimed pesticides use could be dangerous (Table 3). The results indicate that farmers have good knowledge of the health effects of pesticides on humans and the environment. This may be due to good extension and agrochemical services regarding negative health effects of pesticides in the study area. The findings of the study are in line with the findings of a study conducted in Palestine where about 84 % of the respondents indicated that pesticides have detrimental effects on human health (Zyoud et al., 2010). A study carried out in the Brong Ahafo Region of Ghana to assess the pesticide exposure and the use of PPE by cocoa farmers in Ghana revealed that majority (83.7 %) were aware that pesticides have negative health effects on living things if not handled with care, while 18.3 % indicated no knowledge of potential effects of pesticides on the environment (Okoffo et al., 2016). In the contrary, a similar study conducted in the Western Region of Ghana concluded that the farmers knowledge in harm posed by pesticide to the environment was low (Paintsil, 2017). The results from this study show that farmers are less likely to be exposed to pesticides due to the in-depth knowledge in health effects of pesticides.

Farmers' Knowledge of Route of Pesticide entry into the Body

Pesticides can enter human body during and after application through different means. Table 4 also presents the possible pesticide route of exposure known by the farmers in the study area; about 219 (97.0 %) and 218 (97.0 %) farmers claimed that inhalation and mouth respectively were the route of entry, followed by 217 (96.0 %) farmers who reported that skin was the route of entry of pesticides in to the body. This result is an indication that the farmers in the study area have an in-depth knowledge in the route of pesticides into the body. This may be attributed to the intensity of education on pesticides use safety practices by the two main agents of information dissemination (agrochemical shops and extension services) as discovered in the findings of the study (Table 16). Similar observations were made by (Paintsil, 2017). Okoffo et al. (2016) in their research to assess the pesticide exposure and the use of PPE by cocoa farmers in Ghana had similar discoveries in which majority of the respondents were aware that the eye (74.2 %), skin (85 %) and mouth (86.3 %) were the routes by which pesticides may enter the human body, however, contrary to my findings, only 41.3 % were aware that inhalation is also a route of exposure to pesticides whiles about 5 % indicated lack of knowledge of any route of pesticide exposure. Good knowledge in route of pesticide entry in to the body by the farmers may be a guide as to how to protect themselves during pesticide handling.

Table 4: Farmers' Knowledge of Route of Pesticide Entry into the Body and Manufacturers Notification (n = 225)

Variable	Frequency	Percentage (%)
Routes of pesticide entry in to the body		
Can pesticides enter the body through inhalation?		
No	6	3.0
Yes	219	97.0
Can pesticides enter the body through the Skin?		
No	9	4.0
Yes	217	96.0
Can pesticides enter the body through the mouth?		
No	7	3.0
Yes	218	97.0
Manufacturers notification		
Do you read manufacturers notification?		
No	63	28.0
Yes	162	72.0
Do you respect manufacturers notification?		
No	48	21.0
Yes	177	79.0

Factors that Influenced Farmers' Knowledge in the Route of Pesticide Entry into the Body

The chi- square statistics was employed to determine which factors influence farmers' knowledge in route of pesticide entry into the body. The results show that there were statistically significant differences and association between inhalation as a route of pesticide entry in to the body and farmers' years of experience (P = **0.007,** Cr. V = 0.233), agrochemical services (P = **0.05,** Cr. V = 0.108) and pesticide label (P = **0.002**, Cr. V = 0.206). Besides, there was statistically significant differences and association between skin as route of entry of pesticides in to the body and farmers' years of experience (P = **0.000,** Cr. V = 0.303), agrochemical services (P = **0.034**, Cr. V = 0.141) and pesticide label (P = **0.000**, Cr. V = 0.275). However, mouth as a route of pesticide entry into the body showed statistically significant differences and association between agrochemical services only (P = **0.006**, Cr. V = 0.182) (Tables 5, 6 and 7).

Farmers' Years of Experience

The results mean that the more experience the farmers are, the more knowledgeable they become of the route of pesticide entry into the body. This is consistent with the previous studies which reported that farmer's experience with health risk (eg. irritation, cough) when working with pesticides had a statistically significant and positive effect on farmers safety behavior (Feola & Binder, 2010; Sharifzadeh et al., 2018). Thus, the more farmers experience health risks and threats by pesticides, the more knowledgeable they become regarding the safe use of the pesticides. Other studies have also identified farmers' experience of adverse health effects in the past as one of the determinants of applying safety measures during pesticide handling (Feola & Binder, 2010; Hashemi et al., 2012; Sharifzadeh et al., 2018).

Table 5: Association between Farmers' years of Experience and Inhalation, Skin, and Mouth as routes of pesticide entry in to the body (n = 225)

	Years of experience				Measure of
	1 - 3 yrs.	**4 - 6 yrs.**	**7 - 10 yrs.**	**> 10 yrs.**	**association**
Inhalation					
No	2 (33.0)	0 (0.0)	3 (50.0)	1 (17.0)	π^2 = 12.173 P =
Yes	10 (5.0)	62 (28.0)	66 (30.0)	81 (37.0)	**0.007** Cr. V = 0.233
Skin					
No	3 (38.0)	0 (0.0)	4 (50)	1 (12)	π^2 = 20.694 P =
Yes	9 (4.0)	62 (29.0)	63 (30.0)	81 (37.0)	**0.000** Cr. V = 0.303
Mouth					
No	0 (0.0)	1 (14.3)	3 (42.9)	3 (42.9)	π^2 = 1.279 P =
Yes	12 (5.4)	61 (28.0)	66 (30.3)	79 (36.2)	0.734 Cr. V = **0.075**

Agrochemical Shop Services

Agrochemical dealers who sell pesticides to farmers also serve as conduit of dissemination of information regarding pesticide use safety. Therefore, those farmers who to buy pesticides from agrochemical dealers are more likely to receive some information on pesticide route of entry in to the body, which is in line with Rahaman et al.(2018) who commented that farmers mainly sought advice from agrochemical dealers or retailers on pesticide use. Considering this, agrochemical dealers should be well trained so that they can discharge the duties of the extension officers due to low farmer – extension contact ratio.

Table 6: Association between Agrochemical Services and Inhalation, Skin and Mouth as routes of pesticide entry into the body (n = 225)

Variable	Agrochemical shop services		Measure of association
	No	Yes	
Inhalation			
No	1 (17.0)	5 (83.0)	π^2 = 2.632 P = **0.05** Cr. V = 0.108
Yes	110 (50.0)	109 (50.0)	
Skin			
No	1 (12.5)	7 (87.5)	π^2 = 4.502 P = **0.034** Cr. V = 0.141
Yes	110 (51.0)	107 (49)	
Mouth			
No	7 (100.0)	0 (0.0)	π^2 = 7.420 P = **0.006** Cr. V = 0.182
Yes	104 (48.0)	114 (52)	

Pesticide Label

The results indicate that the more a farmer reads the pesticide label the more knowledgeable the farmer becomes in pesticide route of entry into the body. This is confirmed by Damalas et al. (2006), Grey et al. (2005), Lichtenberg and Zimmerman (1999) and Wilkinson et al. (1997) who stated that the most common and important source of information on pesticide product such as route of entry into the body, pre – harvest interval, application rate is the pesticide label. Hence, farmers who read pesticide label are more likely to use pesticides in a safe manner and vice versa.

Table 7: Association between Pesticide Label and Inhalation, Skin and Mouth as Routes of Pesticide entry in to the body (n = 225)

Variable	Pesticide labels		Measure of association
	No	Yes	
Inhalation			
No	4 (67.0)	2 (33.0)	π^2 = 9.572 Pr = 0.002
Yes	209 (95.0)	10 (5.0)	Cr. V = 0.206
Skin			
No	5 (62.5)	3 (37.5)	π^2 = 16.999 Pr = **0.000**
Yes	208 (96)	9 (4)	Cr. V = 0.275
Mouth			
No	6 (86.0)	1 (14.0)	π^2 = 1.147 Pr = 0.287
Yes	207 (95.0)	11 (5.0)	Cr. V = 0.071

Farmers' Knowledge of Manufacturers Notification (labels)

Pesticide label reading and following instructions during application are important for safe handling. The result shows that most 162 (72.0 %) famers claimed they read pesticide labels while 177 (79.0 %) reported that they respected pesticide labels (Table 4). It is obvious from the result that even though 7.0 % of the farmers respect pesticide label, yet they do not read it. This is contrary to another study where only 34.0 % of the famers read pesticide label before pesticide application (Rijal et al., 2018). In the study conducted by (Öztaş et al., 2018) it was reported that 88.6 % of the farmers read pesticide labels. Some of the farmers in the study area claimed they found it difficult to read the label. Additionally, those who read the label also confirmed having difficulty in understanding what they read. Thus, even though they read the label, they do not receive the full benefit of the information on the label. It also came to light during the field survey that illiteracy, inability to handle the label language and poor vision were some of the challenges hindering farmers ability to read the labels. These findings are consistent with the findings of Damalas et al. (2006) and Wilkinson et al. (1997). While education through extension service is to be intensified, it is also advised that Ghana COCOBOD gives out incentive packages such as soft loans to attract highly educated personnel into the cocoa industry to address the issue of illiteracy.

Table 8: Distribution of Farmers' Knowledge of Fate of Pesticide Residues (n = 225)

Variable	Frequency	Percentage (%)
Can pesticide residues be left in the air?		
No	31	14.0
Yes	194	86.0
Can pesticide residues be left in the soil?		
No	28	12.0
Yes	197	88.0
Can pesticide residues be found in the ground water?		
No	40	18.0
Yes	185	82.0
Can pesticide residues be found in fruits?		
No	47	21.0
Yes	178	79.0
Can pesticide residues be found in vegetable?		
No	34	15.0
Yes	191	85.0
Do you know any other method of pest control		
No	197	75.0
Yes	56	25.0

Farmers Knowledge of Fate of Pesticide Residues

When the farmers knowledge regarding fate of the pesticide residues was assessed, majority 197 (88.0 %) said soil, 191 (85.0 %) vegetable, 185 (82.0 %) ground water and 178 (79.0 %) said fruits (Table 8). Yassin et al. (2002) in their studies found out that majority 126 (66.7 %) of the respondents reported that pesticide residues may be detected in soil which is in line with this study, however, regarding the fate in underground water, a contradictory result of 88 (42.3 %) respondents responding in the affirmative was reported. The higher knowledge levels exhibited by the farmers regarding the fate of pesticide residues in the study area may be linked to their high levels of experience in pesticide usage.

Farmers' Attitude towards Pesticide Use

Farmers attitude towards pesticide influences their pesticide use practices. When the farmers were asked to indicate to what extent they agreed or disagreed to the statement, ''proper knowledge is necessary when using pesticide'', 179 (79.0 %) farmers strongly agreed, 43 (19.0 %) farmers agreed, 2 (1.0 %) strongly disagreed. When asked further, whether ''there are minimal health risks attached to pesticide use'' 123 (54.0 %) of the farmers strongly agreed to the statement, 45 (20.0 %) agreed, 40 (18.0 %) disagreed, 11 (5.0 %) strongly disagreed and 6 (3.0 %) neither agreed nor disagreed. 182 (80.0 %) farmers strongly agreed, 40 (17.0 %) agreed, 2 (2.0 %) disagreed and 1 (1.0 %) strongly disagreed when asked whether pesticides should be used with precaution. When they were asked finally whether ''pesticide use should be limited'' 66 (29.0 %) of the farmers strongly agreed, 56 (25.0 %) agreed, 48 (21.0 %) strongly disagreed and 47 (21.0 %) of the farmers disagreed to the statement (Table 9). The result indicates that farmers in the study area have positive attitude towards pesticide use. This results are similar to (Gesesew et al., 2016a) but at variance with (Paintsil, 2017) who concluded that farmers have positive attitude towards pesticides use and poor attitude towards pesticide use respectively. A previous study conducted in Thailand also concluded that about 69.3 % of the farmers had positive attitude towards herbicide use. This result may be due to long term experience of the majority of the farmers in pesticide use in the study area. Health belief models in public health and social psychology argues that individuals with adverse health experiences are likely to undertake preventive behavior (Lichtenberg & Zimmerman, 1999). According to Gesesew et al. (2016), all pesticides have the potential to harm humans, animals or other living things and the environment if not used appropriately. Nalwanga and Ssempebwa (2011) also stated that one of the factors contributing for morbidity and mortality of pesticide exposure is negative attitude towards pesticide use. The farmers should, therefore, be encouraged to let the positive attitude reflects in their pesticide use safety practices.

Table 9: Distribution of Farmer's' Attitude Towards Pesticide Use (n = 225)

Variable	Frequency	Percentage (%)
Do you know proper knowledge is necessary to use pesticide?		
Strongly disagree	2	1.0
Disagree	2	1.0
Agree	43	19.0
Strongly agree	179	79.0
Do you know there are minimal health risks attached to pesticide use?		
Strongly disagree	11	5.0
Disagree	40	18.0
Neither disagree nor agree	6	3.0
Agree	45	20.0
Strongly agree	123	54.0
Do you Know pesticide must be used with caution?		
Strongly disagree	1	1.0
Disagree	2	2.0
Agree	40	17.0
Strongly agree	182	80.0
Do you agree that pesticide use should be limited?		
Strongly disagree	48	21.0
Disagree	47	21.0
Agree nor disagree	8	4.0
Agree	56	25.0
Strongly agree	66	29.0
Do you agree that pesticide use is important to secure good crops?		
Strongly agree	2	1.0
Agree	54	24.0
Strongly disagree	169	75.0

Table 10: Farmers' Knowledge in Pest and Disease Control Methods (n = 225)

	Community									
Variable	KPE	TOG	KPO	LKA	LAG	LOA	BLA	GCH	FOW	Region
	freq. (%)	freq. (%)	freq. (%)	freq. (%)	freq. (%)	freq. (%)	freq. (%)	freq. (%)	freq. (%)	freq. (%)
Knowledge on other method of pest control (N = 225)										
No	16(64.0)	14(56.0)	13(52.0)	25(100.0)	13(52.0)	22(88.0)	23(92.0)	23(92.0)	20(80.0)	169(75.0)
Yes	9(36.0)	11(44.0)	12(48.0)	0(0.0)	12(48.0)	3(12.0)	2(8.0)	2(8.0)	5(20.0)	56(25.0)

KPE=Kpedze, TOG=Togorme, KPO=Kpoeta, LKA=Leklebi Kame, LAG=Leklebi Agbesia, GCH=Gbledi Chebi, FOW=Fodome Woe

Pests and Disease Control Methods Practiced by the Farmers

Insect pests such as mirids, mealy bugs and termites as well as diseases including as black pod and swollen shoot were identified as threats to cocoa trees in the study area. Majority 169 (75.0 %) of the famers interviewed claimed they knew of only chemical pest control method (Table 10). This implies that chemical pesticides were heavily used to control pests and disease in the area. These findings also corroborate previous studies by Antwi-Agyakwa (2013) and Osei-Boadu (2014) who discovered that the most common pest control method employed by the farmers in the study areas was the use of synthetic chemicals. (Abang et al., 2014) who conducted a study among vegetable farmers in Indonesia, on pesticide use and its determinant, concluded that about 92 % of the farmers relied on pesticides to control pests and diseases. Denkyirah et al. (2016) reported similar trend of pesticide use. The rest of the farmers 56 (25.0 %) responded that they have knowledge of alternative methods of pest and disease control apart from the chemical pesticide method (Table 10). The discovery that majority of the farmers knew of only chemical control method is surprising since one of the objectives of the CODAPEC was to train the farmers in other methods of pest control such as cultural method other than the use of synthetic pesticides (Naminse et al., 2011). The over reliance on pesticide for pests and diseases control by the farmers in the study area can be linked to the fact that extension officers though have good knowledge in pests and diseases, lack alternatives pest control methods hence, recommend only chemical pesticides use to the farmers. Ghana COCOBOD should train the extension officers in other pest control methods so that this will be passed on to the farmers.

Chemical Control Method

Pesticide use practices by Farmers

The types of pesticide used by the farmers in the study area are displayed in Table 11. The results revealed a significant and strong association between the types and classes of pesticides used by the farmers and their location. This means that there are no differences between the types and classes of pesticides used by the farmers and the communities in which they lived (Table 11).

Types, Classes and Sources of Common Pesticides Used by Farmers

Of the different common pesticide formulations (n = 22) used in the area, 50 % were those approved by COCOBOD while the other 50 % were neither approved by COCOBOD nor registered by EPA (Tables 11 and 12). For the approved ones, most were insecticide 12 (54.0 %), especially Akate Master, commonly used by 137 (61.0 %) of the farmers (Table 11), because pests were the most serious threat to cocoa production in the area. Insecticides were followed in rank of importance by Herbicides 7 (32.0 %) and fungicides 3 (14.0 %) of which the most used fungicide was champion 65 (29.0 %). The low usage of fungicide recorded could be attributed to the fact that some of the farmers in the area engaged spraying gangs to apply the fungicides for them. This information came to light during the field survey. For the herbicides, 30 (13.0 %) of the farmers used Tackle (Table 11). Some of the farmers claimed they controlled weeds manually to prevent roots of the cocoa trees from being affected by the pesticides.

Table 11: Distribution of the Common COCOBOD Approved Pesticides Used by the Farmers (n = 225)

Pesticide Class	Frequency	Percentage (%)
Insecticides		
Do you use Akate Master?		
No	88	39.0
Yes	137	61.0
Do you use Acati Power?		
No	200	89.0
Yes	25	11.0
Do you use Akate Star?		
No	182	81.0
Yes	43	19.0
Do you use Aceta Star?		
No	181	80.0
Yes	44	20.0
Do you Confidor 200 OD?		
No	110	49.0
Yes	115	51.0
Do you use Miricon EC		
No	195	87.0
Yes	30	13.0
Fungicide		
Do you use Champion WP?		
No	160	71.0
Yes	65	29.0
Do you use Ridomil Gold Plus 66 WP?		
No	197	88.0
Yes	28	12.0
Do you use Nordox Super 75 wg		
No	206	92.0
Yes	19	8.0
Weedicide		

Table 11: Continued

Pesticide Class	Frequency	Percentage (%)
Do you use Eduodzi?		
No	199	88.0
Yes	26	12.0
Do you use Tackle 360 SL?		
No	26	12.0
Yes	195	87.0
Percentage of Pesticide Classes Used		
Insecticide		54.0
Weedicide		32.0
Fungicide		14.0

COCOBOD Unapproved and EPA Unregistered Pesticides and their WHO Hazard Classes Used by the Farmers

Even though, famers demonstrated good knowledge and positive attitude regarding pesticide handling and health implications for wrongful use, the result revealed that farmers in the study area unfortunately used both Ghana COCOBOD approved and unapproved as well as EPA registered and unregistered pesticides (Table 12). The findings are in line with the reports of Antwi-Agyakwa (2013), Denkyirah et al. (2016) and Osei -Boadu (2014)). Some of the COCOBOD unapproved pesticides used included Akate Suro (Diazinon 500 g/ l), Akate Brefo (Acetamiprid / Bifenthrin), Cocoa Star (Imidacloprid), Polythrine 50 EC (Cypermethrin (50 g/ l), Sunpyrifos 48 EC (Chlorpyrifos ethyl (480 g / l) and Dursban 4 E (Imidacloprid (250 g / l). Among the unregistered pesticides identified in the study area were Karach SL (Glyphosate (360 g / l)), Sunphosate (Glyphosate (360 g / l)/ Isopropylamine (480 g / l), Glyking (Glyphosate (480 g / l) and Gramazone (Paraquat dichloride). These pesticides fall within the WHO hazard categories, II, III and

IV, designated as moderately hazardous, slightly hazardous, and non- toxic respectively. About 50.0 % of the pesticides used belong to the World Health Organization (WHO) toxicity class II, 41.0 % class III and 4.0 % class IV. A few 4.5 % were not classified. Dursban 4 E on the other hand which has WHO hazard class of II and has been banned by EPA in 2000 due to its risks to children (Shende et al., 2004) was found in use by the farmers in the study area. The use of banned pesticides by the farmers is a manifestation of the discovery made earlier that farmers had poor knowledge in banned pesticides (Table 3).

The results also revealed that most of the farmers had good knowledge in the COCOBOD approved pesticides. This is in consonance with Antwi-Agyakwa (2013), Denkyirah et al. (2016) and Okoffo (2015) who reported in similar studies that farmers had good knowledge in COCOBOD approved pesticides but at variance with Antwi-Agyakwa et al. (2015) who concluded in a study to assess insecticide use practices in four cocoa growing regions in Ghana that it was worrying that farmers had minimal knowledge in approved insecticides. The fact that most farmers have good knowledge in approved pesticides, yet used unapproved ones raises institutional and public health concerns. The use of unapproved, unregistered, and banned pesticides, apart from causing public health challenges and environmental pollution, can also increase the incidence of chemical residues in cocoa beans, intercrops of cocoa, as well as pesticide resistance and pest resurgence.

Table 12: COCOBOD Unapproved and EPA Unregistered Pesticides used by Farmers

Trade name	Active ingredient (AI)	WHO Chemical Hazard Class	Main use
Unapproved COCOBOD Pesticides			
Akate Suro	Diazinon (500 g/ l)	II	Insecticide
Akate Brefo	Acetamiprid / Bifenthrin	II	Insecticide
Cocoa Star	Imidacloprid	II	Insecticide
Polythrine 50 EC	Cypermethrin (50 g/ l)	II	Insecticide
Sunpyrifos 48 EC	Chlorpyrifos ethyl (480 g /l)	II	Insecticide
Dursban 4 E	Imidacloprid (250 g / l)	II	Insecticide
Unregistered Pesticides			
Karach SL	Glyphosate (360 g / l)	III	Herbicide
Sunphosate	Isopropylamine (480 g / l)	III	Herbicide
Glyking	Glyphosate (480 g / l)	III	Herbicide
Super grow	Ethoxylated Alkylphanol	N/A	fertilizer
Gramazone	Paraquat dichloride	III	Herbicide

*** I = extremely hazardous; II = moderately hazardous; III = slightly hazardous; IV = practically non-toxic; (WHO 2005); N/A = Not Applicable**

When the farmers were asked further to state the source of the pesticides they used, the results show that, agrochemical shops 187 (83.0 %), extension service 162 (72.0 %), general shops 2 (1.0 %) and cooperative societies 6 (3.0 %) (Table 13). It is obvious from the result that majority of the farmers bought the pesticides from the agrochemical shop dealers. This finding is not different from (Denkyirah et al., 2016; Oluwole & Cheke, 2009a) who reported that majority of farmers acquired pesticides from the agrochemical shops. This also agrees with the previous studies by (Denkyirah et al., 2016; Mekonnen &

Agonafir, 2002; Oluwole & Cheke, 2009a).The farmers in the area attributed the resorting to buying of pesticides from the agrochemical dealers to limited supply of the approved pesticides by Ghana COCOBOD. This is in line with (Denkyirah et al., 2016). The farmers also added that the approved pesticides were not readily available in the agrochemical shops to buy, hence they buy any pesticides recommended to them by the agrochemical dealers. This means that majority of the farmers were ignorant about the fact that COCOBOD approved pesticides are not subsidized at the retail level and so agrochemical dealers could not afford them into their shops. Besides, the approved pesticides are not meant for sale. In view of this, agrochemical shops dealers whose interest is to maximize profit, stuffed their shops with less costly pesticides which are adulterated, banned (Asogwa & Dongo, 2009; Auwal-Ahmad & Awoyale, 2008; Victor, 2008), unregistered and unapproved that can easily be afforded by farmers. According to Okoffo (2015), pesticides that are not recommended for cocoa are always cheaper hence, most farmers could afford them. Some of the farmers interviewed claimed that the pesticides they bought from agrochemical shops were more effective than those obtained from the extension officers and that they bought the pesticides based on the price and efficacy.

Farmers' consideration of efficacy and prices of pesticides as basis of buying them as reported in this study was also reported by (Denkyirah et al., 2016; Mengistie et al., 2017a; Oluwole & Cheke, 2009a). Unfortunately, farmers in the area were only interested in the efficacy and prices of the pesticides they used without considering the health risks involved. Following the European Commission's community – wide review process of Active Ingredients (AI) for plant protection products within the European Union in

1991, the most important directive, 91 / 414 / EEC, for registering pest control products was established. This process involves the evaluation of substances, followed by recommendation on their acceptability to the European Commission. The acceptable substances are then included in a positive list of ‘’AI[3]’’ if the risk to consumers, workers and the environment considered acceptable (Bateman, 2008). In view of this directive, COCOBOD approves on pesticides which have minimal adverse effects on human health and the environment. Wang et al. (2013) also advised that pest managers should use insecticides that have minimal impacts on natural enemies whenever possible. To avert this challenge, approved pesticides should be made accessible to the farmers and farmers should be educated on the consequences of the use of unapproved and unregistered pesticides. Additionally, agrochemical dealers who serve farmers due to limited numbers of extension officers, should be trained in the importance of dealing in approved and registered pesticides.

