

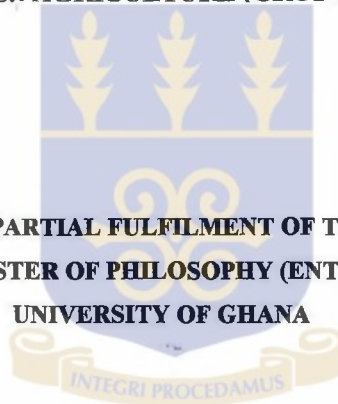
**INSECTICIDE USE PATTERNS AND RESIDUE LEVELS ON CABBAGE,
Brassica oleracea var. *capitata* L., CULTIVATED WITHIN THE
ACCRA-TEMA METROPOLITAN AREA OF GHANA**

BY

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B.Sc. (HONS.) AGRICULTURE (CROP SCIENCE)

**A THESIS PRESENTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF PHILOSOPHY (ENTOMOLOGY) OF THE
UNIVERSITY OF GHANA**



**INSECT SCIENCE PROGRAMME*
UNIVERSITY OF GHANA
LEGON**

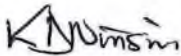
OCTOBER 1997

***JOINT INTERFACULTY INTERNATIONAL PROGRAMME FOR THE TRAINING OF
ENTOMOLOGISTS IN WEST AFRICA.
COLLABORATING DEPARTMENTS: ZOOLOGY (FACULTY OF SCIENCE) & CROP SCIENCE
(FACULTY OF AGRICULTURE)**


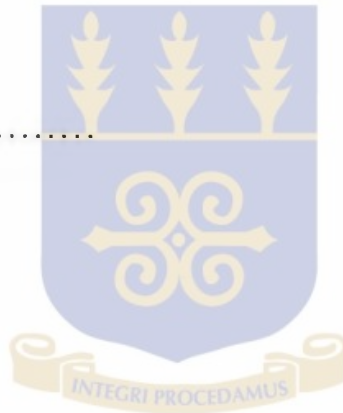


DECLARATION

I hereby declare that, except for reference to other people's work which have only been cited, this work is the result of my own original research and that this thesis has neither in whole nor in part been presented for another degree elsewhere.



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ABSTRACT

Concerns have been expressed by pesticide management specialists about the choice and use of insecticides in cabbage production and fear of toxic residues on harvested cabbage head. This investigation involves a survey to determine cabbage farmers' insecticide use patterns and analysis for insecticide residues on samples of cabbage.

The survey revealed that cabbage growers in the Accra-Tema Metropolitan area of Ghana invariably relied on insecticide retailers/agents for advice on the choice and use of insecticides for insect pest control purposes. The insecticides of choice were, *Bacillus thuringiensis* subsp. *kurstaki* Berliner, Lambdacyhalothrin, Chlorpyrifos, Dimethoate, Deltamethrin, Triazophos, Cypermethrin, Profenofos and Pirimiphos-methyl. These insecticides were used either in alternation or as mixtures. Additionally, the insecticides were sprayed frequently and at short intervals on cabbage without the consideration of threshold levels.

Residues of Karate 2.5 EC (Lambdacyhalothrin) and Deltaphos 262 EC (250g/l Triazophos + 12g/l Deltamethrin) were determined on samples of cabbage, by estimation of biotoxicity to the brine shrimp nauplii. Residues of Lambdacyhalothrin were lower than the FAO/WHO recommended maximum residue level (MRL). The residues of Deltaphos 262 EC detected, however, suggested that the residue levels of Triazophos were likely to be higher than FAO/WHO recommended MRL.

DEDICATION

To my wife, SADIA.



ACKNOWLEDGEMENTS

I wish to express my sincere and profound gratitude to my supervisor, Dr. W. S. K. Gbewonyo, for his keen interest in my work, guidance, criticisms, suggestions, and invaluable assistance which have made the preparation of this thesis possible.

I wish to record my indebtedness to Professor J. N. Ayertey, Dr. I. Ofori, and Dr. C. Y. Brempong-Yeboah also for their invaluable assistance, and all lecturers of the Insect Science Programme for their guidance. My thanks go to the senior members, staff and students of the Biochemistry Department, University of Ghana, whose facilities were put at my disposal for the estimation of insecticide residue levels.

I am very grateful to all the cabbage growers in the Accra-Tema Metropolitan Area who were very helpful during the execution of the survey. I am also very grateful to my family, relatives and friends, especially, my wife Sadia, Emmanuel Oyewo, Godwin Ameleke, Bernard Boateng, Elvis Appiah, Ferdinard Dongdem, and Vincent Eziah for their support.

Finally, I wish to record my sincere gratitude and special thanks to the German Government for the DAAD-In-Country-Scholarship which was awarded for my Master of Philosophy programme.

MAY GOD RICHLY BLESS YOU ALL.

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1. INTRODUCTION

1.1 Background Information

The cultivation and consumption of cabbage in Ghana has been on the increase in recent times. This is predominantly so in the urban areas where there is a high demand for the vegetable. To meet the increasing demand for cabbage, growers in Ghana have resorted to monoculture and intensive cultivation of the crop. This practice has led to an increase in insect pest diversity and infestation which is militating against obtaining optimum yield. Additionally, with the all year round suitable environmental conditions for pest survival and development, pest outbreaks occur with unabating damage (Afun *et al.*, 1992) on cabbage farms.

Among the insect pests that have been implicated in the damage of cabbage in Ghana is the notorious and cosmopolitan pest, diamondback moth, *Plutella xylostella* L. (Lepidoptera : Plutellidae) (Brempong-Yeboah, 1992). The activities of the insect pests on cabbage render the vegetable unattractive and obnoxious, and are therefore rejected by consumers. The growers in a desperate attempt to protect their crop and investment, resort to the use of insecticides to control insect pests of cabbage. In recent times therefore, protected cabbage production, mainly by the use of insecticides, has been stepped up considerably. Brempong-Yeboah (1992) observed in 1986 that cabbage growers in the Accra plains were using unnecessarily large quantities of insecticides, and in various concoctions against the diamondback moth. Not only were the dosages applied very high, but the growers also sprayed at 2-3 day intervals, it was noted. Some of the insecticides recently documented to have been used in Ghana include Permethrin (Brempong-Yeboah, 1992) and chlorpyrifos (Mawuenyegah, 1994). The increased use of insecticides has been compounded by a large number of pesticides on the Ghanaian market.

The success of chemical plant protection is convincing, optimum crop yields are obtained and the quality of farm produce is improved (GTZ, 1979). However, the lack of informed choices and use of pesticides has resulted in the repeated and indiscriminate use of pesticides which has created the problem of human health hazard due to their toxic residues that persist in/on food after their applications (ICAR Extension folder : 59). The pesticide residues which consist of remnants of a pesticide or its toxic metabolite in/on a crop after its use for pest control purposes, may either cause acute or chronic toxicity in humans after the consumption of the treated crop. These toxic effects are more apparent in vegetables since they are sometimes consumed fresh (ICAR Extension folder : 59).

Consumer awareness and concern about the perceived risks that potential residues of pesticides may pose to human health is therefore challenging the global agro-industry, especially the fruits and vegetables industry, to minimize pesticide residues. Most developed and some developing countries have therefore enacted strict legal controls which lay down reasonable safe levels for pesticide residues in food. The main purpose of these legislations is to prevent damage to human health and the environment. The Food and Agricultural Organization (FAO) and World Health Organization (WHO) of the United Nations (UN) which since 1961 have been setting maximum residue limits (MRL) of pesticides in foods, have also been seriously concerned about the acceptable daily intake (ADI) values which takes into consideration the eating habits of consumers (GTZ, 1979).

1.2 Problem Statement

In Ghana, although consumer awareness and legislation on pesticide residues in food are lacking, pesticide management specialists are very concerned about the risks posed by pesticide residues in food to the Ghanaian public. This concern, especially with respect to cabbage wholesomeness, is warranted because of the suspicion of

indiscriminate use of insecticide on the crop, and also the recent desire of consumers to consume this vegetable raw.

The questions frequently asked by these specialists are;

1. What are the farmers' insecticide use patterns on cabbage?
2. Do residues arise from the insecticides that are used?
3. Are the residue levels lower or higher than the FAO/WHO recommended MRLs?

1.3 Research Objectives

In view of the absence of a comprehensive study to determine the insecticide use patterns and residue levels on cabbage in Ghana, the objectives of this present research were set as follows:

1. To determine the insecticide use patterns on cabbage in the Accra-Tema metropolitan area of Ghana.
2. To determine the residue levels of some of the insecticides used on cabbage.
3. To determine whether the residue levels detected are higher than the FAO/WHO MRL.

1.4 Relevance of Research

The findings of this research, it is hoped, will guide researchers and directors of chemical companies in Ghana to organize periodic and comprehensive training programs for extension workers and cabbage growers on the proper choice, handling, and use of insecticides.

The findings should also form the basis for policy makers to pass a pesticide residue bill to protect human health and the environment.

2. LITERATURE REVIEW

2.1 Origin and Importance of Cabbage

Cabbage (*Brassica oleracea* var. *capitata* L.) a biennial herb, is a member of the family Cruciferae (Purseglove, 1969 ; Rice *et al.*, 1993), and an important global vegetable crop. The edible part of the cabbage plant which is the "head" is made up of a series of overlapping expanded leaves which cover a small terminal bud (Purseglove, 1969; Sinnadurai, 1992; Rice *et al.*, 1993).

The crop is of very ancient cultivation and has been grown in Europe since at least 2500 B.C. (Purseglove, 1969). It was introduced into England by the Romans and is now grown throughout the world including lowland tropics (Purseglove, 1969).

Although information on the introduction of the crop into Ghana is not well documented, it is believed that the British introduced it into this country, and that the crop was grown on a small scale around 1940 (Sinnadurai, 1992). The popularity of cabbage among Ghanaians especially those in the urban centers has increased. This is due to the nutritional value of the vegetable (Appendix A) and the desire of the average Ghanaian to indulge in some western dishes. Cabbage is therefore currently eaten in many homes. It is also served in many restaurants and fast food outlets. The booming tourism industry and foreign investment drive in the country, which is attracting many foreigners, have also put pressure on the demand for cabbage.

Stimulated by the increased demand for cabbage, the cultivation of this crop has increased in the last decade. This, apart from meeting the demand of the growing urban population, is also improving the income level and position of cabbage growers and retailers alike.

2.2 Insect Pests of Cabbage

Although cabbage production in Ghana has been on a steady increase over the last decade, there are certain problems which militate against obtaining optimum yield. These constraining factors include unavailability of land and water, marketing problems, and insect pest infestation which happens to be a global problem (Miyata *et al.*, 1986; Cartwright *et al.*, 1987; Brempong-Yeboah, 1992; Hill and Waller, 1994). This problem of insect pest infestation has arisen from monoculture and intensive cabbage production. Monoculture has created conditions favorable for specialized insect species to flourish and become notorious pests (Kumar, 1986). The insect pest problems of cabbage have been compounded by the cultivation of other varieties of *Brassica oleracea* such as Chinese cabbage and cauliflower on plots adjacent to cabbage farms. As a group, the varieties of *B. oleracea* tend to have a similar insect pests spectrum (Hill and Waller, 1994). This practice of cultivating related crops together, according to Way (1976), bridges gaps in the host plant sequence of insect pests resulting in upsurges in pests infestation.

Hill and Waller (1994) mentioned the cabbage aphid, *Brevicoryne brassicae* (L.) (Homoptera : Aphididae) and the leaf eating caterpillars, which include the diamondback moth, *Plutella xylostella* L, as the insect pests that cause the most damage to the *Brassica* spp. in the tropics. In Ghana, Forsyth (1966) recorded the following insects on the cabbage plant :

Allogista serricornis Klbe. (Coleoptera : Alleculidae), *Lagria villosa* F. (Coleoptera : Lagriidae), *Melanagromyza lambi* (Hend.) (Diptera : Agromyzidae), *Diacrisia investigatorum* (Karsch) (Lepidoptera : Arctiidae), *Plusia signata* (F.) (Lepidoptera : Noctuidae), *Spodoptera littoralis* (Boisd.) (Lepidoptera : Noctuidae), *Amauris psytalea* Plotz (Lepidoptera : Nymphalidae), *Appias epaphia* Cram. (Lepidoptera : Pieridae), *Crociodolomia binotalis* Zell. (Lepidoptera : Pyralidae), *Hellula undalis* (F.) (Lepidoptera : Pyralidae), *Hymenia recurvalis* (F.) (Lepidoptera : Pyralidae),

Gymnogyllus lucens (Wlk.) (Orthoptera : Gryllidae). Although, the diamondback moth was not listed by Forsyth (1966), Brempong-Yeboah (1992) considered this pest as a key pest of cabbage in Ghana.

The cabbage aphid transmit turnip mosaic virus and several other viruses specific to the Cruciferae (Hill and Waller, 1994). The leaf eating caterpillars also disfigure the cabbage plant and may completely defoliate it. Thus, these insect pests, acting in concert, can devastate many cabbage plants over a very short time if control measures are not instituted by growers.

2.3 Chemical Control and Pesticide Use in Ghana

Cabbage growers in Ghana protect their investment from the damaging activities of the insect pests by resorting to indiscriminate and multiple insecticide applications on the crop. Brempong-Yeboah (1992), observed that in 1986, cabbage growers in the Accra Plains were using unnecessarily large quantities of insecticides, in various concoctions, and spraying at 2-3 day intervals. The insecticides documented to have been used on cabbage in Ghana include Cymbush 10 EC, Cymbush 25 EC, Ripcord 10 EC, Roxion (Dimethoate), Ambush (Permethrin) (Brempong-Yeboah, 1992), Dursban (Chlorpyrifos), and Actellic (Pirimiphos-methyl) (Mawuenyegah, 1994).

