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DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

ASSESSMENT OF ORGANOPHOSPHATE PESTICIDE RESIDUES ON CABBAGE (*Brassica oleracea*) AT THE FARM GATE IN THE ATWIMA NWABIAGYA DISTRICT, GHANA

A THESIS SUBMITTED TO THE DEPARMENT OF ENVIRONMENTAL SCIENCE, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN ENVIRONMENTAL SCIENCE

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DECLARATION

I, KOFI ADU DANKWAH, do hereby declare that this submission is my own work towards the MSc. (Environmental Science) and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any degree of the university, except where due acknowledgement has been made in the text.

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ABSTRACT

The use of pesticides to control insect pest has gradually increased over the past decade. In Ghana, the increase and inappropriate use of pesticides in vegetable production has led to accumulation of pesticide residue on vegetables. This study sought to find out the types of organophosphate pesticides farmers use and their knowledge about its use, determine the level of organophosphate pesticide residues on cabbage and the level of pesticide residues in the various leafy layers which forms the cabbage head in the Atwima Nwabiagya District of the Ashanti Region of Ghana. Most farmers (82%) do not use a mixture of pesticides as the practice leads to chemicals harmful to the health of farmers. Majority of the respondents (46 %) do apply pesticides 1-5 times before harvesting. For the same period of the cabbage life cycle, spraying intervals also vary. Most farmers (66 %) apply pesticide within 7-14 days after the previous application. All the respondents use knapsack sprayer in controlling insect pest. The organophosphates pesticides that farmers use include Sunpyrifos, Pyrinex 48EC, Dursban 4E, Perferthion, Frankophos and Termex. Using gas chromatography technique, 11 organophosphates pesticide residues (ethoprophos, phorate, dimethoate, fonofos, pirimiphos-methyl, fenitrothion, malathion, chlorpyrifos, parathion, chlorfenvinphos and profenofos) were detected in the cabbage samples. The highest pesticide residue concentrations detected (0.02 mg/kg) was recorded for profenofos and chlorpyrifos. However, none of the pesticide residues detected was above the recommended Maximum Residue Limits (MRL) for cabbage. Fourteen (14) organophosphate pesticide residues were detected in all the various leafy layers of the cabbage samples. Only chlorpyrifos (0.01 mg/kg) was in the third layer which is far below the permissible level. The lower concerntrations and low degree of variability of pesticide residues found in cabbage this study suggests that farmers are adhering to appropriate use of pesticides as recommended by Agric Extension Agents (AEAs), colleague farmers, agro-input dealers and development workers. This shows that cabbage from the study area relatively wholesome for human consumption.

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LIST OF ABBREVIATION AND ACRONYMS

ABA – Akwaboa

AKA – Adankwame

ATA – Atwima Koforidua

BKA – Barekese

EAA – Esaso

ESA – Esease

EU – European Union

GC – Gas Chromatography

KPA – Kapro

MRL – Maximum Residual Limit

NBA – Nwabi

NWA – Nkawie

OP – Organophosphate

PRA –Pasuro

UN – United Nations

USEPA – United States Environmental Protection Agency

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND

Pesticides were introduced after the World War II for their various benefits but general worldwide intensive usage now poses potential hazards to the environment and human health (Chambers *et al.*, 2001). Since 1950, the world has seen a significant increase in the usage of pesticides with 2.5 million tons of pesticides used annually (Farag *et al.*, 2011). Low productivity in agriculture due to damage caused by pests has led to an increased use of pesticides to combat food security - a global issue especially among developing countries.

Pesticides by their nature show some level of toxicity because they are intended to kill certain organisms and thus presents some level of risk to all organisms (Abdelgadirand and Adam, 2011; Zidan, 2009). In view of this, pesticide use has raised serious concerns not only of their potential effect on human health but also about their impacts on wildlife and sensitive ecosystems (Power, 2010).

Over the years, pesticide use has become a common agricultural practice in Ghana. However, lack of knowledge of the types, uses, and the effects of these pesticides among small-and large-scale farmers has resulted in their misuse and consequently their accumulation in various foods and feed items. This has led to several studies on the levels of pesticides residues in food, especially in Africa and Asia where the use of pesticides is high. Research conducted for the past decade in Ghana and internationally point to the presence of pesticide residues in a number of food items including tomato, pepper, onion, cucumber, lettuce, cabbage, okra, oranges, beans, and strawberries (Hanson *et al.*, 2007; Hussain *et al.*, 2002; El-Nahhal, 2004).

One of the key components of food security strategy of Ghana is vegetable production (Parker *et al.*, 2010). One such vegetable is cabbage which is been attacked by wide range of insect pests. For this reason, pesticides such as Attack, Sunpyrifos, Frankocylon, PAWA, Goran, Bypel, Cymetox, Dursban, and Condifor among others are used in Ghana to control these pests. Some of the major pests that attack cabbage in Ghana and for that matter Atwima Nwabiagya district include; cabbage aphids, diamond-black moth and webworms. In Ghana most vegetable farmers use synthetic pesticides which are mostly Organophosphorus base or pyrethroid to control these pests since there is a ban on the importation and sales of Organochlorine base pesticides in the country because of its persistent nature. Organophosphate pesticides however, are generally much more toxic to vertebrates compared to other classes of insecticides even though they rapidly degrade in the environment (Chambers *et al.*, 2001).

Maximum residual level represents the maximum concentration of pesticide residues, which are legally permitted in food crop, and they are interpreted as the maximum concentrations expected to be found, if the pesticides are applied to the crop according to the guidelines. Pesticides can cause both acute and chronic diseases. Skin rashes and blurred vision are the main acute effects of pesticide. Heat stress, heat cramps and neurological diseases are the main effect of repeated exposure to pesticides (Khan *et al.*, 2011). The maximum residue limit of each country should be same because the health of each country human being is paramount since it has direct effect on productivity.

1.2 PROBLEM STATEMENT

The use of pesticides to control insect pest has tremendously increased over the past decade (Hogson, 2003). The increased and inappropriate use of pesticides in vegetable production in Ghana (Obeng-Ofori *et al.*, 2002) has led to increase of residue on vegetables. These pesticides cause some toxicological and environmental problems which include residues in food, water, soil, adverse effect on non-target insects and other beneficial organism as well as the development of resistant strain of insect (Ninsin, 1997). Lack of proper education on the use and handling of these pesticides is threatening the health of most farmers and the consumer of their vegetables alike. The gross and improper use of synthetic pesticide is an issue of much concern.

Most vegetable farmers in their quest to achieve immediate results apply high doses of the chemical which leaves high concentration of the chemical residues on the products. Some apply the pesticide at the wrong time and also use higher doses than it is required. Banned pesticides which have found their way into the market are bought and use by farmers to control insect pest on their vegetables. The use of right pesticides for the wrong purpose is also another challenge. For example, insecticides like Sumico and Cyperdem which is supposed to be used to control insect pest on cotton are rather used to control insect on vegetables by farmers (Amoako, 2008). It has been estimated by the World Health Organization, (WHO) that about 20,000 people die each year from pesticides poisoning and at least three million people suffer acute health effects (Dinham, 1995).

Organophosphorus pesticides (OPs) are one of the most common classes of chemicals used for the control of insects on vegetables because of their high efficacy and broad spectrum of activity. As a result, OP residues are likely to occur in vegetables, such as lettuce, celtuce, and cabbage. The inappropriate and illegal usage of OPs further increases the risk of human exposure. Therefore, it is important to determine the levels of OPs in vegetables to protect human health (de Silva *et al*., 2006; Darko and Akoto, 2008).

Presence of pesticide residues in vegetables and fruits is an indicative change in use pattern of pesticides in Ghana where shift has taken place from organochlorines to the easily degradable groups of pesticides over the last few years. Essumang *et al.* (2008) detected high levels of lambda-cyhalothrin, chlorpyrifos, fenitrothion and cypermethrin residues in tomatoes from Kumasi and Cape Coast, Ghana to be above their respective MRL.

Armah (2010) detected high levels of allethrin and ethoprophos above MRL for cabbage in Ameen Sangari industries and UCC Technology farm in Ghana. But such a study on cabbage have not been carried out under different agro-climatic conditions in the country.

The study seeks to assess the levels of organophosphate pesticides residues on cabbage.

1.3 JUSTIFICATION

Pesticide use is thus a common practice to control pest and diseases in vegetables production in Ghana (Ntow *et al*., 2006). It is estimated that 87 % of farmers in Ghana use pesticides to control pests and on vegetables (Dinham, 2003). Therefore, the tendency that these vegetable farmers who are mostly illiterate or semi-literate to misapply the pesticide and leave high residual levels on crop is high. Knowledge about farmer's perception on pesticide may influence their decisions regarding pesticide use. This knowledge of farmer's perception if it differs from expert opinion will help experts to know why and whether these perceptions lead farmers to take more risks than they realize. Knowledge about farmer's perception on pesticide would inform experts what influence the methods of protection used against pesticides by farmers and tailor technical advice given to farmers on pesticide health effects. It would help us to ascertain whether the farmers use the right pesticides for the right purpose.

1.4 OBJECTIVES

The general objective of this research work was to assess the level of organophosphate pesticide residues on cabbage at the farm gate in the Atwima Nwabiagya District of Ghana.

The specific objectives of this research are:

1. To find out the types of organophosphate pesticides farmers' use and their knowledge about its use.
2. Assess the levels of organophosphate pesticide residues on cabbage in the Atwima Nwabiagya District.
3. To determine the level of pesticide residues in the various leafy layers which form the cabbage head.

CHAPTER TWO

2.0 LITERATURE REVIEW

Use of pesticides has turned out to be an obligatory input to agriculture and public health. Versatile use of pesticides had resulted in contamination of all basic necessities of life, i.e. air, water and food. Among various pesticides, organophosphorus pesticides (OPPs), derivative of phosphoric acid, are the most extensively used insecticides or acaricides in many crops. Due to low persistency and high killing efficiency of OPPs, many agriculturalists regularly use this group of pesticides for various vegetables and fruits crops. The continuous use of pesticides has caused the deleterious effects to the ecosystem.

2.1 TYPES OF PESTICIDES VEGETABLE FARMERS USE IN GHANA

Not surprisingly, pesticide use has increased over time in Ghana and is particularly elevated in the production of high-value cash crops and vegetables (Gerken *et al.*, 2001). Chemical pesticides are used improperly or in dangerous combinations (Obeng-Ofori *et al.*, 2002). The misuse of chemical pesticides is of so much concern that promotion of safe use of pesticides on vegetables has been placed on the agenda of Ghana's Food and Agriculture Sector Development Policy (Ministry of Food and Agriculture, 2002).

In Ghana, most vegetable farmers (87%) use synthetic chemical pesticides to control pests on vegetables including a number of highly persistent OCs pesticides (Essuman *et al.*, 2008). Urban food needs in cities and towns in Ghana are growing, and increasingly vegetables are grown in urban and peri-urban areas to meet the demand. However, traditional vegetable farming systems are incapable of meeting this challenging demand. For instance, pests and diseases which pose big problem in vegetable (especially cabbages and tomatoes) production require intensive pest management to control them. A total of forty three (43) pesticides are being used by vegetable farmers in Ghana. The pesticides comprised of insecticides (33 %), fungicides (23 %) and herbicides (44 %). The types of pesticides farmers use include organochlorines (OCs), organophosphates (OPs) and pyrethroids (Ntow *et al.*, 2006). Examples of types of pesticides applied on vegetables by farmers in Ghana is shown in **.**

Table 1.