Table 13: Sources of Pesticides Used by the Farmers (n = 225)

Variable	Frequency	Percentage (%)
Agrochemical shops		
No	38	17
Yes	187	83
Extension service		
No	63	28
Yes	162	72
General Shops	163	
No	223	99
Yes	2	1
Cooperative societies		
No	219	97
Yes	6	3

Pesticide Mixture for Application

The methods of pesticide mixing before application used by the farmers differed significantly and were associated with the communities in which the farmers lived (Table 14). Specifically, 28 (12.0 %) of farmers claimed they mixed more than one type of pesticides in sprayer, 170 (76.0 %) mixed only one type and 35 (16.0 %) said they mixed their pesticides based on the label instructions (Table 14). These contradict the findings of (Oluwole & Cheke, 2009a) who reported that majority of the farmers in their study area mixed two or more pesticides for application. In a similar study, it was reported that about 89.9 % of the farmers were found mixing two, three or more than three pesticides in a single application (Yassin et al., 2002). The fact that some farmers mixed more than one pesticide at a time and only a few followed label instructions was worrisome. When the farmers were asked why they mixed more than one pesticide at a time, some said it saved time since different pesticides could be applied in a single spraying operation while others claimed the mixtures worked more effectively and efficiently than the single dose mixture because of increase in efficacy and also saved labour. These conform to the findings of (Mengistie et al., 2017b; Oluwole & Cheke, 2009a).

Table 14: Pesticide Mixing Methods Employed by the Farmers (n = 225)

Variable	Frequency	Percentage (%)
Do you mix more than one type pesticides in water		
No	197	88.0
Yes	28	12.0
Do you mix only one type of pesticide in water		
No	55	24.0
Yes	170	76.0
Do you mix pesticides based on label instruction		
No	190	84.0
Yes	35	16.0

According to Ngowi et al. (2007), the interaction between insecticides, fungicides and the mineral content of water can make the pesticide more toxic, less efficient and resistant against fungal pathogen and decrease insect mortality (Mengistie et al., 2017b). Mixed formulations contain higher amount of pesticides than single dose application, hence pose a serious health threat to the applicator, and the environment. Mixed formulations also increase levels of pesticides residues in cocoa beans. Osei Boadu (2014) discovered that the practice of combining pesticides for spraying contributed immensely to the presence of pesticides residues in the cocoa beans being above the Maximum Residual Limit (MRL).

Pesticide label reading and following of instruction before and during application of pesticides are essential for safe handling of pesticides. Pesticide label instructions do not cover cocktail mixtures for application, indicating that farmers did not take precaution when mixing pesticides for application, though

182 (80.0 %) responded in the affirmative that precaution should be taken when dealing with pesticides (Table 3). It is also surprising that only a few farmers followed pesticide label instruction when mixing pesticides for application, even though, about 72.0 % and 79.0 % of farmers claimed they read and obeyed pesticide label instructions respectively (Table 4). This may be attributed to low educational level of the farmers, in that though they read it, they could not understand, hence the non – adherence to it. Additionally, pesticide labels instructions are too technical for farmers to read and follow. Farmers, therefore, fall on the untrained agrochemical dealers or fellow farmers for instructions on mixing of the pesticides due to unavailability of extension service. These observations are in consonance with the report of Okoffo (2015) where though, majority of the farmers were educated, only a few could read the instructions on the chemical themselves due to the technicalities involved. Since extension officers are not readily available, farmers and agrochemical dealers should be trained in the technicalities involved in understanding of the pesticide labels.

Common COCOBOD Approved Pesticides Dosages and the Dosages Used by the Farmers

Majority of the farmers admitted using the ungraduated lid of the pesticide containers to measure the quantity of pesticide needed for spraying. This confirms the finding of (Osei -Boadu, 2014) who stated that majority (72.0 %) of the farmers used the lids of pesticides to measure quantities of pesticides required for spraying. Others used milk and tin tomatoes containers and the measuring cup recommended by the manufacturer. The use of these uncalibrated measuring equipment such as milk and tin tomato containers and the lid of the containers to measure pesticides may result in overdose or underdose of pesticides.

Table 15 displays the dosages of COCOBOD approved pesticides used by the farmers in the study area. For the insecticides, the result showed that about 87 (64.0 %) of the farmers underdosed the most common pesticide (Akate Master – *Bifenthrin*) used by the farmers in the area while 4 (2.0 %) overused it. About 18 (72.0 %) and 42 (98.0 %) of the farmers used more than the recommended rate of Acati Power and Akate Star respectively. For Aceta Star, 28 (64.0 %) of the farmers used below the recommended rate. On the other hand, Confidor was underdosed by 9 (7.0 %) and overdosed by 26 (23.0 %) farmers and 80 (70.0%) of farmers used the recommended dosages. About 17 (57.0 %) and 7 (23.0 %) farmers underused and overused Miricon respectively. With regard to fungicides, all were either used below or above the recommended rate. About 21 (32.0 %) and 1 (2.0 %) of farmers underused and overused Champion, the most used fungicide in the area respectively. Ridomil on the other hand was overused by 12 (43.0 %) of farmers while 1 (4.0 %) and 15 (54.0 %) farmers used below and the recommended rates respectively. Finally, 12 (63.0 %) farmers overused Nordox while 7(37.0 %) used it below the recommended rate. The two herbicides, Aduodzi 16(62.0 %) and Tackle 13 (43.0 %) were used below the recommended rates (Table 15).

It is obvious from the results that majority of the farmers in the study area did not follow the COCOBOD recommended application rates. They attributed the underdose of pesticides to readily unavailability of recommended pesticides, hence applying pesticides in low doses would enable them to still have some to use when the need arose. Overdose, on the other hand, was linked to heavy infestation of pests, diseases and ineffectiveness of some of the recommended pesticides by the farmers. These findings are not different from that of Osei - Boadu (2014) who reported in a study to assess the pesticide residues in cocoa beans that farmers attributed non-adherence to recommended application rate to degree of infestation of cocoa tress and potency of the pesticides. Both overdose and underdose of pesticides can create problems in the areas where they are being practiced.

Table 15: COCOBOD Approved Pesticides and the Dosages used by Farmers

Trade name	Active ingredient concentration	WHO Hazard Class	Recommended rate 11 L / knapsack by CRIG	Percentage of farmers (%)		
				Below	Recommended	Above
Insecticides						
Akate master	Bifenthrin (27 g / l)	II	100 ml	87(64.0)	46 (34.0)	4(2.0)
Acati Power SL	Thiamethoxam (200 g/l)	II	20 ml	0(0.0)	7 (28.0)	18(72.0)
Akate Star 3.5 EC	Bifenthrin (30 g / l)	II	20 ml	0(0.0)	1 (2.0)	42(98.0)
Aceta Star 46 EC	Bifenthrin (30 g / l)	II	120 ml	28(64.0)	16 (36.0)	0(0.0)
Confidor 200 OD	Thiamethoxam (240 g/l)	III	30 ml	9(7.0)	80 (70.0)	26(23.0)
Miricon EC	Pyrethrum (12 g / l) + Deltamethrin (6 g /l)	II	66 ml	17(57.0)	6 (20.0)	7(23.0)
Weedicide						
Aduodzi 757 SG	Glyphosate (757 g / l)	III	200 ml	16 (62.0)	10 (38.0)	0 (0.0)
Tackle360 SL	Glyphosate (360 g / l)	IV	200 ml	13 (43.0)	17 (57.0)	0 (0.0)
Fungicide			**15 l / knapsack**			
Champion WP	Copper Hydroxide (77 %)	III	100 g	21(32.0)	43 (66.0)	1(2.0)
Ridomil Gold Plus 66WP	Cuprous oxide (60 %) + Metaxyl - M (6%)	III	50 g	1 (4.0)	15 (54.0)	12 (43.0)
Nordox Super 75 wg	Cuprous oxide (86 %)	III	75 g	7 (37.0)	0 (0.0)	12 (63.0)

*; I = extremely hazardous;
II = moderately hazardous; III = slightly hazardous IV = non-toxic; (WHO 2005)

Overdose of pesticides for example, does not only cause financial losses due to waste and phytotoxicity but also injure the crop, pollute the environment, affect the health of the applicator, increase pesticide residues in cocoa beans and food crops and the development of resistance by pests, diseases and weeds. Unfortunately, most farmers are not aware of the effects of underdose of pesticides. They think the safest and the economic way to use pesticides is to apply it below the recommended rate. Underdose of pesticides can also lead to resistance and resurgence of pests, diseases and weeds which can cause economic loses through low yields.

The non-compliance to CODAPEC recommended dosages of pesticide application by the farmers raises a question of their sources of information on pesticide application. Surprisingly, majority 128 (57.0 %) of the farmers claimed they obtained information from extension officers for information regarding pesticide application, 114 (50.0) of farmers said they agrochemical dealers, 57 (25.0 %) farmers' years of farming experience, 36 (16.0 %) fellow farmers and 12 (5.0 %) claimed they relied on instructions on the pesticide label (Table 16). These findings agree with the finding of Osei -Boadu (2014) who stated that about 47.6 % of the cocoa farmers in the Western Region of Ghana obtained information on pesticide application from extension officers while 38 .0 % depended on their own experience. Paintsil (2017) also reported the same trend of information acquisition on pesticide application.

Table 16: Farmers' Sources of Information on Pesticide Application (n = 225)

Variable	Frequency	Percentage (%)
Agrochemical shops		
No	111	49.0
Yes	114	50.0
Extension officers		
No	97	43.0
Yes	128	57.0
Pesticide labels on packages		
No	213	95.0
Yes	12	5.0
Fellow farmers		
No	189	84.0
Yes	36	16.0
Own experience		
No	168	75.0
Yes	57	25.0

The fact that majority of the farmers obtained information on pesticide application from the extension officers but still misapplied pesticides is worrisome. It may be gathered from the results that farmers have their own reasons for applying pesticides and do not follow the recommendations of the extension officers. Hence the reasons why farmers applied pesticide was investigated.

When the reasons why the farmers applied pesticides were evaluated, majority 203 (90.2 %) said to protect crops, 79 (35.0 %) said for crops to grow well, 55 (24.0 %) said because others used it and 30 (13.0 %) used it on advice from fellow farmers (Table 17). It is obvious from the findings of this study that though, majority of the farmers claimed they used pesticides to protect crops which is the goal of pesticide application, this did not reflect in their pesticide usage. They rather used pesticide with the intension of maximizing profit. This is in agreement with Moy and Wessel (2000) and Osei -Boadu (2014) who found that farmers used particular pesticides to minimize food loses and increase profit. Mariyono et al. (2018) said the overuse of pesticides does not always result in higher productivity; rather, pesticides are regarded as protective input and usually serve as insurance against expected yield lost. This implies that pesticides will only influence production if and only if diseases and pests occur, otherwise there will be no need for pesticides use.

Table 17: Farmers' Reasons for Pesticide Application (n = 225)

Variables	Frequency	Percentage (%)
Pesticides use to protect crops		
No	22	9.8
Yes	203	90.2
Pesticides use for crops to grow well		
No	146.0	64.9
Yes	79.0	36.1
Used pesticides because others use it		
No	170.0	75.6
Yes	55.0	24.4
Used pesticides on advice		
No	195.0	86.7
Yes	30.0	13.3

Besides, some farmers considered pesticides to be productive inputs instead of protective inputs. Thus, they claimed the pesticides helped the cocoa to grow well and fast. It is a misconception for a farmer to consider pesticides as fertilizers. Pesticides are not fertilizers, hence cannot help cocoa plants to grow fast Mariyono et al. (2018) reported that vegetable farmers in Indonesia perceived pesticides as substitutes for fertilizers and increased their used whenever the prices of fertilizers increased. Considering this misconception, Ghana COCOBOD should intensify mass training in the study area to disabuse this erroneous mindset of the farmers.

The fact that a few farmers claimed they used pesticides because they saw their fellow farmers using them is serious. This is because they may not be facing the same problem and even when facing the same problem their solution may not be the use of chemical pesticides. Farmers in the same community share ideas and so when they are not well educated, they end up distorting the information received from the extension officers.

Factors Associated with the Use of just the presence of Pests and Diseases as Timing for Pesticide Application by the Farmers.

The chi-square and Cramer's V statistics were used to determine factors that influence the use of just presence of pests and diseases as timing for pesticide application by the farmers. The results of Table 18, indicate that degree of pest infestation (P = **0.008,** Cramer's' V = 0.177), calendar spray regime (P = **0.006,** Cramer's' V = 0.485), economic threshold (P = **0.000,** Cramer's' V = 0.242), agrochemical shop service (P = **0.051,** Cramer's' V = 0.130) and farmers' years of experience (P = **0.02,** Cramer's' V = 0.204) were statistically associated with the mere presence of pests and diseases as timing for pesticide application.

Degree of pest infestation

The results also show that degree of pest infestation was associated with the presence of pest as timing for pesticide application. Degree of pest infection influences pesticide application negatively. This is because population density of pests is considered first before considering what control option to take. Therefore, if the pest density is low, there will be no need to apply pesticides but rather look for an alternate method.

Calendar spraying regime

There was statistically strong association between calendar spray regime and the use of presence of pests and diseases as timing for pesticide application. Calendar spray regime is a periodic scheduled regime used to reduce pesticide application by farmers. Calendar spray regime has a negative association with the application of pesticides on the basis of mere presence of pests and diseases. Therefore, farmers who follow the calendar spray schedule will not just apply pesticides for the fact that there are presence of pests and diseases.

Table 18: Factors Influencing the use of just the Presence of Pests and Diseases as Timing for Pesticide Application by Farmers (n = 225)

	Presence of pest and Diseases		
Variable	No (%)	Yes (%)	**Measure of association**
Degree of pest infestation			
No	40 (24.0)	126 (76.0)	Pearson π^2 = 7.078 Pr =
Yes	25 (42.0)	34 (58.0)	**0.008** Cramer's V = 0.177
Calendar spray schedule			
No	30 (17.0)	145 (83.0)	Pearson π^2 = 52.889 Pr = **0.0058** Cramer's V =
Yes	35 (70.0)	15 (30.0)	0.485
Economic thresholds			
No	55 (26.0)	156 (74.0)	Pearson π^2 = 13.151 Pr =
Yes	10 (71.0	4 (29.0)	**0.000** Cramer's V = 0.242
Agrochemical shop services			
No	27 (38.0)	45 (62.0)	Pearson π^2 = 3.822 Pr =
Yes	38 (25.0)	115 (75.0)	**0.051** Cramer's V = 0.130
Farmer's experience			
1 - 3 years	4 (33.0)	8 (67.0)	
4- 6 years	15 (24.0)	47 (76.0)	
7 - 10 years	13 (19.0)	56 (81.0)	Pearson π^2 = 9.319 Pr
More than 10 years	33 (40.0)	49 (60.0)	=**0.02** Cramer's V = 0.204

Economic Threshold (ET)

Economic threshold was also found to be statistically but weakly associated with the use of the presence of pests and diseases as timing for pesticide application. Economic threshold is the maximum acceptable level of pest attack (Mariyono, 2007). With this, the farmer considers pests population and the cost of control before deciding on which control method to use. As farmers become knowledgeable in ET, their level of acceptance of pest attack increases and at the same time pesticide use decreases (Mariyono, 2007).

Agrochemical shop service

Agrochemical shop dealers serves as conduits between Ghana COCOBOD and the farmers. Farmers buy pesticides and also seek advice on application from the dealers. Unfortunately, some of the dealers are not educated and lack knowledge in the time of application, dosages and frequency. They do not also visit farmers' farms to ascertain the degree of pest and disease infestation before recommendations are done. Bearing in mind their profit margin; always encourage farmers to seek chemical control which is not needed in some circumstances. Farmers therefore, consult them anytime they face pest and disease outbreak due to lack of extension services.

Farmers' years of experience

Farmers' years of experience had a statistical association with the use of presence of pests and diseases as timing for pesticide application. Denkyirah et al. (2016) also reported a positive association between farmers' years of experience and the types of pesticides use. Farmers will resort to the use of chemical pesticides when they lack knowledge in alternative pest control methods. Aslam (2003) on the other hand identified negative association between farming experience and pesticide usage by the farmers. He argued that experienced farmers used less pesticides since they may have knowledge in alternative pest control methods. With their experience, they may be able to tell whether the pest and disease population need pesticide control or not.

Multivariate analysis

Predicting Factors that Influence cocoa Farmers' Use of ''just the Presence of Pests and Diseases'' as Timing for Pesticide Application

Table 19 shows the result for the multivariate analysis that were ran for factors influencing farmers' use of '' just the presence of pests and diseases'' as timing for pesticide application. In model 1, degree of pest infestation, calendar spray schedule and economic threshold were statistically significant. However, farmers who depended on degree of pest infestation (OR = 0.185, P< 0.000), calendar spray schedule (OR = 0.057, P < 0.000) and economic threshold (OR = 0.137, P < 0.004) as source of information with regards to timing for pesticide application were less likely to apply chemical pesticides due to just the presence of pests and diseases compared to their counterparts who responded in the negative.

In model 2, the directional and magnitude of odds of key predicting factors influencing farmers' timing for pesticide application remained the same when access of agrochemical services of the farmers were controlled for in the socio - cultural model. The result shows that access to agrochemical services was not significant.

In model 3, contextual factor which influences farmers' timing for pesticide application was considered. Farmers' experience was controlled for in the model. The socio – cultural factor mediated the relationship between the main predictors and the years of farmers' experience. From the result, it was obvious that agrochemical service was not statistically significant in all the two models. Additionally, farmers' years of experience was also not statistically significant. However, the main predictors, degree of pest infestation, calendar spray schedule and economic threshold were statistically significant in models 1, 2 and 3. In terms of strength, farmers who consider degree of pest infestation as timing for pesticide application were 73 % less likely, calendar spray farmers (OR = 0.100, P < 0.000), 90 % less likely and economic threshold farmers were 82 % less likely to apply chemical pesticides due to just the presence of pests and diseases (Table 19).

The results indicate that farmers who considered degree of pest infestation as timing for pesticides application were less likely to apply chemical pesticides due to just the presence of pests and diseases compared to their counterparts who did not. This means that the probability that those farmers will apply chemical pesticides for the mere observance of pests and diseases on cocoa and cocoa trees is very low. This is because they monitor the pests' population levels (numbers of pests per cocoa tress) before deciding on what pest control measure to take. This is in line with the findings of Mariyono (2007) who reported that farmers who regard degree of pest infestation in pest management only apply chemical pesticides when pests attack reach the new maximum acceptable level. For example, a mechanical method such as hand picking can be employed to control mirids on cocoa tress if the pest population is low. The consideration of degree of pests and diseases infestation in pests and diseases management practices, reduces the use of chemical pesticides drastically, safes the environment and enhances public health (Untung, 1996).

Also, farmers who considered economic threshold in determining timing for pesticide application were less likely to apply pesticides to control pests and diseases due to just presence of pests and diseases. This can be explained by the fact that economic threshold considers the pest population density at which control measures are necessary to prevent an increasing population from getting to economic injury level. This delays pesticide application which eventually reduces pesticide use (Mariyono, 2007). Therefore, such farmers will not apply pesticides for the mere presence of pests and diseases. Binns and Nyrop (1992) also stated that economic threshold is a control decision rule used to reduce pesticide use. Farmers should be trained in this principle to minimize pesticide usage.

Farmers who applied pesticide by following calendar spraying regimes were also found to be less likely to apply pesticide due to mere presence of pests and diseases. This is because the calendar spraying regime involves spraying at scheduled periods without considering pests situation (Mochiah et al., 2019). For example, the calendar spaying regime in Ghana for mirid control is between August and December. This is to reduce pesticide use and its negative effects on human health and the environment. In the light of this, Cocoa Research Institute of Ghana (CRIG) should do thorough research in to the life cycle of pests and diseases to come out with proper calendar spraying regimes since farmers claimed the August – December is no more efficient.

Table 19: Likelihood of Predicting Factors that Influence Cocoa Farmers' Timing to Apply Pesticides to Control Pests and Diseases

Variable	Key predictors					Socio- cultural model					Contextual model				
	OR	SE	P-value	CI		OR	SE	P-value	CI		OR	SE	P-value	CI	
Degree of pest infestation (Ref: No)															
Yes	0.250	0.063	**0.000**	0.153	0.409	0.251	0.063	**0.000**	0.154	0.409	0.269	0.067	**0.000**	0.166	0.438
Calendar spray schedule (Ref: No)															
Yes	0.100	0.032	**0.000**	0.053	0.186	0.101	0.032	**0.000**	0.054	0.100	0.100	0.032	**0.000**	0.053	0.189
Economic thresholds (Ref: No)															
Yes	0.168	0.108	**0.006**	0.048	0.592	0.167	0.108	**0.006**	0.047	0.594	0.175	0.113	**0.007**	0.049	0.621
Agrochemical shop services (Ref: No)															
Yes						0.933	0.257	0.802	0.544	1.601	0.966	0.263	0.899	0.566	1.649
Farmer's experience (Ref: 1- 2 years)															
4- 6 years											1.235	0.597	0.662	0.479	3.187
7 - 10 years											1.099	0.516	0.842	0.437	2.759
More than 10 years											0.810	0.374	0.649	0.328	2.003

OR = Odd ration, SE = Standard error, CI = Confidence interval, Bold font represent statistically significant relation

Farmers' Adherence to Ghana COCOBOD Seasonal Spraying Schedule (regime), Frequency and Recommended Equipment

COCOBOD Spraying Regime

According to Ghana COCOBOD, cocoa farms are supposed to be sprayed four times seasonally, starting from August through December with spot applications when necessary (Antwi-Agyakwa, 2013). The results in (Table 20) show that only 77(34.0 %) did follow the seasonal scheduled spraying (August – December) while the majority 148 (66.0 %) were following their own spraying regime. It is clear from the study that most of the farmers had good knowledge in COCOBOD recommended pesticides but did not follow spraying regime. This agrees with the studies of Denkyirah et al. (2016) and Okoffo et al. (2016). While some farmers applied pesticides between August – December as recommended, others applied between June – October, June – September and June – November. It was not surprising that when the farmers were asked what informed their timing for pesticide application, only 50 (22.0 %) claimed they did routine (calendar) application of pesticides to control pests and diseases on their farm (Table 20). According to the farmers, their spraying regime was influenced by the climatic factors (dry and wet seasons) and the presence of pests. They claimed the pests and diseases were more during the wet season than the dry season, therefore, they applied pesticides more often during the rainy season than the dry season. They also added that during the wet season, pesticides wash- off by the rainfall increased, hence the use of the other spraying regimes other that the Ghana COCOBOD recommended regime. This conforms with the findings of Ntow et al. (2006b) who stated that farmers sprayed more often the pesticides during the wet season when pests and diseases proliferate and when increased wash-off by rainfall necessitate further application of pesticides.

The proliferation of pests and diseases as observed in the area may be attributed to the disparities in spraying regime in the area which had resulted in resistance development by pests. It was discovered during the field survey that most of the famers had their farms in the same areas; controlling pests and diseases at different regimes would not be effective since pests could easily migrate from one farm to another. Besides, unsprayed farms serve as alternate habitat for sprayed pests which did not die and those which flew away during the spraying, where they grow to develop resistance to that pesticide applied on them. Antwi-Agyakwa et al. (2015) and Leston (1970) indicated that adult mirids can fly for 2 hours and over 2 kilometers or even double the distance. This probably explains farmers' allegation that some of the Ghana COCOBOD recommended pesticides were no more effective. This is the brain behind a recommended uniform spraying regime (August – December) by COCOBOD for all the farmers except September when harvesting of cocoa is done for effective control of pests and diseases. September has been excluded to prevent the contamination of cocoa beans with pesticides residues.

Spraying frequency

Out of the 225 farmers who used pesticides, only about 86 (38.0 %) farmers claimed to have been following the recommended frequency of four times per season (Table 20). These findings are not different from what Antwi-Agyakwa et al. (2015), Denkyirah et al. (2016), Okoffo (2015) and Okoffo et al. (2016) reported. It is interesting to note that majority 160 (71.0 %) of the farmers (Table 20) indicated that just the presence of pests and diseases on cocoa and cocoa trees informed their timing for pesticide application which corroborated the report of Ntow et al. (2006b) and Paintsil (2017). Furthermore, 59 (26.0 %) used the degree of pest infestation while 14 (6.0 %) used the economic threshold as timing to apply pesticide to control pests and diseases (Table 20).

