KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

COLLEGE OF AGRICULTURE AND NATURAL RESOURCES

FACULTY OF AGRICULTURE

DEPARTMENT OF HORTICULTURE

ASSESSMENT OF PESTICIDES USED TO CONTROL INSECT PESTS AND THEIR EFFECTS ON STORAGE OF CABBAGE *(Brassica oleracea var capitata)* – A CASE STUDY IN EJISU-JUABEN MUNICIPAL AREA

BY

PETER KWAME AMOAKO

JANUARY, 2010

ASSESSMENT OF PESTICIDES USED TO CONTROL INSECT PESTS AND THEIR

EFFECTS ON STORAGE OF CABBAGE *(Brassica oleracea var capitata)* -

A CASE STUDY IN EJISU-JUABEN MUNICIPAL AREA

A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE

STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE

AWARD OF MASTER OF SCIENCE

(MSC. POSTHARVEST PHYSIOLOGY) DEGREE

BY

PETER KWAME AMOAKO

JANUARY, 2010

DECLARATION

I hereby declare that, except for references to other people's work which have been duly acknowledged, this write-up, submitted to the 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.

....

PETER KWAME AMOAKO DATE

(STUDENT)

CERTIFIED BY

....

MR PATRICK KUMAH DATE

(SUPERVISOR)

....

DR B. K. MAALEKUU DATE

(HEAD OF DEPARTMENT)

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to the Almighty God for his numerous blessings, divine protection and direction throughout my studies.

My profound gratitude also goes to Mr Patrick Kumah, my supervisor for his valued criticisms, suggestions and corrections which, no doubt, helped me greatly in preparing this dissertation. Special thanks are due to Mrs Beatrice Asante-Mante, Municipal Director of Agriculture, and staff of MOFA, Ejisu-Juabeng Municipal Assembly for their support and advice.

I am also grateful to the Head and staff of Horticulture Department, Faculty of Agriculture, KNUST for their assistance during the field work. I wish to express my sincere thanks to my family, most especially, my wife, Doris Fofie, my children and my brothers for their support throughout my studies. I also wish to express my sincere thanks to all friends for their valuable contributions which enabled me to be sustained throughout the course.

Finally, it is a great pleasure to record my gratitude to Mr Alfred Osei for sacrificing his precious time to type this dissertation.

ABSTRACT

One of the setbacks to cabbage production in Ejisu-Juaben Municipal Area is insect pests. These insect pests are controlled in various ways; prominent among them is the use of pesticides. However, the use of pesticides in cabbage production comes with various health issues such as residual effects. The objective of this research was therefore, to find out the various pesticides used by farmers to control insect pests in cabbage production, the mode of the application of pesticides and their effects on the quality and safety of cabbage produced. The results of the study showed that majority of cabbage producers were men (representing 88%) and the remaining 12% were female. Eighteen percent (18%) of the farmers had no formal education; eighty percent (80%) of them had basic education and the remaining two percent (2%) with post secondary education. The result showed that about twenty seven (27) different pesticides were used by farmers to control insect pests on cabbage in the municipality. Sixty-one percent (61%) of the farmers mixed two or more pesticides together without considering their compatibility or active ingredients but just relied on trade names on the containers.It was also revealed from the results, that some banned chemicals like Lindane, Endosulfans, and DDT and those not recommended for vegetables like Akate master, Confidor and Cocostar were also being used. This suggested that some farmers misused pesticides which affected the quality and safety of cabbage heads for consumption. Even though, the results revealed that 51% of the farmers did routine (calendar) spraying which was usually done between 3-4 days interval, the rest did it when they noticed the presence of insect pests. The survey results showed that 80% of the farmers interviewed continued spraying pesticides during harvesting period; hence no waiting period was adopted. Only 21% of the farmers adopted one week waiting period on the average, which in many cases was not enough, considering the kinds of pesticides used.

Laboratory analysis confirmed that pesticide residues were indeed present in the cabbage heads and further analysis quantified the amounts present. Analysis of organochlorine residue levels in the cabbage heads at harvest indicated that Alpha BHC, Gamma BHC (Lindane), Beta BHC, Delta BHC, Beta Endosulfan and Heptachlor, had residue levels of 0.321 mg/kg, 0.908 mg/kg, 0.883 mg/kg, 0.394 mg/kg, 0.207 mg/kg and 0.140 mg/kg respectively, which were all higher than the FAO/WHO Guideline value of 0.05 mg/kg. The DDT and DDE had the same residue levels of 0.017mg/kg which is below the FAO/WHO Guideline value of 0.02mg/kg for them. The rest of the organochlorine pesticide residue levels indicated that Endrin, Dieldrin and Endosulfan Sulphate, had residue levels of 0.022 mg/kg, 0.010 mg/kg and 0.005 mg/kg respectively, which are all below the FAO/WHO Guideline value of 0.05 mg/kg for Endrin, Dieldrin and Endosulfan Sulphate, respectively. Analysis of residue levels of the organochlorines, after 14 days storage in a refrigerator at $5^{o}C$ showed significant ($P < 0.05$) reductions in pesticide residues in the cabbage heads. All the pesticide levels fell below the FAO/WHO recommended levels except Gamma BHC (Lindane) and Beta BHC whose levels although dropped significantly ($P < 0.05$), were still higher than the FAO/WHO levels. The analysis showed that storing cabbage for 14 days could remove all traces of Aldrin, Dieldrin and Endosulfan Sulphate. The organochlorine pesticides are banned for vegetable production in Ghana; therefore the detection of these residues in cabbage samples indicates misuse of agrochemicals among cabbage producers in Ejisu-Juaben Municipality. This poses health hazards for consumers, particularly, if the cabbages are consumed soon after harvest.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

LIST OF FIGURES

1.0 INTRODUCTION

The Ejisu-Juaben Municipal Assembly is one of the twenty-seven administrative districts in the Ashanti region. The municipality is located in the central part of the region and shares boundaries with Kumasi metropolis and Kwabre District to the west, Sekyere East and Ashanti Akim North Districts to the east and Bosomtwe Kwanwoma and Asante Akim South Districts to the South. The Municipality covers a total land area of about 6374km^2 forming about 2.6% of the entire area of the region.

The Municipality's economy is dominated by the agriculture sector, absorbing about 59% of the labor force. The service sector (commerce, transportation and other tertiary activities) takes about 27%, industrial sector about 13%, and others (bakery and hospitality industries) 1%. The Agricultural sector is dominated by subsistence farmers with only a few engaged in commercial farming. Major food crops cultivated are cassava, maize, plantain, rice and vegetables. The youth are engaged in vegetable production of which cabbage cultivation predominates (MOFA, 2001).

Cabbage (*Brassica oleracea var capitata*) is a temperate vegetable crop which has become very popular in tropical Africa. Its origin and centre of differentiation is thought to be in the west of the Mediterranean basin or in the Asia Minor. Although, it is a biennial, it is cultivated as an annual. The leaves are undulating, broad, thick smooth or crinkled and covered with a waxy substance. These are clumped around a central bud on a short, stocky stem and form the head. The adult plant develops a root system with a secondary root branching out from the main roots between 45 and 60cm below the soil surface. Cabbage is not sensitive to photoperiod and flowering is triggered mainly by temperature below 10^o C. Because of this requirement for vernalization, seed production is difficult under tropical conditions.

Depending on the growing season and the cultivar grown, yields vary between 10 and 40 tonnes per hectare. The best yields are obtained in cool, dry season with heads weigh between 2 and 2.5 kg. During the hot rainy season, yields of an average weight of head is between 1 and 1.5kg (Romain, 2001*)*.

Cabbage has traditionally been used for medicinal purpose as well as for cooking. It has antiinflammatory property and contains chemicals which can prevent cancer. The ancient Greeks used fresh white cabbage juice to relieve sore or infected eyes and juice from the cabbage stem is a good remedy for ulcers. Traditionally, the Romans and Egyptians would drink cabbage juice before big dinners to prevent intoxication. Cabbage seeds are said to prevent hangovers (Norman and Shealy, 2007).

Production of cabbage in Ghana is faced with numerous constraints. These include the high cost of inputs such as pesticides, fertilizers and attack by insect pests and diseases. Caterpillars of the Diamond back moth (*Plutella xylostella*), the cabbage web worm (*Hellula undalis*) and Cabbage aphids (*Brevicoryne brassicae*) are the most serious pests of cabbage in Ghana. To reduce damages caused by insect pests, various synthetic insecticides are applied at different stages of growth of the plant. These synthetic insecticides cause some toxicological and environmental problems which include toxic residue in food, soil, water, adverse effects on non target insects and other beneficial organisms as well as the development of resistant strains of insects (Ninsin, 1997). The gross and improper use of synthetic insecticides is an issue of much concern. Typical examples of insecticides used are Polythrine C and Cypercal. These insecticides are normally used against insect pests on cotton but these farmers use these products on vegetables. It has been estimated by the World

Health Organization (WHO) that about 20,000 people die each year from pesticide poisoning and at least 3 million people suffer acute health effects (Barbara, 1993).

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 residue 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).

During 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.

At the same time, 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 the cabbage crop from insect pests.

The objectives of this work were to find out the:

1. various pesticides used by farmers to control insect pests in cabbage production;
2. mode of application of pesticides and their effects on the quality and safety of cabbage, and
3. levels of organochlorine pesticide residues in cabbage, immediately after harvest and after 14 days storage in a refrigerator (5^{O} C).

2.0 LITERATURE REVIEW

2.1 HISTORY OF CABBAGE

In the wild, the cabbage plant is native to the Mediterranean region of Europe and is somewhat similar in appearance to a leafy canola plant. Sometime, soon after the domestication of plants began, people in the Mediterranean region began growing this first ancient cabbage plant as a leafy vegetable. Because leaves were the part of the plants which were consumed, it was natural that those plants with the largest leaves would be selectively propagated for next year's crop. This resulted in large and larger-leafed plants slowly being developed as the seed from the largest-leafed plants were favoured. By the 5th century B.C., continued preference for ever-larger leaved plants had led to the development of the vegetable we now know as Kale. Kale is known botanically as *Brassica oleracea* variety *acephala* which translates to mean cabbage, of the vegetable garden without a head. Kale continued to be grown as a leafy vegetable for thousands of years, and is still grown today. As time passed, however some people began to express a preference for those plants with a tight cluster of tender young leaves in the centre of the plant at the top of the stem. Because of this preference for plants in which there were a large number of tender leaves closely packed into the terminal bud at the top of the stem, these plants were selected and propagated more frequently. A continuous favouritism of these plants for hundreds of successive generations resulted in gradual formation of a more and more dense cluster of leaves at the top of the plants. Eventually, the cluster of leaves became so large, it tended to dominate the whole plant, and the cabbage "head" we know today was born. This progression is thought to have been completed in the 1st century AD. This plant was named Brassica *oleracea* variety *capitata* which translate to cabbage of vegetable garden with head (Baldwin, 1995).

2.2 NUTRITIONAL AND HEALTH BENEFITS OF CABBAGE

Cabbage has high nutritive value, supplying essential vitamins, proteins, carbohydrates and vital minerals (Norman, 1992). Tindall (1983) listed the nutritive components of cabbage leaves per 100g edible portion as follows: water – 93ml, calories – 23ml, protein – 1.5g, fat – 0.2g, carbohydrates - 4g, fibre – 0.8g, calcium – 40mg, iron – 0.5, vitamin potency – 30iu, thiamine – 0.05mg, riboflavin – 0.05mg, niacin – 0.3mg and ascorbic acid – 40mg.

A University of Utah School of Medicine study on 600 men revealed that those who ate the most cruciferous vegetables had a much lower risk of colon cancer. On the side of caution, however, consuming excessive amount of cabbage may contribute to thyroid problems, possibly goiter. A well known remedy for healing peptic ulcers is drinking cabbage juice. A medical study at Stanford University's School of Medicine gave thirteen ulcer patients five doses a day of cabbage juice. All were healed within seven to ten days (Allen and Allen, 2009).

It has been known for the past 20 years that phytonutrients work as antioxidants to disarm free radicals before they can damage DNA cell membrane and fat containing molecules such as cholesterol. Now, new research is revealing that phytonutrients in crucifers such as cabbage work at a much deeper level. These compounds actually signal our genes to increase production of enzymes involved in detoxification. Recent studies show that those eating the most cruciferous vegetables have a much lower risk of prostate, colorectal and lung cancer even when compared to those who regularly eat other vegetables (Lin, 2008).

2.3 EFFECT OF PESTICIDES ON STORAGE OF CABBAGE

For best storage, cabbage should be harvested in a slightly immature state. Such heads will retain their green colour for a longer period of time in storage than well, fully matured cabbage. Cabbage should be harvested before the top cover leaves begin to lose their .bright green colour. Varietal selection, growing conditions and cultural practices will affect the maturity date. Field heat should be removed as quickly as possible to ensure maximum storage life. The best results are obtained where a storage temperature of 0^0 C (32^0 F) can be maintained. It is much easier to maintain both the temperature and relative humidity at the optimum level in refrigerator than at room temperature. A head of cabbage is approximately 92% water. From the time of harvest, it is important to cool the cabbage as quickly as possible and maintain a relative humidity of at least 90% or higher. Relative humidity in the storage room can be easily measured with a hydrometer. Where the relative humidity is low and the cabbage is off the floor in container, wetting of the storage floor helps to raise the humidity. It is best to store cabbage by itself. Cabbage should never be stored with fruits, especially apple, even if the temperature and the relative humidity are similar. Fruits and some vegetables give off ethylene gas in storage which will cause the cabbage to discolour. The ethylene also causes individual leaves to form abscission layers where the leaf stalk joins the core. The leaves will subsequently fall off and the heads will be unmarketable. Cabbage can be stored in bulk successfully in carefully handled and piled to a depth of not more than 1.5m with an ample aeration of the pile using forced air. It is important to handle the heads carefully to prevent bruising. Any damage sustained by the cabbage will result in increase susceptibility to disease organisms. Before storage, all dead, damaged and diseased leaves should be removed, any head showing disease symptoms should be discarded since diseases can spread from head to head in storage (Omafra-Uyenaka, 1990).

2.4 MAJOR PESTS OF CABBAGE IN GHANA

2.4.1 Cabbage Aphids (*Brevicoryne brassicae*).

Cabbage Aphids usually occur in large numbers mainly during dry spells. They attack cabbage quite early in the field. Colonies of tiny round greenish grey aphids can be found under the basal leaves of cabbage. They suck large quantities of sap from the leaves, causing them to become wrinkled, short and twisted. Seedlings may die from a heavy attack. The aphids secrete a sweet liquid (horney dew) which collect on the lower leaves. Black sooty mould grows on the honey dew, eventually covering the entire leaf surface. Ants are attracted to the honey dew, and so you will find many ants around the aphid colonies. The natural enemies of cabbage aphids such as ladybird beetle larva usually control these pests effectively (Youdeowei, 2002).

2.4.2 Diamond-Back Moth (DBM) (*Plutella xylostella*)

This pest is commonly known by the initials DBM. It is the most serious pest of cabbage, often occurring in large numbers as the generations develop within a few weeks. The small green caterpillars bore into the main veins of cabbage leaves and also feed on the underside of the leaves. These leaves become covered with holes, wither, turn yellow and eventually drop off. Cabbage plant attacked early may not even develop a head. Heavy perforations in later storages may render them unmarketable. DBM is resistant to many conventional pesticides and so spraying DBM infested cabbage often has little effect on the pest, thus farmers may be tempted to carry out excessive spraying and even give up cabbage production. The main natural enemies of DBM are predatory ants, ladybird larvae and parasitic wasps (Youdeowei, 2002).

2.4.3 Webworms (*Hellula undalis*)

The light brown caterpillars of the cabbage webworm bore into the main veins of leaves of cabbages and later into the centre of the stems where they then feed. This makes the pest difficult to control with pesticides. When webworms attack seedlings and plants, the plants do not survive. In mature cabbage plant, webworms destroy the heads completely making them unsuitable for sale. The main natural enemies of the webworm are predatory ants and parasitic wasps (Youdeowei, 2002).

2.5 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 tones 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).