Table 1: Examples of types of pesticides applied on vegetables in Ghana

PESTICIDE TYPE	ACTIVE INGREDIENT	CHEMICAL GROUP
Herbicide (44%)	Pendimethalin 2, 4 - D Propanil Oxadiazon MCPA – thioethyl Oxyfluorfen Bensulfuron-methyl Glyphosate Paraquat dichloride Acifluorfen Metoachlor Phenmedipharm	Dinitroaniline Aryloxyalkanoic acid Anilide Oxadiazole Aryloxyalkanoic acid Diphenyl ether Sulfonylurea Alycine deriuntive Bipyridylium Diphenyl ether Chloroacetamide Carbamate
Fungicide (23%)	Mancozeb Metalaxyl-M Thiophanate methyl Carbendazim Benomyl	Carbamate Acelalanine Benzimidcizole Benzimidcizole Benzimidcizole
Insecticides (33%)	Lambda cyhalothrin Chlorpyrifos Endosulfan Dimethoate Cypermethrine Deltamethrine	Pyrethroids Organophosphate Organochlorine Organophosphate Pyrethroid Pyrethroid

Source: Ntow *et al.* (2006)

2.2 FARMER'S KNOWLEDGE AND PERCEPTION ABOUT PESTICIDES

According to Banjo *et al.* (2010), research conducted on farmers who grow crops like okro, tomatoes, pumpkin, maize etc shown that 87% of the farmers applied the pesticides at a prescribed dosage while 13% applied them indiscriminately. All farmers agreed that the trend of pesticide usage is increasing and the frequency of pesticides application is high. About 38% of the farmers applied occasionally depending on infestation and 86% of the farmers reputed of not using any preventive measures due to high lost.

Meanwhile, most pesticides are known to be bio-accumulated which means that the pesticides dissolves willingly in fats and oils which gives explanation as to why the pesticides accumulate and become manure concentrated in an organism body. They could present danger to farmers, consumers and factory workers, indirectly through inhalation, dermal absorption and ingestion or directly through dietary intake of food or water (Schopfer and Lockridge, 2012).

In general, the frequency of pesticides application by farmers is high such heavy use of pesticide may result in frequent contact with the pesticide which can lead to significant health problems. Usually farmers assume that pesticides poisoning symptoms are normal, so they got used to them (Banjo *et al.,* 2010; Kishii, *et al.*, 1995).

Various inappropriate practices in the handling and use of pesticides caused possible poisoning symptoms among those farmers who generally did not wear protective clothing. 75 – 100% of pesticides vegetable apply are said to be very effective and 50 – 75% effective and less than < 50% of farm small affect only (Ntow *et al.*, 2006).

Lack of knowledge of the types, use and effects (additive, synergistic, independent and antagonistic) of these pesticides among small and large scale farmers has resulted in their misuse and consequently their accumulation in various foods and feed items (Essuman *et al*., 2008).

Farmers did not necessarily associate hazardous pesticides with better pest control. The introduction of well-targeted training programs for farmers on the need for and safe use of pesticide was thus advocated (Ntow *et al*., 2006).

As part of a programme to promote safe and sound agricultural practices in Ghana, a study was conducted on farmers' perception of pesticides use and application in vegetable production, using a small survey of 137 farmers who applied pesticides. The Survey showed that knapsack sprayers were the most widely used type of equipment for spraying pesticides. However, on large scale vegetable farms of 6-10 acres, motorized sprayers were also used. Various inappropriate practices in the handling and use of pesticides caused possible poisoning symptoms among those farmers who generally did not wear protective clothing. Younger farmers (< 45 years of age) were the most vulnerable group, probably because they did more spraying than older farmers (> 45 years of age) (Banjo et al., 2010).

2.3 LEVELS OF PESTICIDE RESIDUES ON VEGETABLES IN GHANA

Vegetables which are an essential component of our diet due to their nutritional value, suffer several insect pests attack. For better yield and quality, pesticides are applied repeatedly during the entire period of growth. These pesticides are absorbed by the vegetables. It may be hazardous if safe waiting period is not allowed before consumption. As pesticides break down in the environment at different rates, the more persistent ones contaminate food and water and remain in produce for years. Even though we only consume these residues in small amounts, little is known about their long-term effects on human health.

A wide range of pesticides are used in Ghana for crop protection during cultivation of vegetables due to heavy pest infestation throughout the season. It has been revealed that vegetables that contain the residues of pesticides above their respective Maximum Residue Limit (MRL) may present health hazards to consumer (Taneja and Bhanti, 2005)

Pesticide residues, both natural and synthetic, can be found in most of the things we eat, for example, fruits, vegetables, bread, meat, poultry, fish, and the processed foods made from them. Some of these pesticides contamination is legal, but does not mean it is safe. Much of it is illegal, with residues found in excess of regulatory safe levels. Determining the type and level of trace contaminants in our food and environment is critical in protecting and improving human health and the environment. A study to evaluate the residue levels of selected pesticides used on tomato crops in Ghana that are likely to have accumulated in the tomatoes during application confirmed that pesticide residues were indeed present in the tomatoes and further analysis quantified the amount present (Essuman *et al.*, 2008).

Analysis of some organochlorine and organophosphorus residue levels in the tomato fruits indicated that chlorpyrifos, which is an active ingredient of pesticides registered in Ghana under the trade name dursban 4E or terminus 480 EC for use on vegetables, has the greatest residue level of 10.76 mg/kg. The lowest residue level observed was that of pirimiphos-methyl with 0.03 mg/kg. Human health risk assessment performed on the results using Human Health Evaluation computerized software-RISC 4.02, showed cancer risk for adults and children due to the presence of endosulfan and chlopyrifos. Endosulfan is not registered in Ghana as a pesticide for use on vegetables; therefore, the detection of endosulfan in several samples indicates misuse of agrochemicals among Ghanaian farmers (Essuman *et al.,* 2008).

According to Ntow *et al.* (2006) Chlopyrifos (Dursban) was detected on 78% of the lettuce, lindane (Gamalin 20) on 31 %, endosulfan (Thiodan) on 36 %, lambdacyhalothrin (Karate) on 11 %, and dichloro-diphenyl-trichloroethane on 33 %. Most of the residues recorded exceeded the maximum residue limit for consumption.

2.4 ORGANOPHOSPHATE PESTICIDES RESIDUES ON CABBAGE

Cabbage is a vegetable of expanding commercial importance but of limited production in Ghana produced by migrants in peri-urban areas for urban consumers. High rates of pesticide application and water consumption in cabbage production incur negative environmental and health externalities. The diamondback moth, or DBM (*Plutella xylostella*), is the most severe biotic constraint in cabbage production. DBM is a readily adaptable pest that has developed resistance to almost every known or approved insecticide in different parts of the world .According to experts, DBM has already developed resistance to the main insecticides available in Ghana (Obeng-Ofori *et al.,* 2002).

Armah (2011) analysed cabbage samples at the farm-gate to determine the types of pesticides used by vegetable farmers in Cape Coast, Ghana and ascertain whether levels of pesticides residues are below permissible Maximum Residual Limits (MRL). The result indicated that 21 pesticides residues were detected in the cabbage samples of which 9 were Pyrethroids and 12 Organophosphates. More than two-thirds of the total number of the samples had their residual level exceeding Maximum Residual

Limits. Table 2 below shows the European Union (EU) Maximum Residue Limits (MRLs) Permitted in Cabbage.

Table 2: EU Maximum Residue Limits (MRLs) Permitted in Cabbage

Pesticide residue	MRLs	Year of Adoption
Allethrin	0.50 mg kg^{-1}	2008
Bifenthrin	0.50 mg kg^{-1}	1995
Cyfluthrin3	0.10 mg kg-[1]	2008
Fenvalerate	3.00 mg kg^{-1}	-
Permethrin	5.00 mg kg^{-1}	-
Lambda-cyhalothrin	0.30 mg kg^{-1}	2009
Deltamethrin	2.00 mg kg^{-1}	-
Cypermethrin	0.70 µg g^{-1}	2009
Methamidophos	1.00 µg g^{-1}	-
Ethoprophos	0.02 µg g^{-1}	2005
Phorate	0.05 µg g^{-1}	2006
Diazinon	0.50 µg g^{-1}	2005
Chlorpyrifos	1.00 µg g^{-1}	2003
Malathion	0.50 µg g^{-1}	2006
Parathion	0.05 µg g^{-1}	2004
Dimethoate	0.05 µg g^{-1}	2003
Fenitrothion	0.50 µg g^{-1}	-

Source: Armah (2011)

Ghana has ratified CODEX pesticide residues as its Maximum Residual Limits (MRLs) since 1966.

Table 3 below show the CODEX pesticide residues in cabbage.

Table 3: CODEX Pesticide residues in Cabbage

Pesticide residue	MRLs	Year of Adoption
Cyfluthrin3	0.08 mg kg-[1]	2013
Permethrin	5.00 mg kg^{-1}	-
Lambda-cyhalothrin	0.30 mg kg^{-1}	2009
Cypermethrin	1.00 mg kg^{-1}	2009
Diazinon	0.50 mg kg^{-1}	2005
Chlorpyrifos	1.00 mg kg^{-1}	2003
Parathion	0.05 µg g^{-1}	2004
Dimethoate	0.05 µg g^{-1}	2003
Fenitrothion	0.50 µg g^{-1}	-

Source: CODEX Alimentarius (2013).

2.5 HUMAN AND ENVIRONMENTAL HEALTH EFFECTS ASSOCIATED WITH PESTICIDE USE

Pesticides are widely used throughout the world in agriculture to protect crops and in public health to control diseases. Nevertheless, exposure to pesticide can represent a potential risks to humans. Pesticide manufacturing unit workers are at a risk of exposure.

Studies indicate that the health effects on humans especially children of environmental exposure to agricultural pesticides, especially the neurotoxic effects of low-level exposure (Simcox *et al.*, 1995). However, children are thought to be liable to particularly severe acute and chronic developmental, immunological, and neurological symptoms from pesticides. In particular, exposure to neurotoxins at levels that would be safe for adults may cause permanent loss of brain function in infants and toddlers (USEPA, 2007). When a pesticide is introduce into the environment, either through application, disposal or spillage, it is influence by many processes which determine its movements, persistence and fate. The fate can either be beneficial that is leading to targeted area or destroying its potential harmful residues or can be detrimental, leading to reduced control of pest but can cause injury to non-target organisms and the environment.

In Ghana, Environmental Protection Agency (EPA) has banned the importation of 25 agrochemicals because of their toxicological risks to people, animals, crops and the environment. The ban covers toxaphene, captafol, aldrin, endrin, Chlordane and DDT. One hundred and eighteen (118) chemicals were approved for importation after undergoing testing for efficacy and safety under local condition. Twenty four (24) Agrochemicals were given provisional clearance for one year. If these chemicals prove ineffective or dangerous they will be banned (EPA, 2008).

There is concern that African countries have been turned into dumping grounds for hazardous chemicals. The EPA encouraged Ghanaian scientist to put more emphasis on biological control methods to reduce the over-reliance on chemicals. Ghana's action is emblematic of the Rotterdam Convention, an international treaty that gives countries right to refuse import of hazardous chemicals that have been banned in other countries in order to protect human health and the environment (EPA, 2008). Pesticide use raises a number of environmental concerns. Over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species, including non-target species, air, water, and food (Miller, 2004). Pesticide drift occurs when pesticides suspended in the air as particles are carried by wind to other areas potentially contaminating them. Pesticides are one of the causes of water pollution and some pesticides are persistent organic pollutants that contribute to soil contamination. Pesticides can present danger to consumers, bystanders or workers during manufacture, transport or during and after use (USEPA, 2007). The World Health Organization and the UN Environmental Program estimate that each year three million workers in Agriculture in the developing countries experience severe poisoning from pesticides, about 8,000 of whom die (Miller, 2004). Jeyaratnam (1990) indicated that as many as twenty five million workers in the developing countries may suffer mild pesticide poisoning yearly.

