ANALYSIS OF DELTAMETHRIN AND LAMBDA-CYHALOTHRIN PESTICIDE RESIDUES IN SELECTED VEGETABLES FROM URBAN AND RURAL AREAS IN KENYA

BY

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DECEMBER 2006
DECLARATIONS

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I hereby declare that this thesis is my original work and has not been presented for any degree in any other university.

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DEDICATION

This work is dedicated to my dear loving husband Dr. Kithure Kindiki and our lovely daughter Imani, who gave me all the support and inspiration I needed during the study.
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<table>
<thead>
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<th>Abbreviations</th>
<th>Meaning</th>
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<tr>
<td>ADI</td>
<td>Acceptable daily intake</td>
</tr>
<tr>
<td>a.i.</td>
<td>Active ingredient</td>
</tr>
<tr>
<td>CAS</td>
<td>Chemical abstract service</td>
</tr>
<tr>
<td>DA</td>
<td>Dermal absorption</td>
</tr>
<tr>
<td>DAD</td>
<td>Diode array detector</td>
</tr>
<tr>
<td>DDT</td>
<td>Dichlorodiphenyltrichloroethane</td>
</tr>
<tr>
<td>EC (_{50})</td>
<td>Concentration at which the effect occurs in 50 %</td>
</tr>
<tr>
<td>EPA</td>
<td>Environmental protection agency</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and agriculture organisation</td>
</tr>
<tr>
<td>GC/ECD</td>
<td>Gas chromatography with electron capture detector</td>
</tr>
<tr>
<td>GSC</td>
<td>Gas solid chromatography</td>
</tr>
<tr>
<td>ICIPE</td>
<td>International center of insect physiology and ecology</td>
</tr>
<tr>
<td>ID</td>
<td>Internal diameter</td>
</tr>
<tr>
<td>JMPR</td>
<td>Joint meeting on pesticide residues</td>
</tr>
<tr>
<td>MRLs</td>
<td>Maximum residue limits</td>
</tr>
<tr>
<td>ND</td>
<td>Not detected</td>
</tr>
<tr>
<td>NGO</td>
<td>Non-Governmental organisation</td>
</tr>
<tr>
<td>NOEL</td>
<td>No effect level</td>
</tr>
<tr>
<td>ORETFT</td>
<td>Outdoor residential exposure task force</td>
</tr>
<tr>
<td>PDP</td>
<td>Pesticide data programme</td>
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RUP  Restricted use of pesticides
SFC  Supercritical fluid chromatography
SFS  Subjective facial sensation
TGAI  Technical grade active ingredient
TSMP  Toxic substances management policy
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Vegetables are considered a cheaper source of natural nutrients. They are therefore widely consumed and they play a vital role by providing vitamins and minerals in the diet, besides supplying protein and energy. These nutrients from vegetables help to overcome common disorder like anemia, deficiency disorders and other ailments in human beings. Vegetables are also very important in neutralizing the acids produced during digestion and also useful as roughage. However, pests, diseases, and weeds destroy vegetables. There are many chemicals with which they can be controlled, including pesticides. Among the insecticides used are the pyrethroids which include; deltamethrin, lambda-cyhalothrin and chismethrin. Most of these chemicals are poisonous to creatures besides those they are intended to kill. There is need, therefore for monitoring the pesticides residues because they can be injurious to the life of human beings, animals, fish, and birds. Although, vegetables are widely consumed by almost everybody in Kenya, there is little work done on the analysis of pesticides residues in the vegetables. In this study deltamethrin and lambda-cyhalothrin were analysed because they are the most commonly used pesticides on vegetables. Vegetable samples were bought from both urban and rural areas. Pesticide residues were extracted from the samples using organic solvents. The residues were then determined by high performance liquid chromatography. The study showed that, during the dry season there were higher levels of deltamethrin and lambda-cyhalothrin in vegetables than during the wet season in all the samples analysed from both urban and rural areas. This probably is due to wash off effect of the pesticides by the rainwater. Another reason could be probably some farmers rarely apply pesticides on vegetables during the wet seasons because there normally few pests than during the dry seasons. In this case the mean residue levels ranged between 0.0130 and 0.3400 mg/kg during the dry seasons and between non-detectable level and 0.1100 mg/kg during the wet season. The differences in levels of the pyrethroids during the dry and wet seasons were significantly different at 95% confidence limits. It was also found that the vegetables consumed in the urban areas contained higher mean residue levels of deltamethrin and lambda-cyhalothrin than those consumed in the rural areas during the dry and wet seasons. Most of the vegetables consumed in the urban areas are obtained from large-scale farms in the rural areas. The farmers of these large-scale farms therefore, may not have waited for the elapse time before harvesting their vegetables. Maybe they did not follow the application instructions recommended for the pesticides. The mean residue levels in this case ranged between non-detectable level and 0.3400 mg/kg in the samples analysed from the urban areas and between 0.0012 and 0.1100 mg/kg in the samples analysed from the rural areas. The mean residue levels of kale samples from an experimental garden that were analysed in this study, decreased between day one and day five after the application of the pesticides as a result of degradation and wash off effect. However, most of the vegetable samples analysed in this study had the two pesticides’ residue levels exceeding the ADI (acceptable daily intake) although most of them were less than the MRLs (maximum residue limits). This means that those who feed on large amount of vegetables daily may be exposed to high levels of pesticide residues even though the elapse time was waited upon harvesting. Therefore, alternative methods to pesticides use on vegetables may be used like; the biological control of pests or the use of botanical pesticides.
CHAPTER ONE
INTRODUCTION

1.1 Vegetables

The advanced learner's dictionary defines vegetables as a plant or part of a plant that is
eaten as food. It classifies potatoes, bean, onions, cabbages and tomatoes as some of the
vegetables used by people as food. Vegetable production is one of the major branches of
horticulture. Vegetables are considered as an asset for providing a good source of income
to the growers and they form a vital part of the human diet (Gallow et al., 1993). Many of
the vegetable crops have high medicinal value. This has drawn the attention of plant
biochemists and pharmacologists to manufacture medicines of biotic origin. For instance,
onion and garlic are found to have anti-bacterial property, and have been found to lower
the blood sugar of rabbits (Shan, 1989). A study by Unlu et al., 2005 showed that
avocados act as a nutrient "booster," allowing the body to significantly absorb more
nutrients like alpha-carotene, beta-carotene and lycopene found in fruits and vegetables.

There are several reasons for growing vegetables, but the most important one is for food.
Vegetables are essential in the diet; for they provide fibre, trace minerals, vitamins,
folic, carbohydrates and protein (Hollingsworth, 1981). There is increased interest
especially in developing countries to supplement the staple foods with other vegetables
produced locally. This is why the demand for vegetables has increased in many areas of
the world in the development of improved and more diverse methods of vegetables' 
preservation, such as canning, freezing and dehydration. The technology has led to a
more diverse range of types of vegetable and increased quantities called for by the
processors (Hollingsworth, 1981). Coupled with this, there has been a rapid advance of
technology in the vegetables production on a large scale, such as in Europe and the USA where rapid adoption of herbicides suitable for individual crops has led to crop establishment in a relatively weed-free environment (Watts, 1980). It is now becoming increasingly appreciated that successful vegetable production is very dependent upon a supply of satisfactory seeds (FAO/WHO, 1986).

The production areas of vegetables ranges from large-scale farm enterprises and market gardens. Vegetables are also cultivated in some communities for physical recreation or even for a pastime or hobby. There are some relatively small-scale producers who aim at self-sufficiency in vegetables and surplus for sale or exchange in village communities. The market growers in many areas have evolved from this type of disposal of surplus crops to deliberate production of crops for sale. Commercial production has extended considerably during the last few decades in many parts of the world as large-scale enterprises endeavour to provide continuity of supply for the fresh market, processors and export.

Pest, diseases, and weeds can take their toll of vegetables in terms of quality and quantity. Some pests for vegetables include insects and closely related species including butterflies, weevils, mites and larvae. There are currently many chemicals, which can control pests, diseases, and weeds. Many of these chemicals are poisonous to other organisms besides the pests. The pesticides dilemma is not whether to use or not to use-but the choice of agent, when it must be used, how much should be applied and how often it should be applied.
1.2 Pesticides

Pesticides are defined as any agent intended for preventing, destroying, repelling, or mitigating any pest and this classification may be subdivided into groups, such as insecticides, acaricides, nematocides, herbicides, avicides, rodenticides and molluscicides depending upon the species of the pest (Mathew and August, 1975). According to the definition of the FAO International code of conduct on the distribution and use of pesticides, a pesticide is any substance or mixture of substances, intended to prevent, destroy, or control any pest or insect from interfering with production, processing, storage, transfer, or marketing of food, agricultural commodities and wood (Farrelly et al., 1984).