The over-reliance on insecticides in the management of insect pests of cabbage has been compounded by the all year round suitable environmental conditions for pest survival, development and outbreak (Afun *et al.*, 1992), and a very large number of pesticides on the Ghanaian market. According to Bull (1982), in 1980, Ghana was the second biggest West African (excluding Mali and Guinea Bissau) importer of pesticides from the United Kingdom (one of the world's biggest exporter of pesticides). The introduction of these pesticides into the country through both the official and unofficial channels without the corresponding education in its safe use (NARP, 1993), the relaxed legal controls on pesticide import, distribution and use, low literacy rate

among farmers (Youm *et al.*, 1990), and inadequate extension service have contributed to the regular and widespread misuse of pesticides (Bull, 1982) with dire consequences (NARP, 1993). Pesticides have often been used on crops for which they are not recommended, for instance cocoa chemicals are used with impunity on vegetables and cocktail mixtures improvised by farmers have been in rampant use (NARP, 1993). According to NARP(1993), with the present escalating cost of agro-chemicals in the country, only a few farmers are able to afford the use of pesticides efficiently. Consequently most farmers use any pesticide they lay hands on, while these may either be the wrong chemical, may be wrongly applied, or the wrong equipment may be used (NARP, 1993).

2.4 Adverse Effects of Chemical Control

Carson's (1962) "Silent Spring" detailed the hazards and environmental consequences associated with the use of pesticides. There have been many researches and publications, after Silent Spring, that justify her concerns (Metcalf, 1980).

2.4.1 Effects on Biotic Systems

Insecticides often disturb the equilibrium between insect pests and their parasitoids and predators. This is because the natural enemies are often more susceptible to insecticides than the insect pests (Jackai, 1995). The resultant effect of decimating the natural enemies of an insect pest is the resurgence of that pest. For example, when the cabbage aphid, *B. brassicae* was first sprayed commercially, though the initial kill was very high, the destruction of natural enemies resulted within two weeks in the most enormous cabbage aphid outbreaks ever seen in England (Ripper, 1956).

The problem of insecticide resistance, where resistant populations of insect pest are selected through succeeding generations is also widespread in the cabbage aphid (Hill

and Waller, 1994). The control of the diamondback moth has now become very critical as this insect quickly develops resistance to every insecticide soon after the introduction of new compounds (Miyata *et al.*, 1986). Resistance of the diamondback moth, *P. xylostella*, to conventional synthetic insecticides is documented globally (Sun *et al.*, 1978; Liu *et al.*, 1981; Liu *et al.*, 1982; Miyata *et al.*, 1982; Miyata *et al.*, 1986; Chen and Sun, 1986; Tabashnik *et al.*, 1987; Magaro and Edelson, 1990; Brempong-Yeboah, 1992). The diamondback moth has also developed resistance to the benzoylphenylureas (Kohyama *et al.*, 1989; Sinchaisri *et al.*, 1989; Sun *et al.*, 1990; Fahmy *et al.*, 1991), and the biopesticide, *Bacillus thuringiensis* subsp. *kurstaki* Berliner (Tabashnik *et al.*, 1990; Syed, 1992; Shelton *et al.*, 1993; Perez and Shelton, 1997). The ability of the diamondback moth to quickly develop resistance to every insecticide used against it is costing growers of cruciferous vegetables more than \$1 billion yearly (Talekar and Shelton, 1993).

As insecticide resistance, decimation of natural enemies, and resurgence of insect pests act in concert, farmers increase the concentrations of insecticides intended for pest control. However, the insect pests become very resistant to the point that increased concentrations of pesticides are no longer effective. The observation of Brempong-Yeboah (1992) that cabbage growers in the Accra Plains were overusing insecticides against *P. xylostella* buttresses this point. The resultant effect of increased concentrations of insecticides for pest control are the problems of increased financial investment in pesticide purchase, chronic phytotoxicity (Sances *et al.*, 1981; Toscano *et al.*, 1982), soil, water and air pollution (Helweg, 1991; Jackai, 1995), and human health effects.

2.4.2 Human Health Effects

Although insecticides, according to definition, are agents for destroying insects, most of the widely used insecticides are nerve poisons and general biocides with acute toxicity on a weight basis approaching equivalence between mammals and insects (Metcalf, 1980). These insecticides are therefore not only toxic to insects but also toxic and hazardous to human (Oudejans, 1991).

2.5 Insecticide Toxicity To Humans

Insecticide toxicity to humans could either be Acute or Chronic.

2.5.1 Acute Toxicity

Acute toxicity is the immediate poisonous effect of a single dose of a toxicant (insecticide). The risk of acute poisoning is greatest for people who come into direct contact with insecticides, for instance, during pesticide application by farmers. In Africa, pesticide poisoning has become known as "The new developing world disease" (Anonymous, 1989). According to Weir and Schapiro (1981), 53,000 out of the 210,000 metric tons of pesticides produced in the United States of America (USA) are banned, heavily restricted or not registered for use in the USA. These banned or unapproved pesticides are sent to developing countries where majority of users are illiterates and do not understand the hazards of these chemicals (Atteh, 1987). So, though only 20% of the total world pesticide consumption is in developing countries, about half of the poisoning cases and nearly three-quarters of the deaths are estimated to occur in the developing countries (Oudejans, 1991). The International Organization of Consumer Unions puts the figure for 1986 at 375,000 human poisoning cases in developing countries, of which 10,000 died (Oudejans, 1991). These acute pesticide poisonings often result from the use of these toxic chemicals, inadequate knowledge on the proper handling and use of pesticides, and improper disposal of pesticide containers

which are inadvertently used to store water or food. Acute poisoning may also result from the consumption of food containing very high concentrations of pesticide residues. A case in point is the death of 5 members of a household at Kadjebi in the Volta Region of Ghana. These people died a few days after consuming okro allegedly sprayed with an insecticide, Biobit WP (Atsu, 1996).

It is however impossible to secure reliable statistics on the true extent of human morbidity and mortality resulting from the use of insecticides since poisonings are not routinely reported and seldom subjected to laboratory verification (Copplestone, 1977; Davies, 1977).

2.5.2 Chronic Toxicity

Chronic toxicity is the effect of the exposure to repeated small and non-lethal doses of a potentially harmful substance (insecticide). The risk of chronic toxicity is of much public concern with regard to pesticide residues in food.

2.6 Pesticide Residues In Foods

Pesticide residues in food are remnants of a pesticide or its toxic metabolite that can be found in/on a crop after it has been used for pest control purposes (ICAR Extension Folder 59). The repeated and indiscriminate use of pesticide in crop protection have created the problem of human health hazard due to toxic residues that persist in/on food after their application. The small concentrations of these toxic residues may have substantial biological consequence (Kumar, 1986). They may cause damage to the liver and kidneys (Jackai, 1995). They may also be neurotoxic, teratogenic, mutagenic or carcinogenic (EXTOXNET, 1993, 1995). In the USA, for instance, where so much scientific research on pesticide residues in foods and their effects have been conducted, coupled with the high public awareness of the dangers posed by pesticide residues in

food, it has been estimated that pesticide residues with carcinogenic properties may cause an extra 1.4 million cases of cancer among Americans over their life-time (Begley *et al.*, 1989).

To evaluate the chronic toxicity and hazard of pesticides to humans, an array of long term toxicity studies and hazard evaluations are carried out on other mammals. The following are certain chronic toxicity properties of some insecticides compiled by Extension Toxicology Network (EXTOXNET) (1993, 1995):

Dimethoate : - Dimethoate is possibly a human teratogen. It is also a mutagen and carcinogen. Dimethoate may also cause organ toxicity. The testicles of male rats exposed to dimethoate decreased in size. These rats also developed chronic kidney problems.

Deltamethrin : Suspected chronic exposure effects in humans include choreoathetosis, hypotension, prenatal damage and shock.

Cypermethrin : - Cypermethrin is a possible human carcinogen. Long term exposure to cypermethrin may also cause liver changes. Pathological changes in the cortex of the thymus, liver, adrenal glands, lungs, and skin were observed in rabbits repeatedly fed with cypermethrin.

Elderkin *et al.* (1995) have listed illegal pesticides in the US food supply (Table 1).

Table 1. Pesticides illegally present on fruits and vegetables in the United States of America.

No-tolerance violations		Over-tolerance violations	Action Level Violations	Cancelled Pesticide
Acephate ²	Lindane ^{1,3}	Acephate ²	Diel- drin ^{1,3,4,5} Hepta- chlor ^{1,3,5}	Captafol ^{1,5} Captan ^{1,6} Folpet ^{1,5}
Aldicarb ^{3,4}	Mecarbam ⁷	Azinphos- Methyl ⁴		
Bromopropylate ⁷	Methamidophos ⁴	Captan ^{1,5}		
Captan ^{1,5}	Methomyl ^{3,4}	Carbaryl ^{2,3}		
Carbaryl ^{2,3}	Mevinphos ^{4,5}	Chlorothalonil ¹		
Chlorfenvinphos	Monocrotophos ⁵	Chlorprpham		
Chlorothalonil ¹	Myclobutanil	Chlorpyriphos ⁸		
Chlorpyriphos ⁸	Omethoate ^{2,7}	Diazinon		
Chlorpyriphos-Methyl	Oxadiazon ¹	Dimethoate ²		
Cypermethrin ^{2,3}	Oxythioquinox	EBDCs ^{1,3,6}		
DCPA	Pentachlorobenzene	Endosulfan ^{3,4}		
DDT ^{1,3,5}	Pentachlorobenzo- nitrate	Ethion ⁶		
Dicloran	Permethrin ^{2,3}	Methamidophos ⁴		
Dicofol ^{2,3}	Phosmet ²	Methidathion ^{2,4}		
Dimethoate ²	Phosphamidon ²	Methomyl ^{3,4}		
Dioxothion	Pirimiphos-Methyl	Mevinphos ^{4,5}		
Endosulfan ^{3,4}	Procymidone ¹	Parathion ^{2,4}		
EPN ^{2,5}	Profenophos	Parathion- Methyl ^{3,4}		
Esfenvalerate ³	Propoxur ¹	Permethrin ^{2,3}		
Ethion	Prothiofos ⁷	Pronamide ¹		
Etridiazole ¹	Pyrazophos ⁷	Quintozene ²		
Fenarimol	Quintozene ²	Thiabendazole		
Fenitrothion	Thiabendazole	Tridimenol		
Fenthion	Tolyfluanid	Trifluralin ^{2,3}		
Fenvalerate ³	Trifluralin ^{2,3}			
Imazalil	Vinclozolin ³			
Iprodione ¹				

1. Probable Human Carcinogen
2. Possible Human Carcinogen
3. Reproductive Toxins and Endocrine Disruptors

4. Oral Toxicity Category 1 Pesticide. LD₅₀<50mg/kg
5. Banned in the U.S. on all food crops
6. Banned in the U.S. on some food crops
7. Not registered on any crop in the U.S.
8. Potent neurotoxin restricted to use on certain foods to protect children.

2.6.1 Pesticide Residue Analysis

The presence of pesticide residues in food is determined by subjecting food samples to pesticide residue analysis. The method of analysis may either be chemical (analytical) or biological (bioassay). The Gas Chromatograph, which may be fitted with various detectors such as electron capture detector (ECD) and flame ionization detector (FID) depending on the type of pesticide/compound being analyzed, is often used as the analytical method of residue analysis (GTZ, 1979). The multiple residue method (MRM), selective MRM, and single residue method (SRM), are different forms of analytical method (FDA, 1994) that could be used for pesticide residue analysis. Multiple residue method is often used to simultaneously determine a number of residues of different pesticides. Single residue method on the other hand determines one pesticide, while selective MRM determines relatively small number of chemically related pesticides. These types of analytical methods though can detect many metabolites, impurities and alteration products of pesticides, are usually resource intensive per analysis.

Bioassay is however inexpensive and yet sensitive, though it has the limitation of not being able to distinguish metabolites, impurities and alteration products of pesticides from the parent pesticidal compound. Bioassay has been used often in the determination of pesticide residues (Michael *et al.*, 1956; Tarpley, 1958; Grosch, 1967; Ramasubbaiah and Rattan Lal, 1978; Sarode and Rattan Lal, 1981). Studies have also shown that there is a good agreement between insecticide residues obtained using

bioassay and chemical methods. Ramasubbaiah and Rattan Lal (1978) have indicated the existence of a high degree of coefficient of correlation between bioassay and the calorimetric chemical assay. The principal method used by Sarode and Rattan Lal (1981) to determine the persistence of Lindane on cauliflower was also bioassay. Their results were checked by gas-liquid chromatography (Tracer, MT 220 equipped with column of borosilicate glass 1800 X 6.25mm i.d. tube packed with 3% OV-17 liquid stationary phase on 80-100 mesh chromosorb-w; with 63 in electron capture detector). They found that recoveries of Lindane determined on fortified plant samples were 85% for bioassay and 86% for gas-liquid chromatography.

Among the various test organisms available for the determination of pesticide residues in food is the Brine Shrimp, *Artemia salina* Leach. The use of brine shrimp is rapid, inexpensive, and convenient (McLaughlin, 1991). These organisms have been previously utilized in the analysis of pesticide residues by Michael *et al.* (1956), Tarpley (1958), and Grosch (1967). McLaughlin (1991) pointed out that the brine shrimp lethality test is a general bioassay which detects a broad range of biological activities and a diversity of chemical structures. The basic premise here, according to McLaughlin (1991), is that toxicology is simply pharmacology at a higher dose (or conversely, pharmacology is simply toxicology at a lower dose). Therefore, toxic compounds at a lower non-toxic dose might elicit a useful pharmacologic perturbation on a physiological system (McLaughlin, 1991).

2.6.2 Pesticide Residue Legislations

Consumer awareness and concern about the perceived risks that potential residues of pesticides may pose to human health is challenging the agro-industry worldwide, especially the fruits and vegetables industry, to minimize pesticide residues in food. The Food and Agriculture Organization (FAO) and World Health Organization (WHO) of the United Nations (UN), have therefore since 1961 been setting maximum

residue limits (MRL) for pesticides in foods. These organizations have also been seriously concerned about the acceptable daily intake (ADI) values which takes into consideration especially the eating habits of consumers (GTZ, 1979). In most developed and industrialized countries, and some developing countries, strict legal controls have been enacted which lay down reasonable safe levels of pesticide residues in food. For instance, in 1979 the pesticide residues legislation of the then Federal Republic of Germany covered more than 200 different ingredients (GTZ, 1979). In Denmark, the Danish National Food Institute also continuously controls the pesticide residues in Danish food (Helweg, 1991). Various kinds of food are sampled in the market and pesticide residue analysis is carried out, to ensure that the MRL set by Danish Laws is not exceeded. The Indian Institute of Horticultural Research, also publishes recommended pesticides, concentrations, terminal residues, and waiting periods for specific crops (ICAR Extension Folders : 58 and 59). In the USA, which was the first country to enact pesticide residue laws (GTZ, 1979), ensuring the safety of food supply by regulating pesticide residues is the cooperative effort of the United States Environmental Protection Agency (EPA) and the Food and Drug Administration (FDA) (Gal and Mathews, 1992).