2.6 DIFFERENT METHODS OF ANALYSING PESTICIDE RESIDUES IN FRUITS AND VEGETABLES

The literature survey has revealed that gas chromatography has been the most widely used technique for analysis of organophosphate pesticides (OPs). Different scientists all over the world have adopted different extraction procedures for estimation of OPPs using GC.

Gonzalez-Rodriguez *et al.* (2009), estimated the residue of methamidophos in vegetables of Southern Spain (Almeria) by using GC. The samples of chopped tomato and green bean were mixed with 100 g anhydrous sodium sulfate and homogenized in a blender with 100 ml of dichloromethane for 2 min. The homogenate was transferred into a Kuderna Danish tube through a glass wool filter and was concentrated to approximately 0.5 ml. The concentrated filtrate was exposed to the slight stream of nitrogen till dryness. The residue was dissolved in acetone to prepare 4 ml solution. The final solution was subjected to gas chromatography-flame photometric detector (GC-FPD) for analysis. The recovery rates for both vegetable samples were more than 89 % whereas that diminution rate of methamidophos was higher in tomato than in green beans.

Patel *et al.* (2004) developed a method of resistive heating gas chromatography (RH-GC) with FPD for the screening of OPPs (dichlorvos, methamidophos, acephate, fonofos, dimethoate, parathion methyl, ethion, phosmet, chlorpyrifos methyl, chlorpyrifos, diazinon, pyrazophos and etrimfos) in fruits and vegetables (peach, grapes, lettuce and sweet pepper). Organically produced fruits and vegetables were extracted in ethyl acetate solution and analyzed on RH-GC-FPD. 30 g of homogenized sample was mixed with 60 ml ethyl acetate, 30–40 g anhydrous sodium sulfate and 5–6 g sodium hydrogen carbonate. The sample was placed in a water bath at 30 ◦C for at least 20 min and then was homogenized for 30 s. The filtered organic layer was evaporated to dryness under a stream of oxygen-free nitrogen. The resultant extract was reconstituted with ethyl acetate and then injected into RH-GC-FPD for analysis. It took only 4.3 min for the separation of 20 pesticides. Average recoveries obtained were 70% and 116% for pesticides spiked at 0.01 mg/kg and 0.1 mg/kg, respectively, with associated relative standard deviation (RSD) values to be less than 20%.

Parveen *et al*. (2005), monitored number of pesticide residues, viz., endosulfan, chloropyrifos, dimethoate, ethion, methyl parathion, monocrotophos, cypermethrin, deltamethrin, profenfos, carbendazim, metalaxyl, TBZ and acetamiprid belonging to different pesticide classes like OPPs, OCPs, carbamates and pyrethroids in 206 vegetable samples including 27 different types like carrot, garlic, ginger, onion, potato, radish, sugarbeet, brassica leaves, cucumber, mint, methi, chilli, french beans, tomato, pumpkin, cabbage and cauliflower from Karachi, Pakistan. 30 g of sample was extracted with 75 ml of extraction mixture containing tolulene, n-hexane and ethyl acetate in the ratio of 3:1:1. The extracts were analyzed using HPLC and GC-FID. 63 % samples were contaminated with one or another pesticide and 46 % of contaminated samples had pesticide residues more than MRL values as given by FAO/WHO.

Darko and Akoto (2008) reported dietary intake of OPPs residues (methyl-chlorpyrifos, ethyl-chlorpyrifos, dichlorvos, dimethoate, malathion, monocrotophos, omethioate, methyl parathion and ethyl parathion) through vegetables (tomatoes, eggplant and pepper) from Kumasi, Ghana. 2 g of each homogenized vegetable sample was extracted in 5 ml of acetonitrile on rotatory shaker for 15 min. The solvent layer was removed and was centrifuged for 2 min at 3000 rpm. The supernatant layer was shifted into a vial. The extract was concentrated to about 2 ml using a rotary evaporator at 30 ◦C. The internal standard was added to the extract and was made up to 2 ml with acetonitrile and injected into GC-FPD. The residue of ethyl-chlorpyrifos was at an average level of 0.211±0.010 mg/kg in 42% tomato, 0.096±0.035 mg/kg in 10% eggplant and 0.021±0.013 mg/kg in 16% pepper whereas dichlorvos pesticide was present frequently in all samples analyzed. The exceeded levels of malathion residues beyond MRL values (0.1 mg/kg) in tomatoes (0.120±0.101 mg/kg) and pepper (0.143±0.042 mg/kg) were related to the health risks of the population of Ghana. The recoveries achieved for tomato, eggplant and pepper were 88–102%, 90–105% and 91–98%, respectively, whereas LOD of the method ranged from 0.001 mg/kg to 0.015 mg/kg.

Apart from GC method of determine organophosphate pesticide residues in vegetables, other methods of determine organophosphate pesticide residues in vegetable is by enzyme inhibition methods using α-naphthyl acetate esterase or the acetylcholinesterase inhibition method. Recently, the acetylcholinesterase inhibition method has been successfully applied to the determination of OPs in various environmental matrices (Schulze *et al*., 2002). In most cases, the acetylcholinesterase applied in this method is extracted from the head of the fly *Musca domestica*. The flies are cultured in a tightly controlled environment that is free from pollution by any pesticides, especially OPs. With these methods, the extraction procedure is complex and elaborate, and requires perfect technique and low-temperature processing. These limitations make it inconvenient to use acetylcholinesterase for the rapid determination of OPs (Li *et al*., 2008).

The Gas chromatographic method was used for the analysis of OPs in the cabbage samples because it offers notable qualitative and quantitative advantages, even though they are generally time-consuming, expensive, labor-intensive, and use relatively large volumes of solvents.

CHAPTER THREE

3.0 MATERIALS AND METHODS

The research work was carried out in two stages. The first stage was a field survey to assess types of organophosphate pesticides farmers use and their knowledge about its use in controlling insect pest on cabbage production in Atwima Nwabiagya District, Ghana.

The second stage involved the collection of cabbage samples at the farm gate from some selected cabbage farmers for laboratory analysis for organophosphate compounds or pesticides residual levels in the cabbage.

3.1 THE STUDY AREA

The district is situated in the western part of the region and shares common boundaries with Ahafo Ano South and Atwima Mponua district (to the west), Offinso district (to the north), Amansie-west and Atwima kwanwoma district (to the south), Kumasi Metropolis and Kwabre districts (to the east) as shown in Figure 1. The study area covers an estimated area of 354.75 sq km. The district capital (Nkawie) is situated along the Kumasi-Bibiani road and lie approximately on latitude 60 75’ N and between longitude 10 45’ and 20 00’ west (Atwima Nwabiagya District Assembly, 2006).

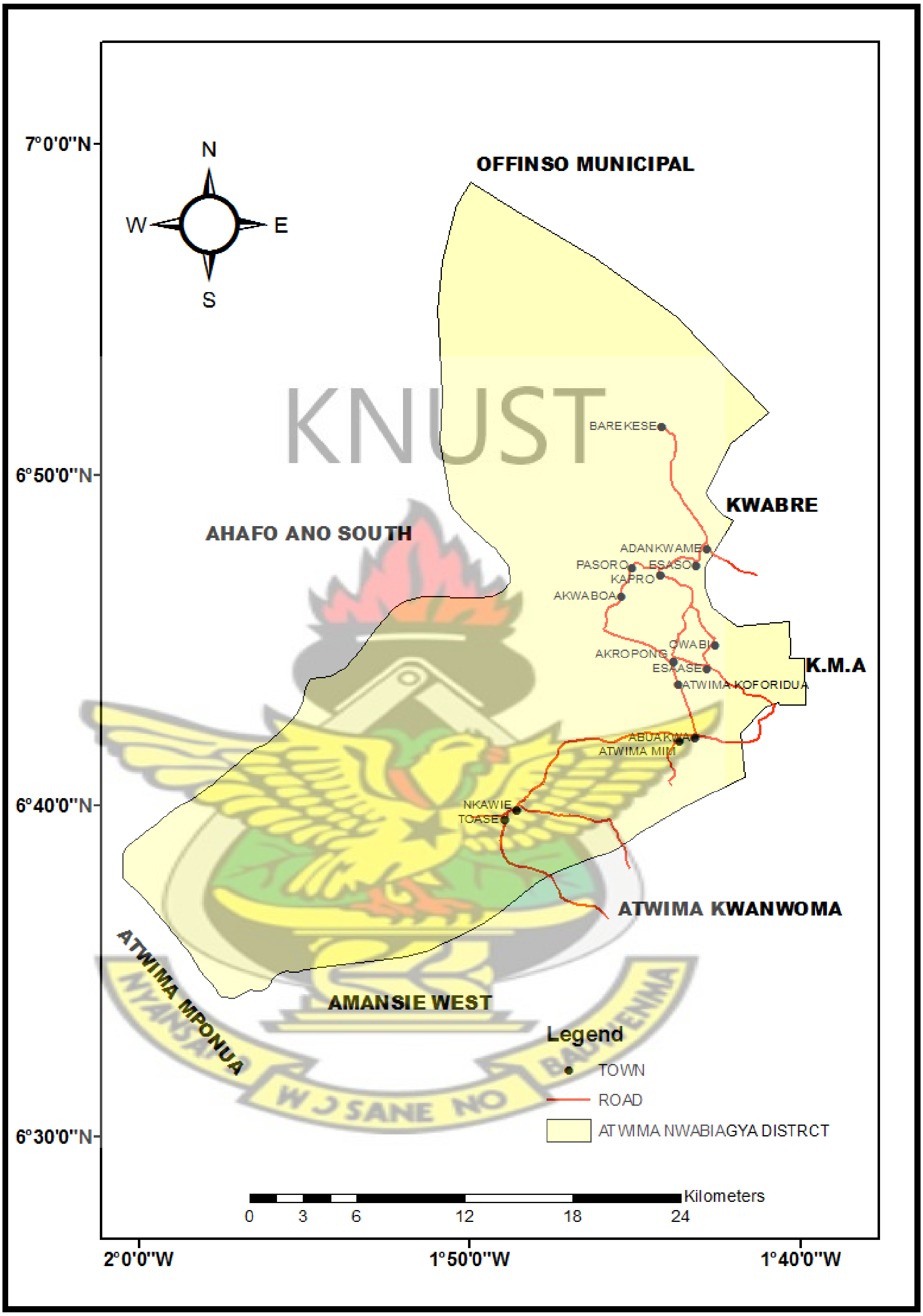

Figure 1: Map showing the study area Atwima Nwabiagya District, Ghana

Topography and Drainage

The study area has an undulating topography. The lands have average height of about 77 metres above sea level. The high lands gentle to steep slopes. The highest points in the district can be found in the Barekese and Atwima Koforidua areas. The Offin and Owabi rivers mainly drain the surface area of the district. There are however, several streams in the district. These include Kobi and Dwahyen. Two major dams, Owabi and Barekese have been constructed across the Owabi and Offin rivers respectively. These dams supply pipe borne water to the residents of Kumasi and its environs (Atwima Nwabiagya District Assembly, 2006).