2.6 APPLICATION AND EFFECTS OF PESTICIDES ON HEALTH

Pesticides are widely used through out 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. The ban would cover toxaphene, captafol, aldrin, endrin, Chlordane and DDT. Another 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. If these chemicals prove ineffective or dangerous they will be banned. 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.

TABLE 1: APPLICATION AND HEALTH EFFECTS OF PESTICIDES COMMONLY USED IN DEVELOPING COUNTRIES

PESTICIDE	APPLICATION	HEALTH EFFECTS
DDT	Effective against wide variety of insects, including domestic insects and mosquitoes.	Chronic liver damage, cirrhosis and chronic hepatitis, endocrine and reproductive disorders, immuno suppression, cytogenic effects, breast cancer, non hodkins lymphoma and polynuritis
Endosulfan	It is used as a broad spectrum non systemic, contact and stomach insecticide, and acaricide against insect pests on various crops.	Affects kidneys, developing foetus and live immuno suppression, decrease in the quality of semen, increase in testicular and prostate cancer, increase in defects in male sex organs and increased insects of breast cancer. It is also mutagenic.
Aldrin	Effective against wireworms and to control termites.	Lung cancer, liver diseases.
Dieldrin	Used against ectoparasites such as blowflies, ticks, lice and wildly employed in cattle and sheep dips. Also used to protect fabrics from moths, beetles and against carrot and cabbage root flies. Also used as seed dressing against wheat and bulb fly.	Liver disease, Parkinson’s & Alzheimer’s diseases.
Heptachlor	It controls soil inhibiting pests	Reproductive disorders, blood dyscariasis.
Chlordane	It is a contact, stomach and respiratory poison suitable for the control of soil pests, white grubs and termites	Reproductive disorders, blood dyscariasis, brain cancer, Non Hodkins lymphoma
Lindane	It is used against sucking and biting pests and as smoke for control of pests in gain stores. It is used to control various soil pests such as flea, beetles and mushroom flies. It is effective as soil dressing against the attacks of soil insects.	Chronic liver damage-cirrhosis and chronic hepatitis, endocrine and reproductive disorders, allergic dermatitis, breast cancer, Non Hodkins lymphoma, polyneuritis.
Fenitrothion	It is a broad spectrum contact insecticide effective for the control of chewing and sucking pest-locust, aphids, caterpillars and leave hoppers. It is also used against domestic insects and mosquitoes	Human epidemiological evidence indicates fenitrothion causes eye effects such as retinal degeneration and myopia. Chronic exposure to fenitrothion can cause frontal lobe impairment. Organophosphates are suspected of causing neurologic deficits.

Profenofos	Used for control of important cotton and vegetable pests. Used against chewing and sucking insects and mice, cotton borers, aphids, cabbage looper and thrips	Cholinesterase inhibition and the associated neurological and neuromuscular effects.
Dimethoate	A systemic and contact insecticide and acaride, effective against red spider mites and thrips on most agricultural and horticultural crops.	Dimethoate might have carcinogenicity, birth defects, reproductive toxicity and mutagenic effects.
	A broad spectrum insecticide used against mosquitoes, fly larvae, cabbage root fly, aphids, codling and winter	Chlorpyrifos has chronic neurobehavioural effects like persistent headaches, blur vision, unusual fatique or muscle
Chlorpyrifos	moths on fruit trees. It is also used in homes, restaurants against cockroaches and other domestic pests. It is also used for the control of termites.	weakness, and problem with mental functions including memory, concentration, depression and irritability.
Diazinon	A contact insecticide effective against a number of soil, fruit, vegetable and rice pests. Example, Cabbage root, carrot and mushroom flies, aphids, spider, mites, thrips and scale insects, domestic pests and livestock pests.	Non Hodkin's lymphoma
Acephate	It is a systemic insecticide effective against chewing and sucking pests.	It is a possible human carcinogen and evidence of mutagenic effects and reproductive toxicity.
Fenvalerate	It acts as contact and stomach poison. It controls the pests on crops of cotton, vegetables and fruits.	Reduction in weight.
Deltamethrin	It is a potent insecticide effective as a contact and a stomach poison against a broad range of pests of cotton, fruit and vegetable crops and stored products.	Potential endocrine disrupter

SOURCE: Kumar (2007).

2.7 PESTICIDE USE AND 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. A study to evaluate the residue levels of selected pesticides used on tomato crops in Ghana that are likely to have accumulated in the tomatoes during application confirmed that pesticide residues were indeed present in the tomatoes and further analysis quantified the amount present. Analysis of some organochlorine and organophosphorus residue levels in the tomato fruits indicated that chlorpyrifos, which is an active ingredient of pesticides registered in Ghana under the trade name dursban 4E or terminus 480 EC for use on vegetables, has the greatest residue level of 10.76 mg/kg. The lowest residue level observed was that of pirimiphos-methyl with 0.03 mg/kg. Human health risk assessment was performed on the results obtained from the analysis using Human Health Evaluation computerized software-RISC 4.02. The risk assessment showed cancer risk for adults and children due to the presence of endosulfan and chlopyrifos. Endosulfan is not registered in Ghana as a pesticide for use on vegetables; therefore, the detection of endosulfan in several samples indicates misuse of agrochemicals among Ghanaian farmers (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 for use and application in vegetable production, using a small survey of 137 farmers who applied pesticides. The Survey showed that knapsack sprayers were the most widely used type of equipment for spraying pesticides. However, on large scale vegetable farms of 6-10 acres, motorized sprayers were also used. Various inappropriate practices in the handling and use of pesticides caused possible poisoning symptoms among those farmers who generally did not wear protective clothing. Younger farmers (< 45 years of age) were the most vulnerable group, probably because they did more spraying than older farmers (> 45 years of age). 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. The samples were analyzed for pesticide residue on lettuce leaves; a total number of faecal coliforms and helminth egg counts on all the three vegetable chlopyrifos (Dursban) were detected on 78% of the lettuce, lindane (Gammalin 20) on 31% endosulfan (thiodan) on 36%, Lambda Cyhalothrin (Karate) on 11% and dichlorodiphenyl-trichloroethane (DDT) on 33%. Most of the residues recorded exceeded the maximum residue limit for consumption. Vegetables from all three cities were faecally contaminated and carried faecal coliform population with geometric mean values ranging from 4.0×10^3 to $9.3 \times 10^{(8)}$ g $^{(-1)}$ wet weight and exceeded recommended standards. Lettuce, cabbage and spring onion also carried an average of 1.1, 0.4 and 2.7 g $^{(-1)}$ helminth eggs respectively. The eggs were identified as those of *Ascaris lumbricoides*, *Ancylostoma duodenale*, *schistosoma heamatobium* and *Tricchuris trichiura*. Because many vegetables are consumed fresh or only slightly cooked, the study shows that intensive vegetable production, common in Ghana and its neighboring countries, threatens public health from the microbiologic and pesticide dimensions. Standard recommendations to address this situation (better legislation, law enforcement or integrated pest management) often do not match the capabilities of farmers and authorities. Amoah *et al*. (2006) indicated that the most appropriate entry point for risk decrease that also addresses postharvest contamination is washing vegetables before food preparation at the household or “chop” bars (Street restaurant).

Organochlorine pesticides are widely used by farmers because of their effectiveness and their broad spectrum activity. 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).

Meat may contain high levels of pesticide residues as a result of concentration of residues in the tissues following cattle dipping or vector control or when they feed on feedstuffs contaminated with these chemicals. Because these chemicals are toxic to living organism, increased accumulation in the food chain may pose serious health hazards to the general populace. (Jayashree and Vasudevan, 2007)

2.8 METABOLISM OF PESTICIDES IN PLANTS

Pesticides are reported to penetrate into the growing plants through the cuticle and stomata of the leaves (Robertson and Kirkwood, 1969). 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 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. Thus, understanding pesticide metabolism in both groups of organisms is crucial for efficient and environmentally sound pesticide management. The pathways of pesticide detoxification in plants have been traditionally divided into several metabolic phases, whereas, bacterial biotransformation are characterized as either metabolic or co-metabolic. 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).

2.9 EFFECTS OF STORAGE AND PROCESSING ON PESTICIDE RESIDUES IN PLANT PRODUCTS

Residues of pesticides in food are influenced by storage, handling and processing that occur between harvesting of raw agricultural commodities and consumption of prepared foodstuffs. Review of extensive literature showed that in most cases these steps lead to large reductions in residue levels in the prepared food, particularly through trimming, washing and cooking operation. Residues of postharvest insecticide treatment on stored staples such as cereal grains and oil seeds generally decline only rather slowly. However, processing into foods again results in large losses except for unrefined oils. The behaviour of residues in storage and processing can be rationalized in terms of the physio-chemical properties of the pesticide and the nature of the process (Holland *et al*., 1994).

An important factor leading to reduction of any residues left on crops at harvest are processing treatments such as washing, peeling, canning or cooking that the majority of foods receive prior to consumption. These can often substantially reduce the residue levels on or in food that has been treated with pesticides. For example, a study tracking chlorothalonil from field to table showed that normal handling and processing of fresh cabbage, celery, cucumber and tomatoes led to large reduction in residue levels (Erlich, 1994).

Most high moisture unprocessed foods must be held in chillers or refrigerators (0-50^{0}C) for longer periods. Studies on a variety of pesticides on whole foodstuffs under cool or frozen storage often have shown that residues are stable or decay only slowly, however, the temperature of storage is important for less stable or more volatile compound. For example residues of the carbamate thiodicarb were stable at -10^{0}C but there were losses at 4.5^{0} C (White and Norwich, 1985).

A large gap exists between consumer and scientific perceptions on the risks that pesticide residue in food poses to human health relative to other dietary risks. One cause of this misconception has been the emphasis placed on "worst case" evaluations and extrapolations of available data, for instance, assuming that all crops are treated with pesticides and that the resulting residues in food as consumed are at maximum permitted levels. Controls on pesticide residues in crops are generally based on Maximum Residue Limits (MRL's) which are set using field trial data for a particular pesticide to arrive at the highest residue levels expected under use according to Good Agricultural Practice *(*GAP*)*. Primary residue studies on food crops are mainly carried out on samples that have received minimal postharvest handling except for perhaps minor trimming and that have been stored deep frozen prior to analysis. Although MRL's are a credible and useful means of enforcing acceptable pesticide use, they are inadequate as a guide to human health risks from residues. Total diet studies have consistently shown that using MRL's as a basis for calculating human dietary consumption of pesticides over-estimate actual intakes by one to three orders of magnitude (Winter, 1992).

An important factor leading to reduction of any residues left on crops at harvest are processing treatments such as washing, peeling, canning or cooking that the majority of foods receive prior to consumption. These can often substantially reduce the residue levels on or in food that has been treated with pesticides (Bates and Gorbach, 1987).

Several reviews have appeared over the last 15 years on the effects of processing on pesticide residues in food (Ritchey, 1982). The emphasis has been mainly on the organochlorine insecticides. The US food industry has published some data showing large reductions in residue levels during commercial processing of vegetables (Elkins, 1989) and the industry has established a database for residues in processed foods (Chin,1991).

Most high moisture unprocessed foods must be held in chillers or refrigerators (0 to 5^{O}C) for short to medium storage or deep frozen (-10 to $-2O^{O}$C) for longer periods. Studies on a variety of pesticides on whole food-stuffs under cool or frozen storage often have shown that residues are stable or decay only slowly (Kawara *et al.*, 1973).

2.10 ORGANOCHLORINE PESTICIDES (INSECTICIDES)

Organochlorine insecticides are organic compounds that persist in the environment bioaccumulation through the food chain and pose a risk of causing adverse effects in human health and the environment. These pesticides, characterized by their cyclic structure; number of Chlorine atoms and low volatility, can be divided into four groups.

They are:

1. Dichlorodiphenyle (such as DDT)
2. Cyclodienes (Such as dieldrin, endosulfan and heptachlor)
3. Chlorinated benzenes (Such as hexachlorobenzene) and
4. Cyclohexanes (Such as lindane)

Although these chemicals were widely used until the mid 1970's, most of them are now banned from use in the developed countries. They are, however, still being produced in other countries. Furthermore, one of these insecticides, endosulfan is still in widespread use through out the world despite its known adverse effects on humans as an endocrinedisrupting compounds (Andersen *et al*., 2000).

Organochlorines are also considered persistent organic pollutants (POPs), a category of chemicals that include nine organochlorides (aldrin, chloradane, DDT, dieldrins, endrin, heptachlor, hexachlorobene, mirex and toxphen), targeted by Stockholm convention in May, 2001 which aimed to eliminate their production and restrict or ban their use throughout the world (Lemarie *et al*., 2004). Many human epidemiologic and animal studies have shown that exposure to organochlorines are positively correlated with endocrine disruption, reproductive and immune dysfunctions (Ayub *et al*., 2003). Human exposure occurs by ingestion (from eating contaminated foods), inhalation, and absorption through skin and often during pest control operations both at home and in farms.

Organochlorines are among the chemicals found most often in the hundreds of tests of human body tissue that have been conducted around the world. Because of their chemical structure, organochlorines breakdown slowly, build up in fatty tissues, and remain in our bodies for a longtime. Pesticides residues on food are major source of organochlorine exposure. Even those chemicals that have been banned for decades are showing up consistently in food samples tested by the US Food and Drug Administration. This can be explained in part by the long life of many organochlorines in the environment (dieldrin and the breakdown products of DDT for example, can remain in the soil for decades) and long distance transport in wind and water current as well as food imports from countries that continue to be used those pesticides. Inhalation and dermal contact are additional routes of exposure, both for individuals working directly with the pesticides and for children who are exposed to pharmaceuticals products, containing organochlorines such as head lice treatments. Infants are also exposed when organochlorine pesticides that have accumulated in their mother's bodies are passed to them in breast milk. Organochlorine compounds have become widely distributed in our environment following their introduction as pesticides during World War II. In general, they tend to become bio-magnified as they pass along food chains. They also have long half-lives in the environment, because they are resistant to physical factors such as light and temperature (Keith and Howard, 1993).

2.11 HEPTACHLOR AND HEPTACLOR EXPOXIDE

Heptachlor is a manufactured chemical and does not occur naturally. Pure heptachlor is a white powder that smells like camphor (mothballs). The Trade names of heptachlor include

Heptagran, Basaklor, Drinox, Soleptax, Termide, Goldcrest H-60 and Velsicol 104. Heptachlor was used extensively in the past for killing insects in homes, building and on food crops. These uses stopped in 1988. Heptachlor epoxide is also a white powder. Bacteria and animals breakdown heptachlor to form heptachlor epoxide. The epoxide is more likely to be found in the environment than heptachlor. There is no reliable information on health effects in humans. Liver damage, excitability and decrease in fertility have been observed in animals ingesting heptachlor. The effects are worse when exposure levels were high or when the exposure lasted many weeks. Although, there is very little information on heptachlor epoxide, it is likely that similar effects would also occur after exposure to this compound. Lifetime exposure to heptachlor resulted in liver tumor in animals. The International Agency for Research on Cancer (IARC) and the EPA (US) have classified heptachlor as a possible human carcinogen. EPA (US) also considers heptachlor epoxide as a possible human carcinogen. The US Food and Drug Administration control the amount of heptachlor epoxide in raw food crops and in edible seafood. The limit on food crops is 0.01 parts heptachlor per million parts food (0.01ppm) (ATSDR, 2007)

Heptachlor is a broad-spectrum insecticide, the use of which has been banned or restricted in many countries. At present, the major use of heptachlor is for termite control by subsurface injection into soil. Heptachlor is quite persistent in soil, where it is mainly transformed to its epoxide. Heptachlor epoxide is very resistant to further degradation. Heptachlor and heptachlor epoxide bind to soil particles and migrate very slowly. Heptachlor and heptachlor epoxide have been found in drinking-water at levels of nanograms per litre. Diet is considered to represent the major source of exposure to heptachlor, although intake is decreasing. Prolonged exposure to heptachlor has been associated with damage to the liver and central nervous system toxicity. In 1991, The International Agency for Research on Cancer (IARC) reviewed the data on heptachlor and concluded that the evidence for carcinogenicity was sufficient in animals and inadequate in humans, classifying it in Group 2B. A health-based value of 0.03mg/litre can be calculated for heptachlor and heptachlor epoxide on the basis of a Provisional Tolerance Daily Intake (PTDI) of 0.1mg/kg of body weight, based on a No-Observed-Adverse-Effect Level (NOAEL) for heptachlor of 0.025 mg/kg of body weight per day from two studies in the dog, taking into consideration inadequacies of the database and allocating 1% of the PTDI to drinking-water. However, because heptachlor and heptachlor epoxide occur at concentrations well below those at which toxic effects are observed, it is not considered necessary to derive a guideline value. It should also be noted that concentrations below 0.1mg/litre are generally not achievable using conventional treatment technology (WHO/FAO, 1992).