Legal regulations governing pesticide use in food in the USA include:

1. 1938 - Federal Food, Drug, and Cosmetic Act (FFDCA)
2. 1947 - Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
3. 1954 - Pesticide Chemical Amendment
4. 1958 - Food Additives Amendment
5. 1972 - Amendment to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).

It is worth noting that the national tolerances set by the legislations of most developed countries are generally lower than the FAO/WHO MRL and ADI (Taksdal, 1973).

The main purpose of the pesticide residue legislations is to prevent damage to human health and environmental quality.

The MRL and ADI set by the FAO/WHO and the specific pesticide residue legislation of any individual country are based on Good Agricultural Practice (GAP). According to Oudejans (1991), GAP in the use of pesticides is the officially recommended or authorized usage of pesticides under practical conditions at any stage of production, storage, transportation, distribution, and processing of food, agricultural commodities and animal feed bearing in mind the variations in requirements within and between regions, which takes into account the minimum quantities necessary to achieve adequate control, applied in such a manner as to leave residue which is the smallest amount practicable and which is toxicologically acceptable. In this definition, the "officially recommended usage of pesticides" is that which complies with the procedures, including formulation, dosage rates, frequency of application and pre-harvest intervals (PHI), approved by the national authorities (Oudejans, 1991).

Oudejans (1991) notes that, GAP in the use of pesticides with the aim of maximizing noxious effects on humans, animals and the environment includes :

1. Choosing the least toxic and least persistent pesticide that will effectively control pests in the field and in storage. As a general rule, persistent and/or cumulative pesticides should not be used on fodder crops.
2. Similarly, choosing a formulation which combines maximum efficiency of the selected pesticide with minimum risk.
3. Applying on the target area only the minimum amount of pesticide required while determining the number of treatments on a need basis in relation to actual pest infestation.

4. Selecting the method of application which offers optimum control with minimum contamination of crops and the environment.
5. Timing of the treatment in relation to vulnerable stages of a pest's development.
6. The interval between last application and harvest should be as long as possible in order to permit the greatest reduction in pesticide residues, bearing in mind the pest incidence, the degree of control required for maximum utilization of the commodity, and the vulnerability of the treated crop immediately prior to harvest. To this end, official PHIs should be established and adhered to.
7. Crop rotation should be adjusted in such a manner that residues in the edible parts of crops, as a result of previous treatments (carry-over effect), will be minimal.

2.6.3 Violations of Pesticide Residue Legislation

Minimizing pesticide residues in food has become very crucial, even in countries that have legislations which set MRLs and ADIs for pesticide residues in food. This is because of the frequent cases of pesticide residues violations. The following are some cases of violations in the United States of America, and India, outlined by Elderkin *et al.* (1995), and ICAR extension folders 58 and 59, respectively.

Elderkin *et al.* (1995), outlined in the publication “Forbidden Fruit”, in respect of fruit and vegetable supply in the USA, as follows :

“Most people believe that the produce they buy meet pesticide safety standards. But fruits and vegetables with illegal pesticides end up on grocery shelves, in kitchens, and in lunchboxes throughout the country every day. Over 90% of the types of violations reported in “Forbidden Fruit” are of two kinds: no-tolerance violations - where the pesticide is found on a crop even though the allowable level for the pesticide on that crop is zero; and over-tolerance violations - where the amount of the pesticide found

exceeds the legal limit (or tolerance) for that crop (Table 1). Some major fruits and vegetables have very high rates of illegal pesticides.”

It was further indicated that, “During 1992 and 1993, one-quarter of all green peas contained illegal pesticides, as did 15.7% of pears, 12.5% of apple juice, 11.7% of green onions, 7.6% of green beans, and 7.4% of all strawberries. From one-third to one-half of all the pesticide residues detected on some crops were illegal. These included 51.7% of the detected residues on apple juice, 50.6% on green peas, 28.4% on pineapples, 26.4% on pears and 22.6% on carrots. There were at least 66 different illegal pesticides (Table 1) on the forty-two fruits and vegetables analyzed. Seventeen different illegal pesticides were found on green peas, 14 on squash, 12 on strawberries, 11 on carrots and pears, and 10 on cantaloupes and bell peppers.”

In the ICAR Extension Folder: 58 and 59, the following were outlined in respect of vegetable and fruit supply in India :

“The periodic monitoring of the market basket samples of various vegetables carried out across the country showed that 40% to 60% samples were contaminated with pesticide residues. In many cases, the extent of residues are above MRLs. Further, it is alarming that most of the contaminated samples were found to be loaded with hard to degrade and highly toxic pesticides like DDT and BHC. There were, however, variations in the level of contamination in different vegetables viz. 48.1% cabbage; 51.1% tomato; 74% chilli; 45.6% potato; 51.7% brinjal; 61.8% cauliflower; 58% okra; 78.1% bean; 33.3% onion; 93.3% gourds; and 96.4% leafy vegetable samples were found contaminated across the country.”

“The contamination of fruits with pesticide residues in India, also, works out to an average of 59.4% samples, ranging between 23.5% to 100% samples of different fruits.

The variation in the contamination of the fruits are as follows; 41.8% mango; 57.3% grape; 47.6% guava; 87.6% banana; 90.9% sweet lemon; 23.5% sapota; 100% plum, and 87.6% apple samples were found contaminated across the country.”

It is evident from the above, the extent of pesticide residue violation even in countries with residue legislations. This reaffirms the need to minimize pesticide residues in agricultural produce, especially vegetables. To minimize the pesticide residues in vegetables, pest control must balance economic pesticide management (Sances *et al.*, 1993), considering the requirement for multiple insecticide application in vegetable production. This level of decision making certainly requires greater information not only from the field with respect to pest density, location, and potential to increase (Sances *et al.*, 1993), but also on insecticide use patterns (FAO/WHO, 1974), and chemical behavior of insecticides once they are applied in the environment (Sances *et al.*, 1993). Other variables such as surfactant, formulation type, micro and macro environmental factors, and individual chemical properties of the pesticide in question, may also have profound effect on degradation and hence the amount of residues in the market place (Sances *et al.*, 1993).

3. MATERIALS AND METHODS

This research was conducted from October 1996 to May 1997. The survey area was the Accra-Tema Metropolitan Area of Ghana. Insecticide residue level estimation was done in the research laboratory of the Biochemistry Department, University of Ghana, Legon, Ghana.

3.1 Survey

The survey to determine farmers' insecticide use patterns on cabbage was conducted from October 1996 to March 1997.

3.1.1 Informal Survey

An informal (reconnaissance) survey (Rhoades, 1995), was done prior to the formal survey. The objective of this reconnaissance survey was to obtain basic information to guide in the planning and conduct of the formal survey, and the subsequent residue level estimation. The subject areas covered in this preliminary investigation were as follows:

- Location of cabbage farms
- Varieties of cabbage grown, and agronomic practices
- Due date for the harvest of cabbage
- Insecticides being used
- Insect pests of cabbage

Location of cabbage farms :

In the absence of a properly organized cabbage growers association, which could provide information on the location of cabbage farms, locating many cabbage farms to enable a sample size of 50 to be chosen was critical. To overcome this problem,

growers in the perennial cabbage growing areas of Accra were approached for information on where to find more growers. Additionally, grocers and friends were also approached for further information on the possible areas to locate cabbage farms.

Varieties of cabbage grown and agronomic practices :

This information was necessary to guide in the cultivation of insecticide free cabbage for the insecticide residue level estimation.

Due date for the harvest of cabbage :

The single-visit formal survey was selected over the multiple-visit formal survey (Horton, 1995), mainly because of lack of enough logistics. The questionnaires for the formal survey were therefore to be administered when cabbages were ready to be harvested for the market. It was expected that all production practices, especially insecticide application, would have been completed at this time. Appointment was booked with the farmers to ensure that they would be ready for the interview at the time of cabbage harvest.

Insecticides being used :

It was necessary to obtain this information to give an insight into the kinds of insecticides being used. This is because cabbage samples for residue level estimation was to be picked from farms that sprayed the predominant insecticide in use.

Insect pests of cabbage :

The relevance of this information was to provide guidance in the collection of the pests of cabbage so that the pests collected could be used as specimen during the formal survey.

3.1.2 Formal Survey

Formal survey based on a written questionnaire was conducted, after the informal survey, to obtain "hard" data needed for quantification (Horton, 1995). The questionnaire was pre-tested and modified to suit farmers understanding. The final questionnaire used is reproduced in Appendix C.

Important data that was needed included :

1. Level of education of farmers.
2. Number of years that the farmer has been in cabbage production.
3. Cropping systems being used.
4. Insecticides being used in cabbage production and their formulations.
5. Concentration of insecticides used.
6. Methods of insecticide application.
7. Pre-harvest intervals observed.
8. Knowledge of insecticide residues.
9. Keeping of records on insecticide use.



Choice of Respondents :

The choice of farmers from a particular cabbage growing area depended on :

1. the number of growing areas identified from the informal survey, and
2. the number of growers in a particular growing area.

In each growing area identified, 12 in the Accra Metropolis and 2 in the Tema Metropolis, a randomly representative number of growers were selected and spoken to (Table 2).

The results of the survey were analyzed by calculating percentages of respondents who gave specific answers to each question. Percentages of respondents of specific answers to each question were compared and discussed.

Table 2. Number of respondents interviewed in each growing area.

□

GROWING AREA	NUMBER OF RESPONDENTS
Christian Village - Accra	2
East Legon - Accra	3
IPS - Accra	1
Haatso - Accra	5
Dzorwulo - Accra	9
North Alajo - Accra	2
Plant Pool - Accra	1
Ablemkpe - Accra	1
Ring Road Central - Accra	1
North Legon - Accra	6
Redco - Accra	5
Tuba - Accra	4
Community 2 - Tema	6
Community 6 - Tema	4

3.2 Insect Pests of Cabbage

Larvae seen to be causing damage to cabbage plants were collected. These were taken to the laboratory and fed on cabbage leaves from insecticide-free cabbage plots to maturity. The insects were then identified using the adult, pupae, larvae, and the damage caused by a particular insect pest. Samples of aphids were also collected from cabbage plants for identification.

3.3 Cabbage Samples

Decision with regard to which farm to collect cabbage samples from, for the insecticide residue analysis was taken, considering the following points :

1. The predominant conventional synthetic chemical insecticide in use.
2. The farmers using the apparent highest and the lowest concentration of the predominant synthetic chemical insecticide.
3. Insecticide with its labeling in French, suspected to have been smuggled into the country.

Based on the results of the informal survey, which was later confirmed by the formal survey, KARATE 2.5 EC was noted to be the most widely used conventional synthetic chemical insecticide. DELTAPHOS 262 EC, which was one of the commonly used insecticide with its labeling in French and suspected to have been smuggled into the country, was also selected. Two cabbage farms which had been sprayed the apparent highest and lowest concentrations of Karate 2.5 EC, and one farm which had been sprayed Deltaphos 262 EC were, therefore randomly selected and cabbages sampled from then.

3.3.1 Sampling for Cabbage

After the farms to be sampled from were identified, sampling for cabbage was done only when the owner of a particular cabbage farm had started harvesting and selling his produce. This precaution was necessary, to ensure that cabbages that were sampled for insecticide residue level estimation were actually ready for consumption.

To ensure that the selection of a particular head of cabbage was purely due to chance, the steps below were followed:

1. The field under cultivation was mapped out on a piece of paper.
2. Numbers were given to rows of plants, and plants in each row. These numbers were written out on pieces of paper, for balloting.
3. The numbers for the rows were first balloted for, followed by the numbers for the plants in each row.

The cabbage plants selected, following the above procedure, were then harvested. In view of inadequate funds, only 3 cabbage farms, as stated above, were selected for sampling (2 farms on which KARATE 2.5 EC were sprayed, and 1 farm on which DELTAPHOS 262 EC was sprayed). For the same reason of lack of funds, only 2 cabbage plants were sampled from each of the 3 farms for insecticide residue analysis. The 2 heads from each farm were cut at the root-stem junction, to include outer wrapper, inner wrapper, and core leaves. They were brushed to remove soil particles and labelled. The heads were then placed in polythene bags and stored in the cold at minus 10°C, and later processed for insecticide residue level estimation.

3.4 Cultivation of Insecticide Free Cabbage

A plot at Oko, a suburb of Accra, was selected in November for the cultivation of insecticide-free cabbages. This plot has neither been cultivated to any crop, nor sprayed with an insecticide for, at least, the last seven years. Seeds of Oxylus, the

predominantly grown cultivar of cabbage identified through the informal survey, were obtained from Aglow Agricultural Services. The seeds were sown thinly in a nursery bed and shaded immediately after sowing. The shade was removed after the emergence of the seedlings. Four weeks after emergence, the seedlings were transplanted onto the field, measuring 4.2m X 2.4m.

A total number of 18 plants, 1 plant/hill, were transplanted onto the plot, using three rows at the spacing of 60 cm X 60 cm. Fertilizer requirements recommended by Sinnadurai (1992) for late cultivar cabbages were used. Watering, weeding, and stirring of soil was done as and when necessary. Insect pests that infested the cabbage plants were hand-picked and crushed. The cabbage was ready for harvesting 60 days after transplanting. Two heads of cabbage from, the middle plants, were harvested at the root-stem junction, and brushed to remove soil particles. The heads of cabbage were then put in a polythene bag and stored at minus 10°C, and processed for residue level estimation later on.

3.5 Residue Level Estimation

The Brine Shrimp, *Artemia salina* Leach, was used as the test organism in the bioassay to estimate levels of the insecticide residues on cabbage.