Table 20: Farmers' Adherence to CODAPEC Seasonal Spraying schedule, Seasonal Pesticide Spraying Frequency, Recommended Spraying Equipment and Pre-harvest Interval (n = 225)

Variable	Frequency	Percentage (%)
Do you follow CODAPEC seasonal spraying schedule?		
No	148	65.8
Yes	77	34.2
Do you follow CODAPEC annual pesticide spraying frequency?		
No	139	61.8
Yes	86	38.2
Which type of spraying equipment do you use?		
Knapsack sprayer	197	87.5
Motorized / mist blower	2	0.9
Both knapsack & motorized	26	11.6
Pre - harvest interval (PHI)		
Just after spraying	2	1.0
1 - 2 days	7	3.0
3 - 6 days	21	9.0
1 week	38	17.0
> 1 week	135	60.0
Manuf. Instruction	22	10.0
Using of crops sprayed with pesticides		
No	32	14.0
Yes	193	86.0

The results showed that some of the farmers applied pesticides as much as eight times while the others sprayed as low as three times. The fact that majority of the farmers though, knew of the Ghana COCOBOD recommended frequency (four times per season) yet applied pesticides on the basis of a mere notice of pests and diseases suggests that farmers in the study area are not guided by the peak of mirid population (degree of infestation) and economic threshold level (6 mirids per 10 trees) in the application of pesticides to control pests and diseases. These findings are similar to that of Antwi-Agyakwa et al. (2015). The non-compliance of degree of pest infestation and economic threshold as criteria that informed farmers as to when to apply pesticide could be attributed to their inability to distinguish between pests and the pests' predators or insects and diseases due to their low education level. This confirms the findings of Mengistie et al. (2017b) who reported that many less literate farmers applied pesticides anyhow and that many of them reported insects as diseases when they were asked to name the diseases that affect their crops.

Economic threshold (ET) is defined as ‘‘a maximum acceptable level of pest attack for which expected value of yield loss associated with the pests is equal to the cost of controlling pests using pesticides’’ (Mariyono, 2007). This implies, the higher the ET, the more likely that the observable level of pests is lower than the ET, hence the value of yield loss associated with pests is lower than the cost of pesticides therefore, there will be no need to apply pesticides and the opposite is true. The use of economic threshold in pest management is very technical. Ghana COCOBOD should train the Extension officers who serve as conduit of exchange of information between the farmers and the COCOBOD in these technicalities.

Table 21: Factors that Determine Timing of Pesticide Application by Farmers (n =225)

Variable	Frequency	Parentage (%)
Presence of pest and diseases		
No	65.0	29.0
Yes	160.0	71.0
Degree of pest infestation		
No	166.0	74.0
Yes	59.0	26.0
On calendar spray schedule		
No	175.0	78.0
Yes	50.0	22.0
On economic thresholds		
No	211.0	94.0
Yes	14.0	6.0

Recommended spraying equipment

The use of appropriate spraying equipment to control pests and diseases does not only ensure effective pest control but also ensures the safety of the applicator, consumer, and the environment. Cocoa Research Institute of Ghana (CRIG) recommended that motorized mist blowers be used for the application of recommended insecticides and fungicides on cocoa trees (Asamoah, 2015). According to Pal and Gupta (1996), motorized mist blowers are suitable for aerial spraying over large areas due to the production of high velocity air which is discharged through the hose as droplets.

With regards to the recommended spraying equipment use, 197 (87.0 %) used knapsack sprayer only, 2 (1.0 %) motorized mist blower only and 26 (12.0 %) both knapsack and motorized mist blower (Table 21). The results show that majority of the farmers applied pesticides with knapsack sprayer. This is at variance with the findings of Osei -Boadu (2014) who reported that majority, 98.0 % of the farmers used motorized mist blower while 1.2.0 % used knapsack sprayers. Majority of the farmers interviewed confirmed having good knowledge in the recommended spraying equipment but attributed the use of the knapsack sprayer at all stages of pests and diseases control to financial constraints, which is similar to the report of Mengistie et al. (2017a). A major cause of danger or poisoning when using knapsack sprayer may pose to the sprayer is the spilling of the pesticide on the back of the sprayer due to leakages as a result of faulty locking cap of the container and hot weather. Besides, Asogwa and Dongo (2009) reported that cracks and leaks in containers and in over aged rubber hoses, as well as not renewing or loosing washers are great causes for leakages that often poison the user. It also wastes pesticides, causes environmental pollution and may become phytotoxic where pesticides fall on crops at high doses. Additionally, due to the low pressure produced by knapsack sprayers, most of the cocoa trees may not be covered adequately by the pesticides, hence, the target pests are missed or partially attacked, resulting in the gradual emergence of resistance strains. To avert this problem, Ghana COCOBOD should provide the farmers with the recommended spraying equipment at subsidized prices. Besides, farmers should be trained in the calibration and maintenance of spraying equipment.

Pre- harvest Interval

According to Rijal et al. (2018), pre- harvest interval (PHI) is the legal time to wait before harvesting a crop after a particular pesticide is applied to a particular crop. PHI of various pesticides, normally form part of the pesticide label. Regarding the adherence of the PHI by the farmers, it was observed that majority 135 (60.0 %) of the farmers responded that they followed more than 7 days PHI, while 38 (17.0 %) waited for 1 week. Furthermore, 22 (10.0 %) of farmers claimed the followed the manufacturers' PHI, 21 (9.0 %) observing between 3 - 6 days PHI, 7 (3.0 %) between 1- 2 days and a few 2 (1.0 %) harvested just after spraying (Table 21). A previous study reported that majority (63.0 %) of the farmers waited for an average of 2 weeks, 29.0 % 3 to 4 weeks, 2.4 % waited for 4 weeks and about 6.0 % did not wait for even 1 week to start harvesting (Rijal et al., 2018). The practice of harvesting crops without observing the pre- harvesting intervals is likely to lead to higher pesticide residues in or on harvested crops, which could pose serious health challenges to the consumers. An elevated concentration of 0.07 mg/kg of permethrin, a synthetic pyrethroid, was found to have exceeded the Japan MRL of 0.05 mg/kg in cocoa beans at Sefwi Wiawso District of the Western Region of Ghana (Osei -Boadu, 2014).

Apart from the contamination of the cocoa beans with pesticides residues, the intercrops of cocoa trees which the farmers use to feed their families can also be poisoned by the pesticides if PHI is not observed. When the farmers' usage of sprayed crops was assessed, the result revealed that out of the 225 farmers interviewed, majority 193 (86.0 %) said they used sprayed crops while 32 (14.0 %) claimed they did not use the crops that were sprayed with pesticides (Table 21). Those who claimed they did not use crops sprayed with pesticides attributed that to food poisoning due to pesticides residues on the crops. This is an indication that some of the farmers are conscious about pesticide food poisoning related issues when PHI is not observed.

Common Crops Grown among Cocoa Trees by Farmers

At various stages of cocoa production, shade is controlled to suppress weeds, development of soil structure (Dzobo, 2016; Padi et al., 1996) and control of pests such as capsids (Collingwood & Marchart, 1969; Dzobo, 2016). In order to manage shade, farmers intercrop cocoa trees with other crops. When the farmers were asked to name some of the crops they grew in their cocoa farms, 169 (75.0 %) farmers mentioned cassava, 138 (61.0 %) plantain, 114 (51.0 %) cocoyam and yam, 100 (44.0 %) palm, 65 (29.0 %) tomatoes, 52 (23.0 %) okra, 44 (20.0 %) oranges, 36 (16.0 %) garden eggs, 30 (13.0 %) and 28 (12.0 %) pawpaw (Table 22). This management practice is in line with Cocoa Health and Extension Division of COCOBOD, in promoting sustainable cocoa production through pests and diseases control. This also agrees with Wessel and Quist-Wessel (2015) who discovered that for sustainable cocoa growing, some degree of shade is required to control insects damage and premature decline of yields. According to Akter et al. (2018), the number of natural enemies and their richness are greatly influenced by intercropping, resulting in wider reduction in pests' population. Some of the farmers added, during the field survey that apart from these intercrops providing shade for pests and disease management, they also serve as source of income and food for their families, a finding which corroborates with that of Amoah et al. (1995) and Ramadasan et al. (1978) who also reported that farmers intercropped cocoa trees with cocoyam, pepper, maize, cassava, plantain or annual crops, serving as cultural practice and food sustenance to the farmer. One important thing, worthy of mentioning is that some of the farmers did not consider cocoa intercropping as an effective, inexpensive and yet environmentally friendly pests and diseases control measure. For this reason, they continued to use chemical pesticides, which pose a threat to flora and fauna. Farmers should, therefore, be trained to embrace cocoa intercropping as both livelihood source and pests and diseases control method.

Table 22: Common Crops Grown among Cocoa trees by Farmers (n = 225)

Variables	Frequency	Percentage (%)
Do you grow tomatoes in cocoa farm?		
No	160	71
Yes	65	29
Do you grow green pepper in cocoa farm?		
No	195	87
Yes	30	13
Do you grow cocoyam in cocoa farm?		
No	111	49
Yes	114	51
Do you grow yam in cocoa farm?		
No	166	74
Yes	114	51
Do you grow garden eggs in cocoa farm?		
No	189	84
Yes	36	16
Do you grow okra in cocoa farm?		
No	173	77
Yes	52	23
Do you grow cassava in cocoa farm?		
No	56	25
Yes	169	75
Do you grow palm nut in cocoa farm?		
No	125	56
Yes	100	44
Do you grow plantain in cocoa farm?		

Table 22: Continued

Variables	Frequency	Percentage (%)
No	87	39
Yes	138	61
Do you grow oranges in cocoa farm?		
No	181	80
Yes	44	20
Do you grow pawpaw in cocoa farm?		
No	197	88
Yes	28	12

Farmers' Protective Equipment (PPE) Use

The results show that a worrying 128 (57.0 %) farmers reported not wearing any PPE during pesticide mixing for application (Table 23). Out of the farmers who reported wearing PPE during pesticide mixing for application, only 21(9.3 %) wore full PPE (gloves, goggles, head cover, oral / nose mask, special boot and overall) (Table 25). Majority of the farmers stated not wearing gloves 154 (68.0 %), nose mask 148 (66.0 %), goggles 159 (71.0 %), headcover 199 (88.0 %), Boot 170 (76.0 %) and overall, 196 (87.0 %) during mixing of pesticides for application (Table 23). This is really a worrisome situation since most of the farmers might have been exposed to pesticides during mixing. When asked why they did not use PPE during mixing, most of them stated that mixing of pesticides for spraying less exposed the farmer to the pesticides as compared to spraying. Some also stated that they did the mixing with care to prevent contact with the skin, though majority of them agreed that inhalation was a route of pesticide entry in to the body (Table 4). According to Yarpuz-Bozdogan (2018), farmers can only minimize pesticides exposure when they use appropriate PPE at all stages of pesticide handling and that sprayers can directly be exposed to pesticides during the preparation of the spraying solutions. Pesticides, before preparation are highly concentrated, hence can easily be inhaled into the body. Adesuyi et al. (2018) and Desalu et al. (2014) reported that inhalation exposure can occur during mixing and spraying of powder and granular forms of pesticides and that inhalation exposure is the fastest route of pesticides entry into the bloodstream. Wearing of gloves and nose masks during pesticides mixing can reduce pesticide exposure to the minimal. Mixing of pesticides without hand gloves exposed the farmers' hands directly to the pesticide. Besides, splashes from the spraying equipment during shaking to obtain homogenous mixtures also exposed the farmers to dermal exposure. This could have been avoided by wearing hand gloves, nose masks, goggles, wellington boots and overall, before mixing of pesticides. The misconception that mixing of pesticides for spraying is less risky than application of pesticides, could be attributed to low educational levels of farmers coupled with low extension contacts.

Table 23: PPE Use and Types during Pesticide Mixing for Application by Farmers (n = 225)

PPE used during mixing of pesticides	Frequency	Percentage (%)
Do you use PPEs during mixing of pesticide?		
No	128	57.0
Yes	97	43.0
Which types of PPEs do you use during mixing of pesticide?		
Glove		
No	154.0	68.0
Yes	71.0	32.0
Google		
No	159	71
Yes	66	29.0
Nose mask		
No	148.0	66.0
Yes	77.0	34.0
Head cover		
No	199.0	88.0
Yes	26.0	12.0
Boot		
No	170.0	76.0
Yes	55.0	24.0
Overall		
No	196.0	87.1
Yes	29.0	12.9

When the use of PPE by the farmer during pesticide application was also evaluated, 56 (25.0 %) wore all (full) the recommended PPE (Table 24). A large number of farmers reported not wearing gloves 118 (52.0 %), goggle 126 (56.0 %) and overall, 139 (62.0 %) while those they most often used were head cover

147 (57.0 %), nose mask 129 (57.0 %) and boots 185 (82.0 %) (Table 24). These findings are similar to Adesuyi et al. (2018) and at variance with Nurcandra et al. (2018) who reported that about 80.0 % of the farmers used complete PPE during mixing and spraying of pesticide. Khan et al. (2010) also reported in a study to assess the risk exposure of pesticide on the health of tobacco farmers in Pakistani that majority of the farmers did not put on PPE during pesticide handling and that only a few wore shoes (13.0 %), mask (14.0 %) and gloves (9.0 %) during spraying. These findings are also in consonance with Okoffo et al. (2016) who in a study to assess the pesticide exposure and the use of PPE by cocoa farmers in Ghana stated that about 35.0 % of the farmers wore complete PPE while 45.0 % wore partial PPE with the respondents indicating the use of overall (47.3 %), wellington boots (56.2 %), nose mask (35.4 %), hat / cap (29.2 %), rubber gloves (34.9 %) and goggles (28.8 %).

Table 24: Distribution of Types of PPEs Used by Farmers during Pesticide Application (n = 225)

PPE used during pesticide application	Frequency	Percentage (%)
Glove	118	52.4
No	107	47.6
Yes		
Goggle	126	56.0
No	99	44.0
Yes		
Head cover	78	34.7
No	147	65.3
Yes		
Nose mask	96	42.7
No	129	57.3
Yes		
Boot		
No	40	17.8
Yes	185	52.2
Overall		
No	139	61.8
Yes	86	38.2

The farmers stated the discomfort they experienced anytime they wore the PPE. Costs and readily unavailability of PPE were also indicated as reasons for not using PPE. Similar observations were made by Crozier et al. (2018), Okoffo et al. (2016), Oluwole and Cheke (2009) and Yassin et al. (2002). It was also observed that some of the farmers used normal long sleeves and trousers made of cotton wool and synthetic material as overalls. Others reported using handkerchiefs or pieces of cloth as nose masks and head covers while some used polythene bags as gloves. These unsafe practices were also reported by Ajayi and Akinnifesi (2007), Khan et al. (2010), Lekei et al. (2014), Nurcandra et al.

(2018) and Oluwole and Cheke (2009a). The use of these materials for protection by the farmers, though unsafe, gives an indication that the farmers are safety coconscious and this buttresses the earlier observation that the farmers did not use PPE due to cost and unavailability of PPE. However, the worrying issue here is the farmers' over confidence of being protected by these unsafe materials and refusal to take appropriate safety precautions which could end up making them more vulnerable to pesticide exposure. For example, materials such as long sleeves and pieces of cloth can absorb the pesticides solutions during spraying, thereby bringing these chemicals closer to the skin of the farmers making them susceptible to pesticide exposure, an observation consistence with Ajayi and Akinnifesi (2007).

Table 25: Distribution of the number of PPEs Used by Farmers During Mixing and Application of Pesticides (n = 225)

Variable	Frequency	Percentage (%)
Number of PPEs used during the mixing of pesticide for application		
Zero	120	53.0
One	7	3.1
Two	16	7.1
Three	37	16.4
Four	10	4.4
Five	14	6.2
full	21	9.3
Number of PPEs used during pesticide for application		
Zero	32	14.0
One	31	14.0
Two	29	13.0
Three	25	11.0
Four	23	10.0
Five	29	13.0
full	56	25.0

Methods of Pesticide Storage, Disposal of Remnant and Empty Containers and Washing of Sprayer after Application of Pesticide used by the Farmers

Pesticide storage

It is undisputable fact that storage of pesticides along with food stuffs could be perilous. The distribution of pesticide storage methods adopted by the farmers in the study area are displayed in Figure 4. Farmers indicated storing pesticides in food storeroom 97 (43.1 %), living room 50 (22.2 %), bed room 19 (8.4 %), agrochemical shop 18 (1.8 %), on the farm 16 (7.1 %), kitchen 9 (4.0 %), in the bush 6 (2.7 %), at the toilet 5 (2.2 %), animal house 3 (1.3 %) and the bathroom 2 (0.9 %) (Fig. 2). It is clear from the result that majority of the farmers stored their pesticides in their residence. This finding is consistent with the previous studies by Aliyi et al. (2018), Oluwole and Cheke (2009a) and Paintsil (2017) who also reported that majority of the farmers in the study areas stored their pesticides at their residence. However, the present finding is not in consonance with the report of Tijani (2006) who discovered that about 87.5 % of cocoa farmers in Ondo State, Nigeria, kept their pesticides in the storerooms with very few (8.3 %) storing them in their bedrooms. The farmers attributed this unsafe practice to lack of chemical storage facilities and the fear that the chemicals may be stollen when kept in the farm. Okoffo et al. (2016) stated that farmers stored their pesticides at their residence due to lack of storage facility while Crozier et al. (2018) and Oluwole and Cheke (2009a) reported that farmers stored pesticides at their residence for the fear of being stollen when stored elsewhere. Exposure and health risk to farmers and their families through leakages of these chemicals do not only cause food poisoning but may also be inhaled and lead to death, most especially among innocent children. Accidental pesticide poisoning, especially among children is on the increase due to lack of facilities for safe storage (Bull, 1982; Haines, 1985; Konradsen et al., 2003) and the readily availability of pesticides in the developing world results in to a far high accidental death rate among children (Konradsen et al., 2003; Singh et al., 1995).

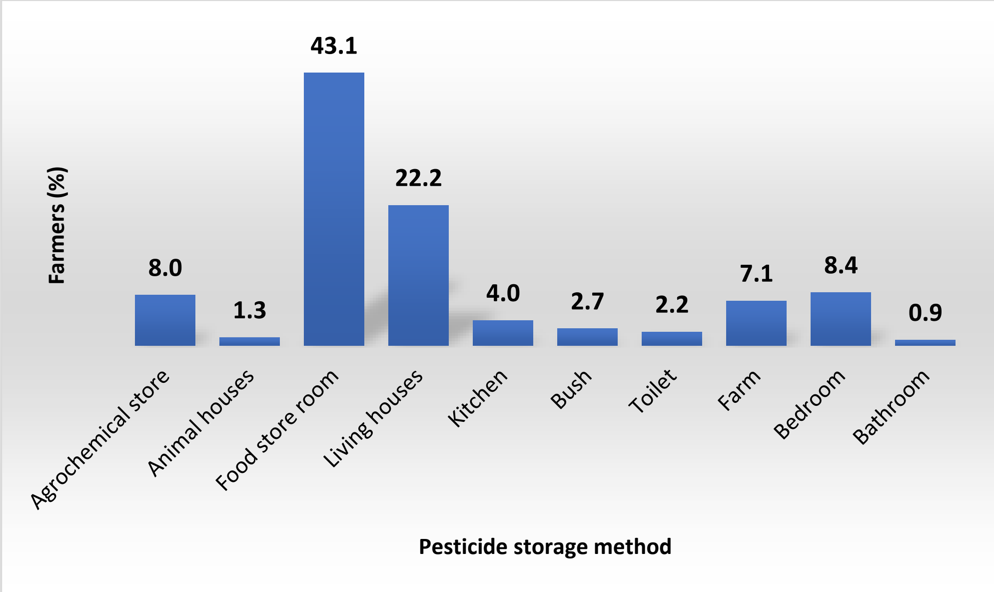

Figure 4: Pesticide Storage Methods use by Farmers

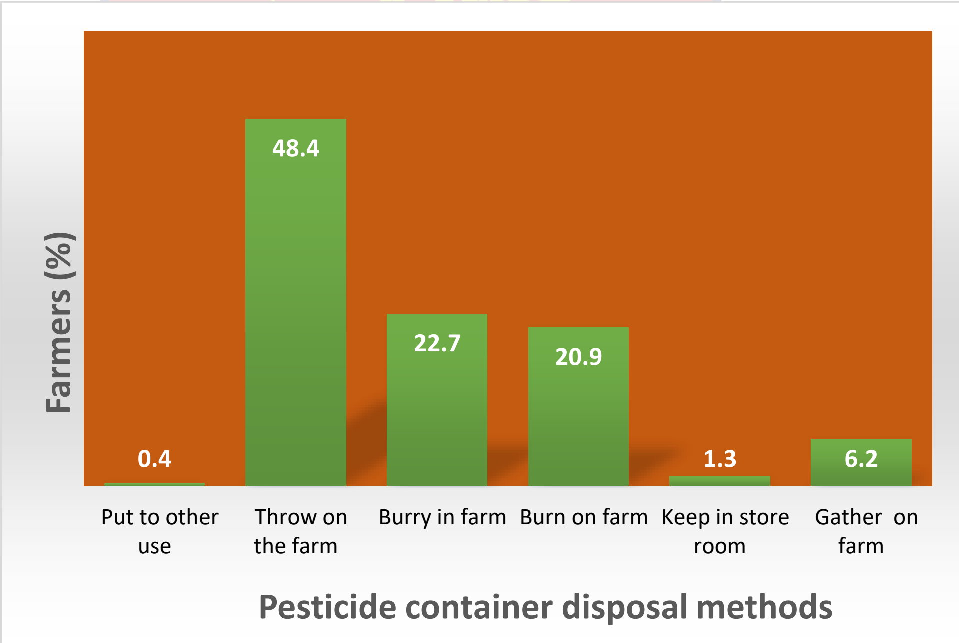

Figure 5: Pesticide Empty Container Disposal Methods used by Farmers

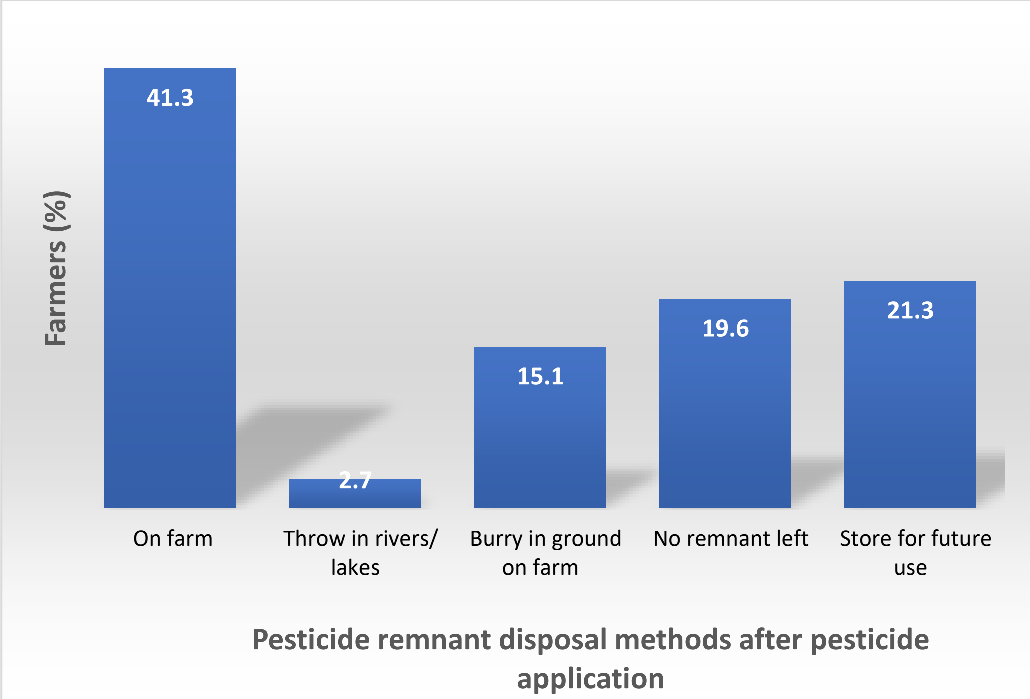

Figure 6: Pesticide Remnant Disposal Methods used by Farmers

The use and application of pesticides and the disposal of the containers in unsafe conditions do not only harm the farmer's health but also have deleterious effect on the environment and public health (Khan et al., 2010). After using the pesticide, 109 (48.0 %), 51(23.0%) and 47 (21.0 %) of the famers threw the empty containers on the farm, buried them on the farm and burned them on the farm, respectively. Others on the other hand 14 (6.0 %) gathered them on the farm, 3 (1.0 %) kept them in the storeroom and 1 (1.0 %) put them in to other uses (Figure 5). According to Lekei et al. (2014), farmers mostly disposed of remnants of pesticides in unsafe or environmentally unfriendly ways which may be an important source of pesticides exposure.

Even though, farmers are aware of the environmental and public health implications of disposing pesticides remnants in unsafe ways, 76 (33.8 %) of farmers threw them on the farm, 48 (21.3 %) stored for future use, 43 (19.1%) did not leave any remnants, 34 (15.1 %) buried in the grounds on farm and 24

(10.7 %) disposed into rivers, lakes or irrigation canals after spraying (Figure 6).

The washing and the disposal of the water used to wash the sprayer by farmers after pesticides application varied from farmer to farmer depending on the resources available. Results from the study revealed that 97 (43.1 %) poured the solution on the farm, 95 (42.2 %) washed under running tap or bucket at home, 24(10.7 %) washed in to rivers, lakes or irrigation canals, 4 (1.8 %) did not wash, 4 (1.8 %) and 1(0.4 %) wiped with piece of cloth or paper and threw away (Figure 7).