About 1,000 years ago salts of metals, sulfur, natural oils, and tobacco products were used as pesticides (Anderson et al., 1981). During the last 60 years chemical synthesis of pesticides has increased considerably, and there are more than 55 classes and 1,500 individual substances produced in more than 100,000 formulations (Anderson et al., 1981).

Not only are pesticides the primary immediate weapon against pest losses, but on growing crops and during transport and storage after harvest. Their use in chemical weed control is also a major factor in increased labor efficiency and reduced drudgery. Apart from the need to increase world pesticides production to ensure adequate food supply, there is also the need for continued high research investment to discover new, more efficient, and safer pesticides, and to find better and safer ways of using those, which are
currently available. The safety record in pesticides is perhaps, nearly the best in any area of modern technology. Through their contribution in economical food production and consequently improvement of health, pesticides are perhaps the greatest benefits to mankind. They are needed in the future to help ensure adequate food for survival (Frejka, 1975). There are various types of pesticides, which include, organochlorines, organophosphates, carbamates and pyrethroids. Pesticides are commonly applied on vegetables during the dry seasons because there are more pests available during this time than during the wet season (Personal communications, farmers and agronomists). As most of the vegetable consumed in the urban areas come from the large scale farms in the rural areas, it is probable that the consumers in the urban areas are exposed to high levels of pesticides than those in the rural areas. The large-scale farmers may be applying more pesticides than the recommended amounts so that their vegetables may be free from pests as much as possible hence attracting more customers. Sometimes some large-scale farmers may get buyers before the elapse time, and because of harsh economic situations end up harvesting the vegetables thus exposing consumers to high levels of pesticides.

1.2.1 Pyrethroid compounds

Pyrethroids are a synthetic version of an extract from the chrysanthemum (pyrethrum flower extract) (Reigart, 1999), and were chemically designed to be more toxic with longer breakdown times. Pyrethrins are a botanical pesticides produced by certain species of the chrysanthemic plant (Reigart, 1999). The insecticidal properties of pyrethrins are derived from ketoalcoholic esters of chrysanthemic and pyrethroic acids. These acids are strongly lipophilic and rapidly penetrate many insects and paralyze their nervous system.
(Reigart, 1999). The enzymes in the insect swiftly detoxify them. Thus, some pests will recover (Costa, 1997). This lead to some synthetic derivatives of the chrysanthemic acids to be developed as insecticides. These are called pyrethroids and tend to be more effective than natural pyrethrins while they are less toxic to mammals (Costa, 1997). Therefore, pyrethroids are synthetic (human made) forms of pyrethroids (Klaassen et al., 1996). Chemically synthetic Pyrethroids are esters of specific acids (for examples, chrysanthemic acid, halo-substituted chrysanthemic acid) and alcohols (for example, allethrolane, 3-phenoxybenzyl alcohol) (Reigart, 1999). They are often formulated by synergists to increase potency and compromise the human body’s ability to detoxify the pesticide (Reigart, 1999).

Pyrethroids are the commonly used class of insecticides on vegetables (Shan, 1989), and are the object of this study. Sythetic pyrethroids compounds vary in their toxicity, as does the natural pyrethrins. Pyrethrum is a botanical insecticide whose active ingredients are pyrethrins I and II, cinelins I and II, and josmolins I and II and are collectively known as pyrethrins. These pyrethrins account for the killing and breakdown properties of pyrethrum extract and it is unlikely that any additional components will be found that add significantly in these areas of biological activity (Georghiou, 1990). Pyrethrin compounds have been used primarily to control human lice, mosquitoes, cockroaches, beetles, and flies. Some pyrethrin dusts used to control insects in horticultural crops are only 0.3 % to 0.5 % pyrethrins (Georghiou, 1990). Other pyrethrin compounds may be used in grain storage and in poultry pens and on dogs and cats to control lice and fleas (Ecobichon, 1991).
Animals exposed to toxic amounts may experience tongue and lip numbness, nausea and diarrhea; symptoms may also include tremors, convulsions, paralysis, respiratory failure, and death (Hayes, 1982). Pyrethroids can cause two quite different responses at near lethal doses in rats; aggressive sparring and sensitivity to external stimuli progressing to tremor (Hayes, 1982). On broken skin, pyrethrum produces irritation and sensitization, which is further aggravated by sun exposure (Hayes, 1982; Occupational health services, 1987).

1.2.1.1 Toxicity effects of pyrethroids to humans and animals’ life and ecology

Pyrethrins appear to have low reproductive toxicity in animals; this is because a study carried out by Hayes (1982), showed that rabbits that received pyrethrins orally at high doses during the sensitive period of pregnancy had normal litters. However, pyrethrum can be damaging to the central nervous system and the immune system (Hayes, 1982). Inhalation of high doses of pyrethrum for 30 minutes each day for 31 days caused slight lung irritation in rats and dogs (Occupational health services, 1987).

Commercial farmers spend a great deal of money on pesticides in order to get the highest possible yields and completely unblemished produce for marketing. The principal active constituents of synthetic pyrethroid compounds are lambda-cyhalothrin, deltamethrin, permethrin, chlorthrin, allethrine, fenvalerate, cypermethrin, and ferpropathrin (Mathew and August, 1975). Two of these pyrethroids (deltamethrin and lambda-cyhalothrin) were analysed in this study because they are the most commonly used pyrethroids on vegetables (Farmers and agronomists, personal communication). These pyrethroids were
analysed in three types of vegetables, which include; kales (*Brassica oleracea C.*), tomatoes (*Lycopersicon esculentum*) and cabbages (*Brassica oleracea A.*). The vegetable samples were obtained from the urban and rural areas during the dry and wet seasons. One of the main aims of the analysis was to determine whether there was a difference in the residue levels of the two pyrethroids between the vegetables consumed during the dry season and those consumed during the wet seasons. Another reason was to investigate whether there was a difference in residue levels between the vegetables consumed in the urban areas and those consumed in the rural areas. The study also analysed the two pyrethroids in kale samples obtained from the experimental garden during the dry and wet seasons. The study aimed at determining whether there was still some residues left in the vegetables even after the elapse time given by the manufacturers.

1.3 Deltamethrin

Trade names for products containing deltamethrin include decis, butoflin, butoss, butox, cislin, crackdown, cresus, decis-prime, K-othrin, and K-otek (Gammon et al., 1981). It is an insecticide used in cotton, vegetables, cereals, ornaments and field crop (Bradbury and Coats, 1989). It is used to control apple and pear suckers, plum fruits moth, caterpillars on brassicas pea and aphids on vegetables. The molecular formula is C_{22}H_{19}Br_{2}NO_{3}. Deltamethrin has very broad-spectrum control and is considered the most powerful of the synthetic pyrethroids adding up to three orders more active than some pyrethroids (Bradbury and Coats, 1989). Most deltamethrin products persist from one to two weeks in the environment, with shorter times in direct sunlight (ETN, Deltamethrin, 1995).

Formulation includes emulsification concentrate, flowable formulations, and granules.
1.3.1 Effects of deltamethrin on humans and animals

Deltamethrin can induce skin sensations in people working with the compound (FAO/WHO, 1986). Several non-fatal cases of poisoning have been reported through occupational exposure resulting from neglect (FAO/WHO, 1986). These include numbness, itching, tingling, and burning of the skin; occasionally, a transient popular or blotchy erythema has been described and most of these symptoms are transient and disappear within 5-7 days (FAO/WHO, 1986). All these symptoms could be due to the presence of Hydrogen cyanide (HCN). From appendix IV we find that degradation of deltamethrin gives HNC as one of it's products. Industrial exposure to hydrogen cyanide solutions has caused dermatitis, itching, scarlet rash, papules, and nose irritation and bleeding. Perforation of the nasal septum has also occurred (Amdur, 1991), which are all the side effects of deltamethrin and most other pyrethroids including lambda-cyhalothrin. Hydrogen cyanide can cause rapid death in humans due to metabolic asphyxiation. Death can occur within seconds or minutes of the inhalation of high concentrations of hydrogen cyanide gas. A recent study reports an estimated LC$_{50}$ in humans of 3,404 ppm for a 1-minute exposure; other sources report that 270 ppm is fatal after 6 to 8 minutes, 181 ppm
after 10 minutes and 135 ppm after 30 minutes [Hathaway et al., 1991]. Therefore pyrethroids are not as safe as we think. In a non-aqueous vehicle, the acute oral toxicity of deltamethrin is high to moderate with LD$_{50}$ values of 19-34 mg/kg (rat) (Mestres et al., 1986). However, in a suspension in water, the toxicity is much less with LD$_{50}$ values exceeding 5000 mg/kg (rat). Clinical signs of poisoning by deltamethrin include tremor, salivation, and convulsion (Mestres et al., 1986).