3.5.1 Extraction and Concentration of Insecticide Residues.

Each cabbage head was separated into outer wrapper leaves, inner wrapper leaves, and core leaves (Appendix C). Fifty grams of the subsample of each of the outer wrapper, inner wrapper, and core leaves was weighed into beakers, using the SARTORIUS 1518 balance, and labelled. A solvent system containing 40 ml Hexane, 40 ml Petroleum ether, and 20 ml Butanone (ethyl-methyl ketone) was made and used for extraction.

For the extraction, the 50 gram subsample was cut up and put into a WARING Products Commercial Blender HGB 200 model 34BL65. Eighty milliliter (80 ml) aliquots of the solvent was then added and homogenized at a minute interval for 4 minutes. The extract (supernatant) was then decanted into a 250 ml conical flask. Another 80 ml aliquots of the solvent was added to the homogenate (homogenized subsample) in the blender, and again blended at a minute interval for four minutes. The extract was also decanted into another 250 ml conical flask. The process of blending the homogenate in another 80 ml aliquots of solvent system at a minute interval for 4 minutes, was repeated for the third time. The three extracts above were then pooled together. The homogenate was then centrifuged in a DENLEY BR401 Refrigerated Centrifuge at 3000 revolutions per minute for 5 minutes at 20°C. The resultant supernatant was added to the three extracts that have been pooled together, and then concentrated.

The Rotary Vacuum Evaporator (RVE) Osk 6989(N-I) was used for concentrating the extract. The Eyela Uni Cool Bath NCB-120 was turned on and set at -10°C for about an hour before the RVE was used. This was to ensure efficient condensation of evaporated solvents. The extract was decanted into a 100 ml Eyela Rotary Vacuum Flask after the flask had been rinsed with a portion of the solvent. The flask containing the extract was then fitted to the RVE, and sat in an Eyela water bath SB-35 at 38°C. The speedivac high vacuum pump ES 200 was used to create pressure in the system and the rotary control on the evaporator was set at 2 revolutions per minute. The extract was then concentrated to about 2 ml and then transferred into a 10 ml vial with a pipette. The rotary vacuum flask was then rinsed twice, each time with 2 ml of the solvent, and added to the concentrated extract in the vial. The processes of extraction and concentration were repeated for each 50g subsample of the outer wrapper, inner wrapper, and core leaves for each cabbage sample. Each of the concentrated

subsamples was then dried under nitrogen gas, redissolved in 5 ml hexane, and stored for bioassay.

3.5.2 Bioassay

The procedure outlined by Meyer *et al.*(1982) was adopted, and modified where necessary.

Hatching Of Brine Shrimp Eggs

Sea water collected from the Mighty Beach at Sakumono was filtered and put in a hatching tank, three-quarters of which was covered (Plate 1). Eggs of the shrimp were added to the covered side of the divided tank. The set up was then placed under light to attract hatched shrimps to the uncovered side of the tank. Two days (48 hours) was allowed for the eggs to hatch and mature, before nauplii were used for bioassay.

Plate 1. Hatching tank for brine shrimp.



Bioassay For Standard Dosage-Mortality Curves :

It was necessary to obtain standard dosage-mortality curves for the insecticides, KARATE 2.5 EC and DELTAPHOS 262 EC, so that the concentrations of insecticides in the cabbages could be estimated from these curves. To do this a series of preliminary bioassay were done to determine the concentrations that give about 90% and 10% mortalities. Based on this preliminary bioassay, 5 ml volume each of 100 $\mu\text{g}/\mu\text{l}$, 10 $\mu\text{g}/\mu\text{l}$, 1 $\mu\text{g}/\mu\text{l}$ and 0.1 $\mu\text{g}/\mu\text{l}$ of both KARATE 2.5 EC and DELTAPHOS 262 EC in hexane, was prepared as stock solutions. A volume of 1 μl each of the stock KARATE 2.5 EC solutions was pipetted into a 10 ml vial. For the DELTAPHOS 262 EC a volume of 25 μl each of the stock solutions was also pipetted into a 10 ml vial. The insecticide solutions in the vials were then dried under nitrogen gas. Two milliliters of sea water was added to each vial and shaken to dissolve the residues of insecticides. Ten shrimps were added to each vial and made up to 5 ml with sea water. Ten shrimps were put in a vial containing 2 ml of sea water, but without any insecticide and this was also made up to the 5 ml mark with sea water to serve as the control. Each of the treatments and control were replicated six times, that is 60 shrimps per insecticide concentration and the control.

The set-up was placed under light, and the number of shrimps that survived after 24 hours of exposure to the insecticides and sea water were counted and recorded for each insecticide dilution and the control. The data obtained was analyzed using probit analysis (Finney, 1971). The $\text{LC}_{50}(24 \text{ hrs})$ for the 48 hour old brine shrimps, and the linear regression equations and curves were obtained for both insecticides.

Bioassay For Cabbage Extracts :

A preliminary bioassay was conducted on the cabbage extracts to determine the volumes of extracts that gave about 90% and 10% mortalities. Based on the results of

this preliminary bioassay, 5 µl each of the subsamples of cabbage extracts was pipetted into 10 ml vials. The extracts were dried under nitrogen gas. Two milliliters of sea water was then added to the dried extracts and shaken to dissolve the extracts. Ten shrimps were added to each vial, and made up to 5 ml with sea water. A set of 10 shrimps was also put into a vial which contained no extract, and made up to 5 ml with sea water, to serve as the control. Each of these treatments and the control were replicated 4 times. The set up was placed under light, and observed 24 hours after the exposure of the shrimps to the extracts and control. Survivors were counted and the shrimps killed were recorded for each extract of subsample and the control.

The Abbott's formula (Abbott, 1925) was used to correct for deaths in control samples:

$$AM = \frac{\%T - \%C}{100 - \%C} \times 100$$

Where, AM= Adjusted mortality,

%T= Percent test effect mortality and

%C= Percent control mortality.



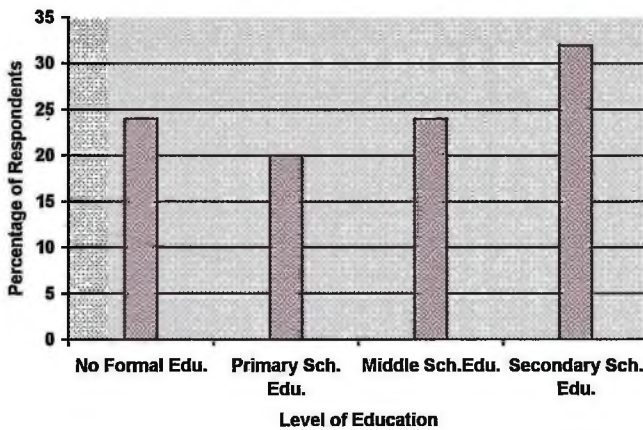
The corrected percentage mortalities were calculated from the mortalities obtained for each treatment. This corrected percentage mortalities were then used to estimate the concentration of insecticide residues in cabbage, from the linear regression equations of dosage-mortality curves of the standard insecticides.

4. RESULTS AND DISCUSSION

4.1 Survey

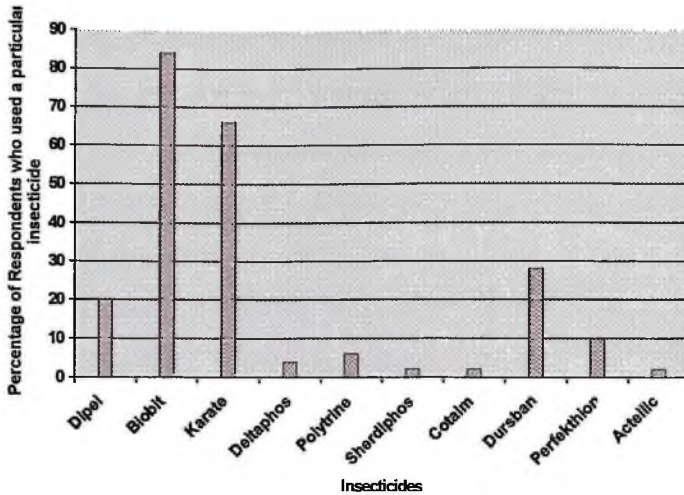
The survey covered a sample size of 50 cabbage growers and their farms in the cabbage growing areas of the Accra-Tema metropolitan area of Ghana. The survey revealed that cabbage growers in the Accra-Tema metropolitan area are mostly male and form 98% of the 50 respondents, with ages from 21 to above 50 years. Regarding the level of education of the respondents, 32% of the respondents had secondary education, 24% had middle school education, 20% had primary school education, and with the remaining 24% having no formal education (fig 1).

Fig. 1. The Level of Education of Respondents.



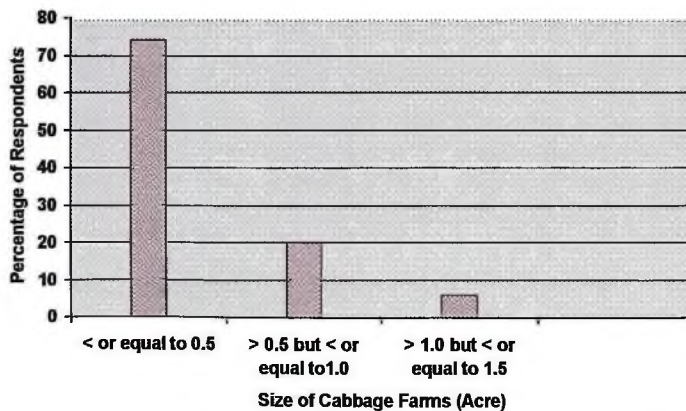
Forty-six percent (46%) of the growers have been in cabbage production for less than 4 years, with 22% and 32% of the remaining respondents in cabbage production for 4-9 years and greater than 9 years respectively (fig 2).

Fig. 2. The Number of Years that Respondents have been in Cabbage Production.



It was also noted that most (74% of the respondents) cabbage growers in the survey area cropped cabbage on small pieces of land, about 0.5 acre of land (fig 3).

Fig. 3. The Sizes of Land Cropped to Cabbage by the Respondents.



Of the remaining 26% respondents, 20% cropped cabbage to between 0.5-1.0 acre of land, while only 6% cropped 1.0-1.5 acres. The survey revealed that 58% of the

cabbage growers who were interviewed relied on drainage water for their water supply, as against 16% who used stream, 10% who relied on dam, and 16% of growers who relied on tap water. The use of drainage water in cabbage production has over the years caused much public concern among cabbage consumers. This is because of the fear that the untreated drainage water, which are likely to contain disease pathogens and other contaminants, may cause diseases in consumers after the consumption of the vegetable. Consumers believed that growers would desist from the use of such water after the outcry, but this has not been the case. The reason for the continuous use of drainage water, given by cabbage growers, was that much as they share the concern of some consumers over the use of drainage water, they had no access to a dam, well or a stream. Neither could they afford the cost of tap water.

Eighty-six percent of growers interviewed cultivated the cabbage cultivar, Oxylyus. This is because of the relatively longer shelf life and small heads of Oxylyus. These attributes, according to the growers, lead to good market. The rest of the growers preferred to cultivate both KK cross and Oxylyus cultivars.

Rot was apparently the only disease encountered on cabbage plots. However, this was not regarded as a problem by the farmers because out of 39 respondents who encountered the disease on their plots, only 4 resorted to chemical control, 3 regulated water supply while the remaining 32 respondents made no attempt to manage the disease. Chemicals that the 4 farmers who controlled the disease used are KOCIDE, CHAMPION, BAVISTIN, TOPSON, RAMO, and DIETIN.

The growers regarded insect pests of cabbage as the major constraining factor to cabbage production. This is because of the extensive damage caused by insect pests to their crop, and the huge financial investment they make towards their control.



Sometimes, no returns are made on their investment towards insect pest control, as the insects would have completely devastated their crop before pest control action is instituted.

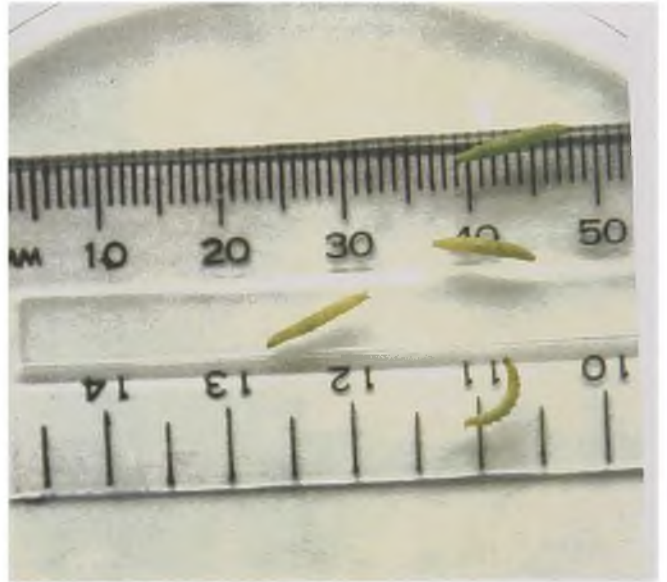
The insects that farmers implicated in the destruction of their crop were the larvae of *Plutella xylostella* (Plate 2), *Spodoptera littoralis* (Plate 3), *Spodoptera* sp. (Plate 4), and an unidentified lepidopterous insect (Plate 5). The other insects implicated were *Brevicoryne brassicae* (Plate 6) and *Zonocerus variegatus* (Plate 7). Although all of the respondents had their crop infested with *P. xylostella*, only 78% had their crop infested with *B. brassicae*. Seventy-two percent of the respondents' crops were attacked by at least one of the following insects; *S. littoralis*, *Spodoptera* sp. and the unidentified lepidoptera while sixteen percent of respondents' cabbage plants were attacked by *Z. variegatus*.

Although Forsyth (1966) did not mention *P. xylostella* as a pest of cabbage in Ghana, Brempong-Yeboah (1992) observed that this insect was a serious pest of cabbage in the Accra Plains of Ghana. The growers who were interviewed also confirmed the key pest status of the diamondback moth, *P. xylostella*. They conceded that the diamondback moth could be so damaging to the point that it completely destroys their crop, and that they consider this insect as the key pest of cabbage in Ghana. *Plutella xylostella* has also been mentioned as a key pest of cabbage, and other crucifers, in many other parts of the world (Miyata *et al.*, 1986; Cartwright *et al.*, 1987; Hill and Waller, 1994). The damaging stage of *P. xylostella* is the larvae. The larvae damage cabbage plants by feeding on the underside of the leaves, making holes right through them (Plate 2).