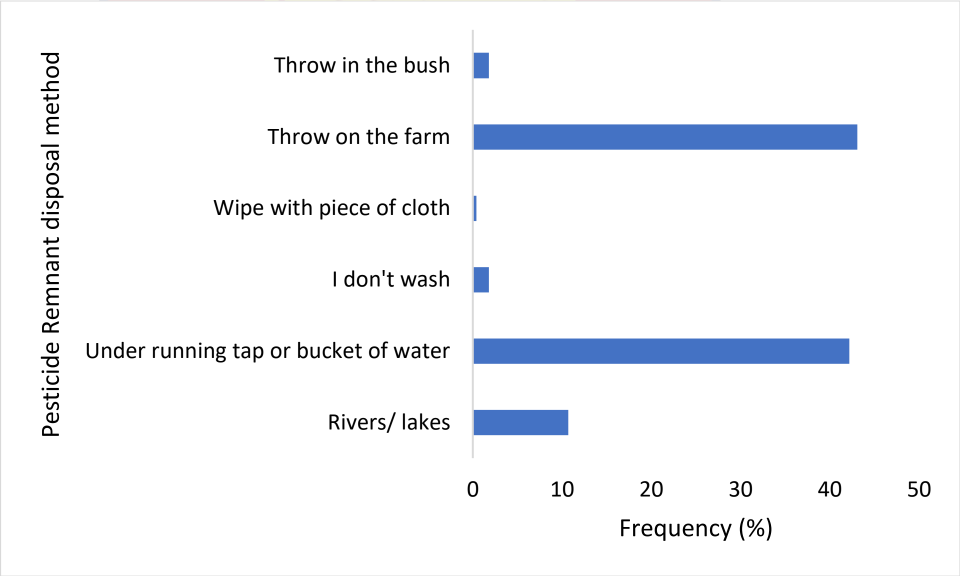

Figure 7: Pesticide Remnant Disposal Methods Used by Farmers

It is clear from the result that most of the farmers dumped empty pesticide containers and the left-over products in an improper and unsafe manner, a finding similar to Ajayi (2000), Esechie and Ibitayo (2011), Ibitayo (2006) and Oluwole and Cheke (2009b). According to Ajayi (2000), Okoffo et al. (2016), Oluwole and Cheke (2009b), majority of the farmers disposed off empty pesticides containers and the pesticide left-overs on the field. This finding lends support to the observations made in this study, with majority of the farmers disposing off empty pesticide containers, remnants of pesticides and wash water of the sprayer on the field. Such practices pose potential risk to nearby streams, animal food and children health (Ajayi, 2000). In most developing countries of which Ghana is part, have limited resources to develop toxic waste collection schemes and facilities for the management of toxic waste hence, many pesticide users are not equipped to dispose of pesticide and related waste safely (UNEP/WHO/FAO, 1999). Burying and throwing of pesticide-related waste are not appropriate options. This is because remnants of pesticides can leak from their containers into the surrounding soil in the farm and spread to pollute large areas. Besides, these pesticides when leached, underground aquifers, rivers, lakes and even the sea can be contaminated. Subsequently, this can damage or destroy aquatic life and affect people and livestock that the water source for drinking, irrigation or washing and may also render the area unusable (Ntow et al., 2006a; UNEP/WHO/FAO, 1999).

Regrettably, a few of the farmers reported dumping the pesticide products into surface water sources (lakes, rivers and irrigation canal). This practice directly kills fish and other aquatic organisms and pollutes large volume of water rendering it unfit for drinking or for irrigational purposes. Remediation of contaminated water is very extremely expensive and, in some cases not possible (UNEP/WHO/FAO, 1999). About 42.2 % of the farmers reported washing sprayer under running tap at home after application of pesticide. This is also another means by which the farmers expose their families to pesticides. Touching the tap with contaminated hands exposes all users of the tap to pesticide exposure. The water from the washed sprayer which is poured on the ground in the house, makes crawling children and those who play in the sand susceptible to pesticide exposure risk. Additionally, burning of pesticide containers in an open place is considered inappropriate. Fumes that come out from the burnt containers are highly toxic and can cause harm to individuals and animals who inhale or encounter them (UNEP/WHO/FAO, 1999).

Pesticide use safety practices such as pesticides storage, disposal of empty containers, remnant and sprayer washed water after spraying were managed in unsafe manner by the farmers in the study area. Practices which have the potential of exposing farmers, their families, and the environment to pesticide exposure risk.

Factors Associated with Farmers' Pesticide Empty Container Disposal Methods

Table 26 displays the results of the chi- square statistics of the factors associated with farmers' pesticide container disposal methods. The results show that there were statistically significant differences between farmers' empty pesticide disposal methods and advice from fellow farmer (P = **0.014**, Cr. V = 0.0252) and agrochemical services (P = **0.001**, Cr. V = 0.311).

Factors Influencing Farmers' Pesticide Storage Method

To see which factors influenced the farmers' storage methods in the study area, the chi-square statistics was used. According to the result, the following factors; education, extension service, cooperative groups, pesticide container labels and advise from fellow farmers significantly influenced the farmers' pesticide storage method. In terms of strength, the Cramer's values indicate that all the factors have strong association with the farmers' pesticide storage methods except education and cooperative groups which had Cramer's V less than 0.3 (Table 27).

Table 26: Factors Influencing Farmers' Empty Pesticide Disposal Method

Variable	Empty pesticide disposal methods						Measure of association
	Put to other use (%)	Throw on the farm (%)	Burn (%)	Burry (%)	Store room (%)	Gather (%)	
Fellow farmer							
No	1(100.0)	85(78.0)	42(89.0)	49(96.0)	3(100.0)	9(64.0)	Pearson π^2 = 14.289 Pr = **0.014** Cramer's V = 0.252
Yes	0(0.0)	24(22.0)	5(11.0)	2(4.0)	0(0.0)	53(6.0)	
Agrochemical shop service							
No	0(0.0)	9(8.0)	12(25.0)	17(33.0)	0(0.0)	0(0.0)	Pearson π^2 = 21.771 Pr = **0.001** Cramer's V = 0.311
Yes	1(100.0)	100(92.0)	35(75.0)	34(67.0)	3(100.0)	14(100.0)	

Advice from Fellow farmer

Taking of advice from fellow famer by other farmers had significantly strong association with the farmers' knowledge in pesticide storage methods and weak association with empty pesticide disposal methods. This means that farmers in the same locality do exchange ideas about agricultural management practices, hence can influence the behavior, pesticide use and handling characteristics such as storage and empty contain disposal of those farmers. A previous study conducted by AL-Zaidi et al. (2019) revealed that about 67.0 % of the farmers reported always getting information about pesticides use from their fellow farmers. AL-Zaidi et al. (2019) also stated that fellow farmers played an important role in exchange of information with one another about proper selection, use and handling of pesticides, adding that fellow farmers were the major source of information for the farmers. If the farmer who gives the advice is not knowledgeable or well educated, he / she may end up giving a wrong or distorted information to the other farmers. According to Lekei et al. (2014) and Sodavy et al. (2000), farmers usually source pesticide information from other famers who are not knowledgeable about pesticide risk. Therefore, farmers should be given capacity building training and supervised in pesticides use and handling such as dosage, storage and disposal of empty containers, since they also serve as conduit for transferring information on agricultural management from the extension officers and agrochemical dealers to the fellow farmers.

Agrochemical Shop Services

Agrochemical shop services had statistically significant differences and strong association between farmers' empty pesticide containers disposal methods. This implies that the probability that a farmer who comes in to contact with an agrochemical dealer will get an information on empty pesticide containers disposal method is high. This is because, apart from selling pesticides to farmers, they also educate farmers on safety usage and handling of pesticides. Matthews (2008) reported that the major source of pesticide safety training and information related to pesticide usage received by the farmers was mostly from local agrochemical dealers. Considering this, Ghana COCOBOD should organize capacity building training for all agrochemical dealers in the country since not all of them are knowledgeable in health risks associated with pesticide use. Similarly, Lekei et al. (2014) and Sodavy et al. (2000) stated that farmers usually source pesticide information from pesticide dealers and from other famers who are not knowledgeable about pesticide risk.

Education

Farmers' education had an influence on the way pesticides are stored. This implies that as the farmers' educational level increases, the probability that the farmers will store pesticides safely is high. The educational level of the farmer increases his/ her knowledge level in the risk involved in unsafe use of pesticides which will motivate him / her to store pesticides safely. Kumari & Reddy (2013) in a study to assess the knowledge and practices of safety use of pesticides among farm workers, reported that good knowledge on safety use of pesticides is significantly influenced by the educational level of the farm workers. Similarly, education is related to higher levels of knowledge and behavior, therefore farmers who are well educated have more knowledge on negative health effects of pesticides and route of contamination of pesticides (Gaber & Abdel-Latif, 2012) while Jallow et al. (2017) and Matthews (2008) also reported that less educated farmers may be hampered in their ability to access information about pesticides and follow recommended safety and application guidance.

Extension Service

Extension officers serve as conduit for transfer of information between Ghana COCOBOD and the farmers. Therefore, extension service has an influence on the safe handling of pesticides by farmers. Farmers who get assess to extension service are more likely to adopt good pesticide storage methods. Hence, extension services can be used to educate farmers and enforce good pesticide usage and handling practices. Jallow et al. (2017), explained that pesticide laws such as sale, distribution, storage and handling are enforced by efficient agricultural extension services through the provision of information and guidance to farmers on safe and judicious use of pesticides.

Cooperative Societies

Cooperative societies influence farmers' pesticides use knowledge. This is because members of the cooperative societies have the likelihood of obtaining information through the societies. These groups aim at educating farmers on new agricultural practice such as pest control methods, safe handling of pesticides and health effects of unsafe use of pesticides. Therefore, cooperative societies are the best-suited organizations for suitable information related to economic and agricultural development (Uwagboe et al., 2012; Waller et al., 1998). Besides, the group also influences the members in the adoption of recommended practices (Waller et al., 1998). Therefore, a farmer who belongs to this group is likely to be taught safe ways of storing pesticides. Farmers should, therefore, be encouraged to join this groups to enrich their knowledge in safe handling of pesticides. Besides, COCOBOD can use these groups as agents to disseminate information to the farmers.

Pesticide Label

Pesticide label reading by the farmers had significantly strong influence on farmers' knowledge in pesticide storage. This implies that as the farmer reads the pesticide label, the probability of him / her knowing the safe method of pesticide handling is high. Therefore, that farmer is more likely to store pesticides in a safe manner than a farmer who does not read the labels. Ghana COCOBOD should encourage more educated young men and women into the cocoa industry through the provision of subsidies and inputs, since only the educated farmers can read and understand pesticide labels.

Table 27: Distribution of Factors Influencing Pesticide Storage Methods Used by Farmers (n = 225)

Variable	Pesticides Storage Methods										Measure of association
	Agrochemical store (%)	Animal houses (%)	Food store room (%)	Living houses (%)	Kitchen (%)	Bush (%)	Toilet (%)	Farm (%)	Bedroom (%)	Bathroom (%)	
Education											
No formal Education	0(0.0)	0(0.0)	6(6.0)	1(2.0)	0(0.0)	0(0.0)	1(20.0)	0(0.0)	1(6)	1(50.0)	Pearson π^2 = 47.244
Primary	8(44.0)	1(33.0)	56(58.0)	40(80.0)	9(89.0)	3(50.0)	1(20.0)	9(56.0)	10(50.0)	1(50.0)	Pr = **0.009**
Secondary	10(56.0)	2(67.0)	29(30.0)	8(16.0)	0(0.0)	3(50.0)	2(40.0)	7(44.0)	5(27.0)	0(0.0)	Cramer's
Tertiary	0(0.0)	0(0.0)	6(6.0)	1(2.0)	1(11.0)	0(0.0)	1(20.0)	0(0.0)	3(17.0)	0(0.0)	V = 0.265
Fellow farmer											
No	17(94.0)	0(0.0)	87(90.0)	40(80.0)	7(78.0)	6(100.0)	2(40.0)	14(88.0)	14(74.0)	2(100.0)	Pearson π^2 = 30.779 Pr = **0.000** Cramer's
Yes	1(6.0)	3(100.0)	10(10.0)	10(20.0)	2(22.0)	0(0.0)	3(60.0)	2(12.0)	5(26.0)	0(0.0)	V = 0.370
Extension service											

Table 27: Continued

Variable	Agrochemical store (%)	Animal houses (%)	Food store room (%)	Living houses (%)	Kitchen (%)	Bush (%)	Toilet (%)	Farm (%)	Bedroom (%)	Bathroom (%)	Measure of association
	Pesticides Storage Methods										
No	3(17.0)	0(0.0)	30(31.0)	9(18.0)	4(44.0)	5(83.0)	1(20.0)	1(6.0	10(53.0)	0(0.0)	Pearson π^2 = 25.935 Pr =**0.002** Cramer's
Yes	15(83.0)	3(100.0)	67(69.0)	41(82.0)	5(56.0)	1(17.0)	4(80.0)	4(80.0)	9(47.0)	2(100.0)	V = 0.340
Cooperatives											
No	18(100.0)	3(100.0)	96(99.0)	49(.98.0)	9(100.0)	6(100.0)	5(100.0)	13(81.0)	18(95.0)	2(100.0)	Pearson π^2 = 18.703 Pr = **0.028** Cramer's
Yes	0(0.0)	0(0.0)	1(1.0)	1(2.0)	0(0.0)	0(0.0)	0(0.0)	3(19.0)	1(5.0)	0(0.0)	V = 0.288
Pesticide label											
No	17(94.0)	3(100.0)	96(99.0)	47(94.0)	9(100.0)	6(100.0)	3(60.0)	13(81.0)	17(89.0)	2(100.0)	Pearson π2 = 23.350 Pr =**0.005** Crame´r's V =
Yes	1(6.0)	0(0.0)	1(1.0)	3(6.0)	0(0.0)	0(0.0)	2(40.0)	3(19.0)	2(11.0)	0(0.0)	0.322

Self-reported Pesticide Toxicological Symptoms of Farmers

The results in Table 28, show that farmers who reported symptoms of headache were 132 (59.0 %), burning eye sensation 143 (64.0 %), weakness 150 (67.0 %), fever (62.0 %), watering eye (49.0 %), skin rashes (52.0 %), itching skin 156 (69.0 %), dizziness 94(42.0 %), chest pain 118 (52.0 %), forgetfulness 88(39.0 %), vomiting 4 (18.0 %) and diarrhea 56 (25.0 %). It is obvious from the result that the more commonly reported heath symptoms by the farmers during or after pesticide application in the study area were headache, burning eye sensation, weakness, fever, skin rashes, itching skin, chest pain while the less commonly reported ones were forgetfulness, vomiting, watering eye, dizziness and diarrhea (Table 28). These findings are consistent with Dzobo (2016), Ngowi et al. (2007) and Yassin et al. (2002). Some of the famers in the study area who reported health symptoms of pesticide toxicity considered that to be normal with the work they do. The worrying aspect of the finding is the fact that some of the farmers even associated some of the health symptoms to the difficult nature of the spraying exercise hence they rarely report these symptoms at health centers for treatment. These findings are in consonance with (Kishi et al., 1995; Ngowi et al., 2007) who reported that farmers thought that pesticide poisoning symptoms were normal and that with time, they got used to them. The result is also similar to a study carried out in Coˆ te d'Ivoire, Indonesia and Tanzania (Ajayi, 2000; Kishi et al., 1995; Ngowi et al., 2007) where pesticide applicators tend to accept a certain level of illness as an expected and normal part of the work of farming, and therefore, do not report the symptoms in official health centers for formal medical assistance. These findings may be attributed to poor PPE use during mixing and application of pesticides identified in the study area (Tables 23,24 and 25) coupled with disregard for pesticides use safety protocols. Education and training in safe use of pesticides should be intensified in the region to avert this challenge.

Table 28: Distribution of Farmers' Self- reported Pesticide Toxicological Symptoms (n = 225)

Self- reported Toxicological Symptom	Frequency	Percentage (%)
Headache		
Not experienced	93	41.0
Experienced within the week	132	59.0
Burning sensation in eye		
Not experienced	82	36.0
Experienced within the week	143	64.0
Weakness		
Not experienced	75	33.0
Experienced within the week	150	67.0
Fever		
Not experienced	86	38.0
Experienced within the week	139	62.0
Watering eyes		
Not experienced	115	51.0
Experienced within the week	110	49.0
Skin rashes		
Not experienced	107	48.0
Experienced within the week	118	52.0
Forgetfulness		
Not experienced	137	61.0
Experienced within the week	88	39.0
Vomiting		
Not experienced	184	82.0
Experienced within the week	4	18.0
Diarrhea		
Not experienced	169	75.0
Experienced within the week	56	25.0
Itching skin		

Table 28: Continued

Self- reported Toxicological Symptom	Frequency	Percentage (%)
Not experienced	69	31.0
Experienced within the week	156	69.0
Dizziness		
Not experienced	131	58.0
Experienced within the week	94	42.0
Chest pain		
Not experienced	107	48.0
Experienced within the week	118	52.0

Factors Associated with some Common Self- reported Pesticide Toxicological Symptoms (headache, fever and skin rashes) in the Study Area.

Pearson chi-square and Cramer's V statistic were used to determine whether the observed differences in PPE use, pre – harvest interval, farm size, method of empty pesticide container disposal, reading of pesticide labels, the community in which the farmers live and the reporting of symptoms of headache, fever and skin rashes were independent. The results in Table 29 indicate that there was statistically significant association between headache and PPE use, pre- harvest interval and the community in which the farmers live. Besides, fever also showed statistically significant association between PPE use, empty pesticide container disposal, pre -harvest interval, farm size and the community in which the farmers live (Table 30). Skin rashes on the other hand, had statistically significant association between PPE use, pre – harvest interval, reading of pesticide label and the community in which the farmers are located (Table 31). This means that the above-named variables influence the occurrence of headache, fever and skin rashes after pesticide handling by the farmers. However, in terms of strength, fever had a strong association between pre – harvest interval, farm size and the community in which the farmers are located (Table 31) while headache and skin rashes had a strong association between the communities in which the farmers are located (Tables 29 and 30).

Table 29: Factors Associated with a Farmer Experiencing Headache (n = 225)

Variables	Headache		Measure of association
	No (Freq. %)	Yes (Freq. %)	
PPES			
No	44 (47.0)	83 (63.0)	Pearson π^2 = 5.928 Pr = **0.015** Cramer's V =
Yes	49 (53.0)	49 (37.)	0.162
Pre -harvest interval			
same day	0 (0.0)	2 (2.0)	
1 -2 days	0 (0.0)	7 (5.0)	Pearson π^2 = 16.297
3 - 6 days	4 (4.0)	17 (13.0)	Pr = **0.006** Cramer's V =
1 week	14 (15.0)	24 (18.0)	0.269
More than 1 week	61 (66.0)	74 (56.0)	
Manufacturers instruction	41 (15.0)	8 (6.0)	
Community			
Kpedze	11(11.8)	14(10.6)	
Togorme	8(8.6)	17(12.9)	Pearson π^2 =
Kpoeta	11(11.8)	14(10.6)	30.352Pr = **0.000** Cramer's V =
Leklebi kame	13(14.0)	12(9.1)	0.367
Logba Alakpeti	6(6.5)	19(14.4)	
Leklebi Agbesia	11(11.8)	14(10.6)	
Bla	21(22.6)	4(3.0)	
Gbledi Chebi	6(6.5)	19(14.4)	
Fodome Woe	6(6.5)	19(14.4)	

Table 30: Factors Associated with a Farmer Experiencing Skin Rashes (n = 225)

Variable	Skin Rashes		Measure of association
	No Freq. (%)	Yes Freq. (%)	
PPES			
No	45 (42.0)	82 (70.0)	Pearson π^2 = 17.181 Pr = **0.000** Cramer's V = 0.275
Yes	62 (58.)	36 (30.0)	
Pre -harvest interval			
same day	0 (0)	2 (2.0)	
1 -2 days	5 (5.0)	2 (2.0)	Pearson π^2 = 11.770 Pr = **0.038** Cramer's V = 0.229
3 - 6 days	5 (5.0)	2 (2.0)	
1 week	14 (13.0)	24 (20.0)	
More than 1 week	72 (67.0)	63 (53.0)	
Manufacturers instruction	11 (10.0)	11 (9.0)	
Pesticide package labels			
No	98(91.6)	115(97.5)	Pearson π2 = 38.828 Pr = **0.050** Cramer's V = 0.130
Yes	9(8.4)	3(2.5)	
Community			
Kpedze	8(32.0)	17.68.0)	
Togorme	6(24.0)	19(76.0)	
Kpoeta	15(60.0)	10(40.0)	Pearson π^2 = 29.332 Pr = **0.000** Cramer's V = 0.361
Leklebi kame	18(72.0)	7(28.0)	
Logba Alakpeti	15(60)	10(40.0)	
Leklebi Agbesia	8(32.0)	17(68.0)	
Bla	18(72.0)	7(28.0)	
Gbledi Chebi	7(28.0)	18(72.2)	
Fodome Woe	12(48.0)	13(52.0)	

Table 31: Factors Associated with a Farmer Experiencing Fever (n = 225)

Variable	Fever		Measure of association
	No Freq. (%)	Yes Freq. (%)	
PPES			
No	35 (41.0)	92 (66.0)	Pearson π^2 = 14.041 Pr = **0.000** Cramer's V = 0.250
Yes	51 (59.0)	47 (34.0)	
Pre -harvest interval			
same day	0 (0.0)	2 (1.0)	
1 -2 days	0 (0.0)	7 (5.0)	Pearson π^2 = 20.895 Pr = **0.001** Cramer's V = 0.305
3 - 6 days	3 (4.0)	18 (13.0)	
1 week	9 (11.0)	29 (21.0)	
More than 1 week	61 (71.0)	74 (53.0)	
Manufacturers instruction	13 (15.0)	9 (7.0)	
Pesticide container disposal			
sell to others	0 (0.0)	1 (1.0)	
Throw on the farm	35 (41.0)	74 (53.0)	Pearson π^2 = 13.045 Pr = **0.023** Cramer's V = 0.241
Burry on farm	20 (23.0)	31 (22.0)	
Burn on farm	18 (21.0)	29 (21.0)	
Store room	2 (2.0)	1 (1.0)	
Gather on farm	11 (13.0)	3 (2.0)	

Table 31 continued

Variable	Fever		Measure of association
	No	Yes	
	Freq. (%)	Freq. (%)	
Farm size			
0.5 - 1.5 acres	12 (14.0)	9 (7.0)	
1.6 - 2.0 acres	18 (21.0)	21 (15.0)	
2.4 - 2.5 acres	10 (12.0)	9 (6.0)	Pearson π^2 = 16.658Pr = **0.020** Cramer's V = 0.272
2.6 - 3.5 acres	19 (22.0)	21 (15.0)	
3.6 - 4.5 acres	12 (14.0)	23 (17.0)	
4.6 - 5.5 acres	5 (6.0)	19 (14.0)	
6.0 - 7.0 acres	4 (5.0)	19 (14.0)	
> 7 acres	6 (7.0)	18 (13.0)	
Community			
Kpedze	9(36.0)	16(64.0)	
Togorme	3(12.0)	22(88.0)	
Kpoeta	11(44.0)	14(56.0)	Pearson π^2 = 30.530 Pr = **0.000** Cramer's V = 0.368
Leklebi kame	13(52.0)	12(48.0)	
Logba Alakpeti	7(28.0)	18(72.0)	
Leklebi Agbesia	13(52.0)	12(48.0)	
Bla	18(72.0)	7(28.0)	
Gbledi Chebi	4(16.0)	21(84.0)	
Fodome Woe	8(32.0)	17(68.0)	

Pre- Harvest Interval (PHI)

The result shows that pre – harvest interval influences the reporting of headache, fever and skin rashes within or a week after pesticide handling. The legal time to wait before harvesting a particular crop after application of a particular pesticide is referred to as pre -harvest interval. Non adherence to PHI may lead to increase in pesticide residues of crops which have the potential of creating health problems to the consumers (Rijal et al., 2018). This is because observance of pre -harvest interval reduces the residue levels within acceptable limits (Cengiz et al., 2007).

Personal Protective Equipment (PPE)

Personal Protective equipment use positively influences farmers' exposure to pesticides during handling. This result can be explained on the basis that a farmer who uses PPE during pesticide handling is likely to experience minimal pesticide exposure. Therefore, farmers who do not use and or use inappropriate PPE are more likely to experience pesticide toxicity symptoms such as headache, fever and skin rashes during or after pesticide application. According to Tsakirakis et al. (2010), several studies conducted have concluded that PPE use can prevent farmers' exposure to pesticide.

Disposal of Empty Pesticide Containers

The result shows that disposal of empty pesticide containers influences the reporting of the symptoms of fever during or after pesticide handling by the farmers. The result may be explained on the basis that when empty containers are disposed of in unsafe manner, they may end up exposing the individuals to pesticides. (Lekei et al., 2014) reported that unsafe disposal of unwanted pesticides and empty pesticide containers may be an important source of pesticide exposure. Disposal methods such as throwing on field, burying in the ground washing them in rivers and irrigation canals and re-use for other purposes can increase exposure among farmers and their families through contamination of nearby streams and rivers. This may also lead to environmental contamination by runoffs, leaching or aerial distribution via other areas (Lekei et al., 2014); hence posing danger to those who use the water.