The 1958 and 1963 WHO International Standards for Drinking-water did not refer to heptachlor and heptachlor epoxide, but the 1971 International Standards suggested that pesticide residues that may occur in community water supplies make only a minimal contribution to the total daily intake of pesticides for the population served. In the first edition of the Guidelines for Drinking-water Quality, published in 1984, a health-based guideline value of 0.1mg/litre was recommended for heptachlor and heptachlor epoxide, based on the acceptable daily intake (ADI) recommended by The Joint FAO/WHO Meeting on Pesticide Residues (JMPR) (WHO, 2003).

It was noted that this guideline value was less than the value that would have been calculated by applying the multistage model at a projected incremental cancer risk of 1 per 100 000 per lifetime. The 1993 Guidelines established a health-based guideline value of 0.03m g/litre for heptachlor, based on an ADI established by JMPR in 1991 and taking into consideration the fact that the main source of exposure seems to be food (WHO/FAO, 1995).

The Joint FAO/WHO meeting on Pesticide residues (JMPR) estimated the acceptable daily intake of heptachlor plus heptachlor epoxide at 0 - 0.0005 mg/kg body (FAO/WHO, 1971). The same meeting arrived at the following recommendations for practical residue limits (FAO/WHO, 1971): 0.01 mg/kg for citrus fruit; 0.5 mg/kg for crude soya bean oil; 0.05 mg/kg for vegetables; and 0.15 mg/kg for milk and milk products.

2.12 DICHLORO DIPHENYL TRICHLOROETHANE (DDT)

Dichloro-diphenyl-trichloroethane (DDT) is an organochlorine insecticide that was used in a broad range of agriculture and non agricultural application worldwide, beginning in 1939. In 1972, DDT was banned in the United States and in many parts of the world, except for use in controlling emergency public health problem. DDT is still being used in certain parts of the world to control vector borne diseases such as malaria. The release of DDT into the environment occurs primarily through spraying applications onto agricultural crops, forest lands, other non-agricultural land and homes. DDT can be degraded through atmospheric photo-oxidation in air or photolysis on the surface of water or soil. DDT can undergo slow biodegradation through reductive dechlorination to form Dichloro-diphenyl-ethane (DDE) and DDD and then be further degraded into other metabolites. The persistence of DDT and its metabolites in combination with their high lipophilicity, have contributed to bioaccumulation and biomagnification of DDT and its products in the environment. DDT, DDE and DDD accumulate in fatty tissues, with tissue concentrations typically increasing the trophic level of the organism. Numerous studies have been conducted on DDT and related compounds in a variety of animal species but data for human are somewhat limited. Most of the information on health effects in humans comes from studies of workers of DDT manufacturing plants or of spray applicators who had exposure over an extended period. Due to these limitations, disease casualty cannot be determined from these studies. The most well-known effect of DDT is impairment of nerve impulse conditions. Effects of DDT on the nervous system have been in both humans and animals and can vary from mild sensation to tremors and convulsions. Humans have been reported to tolerate doses as high as 285mg/kg without fatal result, although vomiting has occurred. There are no documented, unequivocal reports of a fatal human poisoning occurring exclusively from ingestion of pure DDT but deaths have been reported following ingestion of commercial products containing DDT and other substances. Animal deaths following high exposure to DDT are usually caused by respiratory arrest. In addition to being a neurotoxicant, DDT is capable of inducing a marked alternation to reproduction and development in animals. These changes have been attributed to hormone altering effects of DDT isomers and/or metabolites. Studies in animals have shown that DDT can also cause cancer, primarily in the liver.

The possible associations between exposure to DDT and various types of cancer in humans, particularly breast cancer have been studied extensively. Thus far, no conclusive evidence links DDT and related compounds to cancer in humans (ATSDR, 2002).

DDT is very highly persistent in the environment, with a reported half-life of between 215years and is immobile in most soils. Routes of loss and degradation include runoff, volatilization, photolysis and biodegradation (aerobic and anaerobic). These processes generally occur only very slowly. The breakdown products in the soil environment, DDE and DDD, are also highly persistent and have similar chemical and physical properties. DDT does not appear to be taken up or stored by plants to a great extent, it was not translocated into alfalfa or soybean plants and only trace amount of DDT or its metabolites were observed in carrots, radishes and turnips all grown in DDT-treated soils. Some accumulation was reported in grain, maize and rice plants but little translocation occurred and residues were located primarily in the roots (WHO, 2005).

2.13 ENDOSULFAN

There are four relevant forms of endosulfan: alpha endosulfan, beta endosulfan, endosulfan sulphate and technical endosulfan which is 2:1 to 7:3 mixtures of the alpha and beta isomers. Endosulfan is used to control aphids, thrips, beetles, foliar feeding larvae, mites, borers, cutworms, bollworms, whiteflies and leafhoppers. It is also used on cotton, tobacco, camtaloupe, tomatoes, squash, eggplant, sweet potato, broccoli, pears, pumpkins, corn, cereals, oilseeds, potatoes, tea, coffee, cocoa, soyabean and other vegetables. Historically endosulfan is used to control termites and tsetse fly. It was used in some countries as a wood preservative. In the environment, endosulfan is oxidized in plants and in soils to form primarily endosulfan sulfate and endosulfan diol.

Formation of endosulfan sulphate is mediated essentially by micro-organisms, while endosulfan-diol was found to be the major hydrolysis product. The oxidized metabolite, endosulfan sulphate shows an acute toxicity similar to that of the parent compound. In contrast, endosulfan-diol which is another metabolite of endosulfan is found substantially less toxic to fish by about three orders of magnitude. Recent literature has indicated the potential for endosulfan to cause some endocrine disruption in both terrestrial and aquatic species. Effects observed were impaired development in amphibians, reduced cortisol secretion in fish, impaired development of the genital tract in birds and hormone levels, testicular atrophy and reduced sperm production and handling of endosulfan have been linked to congenital physical disorders, mental retardations and deaths in farm workers and villages in developing countries in Africa, Southern Asia and Latin America. Endosulfan was found among the most frequently reported intoxication incident adding unintentionally further evidence to its high toxicity for humans. In animals, endosulfan produces neurotoxicity effects which are believed to result from over-stimulation of the central nervous system. It can also cause haematological effects and nephrotoxicity. (Reigart and Robert, 1999)

2.13.1 Beta Endosulfan

Beta Endosulfan is one form of endosulfan. It looks like a brown-coloured crystal and has an odour like turpentine. Since endosulfan beta has the same chemical structure as endosulfan. Beta endosulfan is used as an insecticide on crops. It has also been used specifically in USA as a wood preservation to protect wood from decay and insect attack. Beta endosulfan can enter the body when you breathe contaminated air. It can be absorbed into the body when it comes into contact with the skin. Endosulfan can leave the body through urine just a few days after exposure. Crops that have been sprayed with endosulfan could also be a source of exposure.

One can also be exposed to beta endosulfan if one worked in an industry that makes or uses it. The central nervous system is the primary target affected by exposure to endosulfan beta. High doses of the endosulfan can cause convulsion and death. The effects of being exposed to low doses of endosulfan beta over a long period of time are not known. However, animals exposed to low doses of endosulfan experienced a number of effects including reduced ability of the immune system to fight infection, problems with the testes in male and the developing fetus in females. The EPA (US) prohibits more than 0.1 to 2.0 parts per million (ppm) of endosulfan to be present food (Reigart and Robert, 1999).

2.14 BETA BENZENE HEXACHLORIDE

Beta benzene hexachloride (Beta BHC) is organochloride insecticide consisting of a cyclohexane substituted with one Chlorine atom on each carbon atom. It is an isomer of lindane. The trade and product names are HCH (Europe), hexachlor (Sweden), hexachloran

(Russia). The chemical function of Beta BHC is insecticide and has no other commercial uses. The major health concern on human is cancer. It also affects the reproductive system, hormone system, stomach, nervous system and cardiovascular system. Gamma benzene hexachloride is one of the purified isomers of hexachlobenzene which is used as a scabicide and pediculicide applied topically to the skin in various lotions, creams and shampoo. Gamma benzene hexachloride can be absorbed through skin. It resembles DDT in its action but is less persistent (Anon, 2008)

2.15 LINDANE (GAMMA BENZENE HEXACHLORIDE)

Lindane is a broad spectrum insecticide which has been used since 1949 for agricultural as well as non-agricultural purposes. Approximately 80% of the total production is used in agriculture mostly for seed and soil treatment.

Wood and timber protection is the major non-agricultural use. Its use is being banned in various countries. It has been banned by the European Union countries for plant protection. In Europe, Lindane usage was reduced by two-third between 1970 and 1996. (USEPA, 2005)

As a pharmaceutical preparation, lindane is an insecticide, lavicide and acaricide. It is used topically in concentration of 1% for treatment of scabies in selected patients. It is also used for the control of disease vectors including mosquitoes, lice and fleas. In the agricultural area, it is mainly used for the treatment of seeds and soils; wood and timber protection are major non agricultural use. In humans, lindane primarily affects the nervous system, liver and kidney and may be a carcinogen and endocrine disruptor (ATSDR, 2005)

The WHO classifies lindane as moderately hazardous and its international trade name is restricted and regulated under the Rotterdam Convention in prior informed consent. It is presently banned in more than 50 countries and is being considered for inclusion in the Stockholm Convention on persistent organic pollutants, which would ban its production and use worldwide (WHO, 2005).

Maximum residue limits (MRLs) have been recommended by the FAO/ WHO Codex Committee for more than 35 commodities, ranging from 0.05 mg/kg on potatoes to 3 mg/kg on strawberries. A level of 0.5 mg/kg was recommended for most fruit and vegetables (FAO/WHO, 1986)

2.16 ALDRIN AND DIELDRIN

Pure aldrin and dieldrin are white powder, while technical grade aldrin and dieldrin are tan powder. Aldrin and dieldrin slowly evaporate into the air. Aldrin evaporates more readily than dieldrin. Both aldrin and dieldrin have mild chemical odours. Aldrin and dieldrin can be found in the soil, in water or in homes where these compounds have been used to kill termites. They can be found in plants and animals near hazardous waste sites. Aldrin and dieldrin are no longer produced or used in the USA. From 1950s until 1970, aldrin and dieldrin were used extensively as insecticide on crops such as corn and cotton. The US Department of Agriculture cancelled all used of aldrin and dieldrin in 1970. In 1972, however, US EPA approved aldrin and dieldrin for killing termites. Use of aldrin and dieldrin to control termites continued until 1987. In 1987, the manufacturer voluntarily canceled the registration for use in controlling termites (ATSDR, 2008).

The two chemicals are discussed together because aldrin readily changes into dieldrin once it enters either environment or the body. The trade names used for aldrin include Alvit, Dieldrix, Octalox, Quintox and Red Shield. For most people, exposure to aldrin and dieldrin occurs when they eat foods contaminated with either chemical. Exposure to aldrin and dieldrin also occur when one drinks, water, breathes air or comes into contact with contaminated soil at hazardous waste sites. Symptoms of aldrin and dieldrin poisoning have been seen in people who were exposed to very large amounts of these pesticides during manufacture. Symptoms of poisoning have also been seen in people who intentionally or accidentally ate or drank large amounts of aldrin and dieldrin. Most of these people experienced convulsions or other nervous system effects and some had kidney damage. Exposure to moderate levels of these chemicals for a long time causes headaches, dizziness, irritability, vomiting or uncontrollable muscle movement.

The International Agency for Research on Cancer has determined that aldrin and dieldrin are not classifiable as to their carcinogenicity to humans. Based on studies in animals, the USEPA has determined that aldrin and dieldrin is probable human carcinogen (ATSDR, 2008).

2.17 ORGANOPHOSPHATE INSECTICIDES

Organophosphate compounds are the most widely used group of insecticides in the world. Their acute toxicity causes hazard both to professional and amateur users. Organophosphates were first recognized in 1854, but their general toxicity was not established until the 1930s. Tetraethyl pyrophosphate (TEPP) was the first organophosphate insecticide which was developed in Germany during world war1 as a by-product of nerve gas development (Minton and Murray, 1988).

Organophosphates as a class have become the most frequently used pesticides because of their rapid breakdown into environmentally safe product. However, they have far more immediate toxicity than DDT and other related products. There are more than 40 different organophosphate pesticides on the market today, and each causes acute and sub-acute toxicity. They are used in agriculture, homes, and gardens and in veterinary practice. They all work by inhibiting acetylcholinesterase (AChE) and cause a similar spectrum of symptoms. In 2003, there were 6442 reported exposures of which 6010 were unintentional, 1695 of these cases were seen in emergency department and there were 16 reported fatalities. Organophosphates are some of the most widely used pesticides in the world. They are used in agriculture, homes, gardens and veterinary practices, replacing the same uses as the organochlorines, many of which have been banned for years. In general, they are not persistent in the environment as they breakdown quickly. Because of their relatively fast rate of degradation, they have been a suitable replacement for the more persistent organochlorine. (Watson *et al*., 2003).

2.18 NOVALURON (RIMON 10 EC)

Novaluron is a new pesticide chemical belonging to the class of insecticides called Insect Growth Regulators (IGR). Insect Growth Regulators slowly kill the insects over a period of few days by disrupting the normal growth and development of immature insects. Novaluron acts as an insecticide mainly by ingestion but has some contact activity. Insects Growth Regulator insecticides are comparatively safer to beneficial insects and environment and are compatible for use in an integrated pest management system. Rimon 10EC is an emulsifier concentrate recommended for the control of whiteflies, thrips, leaf miners, and armyworms. It is also recommended for the control of American Bollworm and Diamond Back Moth of cabbage. To prevent buildup of resistance, rotation with other insecticides having dissimilar mode of action is recommended between successive applications. The manufacturing process indicates that no toxicologically significant impurities such as chlorinated dioxins, nitrosamines, and hexachlorobenzenes are formed. Novaluron belongs to a new class of pesticide chemical called benzoylphenyl ureas. Some compounds of this group are broad spectrum insecticides with insect hormonal mimicking mode of action. These Insect Growth Regulators (IGRs) affect chitin synthesis of immature insects disrupting their normal growth and development. Novaluron is expected to reduce the reliance on organophosphates, (such as acephate, diazinan, chlorpyrifos and dimethoate) carbamates such as (carbaryl and bendiocarb) and pyrethroids such as (bifenthrin and cyfluthrin) Novaluron has low mammalian acute toxicity and has low risk to environment and non- target organisms. It is thus an important component in any integrated pest management system (USEPA, 2001).

2.19 ABAMECTIN

Abamectin is also known as Avermectin B1a. Trade names include Affirm, Agri-mek, Avermectin, Avid, MK 936, Vertimec, Zephr and Mektin 1.8EC. It is classified toxicity class IV. Thus, practically, it is nontoxic and has no precautionary statements on its label.

Abamectin is a mixture of avermectins containing about 80% avermectin B1a 20% Avermectin B1b. These two components, B1a and B1b, have very similar biological and toxicological properties. The avermectins are insecticidal/miticidal compounds derived from the soil bacterium *Streptomyces avermitilis*. Abamectin is a natural fermentation product of this bacterium. It acts as an insecticide by affecting the nervous system of and paralyzing insects. Abamectin is used to control insects and mite pests of citrus, pear and nut tree crops and vegetable crops. It is also used by home owners for the control of fire ants. Abamectin is highly toxic to insects and may be highly toxic to mammals as well. Emulsifiable concentrate formulations may cause slight to moderate eye irritations and mild skin irritations. Symptoms of poisoning observed in laboratory animals include pupil dilation, vomiting, convulsion or tremors and coma. Abamectin acts in insects by interfering with the nervous system. At very high doses, it can affect mammals, causing symptoms of nervous system depression such as incoordination, tremors, lethargy, excitation and pupil dilation. Very high doses have caused death from respiratory failure (Anon, 1996).

