KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

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INSTITUTE OF DISTANCE LEARNING

DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

ORGANOCHLORINE INSECTICIDE RESIDUE IN FRESH TOMATOES (*Lycopersicon esculentum*) AT THE FARM GATE AND MARKET. A CASE STUDY OF THE FANTEAKWA DISTRICT OF EASTERN REGION OF GHANA.

BY

GEORGE PRAH

OCTOBER, 2013

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BY

GEORGE PRAH

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DECLARATION

I, George Prah hereby declare that, except for references to other people's work which have been duly acknowledged, this write-up, submitted to the Institute of Distance Learning, School of Research and Graduate Studies, KNUST, Kumasi is the result of my own original research and that this thesis has not been presented for any degree elsewhere.

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(HEAD OF DEPARTMENT)

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ABSTRACT

Insect pests control is a major challenge in vegetable (tomato) production. The use of various insecticides in the management of insect pests over the years has proven effective. However, the use of pesticides in tomato production comes with various environmental and health issues such as residual effects.

The objective of this research was to ascertain the kind of insecticides being used by farmers to control insect-pests, the mode of application of insecticides and their effects on the quality and safety of tomato produced. The research also sought to determine the levels of organochlorine insecticides in tomatoes at the farm gate and on the market, and to compare the residue level in the various varieties with the international Maximum Residue Level (MRL).

The concentrations of organochlorine insecticide residues in four tomato varieties from seven farming communities in Fanteakwa District (Ntanuam, Krobo Meyiwa, Oboroahoho, Ofosukrom, Apaah, Akoradarko and Dedeso) and three markets (Ahomahomaso, Begoro and Ehiamankyene) were determined using gas chromatography in May and June 2012.

It was observed that 36.6% of the farmers interviewed used and combined hazardous insecticides on their fields with no idea of the active ingredients and their effects on human health and environment. Thus Confidor which is made to control insect pests of cocoa plants are often used by farmers to control insect pests on tomato fields.

Laboratory analysis confirmed that insecticide residues were indeed present in the tomato. A total of twenty different organochlorine insecticides were detected in almost all the samples. The concentrations ranged between 0.0001 to 0.0091 mg/kg. DDT was one of the most abundant with high residual levels detected in all 10 (100 %) samples analyzed, having a concentration range 0.0014 to 0.0091 mg/kg and mean of 0.0058 mg/kg.

The average levels of organochlorine residues in tomatoes sampled in this study were generally below EU MRLs. Therefore, tomatoes from Fanteakwa are safe for consumption.

However, in view of the damaging effects on human health and the environment, regular monitoring and analysis of organochlorine residues in the study area is recommended.

ABBREVIATIONS

A-HCH	Alpha Hexachlorocyclohexane
ANOVA	Analysis of Variance
ATSDR	Agency for Toxic Substances and Disease Registry in the United States
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
EPA	Environmental Protection Agency
EU	European Union
FAO	Food and Agricultural Organization of the United Nations
FASDEP	Food and Agricultural Sector Development Policy
GAEC	Ghana Atomic Energy Commission
GC	Gas Chromatography
HCB	Hexachlorocyclobenzene
HCH	Hexachlorocyclohexane
mg/kg	Microgram per kilogram
MRL	Maximum Residual Limit
MSLC	Middle School Leaving Certificate
ND	Not Detected
OCPs	Organochlorine Pesticides
PPRSD	Plant Protection and Regulatory Services Directorate
sq. km	Square Kilometer
SPSS	Statistical Package for the Social Sciences
USEPA	United States Environmental Protection Agency
WHO	World Health Organization

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CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Ghana's agriculture is characterized by rainfed, low yields and productivity. Although a number of factors contribute to this low agricultural productivity, constraints on technology availability and use are crucial.

The distance or gap between yields that could be achieved from application of recommended practices and actual average yields for most traditional staple crops ranges from 200 to 300% in Ghana (Al-Hassan and Diao, 2007). Such yield gap estimates are not available for vegetable crops, but it is not hard to speculate that similar shortfalls in yields exist in these crops. Low yields and productivity are compounded in the long-run by production shocks due to environmental stresses such as drought, pests, and diseases.

Several hundred pesticides of different chemical nature are widely applied to crops throughout the world. These pesticides provide unquestionable benefits for increasing agricultural production. However, fruit and vegetables usually receive direct application of pesticides in the field or in post-harvest treatment and may retain a proportion as residues in or on the edible portion delivered to the consumer (Maria *et al.*, 1999).

Therefore, public concern about the contamination of food by pesticides has been increasing over the past years due to the uncertainty about the adverse effect those residues may pose over a long-time exposure.

The toxicity of most pesticides and the consumption of raw fruit and vegetables reinforce the concern for contamination of these food substances over other foods (Jos´e *et al.*, 2004). As a result, levels of pesticides in different food items are regulated by international and national organizations in order to protect human health (Flemming, 1981). That is, for the protection of the public against the toxic effects of pesticides, regulatory agencies in many countries have established standards specifying the residue levels of each pesticide in various foodstuffs. At an international level, the WHO, in conjunction with the FAO, has been convening Joint FAO/WHO Meetings on Pesticide Residues annually since 1961. At these meetings, the toxicological and related data are evaluated for the establishment of an acceptable daily intake or provisional tolerable daily intake (Krbic, 2007).

Many African countries are not food secured, resulting in a situation where at least 60% of the food supply is imported to supplement local production. Thus guaranteeing the safety of both imported and locally produced food begins on the farm or at the port and follows through the entire food chain until meals are on the table (WHO, 2005).

1.2 Problem Statement

The livelihood of the average Ghanaian depends either on agriculture or agriculture related business. However, high pre and post-harvest losses due to pests are a major problem for the productivity in the agricultural sector.

Generally, agriculture, particularly vegetable farming, is fraught with abuse, misuse and overuse of pesticides (Asante and Ntow, 2009) Pesticides have become an integral part of Ghanaian agriculture, being used on a number of commodities including vegetables and vegetable farms. It is estimated that 87% of farmers in Ghana use chemical pesticides to manage pests and diseases on vegetables (Dinham, 2003). Of the pesticides used, 44% are herbicides, 33% are insecticides and 23% are fungicides (Ntow *et al*., 2006). Organochlorine pesticides have been used in Ghana for more than 40 years, for agriculture and public health purposes with their residues having been found in water, sediments and crops and in humans (Ntow, 2001).

Vegetables tend to be more susceptible to biotic constraints than are other crops. That notwithstanding, 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-(FASDEP II, 2009).

1.3 Justification

According to Treshow (1970), the hazards and detrimental effects of many agricultural chemicals might well outweigh the benefits derived, if they are not used with discrimination and sagacity. Pesticides have been used in the public health sector for disease vector control and in agriculture to control and eradicate crop pest for the past several decades in Ghana (Clarke *et al.*, 1997). However, there has been a rapid rise in the quantity of pesticides used in Agriculture over the past ten years (Hogson, 2003).

Most pesticides used in Agriculture are employed in the forest zones located in the Ashanti, Brong Ahafo, Western, and Eastern regions of the country (Amoah *et al.*, 2006). Pesticide residues in food items have been a concern to environmental and consumer groups of their wide spread use. Most pesticides especially, organochlorines are very resistant to microbial degradation. They can therefore, accumulate in human body fats and the environment posing problems to human health (Ejobi *et al*., 1996).

Pesticides are considered to be indispensable for the production of adequate food supply for an increasing world population and for the control of insect-borne diseases. Many pesticides are, however, toxic substances and persistent in character. Some of the pesticides are endocrine disrupting compounds (Kluive, 1981).

Over the last two decades there have been growing issues of societal concerns related to public health, environmental quality and food safety. One of the major controversies inciting these concerns involves production and consumption of fresh fruits and vegetables. There is a general belief that diets with greater proportions of fruits and vegetables can prevent or delay a number of debilitating and life-threatening diseases.

However, public acceptance and adoption of these findings is being discouraged by the possible health risk associated with minute amount of pesticide residues, sometimes found in or on these foods. There is, therefore, the need to put in place measures to ensure the safety of farmers and consumers, as well as protecting crops from insect pests.

Many vegetables are consumed fresh or slightly cooked. As a result of the intensive nature of vegetable production common in the urban areas of Ghana, public health is threatened from the use of pesticides on these vegetables.

Pesticide usage in Ghana, therefore, continues to increase as agricultural production is on the increase. However, associated with the increased use of pesticides are environmental and health problems which have arisen due to indiscriminate use and inappropriate handling of the chemicals. Farmers often spray hazardous insecticides like organophosphates and organochlorines up to five or more times in a cropping season when perhaps two or three applications may be sufficient.

1.4 Significance of the Study

One of the major objectives of the Ministry of Food and Agriculture is attaining food security and putting in place emergency preparedness systems (FASDEP II, 2009). This has led to the promotion of crop intensification. However, this agricultural intensification and the threat of pesticide in its widespread use together with very little published information on the levels of insecticides in different environmental compartments make individual interventions in food safety ineffective. In fact there are regulations concerning registration and use of insecticides in Ghana, but there are still some insecticides like OCs in use that have been restricted in some industrialized countries (Malin, 2004).

The study of the levels of insecticide residue in food items is limited in the country. Therefore, the contamination status of vegetables by insecticide residues is limited and known to a few crops in some urbanized areas. This calls for an extensive study of the residue status of agricultural products. To this effect the main focus of this work is to determine the organochlorine insecticide residues in tomato samples available at the farm gate and Fanteakwa market in the Eastern Region of Ghana. Thus the study will be significant to show preliminary data regarding the pollution status of some tomato varieties by organochlorine insecticides.

1.5 Objectives

1.5.1 Main Objective

To determine the levels of organochlorine insecticide concentration in fresh tomato varieties at the farm gate and Fanteakwa market.

1.5.2 Specific Objectives

1. To assess farmers knowledge on insecticide use and agronomic practices.
2. To find out the effects of organochlorine insecticides on the quality and safety of tomato.

3. To determine the residue levels of organochlorine insecticides in the different varieties of tomato at the farm gate and at the market.

CHAPTER TWO

LITERATURE REVIEW

2.1 History of Tomato

Tomato (*Lycopersicon esculentum* Mill.) is a fruity vegetable, which belongs to a large family of plants known as *Solanaceae,* with the common name, the nightshades. The crop is a perennial, which is usually grown as an annual (Norman, 1992).

Tomato is believed to have originated from the Western Coastal Plains of South America, extending from Ecuador to Chile (Harlan, 1992). The crop was introduced into Ghana in the sixteenth or seventeenth century by the Portuguese and has since become the most popular vegetable crop (Norman, 1992; Nkansah *et al.*, 2003). Its versatility in fresh or processed form has played a major role in its rapid and widespread adoption as an important food commodity in Ghana (Norman, 1992; Horna *et al.*, 2006 and Asare-Bediako *et al.*, 2007).

Tomato production in Ghana is mainly a smallholder activity, and its distribution throughout the year is markedly seasonal with a few large scale ventures at designated irrigation sites (FAO, 2005).

Commercially, the small-scale production is concentrated in four out of the five agro-ecological zones, namely Forest, Forest-Savanna Transition, Coastal savanna and Sudan savanna. In the national economy, tomato exports contribute significantly to the foreign exchange portfolio as exemplified by the $437,000 accrued to the country from exports of 4,368 metric tonnes in 2003 (FAO, 2005).

2.2 Importance and Nutritional/Health Benefits Of Tomato

Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular and widely consumed vegetables in the world (Norman,1992).The crop has developed into a great number of cultivated types suitable to different environments, method of production, and food uses. According to Di Mascio *et al*. (1998), tomatoes are major sources of lycopene, a dietary carotenoid found in high concentrations in processed tomato products. This compound is an antioxidant known to combat cancer, heart diseases and premature aging (Wener, 2000).

Tomatoes are high in vitamins A, B and C and also contain good amounts of potassium, iron, and phosphorus (Wener, 2000). Fresh tomatoes and canned tomato products such as concentrates, puree and paste, are increasingly in demand in West Africa where they form an essential part of the diet of the inhabitants (FIAN, 2007).

In Ghana, tomato is probably the most important vegetable grown, and a wide range of areas are suitable for its production (FAO, 1995). It is grown in the forest, transitional and savannah zones (Norman, 1992). According to Wolff (1999), vegetables account for 9.6% of total food expenditure and 4.9% of total expenditure in Ghana, and tomato alone makes up to 38% of the vegetable expenditure. Tomato production is an important source of income for smallholder farmers. In recent years, domestic tomato production has intensified across Ghana but local production is not able to meet the domestic high demand and therefore tomatoes are often imported, mainly from Burkina Faso (Horna *et al.*, 2006).

2.3 Pesticides History and Uses

Pesticide means any substance intended for preventing, destroying, attracting, repelling or controlling any pest including unwanted species of plants or animals during production, storage, transport, distribution and processing of food, agricultural commodities or animal feeds or which may be administered to the animals for the control of ectoparasites. The term includes substances intended for use as a plant growth regulator, defoliant, dessicant, fruit thinning agent and substances applied to the crops either before or after harvest to protect the commodity from deterioration during storage and transport. The term normally excludes fertilizers, plant and animal nutrients, food additives and animal drugs (WHO, 1990).

In history it is known that chemicals have been used to kill or control pests for centuries. The Chinese used arsenic to control insects, the early Romans used common salt to control weeds and sulphur to control insects. In the 1800s pyrethrin was found to have insecticidal properties. Another material developed for insect control in the 1800s was Paris green, a mixture of copper and arsenic salts. Fungi were controlled with Bordeaux mixture, a combination of lime and copper sulphate (Hodgson, 2004)

However, it was not until the 1900s that the compounds were identified as having pesticidal properties came into being. Petroleum oils, distilled from crude mineral oils were introduced in the 1920s to control insects and red spider mites. In 1940s, chlorinated hydrocarbon insecticides such as DDT and the phenoxy herbicides were created to eradicate the Japanese rice crop, and later used as a component of Agent Orange to defoliate large areas in jungle warfare. After World War II these chemicals have been providing enormous benefits for increasing agricultural production (Margaret *et al*., 2004).

2.3.1 The Use of Pesticides for the Control of Insect Pests

According to Gruzdyer *et al*., (1983) about 70,000 species of insects and mites attack all parts of agricultural plants in their growth phase or in storage and about ten thousand species of them cause substantial economic harm.

Stiling (1985) reported that first records of insecticides were made as far back as the year 2500 BC. A real revolution in the chemical protection of plants was, however, made by the appearance in the early 1940's of contact insecticide from a group of chlorinated hydrocarbons such as dichloro-diphenyl-trichloroethane (DDT), hexachloro-cylohexane (HCH), aldrin and dieldrin. These were distinguished by their exceptionally broad spectrum of action and cheapness of manufacture (Gruzdyer *et al*., 1983).

Since 2000 BC humans have utilized pesticide to protect their crops. The first known pesticide was elemental Sulphur dusting used in Somalia about 4500 years ago. By the 15th century, toxic chemicals such as Arsenic, Mercury and Lead were being applied to crops to kill pest. In the 17th century Nicotine Sulphate was extracted from tobacco leaves for use as an insecticide. The 19th century saw the introduction of two more natural pesticides, pyrethrum which is derived from chrysanthemums and rotenone which is derived from the roots of tropical vegetables (Miller, 2002).

In 1939, Paul Muller discovered that DDT was a very effective insecticide. It quickly became the most widely used pesticide in the world. In the 1940's, manufacturing began to produce large amounts of synthetic pesticides and their use became widespread. Some sources consider the 1940's and 1950's to have been the start of pesticide era (Murphy, 2005).

Pesticide use has increased fifty fold. Since 1950, 2.3 million tons of industrial pesticides are now used each year (Miller, 2002). Seventy-five percent (75%) of all pesticides in the world is used in the developed countries but use in the developing countries is increasing (Miller, 2004).