1.4 Lambda-cyhalothrin

Lambda-cyhalothrin is a synthetic pyrethroid insecticides and acaricides used to control a wide range of pests in a variety of applications. Pests controlled include aphids, colorado beetles, and butterfly larvae (Royal Society of Chemistry, 1991). The crops on which it may be applied include cotton, cereals, ornaments, potatoes and vegetables. The molecular formular is C$_{23}$H$_{19}$C$_1$F$_3$N$_0$$_3$.

Lambda-cyhalothrin is a colourless solid at room temperature. Lambda-cyhalothrin is rapidly hydrolysed under alkaline conditions but not in neutral or acidic media. The minimum detection limit of lambda-cyhalothrin during the analysis done by FAO/WHO joint is 0.005 mg/kg (FAO/WHO, 1986). Trade names for products containing lambda-cyhalothrin include charge, excaliber, grenade, hallmark, icon and karate (Hart, 1984). In Kenya it has the trade name karate.
1.4.1 Effects of lambda-cyhalothrin on humans and animals

Lambda-cyhalothrin is known to produce an effect described as subjective facial sensation (SFS) in some people who work with this compound (Hart, 1984), of which could be due to HCN. The extent of sensation is more likely to be related to the amount of the chemical that comes into contact with the facial skin (Hart, 1984). Signs of intoxication are characteristic of type II pyrethroid toxicity and include piloerection, subdued behavior, ataxia, unsteady gait, salivation, incontinence, scouring, and chromodacryorrhoea (Nixon et al., 1981). High levels of these insecticides on consumable foods can be injurious to the population and hence the need for continued monitoring of the levels of pesticides residues in vegetables.

Deltamethrin are more most powerful than the lambda-cyhalothrin (Bradbury and Coats, 1989). Structurally deltamethrin contains some bromide atoms while the lambda-cyhalothrin contains fluorine atoms.
1.5 Statement of the problem and justification

Vegetables are important in neutralizing acids produced during digestion and also useful as roughage. They are important sources of minerals, vitamins and proteins. Unfortunately pests and diseases frequently attack them. Therefore, it is necessary for farmers to use chemicals to control pests and diseases that attack vegetables. Pesticides are widely used to prevent damage by pest and preserve self-life. Toxic residues of these pesticides applied on the vegetables can be injurious to human health, environment, birds, and to the fish (Shan, 1989). There is therefore, need for monitoring the amount of the pesticide residues in farm products. Two types of pyrethroids; deltamethrin and lambda-cyhalothrin are commonly used in vegetables. Farmers rarely apply pesticides on vegetables during the wet season, reason being that, there are hardly any pests on vegetables during this season. During the wet season also there is an issue of the wash off of the pesticides by the rainwater. Therefore, the two pyrethroids’ residue levels in the vegetables during the dry and wet seasons were investigated.

The vegetables consumed in urban areas mainly are obtained from the large-scale farms where by farmers grow them for commercial purposes, while most of the vegetables consumed in rural areas are grown by the farmers in small scale farms mostly for there own consumption. The study therefore analysed samples from the urban and rural areas. An experimental garden was used to check whether there were still some residues left after the elapse time.
1.6 Hypotheses

i. Vegetables consumed in Kenya contain high levels of deltamethrin and lambda-cyhalothrin residues during the dry seasons than during the wet seasons

ii. Vegetables consumed in the urban areas have higher levels of deltamethrin and lambda-cyhalothrin than those consumed in the rural areas

iii. Deltamethrin and lambda-cyhalothrin residues in kales decrease with time

1.7 Objectives

1.7.1 General objective

To determine the amount of some pyrethroid insecticide residues in selected vegetables.

1.7.2 Specific objectives

i. To determine the levels of pyrethroids - deltamethrin and lambda-cyhalothrin in kales, cabbages and tomatoes sold in urban area – Nairobi (Gikomba, Githurai and Ngara) during both dry and wet seasons.

ii. To determine the levels of pyrethroids - deltamethrin and lambda-cyhalothrin in vegetables sold in rural area – Makuyu during dry and wet seasons

iii. To determine the effects of time on the levels of deltamethrin and lambda-cyhalothrin residues in kales, during both dry and wet seasons in an experimental garden.
1.8 Scope and limitation of the study

This study dealt with three commonly used vegetables in Kenya. The vegetables are kales (sukuma wiki) (*Brassica Oleracea A*.), cabbages (*Brassica Oleracea C.*) and tomatoes (*Lycopersicon Esculentum*). Many types of pesticides are used but only two types of pyrethroids were analyzed in this study- deltamethrin and lambda-cyhalothrin. This is because these two types of pyrethroids are the most commonly used pesticides on vegetables in Kenya today. Also due to time limit, lack of enough finances and limited time that was available for the analysis, all pesticides could not be dealt with. The samples were obtained from three urban areas in Nairobi (Gikomba, Githurai and Ngara) and one rural area- Makuyu district. Only one rural area (Makuyu) was dealt with in this study because it is a large area that is representative enough to other rural areas and also due to limited finances and time available for the study more rural areas could not be handled. On the experimental garden, only kales were planted and analysed because they are the most commonly consumed vegetables in Kenya. Kales also take a short period to mature after planting than other vegetables. They were analysed for deltamethrin and lambda-cyhalothrin for five consecutive days after application for three times.
CHAPTER TWO
LITERATURE REVIEW

2.1 Vegetables

Vegetables play a vital role by providing variable vitamins and minerals in the diet, besides supplying protein and energy. The nutrients from the vegetables help in overcoming common disorders like anaemia, deficiency disorders and other ailments in human beings. Vegetables are considered as “protective supplement food” as they contain large quantities of minerals, vitamins, and essential aminoacids, which are required for normal functioning of the human metabolic processes. The vegetables considered in this study are kales, tomatoes, and cabbages, and are briefly discussed in the following subsections.

2.1.1 Tomatoes (Lycopersicon esculentum)

Tomato is one of the most popular vegetables in many countries (Shan, 1989). They have an annual production of 48 million tones (Shan, 1989). In England it is known as ‘Love apple’. It belongs to family Solanaceae which includes other important members like, potato and chilli. Tomato is an annual warm season crop. It is grown in nearly all-home gardens by a large percentage of market gardeners and truck growers. It is also grown as a ‘force crop’ under green house conditions, and as a processing crop it ranks first among the vegetables (Shan, 1989).

Several studies have been done on the analysis of deltamethrin in tomatoes; a study carried out in Germany in 1979 and 1980 obtained the mean residue levels of
deltamethrin in tomatoes as 0.28 and 0.11 mg/kg respectively (Shan, 1989) and another study carried out in South Africa in 1980 on the analysis of deltamethrin in tomatoes obtained a mean residue level of 0.05 mg/kg (Shan, 1989). Appendix XXVI shows a plate of tomatoes growing in a garden.

2.1.2 Cabbage (*Brassica oleracea* A.)

Cabbage is classified as a slow growing biennial vegetable with a distinct period of growth cycle. According to Misra and Singh (1979), cabbage is a cool season crop, which prefers cool moist climate with a monthly average temperature of 15 °C to 0 °C. Cabbage is used both for cooking and for salad. It is also used for pickling or *saner krint*. Cabbage soup is good and nourishing. Appendix XXVII shows a plate of the Researcher buying cabbages for the study at Githurai market in Nairobi; Githurai is one of the popular markets with fresh cabbages and other vegetables.

Being a cool-season crop, cabbage thrives and performs well in cool moist climate, and can tolerate frost and extremely cold temperature, and may be grown in all types of soils (Vasconelles and Minami, 1981).
2.1.3 Kales (*Brassica oleracea* C.)

Kales are very good source of minerals and vitamins. They have very crinkled, decorative leaves. They survive well even in worst winters. They thrive in well-cultivated soil and limed soil that is less acidic, preferably in manured soils (Larkam, 1976). Appendix XXVIII is a plate showing Kales growing in a garden.

Tomatoes, kales and the cabbages normally are attacked by same type of pests which includes; aphids, colorado beetles, and butterfly larvae (Royal Society of Chemistry, 1991). These pests are mostly controlled by the use of pyrethroid pesticides whereby; deltamethrin and lambda-cyhalothrin are the commonly used. Appendix XXIX show plate of a farmer spraying kales with pesticide.

2.2 Synthetic pyrethroids - a profile

The pyrethroids constitute another group of insecticides in addition to organochlorine, organophosphorus, carbamate, and other compounds. Several of the earlier synthetic pyrethroids were successfully commercialized, mainly for the control of household insects. Other more recent pyrethroids have been introduced as agricultural insecticides because of their excellent activity against a wide range of insect pests and their non-persistence in the environment (Leahey, 1985).