3.0 MATERIALS AND METHODS

The research work was carried out in two stages. The first stage was a field survey to assess the use of pesticides to control insect pests on cabbage production in Ejisu-Juaben Municipality. The second stage involved the collection of samples of harvested cabbage from selected farmers' field for laboratory analysis for organochlorine compounds or pesticide residual levels in the cabbage.

3.1 LOCATION

Forty-nine (49) cabbage farmers were randomly selected from ten (10) major cabbage producing communities in the municipality for interview and questionaire administration. The ten communities were New Bomfa, Akyawkrom, Adumasa, Bomfa, Duampompo, Nobewam, Esaase, Wabiri, Peminase and Achiase.

The second stage of the research work involved the collection of a total of thirty (30) samples of harvested cabbage from fifteen (15) selected farmer's field. Five (5) out of ten (10) communities were randomly selected and three (3) farmer fields randomly picked from each of the communities. Two (2) full headed cabbages were randomly harvested from each field for laboratory analysis. The five communities were New Bomfa, Akyawkrom, Duampompo, Bomfa and Peminase. The 30 samples of harvested cabbages were sent to Water Research Institute Laboratory in Accra for the organochlorine pesticide residue analysis which was carried out in two phases:

i. Analysis of organochlorine pesticide residues at harvest ii.

Analysis done after 14 days storage in a refrigerator at 5^oC

3.2 PARAMETERS STUDIED IN THE FIELD SURVEY

Questionnaire (Appendix 15) was prepared to cover the following areas:

a. Types of pesticides used to control insect pests in the municipality

b. Active ingredients of the pesticides

c. Dosage of application of the various pesticides

d. Reasons for choosing a particular pesticide

e. Frequency of spraying in a growing season

f. Time of the day that spraying was done

g. Efficacy of pesticides in controlling insect pests

h. Spraying intervals

i. Safety precautions adopted

j. Period between last spraying and harvesting

k. Distance between farm and permanent source of water

l. How long does it take for harvested cabbages to get to the market?

3.3 ORGANOCHLORINE PESTICIDES ANALYSED IN THE LABORATORY

The following organochlorine compounds and pesticides were studied in the laboratory to find out their respective residual levels in all the thirty (30) samples of the harvested cabbages

a. Alpha Benzene Hexachloride (Alpha BHC).

b. Gamma Benzene Hexachloride (Gamma BHC)

c. Beta Benzene Hexachloride (Beta BHC)

d. Delta Benzene Hexachloride (Delta BHC)

e. Heptachlor

f. Aldrin

g. Alpha Endosulfan

h. Dichcloro diphenyl ethane (DDE)

i. Dieldrin

j. Endrin

k. Beta Endosulfan

l. Endosulfan Sulphate

m. Dichcloro diphenyl trichloroethane (DDT).

3.4 METHODS USED TO EXTRACT PESTICIDE RESIDUES FROM CABBAGE

3.4.1 Materials used:

- Gas Chromatograph 6890N with Electron Capture Detector (ECD)
- Turbovap evaporating unit

- Dichloromethane (DCM)
- Hexane
- Cyclohexane (CH)
- Iso-octane
- Sodium sulphate (as drying agent)
- SPE (Solid Phase Extraction) 500mg with Florisil volume of 3ml
- Glassware

3.4.2 Extraction from cabbage using reflux method:

1. A cabbage head was cut into very small pieces (about 1cm^2), blended or ground in a mortar.
2. Approximately 10g was weighed into a round bottomed flask and mixed with Sodium sulphate (enough to absorb the water present in the sample) and 100ml 1+1 Dichloromethane (DCM)-Hexane mixture was added.
3. The extract was refluxed for 4 hours, cooled, and transferred into evaporation tube and the volume reduced to 0.5ml using the evaporating unit under a stream of Nitrogen gas (a drop of iso-octane was added to act as a keeper).
4. The extract was then transferred into a test tube and the evaporation tube was washed with 2ml 1+1 CH-DCM solvent mixture.
5. Under a gentle stream of nitrogen gas, the volume was gradually reduced to almost dryness.
6. 1ml of Cyclohexane (CH) was added and reduced to almost dryness. Another 1ml of CH was added and the volume finally reduced to 0.5ml

3.4.3 Use of Solid Phase Extraction (SPE) for clean-up

- SPE was conditioned with 3 ml 4+1 CH-DCM mixture followed by 3ml CH (SPE surface was not allowed to dry up).
- With the SPE connected to a test tube, the extract was dropped onto the SPE and eluted (washed out) with 1ml CH, followed by 3ml CH.
- This was then washed down with 3ml 4+1 CH+DCM mixture.
- The final volume was reduced to 0.5ml and transferred into a 3ml vial ready for a Gas Chromatography run.

With the Gas Chromatography (GC), the carrier gas (nitrogen) was the mobile phase and the stationary phase was the column. Temperature programming was used to run the samples. Pesticides Mixture 1 was the standard used for peak identification and the calibration curve for quantification.

3.5 EXPERIMENTAL DESIGN

The Experimental Design used was a 5 X 2 Factorial Randomised Complete Block Design (RCBD) of five levels of different communities as factor one and factor two as analysis of organochlorine pesticides at harvest and analysis after two weeks storage in a refrigerator and replicated three times.

3.6 STATISTICAL ANALYSIS

Data from the survey were statistically analysed using the Statistical Package for the Social Scientist (SPSS). The results were presented in tables and pie charts with values presented in percentages. Laboratory data were analysed by GenStat Statistical package used for ANOVA. Least Significance Difference (LSD) was used to determine the significance of the differences between the means of the measured parameters.

4.0 RESULTS

4.1 FIELD SURVEY

Results of the field survey are shown in Pie Charts covering the varieties of cabbage cultivated, sex and educational levels of respondents, as well as the assessment of pesticides used to control insect pests of cabbage in the Ejisu-Juaben Municipal Assembly

4.1.1 Sex of Respondents

Figure 1 indicates the sex of the respondents. Out of the forty-nine (49) farmers interviewed, forty-three (43) were males, representing 88%, while six (6) were females, representing 12 %

(Appendix 1).

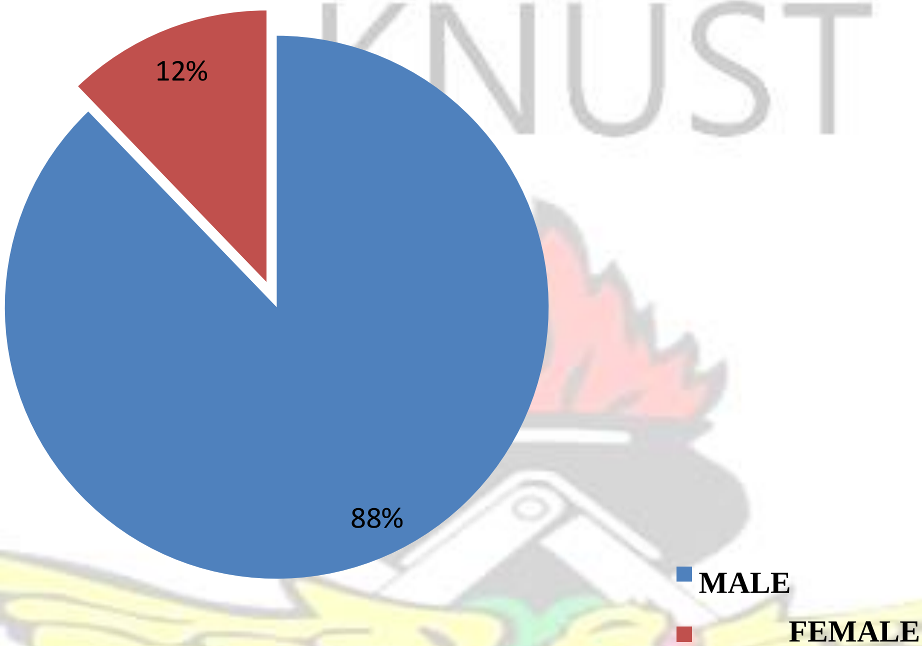

Figure 1: Sex of respondents

4.1.2 Educational Level of Respondents

Figure 2 indicates the educational level of the farmers. Thirty nine (39) of the respondents had basic education (JSS/MSLC), representing 80%. Nine (9) of the farmers had no formal education, representing 18%, and only one farmer had post secondary education representing 2% (Appendix 2).

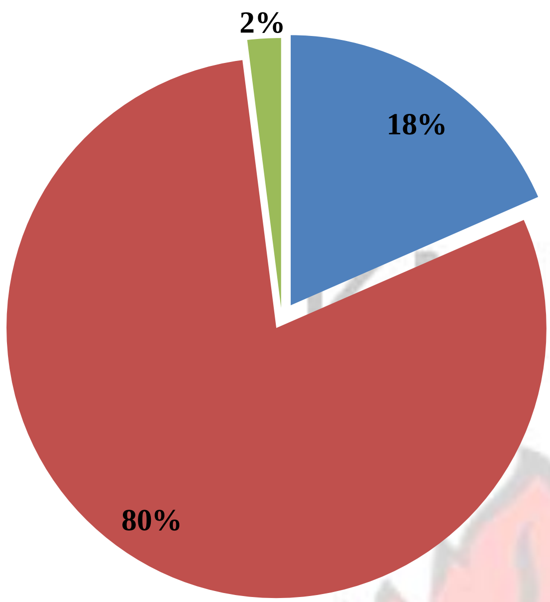

Figure 2: Educational level of respondents

4.1.3 Varieties of Cabbage Cultivated by Farmers

Figure 3 indicates the varieties of cabbage cultivated by farmers in the municipality. The results showed that thirty three (33) respondents cultivated Oxylus variety only, representing 67.3%, three (3) of the respondents cultivated KK cross variety only, representing 6.1%, one respondent cultivated Gloria only, representing 2%, and eleven (11) of the respondents cultivated both KK cross and Oxylus representing 22.4% . Only one respondent cultivated all the three varieties (Oxylus, KK Cross and Gloria F1) representing 2 % (Appendix 3).

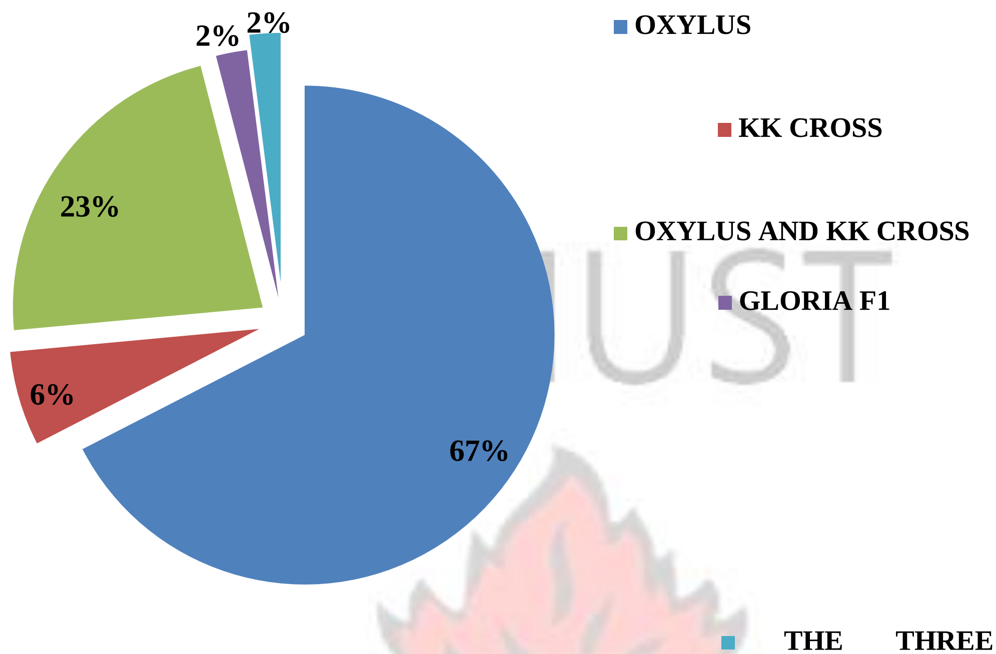

Figure 3: Varieties of cabbage cultivated by farmers

4.1.4 Pesticides Used by Farmers to Control Insect Pest in Cabbage Production in the Municipality

Data in Table 2 indicates various types of pesticides used by farmers to control insect pests in cabbage production from 2004 to 2008. A total of 27 different types of insecticides were used by farmers. The insecticides are indicated in Table 2 as trade or common names and their active ingredients.

Table 2: Pesticides used by farmers to control insect pests on cabbage between 2004–2008

	Common Name (Trade Name)	Active Ingredients	Pre-Harvest Application Intervals
1.	Golan S L	Actemiprid	7 days
2.	Deltapaz 2.5 EC	Deltamethrin	7 days

3.	Cypercal 50 EC	Cypermethrin	7 days
4.	Karate 5EC	Lambda Cyhalothrin	7 days
5.	Pyrical 480 EC	Chloropyriphos Ethyl	7 days
6.	Orthene 750 sp	Acephate	4 days
7.	Pawa 2.5 EC	Lambda Cyhalothrin	4 days
8.	Cymethoate	Cymethoate	7 days
9.	Dimethoate	Dimethoate	15 days
10.	Sumithion	Fenitrithrin	14 days
11.	Dursban 4 E	Chlopyriphos	15 days
12.	Thionex 35 EC	Endosulphan	14 days
13.	Cymthox	Fenvalerate	7 days
14.	Thiodan	Endosulphan	14 days
15.	Mektin 1.5 EC	Abamectin	3 days
16.	Confidor 200sl	Imidacloprid	-
17.	Diazol 50 EC	Diazion	7 days
18.	Wrecko 2.5 EC	Lambda Cyhalothrin	15 days
19.	Endocel	Endosulphan	15 days
20.	Lambda Super 2.5 EC	Lambda Cyhalothrin	3 days
21.	Attack	Emamectin benzoate	7 days
22.	Kombat 2.5 EC	Lambda Cyhalothrin	3 days
23.	Actellic	Pyrimiplus methyl	7 days
24.	Polythrine C	Cypermethrin + profenetos	7 days
25.	Rimon 10 EC	Noraluran	7 days
26.	Cocostar	Bifenthrin + pirimiphasmethyl	7 days
27.	Akate Master	Bifenthrin	7 days

The results also revealed that insecticides such as Cypercal 50 EC, Karate 5 EC, Perical 450EC, Orthene 750sp, Mektin 1.8 EC, Lambda Cyhalothrin groups (Pawa 2.5 EC, Wrecko 2.5 EC, Lambda Super 2.5 EC and Kombat 2.5 EC), Dursban 4 EC, Golan SL, Deltapaz, Dimethoate Cymethoate, Thionex 35EC and Rimon 10 EC were mostly used by farmers between 2004 and 2008 to control insect pests on cabbage production in Ejisu-Juaben Municipal Area. It was observed that quite a number of the farmers used hazardous pesticides usually used to control insect pests in cotton and often labeled in the French language and this suggested that such chemicals were smuggled into the country from neighbouring countries. Also pesticides such as Cocostar, Confidor and Akate Master, which are made to control insect pests of cocoa plants, are often used by farmers to kill insect pests on their cabbage fields.

4.1.5 Mixing of Different Pesticides Together for Spraying

Figure 4 indicates that thirty (30) out of forty-nine (49) farmers interviewed mixed two or three pesticides together for the controlling of insect pests on their cabbage farms, representing 61.2%. The remaining nineteen (19) respondents used single pesticides for the control of insect pests, representing 38.8%. The results further revealed that farmers did the mixing without considering its effectiveness. Thus, farmers usually mixed 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 cabbage heads (Appendix 4).