2.3.2 Pesticide Residues in Vegetables

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 this pesticide contamination is legal, but does not mean it is safe. Much of it is illegal, with residues found in excess of regulatory safe levels. Identifying and determining the level of trace contaminants in our food and environment is critical in protecting and improving human health and the environment.

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 (Essumang *et al*., 2008)

As part of a programme aimed at promoting safe and sound agricultural practices in Ghana, a study was made on farmers' perception of pesticides use and application in vegetable production, using a small survey of 137 farmers who applied pesticides (Ntow *et al*., 2006). 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). Farmers did not necessarily associate hazardous pesticides with better pest control. The introduction of well-targeted training programmes for farmers on the need for and safe use of pesticide was thus advocated (Ntow *et al*., 2006).

Amoah *et al.*, (2006) carried out a study to determine and compare the current level of exposure of the Ghanaian population to hazardous pesticide and faecal coliform contamination through the consumption of fresh vegetables produced in intensive urban and peri-urban smallholder agriculture with informal waste water irrigation. In that study a total of 180 vegetable samples (lettuce, cabbage and spring onion) were randomly collected under normal purchase conditions from 9 major markets and 12 specialized selling points in 3 major Ghanaian cities: Accra, Kumasi and Tamale.

Organochlorine pesticides are widely used by farmers because of their effectiveness and their broad spectrum activity (Amoah *et al.*, 2006). Lindane is a widely used chemical in Ghana on Cocoa plantations, on vegetable farms and for the control of stem borers in maize. Endosulfan, marketed as Thiodan is widely used in cotton growing areas on vegetable farms and on coffee plantations (Gerken *et al*., 2001).
Through their persistence and lipophilicity, the pesticides and their residues may concentrate in the adipose tissues and in the blood serum of animals leading to environmental persistence, bioconcentration and biomagnification through the food chain. Although the organochlorines are banned from importation, sales and use in Ghana, there are evidences of their continued usage and presence in the ecosystem. Work already done in some farming communities in the Ashanti region of Ghana and some other countries indicate the presence of Organochlorine pesticide residues in fish (Osafo and Frempong, 1998).

2.3.3 Metabolism of Pesticides in Plants

The penetration of pesticides through the cuticle is usually determined by the chemical structure of the active ingredient and surface tension of the carrier (Fletcher and Kirkwood, 1982). Pesticides are reported to penetrate into the growing plants through the cuticle and stomata of the leaves (Robertson and Kirkwood, 1969).

Pesticides also undergo metabolism in plants through 20 days depending on the properties of the chemicals (Hudson and Roberts, 1981).

The metabolism of pesticides by plants is a key factor in the susceptibility and tolerance of specie to a given pesticide, whereas metabolism by Prokaryotes is often a key determinant in the environmental fate of that pesticide. There are common transformation mechanisms of many pesticides in both plants and bacteria; however, some prokaryotes are unique because they can completely metabolize certain pesticides to mineral components (mineralization). The diversity of biotransformation in prokaryotic organisms for a given pesticide is also generally greater than in plants (Zablotowicz *et al*., 2005).

2.4 Organochlorine Insecticides (OCs)

Organochlorines (OCs) are chlorinated organic compounds used predominantly as insecticides. It is mainly classified into three categories; namely diphenyl aliphatics such as DDT and its metabolite, cyclodienes which includes aldrin, dieldrin, endrin, heptachlore, endosulfan, and endosulfan sulfate. Hexachlorocyclohexanes exist in several structural isomers such as α-HCH, β-HCH, γ-HCH, and δ-HCH are the most known common organochlorine insecticides (Oztas and Semra, 2004). These insecticides are typically very persistent in the environment, and are known for accumulating in sediments, plants and animals.

Organochlorine insecticides are broad spectrum insecticides active against a great variety of pests. They vary in their chemical structures. The OCs and their metabolites are mainly classified into three categories; namely diphenyl aliphatics, cyclodienes and hexachlorocyclohexanes (Oztas and Semra, 2004).

2.4.1 Properties of Organochlorine Insecticides

Organochlorine insecticides involve organic molecule that contain several halogenated atoms. They are chemically stable and do not degrade in environmental conditions. OCs are fat soluble. Most have a log P_{ow} over 5 (Alderin, DDE, DDT, Dieldrin, Endrin, and heptachlor) and the HCH isomers have a log P_{ow} in the 3-4 range. P_{ow} noted that a connection between hydrophobicity and fat soluble partition coefficients (n-octanol/water). The ratio is reported as a logarithm (log P_{ow}) that can be considered a quantitative measure of the hydrophobicity of a compound (Leo, 2000).

Organochlorine (OC) contaminants generally have chemical characteristics such as non-polarity, lipophilicity, and low volatility due to their multi-chlorinated structure.

2.4.2 Fate of Organochlorine Insecticides in the Environment

Organochlorines are noted for their persistence, bioaccumulative and toxicity characteristics in the environment. Due to their widespread use, these compounds are detected by determination of their residues in various environmental matrices such as water, air, sediments, soil, vegetation and biota. An organochlorine insecticide (OC) residue reaches the aquatic environment through direct run-off, leaching, equipment washing and careless disposal of empty containers etc (Imo *et al.*, 2007). For instance DDT and its metabolites are persistent in the environment and resistant to complete degradation by microorganism, although photochemical degradation does occur (WHO, 2003).

2.5 Impact of Pesticide

Pesticides are used to control or eliminate pests, weeds, fungi and other unwanted species in the agricultural system and in public health programme. However, when they are applied, even non-target organisms, the environment they are in and the users are also affected. The overuse and misuse of pesticides are detrimental to the health of users, consumers and the environment (Kriengkrai, 2006).

The use of large quantities of pesticides has affected the atmosphere, water body, soil, ecosystem resulting in the destruction of fauna and flora and pollution of the environment. Some report from FAO says many countries in Africa stocked pesticide (aldrin, chlordane, DDT, dieldrin and heptachlor) in certain areas and these became waste dump sites (Kriengkrai, 2006).

The other main impact is to human health whether contact with pesticides is direct or indirect. There are many ways that man may be directly exposed to pesticides. Population groups directly exposed to pesticide are manufacturers, formulators, mixers, applicators, suicides and mass poisoning. Exposure to pesticides has been documented to cause health problems and defects such as, attention deficit and hyperactivity disorders in children, birth defects, brain damage, cancer, chronic neurotoxic effects, infertility, miscarriages, and Parkinson's (Kriengkrai, 2006). Indirect impacts of pesticides on humans include consumption of food contaminated with pesticides as well as contact with pesticide residues in the air, water, soil, sediment, food materials, plants and animals (Kriengkrai, 2006).

Pesticide residue research supports the establishment and control of safe levels of pesticides in food. It is important not only for trade purposes but also for ensuring human health. For this reason, maximum residue levels (MRLs) are set in order to ensure appropriate agricultural practices (Juan *et al*., 2008).

Maximum Residue Limit is the maximum concentration of a pesticide residue (expressed as mg/kg), permitted in or on food commodities and animal feeds. MRLs are primarily a check that Good Agricultural Practice is being followed and to assist international trade in produce treated with pesticides. MRLs are not safety limits and exposure to residues in excess of an MRL does not automatically imply a hazard to health (Ellis, 2005).

2.6 Application and Effects of Pesticides on Health

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. Pesticides manufacturing unit workers are prone to possible occupational pesticide exposure. In Ghana, Environmental Protection Agency (EPA) has forbidden the importation of 25 agrochemicals because of their toxicological risks to people, animals, crops and the environment (EPA, 2008). The ban would cover Toxaphene, Captafol, Aldrin, Endrin, Chlordane and DDT. One hundred and eighteen (118) chemicals were approved for importation and after undergoing testing for efficacy and safety under local condition, twenty four agrochemicals were given provisional clearance for one year. 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 from potential harm (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 and 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 eighteen thousand 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.

2.7 Regulatory Requirements Regarding Pesticide Use in Ghana

Owing to the damaging effects of OCPs on human health and the environment, concerns about pesticide residues in food have been growing. Many countries have introduced legislation to protect consumers from the hazards of pesticides. Most national governments today pay considerable attention to the data requirements for pesticide registration. In addition, even registered pesticides should follow a re-registration process which meets today's guidelines, regulatory triggers and safety profiles.

The Pesticides Control and Management Act of 1996 (Act 528) makes the Environmental Protection Agency (EPA) of Ghana the lead Agency responsible for a comprehensive pesticide regulatory programme. In that capacity, the EPA has the sole authority and responsibility to register all pesticides imported, exported, manufactured, distributed, advertised, sold or used within Ghana.

Labelling and packaging should conform to the prescribed EPA standards and records should be kept and made available for inspection on request. The Act provides penalties for various offenses (EPA Act 490, 1994).

The Agency also publishes annually in the Gazette registered pesticides and their classification, provisionally cleared pesticides, suspended or banned pesticides and amendments made to the classification of pesticides (EPA Act 490, 1994).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of Study Area

The Study was conducted in the Fanteakwa District and located exactly in the middle of the Eastern Region of Ghana. It is bordered to the North-West by Kwahu South District, West by Atiwa District, South-West by East Akim Municipal, East by Upper Manya Krobo and North by Kwahu North District (Figure 3.1). It has a population size of 86,154. Fanteakwa District has a total land area of 1,150 square kilometers (sq. km), occupying 7.68% of the total land area within the region (18,310 square kilometers) and constitutes 0.48% of the total land area in Ghana. The total arable land is 76,133 hectares (MOFA, 2011).

Agriculture is the dominant occupation for the inhabitants. Crop, livestock farming, and poultry are the major activities in the district (MOFA, 2011).

The vegetation consists basically of the wet-semi deciduous rain forest and the savanna scrub which is found to the North of the district on the hills close to the Volta Lake. Principal soil type is the forest ochrosol. The major rock types are the Birimian and Voltarian formations (MOFA, 2011).

Crops production includes maize, cassava, tomatoes, garden eggs, pepper, plantain, yam, and exotic vegetables (for export). A map of the study area is shown in Figure 3.1 below.

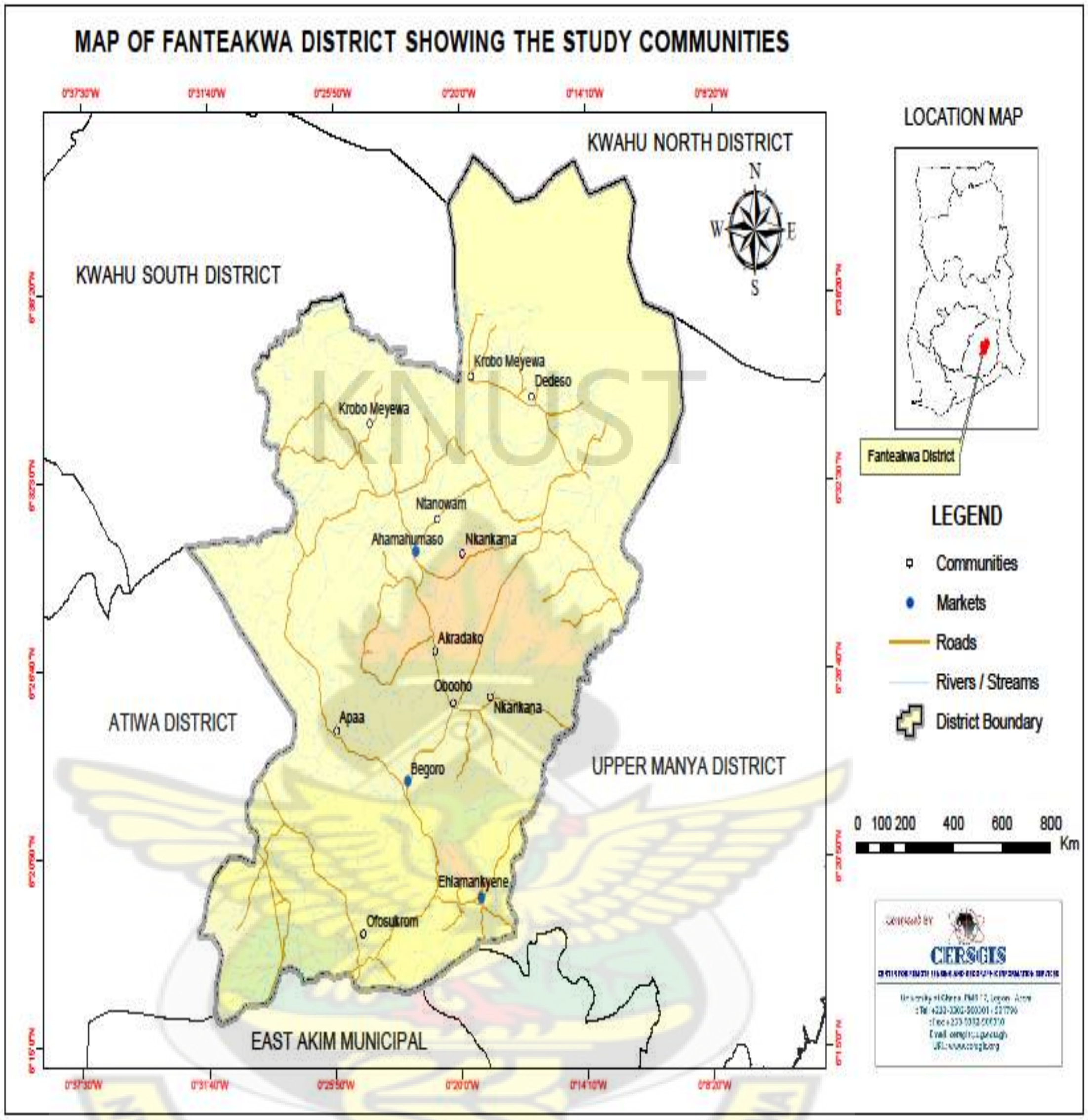

Figure 3.1: A map showing the study communities in Fanteakwa, Eastern Region, Ghana

3.2 Materials and Reagents

The research work was carried out in two stages. The first stage was a field survey to assess the use of insecticides to manage insect pests on tomato production in Fanteakwa District of the Eastern Region of Ghana.

Forty one (41) tomato farmers were randomly selected from eleven (11) major tomato producing communities in the district for interview and questionnaire (Appendix 4) administration.

The eleven (11) communities were Ahomahomasu, Nkankama, Oboroahoho, Obooho, Apaah, Ehiamankyene, Krobo Meyewa, Akoradarko, Ntanuam, Dedeso and Ofosukrom.

The second stage involved the collection of samples of harvested tomato from selected farmers' field and three (3) market centres for laboratory analysis for organochlorine compounds.

A total of 276 samples (10 composite samples) of tomato were purchased from fourteen (14) selected farmers at harvest in seven (7) communities (Oboroahoho, Apaah, Krobo Meyewa, Akoradarko, Ntanuam, Dedeso and Ofosukrom) and three (3) market centres (Ahomahomasu, Ehiamankyene and Begoro).

The tomato samples were wrapped in aluminium foil and placed in a labeled zip lock bag then transported on ice cubes in an ice chest to the Department of Chemistry, Ghana Atomic Energy Commission (GAEC) Laboratory in Accra for analysis of organochlorine insecticide residue levels using Gas Chromatography.

Analytical grade acetone, Sodium tetraoxosulphate (VI), Na_2SO_4, ethyl acetate ($CH_3COOCH_2CH_3$), Potassium Hydro-Carbonate ($KHCO_3$) and Florisil adsorbent (60–100 mesh, Merck, residue grade) were bought from a local chemical shop (Fregeosco Co. Ltd) in Accra who also obtained their supplies from CDH group in

India. Standards of 20 organochlorine insecticides were obtained from Cambridge Isotope Laboratories, Inc.