Climate

The district lies within the wet semi-equatorial zone marked by double maximum rainfall ranging between 170 cm to 185 cm annum. The major rainfall season is from mid-March to July and minor season is between September and mid-June. Rainfall in the district is not distributed throughout the year. It is also not very reliable. It is therefore not safe to practice rain fed agriculture. Agriculture within the district must incorporate soil water conservation measures at all times to ensure good yield (Atwima Nwabiagya District Assembly, 2006).

Temperature is fairly uniform ranging between 27 °C (August) and 31° C (March). Mean relative humidity of about 87 to 91 percent is characteristic of the district. The lowest relative humidity usually occurs in February/April when they are between 83-87 in the morning and 48-67 in the afternoon (Atwima Nwabiagya District Assembly, 2006).

Vegetation

The vegetation found in the district is predominantly the semi-deciduous type. The vegetation type has largely been disturbed by man's activities, thus, depriving it from its original valuable tree species, and other forest product. These include the Owabi Water Works Forest Reserve and Barekese Water Works Forest Reserve, which serves as water species consisting mainly of teak, acacia, gumelina and eucalyptus. However, throughout the activities of humans, parts of the forest vegetation are been lost (Atwima Nwabiagya District Assembly, 2006).

Soil

The predominant soils in the district are the Kumasi-Nsuasi/Nta-Offin compound association and the Bekwai-Nzema/Oda Complex Association. The Kumasi-Nsuasi Compound Associations developed over Cape Coast Granites are generally medium to course textured, good and structured moderately gravelly. The soils have a fairly high moisture holding capacity. The soils are marginal for mechanical cultivation. Hand cultivation is recommended. The soils are good for Agriculture. They are suitable for tree and arable crops such as cocoa, citrus, oil palm, mangoes, guava, avocado, maize, cassava, yam cocoyam, plantain, pawpaw, groundnut, pineapple and ginger. The valley bottom soils are good for the cultivation of rice, sugarcane and vegetable (Atwima Nwabiagya District Assembly, 2006).

Soils of the Kumasi-Asuasi Compound are found at places like Nerebehi, Abuakwa, Nkawie, Toase etc. residential activities and sand winning have currently taken most of these good agriculture lands. Soils of the Bekwai-Nzema/Oda Complex Associations are found in places like Fufuo, Mfensi, Barekese, Adankwame Esease, Akropong etc. (Atwima Nwabiagya District Assembly, 2006).

Geology and Minerals

The district is underlain by lower Birimain rocks, which consist of phyllites, greywacks, achists and gneiss and the Cape Coast Granite. Both the lower Birimain and the Cape Coast Granite are not of the considerable economic importance since they do not bear gold and bauxite. However the rocks (especially the lower Birimain) consist of good clay deposit. The Cape Coast Granite is a good potential for the construction industry (Atwima Nwabiagya District Assembly, 2006).

Population

The total population of the district according to the 2000 population and housing census was (129,375) with an annual growth rate of 3%. The census revealed that the district has a sex ratio of 101:100 male to female. The projected population of the district for 2008 (using geometric method) was 178,989 and population density 439 persons per sq km (Atwima Nwabiagya District Assembly, 2006).

3.2 FIELD SURVEY

Fifty (50) cabbage farmers were randomly selected from fourteen (14) major cabbage producing communities in the Atwima Nwabiagya District for interview and questionnaire administration. The communities studied include; Esease, Pasuro, Abuakwa, Toase, Atwima Mim, Adankwame, Esaso, Nkawie, Kapro, Nwabi, Akwaboa, Atwima Koforidua, Akropong and Barekese.

3.3 SAMPLE COLLECTION

The second stage of the research work involved the collection of a total of one hundred and fifty harvested cabbage heads at the farm gate from the month of May to July, 2013. In each community three different farms with different farmers were randomly selected. In each farm five cabbage heads were randomly picked. This was done in the ten communities in the district selected for the questionnaire administration.

Four out of the five samples collected from each farm was treated as one sample and the fifth sample from each farmer were all put together and treated as one samples to the order of the leafy layers.

3.4 SAMPLE PREPARATION

Four of the five samples collected from each farmer were chopped together into smaller pieces on a wooden board. About 500 g of the chopped sample was taken and wrapped in an aluminum foiled and then put in a well labeled zip locked bag. Each of the 3 farms where samples were taken were labeled A, B and C with some initials of the names of the selected communities as prefix. Samples from Pasuro community: PRA, PRB, PRC, Esease: ESA, ESB, ESC, Adankwame: AKA, AKB, AKC, Nkawie: NWA, NWB, NWC, Akwaboa: ABA, ABB, ABC, Atwima Koforidua: ATA, ATB, ATC, Nwabi: NBA, NBB, NBC, Esaso: EAA, EAB, EAC, Kapro: KPA, KPB, KPC, Barekese: BKA, BKB, BKC. The other thirty cabbage heads, one from each farm had their first five leafy layers removed followed by the next five layers and the last group of layers which were highly fused together. Each group of the layers was chopped together and labeled layer 1, 2 and 3. (LY1, LY2, LY3) These samples were kept under freezing condition and were sent to the Chemistry Laboratory of Ghana Atomic Energy Commission for the analysis.

3.5 EXPERIMENTAL PROCEDURE

3.5.1 Extraction Process

Each of the samples was blended using blender and pour into a clean and a well labeled plastic dish. The blender was washed with distilled water any time a new sample is to be blend to avoid cross contamination. 20 g of each of the homogenized cabbage sample was weighed using Mettle Toledo weighing balance and then put into a glass bottle. 20 g Annular anhydrous sodium sulphate (Na_2SO_4) was added to the homogenized cabbage samples to remove water from the sample matrix and 5 g of sodium hydrogen carbonate ($NaHCO_3$) was added to the samples to neutralize any acid that may be present. The homogenized cabbage sample in the glass bottle was shaken manually for approximately, 2 to 3 minutes. 40 ml of ethyl acetate which was used as solvent was added and sonicated using Bransonic 220 sonicator for 30 minutes. The sonication was repeated two other times for each of the samples. The sonicator applies heat and vibration to ensure that enough of the pesticides residues dissolve in the ethyl acetate and the hexane. The extract was then decanted into a conical flask and covered with aluminium foil. An aliquot was pipette into a round bottomed flask (50 ml) and evaporated to near dryness (about 2 ml) using the Rotary Film Evaporator at a temperature of 35 ^{0}C.

3.5.2 Pre-concentration of extract

The extract was transferred from the conical flask into a round bottomed flask. The conical flask was then rinsed with ethyl acetate (the extraction solvent) into the extract in the round bottomed flask which was then fixed onto the evaporator for pre-concentration at 35 ^{0}C.

3.5.3 Clean-up

A small piece of glass wool was used to plug the end of the chromatographic columns. The column in a glass jar was put on a balance and tarred. 3.0 g of silica (SiO_3) gel was packed into the column. 2.5 g of Na_2SO_4 was also packed into the column on top of the silica gel. The packed column is then conditioned with a 10 ml of ethyl acetate. The extract in the round bottomed flask was eluted first, with 10 ml of ethyl acetate and then, again with 5 ml of ethyl acetate onto the column. The elute was then concentrated below 40 ^{0}C to near dryness on the rotary evaporator. The elute was then picked with a 2 ml ethyl acetate into a GC vial prior to quantization by GC-ECD.

3.6 CHROMATOGRAPHIC CONDITIONS FOR THE DETERMINATION OF PESTICIDE RESIDUE

3.6.1 Chromatographic conditions for organochlorines and pyrethroids

A summary of the typical GC-ECD conditions used for the quantification of the pesticide standards are stated below. Measurements of organochlorine and synthetic pyrethroids were carried out on a Varian CP-3800 gas chromatogram equipped with an Electron Capture Detector (ECD) with a CombiPAL Autosampler. The chromatographic separation was done on an EZ of 30 m + 10 m capillary column guard with 0.25 mm internal diameter fused silica capillary coated with VF-5 ms (0.25µm film thickness) from Varain Inc or equivalent. Detector temperature of 300 ^{0}C, injector (a pulsed splitless mode) 270 ^{0} C, oven for organochlorines: 70 ^{0}C for 2 min, 70 ^{0}C – 180 ^{0}C at 25 ^{0}C min^{-1} maintained for 1 min, 180 ^{0}C – 300 ^{0}C at 5 ^{0}C min $^{-1}$; oven for synthetic pyrethroids: 90 ^{0}C for 1 min, 90 ^{0}C -240 ^{0}C at 30 ^{0}C min $^{-1}$, 240 ^{0}C – 300 ^{0}C at 5 ^{0}C min^{-1} maintained for 5 min, carrier gas (N_2) 1.0 ml min^{-1}, with an injection volume 1 µL.

3.6.2 Chromatographic conditions for organophosphates

Measurements of organophosphates were carried out on a Varian CP-3800 gas chromatogram equipped with a Phosphorus Flame Photometric Detector (PFPD) with a CombiPAL Autosampler. The chromatographic separation was done on an EZ of 30 m capillary column guard with 0.25 mm internal diameter fused silica capillary coated with VF-1701 ms (0.25µm film thickness) from Varain Inc or equivalent. Detector temperature of 280 ^{0}C, injector (a pulsed splitless mode) 270 ^{0} C, oven temperature at 70 ^{0}C for 2 min, and was ramped to 180 ^{0}C at 25 ^{0}C min^{-1} maintained for 1min, and was ramped again to 300 ^{0}C at 5 ^{0}C min $^{-1}$; min^{-1} maintained for 5 min, carrier gas (N_2) 2.0 ml min^{-1}, with an injection volume 1 µL.

3.7 GAS CHROMATOGRAPHY

The instrument used in the GC analysis was Varian CP-3800 GC. It is easily configured to perform online analysis for monitoring critical gas and liquid process steams. A 25 ul glass Hamilton syringe was used to inject the GC samples. Only 2-4 ul of the sample was injected onto the column. The syringe was examined carefully before it was filled. A small amount of the liquid was slowly drawn by raising the plunder and then pressed to expel the liquid back into the liquid. This serves to rinse the syringe with the sample, ensuring that what was measured in the GC run was the composition of the mixture. The rinsing process was repeated twice. Then the plunder was slowly drawn up again while the needle was in the liquid and the syringe was carefully filled with the liquid. Small air bubbles in the syringe did not affect the GC run. The sample was injected into the injector port. Two things were done subsequently and quickly. The needle of the syringe was push through the injector port and immediately the plunder was pressed to inject the sample. Then immediately press the start button on which the recorder was pressed. The reorder was observed for some time. With several minutes, it recorded several peaks and the GC run was ended.

Calculation of the pesticide residue concentration was deduced from the following equation.

$$C = \frac{a}{b} * d * f$$

Where:

C = concentration of pesticide residue (ppm)

a = the concentration of the identified analyte in the sample solution from GC determination step.

b = the sample equivalent in the extraction step (ppm)

d = the dilution factor of GC cleanup step

f = the dilution factor of silica gel column cleanup step

CHAPTER FOUR

4.0 RESULTS

This chapter presents the findings of the study. It begins with the socio-economic characteristics of the farmers. This is followed by the types of organophosphates pesticides farmer use and their knowledge about pesticide usage. Results of levels of organophosphate pesticide residues carried out in the laboratory is presented next. This section concludes with results of levels of pesticide residues in the various leafy layers of cabbage.

4.1 SOCIO-ECONOMIC CHARACTERISTICS OF RESPONDENTS

This is the demographic section which contains the results regarding age, gender, location and the educational level. Fifty (50) respondents were selected from 14 communities in the Atwima Nwabiagya District. **Error! Not a valid bookmark self-reference.** below shows the various communities selected. About 12 percent of the respondents were from Esease. Adankwame, Barekese and Esaso represented a total of 15 respondents representing 30 percent. The lowest number of respondents came from Abuakwa (2%), Atwima Mim (2%) and Toase (2%).