Chemically synthetic pyrethroids are esters of specific acids and alcohols. Among the classes of insecticides, the six natural pyrethrins (See Appendix I) are unique for the intensity rapidity of their action against many species of insects combined with minimal
hazard to mammals under normal conditions. However, all six esters are decomposed in air and light with loss of insecticidal activity and only limited stabilization if feasible (Allan and Miller, 1990). The greatly expanded application of pyrethroids referred to above has been associated with synthetic variants of the natural esters, which are relatively more stable in air and light. A number of commercial pyrethroids are available. These includes; deltamethrin, lambda-cyhalothrin, allethrin, resmethrin, d-phenothrin, cypermethrin, fenvalerate, permethrin, kademthrin, tellallethrin, cyhalothrin among others.

An important characteristic of pyrethroids is their differential potency between insects and mammals (Casida et al., 1983). Toxicological evaluations of several synthetic pyrethroids have been performed by FAO/WHO joint meeting on pesticide residues (JMPR) (FAO/WHO, 1996). The acceptable daily intake (ADI) has been estimated by the JMPR for lambda-cyhalothrin, deltamethrin, cypermethrin, fenvalerate, permethrin, d-phenothrin, cyfluthrin, cyhalothrin, and flucythrinate and others (FAO/WHO, 1996).

2.3 Deltamethrin

Technical grade deltamethrin is an odourless white powder with a melting point of 98-101 °C and contains more than 98 % of the material. The vapour pressure is $2.0 \times 10^{-6}$ pa at 25 °C and it is practically non-volatile. It is insoluble in water, but soluble in organic solvents, such as acetone, cyclohexane, and xylene (FAO/WHO, 1986).
2.3.1 Residues of deltamethrin in food

Supervised trials have been carried out on a wide variety of crops and comprehensive summaries of analyses for residues in these trials can be found in the evaluation reports of the Joint FAO/WHO Meeting on Pesticide Residues (JMPR) (FAO/WHO, 1996).

Deltamethrin was first reviewed in 1982, when a temporary ADI of 0-0.01 mg/kg was estimated (FAO/WHO, 1996). The previously estimated guidelines on pesticide residues on a wide variety of agricultural commodities were converted to temporary maximum residue levels. Residues found in further trials and in good agricultural practice have shown that some of the temporary MRLs are too low. A summary of residue data on leafy vegetables (lettuce and spinach) and fruiting vegetables with edible peel (cucumber, peppers and tomatoes) is available (FAO/WHO, 1996).

Table 2.0 The estimated deltamethrin Maximum Residue Limits (MRLs) for some commodities in mg/kg

<table>
<thead>
<tr>
<th>Commodity</th>
<th>MRL (mg/kg)</th>
<th>Previous estimate (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leafy vegetables</td>
<td>0.50</td>
<td>0.20</td>
</tr>
<tr>
<td>Fruit ing vegetables with edible peel</td>
<td>0.20</td>
<td>0.05</td>
</tr>
<tr>
<td>Wheat flour (wholemeal)</td>
<td>1.00</td>
<td>2.00</td>
</tr>
</tbody>
</table>

Source: FAO/WHO, 1996
2.3.2 Environmental impacts of deltamethrin

Deltamethrin was first marketed in 1977 (Anderson et al., 1981). It is a pyrethroid insecticide that kills insects on contact. It is used in control of insects in cotton, vegetables, cereals, ornaments and field crop (Anderson et al., 1981).

When used alone deltamethrin is effective against most plant pests except cotton mites and cotton boll weevils. It may be applied to food and field crops, market gardens, orchards and vineyards by air or ground spray equipment, at rates recommended by the manufacturer. It may also be sprayed on greenhouse plants, on buildings and other inert surfaces, and on animals. Special formulations for oral or dipping applications have also proved effective against cattle ectoparasites. After an initial period when the product was mainly used on cotton, several major crops were treated with deltamethrin from 1980 to 1987. Some 85% of the total production is used for crop protection. Within this, 45% is used on cotton, 25% on fruit and vegetable crops, 20% on cereals, corn and soybean, and remaining 10% on miscellaneous crops (Anderson et al., 1981).

Deltamethrin is used to protect stored commodities (mainly cereals, grains, coffee beans, and dry beans), in forestry, and in public health to control diseases (for example, chagas disease control in South America, and malaria control in Central America and on the African continent) (Roussel, 1982). It is also used in animals’ facilities and against cattle pest infestation. It is formulated as an emulsifiable concentrate (25-100 g/litre), an ultra-low-volume concentrate (1.5-30 g/litre), a wettable powder (25-50 g/kg), or a dust
powder (0.5-2.5 g/kg) (Roussel, 1982). It is also used in combination with other pesticides and with piperonyl (Roussel, 1982). Deltamethrin has an elapse time of one day according to the manufacturer’s instructions.

2.3.3 Toxicological effects of Deltamethrin to living organisms

Acute exposure of Deltamethrin effects in humans include the following: Ataxia, convulsions leading to muscle fibrillation and paralysis, dermatitis, edema, diarrhea, dyspnea, headache, hepatic microsomal enzyme induction, irritability, peripheral vascular collapse, rhinorrhea, serum alkaline phosphatase elevation, tinnitus, tremors, vomiting and death due to respiratory failure (Hallenbeck and Cunningham-Burns, 1985). Allergic reactions have included the following effects: Anaphylaxis, bronchospasm, eosinophilia, fever, hypersensitivity pneumonia, pallor, pollinosis, sweating, sudden swelling of the face, eyelids, lips and mucous membranes, and tachycardia (Hallenbeck and Cunningham-Burns, 1985).

Suspected chronic exposure effects in humans include the following: Choreoathetosis, hypotension, prenatal damage and shock (Hallenbeck and Cunningham-Burns, 1985). Workers exposed to Deltamethrin during its manufacture for over 7-8 years experienced transient cutaneous and mucous membrane irritation, which could be prevented by use of gloves and facemasks (Hayes and Laws, 1990). The dose without activity in rats over a 90-day period was 10 mg/kg/day (Worthing, 1983).

Deltamethrin was slightly embrotoxic in a three-generation rat study but did not adversely affect reproduction. Deltamethrin did induce significant maternal and perinatal pup weight losses, which were reversed upon cessation of treatment and weaning,
respectively (Krasnykh and Pavlova, 1980). A reproductive 3-generation study in rats reported a reproductive NOEL (No effect level) greater than 2.5 mg/kg/day. Levels tested were 0, 0.1, 1.0 and 2.5 mg/kg/day (U.S. Environmental protection Agency, 1988). Oral administration of deltamethrin to mice on days 7-16 of gestation produced a dosage-related reduction of weight gain but no effect on the number of implants, fetal mortality, fetal weight or malformations (Hayes, 1982).

Deltamethrin has no mutagenic activity (Hayes and Laws, 1990). There was no evidence in the rat, mouse or dog long-term diet studies that deltamethrin caused an increased tumour incidence. This finding, supported by microbial, mammalian cell and in vivo mammalian mutagenic studies suggests that deltamethrin has no carcinogenic potential.

### 2.3.4 Ecological effects of deltamethrin

As is common with many pyrethroids, deltamethrin has a high toxicity to fish under laboratory conditions. However, in field conditions under normal conditions of use, fish are not harmed. Aquatic fauna, particularly crustacea, may be affected (Worthing, 1983). Deltamethrin was found to have an impact on aquatic herbivorous insects, which led to an increase of algae (Worthing, 1983).

Deltamethrin is considered toxic to bees (Leahey, 1985). Deltamethrin had little or no effect on adults or cocoons of *Apanteles plutellae*, a parasite of the diamond back moth in India. Spiders were also indicated to be strongly affected in field investigations (Hayes and Laws, 1990). Deltamethrin is very toxic over long periods to the predatory mite *Typhodromum pyri*, and the parasitic wasp *Encarsia formosa*, released in greenhouses to
combat whitefly, is too sensitive to allow a treatment with deltamethrin against excessive outbreaks of whiteflies (Haug and Hoffman, 1990).

2.3.5 Environmental transport, distribution and transformation of deltamethrin

Degradation pathways for deltamethrin are summarized in Appendix XVI. Muir et al. (1985) monitored the fate and uptake of $^{14}$C-labelled deltamethrin in organisms in experimental ponds over 306 days. Their results indicated that initial concentrations of the pyrethroid ranged from 1.8-2.5 µg/litre. The deltamethrin rapidly became distributed in suspended solids, plants, sediment, and air with a half-life of 2-4 h in the water. Aquatic plants (the floating duckweed *Lemna* sp. and a submerged/floating weed (*Potomageton berchtoldi*) accumulated deltamethrin at concentrations of between 253 and 1021 µg/kg respectively, 24 h after treatment, but the compound had all disappeared within 14 days (Muir et al., 1985). Fathead minnows, *Pimephales promelas*, showed bioconcentration factors of 248-907 (Muir et al., 1985). Although radioactivity remained in the fish throughout the experimental period, presumably in the fat, the levels fell steadily and no effects were seen on the fish (Muir et al., 1985).