3.3 Experimental procedure

3.3.1 Extraction phase/ method

The tomato samples were chopped into small pieces and then blended for about 3-5 minutes. A 40 g portion of the homogenate weighed was transferred into conical flask/beaker and mixed with 50 g Sodium sulphate (to absorb the water present in the sample) and 5 g Potassium Hydro-Carbonate ($KHCO_3$) was added (to neutralize any acidity).

Following, an 80 ml of ethyl acetate was then added to the sample and transferred for mechanical shaking. This was to enable circulation of the solvent around the sample for effective extraction.

The liquid extract was then filtered through an activated charcoal into round bottom flask. The filtrate was refluxed for some time and transferred to the rotary evaporator for concentration thus the volume reduced to about 0.5 ml using the evaporating unit. The concentrated solvent or extract was then transferred into a test tube and was centrifuged and proceeded to clean up step.

3.3.2 Clean-up

A glass clean up column blocked with a piece of glass wool was filled with 3 g of florisil. About 1-2 g of anhydrous sodium sulfate was added on the florisil thus packing to make it compact. The setup was further conditioned by adding 5 ml of ethyl acetate to facilitate the eluting of the residue.

A 5 ml of the concentrated extract was run through the florisil column into a round bottom flask. The pesticide residues were further eluted into the round bottom flask with 10ml of ethyl acetate. The eluted was then concentrated in a rotary evaporator to approximately near dryness. 2 ml of ethyl acetate was added to the eluted concentrate in the round bottom flask by swelling/shaking.

The Pasteur glass pipette was used to pick the eluted concentrate and transferred into a Gas Chromatography vial to run the analysis.

3.3.3 Gas Chromatography Run.

The residues were analyzed by Gas Chromatograph, GC-2010 equipped with ^{63}Ni, electron capture detector that allows the detection of contaminants even at trace level concentrations. The GC conditions and the detector response were adjusted to match the relative retention time and response. The conditions for analysis were capillary column with 0.25 mm internal diameter and 0.25 µm film thickness with 1 m retention gap (0.53 mm, deactivated). The temperature of injector and detector were set at 280^0C and 300^0C respectively. The oven temperature was programmed to 60^0C for 2 minutes and at 180^0C/min up to 300^0C. The injection volume of the GC was 1.0 mL. Nitrogen gas (N_2) was used as a carrier gas, maintained at a constant flow rate of 30 mL/min.

3.4 Quantification

The determination of the quantities of residues in the sample extracts was done by running a standard mixture of known concentration of insecticide and the response of the detector for each compound was ascertained. The area of the corresponding peak in the sample was compared with that of the standard. All analyses were carried out in triplicates and the mean concentrations computed accordingly.

3.5 Quality Control Measures

The efficiency of the analytical method (extraction and clean up) was determined by recoveries of an internal standard. One blended tomato sample was spiked with a 50 μL of 100 ng/ml internal standard (isodrin) and extracted under the same conditions as the analytes. To check for interferences, a blank sample containing no detectable compounds was analyzed.

3.6 Statistical Analysis

Data obtained from the survey were statistically analyzed using the Statistical Package for the Social Scientist (SPSS - version 17 for windows, year 2007). The results were presented in tables and pie charts with values presented in percentages. Laboratory data were also analyzed for ANOVA using Excel software. The level of significance was determined by pairwise comparison and between the means of the measured parameters. Responses to the questionnaire were analyzed using Microsoft Excel.

CHAPTER FOUR

RESULTS

4.1 Field Survey

Results obtained from the field survey are shown in Pie Charts covering the sex and educational levels of respondents, varieties of cabbage cultivated as well as the assessment of pesticides/insecticide used to control insect pests of tomato in the Fanteakwa district.

4.1.1 Sex of Respondents

Out of the forty-one (41) farmers interviewed, thirty four (34) were males, representing 82.9%, while seven (7) were females, representing 17.1 % (Figure 4.1).

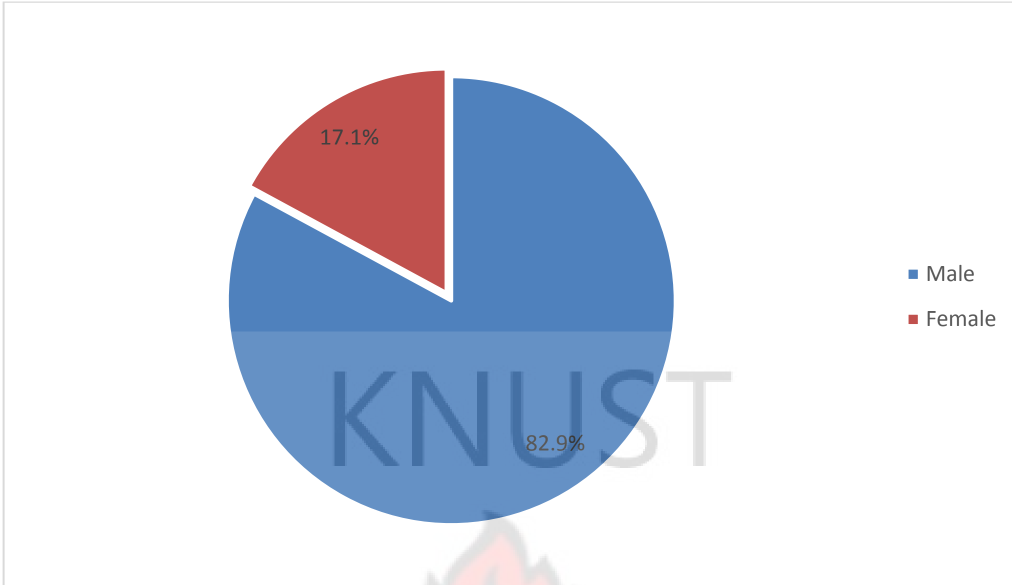

Figure 4.1: Sex of Respondents

4.1.2 Educational Level of Respondents

The educational level of the farmers interviewed is presented in figure 4.2. Twenty five (25) of the respondents had basic education, representing 61%, eight (8) of the farmers had secondary education, representing 19.5%. Two (2) farmers each had post-secondary education and Middle School Leaving Certificate (MSLC) representing 4.9% each. One person out of the respondents (2.4%) had a Non-Formal Education whiles three (3) farmers had no formal education representing 7.3%.

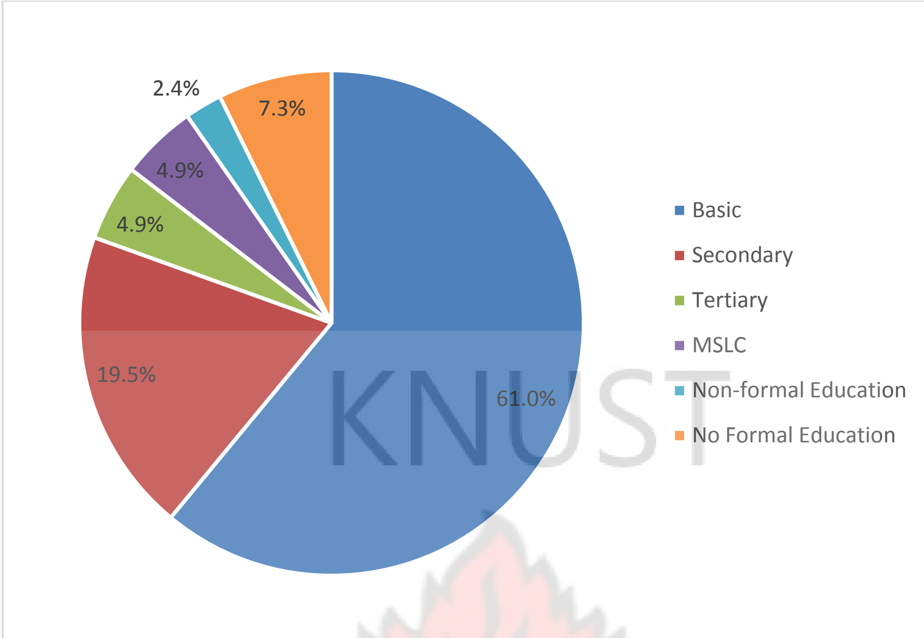

Figure 4.2: Educational Levels of Respondents

4.1.3 Varieties of Tomato Cultivated by Farmers

Figure 4.3 indicates the varieties of tomato cultivated by farmers in the district. The results showed that eight (8) respondents each cultivated the Power and Pectomech varieties only, representing 19.5% respectively. Eleven (11) of the respondents cultivated Roma VF variety only, representing 26.8%. The rest of the respondents either cultivated two or three varieties.

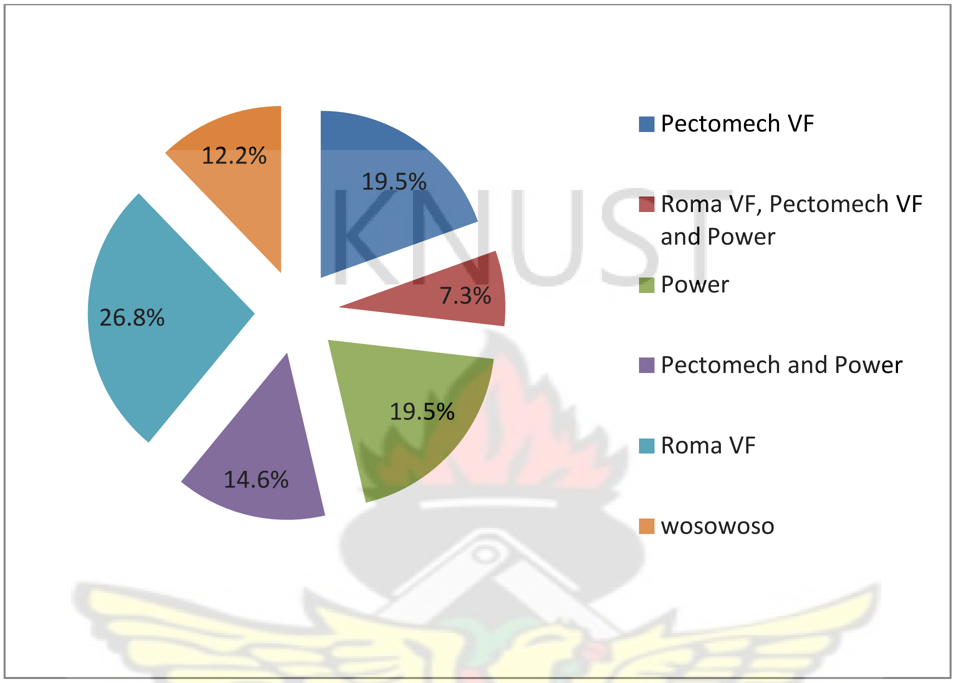

Figure 4.3: Varieties of Tomato Cultivated by Farmers

4.1.4 Insecticides Used by Farmers to Control Insect Pest in Tomato Production in the District

Data in Table 4.1 indicates various types of insecticides used by farmers to control insect pests in tomato production. A total of 15 different types of insecticides were used by the farmers. The insecticides are indicated in the same Table 4.1 as trade names and their active ingredients.

Table 4.1: Pesticides used by farmers to control insect pests on tomato

S/N	Trade Name	Active Ingredients	Pre-Harvest Application Intervals (Average)
1.	PAWA 2.5 EC	Lambda Cyhalothrin	6 days
2.	Golan S L	Actemiprid	7 days
3.	Dursban	Chlopyriphos	7 days
4.	Cymethoate	Cymethoate	7 days
5.	Confidor 200sl	Imidacloprid	7 days
6.	Lambda Super 2.5 EC	Lambda Cyhalothrin	7 days
7.	Attack	Emamectin benzoate	10 days
8.	Kombat 2.5 EC	Lambda Cyhalothrin	6 days
9.	Polythrine C	Cypermethrin + profenetos	5 days
10	Conti-halithrin 2.5 EC	Lambda Cyhalothrin	7 days
11	Karate 5 EC	Lambda Cyhalothrin	8 days
12	Terminix	Chlorpyrifos-ethyl	7 days
13	K – Optimal	lambda + acetamipride	4 days
14	Multifos 40 EC	Chlorpyrifos	7 Days
15	Poison		7 days

The results also revealed that insecticides such as PAWA 2.5 EC, Karate 5 EC, Terminix, Kombat 2.5 EC and Dursban were mostly used by farmers to control insect pests on tomato farms in the district. It was observed that quite a number of the farmers used hazardous pesticides on their fields with no idea of the active ingredients and their effects on human health and environment.

It was also noted that pesticides such as Confidor which is made to control insect pests of cocoa plants are often used by farmers to kill insect pests on their tomato fields.

4.1.5 Combination of Different Pesticides/Insecticide Together for Spraying

Figure 4.4 below indicates that fifteen (15) out of forty-one (41) farmers interviewed mixed two or three pesticides together for controlling insect pests on their tomato farms representing 36.6%. The remaining twenty six (26) respondents used single pesticides for the control of insect pests, representing 63.4%.

Other observations made were that farmers did the combination of chemicals without considering their effectiveness.

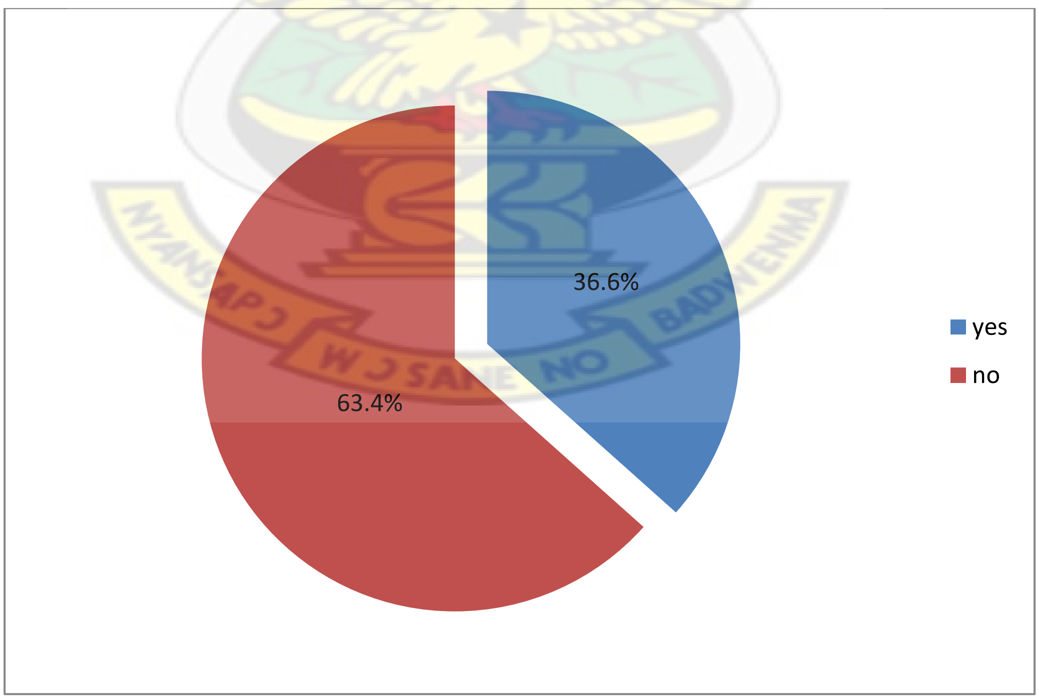

Figure 4.4: Combination of insecticide for spraying

4.1.6 Reason(s) for Choosing Specific Pesticides by Farmers

Figure 4.5 indicates the reasons for the choice of specific insecticide/pesticides by farmers for the control of insect pests on their tomato farms. Out of forty-one (41) farmers interviewed, twenty four (24), representing 58.5% chose pesticides based on their effectiveness in controlling insect pests. Eight (8) farmers, representing 19.5% chose pesticides based on both their effectiveness in controlling insect and availability on market. Again, eight (8) respondents representing 19.5% chose pesticides for the following reasons; low price, availability on market in their area of operations and effectiveness in controlling insect pests. Only one farmer chose pesticides based on moderate price.