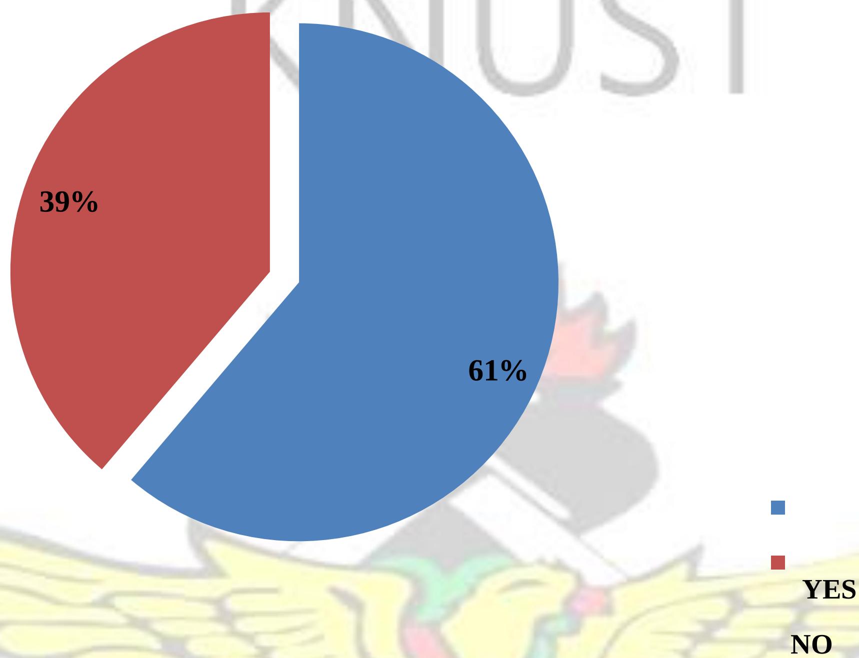

Figure 4: Mixing of different pesticides together for spraying

4.1.6 Reason(s) for Choosing Specific Pesticides by Farmers

Figure 5 indicates the reasons for the choice of specific pesticides by farmers for the control of insect pests in their cabbage farms. Out of forty-nine (49) farmers interviewed, thirty-eight (38), representing 77.6% chose pesticides based on their availability on market in their area of operations. Six (6) farmers, representing 12.2% chose pesticides based on their low price and the remaining five (5) farmers, representing 10.2% respondents chose specific pesticides based on their effectiveness in controlling insect pests (Appendix 5).

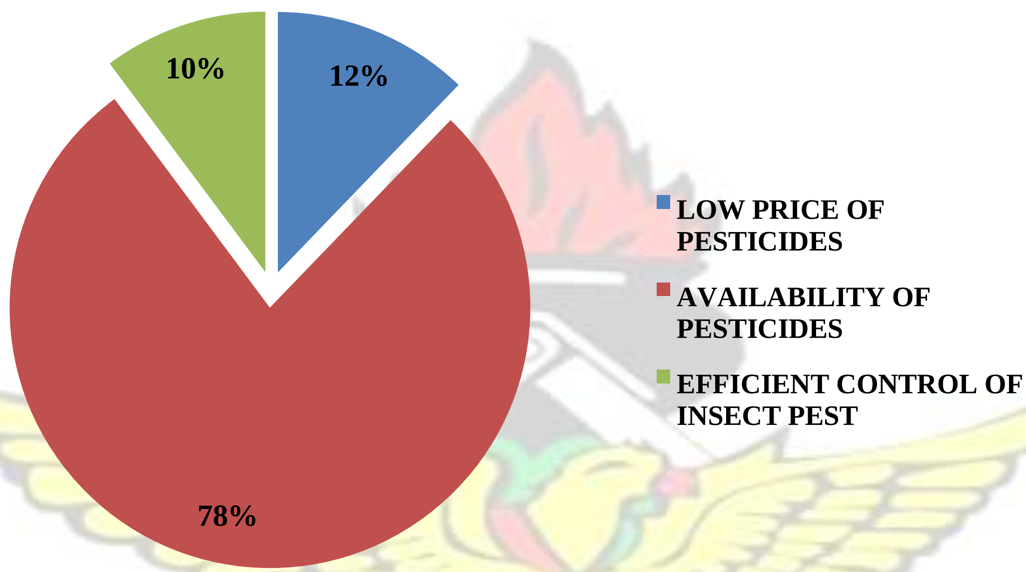

Figure 5: Reasons for choosing specific pesticides

4.1.7 Factors determining when Farmers apply Pesticides to Control Insect Pests Figure 6 indicates that twenty-five (25) out of the forty-nine (49) farmers interviewed, representing 51% did routine (calendar) spraying of pesticides to control insect pests on their cabbage. However, twenty- four (24) out of forty nine (49) farmers, representing 49%, decided to spray pesticides against insect pests upon noticing their presence on their cabbage farms (Appendix 6).

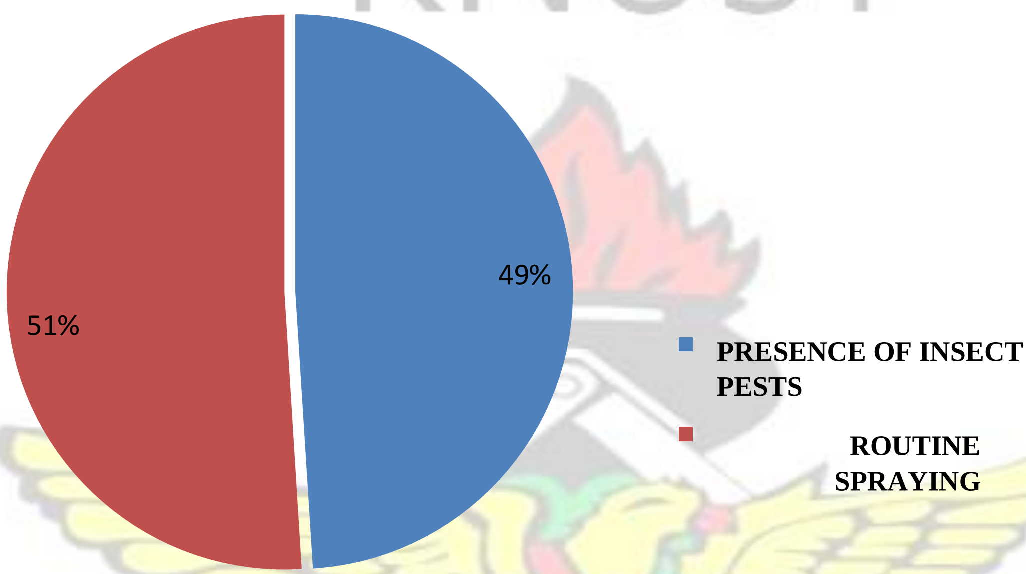

Figure 6: Factors determining when farmers apply pesticides

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

Figure 7 indicates that twenty-two (22) out of forty-nine (49) farmers interviewed, representing 44.9%, did spray pesticides between 11 to 15 times within a growing season of cabbage cultivation to control insect pests' infestation. Thirteen (13) farmers, representing 26.5% sprayed pesticides between 16 to 20 times within a growing season of cabbage cultivation. Those who sprayed between 6 to 10 times were nine (9), representing 18.4%. Four (4) farmers, representing 8.2% sprayed pesticides between 1 and 5 times. Only one farmer, representing 2.0% sprayed more than 20 times within a growing season of cabbage cultivation to control insect pest infestation (Appendix 7).

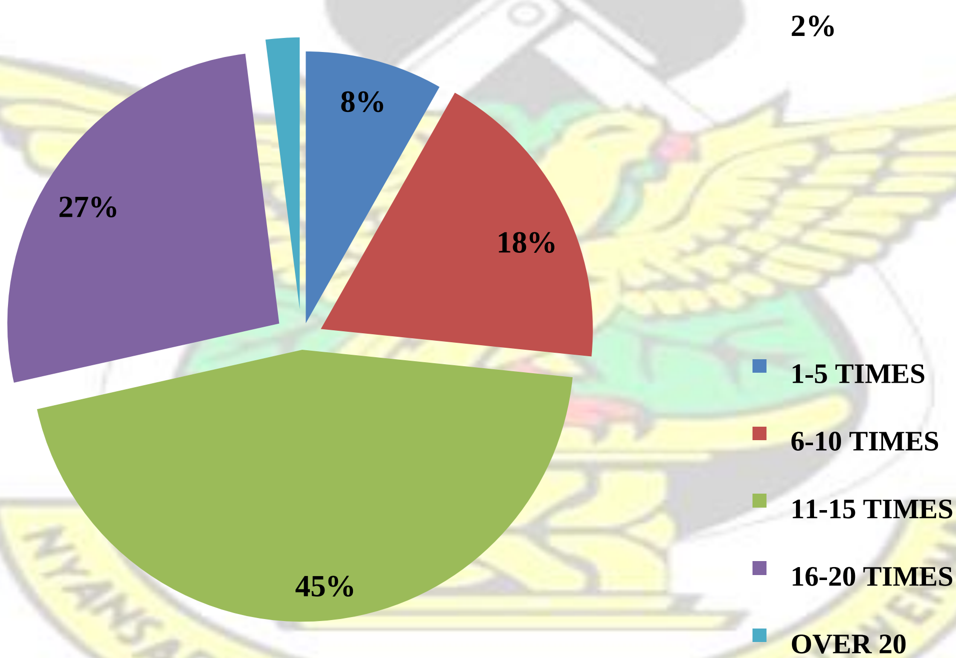

Figure 7: Frequency of spraying pesticides within a growing season

4.1.9 Efficacy of Pesticides Used by Farmers to Control Insect Pests in Cabbage

Cultivation

Sixteen (16) farmers, representing 32.7% ranked pesticides used in controlling insect pests as very effective (80-90% control of insect pests) (Figure 8). Twenty (20) farmers, representing 40.8% ranked pesticides used in controlling insects as effective (60-70% control of insect pests). The remaining 11 out of 49 farmers, representing 22.4% indicated that pesticides used in their cabbage farms were moderately effective in controlling insect pests (40-50% control of insect pests) (Appendix 8).

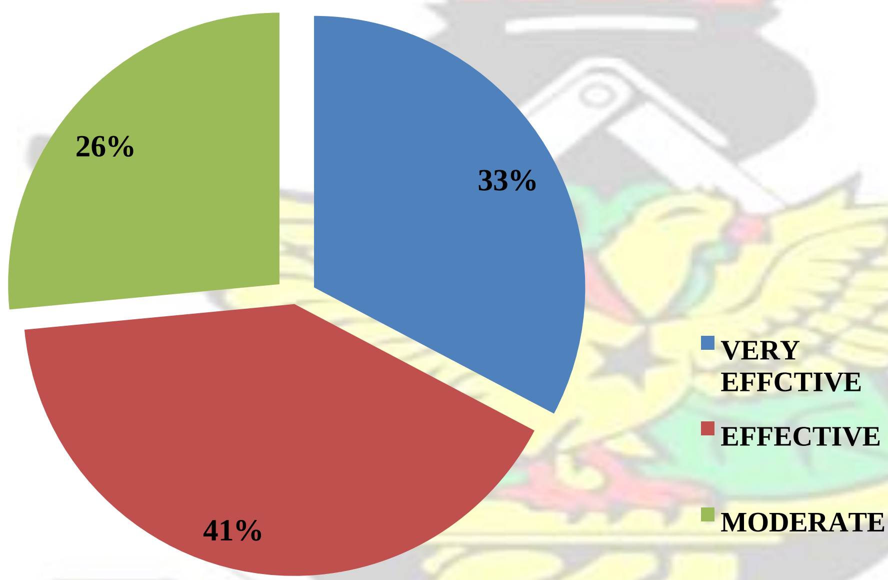

Figure 8: Efficacy of pesticides used by farmers

4.1.10 Time of the Day that Spraying Takes Place

Figure 9 indicates that thirty-eight (38) out of the forty-nine (49) farmers interviewed, representing 77.6% sprayed in the mornings (6am-11am). The remaining eleven (11) farmers, representing 22.4% sprayed in the evenings (4pm-6pm). None of the farmers sprayed in the afternoons (12noon-3pm) (Appendix 9).

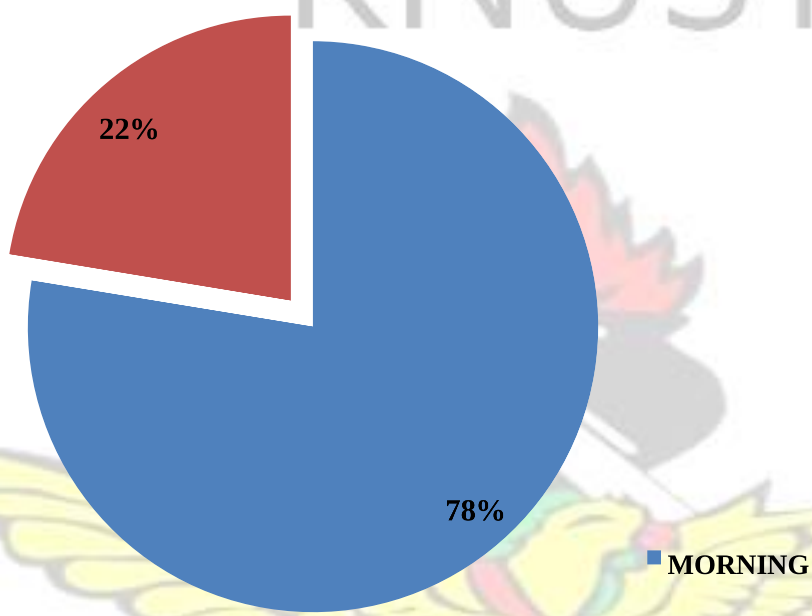

Figure 9: Time of the day that spraying takes place

4.1.11 Spraying Intervals (Intervals between One Spraying Period and the Next) Figure 10 indicates that twenty-two (22) farmers out of forty-nine (49) farmers interviewed, representing 44.9%, sprayed their crops at weekly intervals. Nine (9) of the farmers, representing 18.4% sprayed at 5 days intervals. Eight (8) of the farmers, representing 16.3% sprayed at two weeks interval. Six (6) of the farmers, representing 12.2% sprayed at four days intervals. Three (3) farmers, representing 6.1%, sprayed at six days interval and only one farmer, representing 2.0%, sprayed at three days interval (Appendix10).

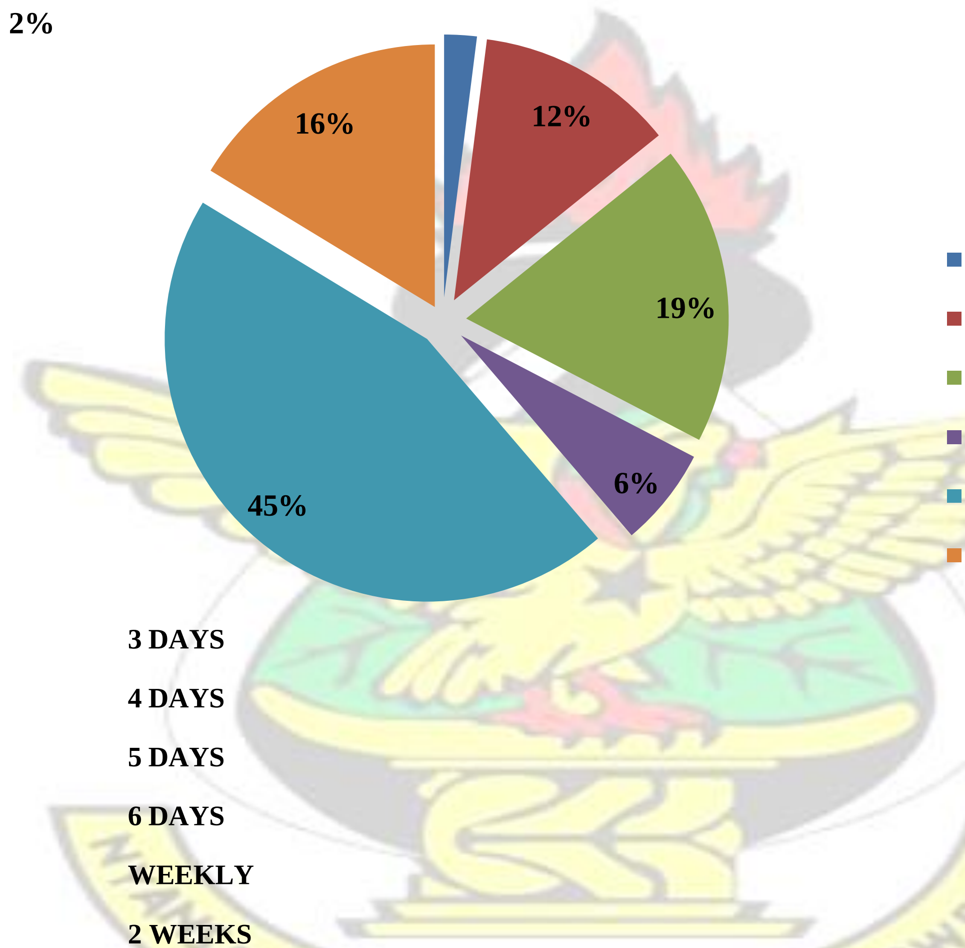

Figure 10: Spraying interval (interval between one spraying period and the next)

4.1.12 Spraying of Pesticides during Harvesting of Cabbage Heads

Figure 11 indicates that thirty-nine (39) out of forty-nine (49) farmers interviewed, representing 79.6% continued spraying of pesticides during time of harvesting cabbage heads. The remaining eleven (11) farmers, representing 20.4%, however, stopped spraying of pesticides during time of harvesting cabbage heads and on the average, five (5) days waiting period was allowed (Appendix 11).