Farm Size

The size of the farm had a strong association with the reporting of fever on pesticide handling. This may be explained that the bigger the farm, the more pesticides and longer time used in the application and the opposite is true. This implies that as the farm size increases, farmers' – pesticide exposure time also increases. Okoffo et al. (2016) identified a positive relationship between farm size and PPE use and explained that since large farms take longer time to apply pesticides, if farmers do not use or use inappropriate PPE due to economic or discomfort, they will be exposed to the harmful effects of the pesticides.

Communities of the Farmers

The communities in which the farmers are located strongly influence their reporting of pesticide toxicity symptoms. This may be explained on the basis that farmers in the same community are socially bonded; hence facilitates easy exchange of ideas regarding technology adoption such as pesticide usage practices. This union does not only ease exchange of ideas but also exerts pressure on group members' behavior and norms (Taher, 1996; Van Den Ban & Hawkins, 1988) ; hence indulging in common agricultural practices. Therefore, any adverse health issues that arise affect majority of the farmers.

Multivariate analyses

The relationship between self-reported disease symptoms by respondents and the use of all required PPE were determined using complementary log-log regression models. These models were used for the analyses of the relationship between the odds of reporting headache, fever, skin rashes and theoretically relevant variables because 55% or more of the responses were affirmative and satisfy the assumption for the model (Armah et al., 2019b).

Three models were operationalized at the multivariate level, the use of all required PPE and biosocial factors (model 1), socio-cultural factors (model 2), and contextual factors (model 3) to assess how they cumulatively influenced exposure to pesticides use and disease symptoms (headache, fever and skin rashes). The complementary log-log regression models outputs (Tables 32, 33 & 34) reveal the OR, robust standard errors, probability values, and CIs in the models.

Likelihood of Farmers and their Counterparts to Report Headache

Model 1 (Table 32) revealed that cocoa farmers who use all required PPE (OR= 0.654, $P<0.05$) were 35% less likely to report headache compared to their counterparts who were not using all required PPE. In model 2, cocoa farmers pre- harvest interval was controlled for. The results show that cocoa farmers who were using all required PPEs (OR=0.692, CI: 0.469-1.022) were 31% less likely to report headache compared to their counterparts who were not using all required PPE. The results also show that cocoa farmers who harvested 2-3 days was not statistically significant. However, 3-6 days (OR=0.087, $P<0.05$), 1 week (OR= 0.054, $P<0.05$), more than 1 week (OR=0.0.044, $P<0.05$) and following manufacturer's instructions (OR=0.028, $P<0.05$) were all less likely to report headache compared to those that harvest immediately pesticides were applied.

Contextual factors were controlled for in model 3. The results (Table 32) indicate that cocoa farmers that used all required PPE (OR=0.837, CI: 0.534-1.312) were 16% less likely to report headache as compared to their counterparts that dd not wear all required PPE. The relationship observed in model 2 between pre-harvest and the incidence of reporting headache still persist with slight increase in the odds. Cocoa farmers who harvested 3-6 days (OR= 0.160, P<0.001), 1 week (OR= 0.067, P<0.001), more than 1 week (OR=0.0.056, P<0.001) and manufacturers instruction (OR=0.033, P<0.001) were all less likely to report headache compared to those that harvested crops immediately. Cocoa farmers at Togorme (OR=1.446, CI: 0.674-3.101), Kpoeta (OR=1.029, CI: 0.473-2.237, Logba Alakpeti (OR=1.387, CI: 0.632-3.045, Gbledi Chebi and (OR=1.573, CI: 0.742-3.334) and Fodome Woe (OR=1.097, CI: 0.469-2.568) were all more likely to report headache compared to their counterparts from the Kpedze community. Also, Cocoa farmers from Leklebi Kame (OR=0.701, CI: 0.290-1.695), Leklebi Agbesia (OR=0.924, CI: 0.427-1.999) and Bla (OR=0.171, CI: 0.053-0.554) communities were less likely to report headache as compared to their counterparts in the Kpedze community.

Table 32: Complementary log-log Regression Model Predicting the Experience of Headache by Farmers

	Key Predictor (Model 1)					Model 2					Model 3				
Variables	**OR**	**SE**	**P-value**	**CI**		**OR**	**SE**	**P-value**	**CI**		**OR**	**SE**	**P - value**	**CI**	
PPES use (Ref: No)															
Yes	0.654	0.122	**0.022**	0.454	0.942	0.692	0.138	0.064	0.469	1.022	0.837	0.192	0.438	0.534	1.312
Pre -harvest interval (Ref: harvest just															
1 -2 days						1.011	0.081	0.896	0.863	1.183	1.480	0.687	0.399	0.595	3.678
3 - 6 days						0.087	0.028	**0.000**	0.046	0.163	0.160	0.065	**0.000**	0.072	0.356
1 week						0.054	0.014	**0.000**	0.032	0.090	0.067	0.028	**0.000**	0.029	0.152
More than 1 week						0.044	0.008	**0.000**	0.031	0.063	0.056	0.020	**0.000**	0.028	0.113
Manufacturers instruction						0.028	0.010	**0.000**	0.014	0.057	0.033	0.015	**0.000**	0.014	0.081
Community (Ref: Kpedze)															
Togorme											1.446	0.563	0.343	0.674	3.101
Kpoeta											1.029	0.408	0.942	0.473	2.237
Leklebi kame											0.701	0.316	0.430	0.290	1.695

Table 32: Continued

	Key Predictor (Model 1)					Model 2					Model 3				
Variables	**OR**	**SE**	**P-value**	**Cont.**	**Int.**	**OR**	**SE**	**P-value**	**Cont.**	**Int.**	**OR**	**SE**	**P - value**	**Cont.**	**Int.**
Logba Alakpeti											1.387	0.557	0.415	0.632	3.045
Leklebi Agbesia											0.924	0.364	0.840	0.427	1.999
Bla											0.171	0.103	**0.003**	0.053	0.554
Gbledi Chebi											1.573	0.603	0.237	0.742	3.334
Fodome Woe											1.097	0.476	0.831	0.469	2.568
					N=225					N=225					N=225

***** OR = Odd ration, SE = Standard error, CI = Confidence interval, Bold font represent statistically significant relation

Likelihood of Farmers and their Counterparts to Report Skin Rashes

In model 1 (Table 33), cocoa farmers who used all required PPE (OR= 0.451, P<0.001) were less likely to report skin rashes compared to their counterparts who were not using all required PPE. Model 1 equally revealed that cocoa farmers that used 1-2 days (OR= 0.017, P<0.001), 3-6 days (P= 0.057, P<0.001), 1 week (P= 0.043, P<0.001), more than one week (P = 0.029, P<0.001), manufacturers instruction (P=0.041, P<0.001), to harvest were less likely to report skin rashes compared to their counterparts that harvest same day.

In model 2, where labels reading was controlled for, cocoa farmers who used all required PPE (P = 0.460, P<0.001), were less likely to report skin rashes compared to those who were did not use all required PPEs. Under this model, cocoa farmers that used 1-2 days (OR= 0.010, P<0.001), 3-6 days (P=0.027, P<0.001), 1 week (P = 0.019, P<0.001), more than one week (P = 0.013, P<0.001), manufacturers instruction (P= 0.020, P<0.001), to harvest were still less likely to report skin rashes compared to their counterparts that harvested crops on the same day. Cocoa farmers who read labels (P= 0.263, CI: 0.061-1.137) were less likely to report skin rashes compared to their counterparts in the reference group (do not read labels) (Table 33).

After controlling for contextual factor (community of residence) in model 3, cocoa farmers who used all required PPEs (P= 0.443, P<0.05), were 56% less likely to report skin rashes compared to their counterparts who were not using all required PPEs. Furthermore, Cocoa farmers that use 1-2 days (OR=0.010, P<0.001), 3-6 days (P=0.038, P<0.001), 1 week (P= 0.016, P<0.001), more than one week (P= 0.014, P<0.001), manufacturers instruction (P= 0.019, P<0.001), to harvest were still less likely to report skin rashes compared to their counterparts that harvested crops on the same day pesticides were applied. Cocoa farmers in the Kpoeta (OR=0.422, P<0.05), Logba Alakpeti ((OR=0.372, P<0.05), Bla (P=0.335, P<0.05) and Fodome Woe (OR=0.352, P<0.05), communities were less likely to report skin rashes compared to their counterparts in the reference group (Kpedze) (Table 33).

Table 33: Complementary log-log Regression Model Predicting the Experience of Skin Rashes by Farmers and their Counterparts

	Key predictors (Model 1)					Bio-social (Model 2)					Contextual model (Model 3)				
Variable	**OR**	**SE**	**P value**	**CI**		**OR**	**SE**	**P value**	**CI**		**OR**	**SE**	**P value**	**CI**	
PPES use (Ref: No)															
Yes	0.451	0.097	**0.000**	0.296	0.688	0.460	0.099	**0.000**	0.302	0.701	0.443	0.111	**0.001**	0.271	0.724
Pre-harvest interval (Ref: same day)															
1 -2 days	0.017	0.012	**0.000**	0.004	0.072	0.009	0.010	**0.000**	0.001	0.071	0.010	0.008	**0.000**	0.002	0.052
3 - 6 days	0.057	0.020	**0.000**	0.028	0.115	0.033	0.027	**0.000**	0.007	0.166	0.038	0.024	**0.000**	0.011	0.134
1 week	0.043	0.012	**0.000**	0.025	0.075	0.026	0.019	**0.000**	0.006	0.112	0.016	0.010	**0.000**	0.005	0.055
More than 1 week	0.029	0.006	**0.000**	0.020	0.044	0.017	0.013	**0.000**	0.004	0.074	0.014	0.008	**0.000**	0.005	0.044
Manufacturers instruction	0.041	0.013	**0.000**	0.022	0.077	0.027	0.020	**0.000**	0.006	0.113	0.019	0.011	**0.000**	0.006	0.060
Labels reading (Ref: No)															
Yes						0.263	0.196	0.074	0.061	1.137	0.427	0.321	0.258	0.098	1.862

Table 33: Continued

Variable	Key predictors (Model 1)					Bio-social (Model 2)					Contextual model (Model 3)				
	OR	SE	P value	Cont.	Int.	OR	SE	P value	Cont.	Int.	OR	SE	P value	Cont.	Int.
Community (Ref: Kpedze)															
Togorme											1.477	0.548	0.294	0.713	3.057
Kpoeta											0.422	0.183	**0.047**	0.180	0.987
Leklebi kame											0.475	0.228	0.120	0.186	1.215
Logba Alakpeti											0.372	0.165	**0.026**	0.155	0.889
Leklebi Agbesia											0.912	0.349	0.811	0.431	1.931
Bla											0.335	0.155	**0.018**	0.135	0.829
Gbledi Chebi											0.852	0.310	0.659	0.418	1.737
Fodome Woe											0.352	0.154	**0.017**	0.150	0.829
					N=225					N=225					N=225

*OR = Odd ration, SE = Standard error, CI = Confidence interval, Bold font represent statistically significant relation

Likelihood of Farmers and their Counterparts to Report Fever

Model 1 output (Table 34) revealed that, cocoa farmers who used all required PPEs (OR= 0.553, CI: 0.366-0.834) were 45% less likely to report fever compared to their counterparts who did not use all required PPEs during the handling of pesticides. Cocoa farmers that threw pesticide container on the farm (P= 0.066, P<0.001), those that buried in ground on farm (P=0.078, P<0.001), burned on farm (P= 0.072, P<0.001), kept in store room (P= 0.031, P<0.001), gathered them together on farm (P= 0.022, P<0.001), were all less likely to report fever compared to their counterparts that sold to others. Model 1 equally reveal that cocoa farmers that used 3-6 days (P=0.082, P<0.001), 1 week (P=0.064, P<0.001), more than one week (P=0.039, P<0.001) and manufacturers instruction (P=0.027, P<0.001), to harvest were respectively 92%, 94%, 96% and 97% less likely to report fever compared to their counterparts that harvest just after pesticide application.

When socio-cultural factors were controlled for in model 2, cocoa farmers who used all required PPEs (P= 0.583, P<0.05), were less likely to report fever compared to those who were not using all required PPE. Under this model, Cocoa farmers that threw pesticide container on the farm (P=0.098, P<0.001), those that buried in ground on farm (P= 0.120, P<0.001), burned on farm (P= 0.111, P<0.001), kept in store room (P=0.054, P<0.001), gathered them together on farm (P= 0.029, P<0.001), were still less likely to report fever compared to their counterparts that sold to others. Cocoa farmers that uses 3-6 days (P=0.050, P<0.001), 1 week (P=0.032, P<0.001), more than one week (P= 0.022, P<0.001), manufacturers instruction (P=0.013, P<0.001), to harvest were still less likely to report fever compared to their counterparts that harvest same day pesticides were applied. Cocoa farmers who had farm size 4.6-5.5 acres (P=2.580, P<0.05), 6.0-7.0 acres (P=2.894, P<0.05), and more than 7 acres (P=2.699, P<0.05), were more likely to report fever compared to their counterparts in the reference group (0.5-1.5 acres) (Table 34).

After controlling for contextual factor (community of residence) in model 3, cocoa farmers who used all required PPE (P= 0.554, P<0.05), were 45% less likely to report fever compared to their counterparts who were not using all required PPEs. Furthermore, Cocoa farmers that threw pesticide container on the farm (P= 0.115, P<0.001), those that buried in ground on farm (P= 0.129, P<0.001), burned on farm (P=0.162, P<0.001), kept in store room (P=0.083, P<0.05), gathered them together on farm (P=0.050, P<0.001), were still less likely to report fever compared to their counterparts that put them in to other use. Cocoa farmers that used 3-6 days (P=0.067, P<0.05), 1 week (P=0.031, P<0.05), more than one week (P=0.019, P<0.05), manufacturers instruction (P= 0.010, P<0.05), to harvest were still less likely to report fever compared to their counterparts that harvested same day pesticides were applied. The observed relationship between cocoa farmers farm size and the incidence of fever vanished in model 3. Cocoa farmers in the Bla community (P= 0.295, P<0.05) were less likely to report fever as compared to their counterparts in the reference group (Kpedze) (Table 34).

Table 34: Complementary log- log Regression Model Predicting the Experience of Fever by Farmers and their Counterparts

	Key predictors (Model 1)					Model 2					Contextual model (Model 3)				
Variables	**OR**	**SE**	**P value**		**CI**	**OR**	**SE**	**P value**		**CI**	**OR**	**SE**	**P value**		**CI**
PPES use (Ref: No)															
Yes	0.553	0.116	**0.005**	0.366	0.834	0.583	0.123	**0.011**	0.385	0.883	0.554	0.139	**0.019**	0.339	0.907
Pesticide container disposal (Ref: put to other use)															
Throw on the farm	0.066	0.012	**0.000**	0.047	0.095	0.098	0.034	**0.000**	0.050	0.194	0.115	0.054	**0.000**	0.046	0.289
Burry in ground on farm	0.078	0.019	**0.000**	0.049	0.124	0.120	0.048	**0.000**	0.054	0.263	0.129	0.061	**0.000**	0.051	0.327
Burn on farm	0.072	0.017	**0.000**	0.045	0.115	0.111	0.045	**0.000**	0.050	0.247	0.162	0.082	**0.000**	0.060	0.437
Keep in store room	0.031	0.031	**0.000**	0.005	0.216	0.054	0.049	**0.001**	0.009	0.323	0.083	0.077	**0.007**	0.014	0.514
Gather them together on farm	0.022	0.013	**0.000**	0.007	0.069	0.029	0.018	**0.000**	0.009	0.097	0.050	0.037	**0.000**	0.012	0.214
Pre -harvest interval (Ref: just after spraying)															
1 -2 days	0.907	0.195	0.650	0.594	1.383	0.600	0.263	0.244	0.254	1.417	0.584	0.366	0.391	0.171	1.993
3 - 6 days	0.082	0.028	**0.000**	0.042	0.160	0.050	0.022	**0.000**	0.021	0.119	0.067	0.035	0.000	**0.024**	0.186

Table 34: Continued

	Key predictors (Model 1)					Model 2					Contextual model (Model 3)				
Variables	**OR**	**SE**	**P value**	**Cont.**	**Int.**	**OR**	**SE**	**P value**	**Cont.**	**Int.**	**OR**	**SE**	**P value**	**Cont.**	**Int.**
1 week	0.064	0.018	**0.000**	0.037	0.111	0.032	0.015	**0.000**	0.013	0.078	0.031	0.016	0.000	**0.011**	0.087
More than 1 week	0.039	0.009	**0.000**	0.024	0.062	0.022	0.008	**0.000**	0.011	0.047	0.019	0.009	0.000	**0.007**	0.048
Manufacturers instruction	0.027	0.010	**0.000**	0.013	0.054	0.013	0.006	**0.000**	0.005	0.033	0.010	0.006	0.000	**0.004**	0.030
Farm size (Ref: 0.5 - 1.5 acres)															
1.6 - 2.0 acres						1.247	0.540	0.610	0.534	2.916	1.124	0.491	0.789	0.478	2.644
2.4 - 2.5 acres						1.083	0.570	0.879	0.386	3.039	1.066	0.568	0.904	0.376	3.026
2.6 - 3.5 acres						1.418	0.609	0.416	0.611	3.290	1.117	0.511	0.809	0.456	2.736
3.6 - 4.5 acres						2.088	0.885	0.082	0.910	4.794	1.853	0.811	0.158	0.787	4.368
4.6 - 5.5 acres						2.580	1.217	**0.044**	1.024	6.504	1.993	0.951	0.148	0.782	5.075
6.0 - 7.0 acres						2.894	1.381	**0.026**	1.136	7.372	1.927	0.915	0.167	0.760	4.889
> 7 acres						2.699	1.315	**0.042**	1.038	7.015	1.633	0.843	0.342	0.594	4.489

* OR = Odd ration, SE = Standard error, CI = Confidence interval, Bold font represent statistically significant relation

Table 34: continued

	Key predictors (Model 1)					Model 2					Contextual model (Model 3)				
Variables	**OR**	**SE**	**P value**	**Cont.**	**CI**	**OR**	**SE**	**P value**	**Cont.**	**Int.**	**OR**	**SE**	**P value**	**Cont.**	**Int.**
Community (Ref: Kpedze)															
Togorme											2.082	0.841	0.069	0.944	4.594
Kpoeta											0.919	0.365	0.831	0.421	2.002
Leklebi kame											0.745	0.353	0.534	0.294	1.885
Logba Alakpeti											0.778	0.334	0.558	0.335	1.804
Leklebi Agbesia											0.493	0.218	0.110	0.207	1.174
Bla											0.295	0.151	**0.017**	0.108	0.804
Gbledi Chebi											1.325	0.517	0.471	0.617	2.846
Fodome Woe											0.598	0.273	0.260	0.245	1.462
n = 225						n = 225					n = 225				

*OR = Odd ration, SE = Standard error, CI = Confidence interval, Bold font represent statistically significant relation

This study set out to predict the combined effect of the farmers experiencing health symptoms such as headache, skin rashes and fever based on the use of PPE during pesticide handling, observance of pre-harvest intervals and the methods employed in empty pesticide container disposal and reading of pesticide labels. More often than not, the assessment of work-related risks on the health and safety of workers is analyzed separately, hence has failed to give a comprehensive understanding of the cumulative effects of chemicals, physical agents and practices on the health of the workers (Armah et al., 2019b). Therefore, there is the need to consider pesticide health risk in multifactorial or combined form.

It is evident from the result that farmers who used PPEs were less likely to experience any of the health symptoms under consideration. A finding, in consonance with (Jensen et al., 2010) who concluded that farmers reduced their risks of poisoning by 55 % for each personal protective measure they adopted. The use of PPEs during pesticide handling minimizes the risk exposure to the applicator. Over 2500 people died out of pesticide self-poisoning annually, accounting for 30 % of the suicide worldwide (Gunnell et al., 2007) due to inadequacy in the protective gears worn (Wilson, 1999, 2005). Therefore, the use of personal protective equipment could help reduce the adverse health effects of pesticides on the farmer.

The results also show that the likelihood of farmers reporting headache, fever and skin rashes as a result of handling pesticides decreased with increasing pre-harvest intervals. Pre-harvest interval though, a very important agrochemical regulation, has received a little attention. It causes both contamination and exposure (Sunding & Zivin, 2000). Observance of pre-harvest interval reduces pesticide residue levels in the crops. This is because pesticides can decay when exposed to the sunlight, rain and other environmental factors when allowed sufficient time, hence the reduction in chemical toxicity (Sunding & Zivin, 2000) to those who go to harvest the crops and consumers.

The likelihood of farmers reporting pesticide health related symptoms increased with corresponding increase in acreages sprayed by the famers. This may be explained using the fact that as the farm size increases, the quantity of pesticide used and the farmer exposure time also increase. A study has indicated that farmers take less precaution when they spray large acreage of form. This is due to the high expenditure on PPEs. Additionally, large acreage sprayed may lead to wear and tear of PPEs therefore, exposing the farmer to the pesticides (Wilson, 2005). Other researchers also reported that farmers tend to be less cautious when a large acreage is sprayed a day due to the discomfort they experience in using PPEs as a result of high temperatures prevailing at the time (Sivayoganathan et al., 1995b; Sodavy et al., 2000; Wilson, 2005).

It is also evident from the result that farmers that throw pesticide container on the farm, burry in ground on farm, burn on farm, keep in store room and gather them together on farm, were less likely to report fever compared to their counterparts that put them in to other uses. The reuse of contaminated containers for domestic purposes such as storing of oil (Jallow et al., 2017) water and food (Dinham, 1993; Oluwole & Cheke, 2009b; Tijani, 2006) pose direct and immediate health risk to the farmers and their families than the other methods mentioned above. Farmers emphasized that they washed the empty containers before reuse and buttressed this by saying that there is no exposure risks because they could not smell the pesticide (Jallow et al., 2017) and are therefore, exposed to the pesticides unknowingly.

The results also show that farmers from Bla, Kpoeta, Logba Alakpeti and Fodome Woe were more likely to report pesticide toxicity symptoms. This may be attributed to unsafe handling of pesticides such non-use of PPEs, bad storage and disposal methods in these communities which are important source of pesticide exposure. Farmers should therefore, be sensitize in the predicted safety practices to reduce pesticide exposure.

Farmers Opinions about the Trend of Pesticide Use

When farmers' opinion about the trend of pesticide use was assessed. The results show that majority 193 (85.0 %) of the farmers stated that pesticide use was increasing while 24 (11.0 %) claimed it was constant (Table 35). Others, 7 (3.0 %) said it was decreasing and 1 (1.0 %) farmer stated that they had no idea. In a similar study, it was concluded that about 53.0 % of the farmers reported increasing trend, 33.0 % constant and 14.0 % decreasing trend. A previous observation also showed that pesticide use grew at an alarming rate of 10.0 % annually, though, the corresponding response in yield growth of major crops has been minimal (Rahman, 2013). To buttress the findings of this study, a previous study conducted in India also reported the rapid increase use of synthetic pesticides during the last four decades which has overshadowed the traditional method of insect pests, diseases and weed control (Chand & Birthal, 1997). The increasing trend of pesticide use indicated by the farmers in the study area may be linked to the development of resistance by pests and diseases (Asogwa & Dongo, 2009; Hashemi &

Damalas, 2010; Meijden, 1998) due to overdose of pesticides (Asogwa & Dongo, 2009; Meijden, 1998).

When the farmers were asked to give reasons for their opinions on the increasing trend of pesticide use, the majority 69 (30.7 %) of the farmers mentioned increased in incidence of pests and diseases and recommendations by pesticide retailers and extension officers , 55 (24.4 %) effectiveness and increased in crop production, 35 (15.6 %) increase in farm sizes, 27 (12.0 %) due to proliferation of pesticides, 10 (4.4 %) pesticides as cheap source of labour, 8 (3.6 %) due to climate change as their reasons for the increasing trend of pesticide use (Table 35). Atteh (1984) reported that many farmers in Nigeria are now tuning to the use of chemical pesticides for pest control due to massive pest damage in the last few years following strenuous advertisement by Ministry of Agriculture. A study carried out in Ethiopia to assess smallholder vegetable farmers' pesticide use, also revealed that one of the reasons for current increasing trend of pesticide use was pressure from retailers, their technical guidance, coupled with high incidence of pests and diseases (Mengistie et al., 2017a). Farmers believed that chemical methods of pest control are very effective in combating serious pest infestation (Shetty1 et al., 2010) thus, they protect crops from pests, enhance crop yields and improve product quality (Chand & Birthal, 1997), therefore, use pesticides extensively. Besides, the findings of this study is in line with (Ngowi et al., 2007) who also discovered that the trend of pesticides use by farmers over the years is probably based on farmers' knowledge on pesticide application in relation to effectiveness of pesticides, pests, farm size and weather condition. The result also shows that 10 (4.0 %) farmers thought that pesticide use was increasing due to its being used for clearing of vegetation following unavailability of labor. This finding is consistent with (Sarwar, 2015) who also reported that chemical insecticides have facilitated the management of larger acreages of farms by fewer individuals due to the reduced labor needed for physical and mechanical control.