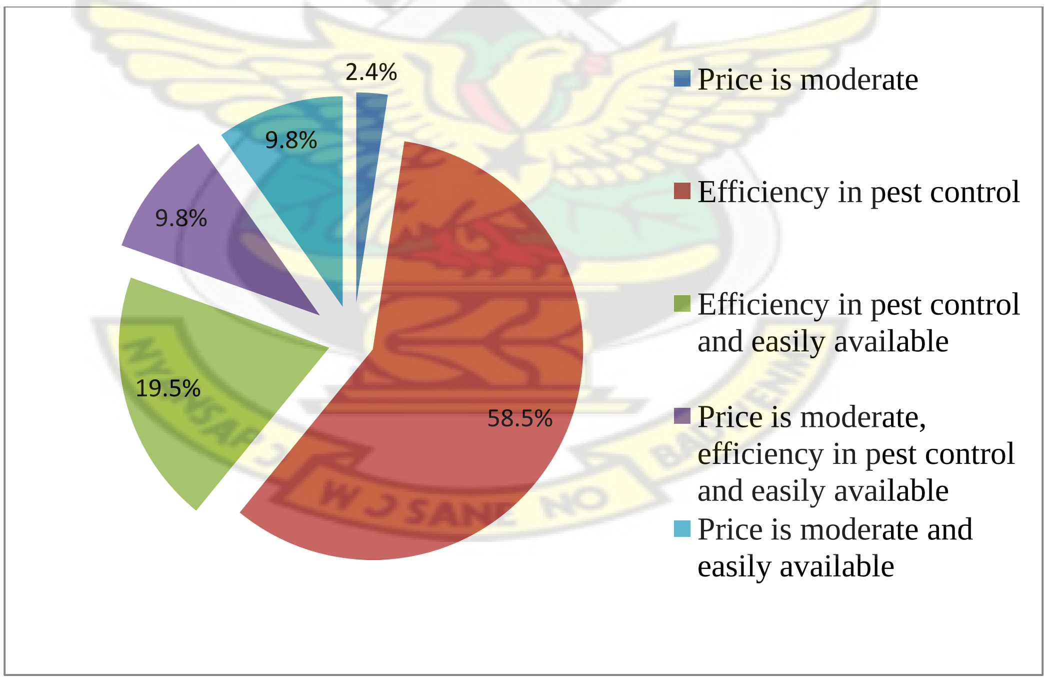

Figure 4.5: Reason(s) for Choosing Specific Pesticides by Farmers

4.1.7 Factors determining when Farmers apply Pesticides to Control Insect Pests

Sixteen (16) out of the forty-one (41) farmers interviewed, representing 39% did routine spraying of pesticides to control insect pests on their tomato (Figure 4.6). Ten (10) of the farmers representing 24.4% did also follow strictly the recommendations of the Agricultural Extension Agents (AEAs) whiles nine (9) farmers with a percentage of 22 decided to spray pesticides against insect pests upon noticing their presence on their farms. Five (5) of the farmers did routine spraying of pesticides to control insect pests on their tomato and also followed the recommendation of the AEAs. Only one farmer followed the recommendation of a colleague farmer.

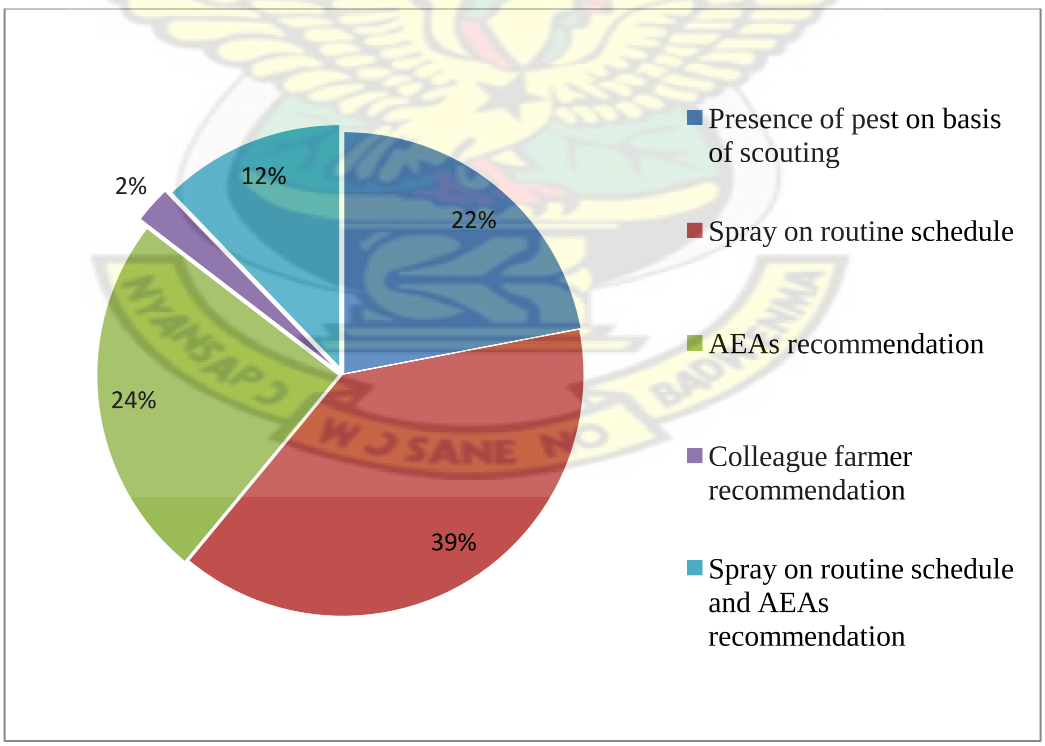

Figure 4.6: Factors determining when Farmers apply Pesticides to Control Insect Pests

4.1.8 Frequency of Spraying Pesticides to Control Insect Pests within a Growing Season of Tomato Cultivation

Figure 4.7 indicates that twenty-two (22) out of forty one (41) farmers interviewed, representing 53.66%, did spray pesticides between 6 and 10 times within a growing season of tomato cultivation to control insect-pests infestation. Twelve (12) farmers, representing 29.27% sprayed pesticides between 11 and 15 times within a growing season. Those who sprayed between 1 and 5 times were six (6), representing 14.63%. Only one farmer, representing 2.4% sprayed more than 20 times within a growing season of tomato cultivation to control insect pest infestation.

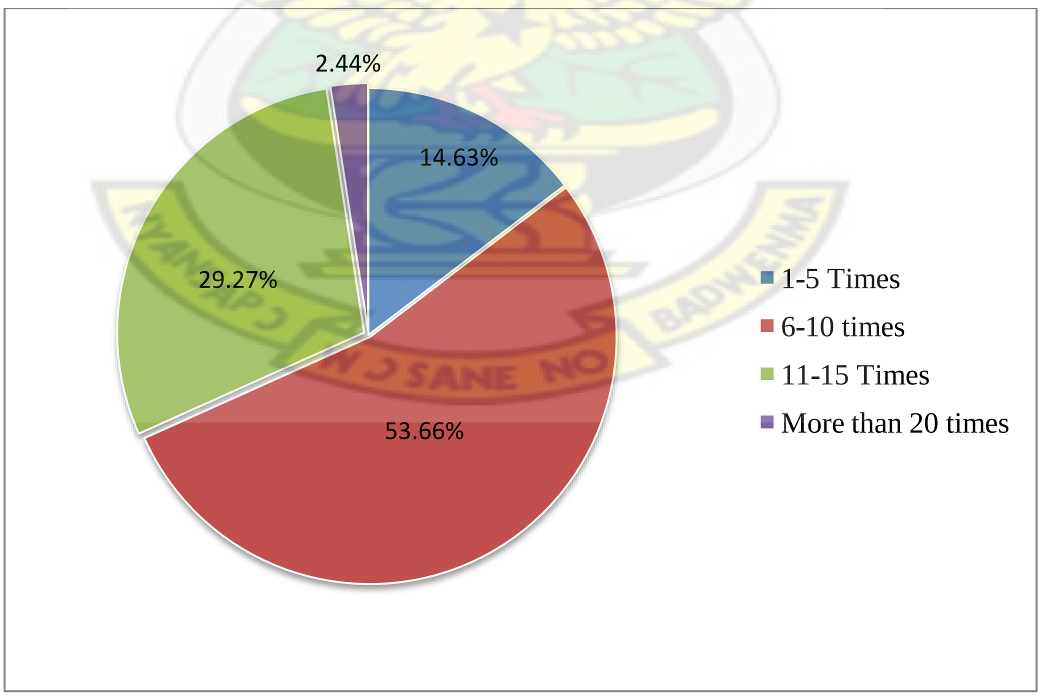

Figure 4.7: Frequency of spraying within a growing season

4.1.9 Efficacy of Insecticides Used by Farmers to Control Insect Pests in Tomato Cultivation

Eighteen (18) farmers, representing 43.9% ranked insecticide/pesticides used in controlling insect pests as very effective (80-90% control of insect pests). Twenty (20) farmers, representing 48.8% ranked insecticides used in controlling insects as effective (60-70% control of insect pests). The remaining three respondents, representing 7.3% indicated that insecticides used in their tomato farms were moderately effective in controlling insect pests (40-50% control of insect pests) (Figure 4.8).

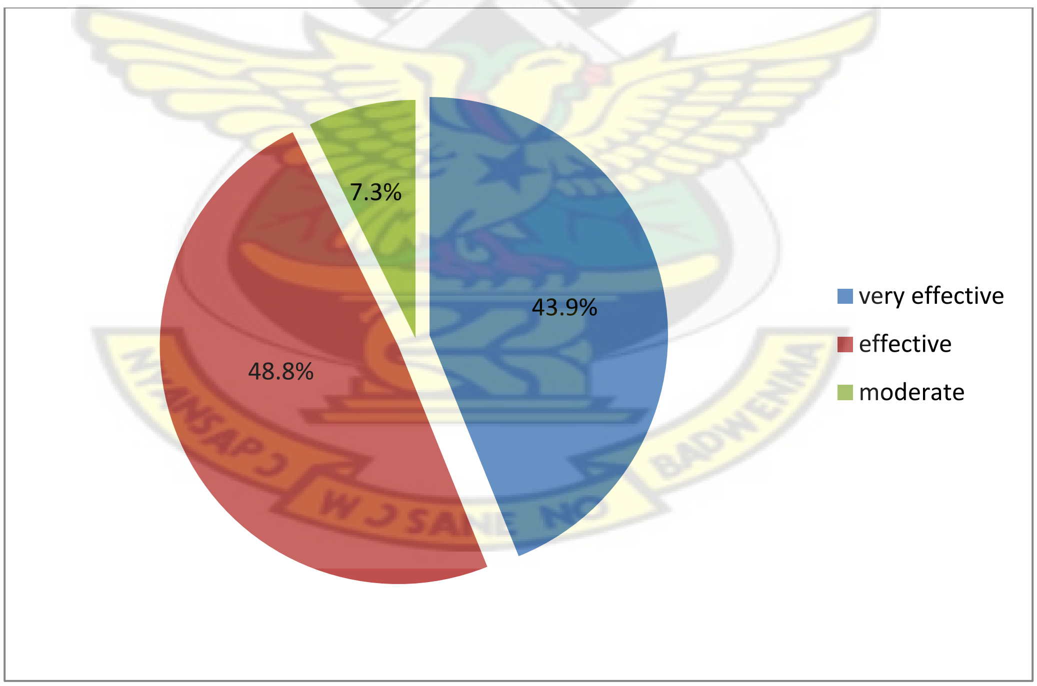

Figure 4.8: Efficiency of insecticides used by farmers

4.1.10 Time of the Day that Spraying Takes Place

Figure 4.9 indicates that thirty-four (34) out of the forty-one (41) farmers interviewed, representing 82.9% sprayed in the mornings (before 12 noon). Five (5) farmers, representing 12.2% did spray both in the mornings and evenings (before 12 noon and between 4pm-6pm). Two of the farmers sprayed at any time of the day including the afternoons (12noon-3pm).

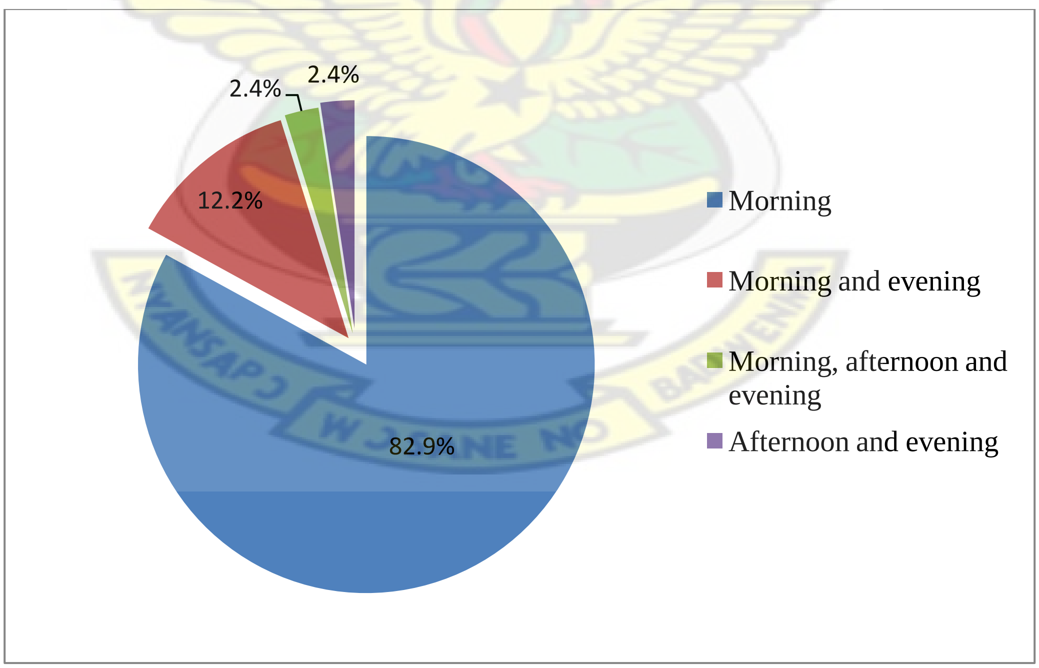

Figure 4.9: Time of the Day that Spraying Takes Place

4.1.11 Spraying Intervals (Intervals between One Spraying Period and the Next)

Figure 4.10 indicates that twenty-nine (29) farmers out of forty-one (41) farmers interviewed, representing 70.7%, sprayed their fields at weekly intervals. Four (4) of the farmers, representing 9.8% sprayed at two weeks interval. Three farmers each representing 14.6% sprayed at both three and five days interval respectively. Again, only two (2) farmers representing 4.8% either sprayed at four of six days interval.