Plate 2. The Larval, Pupal and Adult Stages of *P. xylostella*, and damage done to Cabbage.



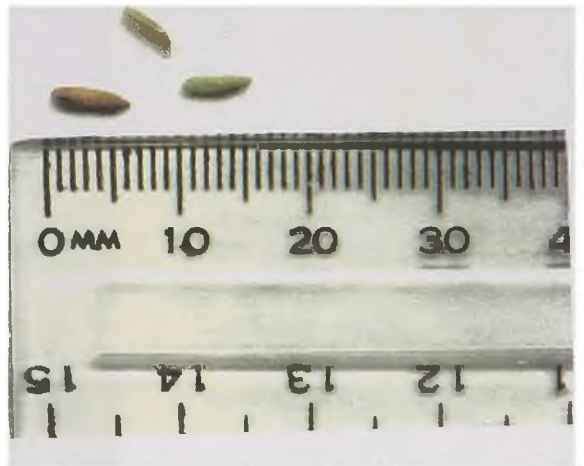
2A. Damage done to Cabbage leaves by larvae of *P. xylostella*



2B. Larvae of *P. xylostella*



2D. Adult of *P. xylostella*



2C. Pupae of *P. xylostella*

Plate 3. The Pupal and Adult Stages of *Spodoptera littoralis*, and damage done to Cabbage.



3A. Damage done to Cabbage leaves by larvae of *S. littoralis*



3B. Pupae of *S. littoralis*



3C. Adult of *S. littoralis*

Plate 4. Adult of *Spodoptera* sp.



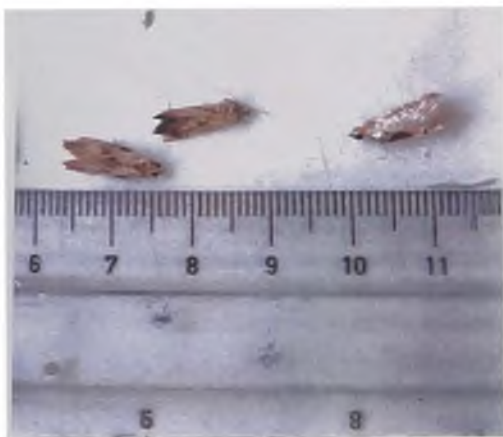
Plate 5. The Larval, Pupal and Adult Stages of the unidentified lepidopterous pest, and damage done to Cabbage.



5A. Damage done to Cabbage leaves by the larvae of unidentified lepidoptera.



5B. Larvae of unidentified lepidoptera



5D. Adult of unidentified lepidoptera



5C. Pupae of unidentified lepidoptera

Plate 6. *Brevicoryne brassicae* - infested Cabbage leaves.

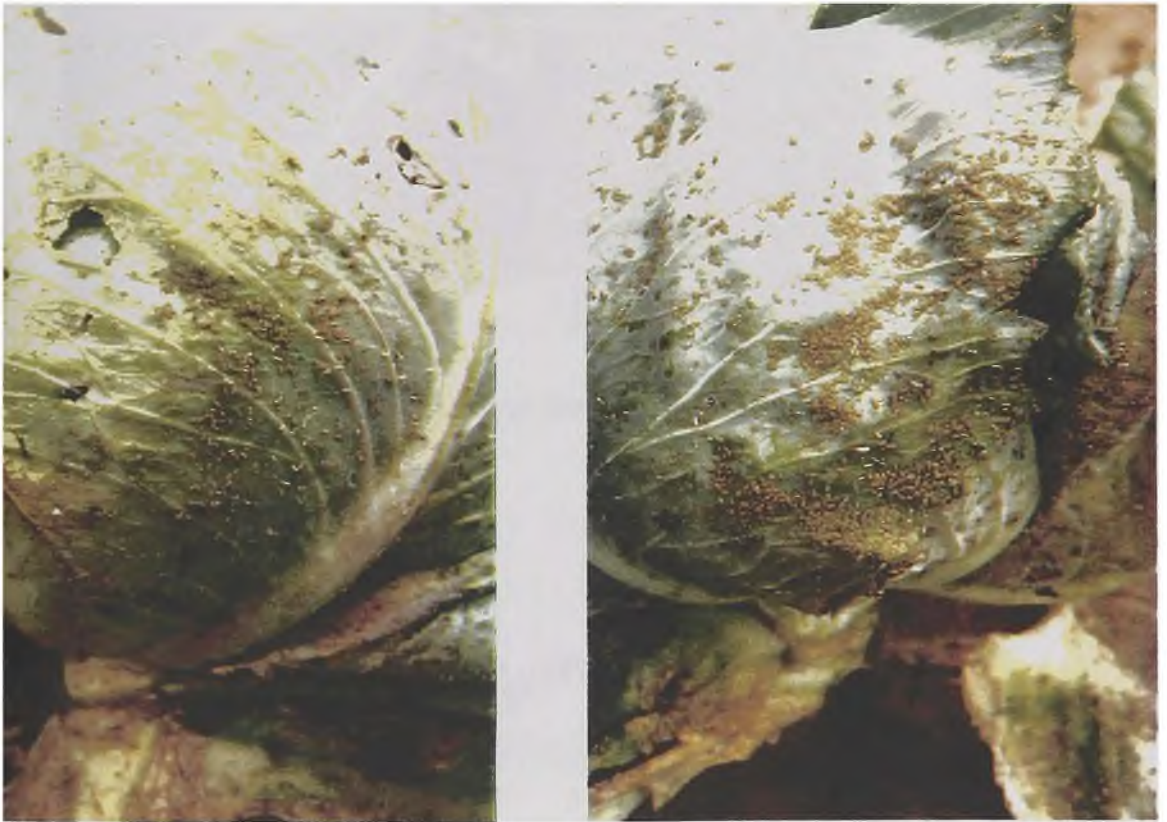
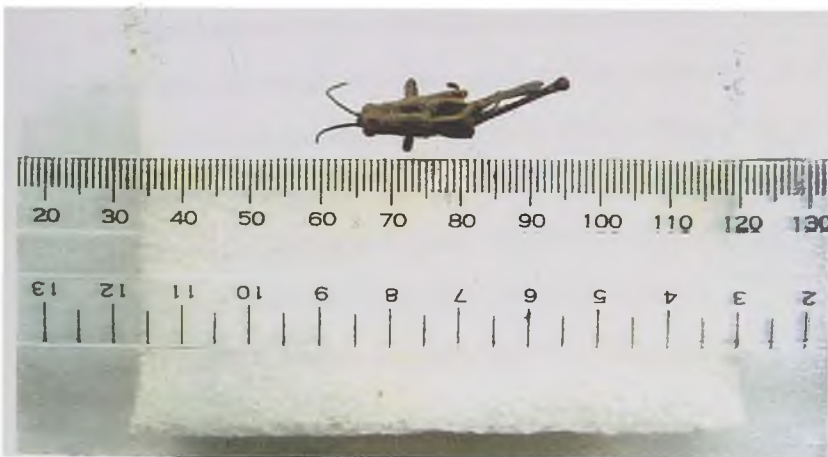


Plate 7. Nymph of *Zonocerus variegatus* and damage done to Cabbage.



7A. Damage done to Cabbage leaves by *Zonocerus variegatus*



7B. Nymph of *Zonocerus variegatus*

The damage caused by *B. brassicae* was not quite evident on the farms that were visited, despite the presence of the aphids on the cabbage plants (Plate 6). The cabbage growers, however, pointed out that they considered the pest status of aphids as being next to that of the diamondback moth. The growers also described stunted plant growth and isolated wilting of their cabbage plants, which they attributed to the aphids. These aphids have been implicated as vector of 23 viral diseases in the Crucifers (Hill and Waller, 1994).

The larvae of *S. littoralis*, *Spodoptera* sp. and the unidentified lepidoptera which are voracious leaf feeders, also caused extensive damage to cabbage leaves. *Zonocerus variegatus*, a sporadically severe pest of many crops (Hill and Waller, 1994), chewed cabbage leaves, leaving characteristic ragged edges or completely defoliated plants (Plate 7).

The increasing incidence of pest infestation on cabbage by the lepidopterous insect and aphids could be attributed to monocropping which is practised by cabbage growers. This practice as Kumar (1986) pointed out has often created conditions favourable for specialized insects to flourish and become notorious pests. Increase in the incidence of insect pest infestation on cabbage could also be attributed to the cropping patterns of farmers in all the growing areas that were visited. It was observed that growers chose to cultivate cabbage at different times of the year. It was therefore common to find cabbage on the field all year round. This practice obviously makes host plants available to insect pests all year round. The growers also pointed out that *P. xylostella* did not only devastate cabbage but also caused damage to their cauliflower and Chinese cabbage.

As cabbage, cauliflower, and Chinese cabbage, are Brassicas, they have similar pest spectrum (Hill and Waller, 1994). Additionally, *P. xylostella* has in particular, been

noted by Miyata *et al.*, (1986) as an important cosmopolitan and notorious pest of Cruciferous plants. Therefore, the all year round cultivation of this variety of cabbage, Chinese cabbage and cauliflower on pieces of land adjacent to plots of cabbage has bridged the gap in the host plant sequence of *P. xylostella* resulting in upsurges in *P. xylostella* infestation, which confirms the observation made by Way (1976).

The improper handling of cabbage residues after harvesting, where growers either leave these residues on the farm or gather and throw them away into nearby bushes is also unacceptable. This is because this practice makes food available for pest to survive, develop and multiply, just as Chinese cabbage, cauliflower and cabbage on the field do.

The inability of growers in a particular growing area to synchronize when to institute crop protection methods, especially insecticide spraying schedules, results in unsprayed cabbage plants serving as refuge at a time when other growers would have sprayed their crop.

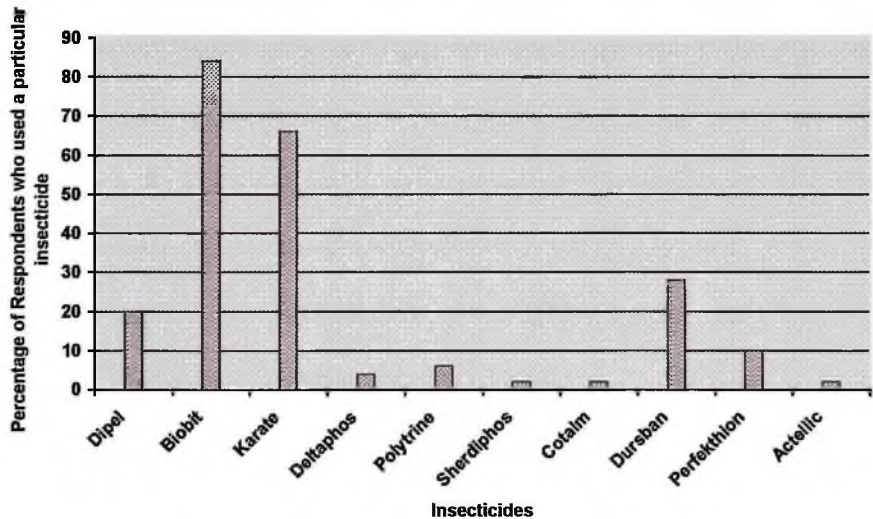
The above practices, acting in concert, create conditions conducive for pest survival, development, and multiplication, which lead to an increase in the incidence of pest infestation and damage.

To protect their investment and crop, all cabbage growers (100% of respondents) resort to the use of insecticides to control the devastating activities of the insect pests of cabbage. The growers relied exclusively on the use of insecticides because they believe that these chemicals are fast acting and so give results shortly after their application. The trade names of insecticides that were used by cabbage growers interviewed were (active ingredient/proprietary names in parenthesis):

1. BIOBIT WP (*Bacillus thuringiensis* subsp. *kurstaki*)
2. DIPEL 2X WP (*Bacillus thuringiensis* subsp. *kurstaki*)
3. KARATE 2.5 EC (Lambdacyhalothrin)
4. DELTAPHOS 262 EC (Deltamethrin + Triazophos)
5. POLYTRINE C 336 EC (Cypermethrin + Profenofos)
6. COTALM. P. 18/150 EC (Lambdacyhalothrin + Profenofos)
7. SHERDIPHOS 420 EC (Cypermethrin + Triazophos + Dimethoate)
8. DURSBAN 48 EC (Chlorpyrifos)
9. PERFEKTHION 40 EC (Dimethoate)
10. ACTELIC 25 EC (Pirimiphos-methyl)

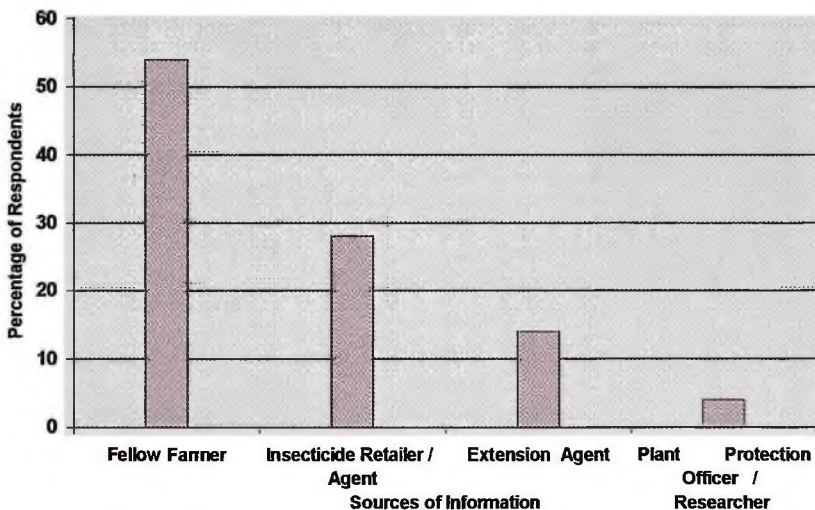
It was observed that growers in the survey area mostly used Biobit (*Bacillus thuringiensis* subsp. *kurstaki*) (84% of respondents) and Karate 2.5 EC (Lambdacyhalothrin) (66% of respondents) (fig 4).

Fig. 4. The different Types of Insecticides used by Respondents against the Insect Pests of Cabbage.