For those who claimed pesticide use trend was constant, 23 (10.2 %) said it was constant due to the adherence to calendar spray regime and 2 (0.9 %) said due to current increase in farm sizes by farmers (Table 35). The calendar spray regime mandates farmers to apply pesticides four times per year. Therefore, if all farmers abide by this regulation, then it is justifiable to say that the trend of pesticide use is constant. This also implies that as the farm size increases, the quantity of pesticide application also increases.

With regards to decreasing trend, 5(2.2 %) farmers attributed the decreasing trend to decrease in soil fertility while 2 (0.9 %) said awareness of negative health effects of pesticides (Table 35). There have been some concerns raised about pesticide use and soil fertility by some researchers. Sarwar (2015) reported that the increased use of pesticides can lead to pesticide build-up because chemicals do not break down easily, resulting in to depleted soil structure which does not make nutrients readily available for plant uptake. As the farmers experienced negative health effects of pesticides, they begin to look for safer alternatives to manage pests and diseases of their crops. A previous research discovered that farmers change their behaviors towards pesticide and look for alternative pest options such as cultural, natural enemies and economic threshold when exposed to pesticide poisoning (Garming & Waibel, 2007; Hashemi & Damalas, 2010).

Table 35: Distribution of Farmers' Opinion and Reasons about Trend of Pesticide Usage (n = 225)

Variable	Frequency	Percentage (%)
Trends in pesticide use reported by farmers		
Increasing	194	86.0
Constant	24	11.0
Decreasing	7	3.0
Opinion of Increasing Trend		
No	156	69.3
Yes	69	30.7
Effectiveness and increase in crop production		
No	170	75.6)
Yes	55	24.4)
Increase in farm size		
No	190	84.4
Yes	35	15.6
Proliferation of pesticides		
No	198	88.00
Yes	27	12.00
As cheap source of labor		
No	215	95.6
Yes	10	4.4
Due to climate change		
No	217	96.4
Yes	8	3.6
Opinion of Constant Trend		
Due to the adherence to calendar spray regime		
No	202	89.8
Yes	22	10.2
Due to current increase in farm sizes by farmers		
No	223	99.0
Yes	2	1.0
Due to decreasing in soil fertility	220	97.8
No	5	2.2
Yes		
Due to awareness of negative health effects of pesticides		
No	221	98.2
Yes	4	1.8

Farmers' Knowledge and Awareness of Names of Alternative Methods of Pest Control

Table 36 displays the results of farmer' knowledge and the awareness of names of other methods of pest control apart from the chemical pesticide method. It is clear from the table that farmers knowledge in other methods of pest control and the awareness of cultural method, botanical pesticide and mechanical methods were statistically significant and had an association with the farmers' location. Regarding the strength of the association, awareness of botanical pesticide and cultural methods were strong while mechanical methods showed weak associations.

The results of the study indicate that the farmers in the study area have good knowledge in effects of pesticides on human health and the environment. Besides, majority of them reported at least one pesticide health related symptom. However, when they were asked whether they knew of any other method of pest control apart from the chemical pesticide, only 56 (25.0 %) responded in the affirmative (Table 36). This is in variance with (Alalade et al., 2017) who reported that majority (73.3 %) of the farmers knew of the chemical pesticide control method. Most of the farmers being aware of only chemical pesticide means of pest control is worrisome since its adverse effects on the human health and the environment is great. The findings may be attributed to shortage of knowledge of and little access to alternative or sustainable techniques and facilities. Most of the farmers interviewed claimed they have found the chemical pesticide to be the most labor- saving, effective and efficient means of pest control. This supports the study of (Damalas & Eleftherohorinos, 2011). In a similar study, (Ngowi et al., 2007) reported that the over reliance of farmers on chemical pesticides is an indication that they are not aware of other pest management methods which are effective, inexpensive yet environmentally friendly. It is obvious from the results that even though extension agents have enough knowledge of pest and diseases, their knowledge in non- chemical pesticide control method is insufficient, hence depend mostly on chemical pesticides as recommendations for farmers. Therefore, the knowledge of other methods of pest control of the extension agents who serve as conduit for transfer of knowledge to the farmers should be broadened.

Awareness of the names of alternative methods of pest control.

When the farmers (n = 56) who claimed to have knowledge in other methods of pest control were asked to name the methods they knew, 49 (87.5 %) mentioned cultural, 24 (42.9 %) mechanical, 19 (33.9 %), 1 (1.8 %) mentioned resistance species and superficial (Table 36). It is obvious from the result that the most known alternative method of pest control in the study area is the cultural method and least is the resistant species method. This finding is in variance with (Alalade et al., 2017) who stated that all the farmers at Kwara State in Nigeria were aware of the cultural method. The dominance of the cultural control method among the other methods may be attributed to its inclusion in the CODAPEC training program for farmers (Naminse et al., 2011). Additionally, cultural methods which include early harvesting of cocoa, timely weed control, removal of infested parts of crops among others are easy to practice and do not need a lot of technical assistance. Farmers and extension officers should be given more awareness and technical assistance in other methods of pest control.

Table 36: Knowledge and Awareness of the names of alternative methods of pest control.

Variable	Community									Measure of association	Region Freq. (%)
	KPE Freq. (%)	TOG Freq. (%)	KPO Freq. (%)	LKA Freq. (%)	LAG Freq. (%)	LOA Freq. (%)	BLA Freq. (%)	GCH Freq. (%)	FOW Freq. (%)		
Knowledge on other method of pest control (n = 225)											
No	16(64.0)	14(56.0)	13(52.0)	25(100.0)	13(52.0)	22(88.0)	23(92.0)	23(92.0)	20(80.0)	Pearson π^2 = 39.275 Pr = **0.000** Cramer's	169(75.0)
Yes	9(36.0)	11(44.0)	12(48.0)	0(0.0)	12(48.0)	3(12.0)	2(8.0)	2(8.0)	5(20.0)	V = 0.418	56(25.0)
Awareness of alternative methods (n = 56)											
Cultural											
No	17(68.0)	18(72.0)	20(80.0)	25(100.0)	13(52.0)	24(96.0)	22(88.0)	23(92.0)	20(80.0)	Pearson π^2 = 31.247 Pr = **0.027** Cramer's	7(12.6)
Yes	8(32.0)	7(28.0)	5(20.0)	0(0.0)	12(48.0)	1(4.0)	3(12.0)	2(8.0)	5(20.0)	V = 0.373	49(87.5)
Botanical pesticide											
No	16(64.0)	16(64.0)	17(68.0)	25(100.0)	13(52.0)	24(96.0)	22(88.0)	23(92.0)	20(80.0)	Pearson π2 = 18.051, Pr = **0.042** Cramer's	37(66.1)
Yes	9(36.0)	9(36.0)	8(32.0)	0(0.0)	12(48.0)	1(4.0)	3(12.0)	2(8.0)	5(20.0)	V = 0.437	19(33.9)
No	17(68.0)	23(92.0)	22(88.0)	25(100.0)	11(84.0)	23(92.0)	24(96.0)	24(96.0)	23(92.0)	Pearson π^2 = 19.310, Pr = **0.010** Cramer's	32(57.1)
Yes	8(32.0)	2(8.0)	3(12.0)	0(0.0)	4(16.0)	2(8.0)	1(4.0)	1(4.0)	2(8.0)	V = 0.293	24(42.9)

KPE=Kpedze, TOG=Togorme, KPO=Kpoeta, LKA=Leklebi Kame, LAG=Leklebi Agbesia, GCH=Gbledi Chebi, FOW=Fodome Woe

Table 36: continued

Variable	Community KPE Freq. (%)	TOG Freq. (%)	KPO Freq. (%)	LKA Freq. (%)	LAG Freq. (%)	LOA Freq. (%)	BLA Freq. (%)	GCH Freq. (%)	FOW Freq. (%)	Measure of association	Region Freq. (%)
Resistant species											
No	25(100.0)	25(100.0)	24(96.0)	25(100.0)	25(100.0)	25(100.0)	25(100.0)	25(100.0)	25(100.0)	Pearson π^2 = 8.036, Pr = 0.439 Cramer's	55(92.2)
Yes	0(0.0)	0(0.0)	1(4.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	V = 0.182	1(7.8)
Supernatural											
No	25(100.0)	25(100.0)	25(100.0)	25(100.0)	25(100.0)	25(100.0)	25(100.0)	25(100.0)	24(96.0)	Pearson π^2 = 8.036, Pr = 0.121 Cramer's	55(92.2)
Yes	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(4.0)	V = 0.189	1(1.8)

KPE=Kpedze, TOG=Togorme, KPO=Kpoeta, LKA=Leklebi Kame, LAG=Leklebi Agbesia, GCH=Gbledi Chebi, FOW=Fodome Woe

Alternative Pest Control Methods Practiced by the Farmers

Chi square and the Cramer' V statistics were used to determine the association between farmers knowledge in alternative methods of pest control and their communities. The results show a significantly strong association between farmers knowledge in cultural and mechanical methods and their communities. However, botanical pesticide method showed a weak significant association while superficial and resistant species methods were not significant (Table 37).

When the farmers (n = 56) who said they used alternative methods apart from the chemical pesticides to control pests and diseases were asked to name the methods they used, 44 (78.6 %) mentioned cultural, 23 (41.1 %) mechanical, 19 (33.9 %) botanical pesticide, 1 (1.8 %) resistant species and 1 (1.8 %) superficial **(**Table 37**).** In Kwara State in Nigeria, all farmers practiced cultural method (Naminse et al., 2011). The fact that the cultural method is the most practiced method after chemical method may be attributable to its being economical and easy to practice with a little or without technical support. According to (Satti, 2012) cultural method is the commonly known simplest, cheapest and the safest method to combating pests and diseases of agricultural crops. The farmers mentioned early harvesting, shade management, early weed control, fertilizer application and sanitation and destruction of infested residues as some of the cultural activities they carried out to control pests and diseases on their farms. The most practiced cultural activity by the farmers was shade management through intercropping. However, this is in contrast to the report of Olaniran et al. (2014) who stated that the most prevalent cultural method of pest control was crop rotation. It can also be gathered from the study that even though majority of the farmers intercropped cocoa with other food crops, they did not know that could help to manage pests such as mirids. Thus, they did not know that intercropping cocoa trees through shade management could be used to control pests and diseases. This observation is in line with Antwi-Agyakwa et al. (2015) and Leston (1970). Serious capsids populations damage are greatly self-controlled by the well-developed cocoa canopies which provide high shade and humidity within the canopies compared with more exposed cocoa with breakages in canopy (Collingwood & Marchart, 1969; Dzobo, 2016).

The result also revealed that about 23 out of the 56 farmers, representing 41.1 % engaged in mechanical or manual pest control method (Table 37). Some of the practices mentioned under the mechanical method included handpicking of insect pests and their eggs for crushing, trapping of rodents, using objects to kill red ants and mealy bugs on the cocoa trees. According to the farmers even though the method was effective, it was very laborious, time consuming and cannot be practiced for commercial production, a finding in consonance with (Obiri et al., 2017). They also added that the method worked effectively for slow moving pests and those that are conspicuous since some camouflage themselves with the color of the vegetation, an observation which lends similarity to Hutson (1920), Litsinger (1994) and Maxwell (1985). The mechanical method works under the principle of physics (mass, energy, force), tool and machines (Litsinger, 1994). Farmers should, therefore, be trained and provided with the tools and machines to ease the difficulty associated with the mechanical method.

The result also shows that about 19 (33.9 %) of the 56 farmers engaged in the use of botanical pesticides for pest control (Table 3). Sources of some of the botanical pesticides used by the farmers include neem (*Azadirachta indica),* garlic (*Allium sativum)*, ginger (Zingib*er officinale)* and wood ash. Botanical pesticides are considered very important in pest management due to their high efficacy, biodegradability, varied mode of action, low toxicity as well as readily availability of source materials (Lengai et al., 2020; Neeraj et al., 2017). Besides, they have short re- entry and pre-harvest intervals (Dutta, 2015; Lengai et al., 2020) and are gaining popularity due to their use of crops that are grown for human consumption (Lengai et al., 2020; Misra, 2014). However, due to challenges in formulation and commercialization which are attributed to lack of chemical data and positive controls, botanical pesticides have not been fully adopted (Lengai et al., 2020).

Nevertheless, farmers mentioned economic, technical, lack of labour as some of the challenges the faced in adopting the IPM in the region, this is not different from the findings of (Aneani, 2012). Some also added that botanical method have been found very effective. However, the challenge they faced was the unavailability of the neem in their communities and the difficulty (labor intensive) involved in the extraction process, a finding in consonance with (Dormon et al., 2007). Ghana COCOBOD should tackle these bottlenecks to motivate farmers to adopt IPM technology in the area.

Sources of Information on Alternative Methods of Pest Control Practiced by the Farmers

Table 38 shows the means of accessing information on alternative methods of pest control among the cocoa farmers in the Volta Region. It is revealed that the major source of accessing information on alternative methods of pest control was farmers' experience 39 (69.6 %) followed by extension service 29 (51.8 %) and fellow farmers 29 (51.8 %). The other mean was agrochemical shops 9 (16.1 %) (Table 37). This result is in variance with the findings of (Alalade et al., 2017) who reported that the major means of accessing information on pest control method was television followed by extension and friends/ family and the others were radio, agrochemical shop and newspapers. The result indicates that experienced farmers, extension service and fellow farmers can be important agents by which information can be extended to farmers generally. It is then suggested that these channels will be means by which government agencies and other stakeholders in the cocoa industry can reach out to farmers on new agricultural practices and technologies.

Table 37: Sources of Information on Alternative Pest Control Methods (n = 225)

Source of Information	Frequency	Percentage (%)
Agrochemical shop		
No	47	83.9
Yes	9	16.1
Fellow farmer		
No	27	48.2
Yes	28	51.8
Extension service		
No	27	48.2
Yes	29	51.8
Farmers' years of experience		
No	17	30.4
Yes	39	69.6

Factors that Influence Farmers Knowledge in Alternative Methods of Pest Control

In order to motivate other farmers to practice alternative pest management, factors associated with farmer's knowledge of alternative pests and diseases control methods were determined. The results in Table 38 show that there were statistically significant associations between alternative methods of pest control by farmers and agrochemical shop services, farmers' years of experience, degree of pest infestation, education and the community in which the farmers are located.

Agrochemical Shop Services

Farmers who depended on agrochemical sellers for advice on pest would hardly adopt alternative method of pest control. This is because the agrochemical dealers sell for profit, hence will not recommend any method than the chemical pesticide. Thus, agrochemical shop service influences alternative method of pest control negatively since limited amount of chemical pesticides are recommended in alternative pest management.

Farmers' years of Experience

Farmers' years of experience was also found to significantly influence their knowledge in alternative method of pest control. Farmers who are experienced in chemical method of pest control would hardly adopt other methods, hence would be less knowledgeable in alternative method of pest control. More experienced famers are less likely to go into new technologies compared to less experience ones. Service & Service (1987) reported that farmers who adopt IPM are less experience than non-adopters.

Degree of pest Infestation

Degree of pest infestation, which takes in to consideration number of pests per tree helps in determining what method of pest control to adopt. It is a key tool in IPM that helps to reduce the use of chemical pesticides. Therefore, farmers who consider degree of pest infestation in pest management process are more likely to be more knowledgeable in alternative pest control methods than their counterparts who do not.

Educational Level

Education influences farmer's adaption of new technology positively. Educated farmers are able to read meaning in to new technologies, weigh the pros and cons better than non-educated ones. Hamilton et al. (1997) stated that education influences the adoption of IPM positive. Therefore, educated farmers are more likely to be knowledgeable in alternative pest control methods than non-educated ones.

Farmers Communities

Members of the same social group share and exchange ideas easily. Farmers belonging to the same community learn from each other about the benefits and usage of new technologies (Mwangi & Kariuki, 2015). The members of a social group also exert pressure on each other in the adoption of new technologies. Therefore, any technology that is accepted by the majority will be adopted by the community members as a whole.

Table 38: Factors influencing knowledge on Alternative methods in pest (

Variable	Alternative methods of pest control No	Yes	Measure of association
Agrochemical shop services			
No	65 (38.0)	7 (13.0)	Pearson π^2 = 13.028 Pr =
Yes	104 (62.0)	49 (87.0)	**0.000** Cramer's V = 0.241
Farmer's experience			
1- 3 years	9 (5.0)	3 (5.0)	
4- 6 years	54 (32.0)	8 (14.0)	
7 - 10 years	45 (27.0)	24 (43.0)	
More than 10 years	61 (36)	21 (38.0)	Pearson π^2 = 8.400 Pr = **0.014** Cramer's V = 0.217
Degree of pest infestation			
No	133 (80.0)	36 (61.0)	Pearson π^2 = 13.028 Pr =
Yes	33 (20.0)	23 (39.0)	**0.000** Cramer's V = 0.241
Education			
No formal education	7 (4.0)	3 (5.0)	
Primary education	113 (67.0)	24 (43.0)	
Secondary Education	42 (25.0)	24 (43.0)	
Tertiary education	7 (4.0)	5 (9.0)	Pearson π^2 = 10.577 Pr = **0.014** Cramer's V = 0.217
Village			
Kpedze	16 (10.0)	9 (16.0)	Pearson π^2 = 39. 275 Pr =
Togorme	14 (8.0)	11 (20.0)	**0.000** Cramer's V = 0.418
Kpoeta	13 (7.0)	12 (21.0)	
Leklebi kame	25 (15.0)	0 (0.0)	
Logba Alakpeti	13 (7.0)	12 (21.0)	
Leklebi Agbesia	22 (13.0)	3 (5.0)	
Bla	23 (14.0)	2 (4.0)	
Gbledi Chebi	23 (14.0)	2 (4.0)	
Fodome Woe	20 (12.0)	5 (9.0)	

Multivariate analysis

Likelihood of Farmers being Knowledgeable of Alternative Methods of Pest Control

Table 39 shows the odd ratios, robust standard error, probability values and confidence intervals associated with the main factors (agrochemical shop services, farmers' years of experience and degree of pest infestation) that predict farmers' knowledge in alternative methods of pest control as well as socio – cultural (education) and conceptual factors (farmers community). Model 1 shows that farmers' own experience was not statistically significant. However, farmers who got access to agrochemical services were 62.0 % less likely to be knowledgeable of other methods of pest control compared to their counterparts who did not consider agrochemical services when considering pest control. However, farmers who considered the degree of pest infestation in pest management (OR = 1.621, P< 0.004) were more likely to be knowledgeable in alternative pest control approach compared to their counterparts who do not consider degree of pest infestation when deciding on which method to use to control pest.

The results in model 2, in which socio - cultural factors were controlled for, show that farmers who got access to agrochemical services (OR = 0.383, P< 0.036) were still less likely to be knowledgeable of other methods of pest control compared to their counterparts who did not rely on agrochemical services when dealing with pest control. Again, farmers who considered degree of pest infestation in pest management (OR = 1.619, P < 0.004) were still more likely to be knowledgeable of alternative methods of pest control compared to their counterparts who did not consider degree of pest infestation in pest management (Table 39).

Table 39: Negative Log – log Regression Model Predicting Factors Influencing Farmers Knowledge of Alternative Methods of Pests and Diseases Control

Variable	Key Determinants					Socio- Cultural Model					Conceptual Model				
	OR	SE	P-value	CI		OR	SE	P-value	CI		OR	SE	P-value	CI	
Agrochemical shop services (Ref: No)															
Yes	0.379	0.185	**0.047**	0.146	0.987	0.383	0.175	**0.036**	0.156	0.938	0.405	0.130	**0.005**	0.216	0.758
Farmer's experience (Ref: 1- 2 years)															
4- 6 years	0.537	0.265	0.208	0.204	1.413	0.551	0.286	0.251	0.199	1.526	0.653	0.307	0.365	0.260	1.641
7 - 10 years	1.147	0.484	0.745	0.501	2.623	1.071	0.482	0.880	0.443	2.589	1.012	0.465	0.980	0.411	2.493
More than 10 years	0.885	0.372	0.771	0.389	2.015	0.841	0.384	0.704	0.344	2.056	0.732	0.330	0.488	0.302	1.771
Degree of pest infestation (Ref: No)															
Yes	1.621	0.272	**0.004**	1.167	2.252	1.619	0.267	**0.004**	1.171	2.237	1.510	0.234	**0.008**	1.114	2.046
Education (Ref: no formal education)															
Primary education						0.611	0.209	0.149	0.313	1.194	0.640	0.209	0.172	0.338	1.214
Secondary Education						1.018	0.340	0.956	0.529	1.960	1.183	0.401	0.619	0.609	2.298

Table 39: Continued

Variable	Key Determinants					Socio- Cultural Model					Conceptual Model				
	OR	**SE**	**P-value**	CI		**OR**	**SE**	**P-value**		CI	**OR**	**SE**	**P-value**		CI
Tertiary education						0.981	0.369	0.960	0.470	2.049	1.065	0.428	0.876	0.484	2.342
Village (Ref: Kpedze)															
Togorme											1.145	0.242	0.522	0.757	1.732
Kpoeta											1.275	0.285	0.278	0.822	1.975
Leklebi kame											9.53e-08	2.93e-08	**0.000**	5.22 e-08	1.74 e-07
Logba Alakpeti											1.423	0.341	0.142	0.889	2.276
Leklebi Agbesia											0.560	0.248	0.191	0.235	1.334
Bla											0.280	0.161	**0.027**	0.091	0.864
Gbledi Chebi											0.287	0.185	**0.053**	0.081	1.014
Fodome Woe											0.817	0.310	0.594	0.388	1.718
	N=225					N=225					N=225				

*OR = Odd ration, SE = Standard error, CI = Confidence interval, Bold font represent statistically significant relation

In model 3, contextual factors which influence farmers knowledge of alternative pests and diseases control methods apart from the use of pesticides were considered. The community of the respondents was controlled for in the model. The socio – cultural factor mediated the relationship between the main predictors and the community of the respondents. From the result, it was interestingly obvious that education was not statistically significant in all the two models. With regards to the communities, Leklebi Kame (OR = 9.53-e 08, P < 0.000), Bla (OR = 0.280, P < 0.027) and Gbledi Chebi (OR = 0.287, P < 0.053) were less likely to be knowledgeable in other method of pest control compared to Kpedze. However, the result of agrochemical services and degree of pest infestation remained the same in all the three models (Table 39).

The probability that a farmer who depends on agrochemical services is less knowledgeable of alternative methods of pest control other than chemical pesticides is high. The presence of agrochemical shops positively influenced farmers to use pesticides as a mean of pest control (Anang & Amikuzuno, 2015). Due to low farmer- extension ratio, many farmers rely on agrochemical dealers for basic information on selection of pesticides and other relevant information on pesticides use. Unfortunately, most of the employees of the agrochemical operators lack technical knowledge, hence give misleading information to the farmers. Besides, agrochemical dealers are profit making organizations, therefore, there may be conflict of interest in prescribing the best pest control methods to the famers and the sale of their products (Rijal et al., 2018). Therefore, extension officers should intensify education on the adoption and the befits of IPM to reduce the use of the chemical pesticides since extension contact negatively influences farmers' excessive use of pesticide.

Degree of pest infestation which explains the pest population per plant is very important when considering options for pest control in IPM (Felsot & Racke, 2006). Farmers who consider degree of pest infestation to decide on pest control method are more likely to be knowledgeable in other methods of pest and diseases control. This is because they consider the cost effectiveness when deciding on pest control methods. They will always want to select the less costly options. For those who do not consider degree of pest infestation, chemical pesticides are applied anytime there is pest attack. Those knowledgeable in IPM will use pesticides based on the observations made, regarding pest population (Mariyono, 2007). Thus, they consider the number of pests per cocoa tree to decide on what action to take. According to Denkyirah et al.(2016), majority of cocoa farmers indicated that the presence of pests and diseases on cocoa trees informed them as to when to apply pesticide. The target of the farmers who do not consider degree of pest infestation is to control the pests rather than managing them. On seeing the pests, they try to eradicate them instantly without considering the severity of pests and diseases infestation and which crop management practice to adopt (Mariyono et al., 2018). Since the consideration of degree of pest infestation in pest management highly predicts farmers' knowledge of other methods of pest control other than chemical pesticides, COCOBOD should train both extension officers and farmers in the concept of pest monitoring and accurate identification for appropriate control decision to be taken based on thresholds.

The result also indicated that farmers from Bla, Gbledi Chebi and Leklebi Kame were less likely to be knowledgeable in other methods of pest control compared to those from Kpedze. This may be due to the fact that the most common pest control method used in these communities is the chemical pesticide method. According to Taher (1996) and Van der Werf et al. (2007), the exchange of information in smaller communal communities is usually easy, fast, and frequent. This is because members have close relations. Moreover, the socio – economic factors establishing the communities are the same, hence may affect the farmers level of technology adoption. The interactions among the members create the avenue to exchange useful ideas as well as exerting pressure on members' behaviors.