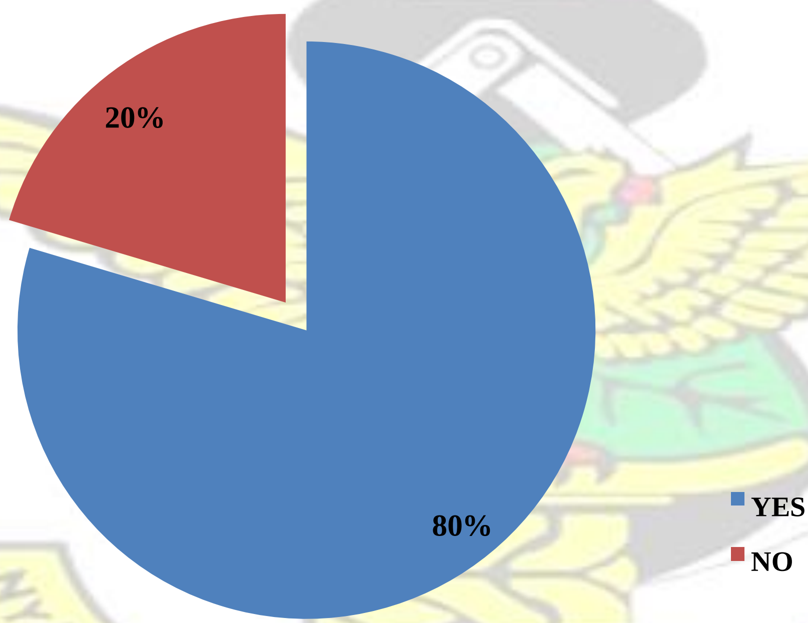

Figure 11: Spraying of pesticides during harvesting

4.1.13 Application Dosage of various Pesticides used by Farmers

Figure 12 reveals that twelve (12) out of the forty-nine (49) farmers interviewed, representing 24.5% used recommended rates of various pesticides for the control of insect pests on their cabbage farms.

Twenty-seven (27) of the farmers, representing 55.1% used dosages above the recommended rate of application of the various pesticides. The remaining ten (10) farmers, representing 20.4% also used dosages below the recommended rate of application of the various pesticides used to control insect pests on their cabbage farm (Appendix 12).

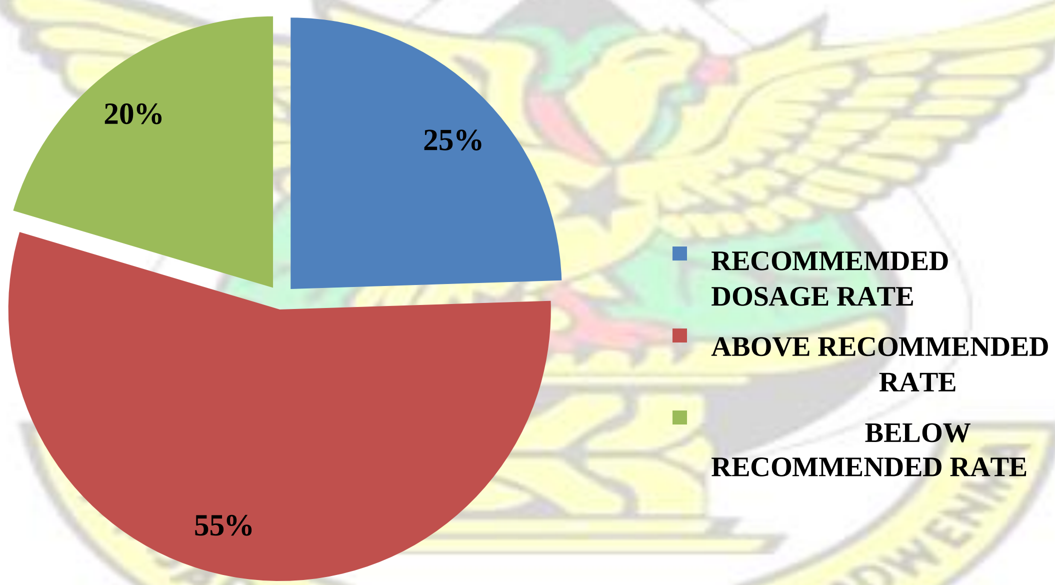

Figure 12: Application dosages of various pesticides used by farmers

4.1.14 Safety Precaution (Such as the use of Protective Clothing and Nose Respirator)

Adopted by Farmers during Spraying of Pesticides

Figure 13 reveals that thirty-three (33) out of forty-nine (49) farmers, representing 67.3% adopted safety precautions such as the use of protective clothing and nose respirators during spraying of pesticides. The remaining sixteen (16) farmers did not adopt any safety precautions during spraying of pesticides (Appendix 13).

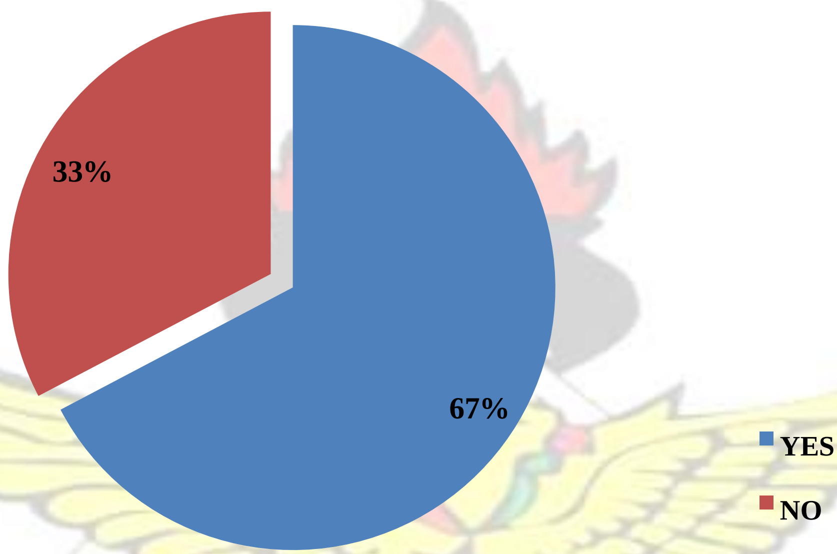

Figure 13: Safety precautions adopted by farmers during spraying

4.2 ORGANOCHLORINE PESTICIDE RESIDUAL ANALYSIS

Cabbage samples from Ejisu-Juaben Municipal area were analyzed for organochlorine pesticide residues (Alpha BHC, Gamma BHC (Lindane), Delta BHC, Heptachlor, Aldrin, DDT, DDE, Endrin, Beta Endosulfan, Dieldrin, Endosulfan sulphate and Beta BHC). The concentrations of the various residues in each sample were calculated in mg/kg. The mean concentration of each pesticide was compared to WHO/FAO (1995) Guideline Value in mg/kg.

Table 3 indicates pesticides analyzed at harvest and after two weeks in storage at 5°C refrigerator temperature. The results show the mean concentration of the various pesticide residues at harvest and after two week storage in a refrigerator.

The mean concentrations of Alpha BHC (0.321 mg/kg), Gamma BHC (lindane) (0.908 mg/kg), Beta BHC (0.883 mg/kg), Delta BHC (0.394mg/kg), Heptachlor (0.142mg/kg) and Beta Endosulfan (0.207mg/kg) residues in the cabbage samples at harvest were higher than the WHO/FAO Guideline value of 0.05mg/kg in vegetables. The concentrations of Alpha BHC, Gamma BHC, Beta BHC, Delta BHC, Heptachlor and Beta Endosulfan were significantly reduced after two weeks in storage to the values of 0.034mg/kg, 0.136mg/kg, 0.05mg/kg, 0.036 mg/kg, 0.003 mg/kg and 0.018mg/kg respectively. With the exception of Gamma BHC which after two weeks in storage was still higher than WHO/FAO Guideline value of 0.05 mg/kg, the concentration of Beta BHC was the same as WHO/FAO Guideline value. Alpha BHC, Delta BHC, Heptachlor and Beta Endosulfan were all lower than the WHO/FAO Guideline value after two weeks in storage. Alpha BHC, Gamma BHC (Lindane), Beta BHC and Delta BHC were each detected in 15 out of 30 samples, representing 50%. Heptachlor and Beta Endosulfan were each detected in 12 out of 30 samples, representing 40%.

The mean concentrations of DDT (0.017mg/kg), DDE (0.017mg/kg), Endrin (0.022mg/kg), Dieldrin (0.010mg/kg) and Endosulfan sulphate (0.005mg/kg) residues in the cabbage samples at harvest were below the WHO/FAO Guideline value; however the concentration of Aldrin residue at harvest was 0.05mg/kg which was the same as the WHO/FAO Guideline value of 0.05mg/kg. There were no detection of Aldrin, Dieldrin, Endrin and Endosulfan sulphate residues after two weeks in storage.

The concentrations of DDT and DDE were significantly reduced to the values of 0.003mg/kg and 0.001mg/kg respectively, after two weeks in storage, which were below the WHO/FAO Guideline value of 0.02mg/kg.

Table 3: Mean Concentration of Organochlorine Pesticide Residual Levels at Harvest and after 14 days storage in refrigerator.

Concentration	Alpha BHC	Gamma BHC	Beta BHC	Delta BHC	Heptachlor	Aldrin	DDT	DDE	Beta Endosulfan	Endrin	Dieldrin	Endosulfan sulphate
Mean concentration at harvest (mg/kg)	0.321	0.908	0.883	0.394	0.140	0.050	0.017	0.017	0.207	0.022	0.010	0.005
Mean concentration After 14 days in storage (mg/kg)	0.034	0.136	0.095	0.036	0.003	0.000	0.003	0.001	0.018	0.008	0.000	0.000
Percentage reduction	89.4	85.0	89.2	90.9	97.9	100.0	82.4	94.1	91.3	63.6	100.0	100.0
LSD (5%)	0.009	0.039	0.040	0.021	0.005	0.025	0.001	0.001	0.001	0.005	0.001	0.002
WHO/FAO Guideline Value in vegetable (mg/kg)	0.05	0.05	0.05	0.05	0.05	0.05	0.02	0.02	0.05	0.05	0.05	0.05

5.0 DISCUSSION

The field study has demonstrated that cabbage production in Ejisu-Juaben Municipal area also encountered the problem of misuse of pesticides to control insect pests as has been previously studied by Ninsin (1997) who suggested that cabbage production in Ghana faced insect pest problems and as a result, hazardous pesticides are being used by farmers to control the insect pests. Therefore, it was not surprising that the field survey revealed that as many as 27 different types of pesticides were used by farmers to control insect pests of cabbage in the municipality between 2004 and 2008. Several insect pests attack the cabbage crop and as a result they are produced under high input pressure which includes the use of hazardous pesticides. Lots of pesticides are therefore used by growers. Indiscriminate use of pesticides and non-adoption of safe waiting period by most of the growers led to the accumulation of pesticide residue in the consumable cabbages.

The field survey revealed that cabbage production in the municipality was dominated by males who were between the ages of twenty (20) and forty-five (45). This was so because cabbage production is laborious and needs intensive care with frequent spraying of pesticides to control insect pests.

The results of the survey also indicated that the common variety of cabbage being cultivated by the farmers was Oxylus. This was preferred by the consumers since it had big, round and compact head that could be stored for longer period even under room temperature.

It was revealed that all kinds of pesticides whether registered or not were being used by farmers to control insect pests since they were readily available on the market, usually those that were not made for vegetable production were cheaper hence most farmers could easily afford. This practice also contributed to indiscriminate use of pesticides which led to the high pesticides residues on or in cabbage heads as was revealed in the laboratory analysis.

The survey results indicated that 80% of farmers interviewed continued spraying while harvesting was on-going. This practice contributed to high pesticide levels in cabbage heads if the waiting period was short. Again, about 61% of farmers interviewed did mix two or more different pesticides together to combat insect pests of cabbage regardless of their side effects. It was a common practice for farmers to mix pesticides with the same active ingredients but different trade names together. This contributed to high pesticide residues in cabbage heads thus affecting safety and quality.

The study showed that the choice of specific pesticides by farmers mostly depended on their availability on the market and not on their efficacy or safety. Farmers even applied pesticides not recommended for vegetables on their cabbage. Some of the pesticides used by farmers are recommended for the control of pests of cotton. These practices could lead to harmful chemicals getting into human food chains with consequent adverse effects on human health. Chemicals or pesticides abuse as indicated by the farmers resulted from ignorance or lack of knowledge. Poor interactions between farmers and their agricultural extension agents might have contributed to this situation. In the absence of such effective interactions, farmers mostly depended on agrochemical dealers and colleague farmers to select pesticides for their fields. The knowledge from these sources may not be any better than that of the receiving farmer. The survey revealed that the spraying pattern adopted by most cabbage growers was routine or calendar spraying and practices of this kind could lead to high pesticide residues in cabbage heads as the waiting period between spraying and harvesting was not adequate to make the vegetable safe.

Even though farmers sprayed in the mornings and evenings, which are safe times of the day for spraying pesticides to combat insect pests however, the practices where farmers applied hazardous pesticides which were not recommended for vegetable on their cabbage could expose them to adverse effects of the pesticides used.

The study also showed that the frequency of spraying depended on the type and the dosage of pesticides used. Those who used recommended pesticides and right dosage prescribed by agricultural extension agents for controlling insect pests in their cabbage fields applied pesticides less frequently (1-2 weeks interval) than those who used non recommended pesticides who sprayed more frequently (3-4 days interval).

The second phase of the work, which involved the pesticide residue analysis of organochlorine, revealed the presence of organochlorine pesticides (Gamma BHC, Beta BHC, Delta BHC, Dieldrin, DDT, DDE, Endosulfan, Aldrin and Heptachlor) which have been banned, because of their toxicological effects on humans, animals, crops and the environment (EPA, 2008).

The results obtained indicated that pesticide residues were indeed present in the cabbage heads. Analysis of some organochlorine residue levels in cabbage heads at harvest indicated that Alpha BHC, Gamma BHC (Lindane), Beta BHC, Delta BHC, Beta Endosulfan and Heptachlor, had residue levels of 0.321 mg/kg, 0.908 mg/kg, 0.883 mg/kg, 0.394 mg/kg, 0.207 mg/kg and 0.140 mg/kg respectively, which were all higher than the FAO/WHO (1995) Guideline value of 0.05 mg/kg.