Table 4: Location of Respondents

Location	Symbols used for selected samples	Frequency	Percentage	Cumulative Percent
Abuakwa*	ABA	1	2.0	2.0
Adankwame	AK	5	10.0	12.0
Akropong*	AKG	3	6.0	18.0
Akwaboa	AB	4	8.0	26.0
Atwima Koforidua	AT	4	8.0	34.0
Atwima Mim*	ATM	1	2.0	36.0
Barekese	BK	5	10.0	46.0
Esaso	EA	5	10.0	56.0
Esease	ES	6	12.0	68.0
Kapro	KA	4	8.0	76.0
Nkawie	NW	3	6.0	82.0
Nwabi	NB	4	8.0	90.0
Pasuro	PA	4	8.0	98.0
Toase*	TOA	1	2.0	100.0
Total		50	100.0	

Source: Field Survey, June, 2013 *__Cabbage samples were not taken from these communities__

Figure 2 below shows the sex of the respondents. Majority of the respondents were males (representing 80%) with females representing 20 percent.

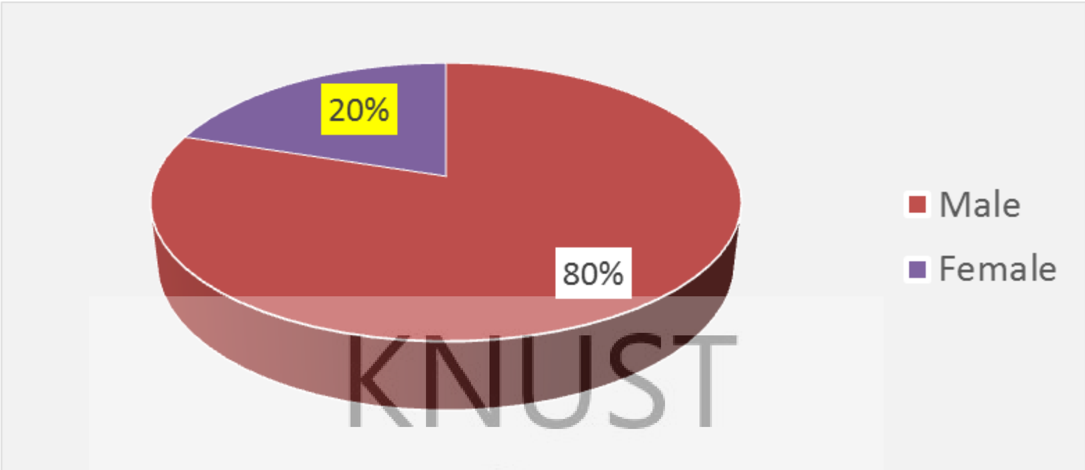

Figure 2: Sex of Respondents

Respondents' highest educational level and age categorized by sex is depicted in

Most respondents (68%) had basic education. Whilst 70 percent of females had basic education, 67.5 percent of males had basic education. Majority (60%) of the respondents were less than 40 years of age. The average age of the respondents was 39.7 years. The minimum and maximum age of the respondents stood at 21 and 65 years respectively.

Figure 3 and 4 below show the highest educational level and age of respondents respectively

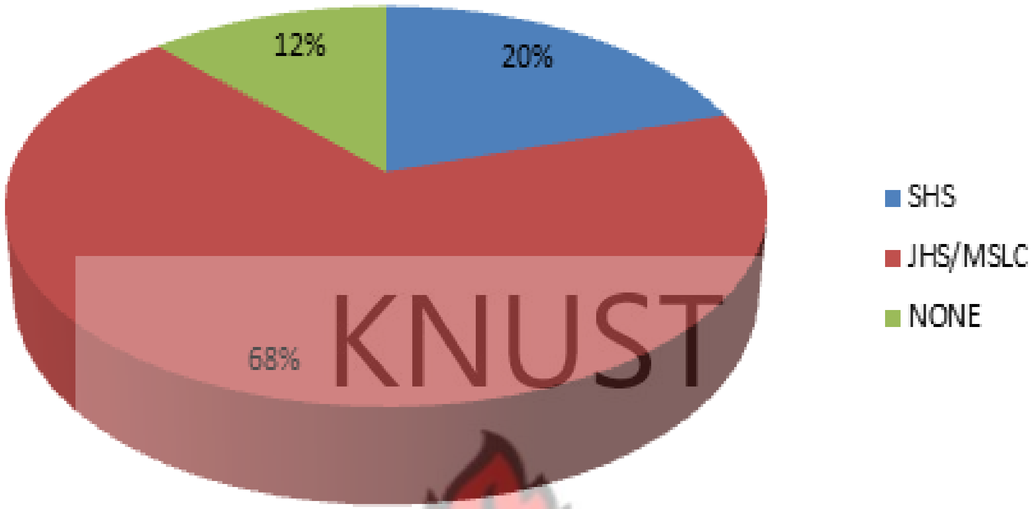

Figure 3: **Educational level of respondents**

Figure 4: **Age of respondents**

On average, the distance from one farm to the other is about 174 m whiles the maximum and minimum distance between farms is 800 m and 50 m apart. The standard deviation of 134.4 m shows that there is high variability between distances from one farm to the other.

4.2 TYPES OF PESTICIDES USED BY FARMERS

Table 5 below shows the various organophosphates pesticides farmers use and their active ingredients. The organophosphates pesticides which farmers use include Sunpyrifos, Pyrinex 48EC, Dursban 4E, Perferthion, Frankophos and Termex. Perferthion and Pyrinex 48EC is the most used organophosphates registering 12% and 10% respectively.

Table 5: **Types of pesticides farmers use**

Pesticides Used	Active Ingredients	Number	Percent (%)	Percent of cases
Organophosphates				
Sunpyrifos	*Chlorpyrifos-methyl*	3	14.3%	6%
Pyrinex 48EC	*Chlorpyrifos*	5	23.8%	10%
Dursban 4E	*Chlorpyrifos*	3	14.3%	6%
Perferthion	*Dimethoate*	6	28.6%	12%
Frankophos	*Chlorfenvinphos*	2	9.5%	4%
Termex	*Chlorpyrifos-ethyl*	2	9.5%	4%
Total		21	100.0%	42.0%

NB: Percent of cases less than 100% (multiple response analysis)

However, it was also observed that farmers also make use of pyrethroids to control insects on cabbage (**Table 6**). These included Lambda super, PAWA, Golan, Attack, K-Optimal, Regent 50SC and Confidor. Attack, Regent 50SC and Golan are the widely used pyrethroid pesticides with 34% of respondents using these pesticides.

Table 6: Pyrethroids used by Farmers

Pesticides Used	Active Ingredients	Number	Percent (%)	Percent of cases
Pyrethroids				
Lambda Super	*Lambda-cyhalothrin*	3	7.9%	6%
PAWA	*Lambda-cyhalothrin*	3	7.9%	6%
Golan	*Acetamiprid*	4	10.5%	8%
Attack	*Emamectin Benzoate*	8	21.1%	16%
K-Optimal	*Lambda-cyhalothrin*	2	5.3%	4%
Regent 50SC	*Fipronil*	5	13.2%	10%
Confidor	*Imidacloprid*	3	7.9%	6%
Others (Biological)				
Bypel	*Pierix rapae darnulosis virus 10000 pib/mg + Bacillus thurinbiensis 15000 μ/mg*	10	26.3%	20%
Total		38	100.0%	76%

A newly viral and bacterial mixture on the pesticide market, Bypel was used by majority of the farmers. Twenty percent (20%) of the farmers were using this new pesticide dsue to its high efficacy in controlling insects on cabbage. About 18 percent of the farmers use more than one pesticide in controlling insect pest.

4.3 FARMERS KNOWLEDGE ABOUT PESTICIDES USAGE

Farmers knowledge about pesticide usage is shown in Table 7 below. Majority (82%) of the farmers do not combine pesticides as this practice leads to formulation harmful to the health of farmers. While 82.5 percent of males do not combine pesticides, 80 percent of females also do not combine pesticides. When the farmers were asked the dosage of the pesticides they use, 40 percent said they use 20 ml, 24 percent use 25 ml, another 20 percent 30 ml and the remaining 16 percent use 15 ml. In buying a particular pesticide on the market, farmers look out for pesticides efficacy (72%) in controlling insects pest. This is followed by the price (24%), then pesticide availability on the market.

Table 7: Farmers knowledge about pesticides usage

Knowledge variables	Females		Males		Total	
	N	%	N	%	N	%
Using pesticides combination						
Yes	2	20.0	7	17.5	9	18.0
No	8	80.0	33	82.5	41	82.0
Total	10	100.0	40	100.0	50	100.0
Pesticide dosage application						
15ml	0	0.0	8	20.0	8	16.0
20ml	6	60.0	14	35.0	20	40.0
25ml	4	40.0	8	20.0	12	24.0
30ml	0	0.0	10	25.0	10	20.0
Total	10	100.0	40	100.0	50	100.0
Reasons for choosing particular pesticide						

Knowledge variables	Females		Males		Total	
	N	%	N	%	N	%
Moderate price	3	30.0	9	22.5	12	24.0
Pesticide efficacy	7	70.0	29	72.5	36	72.0
Availability	0	0.0	2	5.0	2	4.0
Total	10	100.0	40	100.0	50	100.0
Frequency of spraying in a growing season						
1-5 times	4	40.0	19	47.5	23	46.0
6-10 times	4	40.0	17	42.5	21	42.0
More than 10 times	2	20.0	4	10.0	6	12.0
Total	10	100.0	40	100.0	50	100.0
Spraying intervals						
1-6 days	2	20.0	7	17.5	9	18.0
7-14 days	5	50.0	28	70.0	33	66.0
15-21 days	3	30.0	5	12.5	8	16.0
Total	10	100.0	40	100.0	50	100.0
Type of spraying machine used						
Knapsack spraying machine	10	100.0	40	100.0	50	100.0
Total	10	100.0	40	100.0	50	100.0

During a growing season, the frequency of pesticides application varies from 1-13 times. Majority of the respondents representing 46 percent do apply pesticides 1-5 times before harvesting whiles 42 percent also do apply pesticides 6-10 times before harvesting. The remaining 12 percent do apply pesticides more than 10 times during cabbage growing season. For the same period of cabbage life cycle, spraying intervals also vary. Most farmers (66%) spray pesticides within 7-14 days after the previous application. About 16 percent of the farmers also spray at 15-21 days interval from the previous application. The remaining 18 percent also do spray at 1-6 days from the previous application. All the respondents make use of knapsack sprayer in controlling insect pest.

Spraying interval between last spraying and harvesting is presented in Table 8. The results revealed that 60 percent allow 11-14 days to elapse after pesticide application before they harvest produce. Only 10 percent do spray 1-6 days before harvesting with the remaining 30 percent spraying between 7-10 days before harvesting. A higher proportion of males (62.5%) and half of females (50%) spray 11-14 days before harvest.

Table 8: Spraying interval between last spraying and harvesting

Spraying interval between last spraying and harvesting	Female		Male		Total	
	N	%	N	%	N	%
1-6 days	2	20.0	3	7.5	5	10.0
7-10 days	3	30.0	12	30.0	15	30.0
11-14 days	5	50.0	25	62.5	30	60.0
Total	10	100.0	40	100.0	50	100.0

The study also sought to find out whether farmers spray while harvesting to ensure infested produce are not sent to the market. The results shown in Table 9 revealed that only six percent actually sprayed while harvesting with the remaining 94 percent did not spray prior harvesting. No female sprayed pesticides whiles harvesting.