Risk Assessment of Pesticides Handling using EIQ Model

Table 40 displays the results of the calculated Environmental Impact (EI) values per acre of some of the commonly used pesticides, their highest and the lowest application rates and percentage active ingredients by farmers. It is clear from the results that active ingredients with the highest EIQ value (44.4) used in the study area was insecticide (bifenthrin) while the least (15.3) herbicides (glyphosate). This finding is in consonance with Paintsil (2017) who also reported insecticide with the highest active ingredient EIQ values. According to Kovach et al. (1992a), Environmental Impact per acre for an active ingredient is a function of application rate. The result also shows that Bifenthrin and Cuprous oxide recorded the highest EI values of 100 and 199 respectively while the least (3.71) was glyphosate. Based on the EIQ rating, Bifenthrin and Cuprous oxide pose high ecological risks to the environment. This may be attributed to overdose of these chemicals in the study area.

It is also worth noting from the result that when the lowest application rates of Bifenthrin (120 ml/acre) and Cuprous oxide (300 g/acre) used by the farmers were considered, lower EI values of 8.70 and 37.70 were recorded respectively. This means that when the recommended rates of these pesticides are used, they may not impact negatively on the environment.

WHO (2010) hazard classification puts 50 % of these pesticides in to class II (moderately hazardous), 33.7 % III (slightly hazardous) and 16.7 % IV (nontoxic). Therefore, these pesticides usage in the Volta Region need to be monitored since their continual high application rates may pose high risk to humans and ecology.

EIQ Model is an essential tool for determining pest management options which impacts less negatively on the environment. Those pesticides which register low EI values are normally employed in to Integrated Pest Management system. Regarding the Environmental Impact (EI) values obtained, copper hydroxide, Thiamethoxam and Glyphosate are recommended to be used to control fungi, insects and herbs respectively. Based on the EI value of Bifenthrin and Cuprous oxide for both higher and lower application rates, it is recommended that their use should be monitored since the lowest (recommended) rates did not impact negatively on the environment.

Table 40: Calculated EIQ Values and WHO Toxicity Class of some Common Pesticides used by the Farmers

Pesticides	Active ingredient	WHO hazard class	Application Rate (a.i ml /g / acre)	EIQ Value	EI per acre		
					Consumer	Worker	Ecology
Insecticide							
Akate master	Bifenthrin (27 g / l)	II	1200	44.4	5.40	9.40	76.20
			90	44.4	0.40	0.70	5.80
Acati Power	Thiamethoxam (200 g/l)	II	1400	33.3	7.10	6.10	45.90
			210	33.3	1.10	0.90	6.90
Akate Star 3.5 EC	Bifenthrin (30 g / l)	II	1800	44.4	9.00	15.70	**127.10**
			120	44.4	0.60	1.00	8.50
Confidor 200 OD	Thiamethoxam (240 g/l)	III	1200	33.3	6.10	5.20	39.30
			120	33.3	0.60	0.50	3.90
Herbicide							
Aduodzi 757 SG	Glyphosate (757 g / l)	III	1600	15.3	7.70	20.60	89.90
Tackle360 SL	Glyphosate (360 g / l)	IV	1600	15.3	3.70	9.70	42.60

Table 4 continued

Pesticides	Active ingredient	WHO hazard class	Application Rate (a.i ml /g / acre)	EIQ Value	EI per acre		
					Consumer	Worker	Ecology
Fungicide							
Ridomil Gold Plus 66WP	Cuprous oxide (60 %) + Metaxyl - M (6%)	III	600	33.2	7.90	21.50	57.80
			120	33.2	4.00	4.20	11.60
Nordox Super 75 wg	Cuprous oxide (86 %)	III	900	33.2	15.40	41.50	**113.00**
			300	33.2	5.10	13.80	37.70
Champion WP	Copper Hydroxide (77 %)	III	600	33.2	8.80	23.70	64.70
			90	33.2	1.40	3.70	10.10

i.a– Active Ingredient, WHO (2010) - World Health Organization, EIQ Environmental Impact Quotient and EI – Environmental Impact. *Environmental Impact Rating Levels -: < 25- (very low risk): < 50 - (low risk): 50- 99-(Moderate): 100 – 199 (high risk): and 200+ (very high risk).

Bifenthrin has a strong environmental persistence (Li et al., 2017; Mokry & Hoagland, 1990) with a half-life ranging between 65 and 125 days. Considering soil type, pH, moisture content and temperature, bifenthrin's half-life may also range between 2 weeks to over 1 year (Chen et al., 2012; Laskowski, 2002; Lee et al., 2004; Mohapatra & Ahuja, 2009). Bifenthrin has been found to cause potential risk to aquatic life and human health (Chen et al., 2012). Briggs (1992), Keith and Walker (1992) and Seyler (1994) reported that bifenthrin is highly toxic to fish, crustacea and aquatic organism. Even though bifenthrin is moderately toxic to mammal, high doses may result in whole-body tremor, twitching, staggering gait, uncoordinated movement and abnormal posture (Freeman, 1998; Li et al., 2017; Watt, 1998). Another worrying adverse effects of bifenthrin is its toxic effects on pollinators (bees) (Meister, 1992; Seyler, 1994) which could be attributed to the low cocoa yields per tree as reported by the farmers in the area.

Even though copper is an essential element required by all organisms, its elevated concentrations in soils are toxic and may result into reduced biological activity and eventually loss of soil fertility (Dumestre et al., 1999; Van-Zwieten et al., 2004). There exists a significant weight evidence that copper-based fungicides have long-term impact on a wide range of soil biota than other agricultural chemicals.

Relatively low concentrations of copper even influence microbial activity, earthworm activity and bioturbation which affect the health of the soil (Van-Zwieten et al., 2004) and can lead to copper toxicity in plants (Dumestre et al., 1999; Lepp, 1981; Van Assche & Clijsters, 1990; W et al., 2002). Root tissue damage, increased permeability of root cell plasma membranes, inhibition of photosynthesis and DNA damage were some of the detrimental effects of excess uptake of copper identified by (Chang et al., 1992; Dumestre et al., 1999; Owen Jr, 1981; W et al., 2002).

Copper is toxic to aquatic organisms. According to Brooks et al. (2007), copper is bioaccumulated in some organisms while others actively regulate its levels. Organisms such as fish, decapod, crustacea and algae regulate copper levels while bivalves, barnacles and aquatic insects bioaccumulate it (Brix & DeForest, 2000; Kiaune & Singhasemanon, 2011). Copper causes toxicity by impairing osmoregulation and ion regulation in the gills of most aquatic animals (Blanchard & Grosell, 2005; Kiaune & Singhasemanon, 2011; McIntyre et al., 2008)

The Mean Values of the Selected Physicochemical Properties of the Biochar and the Soil Samples

Table 41 shows the results of the mean values of the characterized physico-chemical properties of the biochars; corn cob (CCBC) and rice husk (RHBC) and the soil samples from Ho West District (S_{HW}) and Afadjato South District (S_{AS}). The results revealed that the two biochars; CCBC (8.14) and RHBC (6.13) were alkaline, a finding in line with Chen et al. (2011), Mandal et al. (2017) and Van Zwieten et al. (2010) who reported that CCBC have the highest pH (8.14) followed by RHBC (6.13). The differences observed in pH of the biochars may be attributed to the biochemical compositions of their feedstock (Mandal et al., 2017) and the thermo-chemical processes of production (Yuan et al., 2019). The cation exchange capacity (CEC) of the biochars were 11.72 cmolkg/l and 11.23 cmolkg/l for CCBC and RHBC respectively. This is in consonance with Mandal et al. (2017) who also found

CCBC with the highest CEC. This may be due to the presence of more carboxylate, hydroxyl and carbonyl groups associated with CCBC (Lee et al., 2010; Mandal et al., 2017). The results also show that RHBC recorded a higher organic carbon content of 3.58 % than CCBC (3.32 %). With regards to moisture content, CCBC had a higher moisture content (1.46 %) than RHBC (1.04 %).

Table 41 also indicates that soil from Afadjato South (S_{AS}) had a higher pH of 6.50 while that from Ho West (S_{HW}) had the lower pH of 4.44. In terms of the CEC of the soil samples, S_{AS} recorded the higher value of 16.45 cmol/ kg/L while S_{HW} the lower value of 9.33 cmol /kg. The organic carbon content of S_{AS} was 3.16 while that of S_{HW} was 2.72. Researchers have indicated that sorption of pesticides in soils is influenced by organic matter (Kumar et al., 2015; Sadegh-Zadeh et al., 2017b). Sadegh-Zadeh et al. (2017b) concluded that soils mended with organic matter increased sorption of pesticides and reduced leaching of pesticides in soils. Therefore, all other conditions being constant, S_{AS} will be a good pesticide adsorbent that S_{HW}. However, the textual class of both soils were Sandy Clay Loam with soil particle sizes of sand (54.80 %), clay (37.00 %) and silt (8.20 %) for S_{HW} and sand (51.30 %), clay (34.20 %) and silt (14.50 %) for $S_{AS.}$ Soil clay minerals also play a very important role in the sorption of pesticides in soils (Báez et al., 2015; Davies & Jabeen, 2003; Sadegh-Zadeh et al., 2017b). Aguer et al. (2000) reports that clay increases sorption while organic content has no association. The moisture contents of the soil samples were very close, S_{HW} (0.39 %) while S_{AS} (0.38 %).

Table 41: Selected Physico-chemical Properties Soil and Biochar Samples

Sample	pH	MC (%)	OC (%)	CEC (cmol/ kg)	Sand (%)	Silt (%)	Clay (%)	Textual Class
SHW	4.44(0.1)	0.39(0.01)	2.72(0.1)	9.33(0.3)	54.8(0.5)	8.2(0.2)	37(0.6)	Sandy Clay Loam
SAS	6.5(0.4)	0.38(0.03)	3.16(0.2)	16.45(0.2)	51.3(0.5)	14.5(0.2)	34.2(0.4)	Sandy Clay Loam
CCBC	8.14(0.3)	1.46(0.13)	3.32(0.4)	11.73(0.1)	NA	NA	NA	NA
RHBC	6.13(0.4)	1.O4(0.14)	3.58(0.2)	11.23(0.2)	NA	NA	NA	NA

* MC = Moisture content OC = Organic content CEC = Cation exchange capacity

SHW = Soil sample from Ho West district, SAS = Soil Sample from Afadjato South district, CCBC = Corn cob biochar, RHBC = Rice husk biochar, NA =Not applicable, values in bracket represent standard error.

Mean pH values of the Leachates collected for the Leaching experiment over the four weeks treatment event.

Results of the mean pH values of the leachates collected for the leaching experiment revealed that there were statistically significant differences in treatments (< 0.0001), within weeks (< 0.0001) and treatment within weeks (< 0.0005) for soil samples from Ho West (S_{HW}) while only treatment weeks were statistically significant for soil samples from Afadjato South (S_{AS}) (Table 42).

The results show that the mean pH values of the leachates collected for both soil samples (S_{HW} and S_{AF}) and the amendments before the third week were significantly lower than the pH value measured in the fourth week. The mean pH of SHWC ranged between (5.92 – 7.01). SHW RHBC (1 %) recorded the highest pH value of 8.07 during the fourth week while SHWC the least (7.01). However, all the soil sample treated with rice husk and corn cob biochars recorded increased values in pH. This may be attributed to the biochar added to the soil (Martinsen et al., 2015).

The results also show that there were significant changes in pH values of Afadjato Soil (S_{AS}) samples across the weeks. The pH of SAFC ranged between 6.13 and 7.85. Surprisingly, AS RHBC (0.5 %) recorded the highest pH value of 8.0 during the fourth week while the least (7.85) by SAFC (Table 42).

The result also revealed that the controls of both soil samples recoded the least pH values in the experiments. This therefore, implies that addition of the biochars (corn cob and rice husk) to the soils had led to the increase in pH of the amended soils (Streubel et al., 2011). Acidic soils can therefore, be remediated using any of these biochars.

Table 42: Mean pH values of the leachates for the Leaching Experiment

District	Control / Treatment	Week 1	Week 2	Week 3	Week 4
Ho West District	SHWC	5.92 (0.67) a	6.66(1.4)a	6.70(0.34)a	7.01 (0.13) a
	SHW CC (0.5 %)	6.09 (0.20) bc	5.31(0.22) bc	6.04(0.89) bc	7.22(0.17)bc
	SHW CC (1 %)	5.90 (0.47) ab	5.85(0.19)ab	6.47(0.09)ab	7.95(0.02)ab
	SHW RHBC (0.5 %)	6.09 (0.66) d	5.64 (0.14)d	5.35 (0.01)d	7.76 (0.09)d
	SHW RHBC (1 %)	5.82 (0.72) a	5.61 (0.14) a	7.50 (0.05)a	8.07 (0.10)a
	Repeated Measures Analysis				
	Treatments	**< 0.0001**			
	Weeks	**< 0.0001**			
	Treatments*Weeks	**< 0.0005**			
Afadjato South District	SAFC	6.13 (0.74)a	6.84 (0.10)a	7.93 (0.08)a	7.85 (0.21)a
	AS CCBC (0.5 %)	6.37 (0.42)a	8.3 (0.34)a	8.20 (0.19)a	8.23 (0.08)a
	AS CCBC (1 %)	6.01 (0.15)a	8.00 (0.24)a	8.73 (0.19)a	8.74 (0.06)a
	AS RHBC (0.5 %)	6.52 (0.66)a	8.11 (0.14)a	8.25 (0.01)a	8.82 (0.09)a
	AS RHBC (1 %)	6.44 (0.72)a	8.26 (0.14)a	8.43 (0.05)a	8.57 (0.10)a
	Repeated Measures Analysis				
	Treatments	0.7699			
	Weeks	**< 0.0001**			
	Treatments*Weeks	0.1765			

*Means by the same letter are not significantly different using Tukey's Studentized Range (HSD) Test at P = 0.05 SHW=Soil sample from Ho West, SAF=Soil sample from Afadjato South, SHW RHBC= Soil + Rice husk biochar, SAS RHBC=Soil + Rice husk biochar, SHWC =Ho West soil Control, SAFC = Afadjato Soil control

SHW CCBC=Soil + Corn cob biochar, SAS CCBC=Soil +Corn cob biochar. Values in the bracket represent the standard error.

Mean Concentrations of Bifenthrin in the control and the amended soil samples

The results of the bifenthrin mean concentrations of the leachates collected for the four weeks are presented in Table 43. The results of the soil amended samples of both Ho West District (S_{HW}) and Afadjato South (S_{AS}) indicated that there was statistical significance difference in the treatments, treatment weeks and treatments within weeks. The concentrations of bifenthrin of all the treatments showed the same magnitude after the second leaching event except SAS RHBC (1 %) and HW CCBC (1 %) which recorded least concentrations of 0.013 mg /L and 0.014 mg /L respectively.

The results also showed that the concentration of leachates of S_{AS} amended with 1 % rice husk biochar (RH BC (1 %)) was in the range of 0.016 to 0.013 mg /L while S_{HW} amended with 1 % rice husk was between 0.016 to 0.014 mg/L across the weeks. It is obvious from the result that soil amended with RH BC at 1 % was able to effectively adsorbed the pesticides from both soils. When the corn cob biochar treatments were also considered, it was discovered that SHW at 1 % had the range between 0.016 to 0.013 mg/L while SAS at 0.5 % and 1 % ranged between 0.016 to 0.011 mg/L across the treatment weeks. It is also clear from the results in (Table 43) that the controls recorded the highest bifenthrin concentrations across the four- week period. This implies that both corn cob and rice husk biochars are better adsorbents of pesticide from soil than the soil's organic carbon (Liu et al., 2018). However, corn cob biochar was found to be the most effective adsorbent of bifenthrin in the soil samples, a finding contrary to Mandal et al. (2017) who found rice husk biochar as the most efficient adsorbent for atrazine and imidacloprid . This may be attributed to its higher pH coupled with CEC.

Table 43: Mean Concentrations of Bifenthrin in the Control and the Amended soils

District	Treatment / Control	Week 1	Week 2	Week 3	Week 4
Ho West	HW C	0.016(0.02)	0.016(0.05)	0.019(0.06)	0.016(0.02)
	HW RH (0.5 %)	0.016(0.02)	0.016(0.02)	0.015(0.02)	0.015(0.02)
	HW RH (1 %)	0.016(0.01)	0.016(0.04)	0.015(0.01)	0.014(0.01)
	HW CCBC (0.5 %)	0.016(0.04)	0.016(0.02)	0.015(0.02)	0.015(0.03)
	HW CCBC (1 %)	0.016(0.01)	0.016(0.06)	0.014(0.03)	0.013(0.04)
Repeated Measures Analysis					
Treatments		**< 0.001**			
Weeks		**< 0.001**			
Treatments*Weeks		**< 0.001**			
Afadjato South	AS C	0.016(0.01)	0.016(0.02)	0.016(0.04)	0.015(0.02)
	AS CCBC (0.5%)	0.016(0.03)	0.016(0.01)	0.015(0.03	0.011(0.01)
	AS CCBC (1 %)	0.016(0.02)	0.015(0.03)	0.015(0.01)	0.011(0.02)
	AS RH (0.5%)	0.017(0.02)	0.016(0.02)	0.015(0.02)	0.014(0.01)
	AS RH (1 %)	0.016(0.04)	0.016(0.03)	0.013(0.05)	0.013(0.03)
Repeated Measures Analysis		*p*			
Treatments		**< 0.001**			
Weeks		**< 0.001**			
Treatments*Weeks		**< 0.001**			

Weekly values are means of three replicates; Repeated Measures Analysis performed with SPPSS. 20
GLM, significance at p<0.05, Values in brackets represent standard error, All concentrations in (mg /L)

Adsorption Distribution Coefficient (Kd) and Organic Carbon Sorption Distribution Coefficient (Koc) values of untreated and treated soil samples

The adsorption distribution coefficient (Kd) and the corresponding organic carbon sorption distribution coefficient (Koc) values of bifenthrin in the soil samples and the biochars are displayed in Table 44. It is obvious from the result that soil samples (S_{AS}, S_{HW}) treated with the biochars (RHBC, CCBC) had higher Kd values of bifenthrin than the untreated soil samples. In terms of percentage, the Kd values of bifenthrin for SHW were 49 % and 51 % higher for rice husk biochar (RHBC) and corn cob biochar (CCBC) respectively. The same trend was observed in the SAS. With regards to the Koc values, the results show that soil samples treated with biochars recorded higher Kd values as compared to the untreated soil samples. This may be attributed to the increase of organic carbon in the soil due to the addition of the biochar (Kavitha et al., 2018). Koc values for S_{HW} were 132.0 cm^3 g^{-1} and 140 cm^3 g^{-1} for rice husk biochar and corn cob biochar respectively while that of S_{AS} were 135 cm^3 g^{-1} and 145 cm^3 g^{-1} respectively (Table 44).

The higher Kd values recorded by the treated soil samples is an indication that the biochars are good adsorbent of bifenthrin. Thus, the bifenthrin was mainly transported from the liquid phase in to the solid phase (biochars). This also indicates that the bifenthrin was strongly sorbed to the biochars and it will be relatively immobile in the soil (Khan et al., 2010; Wauchope et al., 2002) as compared to the untreated soil samples. The higher Kd values of corn cob biochar (CCBC) in both soil samples show that rice husk biochar is more efficient adsorbent than rice husk biochar.

The Koc is the measure of affinity of pesticide for water or solid (soil or biochar) (Pérez-Lucas et al., 2018). The Koc values of the soil treated with biochars show that the biochars have higher affinity for bifenthrin than the untreated soil samples. However, corn cob biochar exhibited more affinity for bifenthrin than the rice husk. Therefore, corn cob can be an effective adsorbent for the remediation of pesticide polluted soils in the Volta Region.

Table 44: Adsorption distribution coefficient (Kd) and Organic carbon sorption distribution coefficient (Koc) values of untreated and treated soil samples

Treatment / Control	Pesticide	Adsorption distribution coefficient (Kd) (cm^3 g^{-1})	Koc (cm^3 g^{-1})
SHW		2.67(0.01)	98.2 (0.12)
SAF		3.79 (0.00)	119.9 (0.6)
SHW RHBC	Bifenthrin	4.73 (0.01)	132.0 (0.10)
SAF RHBC		4.89 (0.00)	135.2 (0.05)
SHW CCBC		4.68 (0.01)	140.0 (1.00)
SAF CCBC		4.79 (0.01)	145.0 (0.58)

SHW=Soil sample from Ho West, SAF=Soil sample from Afadjato South, SHW RHBC= Soil + Rice husk biochar, SAS RHBC=Soil + Rice husk biochar,

SHW CCBC=Soil + Corn cob biochar, SAS CCBC=Soil +Corn cob biochar, Kd = Adsorption distribution coefficient, Koc = Organic carbon distribution coefficient, Values in brackets represent standard error.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Introduction

This chapter presents the summary, conclusion and recommendations of the study. Summary of the results and the conclusions have been organized based on the specific objectives and the hypotheses of the study. This section also provides suggested areas for further studies.

Summary of Findings

The adverse effects of pesticides on human health and the environment have raised a lot of concerns among individual consumers, stakeholders, government and non-governmental organizations and the world at large. As these pesticides help to maximize crop production to meet the demands of the increasing population, care must also be taken not to jeopardize the health of the population and the environment.

Many are with the view that proper policies put in place can help to curb this menace. Others also think proper education about the adverse effects of these chemicals is the solution. Studies have shown that only a little information is available there to the general public about how these chemicals are handle by the users, hence making it difficult for policies to be made regarding safe usage of chemicals. Assessing the knowledge levels of farmers, their attitude, practices and the adverse effects on their health regarding pesticide usage can provide a lot of information that can help in the formulation of policies for safe use of these chemicals. Besides, EIQ, a pesticide risk indicator, also provides information about the negative effects of pesticides on the health of humans and the environment to the farmer and the policy makers. Since the fate of these pesticides in the environment is not known to the farmers and the policy makers, information gotten from the EIQ may be a useful guide for safe usage of pesticides and which remediation methods to adopt to clean the polluted soils. Adsorbents such as rice husk and corn cob biochars can be used to remediate soils polluted by pesticides.

The general objective of the study was to examine farmers' knowledge, attitude, practices and health risks associated with pesticide use and its impacts on the environment. specifically, the study sought to: (a) establish the association between farmers' knowledge, attitude and pesticide use practices (b) examine the use of other pests and diseases control methods by the farmers and factors that influence their knowledge (c) assess the risks posed to humans and the environment by pesticides, using the EIQ Model and the self – reported toxicological symptoms (d) predict mobility of pesticides in the soil of the study area using column leaching experiment and remediation method.

Field survey and experimental research designs were used for the study. The target population for the study were all smallholder cocoa farmers in three districts (Ho West, Afadjato South and Hohoe) in the Volta Region who applied pesticides themselves on their farms. A multi-stage sampling procedure which includes purposive and simple random sampling techniques was employed to sample 225 farmers. Content validated structured questionnaires and face-to-face interviews were used to collect both quantitative and qualitative data from the respondents. The data were analyzed using frequencies, percentages, Pearson chi-square and Cramer's V to examine significance association between variables. Generalized linear models (GLMs) was also used to predict the likelihood of effects of certain variables. Part of the data analyzed were plucked into the EIQ model to assess the pesticides with the least environmental load in the study area. Finally, Column Leaching experiment, using the most common pesticide used in the study area, an information obtained from the data analyzed earlier was conducted on the soil samples to predict the mobility of pesticides in the soils in the study area. The summary of the main findings in relation to the specific objectives of the study is as follows:

Establish the association between farmers' knowledge, attitude and pesticide use practices

Farmers knowledge of pesticide

It was evident from the study that male dominated cocoa farming in the Volta Region of Ghana. The mean age of the farmers was 51 years, with the minimum being 20 years and the maximum 84 years. The educational levels of the farmers were very low as majority 137 (61.0 %) had primary education. In terms of years of experience, majority 86 (36.0) had more than 10 years in pesticide usage.

The farmers knowledge of pesticide was assessed based on (a) Names of pesticides used and Common pests and diseases (b) Health effects on humans (c) Route of pesticide entry in to the body, and (d) Fate of pesticide residues. With regards to farmers' knowledge in pesticide usage, smallholder cocoa farmers in the Volta Region of Ghana have proper knowledge of the names of pesticides used and the common pests and diseases of cocoa in the area, health effects of pesticides, routes of pesticides entry in to the body and fate of pesticide residues.. Factors such as farmers' years of experience, agrochemical services and reading of pesticide label were found to have influence on farmers' knowledge in the route of pesticides entry in to the body.

Farmers' attitude towards pesticide usage

The findings of the study indicated that farmers in the study area have positive attitude towards pesticide usage. Farmers attitude was evaluated by asking them to indicate to what extent they agreed or disagreed to the statements; (a) Proper knowledge is necessary when using pesticide (b) There are minimal health risks attached to pesticide use (c) Pesticides should be used with precaution (d) Pesticide use should be limited. Majority of the farmers agreed strongly to the above listed statements, indicating that they have positive attitude towards pesticide usage. It is hoped that the positive attitude will reflect good pesticide use practices.