The results further showed that other organochlorine pesticides such as DDT, DDE, Endrin, Dieldrin and Endosulfan Sulphate, had residue levels of 0.017 mg/kg, 0.017 mg/kg, 0.022 mg/kg, 0.010 mg/kg and 0.005 mg/kg respectively, which were all below the FAO/WHO (1995) Guideline value of 0.02 mg/kg for DDT and DDE, and 0.05 mg/kg for Endrin, Dieldrin and Endosulfan Sulphate. The organochlorine pesticides are banned for vegetable production in Ghana therefore; the detection of these organochlorine pesticide residues in cabbage heads indicates misuse of agrochemicals among the farmers covered in the study. A possibility exists that the situation elsewhere may be similar to the Ejisu-Juaben situation.

Work already done in some farming communities in the Ashanti Region of Ghana and some other countries indicated the presence of organochlorine pesticide residue in fish (Osafo and Frimpong, 1998), vegetables, water sediments, mother's milk and blood samples (Ntow, 2001). Since these chemicals are toxic to living organisms, increased accumulation in the food chain may pose serious health hazards to the general populace (Jayashree and Vasudevan, 2007).

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.

Results of organochlorine pesticide residue analysis done after 14 days in storage revealed that, in most cases, there was significant ($P < 0.05$) reduction in the levels of pesticide residues as compared to analysis done immediately after harvest. This result implies that consumers will have to store cabbage for some days before eating as they may not know the chemicals applied and when they were applied.

Residues of pesticides in food are influenced by storage, handling and processing that occur between harvesting of raw agricultural commodities and consumption of prepared foodstuffs. A review of literature showed that in most cases storage leads to large reduction in residue levels in vegetables. Good practices such as effective washing and trimming also may reduce residue levels in prepared food. Residues of post harvest insecticide treatment on stored staples such as cereal grains and oil seeds generally decline only rather slowly. However, processing into foods again results in large losses except for unrefined oils. The behaviour of chemical residues in storage and processing depend on the physio-chemical properties of the pesticide and the nature of the process (Holland *et al*., 1994).

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

The research work was carried out in two phases. The result of the field survey revealed that as many as 27 different pesticides were used to control insect pests on cabbage production in Ejisu-Juaben municipality. These practices which include the use of non recommended and banned pesticides affected the safety and quality of cabbage produced. The laboratory analysis revealed that banned organochlorine pesticides such as lindane, endosulfan, dieldrin, aldrin and DDT were detected in cabbage samples. The result of the laboratory work also showed that the pesticide residual levels of cabbage samples stored in refrigerator for 14 days were reduced between 50-100%. The residue levels are often higher at harvest (often higher than acceptable levels recommended by WHO/FAO).

The results of the study have revealed that cabbage growers in the Ejisu-Juaben Municipal area misuse pesticides up to the extent that organochlorine pesticide residues were detected in all cabbage samples analysed.

Education, training and information on the use of pesticides and their residues should be made available to farmers in the Municipality. Stakeholders such as the Ministry of Food and Agriculture, EPA and Associations of Agrochemical dealers must form a common platform to combat the importation and smuggling of banned pesticides into the country. The security agencies and Staff of Plant Protection and Regulatory Services of Ministry of Food and Agriculture at the various border posts should be well trained on pesticides and their effects on health so as to make them appreciate more the need to stop dangerous pesticides from entering the country.

The Ministry of Food and Agriculture should intensify the education, training and information dissemination activities on pesticides and their effects on health in all the farming communities in the country, especially communities noted for the production of vegetables. This would help minimize the mishandling and misuse of pesticides which is becoming a health threat to both consumers and growers

Cabbage heads could be stored for some few days before consumption since the results of the laboratory analysis showed that the pesticides residual levels of cabbage samples stored in the refrigerator for 14 days were reduced between 50-100%. Cabbage heads must be properly washed with salt water (brine) to reduce chemical residues and other unwanted materials deposited on the cabbage heads.

REFERENCES

1. Allen, Z. and Allen, R. (2009). *The Health and Nutritional Benefit of Cabbage*. [on line] Available from: http://www.vegparadise.com/highestPerch33.html [Accessed 28/10/08].

2. Amoah, P., Drechsel, P., Abaidoo, R. C. and Ntow, W.I. (2006). Pesticide and pathogen contamination of vegetables in Ghana's urban markets. Environ. Contam. Toxicol. 50, 1-6.

3. Andersen, H. R., Vinggard, A. M., Rasmussen, T. H., Gjemadsen, I. M. and BonefeldJorrgensen, E. C. (2000). Effects of currently used pesticides in Assays for estrogenicity, androgenity and aromatase activity in-vitro Toxicol. Appl Pharmacol 179, 1-12.

4. Anon (EXTOXNET). Extension Toxicology Network (1996). Pesticide Information Profile. Revised June 1996 Edition. Pp. 1- 4.

5. Anon (Wikipedia) (2008). *Profile of Beta Benzene Hexachloride* [on line] Available from http// en.wikipedia.org/wiki/Beta-Benzenehexachloride [Accessed 27-10-08].

6. ATSDR (2002). Toxicological Profile for DDT, DDE and DDA, (Agency for Toxic Substances and Disease) Atlanta. US Department of Health and Human Services.

7. ATSDR (2005). Toxicological Profile for Aldrin and Dieldrin. (Agency for Toxic Substances and Disease Registry) [on line] Available from http//www.ATSDR-Publichealthstatement aldrin-dieldrin.html [Accessed 28-10-08].

8. ATSDR (2007). Toxicological Profile for Heptachlor and Heptachlor Epoxide. (Agency for Toxic Substances and Disease Registry). Atlanta, GA: US Department of Health and Human Services. Public Health Service.

9. Ayub, S., Verma, J. and Das, N. (2003). Effect of endosulfan and marathion on lipid peroxidation, nitrate and T N F and release by rat peritoneal macrophages. Int. Immunopharmacol 3, 1819-1826.

10. Baldwin, B. (1995). *History of cabbage*. [on line] Available from http//gardenline. usaskca/veg/cabbage.html [Accessed 27-10-08].

11. Barbara, S. (1993). *The Pesticides Hazards*. Zeb book Ltd in Association with Pesticide Trust. London and USA. Pp 3-5.

12. Bates, J. A. R and Gorbach, S. (1987). Approach to evaluating risk from pesticides residues in food. Pure & appl. chemical 59, p 611 – 624.

13. Chin, H. B. (1991). Pesticide residues and food safety-A harvest of viewpoint. American Chemical Society Symp. Ser. 446, p 175-181, American Chemical Society, Washington DC.

14. Clarke, E. E. K., Levy, L. S., Spurgeon, A. and Calvert, I. A. (1997). The Problems associated with pesticides use by irrigation workers in Ghana. Occup. Med, 47 (5), 301308.

15. Darko, G. and Acquaah, S. (2007). Levels of Organochlorine pesticide residues in meat. Department of Chemistry (KNUST), Kumasi Ghana. Int J. Environ Sci Tech; 4(4): 521524.

16. Ejobi, F., Kanja, L. W., Kyule, M. N., Muller, P., Kruger, J. and Latigo, A. A. R. (1996). Organochlorine pesticide residues in mother's milk in Uganda. Bull Environ. Contam. Toxicol. 56, 873-880.

17. Elkins, E. R. (1989). Residues on organochlorine pesticides. J. Assoc. of Anal. Chem., 72, p 533-535.

18. EPA (2008). *Ban of some agrochemicals in Ghana*. (Environmental Protection Agency-Ghana) [on line] Available from: http://www.pauna.org/resources/paup [Accessed 1-10-08]

19. Erlich, G. L. (1994). Factors leading to reduction of residues left on crops at harvest. International Union of Pure and Applied Chemistry. Technical Report 31. p 337.

20. Essumang, D. K., Dodoo, D. K., Adokoh, C. K. and Fumador, F. A. (2008). Analysis of some pesticide residues in tomatoes in Ghana. Human and ecological risk assessment, 14, (4): 796-806.

21. FAO/WHO (1971). Joint Meeting of the FAO Panel of Experts on Pesticide Residues in Food and the Environment and WHO Expert Group on Pesticide Residues. Geneva.

22. FAO/WHO (1986). Heptachlor in 1971 evaluation of some pesticides residues in food. Rome; Food and Agriculture Organization of the United Nations.

23. FAO/WHO (1995). Pesticide Residues in Food. Report of the joint meeting of the FAO Panel of Experts on pesticides residues in food and the environment. WHO toxicological and Environmental Core Assessment Groups. Rome, FAO Plant Production and Protection Paper 127.

24. Fletcher, W. W. and Kirkwood, R. C. (1982). *Herbicides and Plant Growth Regulators.* Granada Publishing Ltd. London. 104-146.

25. Gerken, A., Suglo, J. V. and Braun, M. (2001). Pesticide Policy in Ghana. MOFA/PPRSD, ICP project. Pesticide policy project/GTZ, Accra, Ghana.

26. Gruzdyer, G. S., Zinchenko, V. A., Kalinin, V. A. and Slovtov, R. I. (1983). The Chemical Protection of Plants. G.S. Gruzdyer (editor) Mir Publishers, Moscow. Pp1-471.

27. Hogson, A. (2003). The high cost of pesticide poisoning in Northern Ghana. Pesticides News, 62 (3), 4-8.

28. Holland, P. T., Hamilton, D., Ohlin, B. and Skiadmore, M. W. (1994). The effects of storage and processing on pesticide residues in plants products. Pure and Applied Chem.
66 (2): 335-366.

29. Hudson, D. H. and Roberts, T. R. (1981). *Progress in Pesticide Biochemistry*. Publishers: John Wiley and Sons Ltd. New York. Pp. 82.

30. Jayashree, R. and Vasudevan, N. (2007). Effects of tween 8 added to the soil on the degradation of endosulfan by *Pseudomonas acruginosa*. Int. J. Environ. Sci Tech., 4 (20):
203-210.

31. Jeyaratnam, J. (1990). Acute Pesticide Poisoning: A Major Global Health Problem. World Health Statistic Quarterly. 43 (3): 139-144.

32. Kawara, N. S., Batista, C. and Gunther, F. A. (1973). Pesticide residues. Residues Reviews 48, 45-60.

33. Keith, A. R. and Howard, G. A. (1993). Organochlorine pesticide in adipose tissue of persons from Elpaso. Texas. Journal of Environ Health, 56: 4-41

34. Kluive, M. W. (1981). Acute Toxicology of 1, 2 dibromo-3 chloropropane in the F344 male rat. Dose response relationships and differences in routes of exposure. J Agric. Food Chem. 59, 71-83.

35. Kumar, M. (2007). *Application and health effects of pesticides commonly used in India*.

[on line] Unpublished PhD, Research Associate, School of Public Health, Department of Anesthesia. Available from: http://www.eco-wes/editorial/070526.html [Accessed 15/11/07].

36. Lemaire, G., Terouanne, B., Mauvais, P., Michel, S. and Rahman, R. (2004). Effect of organochlorine pesticides on human androgen receptor activations in Vitro. Toxicol. Appl. Pharmacol 196, 235-246.

37. Lin, H. Z. (2008). *The Medicinal Properties of Cabbage* [on line] Optimize Cells Detoxification or Cleaning Ability of Cabbage. Available from: http//www.whfoods.com/genpagephp?tname= foodspice&bid=49. [Accessed 1-10-08].

38. Miller, G. T. (2002). *Living in the Environment* (12th edition). Belmont: Wadsworth/ Thomson Learning. ISBN 5, 34-37.

39. Miller, G. T. (2004). *Sustaining the Earth* (6th edition). Thompson learning Inc. Pacific Grove, California. Chapter 9. 211-216.

40. Minton, N. A. and Murray, V. S. G. (1988). A review of organophosphate poisoning. Medical Toxicology, 3 (3): 350-375.

41. MOFA (2001). Profile of District Agricultural Development in Ejisu-Juaben District. Technical document. Pp 1and 8., Accra, Ghana.

42. Murphy, G. (2005). Resistance Management. Pesticides Rotation. Ministry of Agriculture, Food and Rural Affairs. Ontario, Canada.

43. Ninsin, D. K. (1997). Insecticides use pattern and residue levels in cabbage cultivated within the Accra-Tema Metropolitan areas of Ghana. Unpublished Master of Philosophy thesis. Insect Science Programme. University of Ghana, Legon. 85p.

44. Norman, J. C. (1992). *Tropical Vegetable Crops*. Arthur H. Stockwell Ltd. Ilfracombe, Devon. Pp 160-161.

45. Norman, C. and Shealy, M. D. (2007). *Illustrated Encyclopedia of Healing Remedies*. [on line] PhD. Elements Book Inc. 160 North Washington Street. Boston MA 02114. Available from: http://www.hcvn.com/healthandhealingz/kcabbage/index.htm [Accessed 17/06/07].

46. Ntow, W. J. (2001). Organochlorine pesticide in water, sediments, crops and human fluids in a farming community in Ghana. Arch. Environ. Contam. Toxicol., 40, 557 – 563.

47. Ntow, W. J., Gijzen, H. J. and Drechsel, P. (2006). Farmer perceptions and pesticide use practices in vegetable production in Ghana. Pest Manage. Sci 62(4), 356-365.

48. Omafra-Uyenaka, J. R. (1990). *Revision of factsheet-storage of cabbage*. [on line] Agdex No. 252. Order no. 90-055. Available from: http:www.omafra.gov.cn.ca/English/crops/90-055htm [Accessed 29-9-08].

49. Osafo, A. S. and Frempong, E. (1998). Lindane and Endosulfan residues in water and fish in Ashanti Region of Ghana. J. Ghana Sci Assoc 1(1), 135-140.

50. Reigart, R. J. and Robert, J. R. (1999). Recognition and Management of Pesticide poisoning. Fifth Edition. Medical University of South Carolina. Washington D. C. US Environmental Protection Agency. Office of Pesticide Programmes.

51. Ritchey, S. T. (1982). *Handbook of nutritive values of processed foods*. Vol. 1. P 609614, M. Rechcigal edition, CRC press Boca Raton, Fla.

52. Robertson, M. M. and Kirkwood, R. C. (1969). The wood action of the foliage-applied translocated herbicides with particular reference to phenoxy-acid compound herbicide absorptions. Weed Res 9, 224-240.

53. Romain, H. R. (2001). Crop Production in Tropical Africa. Published by Ministry of Foreign Affairs. External trade and International co-operation. Brussels, Belgium. Pp 424-430

54. Stiling, P. D. (1985). *An Introduction to Insect Pest and Their Control*. Macmillan Publishers Ltd. New York pp 97.

55. Tindall, H. D. (1983). *Vegetables in the Tropics*. Macmillan Education Ltd. Basingstore, Hampshire and London, Britain. Pp. 139-140.

56. Treshow, M. (1970). *Environment and Plant Response*. McGraw Hill Inc. New York. Pp.377-397.

57. USEPA (2001). Conditional Registration of Novaluron. (United States Environmental Protection Agency). Office of Prevention, Pesticides and Toxic Substances (7501C). Pesticide Fact Sheet. CAS Number: 116714-46-6. Pp 1-4.

58. USEPA (2005). *Uses of Lindane*. (United States Environmental Protection Agency). [on line] Available from: http://en.wikipedia.org/wiki/lindane [Accessed Sept.15, 2007]

59. USEPA (2007*).What is pesticide?* (United States Environmental Protection Agency) [on line] Available from: http:// www.epa.gov? [Accessed Sept. 15, 2007]

60. Watson, W. A., Litovtz, T. L., Klein-Schwartz, W., Rodgers, G. C., Youniss, J., Reid, N., Rouse, W. G., Rembert, R. S. and Borys, D. (2003). Toxic Exposure Surveillance

System. Annual Report of the American Association of Poison Control Centers. Am. J. Emerg Med. 2004. 22(5): 335-404.

61. White, N. D. G. and Norwich, T. W. (1985). Effect of Storage on Pesticide Residues in Plant Products. J. Stored Prod res. 21: 111-115.

62. Winter, C. K. (1992). Pesticide residues in plant products. Rev. Environ. Contam. Toxicol. 127:23-66.

63. WHO/FAO (1992). Pesticide residues in food – 1991. Evaluations – 1991. Part *II.* To Pesticide Residuexicology. Geneva, World Health Organization, Joint FAO/WHO Meeting on (WHO/PCS/92.52).