Using three different soils (silty clay, silty clay loam, and loamy sand), Kaufman et al. (1981) found that deltamethrin was practically immobile in soil columns. In soil, degradation occurs within 1-2 weeks (Kidd and James, 1991). Deltamethrin in pond water was most rapidly adsorbed by sediment, in addition to uptake by plants and evaporation into the air (Haug and Hoffman, 1990).
2.3.6 Mode of action of deltamethrin on target species

Deltamethrin is a synthetic insecticide based structurally on natural pyrethrins, which rapidly paralyze the insect nervous system giving a quick knockdown effect (Haug and Hoffman, 1990). It kills insects on contact and through digestion. It is used to control apple and pear suckers, plum fruits moth, caterpillars on brassicas pea and aphids on vegetables. Deltamethrin has a rapidly disabling effect on feeding insects (Hayes and Laws, 1990).

Deltamethrin's mode of action is thought to be mainly in central in action (in central nervous system), or at least originate in higher nerve centers of the brain. This must be due to the HNC of the deltamethrin. Death of insects seems to be due to irreversible damage to the nervous system that occurs when poisoning lasts more than a few hours (Leahey, 1985). Deltamethrin poisoning occurs through cuticular penetration or oral uptake. The susceptibility of insects is dependent on a variety of factors and can vary, with many insecticides, depending on the environmental conditions. Flies are most susceptible to pyrethroid poisoning shortly before dawn and the LD$_{50}$ drops by the factor of 2 as compared to full daylight activity (Haug and Hoffman, 1990; Bradbury and Coats, 1989). Table 2.1 shows the maximum Residue Limits of deltamethrin (MRLs) in mg/kg suggested by FAO/WHO (1986).
Table 2.1 The MRLs of deltamethrin in some commodities in mg/kg

<table>
<thead>
<tr>
<th>Commodities</th>
<th>MRL (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tea</td>
<td>10.0</td>
</tr>
<tr>
<td>Hops dry, wheat bran unprocessed</td>
<td>5.0</td>
</tr>
<tr>
<td>Coffee beans (post-harvest)</td>
<td>2.0</td>
</tr>
<tr>
<td>Wheat wholemeal, cereal grains, (Ph) lentil (dry), beans (dry), Field pea (dry)</td>
<td>1.0</td>
</tr>
<tr>
<td>Straw and fodder (dry) of cereal Grains, legume animal feeds (dry Weight), leafy vegetables</td>
<td>0.5</td>
</tr>
<tr>
<td>Artichokes, bananas, clementines, Coco beans, grapes, kiwi fruit, Oranges (sweet, sour), stone Fruits/strawberries</td>
<td>0.05</td>
</tr>
<tr>
<td>Legume oilseeds, melons, Mushrooms, pineapples, root and Tuber vegetables, milks</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Source: FAO/WHO, 1986

2.4 Lambda-cyhalothrin

Lambda-cyhalothrin controls pests like, aphids, colorado, beetles, and butterfly larvae (Royal Society of Chemistry, 1991). Technical grade lambda-cyhalothrin is yellow-brown viscous liquid (melting point of approximately 10 °C) and contains more than 90 % active material. It is composed of four cis isomers in the ratio of 1:1:1:1. Although it is insoluble in water, it’s soluble in a range of organic solvents such as aliphatic and aromatic hydrocarbons. It is stable to light and heat and has low vapour pressure.
Lambda-cyhalothrin is highly stable to light and at temperature below 220 °C (Hart, 1984). It is also stable in water at pH 7 and pH 9 and has a half-life of 7 days; and there is racemization at the alpha-cyano carbon to yield a 1:1 mixture of enantiomer pairs (Hart, 1984). At pH 9, the ether bond is fairly readily hydrolysed (Collis and Leaheys, 1984). Lambda-cyhalothrin has an elapse time of three days according to the manufacturer’s instructions.

2.4.1 Residues of lambda-cyhalothrin in food

Supervised trials have been carried out on a variety of crops, and comprehensive summaries of residue analysis in these trials are found in the evaluation reports of the joint FAO/WHO meeting on pesticide residues (JMPR) (FAO/WHO, 1996).

Data reviewed by the JMPR showed that in studies on apples and pears, when different rates of application were used in the same trial, initial residues reflected the different rates applied (FAO/WHO, 1996). When the spray programme was doubled from three to six applications per season, there was no increase in the lambda-cyhalothrin residue levels over those obtained with the three applications programme at the same rates (FAO/WHO, 1996). Lambda-cyhalothrin residue levels on apples often declined relatively slowly, although this was not always the case. There were no obvious differences in residue levels arising from the use of the different strengths of emulsion concentrate formulations or from the use of either low volume or high volume rates of application (FAO/WHO, 1996).
2.4.2 Transportation and distribution of lambda-cyhalothrin between media

Lambda-cyhalothrin has a low potential for leaching owing to its low solubility in water and strong adsorption to soil. It is unlikely to volatilize from moist soil and water surfaces based on its low vapour pressure and Henry's Law Constant. Lambda-cyhalothrin is stable to hydrolysis at pHs ≤ 7, but at pHs greater than 7, hydrolysis becomes more important as a route of transformation (FAO/WHO, 1986). Lambda-cyhalothrin on soil is not photo transformed in the environment, however in the photic zone of aquatic systems, phototransformation may be important (Bennett et al., 1997).

As the potential use pattern of lambda-cyhalothrin involves indoors residential (structure, surrounding soil, ornamental and residential outdoor), and this molecule is not highly mobile in the soil, it is unlikely that lambda-cyhalothrin migrates from the treated area to the open water where aqueous photolysis could occur. Consequently, under the use pattern, the formation of phototransformation products is unlikely (McCall et al., 1981).

Lambda-cyhalothrin degradation in the outdoor environment may occur by either biological or photochemical processes. In most cases, biological processes are by far the most important, although photochemical reactions can sometimes contribute to the degradation of residues on exposed surfaces. At residue level that are likely to occur under normal field conditions, lambda-cyhalothrin is degraded rapidly in soil (Bennett et al., 1997).
2.4.3 Metabolism of lambda-cyhalothrin in living organisms

In studies by Leahey (1985), soya beans plants were treated with $^{14}$C-cyhalopropane –labelled and $^{14}$C-benzyl-labelled lambda-cyhalothrin. The plants were analysed at maturity, 39 days after the second application, which left radioactive residues on the leaves ranging from 1.2 mg/kg (benzyl-labelled treatment) to 1.5 mg/kg (cyclopropane-labelled treatment), and very little radioactivity was translocated into seeds (< 0.01 mg/kg) (Leahey, 1985).

At harvest, the major constituents of the radioactive residue on the leaves of both cotton and soya beans were lambda-cyhalothrin and other isomeric forms of lambda-cyhalothrin resulting from photochemically initiated interconversions (Soya: 52 % benzyl-label, 45% cyclopropane-label, cotton: 52 % benzyl-label, 37 % cyclopropane-label) (US Environmental Protection Agency, 1988). The metabolites detected on the leaves of both plants resulted from a range of hydrolytic and oxidative reactions (US Environmental Protection Agency, 1988). A metabolic pathway of lambda-cyhalothrin in plant illustrating these reactions is shown in Appendix V.

Karate was found to be non-irritating to the skin of rabbits (US Environmental Protection Agency, 1988), and non-sensitizing to the skin of guinea pigs (Royal Society of Chemistry, 1991) but may cause mild eye irritation in rabbits (US Environmental Protection Agency, 1988). Primarily eye irritation was observed with the technical product (US Environmental Protection Agency, 1988).
In two studies, lambda-cyhalothrin caused reduced body weight gain at doses of 15 mg/kg per day in pregnant rats (highest dose tested) and at doses of 30 mg/kg per day in pregnant rabbits also the highest dose tested but these doses produced no observable reproductive effects (US Environmental protection agency, 1988). Lambda-cyhalothrin produced negative results in all mutagenicity assays (Royal Society of Chemistry, 1991). Results of other in-vitro cycogenetic assays and chromosomal structure aberration tests indicated no mutagenic or genotoxic effects (Meister, 1992). The nervous system however may be affected after acute exposure (US Environmental Protection Agency, 1988).