The survey also revealed that farmers were not adequately informed with regard to the choice and use of insecticides for the control of insect pest of cabbage. To be adequately informed with regard to the management of insecticides results in the reaping of the optimum benefits from chemical crop protection without compromising environmental quality and human health. When growers were asked whether they received professional advice on the handling of insecticides, 44 of the 50 respondents said they did not. Out of the remaining 6 respondents who said they received professional advice, 3 growers received advice from chemical agents and the other 3 from extension officers. They (the six who received the advice), however, lamented that such advice was given occasionally. Therefore when confronted with serious incidence of insect pests infestation and damage on cabbage, cabbage growers rely on fellow farmers and insecticide retailers/agents for advice on the choice and use of insecticides (fig. 5).

Fig. 5. The Sources of Information available to Respondents with regard to the Choice and Use of Insecticides.



Reliance of cabbage growers on agents/retailers of insecticides, who are always competing among themselves to sell their products, resulted in the use of highly concentrated insecticide formulations on cabbage.

These insecticides: DELTAPHOS 262 EC, POYTRINE.C 336 EC, COTALM. P 18/150 EC, and SHERDIPHOS 420 EC, are distributed by Ivorian Chemical Companies. What is most alarming about these insecticides is that they are recommended to be used on cotton in the La Cote d'Ivoire, and neither on cabbage nor any other vegetable. Additionally, the fact that the relevant information on the product label concerning the safe and effective use of these insecticides written in French suggests that these products are not registered for use in Ghana. These insecticides could therefore be considered as having been smuggled into this country, confirming NARP's (1993) observation, and defying the Pesticides Control and Management Act 528 of Ghana (1996).

Ninety-two percent of growers, that is, 46 of the 50 respondents, also used more than one insecticide to control the insect pests of cabbage. The different combinations of insecticides used by the growers are as follows:

1. Biobit, Karate, and Polytrine
2. Biobit, Karate, and Perfekthion
3. Dipel/Biobit, Karate, and Dursban
4. Biobit, Karate and Actellic
5. Biobit and Perfekthion
6. Biobit and Karate
7. Biobit and Dursban
8. Biobit and Sherdiphos
9. Biobit and Cotalm
10. Biobit and Deltaphos.



Of the 46 growers who used more than one insecticide, 30 used these insecticides as mixtures, while the remaining 16 growers alternated their use. The use of the different combinations of insecticides may have also contributed to the increase in the incidence of insect pest infestation on cabbage. This is because this practice defies some of the basic principles of insecticide management, which aims at delaying the onset of insecticide resistance or more realistically preserving the susceptibility in the target insect pests (Metcalf, 1980).

Metcalf (1980), recommended that :

1. The use of mixtures of insecticides must be avoided. This is important since mixtures of insecticides generally results in the simultaneous development of resistance, as each compound seems to develop the residual inheritance of the supporting genome for resistance in the other.
2. Extend the useful life of a satisfactory insecticide as long as possible, but monitor susceptibility, and replace the insecticide before control fails.
3. Choose a sequence of suitable alternative insecticides based on genetic considerations affecting cross-resistance and multiple resistance.

As these basic principles are defied, and insecticides are applied in such combinations against an insect pest as notorious as *P xylostella*, chemical control is certainly bound to fail. This is in view of the fact that *P xylostella* quickly develops resistance to all insecticides soon after the introduction of new compounds (Miyata *et al.*, 1986). *Plutella xylostella* has been reported to develop resistance to many insecticides. These include the conventional insecticides (Sun *et al.*, 1978; Liu *et al.*, 1981; Liu *et al.*, 1982; Miyata *et al.*, 1982; Miyata *et al.*, 1986; Chen and Sun, 1986; Tabashnik *et al.*, 1987; Magaro and Edelson, 1990; Brempong-Yeboah, 1992), Benzoylphenylureas (Sinchaisri *et al.*, 1989; Kohyama *et al.*, 1989; Sun *et al.*, 1990; Fahmy *et al.*, 1991), and *B. thuringiensis* subsp. *Kurstaki* (Tabashnik *et al.*, 1990; Syed, 1992; Shelton *et*

al., 1993; Perez and Shelton, 1997). It was also observed during the survey that Biobit with *B. t. subsp. kurstaki* potency of 16,000 IU/MG which was previously in use had been withdrawn from the market and replaced with one with a higher potency of 32,000 IU/MG. The implication here is that the target insect pests were at a point in time not being killed by the 16,000 IU/MG Biobit, a sign of resistance, thus necessitating its replacement with a more concentrated, 32,000 IU/MG, Biobit.

The growers also sprayed insecticides frequently (fig. 6), and at short intervals (fig. 7), just as was observed by Brempong-Yeboah (1992).

Fig. 6. The Frequency of Insecticide Application used by Respondents on Cabbage during its Growth Cycle.

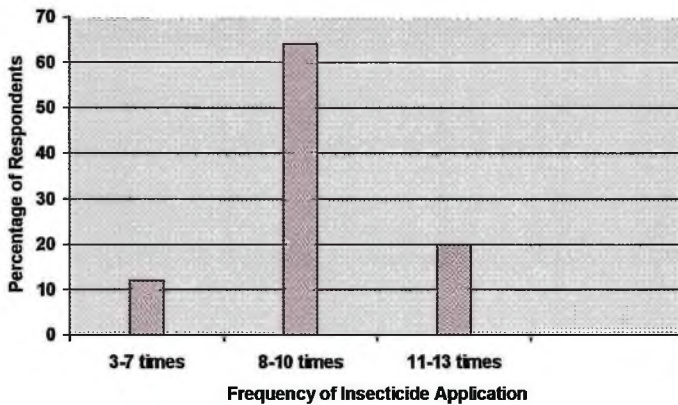
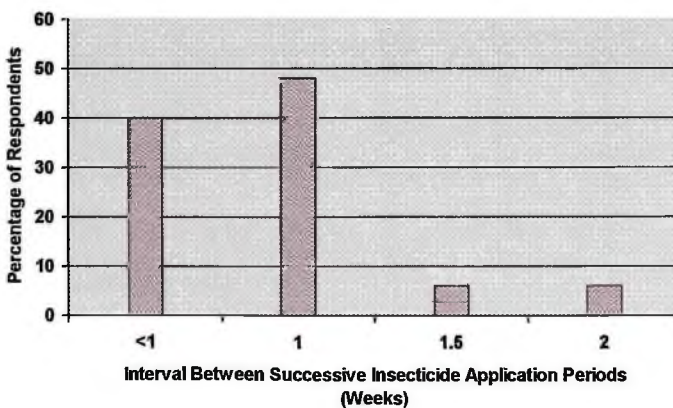


Fig. 7. Insecticide Spraying Regimes Used by Respondents.



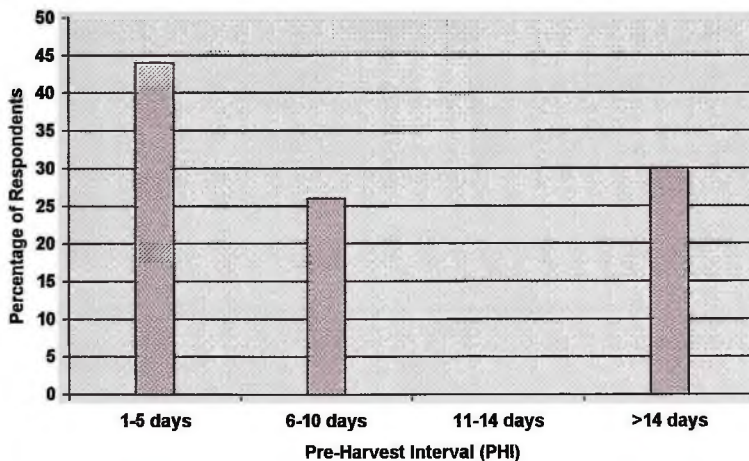
Considering the growers' choice and use of insecticides, and the observations made above, it is possible that the insect pests of cabbage, especially the diamondback moth, may have developed resistance to many of the insecticides being used on cabbage in the Accra-Tema Metropolitan Area of Ghana.

Another reason, apart from insecticide resistance, that may have contributed to the frequent insecticide application at short intervals could be inefficient irrigation methods. The results of the survey revealed that 76% of the respondents irrigated their crop everyday, while the remaining 24% of the respondents irrigated either every other day or every three days. Although the daily irrigation may be necessary for the plants' proper growth and development, the method of irrigation where water is applied to the entire plant as practised by 80% of the respondents is likely to wash off the insecticides that have been sprayed onto the crops. This is especially true where most of the insecticides being used have little or no systemic activity. The crop is eventually stripped of the chemical that is meant to protect. Such a situation results in increased insect pest infestation and damage, prompting the frequently use of insecticides.

It was observed that most of the growers used the manually operated knapsack sprayers and the cone nozzle during insecticide application, although four of the respondents used the motorized knapsack sprayers and the simple syringes/hand sprayers, which is normally used in the control of medical insect vectors. The growers were able to give the various volumes of insecticides used in a specified quantity of water, however, the application rates of the insecticides could not be estimated because the application equipment were not calibrated before use. Growers were also not able to estimate the approximate number of plants they sprayed with their stated concentrations of insecticides.

Fifty-eight percent of the respondents used insecticides prophylactically. The remaining 42% used the insecticides only when insect pests were observed to be feeding on the cabbages, but did not rely on economic threshold levels before spraying decisions were made. The survey revealed that the practice of prophylactic use of insecticides in cabbage production is not influenced by level of education of the cabbage growers. This is because 58% of the growers who had no formal education, 60% the growers who had primary school education, 58% of the growers with middle school education, and 56% of the growers who received secondary school education, used insecticides prophylactically on cabbage. However, 70% of the growers who had been in cabbage production for less than 4 years, 64% of those involved in cabbage production for 4 - 9 years and only 38% of growers involved in cabbage production for over 9 years used insecticide prophylactically. This suggests that the longer a grower is involved in cabbage production, the less likely the person would use insecticide prophylactically. Some farmers observed PHI as short as 1 - 5 days (fig 8).

Fig. 8. Pre-Harvest Intervals Observed by Respondents.



The PHI of 1 – 5 days observed by some of the growers could be attributed to the labels displayed on some of the insecticides in use, thus the insecticide could be used right up to harvest. These recommendations are given on labels though a given compound may be safe to man, wildlife, fish and beneficial insects, it is advised that normal spraying precautions should be observed (Anonymous, 1989). It was observed that 88% of the respondents do not wear any protective clothing during insecticide application. This attitude of the growers, predisposes them to the risk of insecticide poisoning, “The New Developing World Disease” (Anonymous, 1989). Forty-six of the 50 respondents also did not keep records on the insecticides used. This is because some regarded record keeping on insecticide use as unnecessary since they were self-employed. Others, however, attributed the reason why records are not kept to forgetfulness. With regard to the perceived risk of insecticide residue in food, 82% of respondents had no idea.

4.2 Insecticide Residue Level Determination

Insecticide residues were determined on 6 heads of cabbage that were sampled from 3 farms (2 heads from each farm). On two of the farms, KARATE 2.5 EC, the widely used synthetic insecticide had been sprayed to control the insect pests of cabbage. DELTAPHOS 262 EC, one of the compounded insecticides recommended for use on cotton in La Cote d’Ivoire was used on the other farm to control insect pests of cabbage.

The residues on the heads of cabbage were estimated from regression equations of the standard insecticide curves (figs. 9 and 10):

Fig. 9. A standard dosage-mortality curve of lambda-cyhalothrin against observed probit mortality of 48-hour-old *A. salina*. Mortality was recorded after 24 hours.

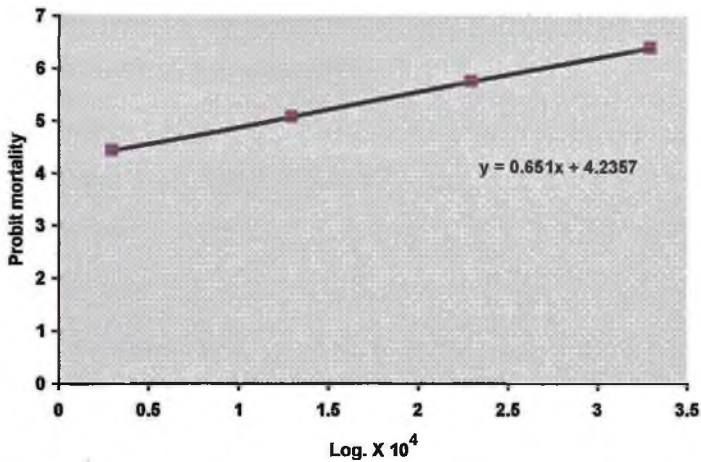
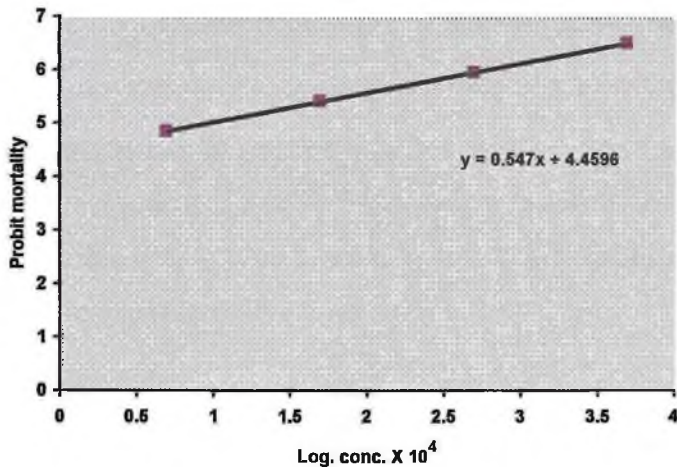


Fig. 10. A standard dosage-mortality curve of Deltaphos 262 EC against probit mortality of 48-hour-old *A. salina*. Mortality was recorded after 24 hours.



The regression equation for the standard Karate 2.5 EC curve is $Y = 0.651X + 4.236$ (fig. 9), with a coefficient of determination, r^2 , of 0.9969 (regression coefficient: 0.651 ± 0.026 ; $P = 0.0016$). In addition to an F-value of 635.384 ($P = 0.0016$), these values show that the regression analysis for the standard Karate 2.5 EC curve is highly significant, and thus very dependable.