Farmers' pesticide use practices

Farmers' pesticide use practices in the study area revealed that even though farmers had good knowledge and positive attitude, these did not translate in to good pesticide practices. This implies that there is a negative association between farmers knowledge and attitude, and pesticide use practices. The main pests and diseases control method used in the area was chemical pesticides. Insecticides were found to be mostly used by the farmers and the most common among them was Akate Master (Bifenthrin).

It was also discovered that farmers used Ghana COCOBOD approved as well as unapproved pesticides. These pesticides fall under WHO Hazard classes II, III and IV. COCOBOD banned pesticide, Durban was also found in use by the farmers.

The study also disclosed that majority of the farmers obtained their pesticides from the agrochemical shops. This, they attributed to unavailability of approved pesticides and the low efficacy of those supplied to them by

COCOBOD. Farmers used uncalibrated measuring equipment to measure pesticides. Though the farmers claimed they read and respected pesticide labels, only a few used it during mixing of pesticides. Pesticides were found to be underdosed and overdosed by the farmers. A few farmers mixed more than one pesticide (cocktail) for application. It was also found out that majority of the farmers did not follow CODAPEC spraying regime of August to December and frequency. While some farmers sprayed as low as three times in a season, some sprayed about eight times. The most common spraying equipment used in the study area was knapsack sprayer.

Degree of pest infestation, calendar spray schedule, and economic threshold agrochemical shop services and farmers' years of experience were found to influence farmers' timing for pesticide application. GLM analysis showed that farmers who considered degree of pest infestation, calendar spray schedule, economic threshold were less likely to apply pesticides for a mere observation of pests and diseases while farmers who consult agrochemical dealers were more likely to apply pesticides for the mere observation of pests and diseases for the first time.

Pesticide use safety practices such as pre-harvest intervals, pesticides storage, disposal of empty containers, remnant and sprayer washed water after spraying were managed in unsafe manner by the farmers in the study area. Practices which have the potential of exposing farmers, their families, and the environment to pesticide exposure risk. It was also found out that farmers have negative attitude towards PPEs use. Majority of the farmers did not use PPE during mixing of pesticides while only a few wore complete PPE during pesticide application.

Examine the alternative methods used by farmers to control pests and diseases and the factors that influence their knowledge of alternative pests and diseases control.

Notwithstanding, the fact that majority of the farmers knew of the adverse effects of pesticides, only 56 (25.0 %) knew of alternative methods of pests and diseases control apart from the chemical pesticide method. The alternative pest and diseases control methods practiced by the farmers in the study area included; botanical pesticide, cultural, mechanical, resistance species and superficial. The most commonly practiced method among them was the cultural method which entailed shade management through intercropping. It was also found out that though, majority of the farmers intercropped cocoa, they did not know that could serve as means of controlling pests like mirids.

Farmers' years of experience, extension service and advice from fellow farmers were identified as the major sources of means of reaching out to farmers on new agricultural technologies. Economic, technical and unavailability of labor were some of the factors mentioned as militating against the implementation of the alternative methods of pests and diseases control in the study area.

It was also discovered that farmers knowledge in other methods of pests and diseases control were influenced by agrochemical shop service, degree of pest infestation, farmers' location and farmers years of experience. The study also reveals that farmers who considered degree of pest infestation in pest management were more likely to be knowledgeable in alternative methods of pest control compared to those who did not. Additionally, farmers who consulted agrochemical shop dealer about pest management were however, found to be less likely to be knowledgeable in other methods of pests and diseases control than those who did not

Assess the Risks Posed to Humans and the Environment by Pesticides, using the EIQ Model and the Self – reported Toxicological Symptoms

The EIQ model results and the self-reported toxicological symptoms by farmers were used to assess the risks posed to humans and the environment by the pesticides used by farmers. Insecticides (Akate star - Bifenthrin) and fungicides (Nordox Super - Cuprous oxide) were found to have the highest adverse impacts on the environment while the herbicides recorded the least based on the Environmental Impact (EI) per acre values. Bifenthrin is highly toxic to fish and aquatic organism, honeybees and mammals. Cuprous oxide in elevated concentrations is toxic to humans and in soil which may reduce bioactivity and eventually loss of soil fertility. Even though, the active ingredients of the other commonly used pesticides did not record higher EI values, care needs to be taken when handling them since they can bioaccumulate due to overdose and increase in frequency of application.

The study also revealed that farmers were at risks as far as pesticide usage was concern. Over fifty percent of the farmers reported at least five toxicological symptoms. The Commonly reported heath symptoms by the farmers during or after pesticide application in the study area were headache, burning eye sensation, weakness, fever, skin rashes, itching skin and chest pain. It was also discovered that some of the farmers considered these symptoms as normal with their work and so did not seek medical attention.

Predict mobility of pesticides in the soil of the study area using equilibrium model and determine the effective adsorbent for their remediation

It was discovered that the mobility of bifenthrin in the soil samples was influenced by the pH, cation exchange capacity and organic matter content for both the soil and the biochar. The pH of the soil samples treated with biochar were higher than the untreated ones. The Kd and the Koc values of the amended soil samples were found to be higher than the untreated soil samples. This means that the biochars are good adsorbent of bifenthrin and also have higher affinity for bifenthrin than the untreated soil samples. The concentrations of bifenthrin analyzed from the leachates collected for the four-week period indicated that biochar amended soils recoded lower concentrations than the untreated soil samples. This means that mobility of bifenthrin is relatively higher in the untreated soil samples.

Even though, it was observed that rice husk and corn cob biochars are good adsorbent of bifenthrin, corn cob biochar at 1% was found to be more efficient adsorbent for bifenthrin in the polluted soil.

Conclusions

Based on the results, four main conclusions are made according to the research questions.

A conclusion drawn from the first research question indicate that farmers in the study area have good knowledge and positive attitude towards pesticide use however, this was not reflective of their pesticide use and safety practices. It was also concluded from the objective 2 that only a few farmers were found engaging in alternative pest and disease control methods. Notable among the methods were cultural, mechanical and biological pesticides. The most common practiced method was cultural method through intercropping to manage shade. Factors identified, militating against the promotion of alternative methods were lack of financial and technical support, laborious nature of the methods and readily unavailability of some of the raw materials for the biological pesticides. Farmers' knowledge of alternative pests and diseases control methods is influenced by their knowledge of degree of pest infestation, agrochemical shop services, years' of experience and the location of the farmers. Experienced farmers, extension service and fellow farmers can be important agents by which information can be extended to farmers generally.

The study also concluded from the EIQ Model and the Self-reported toxicological results that both human health and the environment are at risk. Bifenthrin and cuprous oxide were found to have the likelihood of posing high risk to humans, pollinators, soil and aquatic organisms and plant (cocoa) life, hence their rate of application should be monitored. Majority of the farmers reported at least five pesticide toxicological symptoms, a situation which confirms pesticide exposure in the study area.

A further conclusion drawn from the study was that corn cob and rice husk biochars are capable of removing bifenthrin from soil. However, Corn cob biochar at 1 % was found to be the most efficient adsorbent of bifenthrin. This finally, concluded that bifenthrin will be relatively immobile in the biochar amended soil as compared to unamended soil.

Recommendations

Based on the results obtained, the following actions are made for:

a. Policy review

b. Further study

It is recommended that;

1. Educational programs and legislation to promote safer use of pesticides should be intensified by Environmental Pretention Agency.
2. Cocoa Research Institute of Ghana should review the calendar spray regime to suit the new emerging pests and diseases.
3. Cocoa farmers and agrochemical dealers should be given sensitization training in PPE use during mixing and application of pesticides by extension officials.
4. Ghana COCOBOD recommended pesticides should be made readily accessible to farmers by COCOBOD.
5. Farmers and agrochemical dealers should be trained in proper and safe methods of disposing pesticide containers and remnants after spraying by extension officers.
6. Farmers should be trained in the concepts of degree of pest infestation, economic threshold of pests and IPM by COCOBOD to reduce pesticide use.
7. Further studies on pesticide residues on cocoa beans, intercrops of cocoa trees and thorough toxicological examination be conducted on the farmers.

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APPENDIXS

APPENDIX A

Methods of pesticides storage, disposal of remnant and empty containers and washing of sprayer after application of pesticide used by the farmers

Variable	Community: KPE Freq. (%)	TOG Freq. (%)	KPO Freq. (%)	LKA Freq. (%)	LAG Freq. (%)	LOA Freq. (%)	BLA Freq. (%)	GCH Freq. (%)	FOW Freq. (%)	Measure of association	Region Freq. (%)
Where farmers store their pesticides											
Agrochemical store	2(8.0)	4(16.0)	6(24.0)	2(8.0)	0(0.0)	2(8.0)	2(8.0)	0(0.0)	0(0.0)	Pearson π2 = 118 Pr = 0.000 Crame´r's V = 0.257	14(8.1)
Animal houses	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(4.0)	0(0.0)	1(4.0)	0(0.0)	1(4.0)		3(1.3)
Food store room	11(44.0)	8(32.0)	8(32.0)	14(56.0)	16(64.0)	14(56.0)	4(16.0)	14(56.0)	8(32.0)		97(43.1)
Living houses	5(20.0)	9(36.0)	6(24.0)	1(4.0)	4(16.0)	2(8.0)	9(36.0)	6(24.0)	8(32.0)		50(22.2)
Kitchen	1(4.0)	0(0.0)	2(8.0)	1(4.0)	0(0.0)	4(16.0)	0(0.0)	0(0.0)	1(4.0)		9(4.0)
Bush	0(0.0)	2(8.0)	0(0.0)	1(4.0)	0(0.0)	0(0.0)	1(4.0)	2(8.0)	0(0.0)		6(2.7)
Toilet	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(4.0)	1(4.0)	3(12.0)	0(0.0)	0(0.0)		5(2.2)
Farm	2(8.0)	2(8.0)	1(4.0)	5(20.0)	2(8.0)	0(0.0)	4(16.0)	0(0.0)	0(0.0)		16(7.1)

Bedroom	4(16.0)	0(0.0)	2(8.0)	1(4.0)	1(4.0)	1(4.0)	1(4.0)	3(12.0)	6(24.0)		19(8.4)
Bathroom	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(4.0)	0(0.0)	0(0.0)	1(4.0)		2(2.2)
Where farmers dispose empty pesticide containers											
Put to other use	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(4.0)	0(0.0)	Pearson π2	1(1.0)
Throw on the farm	14(56.0)	19(76.0)	9(36.0)	4(16.0)	8(32.0)	8(32.0)	14(56.0)	13(52.0)	20(80.0)	= 92.301Pr = 0.000	109 (48.0)
Burry in farm	3(12.0)	6(24.0)	9(28.0)	6(24.0)	9(36.0)	8(32.0)	1(4.0)	8(32.0)	3(12.0)	Crame´r's V = 0.286	51 (23.0)
Burn on farm	5(20.0)	0(0.0)	6(24.0)	12(48.0)	8(32.0)	8(32.0)	3(12.0)	3(12.0)	2(8.0)		47 (21.0)
Keep in store room	0(0.0)	0(0.0)	2(8.0)	0(0.0)	0(0.0)	0(0.0)	1(4.0)	0(0.0)	0(0.0)		3 (1.0)
Gather them on on farm	3(12.0)	0(0.0)	1(4.0)	3(12.0)	0(0.0)	1(4.0)	6(24.0)	0(0.0)	0(0.0)		14 (6.0)

Variable	Community									Measure of association	Region Freq. (%)
	KPE Freq. (%)	TOG Freq. (%)	KPO Freq. (%)	LKA Freq. (%)	LAG Freq. (%)	LOA Freq. (%)	BLA Freq. (%)	GCH Freq. (%)	FOW Freq. (%)		
Where remnants of pestices are disposed after application											
On farm	6(24.0)	8(32.0)	10(40.0)	9(36.0)	9(36.0)	9(36.0)	17(68.0)	7(28.0)	18(72.0)	Pearson π2 = 85.546	93(41.3)
Throw in rivers/ lakes	0(0.0)	3(12.0)	0(0.0)	1(4.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	2(8.0)	Pr = 0.000	6(2.7)
Burry in ground in farm	4(16.0)	3(12.0)	1(4.0)	7(28.0)	3(12.0)	5(20.0)	0(0.0)	10(40.0)	1(4.0)	Crame´r's V = 0.308	34(15.1)
No remnant left	7(28.0)	9(36.0)	10(40.0)	5(20.0)	1(4.0)	4(16.0)	5(20.0)	1(4.0)	2(8.0)		45(19.6)
Store for future use	8(32.0)	2(8.0)	4(16.0)	3(12.0)	12(48.0)	7(28.0)	5(12.0)	7(28.0)	2(8.0)		50(21.3)

Where sprayer is washed after pesticide application

										Pearson π2	
Rivers/ lakes	1(4.0)	5(20.0)	3(12.0)	2(8.0)	1(4.0)	6(24.0)	0(0.0)	1(4.0)	5(20.0)	= 104.437	23(10.7)
Under running tap or bucket of water	8(32.0)	14(56.0)	11(44.0)	2(8.0)	6(24.0)	6(24.0)	13(52.0)	23(92.0)	12(48.0)	Pr = 0.000	97(42.2)
I don't wash	3(12.0)	1(4.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	Crame´r's V =	4(1.8)
Wipe with piece of cloth	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	1(4.0)	0(0.0)	0.305	1(0.4)
Throw on the farm	12(48.0)	5(20.0)	11(44.0)	19(76.0)	18(72.0)	12(48.0)	12(48.0)	0(0.0)	8(32.0)		97(43.1)
Throw in the bush	1(4.0)	0(0.0)	0(0.0)	2(8.0)	0(0.0)	1(4.0)	0(0.0)	0(0.0)	0(0.0)		4(1.8)

KPE=Kpedze, TOG=Togorme, KPO=Kpoeta, LKA=Leklebi Kame, LAG=Leklebi Agbesia, GCH=Gbledi Chebi, FOW=Fodome Woe

APPENDIX B

ASSESSMENT OF PESTICIDE USES IN THE VOLTA REGION, GHANA

Personal particulars of the respondent

Village………… District: …………... Date: …………. Questionnaire no ……

a) BACKGROUND

1. Are you

☐ Male (1)

☐ Female (2)

2. What is your age?

…………………

3. Which ethnic group do you belong?

……................................

4. What is your occupation?

……………………………

5. What is your religion?

☐ Christian (1)

☐ Muslim (2)

☐ Traditionalist (3)

☐ Other (specify)

……………..

6. What formal education do you have?

☐ No formal education

☐ Primary education

☐ Secondary education Level

☐

7. What is your position in the family?

☐ Father (1)

☐ Mother (2)

☐ Daughter (3)

☐ Son (4)

☐ Other (Specify) ……………

8. What is the main economic activity in your household?

☐ Farming (1)

☐ Day worker (2)

☐ Small business (3)

☐

Other (Specify) ……………………………...................
…………… ...

9. How many people live in your household?

10. How many of the household members are below 18 years old?
….………………………………

Certificate/diploma

11. What is the app. size of your farm?:

☐ Degree level
…………………………………….....

☐ Other (specify) …………..

12. Which of the following crops do you grow for own use and sale?

Tick (√) against		Crops	Tick(√) against		Crops
For own use	For sale		For own use	For sale	
		Tomatoes			Palm nut
		Onion			Cowpea
		Cabbages			Maize
		Cocoa			Rice
		Green pepper			Plantain
		Carrot			Sugarcane
		Cocoyam			Oranges
		Yam			Mangoes
		Garden egg			Pawpaw
		Okra			Millets
		Melon			Sweet potatoes
		Beans			Cucumber
		Cassava			Others: (i) ………………

b] PESTICIDE KNOWLEDGE

13. Which pesticides do you know by name?

……………………………………

……………………….....................

……………………………………

14. Which forbidden pesticides do you know?

…………………………………..

……………………….................

…………………………………..

15. Can pesticides cause negative health effects?

- ☐ Yes (2)
- ☐ No (1)
- ☐ I don't know (1)

16. Do all pesticides have the same health effect?

- ☐ Yes(2)
- ☐ No (1)
- ☐ I don't know (1)

17. Can pesticides be dangerous to use?

- ☐ Yes(2)
- ☐ No(1)
- ☐ I don't know(1)

18. Can pesticides enter the body through inhalation?

- ☐ Yes (2)
- ☐ No (1)
- ☐ I don't know (1)

19. Can pesticides enter the body through the skin?

- ☐ Yes (2)
- ☐ No (1)
- ☐ I don't know (1)

20. Can pesticides enter the body thr☐h the mouth?

- Yes (2)
- ☐ No (1)
- ☐ I don't know (1)

21. Can pesticide residues be left in the air?

☐ Yes (2)
☐ No (1)
☐ I don't know (1)

22. Can pesticide residues be left in the soil?

☐ Yes (2)
☐ No (1)
☐ I don't know (1)

23. Can pesticide residues be found in the groundwater?

☐ Yes (2)
☐ No (1)
☐ I don't know (1)

24. Can pesticide residues be found in fruits?

☐ Yes (2)
☐ No (1)
☐ I don't know (1)

25. Can pesticide residues be found on vegetables?

☐ Yes (2)
☐ No (1)
☐ I don't know (1)

26. Do you read manufacturer notifications?

☐ Yes (2)
☐ No (1)
☐ I don't know (1)

27. Do you respect manufacturer notifications?

☐ Yes (2)
☐ No (1)
☐ I don't know (1)

(C) PESTICIDE USE

28. Have you ever used pesticides?

☐ Yes, I currently do (go to no. 29)
☐ Yes, in the past (go to no. 30)
☐ No (go to no. 33)

29. How many years of experience did you have with pesticide use?

☐ 1 – 2 years
☐ 4 – 6 years
☐ 7 – 10 years

☐ More than 10 years

30. Why do you use pesticides?

☐ To protect crops against insects

☐ To make crops grow better

☐ Because others use pesticides

☐ Because I was advised to use pesticides

☐ Other……………………….

31. Why did you stop using pesticides?

☐ Did not show good response (1)

☐ Scarcity availability of pesticides (2)

☐ High buying costs (3)

☐ Other..................................

32. Where do you get/buy the pesticides that you use?

☐ Agrochemical shops in town (1)

☐ Local agrochemical shops in the village (2)

☐ Extension officers (3)

☐ General shops (4)

☐ Cooperative societies (5)

☐ Other…………

33) If you currently use pesticides (answered "Yes" on no 28), mention the insecticides, fungicides and herbicides you use

Type of pesticides	**Crop that uses**	**Season of use**	**Amount per each application pr. Area**	**Interval of use (last spraying before harvest could be interesting to know or post-harvest)**	**Application methods, e.g. knapsack sprayers**
Insecticides :					
Fungicides:					
Herbicides:					

34. What are the common crop pests do you encounter in your farm?

(i)…………………………………

(ii)…………………………………

(iii)………………………………

(iv)

……………………………………

35. What are the common crop diseases you encounter in your farm?

(i)

……………………………………

(ii)

……………………………………

(iii)

……………………………………

(iv)

……………………………………

- [ ] shops(1)
- [ ] Extension officers (2)
- [ ] Pesticides labels on packages (3)
- [ ] Fellow farmers (4)
- [ ] Own experience (5)

36. What makes you to decide the time to apply pesticides to your farm?

- [ ] Presence of pests (1)
- [ ] Degree of pest infestation (2)
- [ ] Date of planting (3)
- [ ] On calendar spray
- [ ] schedules (4)

On economic thresholds (5)

- [ ] Others

…………………………

37. Where did you get the knowledge on pesticides application methods and rate?

- [ ] Agrochemical

38. How do you dilute/mix the pesticide before application?

- [ ] Mix more than one types of pesticides with water in one container (1)
- [ ] Mix one type of pesticide
- [ ] with water in a container (2)

Depending with instructions

- [ ] on the label (3)
- [ ] Don't know (4)

D) ATTITUDES TOWARDS PESTICIDE USE

To what degree do you agree or disagree with the following statements:

39. Proper knowledge is necessary when using pesticides.

☐ Strongly agree (5)
☐ Agree (4)
☐ Neither agree nor disagree (3)

41. Pesticides should be used with precautions.

☐ Strongly agree (5)
☐ Agree (4)
☐ Neither agree nor disagree (3)
☐ Disagree (2)
☐ Strongly disagree (1)
☐
☐

☐ Disagree (2)
☐ Strongly disagree (1)

40. There are minimal health risks attached to pesticide use.

☐ Strongly agree (5)
☐ Agree (4)
☐ Neither agree nor disagree (3)
☐ Disagree (2)
☐ Strongly disagree (1)

42. Pesticides use is important to secure good crops.

☐ Strongly agree (5)
☐ Agree (4)
☐ Neither agree nor disagree (3)
☐ Disagree (2)
☐ Strongly disagree (1)

43. Pesticides use should be limited.

Strongly agree(5)

Agree (4)

☐ Neither agree nor disagree (3)

☐ Disagree (2)

☐ Strongly disagree (1)

E) PROTECTIVE MEASURES

43. During the last three months, when you applied pesticides...

a) ...did you wear gloves?

☐ Yes ☐ No

b)... did you wear goggles?

☐ Yes ☐ No

c) ... did you wear something on your head?

☐ Yes ☐ No

d) ... did you wear oral/nose mask?

☐ Yes ☐ No

e)... did you wear special boots?

☐ Yes ☐ No

f) ... did you wear overall?

☐ Yes ☐ No

45. Have you ever used protective gears during handling (mixing, spraying) of pesticides?

☐ Yes (go to no.40)

☐ No (go to no.41)

46. If answered "yes", mention the gears you have ever used

……………………………………

……………………………………

……………………………………

…………………………………..

47. In your opinion, is the trend of pesticide use increasing, constant or decreasing?

☐ Increasing (3)

☐ Constant (2)

☐ Decreasing (1)

48. In your opinion, what are the reasons for the increase, constant or decrease?:

(a) Increase

……………………………………
……………………………………
……………………………………
……………………………………
……………………………………

(b) Decrease

………………………………
………………………………
………………………………
………………………………

(c) Constant

………………………………
………………………………
………………………………
………………………………

49. Where do you store the pesticides?

- ☐ Agrochemical store (1)
- ☐ Animal houses (2)
- ☐ Store room (3)
- ☐ Living house (4)
- ☐ Kitchen (5)
- ☐ Bush (6)
- ☐ Toilet (7)
- ☐ Farm (8)
- ☐ Bedroom (9)
- ☐ Bathroom

50. Where do you dispose empty pesticide containers?

- ☐ Sell to others (1)
- ☐ Put in other uses/give to others (2)
- ☐ Throw away on farm (3)
- ☐ Bury in ground on farm (4)
- ☐ Burn on farm (5)
- ☐ Keep it in the store room (6)
- ☐ Gather them together (7)

51. Where do you dispose remnants of pesticides after end of application?

- ☐ On farm (1)

☐ Throw in rivers, lakes or irrigation canal (2)

☐ Bury in the ground on farm (3)

☐ No remnants left (4)

☐ Store for future use (5)

52. Where do you wash the sprayers after application of pesticides?

☐ In rivers, lakes or irrigation canal (1)

☐ At home using tap or bucket water(2)

☐ I don't wash (3)

☐ Wipe with piece of cloth or paper and throw it away (4)

☐ Farm (5)

☐ Bush (6)

53. How long do you wait from last spraying to selling of crops?

☐ I sell just after pesticide spraying (1)

☐ 1-2days (2)

☐ 3 - 6 days (3)

☐ One week (4)

☐ More than one week (5)

☐ Depending on manufacturer's instructions (6)

Others ....

54. Do you use the crops you spray with pesticides as food in your family?

☐ Yes (2)

☐ No (1)

55. After application of pesticides to crops, have you ever experienced...

a) ...headache?

☐ Yes ☐ No

b)...burning sensations in eyes/face?

☐ Yes ☐ No

c)... weakness?

☐ Yes ☐ No

d)... fever?

☐ Yes ☐ No

e)... watering eyes?

☐ Yes ☐ No

f) ... skin rash?

☐ Yes ☐ No

g) ...itching and skin irritation?

☐ Yes ☐ No

h) ... dizziness?

☐ Yes ☐ No

i)... chest pain?

☐ Yes ☐ No

j)...forgetfulness?

☐ Yes ☐ No

k)... vomiting?

☐ Yes ☐ No

i) ... diarrhoea?

☐ Yes ☐ No

Thank you for your Cooperation

56. What common diseases (health problems) do you get in your family?

………………………………………

………………………………………

………………………………………

57. What are the common medication do you normally use?……………………………

………………………………………

………………………………………

58. Do you know any other methods of pests control apart from using pesticides?

☐ Yes (2)

☐ No (1)

59. If answered "Yes" on question 58, mention the alternative methods of pest control and source of information. Name those that you practice on your farm.

i)……………………………………

………………………………………

ii)……………………………………

………………………………………

…………

iii)

………………………………………

……………………………………