64. WHO/FAO (1995). Pesticide residues in food – 1994. Report of the Joint Meeting of the FAO Panel of Experts on Pesticide Residues in Food and the Environment and WHO Toxicological and Environmental Core Assessment Groups. Rome, Food and Agriculture Organization of the United Nations Plant Production and Protection. Paper 127.

65. WHO (2003). Heptachlor and heptachlor epoxide in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality. Geneva, World Health Organization (WHO/SDE/WSH/03.04/99)

66. WHO (2005). *Toxicological Profile of DDT. [on line] Available from:* http://en.wikipedia.org/wiki/DDT. [Accessed 20/10/08]

67. Youdeowei, A. (2002). Integrated Pest Management Practice for the Production of vegetables in Ghana. Integrated Pest Management Extension Guide 4. MOFA/GTZ. Pp 12-14.

68. Zablotowicz, R. M., Hoagland, R. E. and Hall, J. C. (2005). Pesticide metabolism in plants and prokaryotes. (J. M. Clark and H. Ohkawa Ed.) In: Environmental Fate and Safety Management of Agrochemicals Herbicides. American Chemical Society Symposium Series 899: 168-184.

APPENDICES

Appendix 1: Sex of Respondents

Sex	**Frequency**	**Percent**	**Cumulative Percent**
MALE	43	87.8	87.8
FEMALE	6	12.2	100.0
Total	**49**	**100.0**	

Appendix 2: Educational level of Respondent

Educational level	Frequency	Percent	Cumulative Percent
Illiterate	9	18.4	18.4
Primary/JSS/MSLC	39	79.6	98.0
Post	1	2.0	100.0
Total	**49**	**100.0**	

Appendix 3: Varieties of Cabbage cultivated by Farmers

Variety	Frequency	Percent	Cumulative Frequency
Oxylus	33	67.4	67.4
KK Cross	3	6.1	73.5
Oxylus and KK Cross	11	22.5	96.0
Gloria F1	1	2.0	98.0
The three combined	1	2.0	100. 00
Total	**49**	**100.00**	

Appendix 4: Mixing of Different Pesticides Together For Spraying

Response	Frequency	Percentage
YES	30	61.2
NO	19	38.8
Total	**49**	**100.0**

Appendix 5: Reasons for Choosing Specific Pesticides by Farmers

Reasons	Frequency	Percentage
Low price of Pesticides	6	12.2
Availability of Pesticides	38	77.6
Efficient controlling of insect pests	5	10.2
Total	**49**	**100.0**

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

Spraying Indicator	Frequency	Percentage	Cumulative Percentage
Presence of insect pests	24	49.00	49.00
Routine spraying Schedule	25	51.00	100.00
Total	**49**	**100.00**	

Appendix 7: Frequency of Spraying Pesticides to Control Insect Pests within a Growing Season of Cabbage Cultivation

Period	Frequency	Percentage	Cumulative Percentage
1 – 5 times	4	8.2	8.2
6 - 10 times	9	18.4	26.6
11 – 15 times	22	44.9	71.5
16 – 20 times	13	26.5	98.0
Over 20 times	1	2.0	100.0
Total	**49**	**100.0**	

Appendix 8: Efficacy of Pesticides Used by Farmers to Control Insect Pests in Cabbage Cultivation

Effectiveness	Frequency	Percentage	Cumulative Percentage
Very Effective	16	32.7	32.7
Effective	20	40.8	73.5
Moderate	13	26.5	100.0

Total	**49**	**100.0**	

Appendix 9: Time of the Day that Spraying Took Place

Time of the Day	**Frequency**	**Percentage**	**Cumulative Percentage**
Morning	38	77.6	77.6
Evening	11	22.4	100.0
Total	**49**	**100.0**	

Appendix 10: Spraying Intervals (interval between one spraying period and the next)

Spraying Interval	**Frequency**	**Percentage**	**Cumulative Percentage**
3 Days	1	2.0	2.0
4 Days	6	12.3	14.3
5 Days	9	18.4	32.7
6 Days	3	6.1	38.8
Weekly	22	44.9	83.7
2 weeks	8	16.3	100.0
Total	**49**	**100.0**	

Appendix 11: Spraying of Pesticides during Harvesting of Cabbage Heads

Response	**Frequency**	**Percentage**	**Cumulative percentage**
Yes	39	79.6	79.6
No	10	20.4	100.0
Total	**49**	**100.0**	

Appendix 12: Application Dosages of various pesticides used by farmers

Dosage Rates	Frequency	Percentage	Cumulative percentage
Recommended Dosage Rate	12	24.5	24.5
Above Recommended Rate	27	55.1	79.6
Below Recommended Rate	10	20.4	100.0
Total	**49**	**100.0**	

Appendix 13: Safety precautions adopted by farmers during spraying of pesticides

Response	Frequency	Percentage	Cumulative percentage
Yes	33	67.3	67.3
No	16	32.7	100.0
Total	**49**	**100.0**	

APPENDIX 14: Analysis of Variance

1. Variate: A (Alpha BHC)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
CM	4	0.3986730	0.0996683	630.41	<.001
PRD	1	0.6660300	0.6660300	4212.71	<.001
CM.PRD	4	0.4819650	0.1204912	762.12	<.001
Residual	20	0.0031620	0.0001581		
Total	29	1.5498300			

Grand mean 0.1720

*** Least significant differences of means (5% level) ***

Table	CM	PRD	CM PRD
rep.	6	15	3
d.f.	20	20	20
l.s.d.	0.01514	0.00958	0.02142

d.f.	s.e.	cv%
20	0.01257	7.3

2. Variate: AE (Alpha Endosulphan)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
CM	4	4.8000E-06	1.2000E-06		
PRD	1	1.2000E-06	1.2000E-06		
CM.PRD	4	4.8000E-06	1.2000E-06		
Residual	20	0.0000E+00	0.0000E+00		
Total	29	1.0800E-05			

Grand mean 0.00

*** Least significant differences of means (5% level) ***

Table	CM	PRD	CM
PRD rep.	6	15	3
d.f.	*	*	*
l.s.d.	0.000	0.000	0.000

d.f. s.e. cv%

20	0.000	0.0

CM -------- Different communities where cabbage samples were taken

PRD-------- Levels of pesticide residual detection (At harvest and after two weeks in storage)

CM.PRD---Interaction between CM and PRD.

3. Variate: AL (Aldrin)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
CM	4	0.011520	0.002880	2.66	0.063
PRD	1	0.007680	0.007680	7.10	0.015
CM.PRD	4	0.011520	0.002880	2.66	0.063
Residual	20	0.021642	0.001082		
Total	29	0.052362			

Grand mean 0.0160

Table	CM	PRD	CM
	PRD rep.		6
15	3		
d.f.	20	20	20
e.s.e.	0.01343	0.00849	0.01899

*** Least significant differences of means (5% level) ***

Table	CM	PRD	CM PRD
rep.	6	15	3
d.f.	20	20	20
l.s.d.	0.03962	0.02506	0.05603

d.f.	s.e.	cv%
20	0.03290	205.6

4. Variate: B (Beta BHC)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr. CM
4	0.558687	0.139672	51.29	<.001	
PRD	1	4.661809	4.661809	1711.82	<.001
CM.PRD	4	0.697070	0.174267	63.99	<.001
Residual	20	0.054466	0.002723		

Total	29	5.972032

Grand mean 0.4890

*** Least significant differences of means (5% level) ***

Table	CM	PRD	CM
PRD rep.	6	15	3
d.f.	20	20	20
l.s.d.	0.06285	0.03975	0.08888

d.f.	s.e.	cv%
20	0.05219	10.7

5. Variate: BE (Beta Endosulfan)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
CM	4	1.091E-01	2.729E-02	7180.74	<.001
PRD	1	5.267E-02	5.267E-02	13860.08	<.001
CM.PRD	4	8.186E-02	2.046E-02	5385.47	<.001
Residual	20	7.600E-05	3.800E-06		
Total	29	2.438E-01			

Grand mean 0.04910

*** Least significant differences of means (5% level) ***

Table	CM	PRD	CM
	PRD rep.		6
15	3		
d.f.	20	20	20
l.s.d.	0.002348	0.001485	0.003320

d.f.	s.e.	cv%
20	0.001949	4.0

6. Variate: D (Delta BHC)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr. CM
4	2.4349170	0.6087292	739.83	<.001	
PRD	1	1.0035723	1.0035723	1219.70	<.001
CM.PRD	4	2.6792742	0.6698186	814.07	<.001
Residual	20	0.0164560	0.0008228		
Total	29	6.1342195			

Grand mean 0.2115

*** Least significant differences of means (5% level) ***

Table	CM	PRD	CM PRD
rep.	6	15	3
d.f.	20	20	20
l.s.d.	0.03455	0.02185	0.04885

7. Variate: DE (DDE)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
CM	4	6.618E-04	1.655E-04	37.60	<.001
PRD	1	1.229E-03	1.229E-03	279.27	<.001
CM.PRD	4	5.562E-04	1.391E-04	31.60	<.001
Residual	20	8.800E-05	4.400E-06		
Total	29	2.535E-03			

Grand mean 0.00680

*** Least significant differences of means (5% level) ***

Table	CM	PRD	CM PRD
rep.	6	15	3
d.f.	20	20	2 0
l.s.d.	0.002526	0.001598	0.003573

d.f.	s.e.	cv%
20	0.002098	30.8

8. Variate: DI (Dieldrin)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
CM	4	1.955E-04	4.888E-05	28.20	<.001
PRD	1	4.961E-04	4.961E-04	286.23	<.001
CM.PRD	4	1.735E-04	4.338E-05	25.03	<.001
Residual	20	3.467E-05	1.733E-06		
Total	29	8.999E-04			

Grand mean 0.00427

*** Least significant differences of means (5% level) ***

Table	CM	PRD	CM PRD
rep.	6	15	3
d.f.	20	20	20
l.s.d.	0.001586	0.001003	0.002242

d.f.	s.e.	cv%
20	0.001317	30.9

9. Variate: DT (DDT)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
CM	4	1.182E-03	2.955E-04	591.00	<.001
PRD	1	1.875E-04	1.875E-04	375.00	<.001
CM.PRD	4	5.520E-04	1.380E-04	276.00	<.001
Residual	20	1.000E-05	5.000E-07		
Total	29	1.932E-03			

Grand mean 0.00450

*** Least significant differences of means (5% level) ***

Table	CM	PRD	CM
PRD rep.	6	15	3
d.f.	20	20	20
l.s.d.	0.000852	0.000539	0.001204

d.f.	s.e.	cv%
20	0.000707	15.7

10. Variate: E (Endrin)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
CM	4	0.00308520	0.00077130	20.51	<.001
PRD	1	0.00025230	0.00025230	6.71	0.017
CM.PRD	4	0.00054720	0.00013680	3.64	0.022
Residual	20	0.00075200	0.00003760		
Total	9	0.00463670			

Grand mean 0.0059

*** Least significant differences of means (5% level) ***

Table	CM	PRD	CM
PRD rep.	6	15	3
d.f.	20	20	20
l.s.d.	0.00738	0.00467	0.01044

d.f.	s.e.	cv%
20	0.00613	103.9

11. Variate: ES (Endosulfan Sulphate)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.

CM	4	5.520E-05	1.380E-05	2.82	0.053
PRD	1	7.500E-06	7.500E-06	1.53	0.230
CM.PRD	4	7.200E-05	1.800E-05	3.67	0.021
Residual	20	9.800E-05	4.900E-06		
Total	29	2.327E-04			

Grand mean 0.00090

*** Least significant differences of means (5% level) ***

Table	CM	PRD	CM PRD
rep.	6	15	3
d.f.	20	20	20
l.s.d.	0.002666	0.001686	0.003770

d.f.	s.e.	cv%
20	0.002214	246.0

12. Variate: G (Gamma BHC)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
CM	4	0.914536	0.228634	85.17	<.001
PRD	1	4.467564	4.467564	1664.21	<.001
CM.PRD	4	1.595326	0.398832	148.57	<.001
Residual	20	0.053690	0.002684		
Total	29	7.031117			

Grand mean 0.5219

*** Least significant differences of means (5% level) ***

Table	CM	PRD	CM PRD
rep.	6	15	3
d.f.	20	20	20
l.s.d.	0.06240	0.03946	0.08825

d.f.	s.e.	cv%
20	0.05181	9.9

13. Variate: H (Heptaclor)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
CM	4	0.23700900	0.05925225	1226.75	<.001
PRD	1	0.09644670	0.09644670	1996.83	<.001
CM.PRD	4	0.23408580	0.05852145	1211.62	<.001
Residual	20	0.00096600	0.00004830		
Total	29	0.56850750			

Grand mean 0.0585
*** Least significant differences of means (5% level) ***

Table	CM	PRD	CM PRD
rep.	6	15	3
d.f.	20	20	20
l.s.d.	0.00837	0.00529	0.01184

d.f.	s.e.	cv%
20	0.00695	11.9

APPENDIX 15: Sample of Questionnaire Used

1. PROFILE OF THE FARMER:

AGE: [ ]

GENDER: Male [ ] Female [ ]

EDUCATION:..

2. LOCATION:...

3. STATE VARIETY/VARIETIES OF CABBAGE CULTIVATED: *(tick)*

(i) Oxylus [ ]

(ii) K K Cross [ ]

(iii) Gloria F1 [ ]

(v) Oxylus and Gloria F1 [ ]

(vi) KK Cross and Gloria F1 [ ]

(vii) The three combined [ ]

(iv) Oxylus and K K Cross [ ] (viii) Others [ ] Specify......................

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

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

(i) YES [ ]

(ii) NO [ ]

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

7. ACTIVE INGREDIENTS OF PESTICIDES MENTIONED ABOVE.

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

9. REASON(S) FOR CHOOSING PARTICULAR PESTICIDES *(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 PESTICIDES ON YOUR CABBAGE? *Tick)*

(i) Presence of pest on basis of scouting [ ]

(ii) Spray on routine schedule [ ]

(iii) Agric Extension Agent’s recommendation [ ]

(iv) Agro chemical dealer’s recommendation [ ]

(v) Colleague farmer’s recommendation [ ]

(vi) Others [ ] (Specify).............................

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

(i) 1- 5 times [ ]

(ii) 6 – 10 times [ ]

(iii) 11 – 15 times [ ]

(iv) 16 – 20 times [ ]

(v) Others [ ] Specify...

12. EFFICIENCY OF PESTICIDES IN TERMS OF ELIMINATING/CONTROLLING INSECT PESTS *(tick)*

(i) Very effective (80-90%) [ ]

(ii) Effective (60 -70%) [ ]

(iii) Moderate (40-50%) [ ] (iv) Poor (below 40%) [ ]

13. TIME OF THE DAY THAT SPRAYING USUALLY TAKES PLACE *(tick).*

(i) Morning [ ]

(ii) Afternoon [ ]

(iii) Evening [ ]

14. SPRAYING INTERVALS *(tick).*

(i) 2 days [ ] (v) 6 days [ ]

(ii) 3 days [ ] (vi) weekly [ ]

(iii) 4 days [ ] (vii) Others [ ] Specify....................................

(iv) 5 days [ ]

15. DO YOU CONTINUE SPYAING WHILE HARVESTING? *(tick)*

(i) YES [ ]

(ii) NO [ ]

16. IF NO, STATE SPRAYING INTERVAL BETWEEN LAST SPRAYING AND HARVESTING.

(i) 1- 3 days [ ]

(ii) 4 -6 days [ ]

(iii) 7 – 10 days [ ]

(iv) 11 – 14 days [ ]

(v) Others [ ] Specify...

17. DO YOU TAKE ANY SAFETY PRECAUTIONARY MEASURES DURING SPRAYING OF PESTICIDES?

(i) YES [ ]

(ii) NO [ ]

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

(i) Motorized spraying machine [ ]

(ii) Knapsack spraying machine [ ]

(ii) Others [ ] Specify...

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

(i) 50 m [ ]

(ii) 100m [ ]

(iii) 150m [ ]

(iv) Others [ ] Specify..