The regression equation for the standard Deltaphos 262 EC is $Y = 0.547X + 4.460$ (fig. 10) with a coefficient of determination, r^2 , of 0.9945 (regression coefficient: 0.547 ± 0.029 ; $P = 0.0027$). In addition to an F-value of 363.559 ($P = 0.0027$), these values also show that the regression analysis for the standard Deltaphos 2.5 EC curve is highly significant, and thus equally very dependable (See appendices D and E). The estimated residue levels of Karate 2.5 EC (lambdacyhalothrin) and Deltaphos 262 EC (Triazophos + Deltamethrin) on the cabbage are presented in Tables 3 and 4.

The residues of Lambdacyhalothrin, and Deltaphos (triazophos + deltamethrin) showed less levels on the core leaves than on the wrapper leaves. This is because the wrapper leaves covered the core leaves, therefore preventing the contact insecticides which are applied as foliar sprays from getting onto the core leaves. These results are in agreement with those from work done by Sances *et al.* (1993) on head lettuce which has similar physical architecture as the head cabbage showed that the physical architecture of head lettuce affects pesticide residue levels in the heart tissue (core leaves) from foliar sprays and is correlated with the relative sizes of wrapper and basal leaves. There is however no architectural effect when pesticides are absorbed from the soil through the roots (Cabras *et al.*, 1988)

Table 3. Residues of Karate 2.5 EC (Lambdacyhalothrin) on Cabbage Samples.

Cabbage Sample	Cabbage Part	Residue of lambdacyhalothrin detected Mg/kg cabbage	FAO/WHO MRL mg/kg cabbage (FAO/WHO, 1986)	FAO/WHO max. ADI mg/kg body weight (FAO/WHO, 1986)
1	Core with inner leaves	0.0064	0.2	0.02
	Core leaves	0.0030		
	Inner leaves	0.0034		
	Outer leaves	0.0195		
2	Core with inner leaves	0.0075		
	Core leaves	0.0018		
	Inner leaves	0.0057		
	Outer leaves	0.0355		
3	Core with inner leaves	0.0142		
	Core leaves	0.0018		
	Inner leaves	0.0123		
	Outer leaves	0.0991		
4	Core with inner leaves	0.0096		
	Core leaves	0.0014		
	Inner leaves	0.0582		
	Outer leaves	0.1462		

Table 4. Residues of Deltaphos 262 EC (250g/l Triazophos + 12g/l Deltamethrin) on the Samples of Cabbage.

Cabbage Sample	Cabbage Part	Residue of Deltaphos Detected mg/kg cabbage
5	Core with inner leaves	0.2223
	Core leaves	0.0080
	Inner leaves	0.2143
	Outer leaves	0.1812
6	Core with inner leaves	0.6744
	Core leaves	0.0060
	Inner leaves	0.6684
	Outer leaves	0.2535

The residues of Lambdacyhalothrin detected on each of the 4 samples of cabbages sprayed with KARATE 2.5 EC, does not exceed the FAO/WHO MRL of 0.2 mg/kg of cabbage leaves (Table 3). This low residue level of Lambdacyhalothrin detected may be due to the use of a lower rate of application of the insecticide by the growers from whom the cabbage samples were picked.

Alternatively, the low residue levels of Lambdacyhalothrin could have resulted from the irrigation method used by the growers from whom the samples were picked. During their routine daily irrigation these growers poured water onto the entire cabbage plant which is likely to have washed out this insecticide which has contact activity. Considering the high insect pest infestation and the extensive damage done to the cabbage leaves which resulted in the frequent application of the insecticide, the more probable explanation for the low residue of Lambdacyhalothrin is the method of irrigation which washes off the insecticide from the cabbage leaves.

Deltaphos 262 EC consists of 250g/l triazophos and 12g/l deltamethrin. This implies that much (over 95%) of the biological activity of Deltaphos 262 EC residue could be attributed to triazophos. It is therefore quite probable to have triazophos residue levels of about 0.2122 mg/kg and 0.6433 mg/kg (representing the proportion of triazophos) on the core with inner leaves of the cabbage samples (from Table 4). This seems to suggest that the residue levels in the cabbage samples may exceed the FAO/WHO recommended MRL of 0.1 mg/kg (FAO/WHO, 1983).

From the results of the residue level estimation, it is evident that the use of Deltaphos 262 EC (which contains over 95% Triazophos), for the control of pest of cabbage has to be discouraged. This is because of the probable 2-fold and 6-fold violation of the FAO/WHO recommended MRL of Triazophos residue on cabbage. It is even possible that the residue level of triazophos on the cabbage leaves could have been higher had it not been for the pouring of water onto the cabbage plant during irrigation, thereby washing some of the triazophos residue off the cabbage leaves.

5. CONCLUSION AND RECOMMENDATION

This research has shown that the cabbage growing patterns of growers in the Accra-Tema Metropolitan Area of Ghana provides a very conducive environment for insect pests to survive, develop, and multiply, resulting in the persistent insect pest outbreaks on cabbage. Additionally, the growing of cauliflower and Chinese cabbage on adjacent plots, and the improper handling of crop residues (poor crop sanitation) also contributed to the persistent outbreaks. The growers were unanimous on the key pest status of the diamondback moth, which they said is capable of completely destroying their crop.

To protect their investment from insect pest damage, the growers relied exclusively on the use of insecticides. It was revealed that the insecticide use patterns of the cabbage growers were not commendable. This is because the growers depended on insecticide retailers/agents, and fellow cabbage growers for advice on the choice and the use of insecticides in the control of the pest of cabbage. Advice on the insecticide(s) to use therefore had no scientific basis, despite the use of the bioinsecticide, *B. t. subsp. kurstaki* Berliner which is highly recommended in integrated pest management practices, by many of the growers. Insecticide retailers/agents cannot be relied on because they compete among themselves to sell their products, and can only recommend and sell to the growers chemicals that they have in stock. Fellow cabbage growers also only advised the growers to purchase insecticides on the basis that the particular insecticide has the capacity to kill the target insect pest. This situation resulted in the use of mixtures of insecticides such as Biobit WP, Karate 2.5 EC, and Polytrine.C 336 EC, which is contrary to the principles of pesticide management. This same situation also resulted in the use of the highly concentrated insecticides,

Deltaphos 262 EC, Polytrine.C 336 EC, Cotalm P 18/150 EC, and Sherdiphos 420 EC, that are recommended for use on cotton, and not registered for use in Ghana.

These insecticides were applied frequently, and at short intervals, without the consideration of threshold levels. Application equipment was also not calibrated before use. The pre-harvest intervals observed by these growers were also not commendable, because the half lives and degradation patterns of the insecticides are not taken into consideration. Additionally, the labels of insecticides also do not adequately inform users on the proper handling and use of these chemicals.

The results of residue level estimation have shown that the insecticide residue problem on cabbage has to be taken seriously in this country. This is because 33% of the cabbage samples bioassayed showed residue levels, which are likely to be 2-6 fold higher than the FAO/WHO MRL for Triazophos.

It is therefore recommended that consumers endeavour to use only the core leaves of cabbage, as this usually contains levels of residues lower than the FAO/WHO MRL. Urgent steps must also be taken to help farmers control the insect pests of cabbage without compromising human health, while assuring them of optimum yield of cabbage, and their income. To achieve this, insecticide companies must collaborate with researchers to educate cabbage growers to be able to make informed choices with respect to which insecticide to use in chemical cabbage protection. The growers have to be educated also on the proper handling and use of insecticide, and insecticide application equipment, especially its calibration. The National Agricultural Extension Service has to be strengthened to enable them undertake this education. This is because the research revealed that the extension service's education of cabbage growers is woefully inadequate.

The Environmental Protection Agency of Ghana must equip itself with the provisions of the Pesticide Control and Management Act (528) to rid the market of pesticides not registered for use in Ghana, and prevent their importation. Insecticide resistance in insect pests of cabbage has to be monitored often. This is especially necessary considering the key pest status of *P. xylostella* and its ability to quickly develop resistance to insecticides. Insecticide residues on cabbage also have to be monitored often. Analytical method is recommended to be used for the residue analysis so as to be able to identify the parent pesticide compounds and their metabolites, and also establish precise amounts of the residues. There also appears to be the need to pass a pesticide residue bill, which is based on extensive research on recommended use patterns of insecticides and the residues that arise from them. A socially acceptable and economical Integrated Pest Management (IPM) strategy that could be easily adapted by cabbage growers must be researched into and recommended to the growers, as a matter of urgency. This certainly requires better equipping and strengthening of the existing national agricultural research systems. The cabbage growers confided that they could not afford the cost of providing alternative source of water for cabbage irrigation, if they have to stop the use of untreated water for irrigating their crop. It is recommended that the Ministry of Food and Agriculture in collaboration with Non-Governmental Agencies make available alternative source of water to the cabbage growers. Wells can be dug or dams constructed for the cabbage growers.

Finally, it is recommended that the insecticide use patterns and residues on other crops, especially fruits and vegetables be investigated.

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APPENDICES**APPENDIX A**

Nutritional value of cabbage (leaves), nutrient per 100g of edible portion (Rice *et al.*, 1993).

Nutrient	Content
Water	90g
Calories	23
Protein	1.5g
Fat	0.2g
Carbohydrate	5g
Fibre	1g
Calcium	24mg
Phosphorous	28mg
Iron	0.5mg
Thiamine	0.1mg
Riboflavin	0.7mg
Niacin	0.7mg
Ascorbic Acid	40mg
β -Carotene	18 μ g

APPENDIX B**AFRICAN REGIONAL POST GRADUATE PROGRAMME IN INSECT SCIENCE****(ARPPIS), UNIVERSITY OF GHANA, LEGON, GHANA**

Questionnaire for the determination and assessment of farmers' insecticide use patterns on

Cabbage, *Brassica oleracea* var. *capitata* L. (SAMPLE)

(Please either fill in the blank space provide, or tick where applicable)

GENERAL INFORMATION

1. Date of interview

2. Questionnaire code

**BACKGROUND OF FARMER (DEMOGRAPHY)**

3. Name of respondent

4. Sex of respondent. 1. Male 2. Female

5. Age of respondent. 1. Less than 21 2. Btn 21 and 30

3. Btn 31 and 40 4. Btn 41 and 50

5. More than 50

6. Level of education of respondent.

1. No schooling 2. primary school

3. Middle school 4. Secondary school

5. Tertiary institution

6. Other (specify).....

7. Location of farm.....

8. For how long have you been cultivating cabbage?.....

LAND TENURE

9. How did you acquire your land? 1. on tenancy from chief

2. on tenancy from a community member

3. on tenancy from family head

4. own land/purchased

5. Other (specify)

10. If a tenant farmer, which type of tenancy?

1. Abusa

2. abunu

3. Fixed rent

4. Leasehold

5. Other (specify)

11. As a tenant farmer, for how many years can you farm the land?

1. 1Yr

2. 2Yrs

3. 3Yrs

4. 4Yrs and above

AGRONOMIC PRACTICES

12. What is the size of your farm cultivated to cabbage in acres?

1. less or equal to 0.5

2. More than 0.5 but less or equal 1.0

3. More than 1.0 but less or equal to 1.5

4. More than 1.5 but less of equal to 2.0

5. More than 2.0

13. What form of cropping system do you practice?

1. Mono cropping

2. Mixed cropping

14. Do you practice continuous cropping?

1. Yes

2. No

15. If yes, how many years of continuous cropping?

1. 1Yr

2. 2Yrs

3. 3Yrs

4. 4Yrs

5. 5Yrs

6. Over 5yrs

16. What variety of cabbage do you grow? 1. KK cross 2. Oxylus 3. other

(specify)

17. Why this variety?

18. What planting material do you use?

1. seeds

2. seedlings

19. What is the source of your planting material?.....

20. If you use seeds, do you 1.do direct seeding, or 2.nurse seeds at

nursery

21. If 20(2) applies, how long do seedlings stay in nursery?

1. 1 week

2. 2 weeks

3. 3 weeks

4. 4 weeks

22. What is the plant spacing?.....

23. What is the duration after transplanting to harvest?

1. 8 weeks

2. 9 weeks

3.10 weeks

24. In which months do you normally grow cabbage?.....

25. What is the source of water for your cabbage?

1. Rain

2. Stream

3. Dam

4. Drainage water

5. Tap water

6. Other(specify)

26. If you irrigate/collect water from any of the sources above and apply yourself, which of the following is applicable? 1. water is applied to the entire plant

2. water is applied directly to the soil

27. How often do you collect water and apply yourself/irrigate?

1. every day

2. every 2 days

3. every 3 days

4. every 4 days

5. every 5 days

6. every 6 days

7. other (specify)

28. Do you apply fertilizer to your cabbage

1. Yes

2. No

29. If yes, how often do you apply fertilizer during growth cycle of cabbage?

- 1. 1X
- 2. 2X

30. Please, mention the name of the fertilizer.

- 1. 15:15:15
- 2. Urea
- 3. other (specify)

31. How do you get rid of weeds on your farm?

- 1. manual weeding
- 2. apply herbicide

32. If herbicide is applied, please name it.

33. How many times do you apply herbicide during the growth cycle of cabbage?

- 1. 1X
- 2. 2X

34. If you do not apply herbicide, why?

35. I manual weeding is applicable, how many times do you do this?

- 1. 1X
- 2. 2X

36. After harvesting cabbage, do you still control weeds?

- 1. Yes
- 2. No

37. How do you handle cabbage residue, including roots, after harvest?

- 1. leave them in the farm
- 2. plough to bury
- 3. collect them and throw away
- 4. burn them

INSECT PEST AND DISEASE PROBLEMS. AND THEIR CONTROL

38. Do you have disease problems on your cabbages?

- 1. Yes
- 2. No

39. If yes, what are the kinds of diseases?

- 1.
- 2.
- 3.
- 4.

40. Where do diseases come from?

- 1. Nursery
- other farmers' field
- 3. Others (specify).....