2.4.4 Ecological effects of lambda-cyhalothrin

Lambda-cyhalothrin's toxicity to birds ranges from slightly toxic to practically non-toxic. In the mallard deck, the reported oral LD$_{50}$ is greater than 3,950 mg/kg (Kidd and James, 1991; US Environmental Protection Agency, 1988), and the reported dietary LC$_{50}$ is 3,948 ppm (US Environmental Protection Agency, 1988). There is evidence that lambda-cyhalothrin does not accumulate in the eggs or tissue of birds (Kidd and James, 1991). Lambda-cyhalothrin is highly toxic to many fish and aquatic invertebrate species, with reported LC$_{50}$ in bluegill and sunfish is 0.21 µg/L (Kidd and James, 1991).

Bioconcentration is possible in aquatic species, but bioaccumulation is not likely. Bioconcentration in channel catfish has been reported as minimal, with rapid elimination (US Environmental Protection Agency, 1995). A bioconcentration factor of 858 has been
reported in fish (4, species unspecified), but concentration was confined to non-edible tissues and rapid depuration was observed (US Environmental Protection Agency, 1988).

### 2.4.5 Previous evaluations by international bodies

Lambda-cyhalothrin was discussed at the 1984 and 1986 FAO/WHO joint meeting on pesticide residues (JMPR), where an acceptable daily intake (ADI) for cyhalothrin of 0-0.02-mg/kg-body weight was established (FAO/WHO, 1996). Very little has been done on levels of pyrethroids in vegetables, fruits and other foods in this country and therefore, there is need to determine the levels of some pesticides in food grown in Kenya. Table 2.2 shows the estimated maximum residue limits (MRLs) for lambda-cyhalothrin in some commodities by JMPR (FAO/WHO, 1996).

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Maximum residue limit (mg/kg)</th>
<th>Pre-harvest interval (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pome fruits</td>
<td>0.2</td>
<td>14</td>
</tr>
<tr>
<td>Vegetables</td>
<td>0.2</td>
<td>3-4</td>
</tr>
<tr>
<td>Potatoes</td>
<td>0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Non-specified</td>
</tr>
<tr>
<td>Cotton seed</td>
<td>0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>21</td>
</tr>
<tr>
<td>Cotton seed oil, crude</td>
<td>0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Non-specified</td>
</tr>
<tr>
<td>Cotton seed oil, edible</td>
<td>0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Non-specified</td>
</tr>
</tbody>
</table>

Source: JMPR (FAO/WHO, 1996)
2.5 Methods of analysis

Pyrethroids are usually analyzed using chromatographic techniques including: Gas Liquid Chromatography (GLC) (Nakamura et al., 1990), High Performance Liquid Chromatography (HPLC) (Ando et al., 1986) and Thin Layer Chromatography (TLC) (Jork et al., 1981). The TLC is much slower than the other chromatographic methods. The HPLC technique was used for this study because of speed, selectivity, sensitivity and availability.

2.5.1 Scope of HPLC

High performance liquid chromatography is the most widely used of all the analytical separation techniques, with annual sales of HPLC equipment approaching the billion-dollar mark worldwide (Brown et al., 1990). The reasons for the popularity of the method are its sensitivity, its ready adaptability to accurate quantitative determinations, its suitability for separating non-volatile species and thermally fragile ones, and above all, its widespread applicability to substances that are of prime interest to industry, to many fields of science, and to the public. Examples of such materials include amino acids, proteins, nucleic acids, hydrocarbons, carbohydrates, drugs, terpenoids, pesticides, antibiotics, steroids, metal-organic species, and a variety of inorganic substances (Brown et al., 1990).

HPLC is a fast growing separation technique suitable for the analysis of technical and formulated material of pyrethroids. This method is better than GLC in that some pyrethroids do not degrade since the procedure does not involve high temperatures. The
UV has emerged as the most popular HPLC detection although refractive index, and fluorescence have also been used in pyrethroids analysis (Brown et al., 1990). Due to increased availability of HPLC in the modern analytical chemistry laboratory, this methodology has become very popular in the quantification of pyrethroids. HPLC can analyze many compounds at a very short time. In HPLC liquid is used as the mobile phase; where all four modes of separation including surface adsorption, partition, ion exchange, and exclusion are possible.

In order to realize reasonable eluent flow rates with parking in the 5 to 10 μm particle sizes, which are common in modern HPLC, pumping pressure of up to several thousands, pounds per square inch are required. As a consequence of these high pressure, the equipment required for HPLC tends to be more elaborate and expensive than that encountered in other liquid chromatographic techniques. As the bands migrate they always broaden and resolution of components into discrete separate bands will occur only if the bands widen to lesser extent than their maxima separate. For a well-behaved chromatograph the peaks should be symmetrical i.e. have Gassian shape (Simpson, 1986). Figure 2.0 is a block diagram of HPLC.
3.1 Research design

3.1.1 Area of study

The research had two parts: The first part was to determine the residue levels of some pyrethroids (deltamethrin and lambda-cyhalothrin) in vegetables sold in the markets in the urban and rural areas during the dry and wet seasons in Kenya. The urban area was Nairobi city, which included Githurai, Ngara and Gikomba, while the rural area was Makuyu. The second part involved planting kales in an experimental garden, applying the pyrethroids (deltamethrin and lambda-cyhalothrin) on them and then monitoring the pyrethroids' residue levels over a period of five days.

3.1.2 The Experimental garden

In this project a small plot of 5 m by 10m was planted with vegetables to act as an experimental garden. This was done at Kenyatta University. The plot was divided into two equal portions of 5 m by 5 m, and kales were evenly planted. The first portion was sprayed with deltamethrin and the second portion was sprayed with lambda-cyhalothrin. The spraying was done after every seven days as per the manufacturers' instructions. This was repeated three times.

The vegetable samples were picked randomly and separately from the two portions, for five consecutive days after spraying. The deltamethrin has a lapse time of 1 day after application while lambda-cyhalothrin has a lapse time of 3 days after application. The analysis of pyrethroid residues was therefore done for 5 consecutive days on the three
different samples from the two portions. This was to investigate whether the farmers follow the manufacturers’ instructions before and after application.

3.2 Cleaning of glass and plastic containers

All the glassware used in this study was soaked for 12 hours in freshly prepared chromic acid. They were then rinsed with distilled-deionised water. They were then soaked in distilled-deionised water for about 6 hours to leach off any adsorbed chromic ions. Finally they were dried in an open rack after rinsing them with fresh distilled-deionised water. Plastic containers were thoroughly cleaned with a detergent and then rinsed several times with 6 M Analar nitric acid. They were then rinsed thoroughly with distilled-deionised water and dried in an open rack.

3.3 Instruments

The following instruments were used in this study:

i. Rotatory vacuum evaporator (Rotavapor R with a bath temperature of 40 °C).

ii. HPLC- Beckman system gold series coupled with diode array detector module 168, with variable injector and wavelength detector.

iii. Centrifuge

iv. Blender
3.4 Reagents and solvents

The reagents used in this study were as follows:

i. Hexane-Glass distilled—from Kobian distributors limited (Nairobi, Kenya)

ii. Acetone- Glass distilled—from Kobian distributors limited (Nairobi, Kenya)

iii. Florisil—from Kobian distributors limited (Nairobi, Kenya)

iv. Diethyl ether- Glass distilled—from Kobian distributors limited (Nairobi, Kenya)

v. Deltamethrin-from Aldrich chemicals limited, Britain

vi. Lambda-cyhalothrin-from Aldrich chemicals limited Britain

vii. Acetonitrile- HPLC grade—from Kobian distributors limited (Nairobi, Kenya)

3.5 Sampling and sample pre-treatment

The vegetable samples analysed for the two pyrethroids (deltamethrin and lambda-cyhalothrin) were obtained using the random method of sampling from both rural (Makuyu) and urban -Nairobi (Gikomba, Ngara and Githurai) areas, and from the experimental garden. Appendix XXX shows a plate of the three types of vegetables that were analysed in this study. The vegetable samples was bought and stored in refrigerator.

The sampling was done during both dry and wet seasons. A total of 120 samples were collected, which were analysed in duplicates, for the two pyrethroids from both the urban and rural areas. Other samples were collected from the experimental garden where only kales were planted. According to the manufacturers’ instructions the elapse time for
deltamethrin is 1 day and the lambda-cyhalothrin is 3 days. Therefore, fifteen samples were analysed in duplicate for each pyrethroid during each season; that is, five samples after each application making a total of 60 samples analysed in duplicate.

Therefore, 180 samples were collected and analysed in duplicates in the whole study.

3.6 Sample extraction and clean-up procedure

The same procedure for extraction and clean-up was used for the two pyrethroids (Hill et al., 1982).