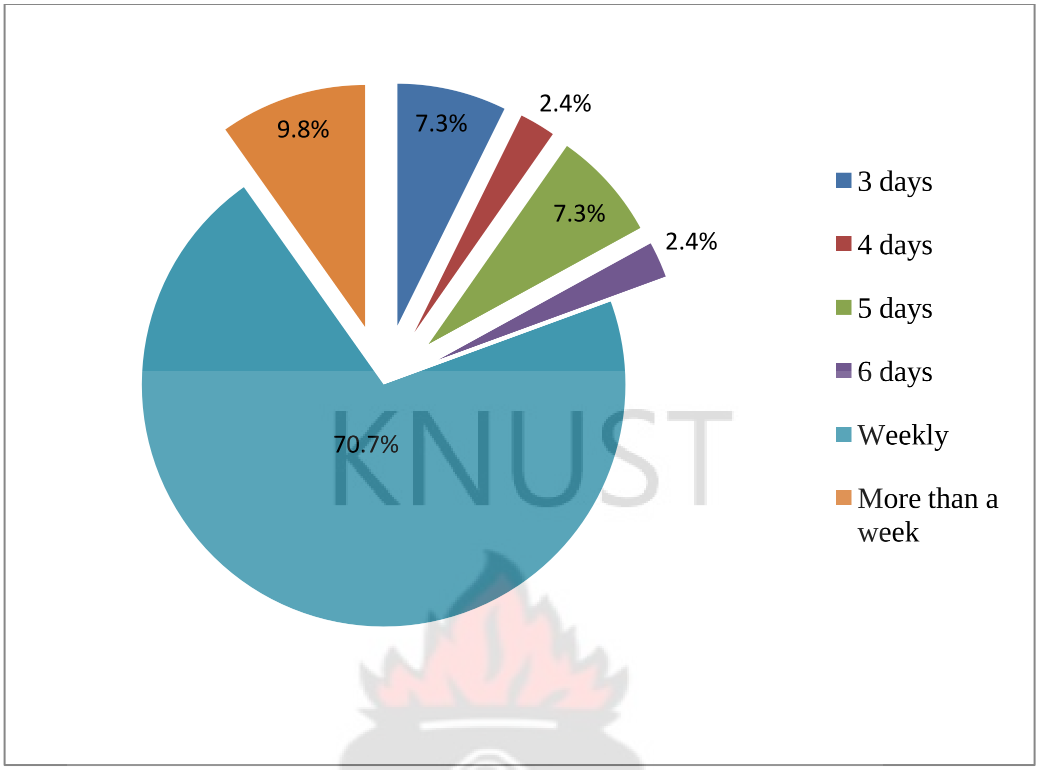

Figure 4.10: Spraying Intervals (Intervals between One Spraying Period and the Next)

4.1.12 Spraying of Pesticides during Harvesting of Tomato

Figure 4.11 indicates that sixteen (16) out of forty-one (41) farmers interviewed, representing 39% continued spraying of pesticides during time of harvesting of tomatoes. Quite a higher number of farmers, twenty five (25) representing 61%, however, stopped spraying of pesticides/chemicals during time of harvesting and on the average, seven (7) days waiting period was allowed.

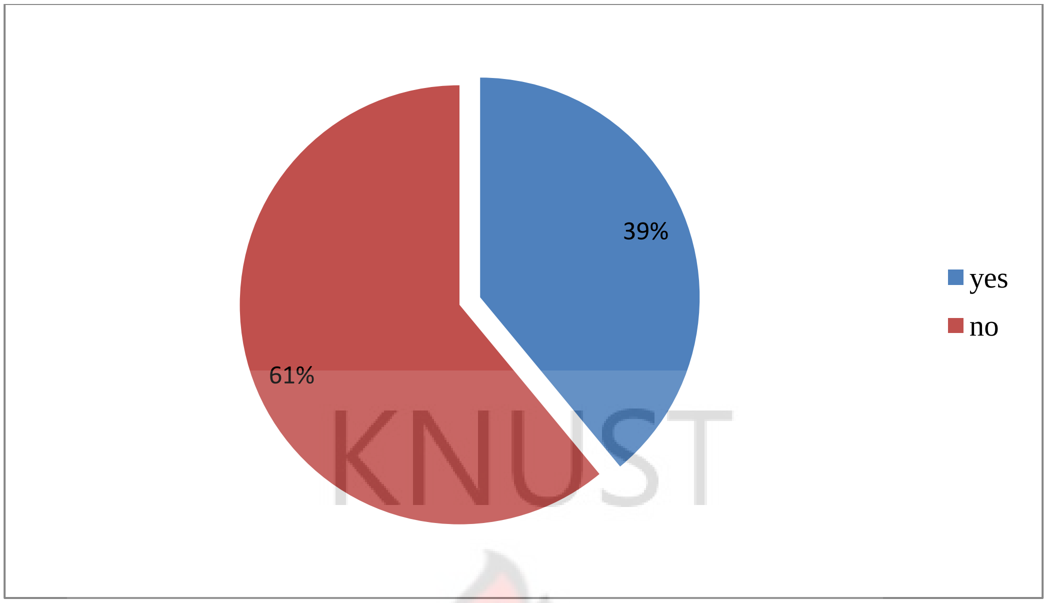

Figure 4.11: Spraying of Pesticides during Harvesting of Tomato

4.1.13 Safety Precaution (Such as the use of Protective Clothing) Adopted by Farmers during Spraying of Pesticides

Figure 4.12 reveals that thirty-nine (39) out of forty-one (41) farmers, representing 95.1% adopted safety precautions such as the use of protective clothing, goggle, wellington boot, mouth and nose respirators during spraying of pesticides. The remaining two (2) farmers did not adopt any safety precautions during spraying of pesticides.

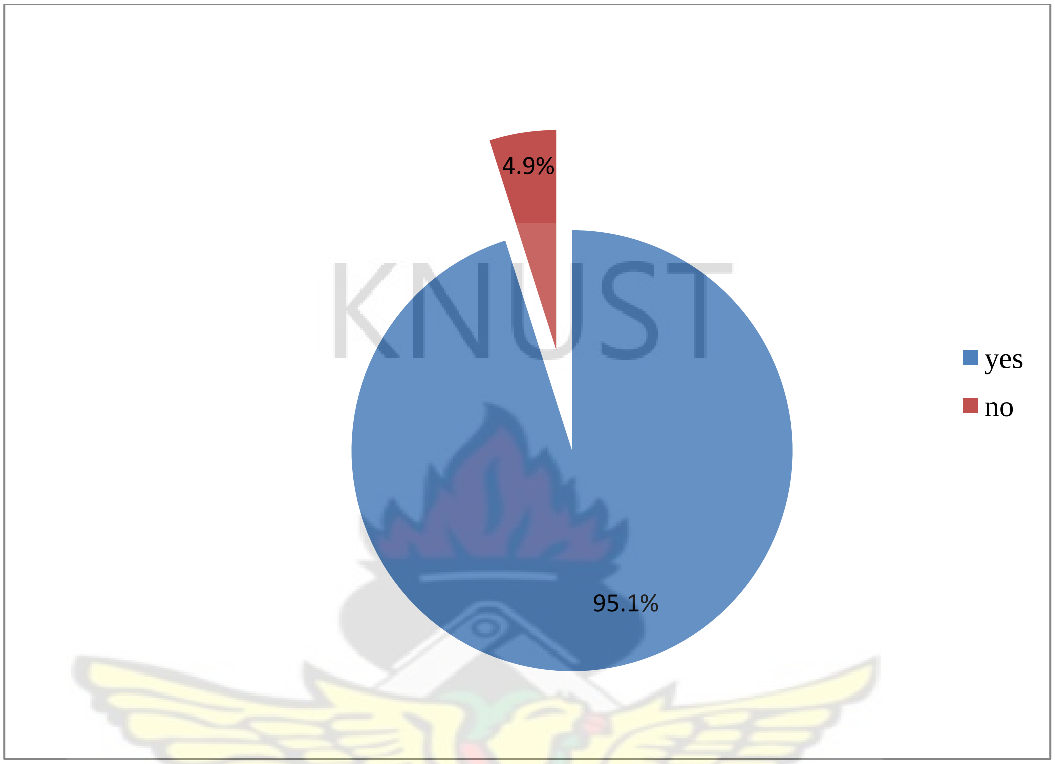

Figure 4.12: Safety Precaution Adopted by Farmers during Spraying

4.2 Organochlorine Pesticide Residual Analysis

Tomato samples from Fanteakwa district were analyzed for 20 organochlorine insecticide residues. Almost all the 20 different organochlorine insecticide residues were detected in fresh tomato fruits sampled from both the farming communities and the market. The concentrations of the various residues in each sample were calculated in mg/kg. The mean concentration of each insecticide in the samples was compared to European Union Standards/Guideline Value in mg/kg.

4.3 Occurrence and Levels of Organochlorine Insecticides in Tomato Samples

Tables 4.2 and 4.3 below (pages 42 and 43) show that a total of twenty organochlorine insecticides were detected in tomato samples at the farmers' fields and markets.

The concentrations of organochlorines ranged between 0.0001 to 0.0091 mg/kg. The level of P,P-DDT was the highest (0.0091 mg/kg) which was found in the Roma VF samples at Ahomahomaso market. The lowest was 0.0001, found in Pectomech at Ehiamankyene market was P'P-DDD (Table 4.3).

4.4 Comparison of mean concentrations of Organochlorine insecticide residues among the varieties of tomatoes

The mean concentrations of the organochlorines in the various tomato varieties are shown in table 4.2 below (page 42).

Pairwise comparison shows that there are significant differences of concentrations of the organochlorine residues among the varieties ($p<0.05$). The pairwise comparison of A-HCH concentration between Roma VF and Pectomech showed a significant difference ($p=0.04968$) as shown in Appendix 2 (table 1b).

4.5 Comparison of Mean Concentrations (Mg/Kg) Of Organochlorine Insecticides Residues in Tomato Samples with EU MRLs

Figure 4.5.1 below compares the average concentration of organochlorine insecticides residues in tomato samples (four varieties) with that of the EU MRLs. The level of concentrations showed that all the organochlorines detected were found to be far below the EU MRLs concentration of 0.05 mg/kg.

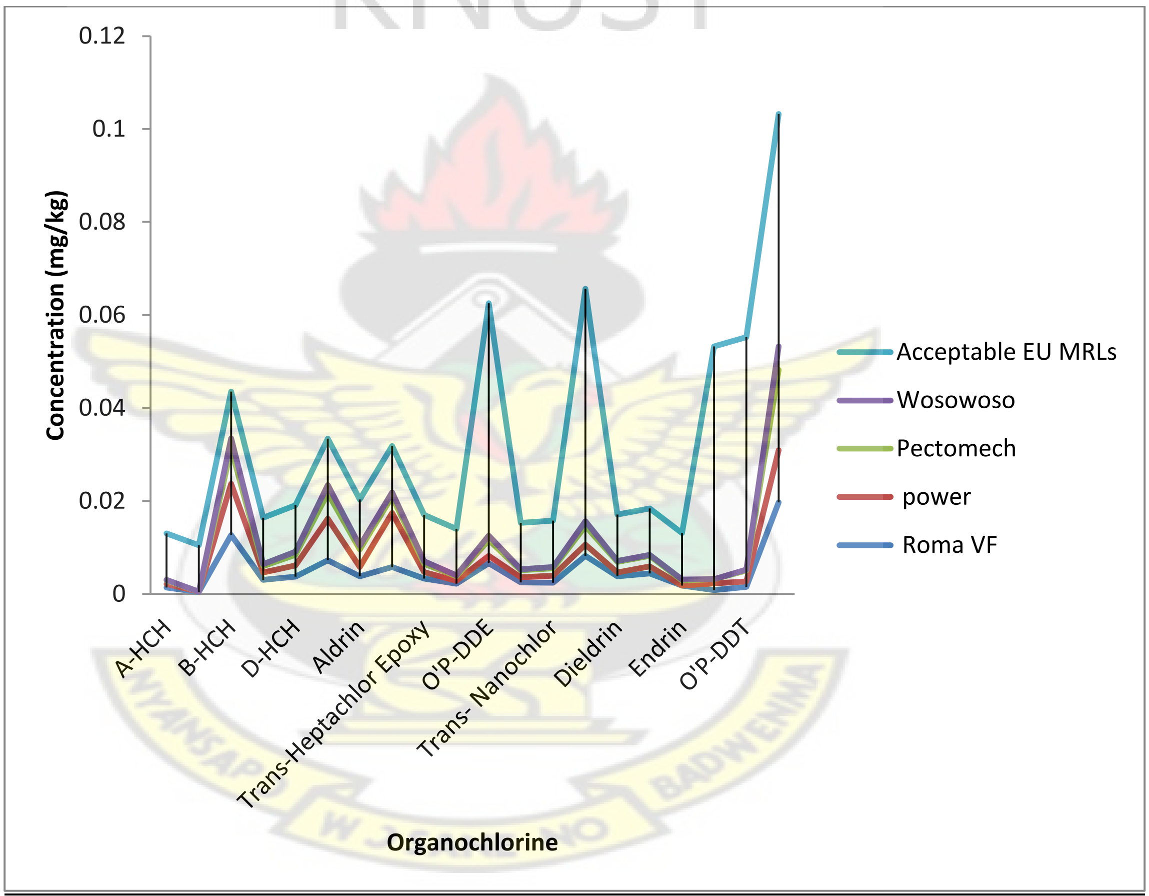

Figure 4.13: Comparison of organochlorine residues with the EU MRLs

4.6 Comparison of Mean Concentrations of Organochlorine Insecticide Residues among the Sampling Locations (Farmers' Fields and Market).

Tables 4.2 and 4.3 below (page 42 and 43 respectively) shows the average concentrations of the organochlorines at the farmers' field (communities) and markets respectively. Pairwise comparison of concentrations of the organochlorine insecticide residues among the sampling locations using ANOVA shows that all the organochlorine residues levels were statistically significant ($p<0.05$).

Table 4.2: Concentration of Organochlorines in 4 tomato varieties (mg/kg) cultivated by farmers in seven study areas in Fanteakwa District

Compound Names/ID	Ntanuam (Roma VF)	Krobo Meyiwa (Roma VF)	Oboroahoho (Power)	Ofosukrom (Power)	Apaah (Pectomech)	Akora darko (Pectomech)	Dedeso (Wosowoso)
A-HCH	0.0008	0.0001	0.0002	0.0003	0.0005	0.0001	0.0001
HCB	0.0003	ND	0.0001	ND	ND	ND	ND
B-HCH	0.0061	0.0010	0.0060	0.0014	0.0026	0.0020	0.0023
G-HCH	0.0011	0.0004	0.0007	0.0006	0.0004	0.0007	0.0004
D-HCH	0.0020	0.0002	0.0008	0.0006	0.0008	0.0007	0.0007
Heptachlor	0.0031	0.0007	0.0048	0.0024	0.0020	0.0017	0.0018
Aldrin	0.0015	0.0005	0.0006	0.0005	0.0013	0.0019	0.0007
Cis- heptachlor epoxy	0.0019	0.0008	0.0089	0.0018	0.0012	0.0020	0.0009
Trans-Heptachlor Epoxy	0.0017	0.0001	0.0002	0.0002	0.0008	0.0006	0.0005
Trans Chlordane	0.0011	0.0001	0.0001	0.0001	0.0005	0.0002	0.0002
O'P-DDE	0.0020	0.0009	0.0003	0.0003	0.0009	0.0020	0.0009
Cis-Chlordane	0.0007	0.0003	0.0002	0.0002	0.0006	0.0007	0.0002
Trans- Nanochlor	0.0011	0.0001	0.0001	0.0002	0.0006	0.0004	0.0003
P'P DDE	0.0031	0.0012	0.0007	0.0005	0.0017	0.0020	0.0010
Dieldrin	0.0011	0.0002	0.0002	0.0002	0.0009	0.0011	0.0002
O'P-DDD	0.0020	0.0001	0.0003	0.0001	0.0011	0.0009	0.0002
Endrin	0.0010	ND	ND	ND	0.0005	0.0004	0.0002
P'P DDD	0.0004	ND	0.0006	0.0002	0.0004	0.0004	ND
O'P-DDT	0.0007	0.0002	0.0005	0.0002	0.0007	0.0007	0.0002
PP-DDT	0.0090	0.0016	0.0025	0.0014	0.0079	0.0037	0.0050

ND – Not Detected

Table 4.3: Concentration of Organochlorines in 3 tomato varieties (mg/kg) at 3 major markets from Fanteakwa District