Table 9: Continue spraying while harvesting

Continue spraying whiles harvesting	Female		Male		Total	
	N	%	N	%	N	%
Yes	0	0.0	3	7.5	3	6.0
No	10	100.0	37	92.5	47	94.0
Total	10	100.0	40	100.0	50	100.0

Farmers also considered the efficacy of the pesticides they use before purchasing the pesticide (Figure). Most farmers (60%) believe that the pesticides they use are effective. +

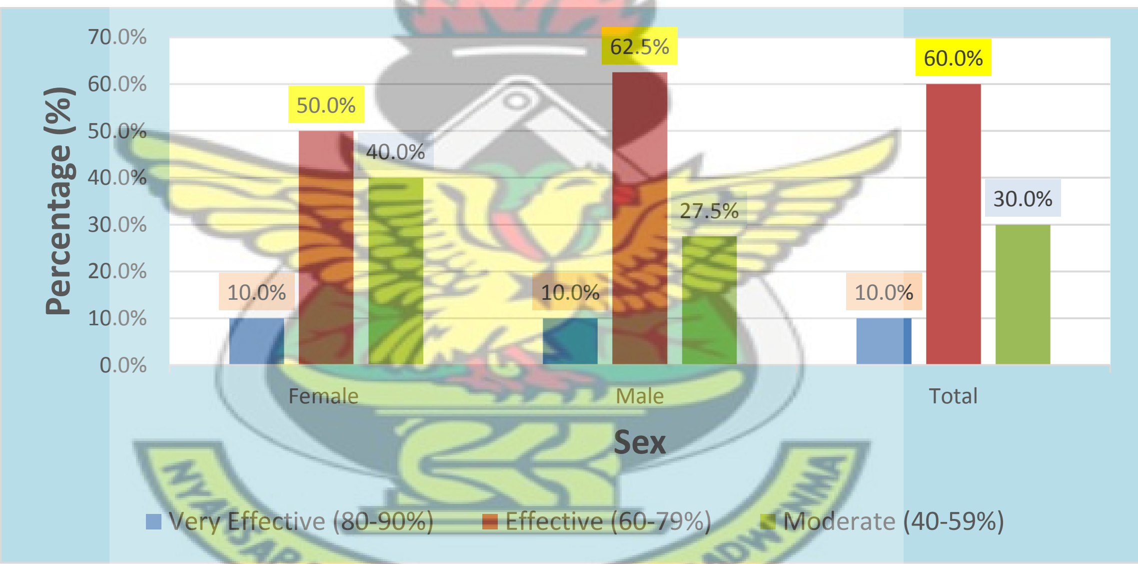

Figure 5: Pesticides Efficacy assessment by farmers

About 30 percent also assessed the pesticides as moderately effective. Only 10 percent considered the pesticides as very effective. The male farmers, (62.5 %) said their pesticides were effective as compared to 50 percent of the females who said their pesticides were effective in controlling insect pests (Table 10).

Pesticides efficacy is also affected by time of spraying. The study revealed that 49 (98%) farmers apply pesticides in the morning while 12 (24%), also prefered pesticide application in the evening. This suggest that 22 percent of them carry out pesticide application either in the morning or in the evening (See Table 10). No farmer carried out pesticide application in the afternoon.

Table 10: Time of spraying the crop in the field

Time of spraying	Responses		Percent of Cases
	N	Percent	
Morning	49	80.3%	98.0%
Evening	12	19.7%	24.0%
Total	61	100.0%	122.0%

NB: Percent of cases more than 100% (multiple response analysis)

Farmers' decision to apply pesticide was informed by various sources as shown in Table 11. Farmers (44.3%) mainly scout for presence of pest on plot to inform them on when to apply pesticide. Having a spraying routine schedule has also helped about 17 percent of the respondents to effectively control insect pest. Others (15.7%) received recommendation from agrochemical dealers in order to decide when to apply pesticide. Only six farmers (8.6%) consulted AEAs to advise them on when to apply pesticides but 10 farmers prefer to receive recommendation from fellow farmers.

Table 11: Decision to apply pesticides

Decision to apply pesticides	Responses		Percent of Cases
	N	Percent	
Presence of pest on basis of scouting	31	44.3%	62.0%
Spray on routine schedule	12	17.1%	24.0%
Agric Extension Agent's recommendation	6	8.6%	12.0%
Agro chemical dealers recommendation	11	15.7%	22.0%
Colleague farmer's recommendation	10	14.3%	20.0%
Total	70	100.0%	140.0%

NB: Percent of cases more than 100% (multiple response analysis)

Farmers were then asked if they apply safety precaution measures during pesticide application. Results presented in Figure shows that 80 percent of the farmers do apply safety precaution measures during pesticide application. This result was same for both sexes.

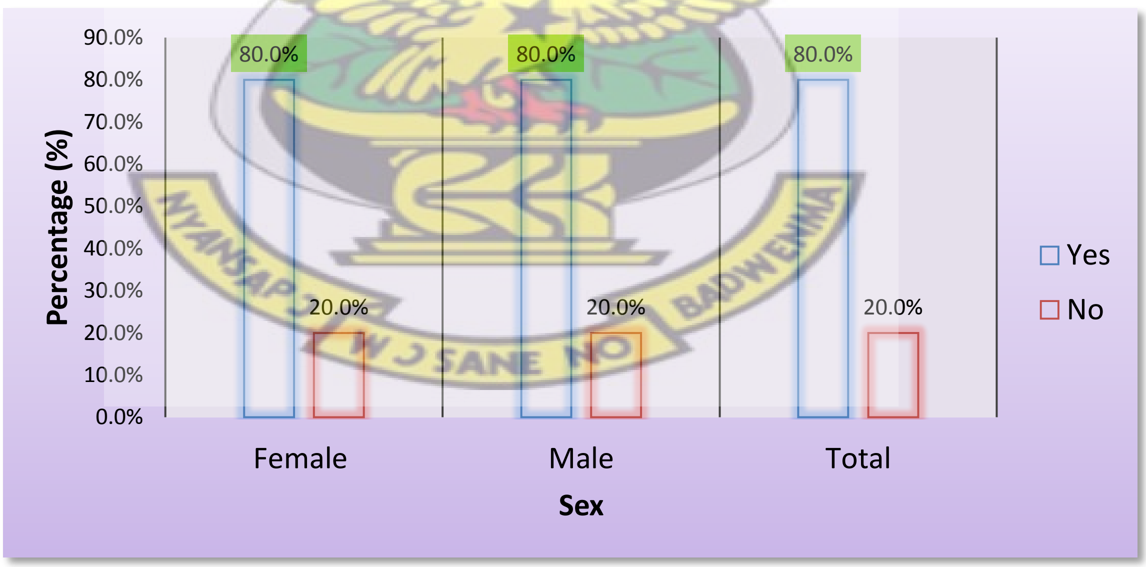

Figure 6: Application of safety precaution measures during spraying of pesticides

However, direct field observation showed that they do not completely protect themselves. Table 12 shows that only 39 farmers representing 68 percent use nose and mouth protector, 18 percent use protective cloth, 12 percent use gloves and only 1 farmer (1.8%) use goggle. Only 14 percent use more than one protective equipment.

Table 12: Use of protective equipment during pesticide application

Use of protective equipment	Responses		Percent of Cases
	N	Percent	
Use of nose and mouth protection	39	68.4%	78.0%
Special Clothing	10	17.5%	20.0%
Gloves	7	12.3%	14.0%
Goggle	1	1.8%	2.0%
Total	57	100.0%	114.0%

NB: Percent of cases more than 100% (multiple response analysis)

4.4 LEVELS OF ORGANOPHOSPHATE PESTICIDE RESIDUES

Eleven organophosphate pesticide residues were detected in the cabbage samples. These are ethoprophos, phorate, dimethoate, fonofos, pirimiphos-methyl, fenitrothion, malathion, chlorpyrifos, parathion, chlorfenvinphos and profenofos (Table 13).

Chlorpyrifos was detected in more samples (56.6%) than any other pesticide residue. This is followed by pirimiphos-methyl (26.7%), fenitrothion (26.7%) and profenofos (26.7%). The highest concentration of chlorpyrifos (0.02 mg/kg) was observed in the third sample from Pasuro but this was far below the MRL. Levels of chlorpyrifos detected in all samples fall below the MRL for cabbage. The EU maximum residual limit permitted in cabbage is 1.0 mg/kg.

In Adankwame, six (ethoprophos, phorate, fenitrothion, chlorpyrifos, parathion and chlorfenvinphos) pesticide residues were detected. Only 4 pesticide residues were detected in samples from Esaso and Esease. Pasuro recorded the highest level of pesticide residues with 10 pesticide residues detected (Table). All concentration of pesticide residues detected in the samples were within the permissible levels in food stipulated under the laws of the European Union Standards.

Table 13: Types and levels of Organophosphate pesticide residues in samples from five communities in the Atwima Nwabiagya district

Pesticide Residue	ABA	ABB	ABC	AKA	AKB	AKC	ATA	ATB	ATC	BKA	BKB	BKC	EAA	EAB	EAC
Methamidophos	Nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Ethoprophos	Nd	nd	nd	<0.01	nd	nd	<0.01	nd	nd	nd	<0.01	nd	nd	nd	nd
Phorate	Nd	nd	nd	<0.01	nd	nd	nd	nd	<0.01	nd	nd	nd	nd	nd	nd
Dimethoate	Nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	<0.01	nd	nd	nd
Fonofos	Nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	<0.01	nd
Pirimiphos-methyl	Nd	<0.01	<0.01	nd	nd	nd	nd	<0.01	nd	nd	nd	nd	nd	<0.01	nd
Fenitrothion	Nd	nd	nd	nd	<0.01	nd	nd	nd	nd	nd	<0.01	<0.01	nd	nd	nd
Malathion	<0.01	nd	nd	nd	nd	nd	nd	nd	<0.01	<0.01	nd	nd	nd	nd	nd
Chlorpyrifos	<0.01	<0.01	<0.01	nd	<0.01	nd	<0.01	nd	nd	<0.01	nd	nd	<0.01	nd	nd
Parathion	Nd	nd	nd	<0.01	nd	nd	nd	nd	nd	nd	nd	<0.01	nd	nd	nd
Chlorfenvinphos	<0.01	nd	nd	nd	<0.01	nd	nd	nd	nd	nd	nd	nd	nd	<0.01	nd
Profenofos	Nd	0.02	nd	nd	nd	nd	<0.01	nd	<0.01	nd	<0.01	nd	nd	nd	nd

ND= Not detected. The five communities were AB= Akwaboa, AK=Adankwame; AT=Atwima Koforidua; BK=Barekese and EA=Esaso. A-C in the last name refers to the three farmers at each village.