3.6.1 Extraction

Prior to extraction of the pyrethroids (deltamethrin and lambda-cyhalothrin), vegetable samples were rinsed in organic free water. In this case, 50.00 g of each vegetable sample were weighed in mason jars. The sample was blended in 100 mL of the extracting mixture of solvents in the ratio of 1:1 (50 mL of hexane and 50 mL of acetone) for about 5 minutes. The slurry was allowed to stand for about 16 hours (to ensure proper extraction), in temperatures of – 4 °C. This was then filtered using the qualitative Whatman filter papers number 1 in a vacuum.

3.6.2 Clean-up processes

Partitioning and column chromatographic clean-up processes were used as described by (Takimoto et al., 1984).
3.6.2.1 Partitioning—for clean-up

Partitioning is usually used as a preliminary clean up prior to column chromatography. In this study therefore, partitioning was done on the filtrate in hexane using 125 mL separatory funnel. This was to make the pyrethroids (deltamethrin and lambda-cyhalothrin) present in the sample dissolve in the hexane because they were both more soluble in hexane than in acetone. The partitioning process also assisted in removing the acetone (lower layer) from the filtrate. The partitioning solvent used in the study was hexane. The partitioning process conditions were adjusted so that the partition coefficient becomes favorable for the transfer of the pesticides into the desired phase. The filtrate was then concentrated by evaporating much of the hexane using the rotatory vacuum evaporator (Rotavapor R with a bath temperature of 40 °C). Further clean up was then done without delay; otherwise, the pyrethroids would be degraded due to high temperatures.

3.6.2.2 Column chromatography—for clean-up

The sample was then cleaned-up using the chromatographic column (50 cm × 1 cm) packed with florisil—the best packing material for pesticides (Takimoto et al., 1984), with a mixture of hexane and diethyl ether in the ratio of 1:6 as the eluent. The sample was then dried on a rotatory vacuum evaporator (Takimoto et al., 1984).

3.7 Preparation of standards

0.25 g of the pyrethroid standard was weighed into a 250 mL volumetric flask and dissolved to the mark with methanol to make a solution of 0.001 g/mL. Therefore the
known concentrations of 0.001 mg/g of both deltamethrin and lambda-cyhalothrin standards was used in the calculations in order to determine the unknown residue concentrations of the samples in mg/kg. Standards were stored at 4 °C.

3.8 Sample analysis

A 0.25 g of the cleaned up sample was weighed into 250 ml volumetric flask, then dissolved to the mark with methanol. Equal volumes of samples and standards were prepared using methanol with a known concentration of the standard. A 20 µl portion of the sample and standard solutions was injected into the HPLC. The concentration of the standard and peak area of each peak enabled us to calculate the concentration of the residues. The HPLC elution used in this study was the isocratic elution, and was carried out at International Center of Insects Pathology and Ecology (ICIPE). The HPLC-model that was used is Beckman system gold series coupled with diode array detector module 168, with variable injector and wavelength detector. Detection for deltamethrin and lambda-cyhalothrin were fixed at 290 nm and 210 nm respectively. Separation was carried out on reverse phase octyl column, (25cm x 4.6 mm), 0.5- µm particle size, sigma Aldrich Germany, maintained at ambient temperature.

The HPLC was operated under the following conditions:

a. Eluent: For Lambda-cyhalothrin

Acetonitrile  80%
Water         20%

For Deltamethrin
Acetonitrile  90%
Water      10%

b. Elution: Isocratic
c. Flow rate: 1.4 mL/min
d. Injector (Injection volume- 20 μL)

3.9 Data analysis

The amount of the pyrethroid residues was calculated using the relationship explained by Sherma (1996).

\[ \text{Residue} = \frac{\text{PA (S)}}{\text{PA (std.)}} \times \frac{\text{C (std.)} \times \text{V (S)}}{\text{W (S)}} \text{ mg/kg} \]

Where:

\( \text{PA (S)} \) = Peak area recorded for sample (cm\(^2\))

\( \text{PA (std)} \) = Peak area recorded for reference standard (cm\(^2\))

\( \text{C (std)} \) = The concentration of standard

\( \text{V (S)} \) = Volume of the solvent of extraction (ml)

\( \text{W (S)} \) = Weight of the sample extracted (ml)

The data was analysed statistically using t-test and regression analysis.
CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Introduction

A total of 180 samples of different types of vegetables were analysed in duplicates for deltamethrin and lambda-cyhalothrin. Vegetables were collected during the dry season (January to February and August to September) and wet season (March to April and November to December) from urban and rural areas, while others were picked from the experimental garden. Each sample was analysed in duplicate and the results are presented in this chapter.

4.2 Mean residue levels of deltamethrin in vegetable samples from the urban areas (dry and wet seasons)

Vegetable samples obtained from the urban area during the dry and wet seasons were analysed for deltamethrin. Five samples of each vegetable type were analysed in duplicate during the dry season and also during the wet season making a total of 60 samples as shown in Figure 3.0. The raw data results are as shown in Appendices XIV and XV from where it can be seen that the deltamethrin residue levels were higher during the dry season than during the wet season. Only one sample during the dry season had undetectable levels of deltamethrin unlike the wet season where most of the samples had undetectable levels. The mean residue levels during the dry season varied from non-detectable levels to 0.3800 mg/kg, with kales having the highest level.

The deltamethrin mean residue levels of samples $S_1$ - $S_5$ from the raw data in Appendices XIV and XV are as shown in Table 4.0 and Figure 4.0.
Table 4.0 Mean residue levels of deltamethrin in mg/kg of the samples from the urban areas (Mean ± SD, n=10)

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Dry season</th>
<th>Wet season</th>
<th>t (8, 0.05)</th>
<th>t calculated</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kales</td>
<td>0.2000±0.1000</td>
<td>0.0400±0.0001</td>
<td>2.31</td>
<td>4.40</td>
<td>Significant</td>
</tr>
<tr>
<td>Cabbage</td>
<td>0.0700±0.0200</td>
<td>0.0200±0.0070</td>
<td>2.31</td>
<td>5.27</td>
<td>Significant</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0.1100±0.0400</td>
<td>0.0080±0.0500</td>
<td>2.31</td>
<td>3.60</td>
<td>Significant</td>
</tr>
</tbody>
</table>

It can be see from Table 4.0 that the mean residue levels of deltamethrin in the vegetable samples obtained from the urban areas, ranged between 0.0700 mg/kg and 0.2000 mg/kg during the dry seasons, and between 0.008 mg/kg and 0.0400 mg/kg during the wet season, with kales having the highest level of deltamethrin and cabbage having the least.

From Table 4.0, all the mean residue levels of deltamethrin in the samples analysed during the dry season were significantly higher than those analysed during the wet season. The graphical presentation of this is shown in Figure 4.0

![Figure 4.0 Graphical presentation of mean residue levels of deltamethrin in samples analysed from the urban areas](image-url)
4.2.1 Deltamethrin residue levels in kales from urban areas

Generally, kales are the most consumed vegetables compared to the other types. This is because they mature fast, and are cheap, hence affordable to many people especially the low-income earners. As shown in Table 4.0 and Figure 4.0 the kale samples from the urban areas were found to have a significantly higher deltamethrin mean residue level of 0.2000 mg/kg during the dry season compared to 0.0400 mg/kg during the wet season. ($t_{(8, 0.05)} = 2.31$, $t_{\text{calculated}} = 4.40$). This may be due to wash out effect by the rainwaters. Another reason could be because some farmers rarely apply pesticides on vegetables during the wet seasons. Therefore during the dry season, consumers are exposed to significantly higher levels of deltamethrin than during the wet season. Considering the average daily intake (ADI) recommended by WHO for deltamethrin residues in kales of 0.05 mg/kg (FAO/WHO, 1996), it was found that during the dry seasons consumers were exposed to high levels of deltamethrin in kales but during the wet seasons the levels were lower than ADI. However, the levels of deltamethrin in kales analysed were lower than the MRLs recommended by FAO/WHO (1986), which is 0.5 mg/kg, for both seasons. However if one were to consume 1 kg of kales daily, then they would be exceeding the recommended daily intake during the dry seasons. Kales have higher deltamethrin residue levels than the cabbage and tomatoes.

A study done by Lee and Seeneevassen (1997) on the analysis of deltamethrin in a lettuce sample obtained a value of 0.0020 mg/kg (See Appendix XIII). Deltamethrin residue level obtained from the present study of kale samples from urban area during the wet season of 0.0400 mg/kg was higher than that of Lee and Seeneevassen (1997).
Another study done in France on the analysis of deltamethrin in lettuce by FAO/WHO (1996) (See Appendix X), obtained mean residue level of 0.2100 mg/kg. Comparing this with the mean residue level of the kales analysed from the urban areas during the dry season of 0.200 mg/kg, no significant difference was found between their results and the results of this study ($t_{(5, 0.05)} = 2.57$ and $t_{calculated} = 2.0$).