Compound Names/ID	BEGORO (Power)	AHOMAHOMASO (Roma VF)	EHIAMANKYENE (Pectomech)
A-HCH	0.0002	0.0005	0.0002
HCB	ND	0.0001	ND
B-HCH	0.0036	0.0056	0.0029
G-HCH	0.0003	0.0015	0.0003
D-HCH	0.0010	0.0015	0.0008
Heptachlor	0.0018	0.0034	0.0017
Aldrin	0.0009	0.0018	0.0006
Cis- heptachlor epoxy	0.0009	0.0031	0.0003
Trans-Heptachlor Epoxy	0.0010	0.0015	0.0004
Trans Chlordane	0.0004	0.0010	0.0003
O'P-DDE	0.0010	0.0037	0.0005
Cis-Chlordane	0.0007	0.0015	0.0002
Trans- Nanochlor	0.0012	0.0012	0.0006
P'P DDE	0.0012	0.0039	0.0003
Dieldrin	0.0004	0.0025	0.0003
O'P-DDD	0.0011	0.0023	0.0003
Endrin	ND	0.0008	0.0002
P'P DDD	0.0007	0.0004	0.0001
O'P-DDT	0.0005	0.0006	0.0009
PP-DDT	0.0073	0.0091	0.0057

ND – Not Detected

Table 4.4: Mean Concentration of 3 tomato varieties compared with market concentration and acceptable EU MRLs

Compound Names/ID	Mean Concentration at harvest (Power)	Begoro Market (Power)	Mean Concentration at harvest (Roma VF)	Ahomahomaso Market (Roma VF)	Mean Concentration at harvest (Pectomech)	Ehiamankyene Market (Pectomech)	Acceptable EU MRLs (2011)
A-HCH	0.0002	0.0002	0.0005	0.0005	0.0003	0.0002	**0.01**
HCB	0.0001	ND	0.0002	0.0001	ND	ND	**0.01**
B-HCH	0.0037	0.0036	0.0036	0.0056	0.0023	0.0029	**0.01**
G-HCH	0.0006	0.0003	0.0008	0.0015	0.0005	0.0003	**0.01**
D-HCH	0.0007	0.0010	0.0011	0.0015	0.0007	0.0008	**0.01**
Heptachlor	0.0036	0.0018	0.0019	0.0034	0.0018	0.0017	**0.01**
Aldrin	0.0005	0.0009	0.0010	0.0018	0.0025	0.0006	**0.01**
Cis- heptachlor epoxy	0.0053	0.0009	0.0013	0.0031	0.0016	0.0003	**0.01**
Trans-Heptachlor Epoxy	0.0002	0.0010	0.0009	0.0015	0.0007	0.0004	**0.01**
Trans Chlordane	0.0001	0.0004	0.0006	0.0010	0.0003	0.0003	**0.01**
O'P-DDE	0.0003	0.0010	0.0014	0.0037	0.0014	0.0005	**0.05**
Cis-Chlordane	0.0002	0.0007	0.0005	0.0015	0.0006	0.0002	**0.01**
Trans- Nanochlor	0.0002	0.0012	0.0006	0.0012	0.0005	0.0006	**0.01**
P'P DDE	0.0006	0.0012	0.0022	0.0039	0.0018	0.0003	**0.05**
Dieldrin	0.0002	0.0004	0.0007	0.0025	0.0010	0.0003	**0.01**
O'P-DDD	0.0002	0.0011	0.0011	0.0023	0.0010	0.0003	**0.01**
Endrin	ND	ND	0.0005	0.0008	0.0004	0.0002	**0.01**
P'P DDD	0.0004	0.0007	0.0002	0.0004	0.0004	0.0001	**0.05**
O'P-DDT	0.0004	0.0005	0.0005	0.0006	0.0007	0.0009	**0.05**
PP-DDT	0.0020	0.0073	0.0053	0.0091	0.0058	0.0057	**0.05**

ND – Not Detected

CHAPTER FIVE

DISCUSSION

5.1 Bio-data of Tomato farmers in Fanteakwa District

The field survey revealed that tomato production in the district was dominated by males (Figure 4.1) especially the energetic youth between the ages of twenty five (25) and forty-five (45).

The high percentage (82.9%) of farmers being males with only 17.1% being females as revealed from the survey may be because, in Ghana, tomato production is known to attract more men than women (Clottey *et al.*, 2009). This could be attributed to the fact that tomato production is quite arduous and demanding, especially with the frequency of spraying to manage insect pests. It is also capital intensive and that men are known to have more access to financial capital than women. As reported by Mamudu *et al.* (2009), about 44 per cent of the credit portfolios of Rural Banks in Ghana go to women while the remaining 56 per cent goes to men.

Besides these, tomato production is regarded as a risky venture and women appeared not to be ready to take so much risk for fear of incurring debts (Clottey *et al.*, 2009).

5.2 Application of Insecticides in the control of insect pest

The survey revealed the usage of all kinds of insecticides whether registered or not. Some banned insecticides were being used by farmers to manage insect pests since they were readily available on the market. Another is that, usually insecticides made for other commodities either than vegetable production were found cheaper hence most farmers could easily afford.

It has been established that pesticides could become a nuisance if they are misused. Some of the negative effects of pesticide misuse include low crop yield, destruction of soil micro-fauna and flora, and undesirable residue accumulation in food crops (Edwards, 1986).

Fifteen (15) different kinds of insecticides were recorded in the field survey as being used by farmers in the control of tomato insect-pests (Table 4.1). Again, some farmers used chemicals they termed "poison" which is believed to be DDT. There was however, no evidence of proof on the field. Farmers practice of indiscriminate use and combination of different chemicals as well as spraying even during harvesting could have contributed to the detection of insecticides residues on or in tomato samples as was revealed in the laboratory analysis. This then validates the misuse of chemicals among the farmers.

The soil in the study area was not tested prior to the commencement of the project. However, since organochlorines can persist or bioaccumulate in an environment for decades, there is the likelihood of the bioaccumulation effects of these banned products even though they are likely not in use.

This may therefore validate the reason that DDT and its metabolites are persistent in the environment and resistant to complete degradation by microorganism, although photochemical degradation does occur as reported by Imo *et al.*, (2007).

Furthermore, it was observed that quite a number of the farmers used hazardous pesticides on their fields with no idea of the active ingredients and their effects on human health and environment. It was also noted that pesticides such as Confidor which is made to control insect pests of cocoa plants are often used by farmers to kill or control insect pests on their tomato fields.

5.3 Mode and frequency of insecticide use

Minority of farmers interviewed (39%) continued spraying while harvesting was on-going. The remaining 61%, however, stopped spraying during time of harvesting and on the average, seven (7) days waiting period was allowed. This practice contributed to the insecticide levels in the tomato samples especially when the waiting period was short.

Again, it was observed that about 37% of farmers did combine two or more chemicals to combat insect pests of tomato without considering its effectiveness and regardless of their side effects. Thus, it was a common practice for farmers to mix together chemicals with the same active ingredients but different trade names. Typical example was Lambda Cyhalothrin groups and this was a clear misuse of pesticides which would affect the health of growers and the consumers as well as the quality of the commodity. These practices could lead to harmful chemicals getting into human food chains with consequent adverse effects on human health.

Work done by Kriengkrai, (2006), comfirms that, the overuse and misuse of pesticides are detrimental to the health of users, consumers and the environment.

The survey also revealed that the spraying pattern adopted by most tomato farmers (39%) was routine spraying and practices of this kind could lead to the buildup of insecticide residues in tomato especially when the waiting period between spraying and harvesting was not adequate to make the tomato fruits safe.

Even though farmers sprayed in the mornings and or evenings, which are safe periods of the day for spraying against insect pests attack, the practices where farmers used hazardous insecticides which were not recommended for vegetable (tomato) could expose them to adverse effects of the insecticides used.

The study also showed that the frequency of spraying depended on the type and the dosage of insecticides used. Those who used recommended insecticides and right dosage prescribed by Agricultural Extension Agents (AEAs) for controlling insect pests in their fields applied less frequently (1 week interval) than those who used non recommended insecticides who sprayed more frequently (3-4 days interval).

Chemicals or insecticides abuse as indicated by the farmers could be a result of ignorance or lack of knowledge as 7.3% of the respondents had no education and majority (61%) had only basic education. Again, poor interactions between farmers and their agricultural extension agents might have contributed to this situation.

5.4 Occurrence and levels of Organochlorine Insecticides in Tomato Samples

The second phase of the work, involved the analysis of organochlorine insecticide residues. The analysis revealed the presence of 20 organochlorine insecticides

(Heptachlor, HCB-Hexachlorobenzene, Dieldrin, Aldrin, Alpha-Endosulfan, Gamma-HCH, Beta-HCH, Alpha-HCH, Delta-HCH, p,p-DDT, p,p-DDE, o'p-DDT, o'p-DDE, Endrin, Endrin aldehyde, Cis-chlordane, Trans-chlordane, Trans-nonachlor, Trans-Heptachlor and Dichlorodiphenyltrichloroethane-DDT) which have been banned, because of their toxicological effects on humans, animals, crops and the environment (EPA, 2008).

The analysis of these organochlorine residue levels were carried out for the different tomato varieties at harvest and on the market. The results (Table 4.4) indicated all the samples had residual levels which were lower and were within the EU acceptable MRLs (EU Pesticide Database, 2012). The low concentrations detected could mean the past usage of the insecticides.

The concentrations ranged between 0.0001 to 0.0091 mg/kg. The highest residue value of 0.0091 mg/kg of organochlorine was PP-DDT which was found in the Roma VF samples at Ahomahomaso market and the lowest (0.0001) found in Pectomech at Ehiamankyene was P'P-DDD (Table 4.3). DDT was one of the most abundant with high residual levels detected in all 10 (100 %) samples analysed, having a concentration range of 0.0014 to 0.0091 mg/kg and mean of 0.0058 mg/kg.

The result further showed that, even though DDT was below the acceptable level was high compared to the others in all the varieties across the various communities.

This further substantiates the view that, the “poison” being used by the farmers was actually DDT.

Although DDT is banned for agricultural use in Ghana, it was detected in the samples, along with its metabolite, DDE. This clearly demonstrates how well-known environmental persistence of this substance, even in tropical environments (Kidd *et al*., 2001), thus justifying its prohibition from agricultural use in Ghana. The DDT concentration in the samples, however, was higher than the DDE level indicating a low degradation rate.

This also suggests a recent use of DDT in these areas, since p,p-DDT is the major component of technical-grade DDT. Following, the detection of the breakdown products of DDT (DDE and DDD) is an indication of photochemical degradation of the DDT (Wandiga, 1995).

The laboratory results as shown in Tables 4.2 and 4.3 above (pages 42 and 43) indicate that in all communities and markets, the concentrations of gamma HCH were higher than alpha HCH. This suggests a fresh input of the gamma HCH (lindane), since photochemical transformation of the gamma isomer yield the alpha isomer.

The mean concentration of heptachlor was higher in all the samples than that of heptachlor epoxy. For example, the average concentration of heptachlor in Power, Pectomech VF, Roma VF at both the farm gate and market were higher than that of trans-heptachlor epoxy and cis-heptachlor epoxy respectively. Heptachlor undergoes both biological and chemical transformation to heptachlor epoxy and other degradation products in the environment. Heptachlor epoxy degrades more slowly and, as a result, is more persistent than heptachlor (ATSDR 2005a).

Therefore, the higher concentrations of heptachlor than heptachlor epoxy indicate that this insecticide has been used recently.

5.5 Comparison of mean concentrations (mg/kg) of organochlorine insecticides residues in tomato samples with EU MRLs

Table 4.4 above (page 44) shows that all the twenty organochlorine insecticides detected were low and below the EU MRLs. This presupposes that tomatoes from the selected communities and markets poses minimal hazard to consumers and therefore safe for consumption. However, it is important to note that, the effect of a pesticide on human health is dependent on the quantity of the pesticide accumulated as well as the frequency of exposure and the health of the person at the time of the exposure (Karalliedde *et al*., 2003).

Therefore, even though the levels are lower than the EU MRLs, there is still a cause for concern. This is because consumers who frequently consume these tomatoes may have these organochlorines accumulated in their bodies.

The results of the present study are comparable with those of other studies. For example, Darko and Acquaah (2007) found that the levels of organochlorines in meat from the Kumasi and Buoho abattoirs were lower than the maximum limits set by FAO/WHO. In a similar study, Usman *et al*., (2009) found that all the marketed fruits and vegetables sampled from Lahore, Parksitan had residue levels below the maximum residue limit (MRL) set by WHO.

Again, the detection of these organochlorine insecticide residues in the samples could possibly mean either pass usage of organochlorines or misuse of agrochemicals among the farmers covered in the study.

This is evident in some work already done in some farming communities in the Ashanti Region of Ghana and some other countries; the presence of organochlorine pesticide residue in fish (Osafo and Frempong, 1998), vegetables, water sediments, mother's milk and blood samples (Ntow, 2001).

There are other evidences that substantiate these results. Previous work done by Gerken *et al*., (2001) suggested that organochlorine pesticides are widely used by farmers because of their effectiveness and their broad spectrum activity. Lindane (Gamma BHC) is widely used in Ghana in cocoa plantations, on vegetable farms and for the control of stem borers in maize. Endosulfan, marketed as Thiodan, is widely used in cotton growing areas on vegetable farms and on coffee plantations.

5.6 Comparison of mean concentrations of organochlorine residues among the varieties of tomatoes.

Statistical analysis shows significant differences in the mean concentrations of almost all the organochlorine residue among the varieties ($p<0.05$) as shown in Appendix 2 (tables 1b, 2b, 3b, 4b, 5b, 12b, 13b, 15b, 17b, 18b, 19b, 20b).

The tomatoes were grown in different zones of the district and possibly having differences in soil conditions. Differences in agronomic practices could have affected the concentration levels. Therefore, the significant differences between the varieties suggest that their absorption or accumulation abilities differ. Again, the significant differences in insecticide residues could be attributed to cuticle thickness.

The cuticle of fruits limits the loss of substances from the fruits internal tissues, protects the fruits against physical, chemical, and biological attacks and protects the fruits against the external environment while the fruit is on the plant as well after harvest (Antonio *et al*., 2005).

5.7 Comparison of mean concentrations of organochlorine residues among locations

Appendix 3 with reference to all tables comparing organochlorines by location shows that statistically, there were significant differences in the mean concentrations of all the organochlorine residues among the sampling locations. This variation may be due to differences in the agronomic practices especially in the use of insecticides. The time elapsed between application and harvest could result in the differences.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The research work was carried out in two phases. The result of the field survey showed that 15 different insecticides were used to control insect pests on tomato production in the Fanteakwa district.

The field survey also established that, tomato production in the Fanteakwa District in one way or the other had the problem of misuse and improper combinations of insecticides to control insect pests. Chemical pesticides are used improperly or in dangerous combinations (Obeng-Ofori *et al*. 2002).

The laboratory analysis revealed the presence of banned organochlorine pesticides in tomato samples. The average levels of organochlorine residues in tomatoes sampled in this study were generally below the EU MRLs. Therefore, tomatoes from Fanteakwa are safe for consumption. However, because of their lipid solubility and resistance to metabolism, they can bioaccumulate in human tissues of consumers. So, chronic exposure could pose health problems.

The results of the study also revealed the misuse of insecticides. Although the concentrations are generally low, the study shows that the organochlorine insecticides are still being used despite the fact that they have been banned from use in Ghana.