Table 14 b: Types and levels of Organophosphate pesticide residues in samples from five communities in Atwima Nwabiagya district (continued)

Pesticide Residue	ESA	ESB	ESC	KPA	KPB	KPC	NBA	NBB	NBC	NWA	NWB	NWC	PRA	PRB	PRC
Methamidophos	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Ethoprophos	nd	nd	nd	<0.01	nd	<0.01	nd	nd	nd	nd	<0.01	<0.01	nd	nd	nd
Phorate	nd	nd	nd	nd	nd	nd	nd	nd	nd	<0.01	nd	nd	nd	<0.01	<0.01
Dimethoate	nd	nd	nd	nd	nd	nd	nd	<0.01	nd	<0.01	nd	nd	nd	nd	nd
Fonofos	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	<0.01	nd	nd	nd
Pirimiphos-methyl	nd	nd	<0.01	nd	nd	nd	nd	nd	<0.01	nd	nd	<0.01	nd	<0.01	nd
Fenitrothion	nd	nd	nd	<0.01	nd	nd	<0.01	nd	nd	nd	<0.01	nd	nd	<0.01	<0.01
Malathion	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	<0.01	nd	nd
Chlorpyrifos	nd	0.01	<0.01	<0.01	nd	nd	<0.01	nd	<0.01	0.01	<0.01	nd	<0.01	<0.01	0.02
Parathion	nd	nd	<0.01	nd	nd	nd	nd	nd	<0.01	nd	nd	<0.01	nd	<0.01	<0.01
Chlorfenvinphos	nd	nd	nd	<0.01	<0.01	nd	nd	nd	nd	nd	nd	nd	nd	nd	<0.01
Profenofos	<0.01	nd	<0.01	nd	<0.01	0.02	nd	nd	nd	nd	nd	nd	nd	nd	nd

ND= Not detected. The five communities were ES= Esease, KP=Kapro; NB=Nwabi; NW=Nkawie and PR=Pasura. A-C in the last name refers to the three farmers at each village.

Table 14 shows the summary of pesticide residue concentrations detected. It shows low degree of variability as reported by their standard deviations. The highest pesticide residue concentration (0.02 mg/kg) was in the case of profenofos, and chlorpyrifos. The remaining pesticide residues recorded lower levels of concentrations (<0.01mg/kg).

Table 14: Summary of different pesticide residue concentrations detected in the pooled samples

Pesticide Residue	Number of samples detected	Min (mg/kg)	Max (mg/kg)	Mean (mg/kg)	Std. Deviation
Ethoprophos	7	0.01	0.01	0.0100	±0.00000
Phorate	5	0.01	0.01	0.0100	±0.00000
Dimethoate	3	0.01	0.01	0.0100	±0.00000
Fonofos	2	0.01	0.01	0.0100	±0.00000
Pirimiphos_methyl	8	0.01	0.01	0.0100	±0.00000
Fenitrothion	8	0.01	0.01	0.0100	±0.00000
Malathion	4	0.01	0.01	0.0100	±0.00000
Chlorpyrifos	17	0.01	0.02	0.0106	±0.00243
Parathion	7	0.01	0.01	0.0100	±0.00000
Chlorfenvinphos	6	0.01	0.01	0.0100	±0.00000
Profenofos	8	0.01	0.02	0.0125	±0.00463

4.5 CONCENTRATION OF THE PESTICIDE RESIDUES IN THE VARIOUS LEAFY LAYERS

Table 15 shows the types and concentrations of oganophosphate pesticide residues in various leaf layers of cabbage. Six organophosphate pesticide residues (ethoprophos, dimethoate, fenitrothion, malathion, parathion and profenofos) were detected in the first layer; 7 (phorate, dimethoate, pirimiphos-methyl, malathion, chlorpyrifos, parathion and profenofos) organophosphate pesticide residues were detected in the second layer. The third layer contained only chlorpyrifos at 0.01 mg/kg which is far below the MRL.

Table 15: Types and levels of organophosphate pesticide residues in the various leafy layers

Pesticide residue	**LY1**	**LY2**	**LY3**
Methamidophos	nd	nd	nd
Ethoprophos	<0.01	nd	nd
Phorate	nd	<0.01	nd
Dimethoate	<0.01	<0.01	nd
Fonofos	nd	nd	nd
Pirimiphos-methyl	nd	<0.01	nd
Fenitrothion	<0.01	nd	nd
Malathion	<0.01	<0.01	nd
Chlorpyrifos	nd	0.01	0.01
Parathion	<0.01	<0.01	nd
Chlorfenvinphos	nd	nd	nd
Profenofos	<0.01	<0.01	nd

nd= Not detected; LY1 refers to first outer layer, LY2 refers to the second outer layer and LY3 the third outer layer.

CHAPTER FIVE

5.0 DISCUSSION

5.1 SOCIO-ECONOMIC CHARACTERISTICS OF RESPONDENTS

In this study 60% of the farmers were between the ages of 30 and 40 years. Similar results were obtained by other researchers in Brazil and Nepal (Recena *et al*., 2006; Atreya 2007). The present study indicated that more males (80%) were into cabbage cultivation presumably because of the labour intensive nature of cabbage production. The educational background of the farmers in the study area was low. Most of the respondents (67.5%) had basic education while 27% mostly males had secondary education. Similar results are reported in pertinent literature for developing countries (Hurtig *et al*., 2003; Recena *et al*., 2006; Oliveira-Silva *et al*., 2001; Mekonnen & Agonafir, 2002). None of the respondents had tertiary education, presumably because agriculture is less attractive for graduates in this country.

5.2 FARMERS KNOWLEDGE ABOUT PESTICIDES USAGE

It was observed that most of the farmers (82%) do not combined pesticides for spraying, as the practice could put the farmer at risk due to the synergistic or potentiating effects of chemicals (Allaby, 1994). Contrary to the findings of Amoako (2008), sixty one percent (61%) of cabbage farmers in the Ejisu-Juaben Municipality mixed different pesticides together for spraying. The prevalence of mixing two or more pesticides and using more than the recommended concentration of pesticides was also prevalent among farmers in West Bank, Palestine (Sa'ed et al.2010). The other 18% of the respondents who combine two or more chemicals pesticides for spraying do so to ensure rapid control of the insect pests. This result is consistent with Ntow *et al*. (2006), some farmers believe mixing of pesticides give a good result. Mixing of pesticides was encouraged by the farmers' desire to have rapid knockdown of pests. The practice defies some of the basic principles of insecticide management. For instance, Metcalf (1980), recommended that the use of mixtures of insecticides must be avoided, since mixtures of insecticides generally result in the simultaneous development of resistance.

In this present study majority 94% of the farmers interviewed did not continue spraying while harvesting. Most of the farmers in the study area were aware of the harmful effect on the environment and human alike. Most of the farmers allow one to two weeks interval after the last spraying before harvesting (pre-harvest interval).The adherence of farmers to this good farm practice might have attributed to the low level pesticides residues of the cabbage samples that were analysed in the laboratory. Majority of the respondents representing (46 %) sprayed pesticides 1-5 times before harvesting. The number of sprays per crop season, however, varied among different weather conditions, locations and variety of cabbage.

For the same period of cabbage life cycle, spraying intervals also vary. Most farmers (66%) do pesticide application within 7-14 days after the previous application.

Most of the farmers (78%) used one or more protective measures during pesticides application which is an indication of good pesticides use knowledge of farmers. This is agrees with the report of Sa'ed *et al*. (2010).

5.3 TYPES OF PESTICIDES USED BY FARMERS

Pests and diseases are major problems in vegetable production. All respondents in the present survey sprayed their crops with pesticides to control pests and diseases. Indeed, pesticides were used extensively on vegetable farms, small or large, and farmers used a wide range of chemicals as herbicides, fungicides and/or insecticides (Ntow *et al*. 2006).

From the survey, fourteen (14) different pesticides were used by the cabbage farmers in the Atwima Nwabigya District. These included six (6) organophosphates, seven (7) pyrithroids and one (1) biopesticide; refer to (Table 6).

Some of the organophosphates pesticides used on cabbage in Atwima Nwabiagya District include Sunpyrifos, Pyrinex 48EC, Dursban 4E, Perferthion, Frankophos and Termex. Armah (2010) also observed that cabbage farmers in Cape Coast use pesticides that contain chlorpyrifos such as Desbin, Dursban 4E and Pyrinex. This suggest that chlorpyrifos based pesticides is one of the major pesticides cabbage farmers use to control insect pests in Ghana. Farmers in the study area chose to use these pesticides because they are effective (72%) and the prices are affordable (24%). Respondents indicated that chlorpyrifos based pesticides are more effective in controlling cabbage pest.

5.4 ORGANOPHOSPHATE PESTICIDE RESIDUESIN CABBAGE

Eleven (11) organphosphate pesticide residues were detected in cabbage samples. The highest pesticide residue concentration was attributable to profenofos, and chlorpyrifos (0.01-0.02 mg/kg). However, none of the pesticide residues detected was above the Maximum Residue Limits for cabbage (Tables 2 and 3). This may be attributed to the fact that farmers adhere to proper use of pesticides and as such harvesting was done 14 days after pesticide application which allow most pesticide residues to decompose or degrade.

Methamidophos was not detected in any cabbage sample from the district. This result agrees with Armah (2010) who reported that methamidophos was not detected in any of the samples. This may be attributed to the fact that farmers do not use pesticides that contain methamidophos as an active ingredient or presumably complete decomposition of methamidophos has already taken place before the analysis was carried out.

Armah (2010) detected high levels of allethrin above MRL for cabbage in Ameen Sangari industries and University of Cape Coast Technology farm. Residues of ethoprophos detected in cabbage from vegetable farm behind Ameen Sangari industries were above the maximum residue limit by factors ranging from 58.3 and 80.1. In this study residual levels were lower than what was reported by Armah (2010) given the fact that most of the levels of pesticide residues detected were below the MRL for cabbage. It is important to note that Armah (2010) carried out his studies under different agro-climatic condition and different socio-economic characteristics of respondents. Furthermore, farmers knowledge about pesticide usage may vary as one move from one agro-climatic condition to another. This study however confirms the work of Ripley *et al.* (2000) who reported that pesticide residues in vegetables (cabbage) and fruits in Canada to be far below the MRLs.

Essuman *et al.* (2008), found high levels of lambda-cyhalothrin, chlorpyrifos, fenitrothion and cypermethrin residues in tomatoes above their respective MRL values. However, this work was done on tomatoes obtained from market places in Kumasi in the Ashanti Region and Cape Coast in the Central Region of Ghana. It should be noted that application of pesticides on tomatoes differ from that on cabbage with respect to dosage and frequency of application.

5.5 LEVELS OF ORGANOPHOSPHATE PESTICIDE RESIDUES IN THE VARIOUS GROUPS OF LEAFY LAYERS

Nine (9) organophosphate pesticide residues were detected in all the various leafy layers of the cabbage samples (Table 17). Most of the pesticide residues were detected in the first two groups (layer 1 and 2) of the leafy layers. With the exception of chlorpyrifos none of the organophosphate pesticide residues were detected in the third layer. All the organophosphate pesticide residues detected had residual level of 0.01 mg/kg or less which is far below the MRL.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 SUMMARY AND CONCLUSION

The research work was carried out into in two phases. The result of the field survey revealed that as many as 14 different pesticides were used to control insect pests on cabbage production in the Atwima Nwabiagya District. Majority of these pesticides has chlorpyrifos as its active ingredient. The field survey showed that cabbage farmers in the district have some appreciable knowledge about pesticides and its application or use. Eighty two percent (82%) of the sampled population did not combine different pesticides for spraying activities at a particular time, being aware of its possible consequences.

The field survey also indicated that a fairly good number of the cabbage farmers use the right dosage of the pesticides and also allowed 10-14 days pre-harvest interval. In addition, most of the farmers did not use protective clothing when handling or applying the pesticides, although most of them were aware of the possible health applications of their actions.

In the laboratory analysis, eleven (11) organophosphate pesticide residues were detected in the samples. Chlorpyrifos was detected in most of the cabbage samples (56%) than any other pesticide residue. Both the field survey and the laboratory analysis revealed that chlorpyrifos is the main pesticide cabbage farmers in the district use in controlling insect pest.