41. Do you get rid of disease when they infect cabbages?

1. Yes 2. No
42. If yes, what id the principal method that you use?
1. by applying chemicals 2. by crop rotation
3. other (specify).
43. If you use chemicals, please name them.
1. 2.
3. 4.
44. Do you have insect pests attacking your crop?
1. Yes 2. No
45. If yes, please name insects. 1. Diamondback moth
2. aphids 3. Other (specify).
46. Where do insects come from? 1. Nursery
2. other farmers' field 3. other (specify).
47. If any insect pest of cabbage consumes other crop(s), please mention pest and crop(s)
.....
48. Do you get rid of insect pest when they attack your crop?
1. Yes 2. No
49. If yes, what is the principal method that you use?
1. by applying insecticides
2. by crop rotation
3. by weeding
4. other (specify)
50. Why do you use this method?
1. method gets rid of insect pest quickly
2. method is cheap
3. method is environmentally friendly and sustainable
4. method eliminates insecticide residues

5. method reduces insecticide residues

6. other (specify)

51. Who recommended this method?

1. fellow farmer

2. extension officer

3. chemical retailer/agent

4. other (specify)

52. Do you use other methods in addition to the principal method?

1. Yes

2. No

53. If yes, indicate which methods are applicable.

1. by applying insecticides

2. by crop rotation

3. by weeding

4. other (specify)

54. Give reasons for your answer to question 53 if applicable.

1. method gets rid of insect pest quickly

2. method is cheap

3. method is environmentally friendly and sustainable

4. method eliminates insecticide residues

5. method reduces insecticide residues

6. other (specify)

INSECTICIDE APPLICATION

55. If you use insects to get rid of insects, please indicate the primary insecticide.

1. Dimethoate

2. Cymethoate

3. Dursban

4. Actellic

5. Dipel 2X

1. Other (specify)

56. Why do you use this insecticide?

1. gets rid of insect pest effectively

2. it is cheap

3. other (specify)

57. Who recommended this insecticide?

1. fellow farmer

2. extension officer

3. chemical retailer/agent

4. other (specify)

58. Do you use other insecticide?

1. Yes

2. No

59. If yes, name insecticide.

1. Dimethoate

2. Cymethoate

3. Dursban

4. Actellic

5. Dipel 2X

6. Other (specify)

60. Why do you use this/these other insecticides?

1. Effective in combination with the above

2. it is cheap

3. other (specify)

61. Who recommended this/these other insecticide(s)?

1. fellow farmer

2. extension officer

3. chemical retailer/agent
4. other (specify)

62. How do you use the various insecticides?

1. alternatively (one after the other)
2. as mixtures

63. Give reasons for your answer to question (62).

1. gets rid of insect pest effectively
2. cost is cheaper
3. other (specify)

64. What are the formulation of insecticides used?

1. Dimethoate.
2. Cymethoate.
3. Dursban.
4. Actellic.
5. Dipel 2X.
6. Other (specify).

65. State the precise dosage applied by you of the insecticides you use.

1. Dimethoate.
2. Cymethoate.
3. Dursban.
4. Actellic.
5. Dipel 2X.
6. Other (specify).

66. How many cabbage plants do you spray with your stated concentration of insecticides?

.....

67. How many times do you apply insecticides before harvest?

- | | | | | |
|-------|-------|-------|-------|-------|
| 1. 1X | 2. 2X | 3. 3X | 4. 4X | 5. 5X |
|-------|-------|-------|-------|-------|

3. Polyjet green

4. Polyjet blue

5. Cone

76. Do you receive any professional advice on the proper handling of insecticide?

1. Yes

2. No

77. If yes, who is source of information?

1. fellow farmer

2. extension officer

3. chemical retailer/agent

4. other (specify).

78. How often do you receive such advice?

1. fortnightly

2. monthly

3. other (specify)

79. Do you keep farm records on your insecticide use patterns?

1. Yes

2. No

80. Give reasons for your answer.

MARKETING

81. Who buys your cabbage?

82. Do you have problems selling the cabbage?

1. Yes

2. No

83. If yes, please specify the kind of problem.

SOCIO-ECONOMIC

84. Number of dependents.

85. What percentage of cabbage grown is consumed by your family?

..

86. What percentage of your income is derived from the sale of cabbage?

.

87. What other sources of income do you have?

INSECTICIDE RESIDUES

88. Do you have any knowledge on the problems associated with insecticide residues in foods?

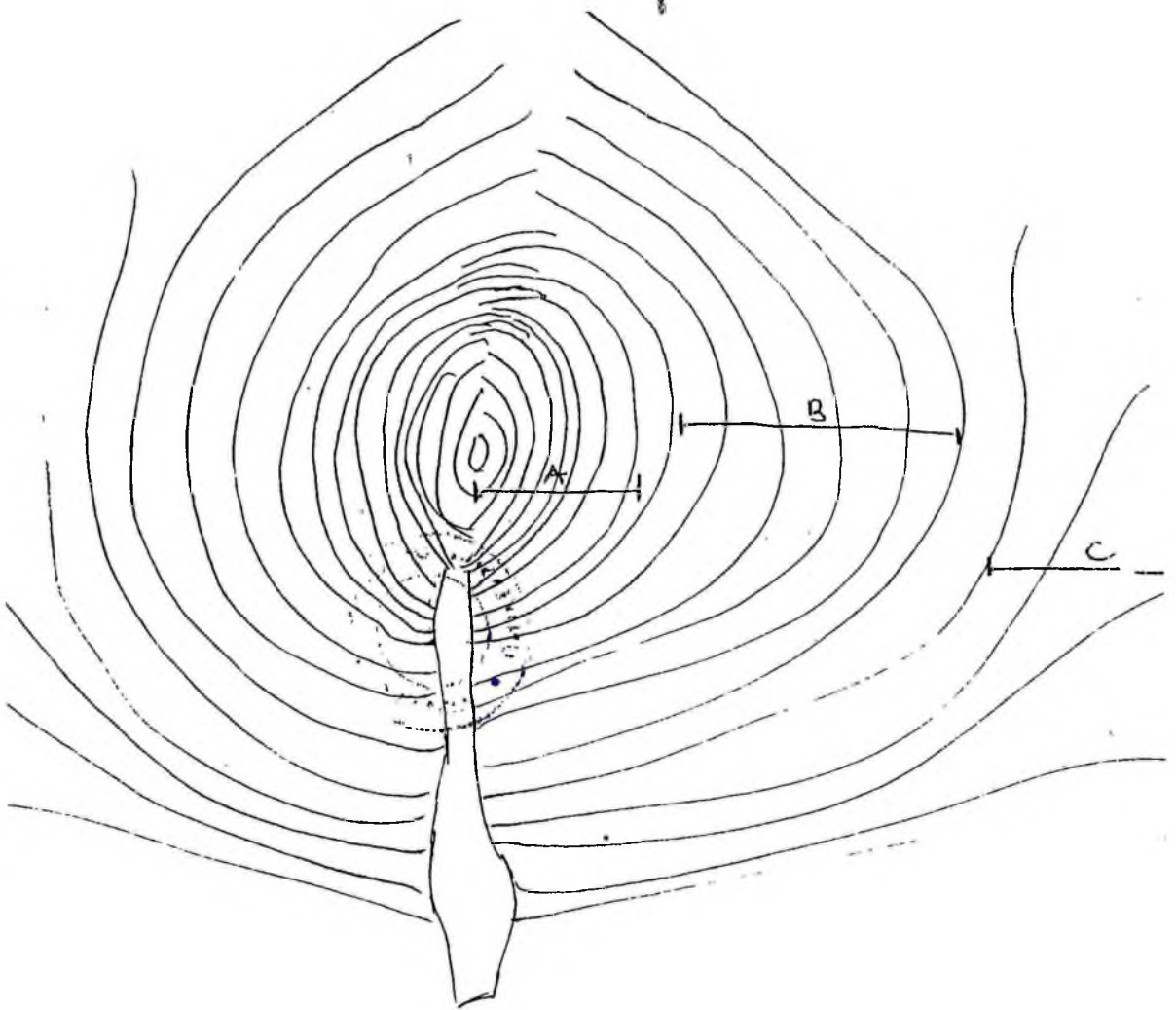
1. Yes

2. No

89. If yes, please elaborate.

THANK YOU

APPENDIX C



Schematic representation of the longitudinal view of cabbage leaves analyzed for insecticide residues: A: Core leaves - tightly packed leaves usually light green in colour as a result of minimum chlorophyll. B: Inner wrapper leaves - loosely packed leaves that covers the core leaves, usually has dark green colouration. C: Outer wrapper leaves - dark green leaves that are usually wide open.

APPENDIX D

D1. The standard dosage-mortality data after the exposure of 48 hour old nauplii of *Artemia salina* Leach to Karate 2.5 EC (lambdacyhalothrin) for 24 hours.

Concentration of lambdacyhalothrin (μ g/ml)	Log. Concentration $\times 10^5$	Number of <i>A. salina</i> exposed	Mortality
0.02	3.30	60	55
0.002	2.30	60	46
0.0002	1.30	60	34
0.00002	0.30	60	17
Control	-	60	1

% Mortality	Adjusted % Mortality	Observed Probit mortality	Expected Probit Mortality
91.63	91.50	6.37	6.384
76.67	76.30	5.72	5.733
56.67	55.90	5.15	5.082
28.33	27.10	4.39	4.431
1.67	0	-	-

$LC_{50}(24hrs)$ Brine shrimp: 0.000139 mg/ml

Regression Coefficient: 0.651 ± 0.026 ; P-value = 0.0016

Intercept: 4.236 ± 0.055 ; P-value = 0.0002

Coefficient of determination, r^2 : 0.9969

Regression equation: $Y = 0.651X + 4.236$

D2. Regression ANOVA (on the observed probit mortality, for Karate 2.5 EC).

	Degrees of freedom	Sum Of Squares	Mean square	F-value	P-value
Model	1	2.119	2.119	635.384	0.0016
Error	2	0.007	0.003		
Total	3	2.126			

D3. Bioassay to determine the level of lambdacyhalothrin residue on cabbage.

Cabbage sample	Cabbage part	Number of shrimps exposed to 5 μ l extract	Mortality	Percent Mortality	Adjusted Percent Mortality	Probit Mortality	Estimated conc. of Lambdacyhalo-thrin in 5 μ l extract (μ g/ml)	Estimated conc. of Lambdacyhalo-thrin in 50g cabbage subsample (μ g/ml)	Estimated conc. of Lambdacyhalo-thrin of 1kg cabbage (mg/kg)
1	Core leaves	40	22	55.0	50.0	5.00	0.0001493	0.1493	0.002986
	Inner leaves	40	23	57.5	51.4	5.04	0.0001722	0.1722	0.003444
	Outer leaves	40	29	72.5	70.3	5.53	0.0009728	0.9728	0.019456
2	Core leaves	40	20	50.0	44.4	4.86	0.0000910	0.0910	0.001820
	Inner leaves	40	25	62.5	57.1	5.18	0.0002825	0.2825	0.005650
	Outer leaves	40	31	77.5	75.7	5.70	0.0017742	1.7742	0.035484
3	Core leaves	40	20	50.0	44.4	4.86	0.0000910	0.0910	0.001820
	Inner leaves	40	28	70.0	65.7	5.40	0.0006152	0.6152	0.012304
	Outer leaves	40	34	85.0	83.0	5.99	0.0049545	4.9545	0.099090
4	Core leaves	40	21	47.5	41.7	4.79	0.0000712	0.0712	0.001424
	Inner leaves	40	33	82.5	80.0	5.84	0.0029107	2.9107	0.058214
	Outer leaves	40	35	87.5	86.5	6.10	0.0073114	7.3114	0.146228
No insecticide	Core leaves	40	4	10.0	0	-			
	Inner leaves	40	5	12.5	0	-			
	Outer leaves	40	3	7.5	0	-			
Control	Sea water	40	0	0	-	-			

APPENDIX E

E1. The Standard dosage-mortality data after the exposure of 48 hour old nauplii of *A. salina*

Leach to Deltaphos 262 EC for 24 hours.

Concentration of Deltaphos ($\mu\text{g/ml}$)	Log. Concentration $\times 10^4$	Number of <i>A. salina</i> exposed	Mortality
0.5	3.699	60	56
0.05	2.699	60	49
0.005	1.699	60	41
0.0005	0.699	60	26
Control	-	60	1

% Mortality	Adjusted % Mortality	Observed Probit Mortality	Expected Probit Mortality
93.33	93.20	6.49	6.483
81.67	81.40	5.89	5.936
68.33	67.80	5.46	5.389
43.33	42.40	4.81	4.842
1.67	0	-	-

$LC_{50}(24\text{hours})$ Brine shrimp: 0.000973

Regression coefficient: 0.547 ± 0.029 ; P-value = 0.0027

Intercept: 4.46 ± 0.071 ; P-value = 0.0003

Coefficient of determination, r^2 : 0.9945

Regression equation: $Y = 0.547X + 4.46$

E2. Regression ANOVA (on the observed probit mortality for Deltaphos 262 E.C).

	Degrees of Freedom	Sum of squares	Mean square	F-value	P-value
Model	1	1.496	1.496	363.559	0.0027
Error	2	0.008	0.004		
Total	3	1.504			

E3. Bioassay to determine the level of Deltaphos 262 EC residues on cabbage.

Cabbage sample	Cabbage part	Number of <i>A. salina</i> exposed to 5 μ l of extract	Mortality	Percent Mortality	Adjusted Percent Mortality	Probit Mortality	Estimated conc. Of Deltaphos in 5 μ l extract (μ g/ml)	Estimated conc. Of Deltaphos in 50g subsample (μ g/ml)	Estimated conc. Of Deltaphos in 1kg cabbage (mg/kg)
5	Core leaves	40	19	47.5	41.7	4.79	0.0004018	0.4018	0.008036
	Inner leaves	40	30	75.0	71.4	5.57	0.0107152	10.7152	0.214304
	Outer leaves	40	29	72.5	70.3	5.53	0.0090573	9.0573	0.181146
6	Core leaves	40	18	45.0	38.9	4.72	0.0002992	0.2992	0.005984
	Inner leaves	40	33	82.5	80.0	5.84	0.0334195	33.4195	0.668390
	Outer leaves	40	30	75.0	73.0	5.61	0.0126765	12.6765	0.25353
No insecticide	Core leaves	40	4	10.0	0	-			
	Inner leaves	40	5	12.5	0	-			
	Outer leaves	40	3	7.5	0	-			
Control	Sea water	40	0	0	-	-			