6.2 Recommendations

Taking cognizance of the fact that organochlorines impact negatively on health and environment, there is the need for the tomato farmers to be sensitized against illegal use of banned insecticides. In addition, the following recommendations are made:

1. Educative and informative programmes on the use of insecticides and their residues should be organized for farmers in the district.
2. EPA and PPRSD must ensure the enforcement of the laws banning the use of organochlorine insecticides.
3. Stakeholders such as the Ministry of Food and Agriculture, EPA and Ghana Association of Agro Input dealers should be resourced and motivated to combat the importation and smuggling of banned pesticides into the country.
4. Similar research should be conducted to determine organochlorine residues in other crops and soils from the district to ascertain if there is a relationship between the residues in fruits from farms and the soil.
5. The need for constant monitoring of organochlorine residues in the study area is essential.
6. Tomatoes must be properly washed with salt water (brine) to reduce chemical residues and other unwanted materials deposited on the fruits.

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APPENDICES

Appendix 1 (Responses from Questionnaire)

Table 1: Sex of Respondent

Sex/Gender	Frequency	Percent	Cumulative Percent
Male	34	82.9	82.9
Female	7	17.1	100.0
Total	41	100.0	

Table 2: Educational Level of Respondents

Educational Level	Frequency	Percent	Cumulative Percent
Basic	25	61.0	61.0
Secondary	8	19.5	80.5
Tertiary	2	4.9	85.4
No Formal Education	3	7.3	92.7
Non-Formal Education	1	2.4	95.1
MSLC	2	4.9	100.0
Total	41	100.0	

Table 3: Varieties of Tomato Cultivated by Farmers

Variety	Frequency	Percent	Cumulative Percent
Pectomech VF	8	19.5	19.5
Power	8	19.5	39.0
Roma VF	11	26.8	65.9
Wosowoso	5	12.2	78.0
Pectomech and Power	6	14.6	92.7
Roma VF, Pectomech VF and Power	3	7.3	100.0
Total	41	100.0	

Table 4: Combination of insecticide for spraying

Response	Frequency	Percent	Cumulative Percent
Yes	15	36.6	36.6
No	26	63.4	100.0
Total	41	100.0	

Table 5: Reason for choosing particular insecticide

Reason	Frequency	Percent	Cumulative Percent
Price is moderate	1	2.4	2.4
Efficiency in pest control	24	58.5	61.0
Efficiency in pest control and easily available	8	19.5	80.5
Price is moderate, efficiency in pest control and easily available	4	9.8	90.2
Price is moderate and easily available	4	9.8	100.0
Total	41	100.0	

Table 6: Factors Determining when Farmers Apply Pesticides to Control Insect Pests

Spraying Indicator	Frequency	Percent	Cumulative Percent
Presence of pest on basis of scouting	9	22.0	22.0
Spray on routine schedule	16	39.0	61.0
AEAs recommendation	10	24.4	85.4
Colleague farmer recommendation	1	2.4	87.8
Spray on routine schedule and AEAs recommendation	5	12.2	100.0
Total	41	100.0	

Table 7: Frequency of spraying within a growing season

Periods	Frequency	Percent	Cumulative Percent
1-5 times	6	14.6	14.6
6-10 times	22	53.7	68.3
11-15 times	12	29.3	97.6
more than 20 times	1	2.4	100.0
Total	41	100.0	

Table 8: Efficacy of Pesticides Used by Farmers to Control Insect Pests in Tomato Cultivation

Effectiveness	Frequency	Percent	Cumulative Percent
very effective	18	43.9	43.9
Effective	20	48.8	92.7
Moderate	3	7.3	100.0
Total	41	100.0	

Table 9: Time of Day that Praying took place

Time of day	Frequency	Percent	Cumulative Percent
Morning	34	82.9	82.9
Morning and evening	5	12.2	95.1
Morning, afternoon and evening	1	2.4	97.6
Afternoon and evening	1	2.4	100.0
Total	41	100.0	

Table 10: Spraying Intervals (Intervals between One Spraying Period and the Next)

Spraying Interval	Frequency	Percent	Cumulative Percent
3 days	3	7.3	7.3
4 days	1	2.4	9.8
5 days	3	7.3	17.1
6 days	1	2.4	19.5
Weekly	29	70.7	90.2
More than a week	4	9.8	100.0
Total	41	100.0	

Table 11: Spraying of Pesticides during Harvesting of Tomato

Response	Frequency	Percent	Cumulative Percent
Yes	16	39.0	39.0
No	25	61.0	100.0
Total	41	100.0	

Table 12: Safety Precaution Adopted by Farmers during Spraying of Pesticides

Response	Frequency	Percent	Cumulative Percent
Yes	39	95.1	95.1
No	2	4.9	100.0
Total	41	100.0	

Appendix 2: Analysis of Variance of mean concentrations of insecticides among varieties of tomatoes

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.04652	4	0.023260	0.070125	0.05343	0.875119
Within Groups	0.09844	16	0.049219			
Total	0.14496	20				

Table 1a: ANOVA of A- HCH and varieties

Table 1b: Comparison of A-HCH by variety

Paired variety	Mean difference	P-Value
Roma VF vs Power	0.00023	0.04977
Roma VF vs Pectomech	0.0003	0.04968
Roma VF vs Wosowoso	0.0004	0.04963
Power vs Pectomech	0.00008	0.04992
Power vs Wosowoso	0.00013	0.04987
Pectomech vs Wosowoso	0.00005	0.04995

Table 2a ANOVA of HCB and varieties

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.04652	4	0.023260	0.070125	0.059981	0.875119
Within Groups	0.09844	16	0.049219			
Total	0.14496	20				

Table 2b: Comparison of HCB by variety

Paired variety	Mean difference	P-Value
Roma VF vs Power	0.00023	0.04977
Roma VF vs Pectomech	0.0003	0.04968
Roma VF vs Wosowoso	0.0004	0.04963
Power vs Pectomech	0.00008	0.04992
Power vs Wosowoso	0.00013	0.04987
Pectomech vs Wosowoso	0.00005	0.04995

Table 3a: ANOVA of B-HCH against varieties

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00023	4	0.000437	9.007	0.019121	2.1114
Within Groups	0.00093	16	0.000110			
Total	0.00112	20				

Table 3b: Comparison of B-HCH by varieties

Paired variety	Mean difference	P-Value
Roma VF vs Power	0.00057	0.04943
Roma VF vs Pectomech	0.0018	0.04822
Roma VF vs Wosowoso	0.0019	0.04807
Power vs Pectomech	0.00122	0.04878
Power vs Wosowoso	0.00137	0.04863
Pectomech vs Wosowoso	0.00015	0.04985

Table 4a: ANOVA of G-HCH against varieties

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00023	4	0.000437	0.114147	0.063191	0.22145
Within Groups	0.00093	16	0.000110			
Total	0.00112	20				

Table 4b: Comparison of G-HCH by variety

Paired variety	Mean difference	P-Value
Roma VF vs Power	0.00047	0.04953
Roma VF vs Pectomech	0.0005	0.04950
Roma VF vs Wosowoso	0.0006	0.04940
Power vs Pectomech	0.00003	0.04997
Power vs Wosowoso	0.00013	0.04987
Pectomech vs Wosowoso	0.00010	0.04990

Table 5a: ANOVA of D-HCH and variety

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00433	4	0.000437	1.907869	0.157863	1.98997
Within Groups	0.00769	16	0.000110			
Total	0.01201	20				

Table 5b: Comparison of D-HCH by variety

Paired variety	Mean difference	P-Value
Roma VF vs Power	0.00043	0.04957
Roma VF vs Pectomech	0.0005	0.04952
Roma VF vs Wosowoso	0.0005	0.04947
Power vs Pectomech	0.00005	0.04995
Power vs Wosowoso	0.00010	0.04990
Pectomech vs Wosowoso	0.00005	0.04995

Table 6a: ANOVA of Heptachlor and variety

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.99704	4	0.006758	8.5478	0.044444	2.98613
Within Groups	1.89765	16	0.009329			
Total	2.89469	20				

Table 6b: Comparison of Heptachlor by variety

Paired variety	Mean difference	P-Value
Roma VF vs Power	-0.00060	0.05060
Roma VF vs Pectomech	0.0007	0.04930
Roma VF vs Wosowoso	0.0006	0.04940
Power vs Pectomech	0.00130	0.04870
Power vs Wosowoso	0.00120	0.04880
Pectomech vs Wosowoso	-0.00010	0.05010

Table 7a: ANOVA of Aldrin and variety

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.13704	4	0.000276	1.5478	0.187007	0.05613
Within Groups	0.25677	16	0.009329			
Total	0.39381	20				

Table 7b: Comparison of Aldrin by variety

Paired variety	Mean difference	P-Value
Roma VF vs Power	0.00060	0.04940
Roma VF vs Pectomech	0.0000	0.04998
Roma VF vs Wosowoso	0.0006	0.04943
Power vs Pectomech	-0.00058	0.05058
Power vs Wosowoso	-0.00003	0.05003
Pectomech vs Wosowoso	0.00055	0.04945

Table 8a ANOVA of Cis-heptachlor epoxy and variety

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.13704	4	0.000276	0.0053	0.046873	0.5478
Within Groups	0.25677	16	0.009329			
Total	0.39381	20				

Table 8b: Comparison of Cis-heptachlor epoxy by variety

Paired variety	Mean difference	P-Value
Roma VF vs Power	-0.00193	0.05193
Roma VF vs Pectomech	0.0008	0.04922
Roma VF vs Wosowoso	0.0010	0.04897
Power vs Pectomech	0.00272	0.04728
Power vs Wosowoso	0.00297	0.04703
Pectomech vs Wosowoso	0.00025	0.04975

Table 9a: ANOVA of Trans –heptachlor Epoxy and variety

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.06754	4	0.000276	O.98634	0.111718	1.097895
Within Groups	0.08765	16	0.009329			
Total	0.15519	20				

Table 9b: comparison of trans-heptachlor epoxy by variety

Paired variety	Mean difference	P-Value
Roma VF vs Power	0.00063	0.04937
Roma VF vs Pectomech	0.0006	0.04940
Roma VF vs Wosowoso	0.0006	0.04940
Power vs Pectomech	-0.00003	0.05003
Power vs Wosowoso	-0.00003	0.05003
Pectomech vs Wosowoso	0.00000	0.05000

Table 10a: ANOVA of Trans –Chlordane and variety

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00056	4	0.000276	1.0985	0.060716	1.98976
Within Groups	0.00657	16	0.000213			
Total	0.00714	20				

Table 10b: Comparison of Trans- chlordane by variety

Paired variety	Mean difference	P-Value
Roma VF vs Power	0.00053	0.04947
Roma VF vs Pectomech	0.0005	0.04952
Roma VF vs Wosowoso	0.0005	0.04947
Power vs Pectomech	-0.00005	0.05005
Power vs Wosowoso	0.00000	0.05000
Pectomech vs Wosowoso	0.00005	0.04995

Table 11a: ANOVA of O`P-DDE and variety

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00076	4	0.000276	0.0985	0.060716	0.09976
Within Groups	0.00657	16	0.000213			
Total	0.00734	20				

Table 11b: Comparison of O`P-DDE by variety

Paired variety	Mean difference	P-Value
Roma VF vs Power	0.00167	0.04833
Roma VF vs Pectomech	0.0010	0.04905
Roma VF vs Wosowoso	0.0013	0.04870
Power vs Pectomech	-0.00072	0.05072
Power vs Wosowoso	-0.00037	0.05037
Pectomech vs Wosowoso	0.00035	0.04965

Table 12a: ANOVA of Cis-chlordane and variety

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00046	4	0.000276	0.091185	0.075288	0.987976
Within Groups	0.00765	16	0.000213			
Total	0.00811	20				

Table 12b: Comparison of Cis-chlordane by variety

Paired variety	Mean difference	P-Value
Roma VF vs Power	0.00047	0.00203
Roma VF vs Pectomech	0.0004	0.00212
Roma VF vs Wosowoso	0.0006	0.00187
Power vs Pectomech	-0.00008	0.00258
Power vs Wosowoso	0.00017	0.00233
Pectomech vs Wosowoso	0.00025	0.00225

Table 13a: ANOVA of Trans-Nanochlor and variety

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00456	4	0.000276	1.897119	0.075288	1.997976
Within Groups	0.00977	16	0.000213			
Total	0.01433	20				

Table 13b: Comparison of Trans-Nanochlor by variety

Paired variety	Mean difference	P-Value
Roma VF vs Power	0.00030	0.02470
Roma VF vs Pectomech	0.0003	0.02470
Roma VF vs Wosowoso	0.0005	0.02450
Power vs Pectomech	0.00000	0.02500
Power vs Wosowoso	0.00020	0.02480
Pectomech vs Wosowoso	0.00020	0.02480

Table 14a: ANOVA of PP-DDE and variety

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00456	4	0.000276	1.897119	0.27201	1.997976
Within Groups	0.00977	16	0.000213			
Total	0.01433	20				

Table 14b: Comparison of PP-DDE by variety

Paired variety	Mean difference	P-Value
Roma VF vs Power	0.00193	0.00307
Roma VF vs Pectomech	0.0016	0.00342
Roma VF vs Wosowoso	0.0017	0.00327
Power vs Pectomech	-0.00035	0.00535
Power vs Wosowoso	-0.00020	0.00520
Pectomech vs Wosowoso	0.00015	0.00485

Table 15a: ANOVA of Dieldrin and variety

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00877	4	0.003460	2.98787	0.099575	3.00876
Within Groups	0.02977	16	0.004321			
Total	0.03853	20				

Table 15b: Comparison of Dieldrin by variety

Paired variety	Mean difference	P-Value
Roma VF vs Power	0.00100	0.02400
Roma VF vs Pectomech	0.0006	0.02443
Roma VF vs Wosowoso	0.0011	0.02393
Power vs Pectomech	-0.00043	0.02543
Power vs Wosowoso	0.00007	0.02493
Pectomech vs Wosowoso	0.00050	0.02450

Table 16a: ANOVA of O`P-DDD and variety

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00877	4	0.003460	1.009988	0.119004	1.01876
Within Groups	0.02977	16	0.004321			
Total	0.03853	20				

Table 16b: Comparison of OP-DDD by variety

Paired variety	Mean difference	P-Value
Roma VF vs Power	0.00097	0.04903
Roma VF vs Pectomech	0.0009	0.04913
Roma VF vs Wosowoso	0.0013	0.04873
Power vs Pectomech	-0.00010	0.05010
Power vs Wosowoso	0.00030	0.04970
Pectomech vs Wosowoso	0.00040	0.04960

Table 17a ANOVA of Endrin and variety

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00877	4	0.003460	3.009988	0.191573	4.00876
Within Groups	0.02977	16	0.004321			
Total	0.03853	20				

Table 17b: Comparison of Endrin by variety

Paired variety	Mean difference	P-Value
Roma VF vs Power	0.00060	0.02440
Roma VF vs Pectomech	0.0003	0.02470
Roma VF vs Wosowoso	0.0004	0.02460
Power vs Pectomech	-0.00030	0.02530
Power vs Wosowoso	-0.00020	0.02520
Pectomech vs Wosowoso	0.00010	0.02490

Table 18a: ANOVA of PP-DDD and variety

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00813	4	0.003460	0.069988	0.098859	0.098088
Within Groups	0.06598	16	0.004321			
Total	0.07410	20				

Table 18b: Comparison of PP-DDD by variety

Paired variety	Mean difference	P-Value
Roma VF vs Power	-0.00023	0.00273
Roma VF vs Pectomech	0.0000	0.00248
Roma VF vs Wosowoso	0.0003	0.00223
Power vs Pectomech	0.00025	0.00225
Power vs Wosowoso	0.00050	0.00200
Pectomech vs Wosowoso	0.00025	0.00225

Table 19a: ANOVA of OP-DDT and variety

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.04320	4	0.003460	0.020125	0.060716	0.066119
Within Groups	0.05439	16	0.004321			
Total	0.09759	20				