The laboratory analysis also showed that most of the organophosphate pesticides used by the cabbage farmers do not leave any high levels of pesticides residues in the vegetable, even those that were detected in the laboratory analysis (0.01mg/kg -0.02mg/kg) were below both EU Maximum Residual Limits (MRLs) and CODEX MRLs permitted in cabbage. The laboratory analysis revealed different organophosphate pesticide residues can be found in the first 10 layers of cabbage but a very low concentrations the inner most layers may not have any pesticide residues.

6.2 RECOMMENDATIONS

1. The Ministry of Food and Agriculture (MoFA), Environmental Protection Agency should intensify the education, training and information dissemination activities on pesticides and their effects on health in all the farming communities in the country, especially communities noted for the production of vegetables. This will help minimise the mishandling and misuse of pesticides which is becoming health threat to both consumer and growers.
2. The Ministry of Food and Agriculture and NGOs should also have to encourage and advise farmers to continue to apply the pesticides with the right dosage and time interval. They should be made to appreciate how far their activities in the farm negatively affect the health of consumers.
3. The Environmental Protection Agency, Chemical sellers and MoFA should encourage vegetable farmers to use Organophosphate based pesticides to control pest on their products since it biodegrade faster and less or no pesticide residues on the vegetables as compare to other classes of pesticides.
4. The Ministry of Food and Agriculture and NGOs, should help to clear the notion that cabbage grown in Ghana contain high levels pesticide residues. Because this

research has revealed that the levels of pesticide residues on cabbage is far below the European Union (EU) MRLs permitted on cabbage.

5. The availability and the use of protective clothing by farmers should be ensured by appropriate bodies such as the government, chemical sellers, since they are the most appropriate measures at which risks and hazards associated with the use of these chemicals can be controlled.
6. Much research work should be done by the Scientific Community such as the CSIR and the Universities to come out with more pest and disease resistant cultivars of cabbage to minimise the amount of pesticides use. The use of genetically modified (GM) variety to address the pest and disease constraints is therefore an option worth examining.

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APPENDICES

Appendix 1: Questionnaire

1. PROFILE OF THE FARMER:
AGE: [ ]
GENDER: Male [ ] Female [ ]
EDUCATION: ....

2. LOCATION: ....

3. STATE THE TYPES OF PESTICIDES USED TO CONTROL INSECT PESTS ON CABBAGE.

4. DO YOU USE COMBINATION OF PESTICIDES IN CONTROLLING INSECT PESTS
IN A GROWING SEASON? *(Tick)*
(i) YES [ ]
(ii) NO [ ]

5. IF YES, NAME THEM (COMBINATION OF PESTICIDES)

6. ACTIVE INGREDIENTS OF PESTICIDES MENTIONED ABOVE.

7. STATE THE DOSAGE OF APPLICATION OF PESTICIDES MENTIONED ABOVE.

8. REASON(S) FOR CHOOSING PARTICULAR PESTICIDES *(tick):*
(i) Price is moderate [ ]
(ii) Efficiency of eliminating/controlling insect pests [ ]
(iii) Easily available [ ]
(iv) Others [ ] (Specify)..

9. WHEN DO YOU DECIDE TO APPLY PESTICIDES ON YOUR CABBAGE? *Tick)*
(i) Presence of pest on basis of scouting [ ]
(ii) Spray on routine schedule [ ]
(iii) Agric Extension Agent's recommendation [ ]
(iv) Agro chemical dealer's recommendation [ ]
(v) Colleague farmer's recommendation [ ]
(vi) Others [ ] (Specify)..............................

10. FREQUENCY OF SPRAYING IN A GROWING SEASON (*Tick)*
(i) 1- 5 times [ ]
(ii) 6 – 10 times [ ]
(iii) 11 – 15 times [ ]
(iv) 16 – 20 times [ ]

(v) Others [ ] Specify..

11. EFFICIENCY OF PESTICIDES IN TERMS OF ELIMINATING/CONTROLLING INSECT PESTS *(tick)*
(i) Very effective (80-90%) [ ]
(ii) Effective (60 -70%) [ ]
(iii) Moderate (40-50%) [ ]
(iv) Poor (below 40%) [ ]

12. TIME OF THE DAY THAT SPRAYING USUALLY TAKES PLACE *(tick).*
(i) Morning [ ]
(ii) Afternoon [ ]
(iii) Evening [ ]

13. SPRAYING INTERVALS *(tick).*
(i) 2 days [ ] (v) 6 days [ ]
(ii) 3 days [ ] (vi) weekly [ ]
(iii) 4 days [ ] (vii) others [ ] Specify....................................
(iv) 5 days [ ]

14. DO YOU CONTINUE SPYAING WHILE HARVESTING? *(tick)*
(i) YES [ ]
(ii) NO [ ]

15. IF NO, STATE SPRAYING INTERVAL BETWEEN LAST SPRAYING AND HARVESTING.
(i) 1- 3 days [ ]
(ii) 4 -6 days [ ]
(iii) 7 – 10 days [ ]
(iv) 11 – 14 days [ ]
(v) Others [ ] Specify...

16. DO YOU TAKE ANY SAFETY PRECAUTIONARY MEASURES DURING SPRAYING OF PESTICIDES?
(i) YES [ ]
(ii) NO [ ]

17. IF YES, INDICATE (*tick*).
(i) The use of nose and mouth protection [ ]
(ii) Special clothing [ ]
(iii) Hand gloves [ ]
(iv) Eye goggle [ ]
(v) Others [ ] Specify...

18. TYPE OF SPRAYING MACHINE USED *(Tick.)*
(i) Motorized spraying machine [ ]

(ii) Knapsack spraying machine [ ]
(ii) Others [ ] Specify..

19. STATE THE DISTANCE BETWEEN ONE CABBAGE FARM AND ANOTHER (*tick*).

(i) 50 m [ ] (ii) 100m [ ] (iii) 150m [ ]

(iv) Others [ ] Specify...

Table 16: Respondents Highest Educational level and Age by Gender

Socioeconomic variables	Females		Males		Total	
	N	%	N	%	N	%
Education						
SHS	2	20.0%	8	20.0%	10	20.0%
JHS/MSLC	7	70.0%	27	67.5%	34	68.0%
None	1	10.0%	5	12.5%	6	12.0%
Total	10	100.0%	40	100.0%	50	100.0%
Age						
Less than 40	6	60.0%	24	60.0%	30	60.0%
More than 40	4	40.0%	16	40.0%	20	40.0%
Total	10	100.0%	40	100.0%	50	100.0%

Source: Field Survey, June, 2013

Appendix 2: Laboratory Results

Organochlorine

mg/kg	**Organochlorine**	ABA	ABB	ABC	AKA	AKB	AKC	ATA	ATB	ATC	BKA	BKB	BKC	EAA	EAB	EAC
BHC	Beta-HCH	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
DHC	Delta-HCH	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
PDE	p,p'-DDE	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
DIE	Dieldrin	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
END	Endrin	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
AEN	Alpha-Endosulfan	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
BEN	Beta-Endosulfan	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
ENS	Endosulfan Sulfate	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
PDD	p,p'-DDD	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
PDT	p,p'-DDT	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
GHC	Lindane	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
HEP	Heptachlor	<0.01	<0.01	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	<0.01	nd	nd
ALD	Aldrin	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
GCH	Gamma Chlordane	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
MET	Methoxychlor	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
DIA	Diazinon	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	<0.01	nd	nd

ND= Not detected. The five communities were AB= Akwaboa, AK=Adankwame; AT=Atwima Koforidua; BK=Barekese and EA=Esaso. A-C in the last name refers to the three farmers at each village.

Organochlorine (mg/kg)

	Organochlorine	ESA	ESB	ESC	KPA	KPB	KPC	NBA	NBB	NBC	NWA	NWB	NWC	PRA	PRB	PRC
BHC	Beta-HCH	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
DHC	Delta-HCH	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
PDE	p,p'-DDE	nd	nd	<0.01	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	<0.01
DIE	Dieldrin	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
END	Endrin	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
AEN	Alpha-Endosulfan	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	<0.01	<0.01
BEN	Beta-Endosulfan	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	<0.01	nd
ENS	Endosulfan Sulfate	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
PDD	p,p'-DDD	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
PDT	p,p'-DDT	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	<0.01	nd
GHC	Lindane	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
HEP	Heptachlor	<0.01	<0.01	<0.01	nd	nd	nd	nd	nd	<0.01	nd	nd	nd	nd	nd	<0.01
ALD	Aldrin	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
GCH	Gamma Chlordane	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
MET	Methoxychlor	nd	nd	<0.01	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
DIA	Diazinon	nd	nd	<0.01	<0.01	nd	nd	nd	nd	<0.01	nd	nd	nd	nd	<0.01	nd

ND= Not detected. The five communities were ES= Esease, KP=Kapro; NB=Nwabi; NW=Nkawie and PR=Pasura. A-C in the last name refers to the three farmers at each village.

Pyrethroids

Pyrethroids	ABA	ABB	ABC	AKA	AKB	AKC	ATA	ATB	ATC	BKA	BKB	BKC	EAA	EAB	EAC
Bifenthrin	nd	<0.01	Nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Fenpropathrin	nd	nd	Nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Lambda-cyhalothrin	nd	<0.01	Nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Permethrin	nd	nd	Nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Cyfluthrin	nd	nd	Nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	<0.01	nd
Cypermethrin	nd	nd	Nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Fenvalerate	nd	nd	Nd	nd	nd	nd	nd	nd	nd	nd	nd	<0.01	nd	nd	nd
Deltamethrin	<0.01	nd	Nd	nd	nd	nd	nd	nd	nd	nd	nd	<0.01	nd	nd	nd
Allethrin	nd	nd	Nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd

ND= Not detected. The five communities were AB= Akwaboa, AK=Adankwame; AT=Atwima Koforidua; BK=Barekese and EA=Esaso. A-C in the last name refers to the three farmers at each village.

Pyrethroids (continued)

Pyrethroids	ESA	ESB	ESC	KPA	KPB	KPC	NBA	NBB	NBC	NWA	NWB	NWC	PRA	PRB	PRC
Bifenthrin	nd	nd	Nd	nd	nd	nd	nd	<0.01	nd	nd	nd	nd	nd	<0.01	nd
Fenpropathrin	nd	nd	Nd	nd	nd	nd	nd	<0.01	nd	nd	nd	nd	nd	nd	nd
Lambda-cyhalothrin	nd	nd	Nd	nd	nd	nd	nd	<0.01	nd	nd	nd	nd	nd	nd	nd
Permethrin	nd	nd	Nd	nd	nd	nd	nd	<0.01	nd	nd	nd	nd	nd	nd	nd
Cyfluthrin	nd	nd	Nd	nd	nd	nd	nd	<0.01	nd	nd	nd	nd	nd	nd	nd
Cypermethrin	nd	nd	Nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Fenvalerate	nd	nd	<0.01	nd	<0.01	nd	nd	<0.01	nd	nd	nd	nd	<0.01	<0.01	nd
Deltamethrin	nd	nd	Nd	nd	<0.01	nd	nd	nd	nd	nd	nd	<0.01	nd	nd	nd
Allethrin	nd	nd	Nd	nd	nd	nd	nd	<0.01	nd	nd	nd	nd	nd	nd	nd

ND= Not detected. The five communities were ES= Esease, KP=Kapro; NB=Nwabi; NW=Nkawie and PR=Pasura. A-C in the last name refers to the three farmers at each village.