Table 19b: Comparison of OP-DDT by variety

Paired variety	Mean difference	P-Value
Roma VF vs Power	0.00010	0.00240
Roma VF vs Pectomech	-0.0003	0.00280
Roma VF vs Wosowoso	0.0003	0.00220
Power vs Pectomech	-0.00040	0.00290
Power vs Wosowoso	0.00020	0.00230
Pectomech vs Wosowoso	0.00060	0.00190

Table 20a ANOVA of PP-DDT and variety

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.04652	4	0.023260	0.070125	0.026746	0.065119
Within Groups	0.09844	16	0.049219			
Total	0.14496	20				

Table 20b: Comparison of PP-DDT by variety

Paired variety	Mean difference	P-Value
Roma VF vs Power	0.00010	0.00240
Roma VF vs Pectomech	-0.0003	0.00280
Roma VF vs Wosowoso	0.0003	0.00220
Power vs Pectomech	-0.00040	0.00290
Power vs Wosowoso	0.00020	0.00230
Pectomech vs Wosowoso	0.00060	0.00190

Appendix 3: Analysis of variance of mean concentrations of insecticides among locations

Table 1a: ANOVA of A-HCH and location

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.04652	3	0.015507	0.02001	0.05998	0.03675
Within Groups	0.09844	17	0.049219			
Total	0.14496	20				

Table 1b: Comparison of A-HCH by location

Paired sample location	Mean difference	P-Value
Begoro*Oboroahoho/Ofosukrom	0.00030	0.02460
Ehiamankyene*Apaah /AkoraDarko	0.0004	0.02470
Ahomahomaso*Ntanuam/Krobo Meyewa	0.0004	0.02500

Table 2a: ANOVA of HCB and location

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.01262	3	0.004207	0.02001	0.054487	0.03675
Within Groups	0.01284	17	0.006422			
Total	0.02546	20				

Table 2b: Comparison of HCB by location

Paired sample location	Mean difference	P-Value
Begoro*Oboroahoho/ Ofosukrom	0.00010	0.02480
Ehiamankyene*Apaah /AkoraDarko	0.0000	0.02490
Ahomahomaso*Ntanuam/Krobo Meyewa	0.0002	0.02500

Table 3a Anova of B-HCH and location

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00232	3	0.000772	0.99273	0.004624	0.95438
Within Groups	0.08721	17	0.043607			
Total	0.08953	20				

Table 3b: Comparison of B-HCH by location

Paired sample location	Mean difference	P-Value
Begoro*Oboroahoho/ Ofosukrom	0.00380	0.02350
Ehiamankyene*Apaah /AkoraDarko	0.0017	0.02120
Ahomahomaso*Ntanuam/Krobo Meyewa	0.0015	0.02330

Table 4a: Anova of G-HCH and location

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.03493	3	0.011644	0.59843	0.05358	0.63894
Within Groups	0.05472	17	0.003219			
Total	0.08965	20				

Table 4b: Comparison of G-HCH by location

Paired Sample location	Mean difference	P-Value
Begoro*Oboroahoho/ Ofosukrom	0.00100	0.02500
Ehiamankyene*Apaah /AkoraDarko	0.0008	0.02400
Ahomahomaso*Ntanuam/Krobo Meyewa	0.0000	0.02420

Table 5a ANOVA of D-HCH and location

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00435	3	0.001450	0.005432	0.065476	0.00592
Within Groups	0.05544	17	0.003261			
Total	0.05979	20				

Table 5b: Comparison of D-HCH by location

Paired sample location	Mean difference	P-Value
Begoro*Oboroahoho/ Ofosukrom	-0.00040	0.02430
Ehiamankyene*Apaah /AkoraDarko	0.0007	0.02540
Ahomahomaso*Ntanuam/Krobo Meyewa	0.0007	0.02430

Table 6a: ANOVA of Heptachlor and location

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00435	3	0.001450	1.00932	0.04516	0.97659
Within Groups	0.05544	17	0.003261			
Total	0.05979	20				

Table 6b: Comparison of Heptachlor by location

Paired sample location	Mean difference	P-Value
Begoro*Oboroahoho/ Ofosukrom	0.00540	0.02460
Ehiamankyene*Apaah /AkoraDarko	0.0020	0.01960
Ahomahomaso*Ntanuam/Krobo Meyewa	0.0004	0.02300

Table 7a: ANOVA of Aldrin and location

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00547	3	0.001822	0.9287	0.064	1.0867
Within Groups	0.05544	17	0.003261			
Total	0.06090	20				

Table 7b: Comparison of Aldrin by location

Paired sample location	Mean difference	P-Value
Begoro*Oboroahoho/ Ofosukrom	0.00020	0.02480
Ehiamankyene*Apaah /AkoraDarko	0.0026	0.02480
Ahomahomaso*Ntanuam/Krobo Meyewa	0.0002	0.02240

Table 8a: ANOVA of cis-heptachlor epoxy and location

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00547	3	0.001822	0.8787	0.0864	1.87667
Within Groups	0.04354	17	0.002561			
Total	0.04901	20				

Table 8b: Comparison of cis-heptachlor by location

Paired sample location	Mean difference	P-Value
Begoro*Oboroahoho/ Ofosukrom	0.00980	0.02540
Ehiamankyene*Apaah /AkoraDarko	0.0029	0.01520
Ahomahomaso*Ntanuam/Krobo Meyewa	-0.0004	0.02210

Table 9a: ANOVA of Trans-heptachlor epoxy and location

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.46547	3	0.155156	0.99107	0.0987	1.00467
Within Groups	0.04354	17	0.002561			
Total	0.50901	20				

Table 9b: Comparison of B-HCH by location

Paired sample location	Mean difference	P-Value
Begoro*Oboroahoho/ Ofosukrom	0.00980	0.02540
Ehiamankyene*Apaah /AkoraDarko	0.0029	0.01520
Ahomahomaso*Ntanuam/Krobo Meyewa	-0.0004	0.02210

Table 10a ANOVA of Trans-chlordane and location

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.06799	3	0.022663	2.99107	0.1987	3.00467
Within Groups	0.37214	17	0.021891			
Total	0.44013	20				

Table10b: Comparison of B-HCH by location

Paired sample location	Mean difference	P-Value
Begoro*Oboroahoho/ Ofosukrom	0.00980	0.02540
Ehiamankyene*Apaah /AkoraDarko	0.0029	0.01520
Ahomahomaso*Ntanuam/Krobo Meyewa	-0.0004	0.02210

Table 11a ANOVA of OP-DDE and location

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00680	3	0.002266	1.90107	0.24987	1.998
Within Groups	0.93721	17	0.055130			
Total	0.94401	20				

Table 11b comparison of OP-DDE by location

Paired sample location	Mean difference	P-Value
Begoro*Oboroahoho/ Ofosukrom	0.00020	0.02480
Ehiamankyene*Apaah /AkoraDarko	0.0026	0.02480
Ahomahomaso*Ntanuam/Krobo Meyewa	0.0002	0.02240

Table 12a ANOVA of Cis-chlordane and location

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00780	3	0.002600	0.90107	0.0954	1.998
Within Groups	0.98721	17	0.058071			
Total	0.99501	20				

Table 12b comparison of Cis-chlordane by location

Paired sample location	Mean difference	P-Value
Begoro*Oboroahoho/ Ofosukrom	-0.00030	0.02550
Ehiamankyene*Apaah /AkoraDarko	0.0011	0.02530
Ahomahomaso*Ntanuam/Krobo Meyewa	-0.0005	0.02390

Table 13a: ANOVA of Trans-Nanochlor and location

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.76780	3	0.255933	1.00978	0.066754	1.0124
Within Groups	0.72140	17	0.042435			
Total	1.48920	20				

Table 13b: Comparison of B-HCH by location

Paired sample location	Mean difference	P-Value
Begoro*Oboroahoho/ Ofosukrom	-0.00090	0.02500
Ehiamankyene*Apaah /AkoraDarko	0.0004	0.02590
Ahomahomaso*Ntanuam/Krobo Meyewa	0.0000	0.02460

Table 14a: ANOVA of PP-DDE and location

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.06768	3	0.022559	1.10978	0.097675	1.90124
Within Groups	0.04721	17	0.002777			
Total	0.11489	20				

Table 14b: Comparison of PP-DDE by location

Paired sample location	Mean difference	P-Value
Begoro*Oboroahoho/ Ofosukrom	0.00000	0.02460
Ehiamankyene*Apaah /AkoraDarko	0.0034	0.02500
Ahomahomaso*Ntanuam/Krobo Meyewa	0.0004	0.02160

Table 15a: ANOVA of Dieldrin and location

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.06077	3	0.020256	1.10978	0.084576	1.87301
Within Groups	0.65332	17	0.038431			
Total	0.71409	20				

Table 15b: Comparison of Dieldrin by location

Paired sample location	Mean difference	P-Value
Begoro*Oboroahoho/ Ofosukrom	0.00000	0.02620
Ehiamankyene*Apaah /AkoraDarko	0.0017	0.02500
Ahomahomaso*Ntanuam/Krobo Meyewa	-0.0012	0.02330

Table 16a: ANOVA of OP-DDD and location

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.08978	3	0.029927	1.10978	0.187658	1.76037
Within Groups	0.69853	17	0.041090			
Total	0.78831	20				

Table 16b: Comparison of OP-DDD by location

Paired sample location	Mean difference	P-Value
Begoro*Oboroahoho/ Ofosukrom	-0.00070	0.02520
Ehiamankyene*Apaah /AkoraDarko	0.0017	0.02570
Ahomahomaso*Ntanuam/Krobo Meyewa	-0.0002	0.02330

Table 17a ANOVA of Endrin and location

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00978	3	0.003260	0.00978	0.057676	1.56037
Within Groups	0.09699	17	0.005705			
Total	0.10677	20				

Table 17b: Comparison of Endrin by location

Paired sample location	Mean difference	P-Value
Begoro*Oboroahoho/ Ofosukrom	0.00000	0.02480
Ehiamankyene*Apaah /AkoraDarko	0.0007	0.02500
Ahomahomaso*Ntanuam/Krobo Meyewa	0.0002	0.02430

Table 18a: ANOVA of PP-DDD and location

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.01099	3	0.003663	0.01978	0.067676	0.50373
Within Groups	0.00699	17	0.000411			
Total	0.01798	20				

Table 18b: Comparison of PP-DDD by location

Paired sample location	Mean difference	P-Value
Begoro*Oboroahoho/ Ofosukrom	0.00010	0.02500
Ehiamankyene*Apaah /AkoraDarko	0.0007	0.02490
Ahomahomaso*Ntanuam/Krobo Meyewa	0.0000	0.02430

Table 19a: ANOVA of PP-DDE and location

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.89896	3	0.299654	0.926778	0.15	1.37301
Within Groups	0.05989	17	0.003523			
Total	0.95885	20				

Table 19b: Comparison of PP-DDE by location

Paired sample location	Mean difference	P-Value
Begoro*Oboroahoho/ Ofosukrom	0.00020	0.02470
Ehiamankyene*Apaah /AkoraDarko	0.0005	0.02480
Ahomahomaso*Ntanuam/Krobo Meyewa	0.0003	0.02450

Table 20a: ANOVA of PP-DDT and location

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.89896	3	0.299654	1.098	0.043	1.07301
Within Groups	0.09899	17	0.005823			
Total	0.99795	20				

Table 20b: Comparison of PP-DDT by location

Paired sample location	Mean difference	P-Value
Begoro*Oboroahoho/ Ofosukrom	-0.00340	0.02350
Ehiamankyene*Apaah /AkoraDarko	0.0059	0.02840
Ahomahomaso*Ntanuam/Krobo Meyewa	0.0015	0.01910

Appendix 4: Sample of Questionnaire Used

Questionnaire for Survey on Farmers' Knowledge on Insecticide Use and Practices

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

NB: information obtained from this survey is strictly for academic purpose. Thank you for your cooperation.

1. PROFILE OF THE FARMER

Age:..

Gender: *(Please Tick)* Male [ ] Female[ ]

Education:..

2. LOCATION:..

3. STATE VARIETY/VARIETIES OF TOMATO CULTIVATED: *(Please Tick)*

(i)	Roma VF	[ ]	(v)	Rio Grande 70	[ ]
(ii)	Pectomech VF	[ ]	(vi)	F1 Mongal	[ ]
(iii)	Tripomech	[ ]	(vii)	Wosowoso	[ ]
(iv)	Laurano 70	[ ]	(viii)	Others	[ ] Specify..

4. STATE THE TYPES OF INSECTICIDES USED TO CONTROL INSECT PEST ON TOMATOES

5. DO YOU USE COMBINATION OF INSECTICIDES IN CONTROLLING INSECT PESTS IN A GROWING SEASON? *(Please Tick)*

(i) Yes [ ]

(ii) No [ ]

6. IF YES, NAME THEM (COMBINATION OF INSECTICIDES)

7. ACTIVE INGREDIENTS OF INSECTICIDES MENTIONED ABOVE

8. STATE THE DOSAGE OF APPLICATION OF INSECTICIDES MENTIONED ABOVE

9. REASON(S) FOR CHOOSING PARTICULAR INSECTICIDES. *(Please Tick)*

(i) Price is moderate [ ]
(ii) Efficiency of eliminating/controlling insect pests [ ]
(iii) Easily available [ ]
(iv) Others [ ] Specify:..................

10. WHEN DO YOU DECIDE TO APPLY INSECTICIDES ON YOUR TOMATO? *(Please 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..................

11. FREQUENCY OF SPRAYING IN A GROWING SEASON. *(Please Tick)*

(i) 1 – 5 times [ ]
(ii) 6 – 10 times [ ]
(iii) 11 – 15 times [ ]
(iv) 16 – 20 times [ ]
(v) Others [ ] Specify................................

12. EFFICIENCY OF INSECTICIDES IN TERMS OF ELIMINATING/CONTROLLING INSECTICIDES. *(Please Tick)*

(i) Very effective (80 – 90%) [ ]
(ii) Effective (60 – 70%) [ ]

(iii) Moderate (40 – 50%) [ ]
(iv) Poor (bellow 40%) [ ]

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

14. SPRAYING INTERVALS *(Please Tick)*

(i) 2 days [ ]
(ii) 3 days [ ]
(iii) 4 days [ ]
(iv) 5 days [ ]
(v) 6 days [ ]
(vi) weekly [ ]
(vii) others [ ]

15. DO YOU CONTINUE SPRAYING WHILE HARVESTING? *(Please Tick)*

(i) Yes [ ]
(ii) No [ ]

16. IF NO, STATE SPRAYING INTERVAL BETWEEN LAST SPRAYING AND HARVESTING. *(Please Tick)*

(i) 1 – 3 days [ ]
(ii) 4 – 6 days [ ]
(iii) 7 – 10 days [ ]
(iv) 11 – 14 days [ ]
(v) Others [ ] Specify..
....

17. DO YOU TAKE ANY SAFETY PRECAUTIONARY MEASURES DURING SPRYAING OF INSECTICIDES? *(Please Tick)*

(i) Yes [ ]

(ii) No [ ]

18. IF YES, INDICATE. *(Please Tick)*

(i) The use of nose and mouth protection [ ]
(ii) Special clothing [ ]
(iii) Hand Gloves [ ]
(iv) Eye Goggle [ ]
(v) Others [ ] Specify................................

19. TYPE OF SPRAYING MACHINE USED. *(Please Tick)*

(i) Motorized spraying machine [ ]
(ii) Knapsack spraying machine [ ]
(iii) Others [ ] Specify................................

20. STATE THE DISTANCE BETWEEN ONE TOMATO FARM AND ANOTHER. *(Please Tick)*

(i) 50m [ ]
(ii) 100m [ ]
(iii) 150m [ ]
(iv) Others [ ] Specify................................