4.2.2 Deltamethrin residues in cabbages from urban areas

Deltamethrin levels in cabbages consumed in the urban areas were found to be 0.0700 mg/kg during the dry season, which was much higher than the levels obtained during the wet season of 0.0200 mg/kg. There was a significant difference ($t_{(5, 0.05)} = 2.31$ and $t_{calculated} = 5.27$) between the two values. The mean residue level of the deltamethrin in cabbage samples exceeded the ADI recommended by the FAO/WHO (1996) of 0.05 mg/kg during the dry season. However, the mean residue levels of deltamethrin in cabbages during the dry and wet seasons were both less than the Maximum Residue Limits (MRLs) recommended by the FAO/WHO (1996) of 0.5 mg/kg. However, if one has to take many servings (about 1 kg) of cabbages in a day then they may be exposed to higher levels of deltamethrin residues during the dry season than ADI.

Lee and Seeneevassen (1997) reported a deltamethrin residue level in cabbages of 0.0170 mg/kg (See Appendix XXI). Their value is almost equal to that of the present study of 0.0200 mg/kg, in the cabbage samples from the urban areas during the wet season (See Table 4.0), but lower than the mean residue level of deltamethrin obtained during the dry season of 0.0700 mg/kg.
4.2.3 Levels of deltamethrin residues in tomatoes from urban areas

In the case of tomatoes consumed in the urban areas, the same trend was observed where the mean residue level of deltamethrin during the dry season of 0.1100 mg/kg exceeded that of the wet season, which was 0.0080 mg/kg (See Table 4.0 and Figure 4.0). There was therefore a significant difference between the two mean residue levels ($t_{(8, 0.05)} = 2.31$ and $t_{\text{calculated}} = 3.60$). Thus during the dry season consumers were exposed to high levels of deltamethrin and the levels exceeded the WHO’s ADI of 0.05 mg/kg (FAO/WHO, 1996). However the two levels were below the WHO’s MRLs of 0.5 mg/kg (FAO/WHO, 1996).

Lee and Seeenevassen (1997) reported yet another study on the analysis of deltamethrin in tomatoes throughout the year where they obtained a mean residue level of deltamethrin ranging between 0.0040- 1.0700 mg/kg (See Appendix XIII). Assuming that the mean residue level of 1.0700 mg/kg was obtained during the dry season, then the reported value was much higher than for the current study. On the other hand assuming that deltamethrin mean residue level of 0.0040 mg/kg was obtained during the wet season, then the present study’s deltamethrin mean residue levels in the tomato samples obtained during the wet season of 0.0080 mg/kg (Table 4.0 and Figure 4.0), was slightly higher.

The FAO/WHO (1986) reported deltamethrin levels in tomatoes of 0.2800 mg/kg (See Appendix XII). Comparing this value with the deltamethrin mean residue level of 0.1100 mg/kg (Table 4.0 and Figure 4.0) from this study there is no significant difference between the two mean residue levels ($t_{(6, 0.05)} = 2.57$ and $t_{\text{calculated}} = 0.67$). This shows that
the results of deltamethrin obtained in this study are comparable to those obtained by researchers in other countries.

4.3 Deltamethrin mean residue levels in the vegetable samples analysed from the rural areas (dry and wet seasons)

The analysis of deltamethrin was also done on vegetable samples obtained from the rural area during the dry and the wet seasons. Appendices XVI and XVII gives the raw data of the deltamethrin analysis. Five samples of each vegetable type were analysed in duplicate during the dry season and also during the wet season making a total of 60 samples as shown in Figure 3.0.

It can be seen from Appendices XVI and XVII that most of the deltamethrin residue levels were higher during the dry seasons than during the wet seasons in the vegetable samples analysed from the rural area. During the wet season (Appendix XVII) several samples had undetectable levels of deltamethrin unlike during the dry season (Appendices XVI) where only one sample had undetectable levels.

The deltamethrin mean residue levels of samples S1 - S5 from the raw data in (See Appendices XVI and XVII) are as shown in Table 4.1.

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Dry season</th>
<th>Wet season</th>
<th>( t ) ((8, 0.05))</th>
<th>( t ) calculated</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kales</td>
<td>0.1200±0.0300</td>
<td>0.1100±0.0080</td>
<td>2.31</td>
<td>0.71</td>
<td>Not significant</td>
</tr>
<tr>
<td>Cabbage</td>
<td>0.1400±0.0800</td>
<td>0.0012±0.0016</td>
<td>2.31</td>
<td>3.87</td>
<td>Significant</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0.0800±0.1300</td>
<td>0.0042±0.0075</td>
<td>2.31</td>
<td>1.30</td>
<td>Not significant</td>
</tr>
</tbody>
</table>
From Table 4.1 the mean residue levels of the deltamethrin in the samples obtained from the rural areas, ranged between 0.0800 mg/kg and 0.1400 mg/kg during the dry seasons, and between 0.0012 mg/kg and 0.1100 mg/kg during the wet season, with cabbage having the highest levels of deltamethrin during the dry season and lowest during the wet season. In some Tables (for example Table 4.1), we find that the standard deviations are greater than the mean. This is because the samples were obtained randomly, a probable reason that some samples had much higher pesticide residues than others. The graphical presentation of this is shown in Figure 4.1

![Graphical presentation of the mean residue levels of deltamethrin in samples analysed from the rural area](image)

**Figure 4.1** Graphical presentation of the mean residue levels of deltamethrin in samples analysed from the rural area

### 4.3.1 Levels of deltamethrin in kales from rural area

The deltamethrin mean residue levels in kales analysed from the rural areas during the dry season of 0.1200 mg/kg, is higher than that of the wet season of 0.1100 mg/kg (See Table 4.1 and Figure 4.1). However the difference between the two values was not significant ($t_{(8, 0.05)} = 2.31$ and $t_{\text{calculated}} = 0.71$). Most of the vegetables consumed in the rural areas are obtained from the small-scale farms whereby the farmers plant them mainly for their own consumptions. This therefore, probably makes them to be very
careful when applying the pesticides on the vegetables, (that is, they wait for the elapse time before harvesting and also may be they use the recommended amount of pesticide carefully when applying).

A study done by Lee and Seenevassen (1997) on the analysis of deltamethrin in a lettuce sample, reported the residue level of deltamethrin of 0.0020 mg/kg (See Appendix XIII) which is lower than the levels obtained in kales grown in rural area during the both seasons. For instance during the dry season the residue levels of deltamethrin from the kale samples in the study were 0.1200 mg/kg while during the wet season they were 0.1100 mg/kg (Table 4.1 and Figure 4.1).

4.3.2 Levels of deltamethrin in cabbages from rural area

The deltamethrin mean residue levels in cabbage samples analysed from the rural areas, during the dry seasons of 0.1400 mg/kg, was significantly higher than those of wet season of 0.0012 mg/kg (See Table 4.1 and Figure 4.1) \( t(8, 0.05) = 2.31 \text{ and } t_{\text{calculated}} = 3.87 \). Thus people who eat cabbage were exposed to higher deltamethrin residues levels during the dry season than during the wet season. Both seasons had residues levels below the MRLs recommended by the WHO of 0.5 mg/kg (FAO/WHO, 1996). The dry season's mean residue levels were higher than the ADI of 0.05 mg/kg recommended by the WHO, while those obtained during the wet season are much lower than the ADI (FAO/WHO, 1996).

Lee and Seenevassen (1997) reported a deltamethrin residue levels in cabbage of 0.0170 mg/kg (See Appendix XI), which were much lower than the deltamethrin residue levels
obtained in the cabbage samples analysed from the rural areas during the dry season with a mean of 0.1400 mg/kg but higher than the residues obtained during the wet season of 0.0012 mg/kg (Table 4.1 and Figure 4.1).

4.3.3 Deltamethrin residues in tomatoes from rural area

The tomato samples analysed from the rural areas during the dry season had a higher residue level of 0.0800 mg/kg than the ones analysed during the wet season, which had a residue levels of 0.0042 mg/kg. The difference between the two levels was not significantly different \( t_{(8, 0.05)} = 2.31 \) and \( t_{\text{calculated}} = 1.30 \). The two levels were less than the MRLs by the FAO/WHO (1996) of 0.5 mg/kg. The ones analysed during the wet season had levels that were less than the ADI by FAO/WHO (1996) of 0.05 mg/kg, while, those analysed during the dry season had higher levels than the FAO/WHO (1996) ADI value.

The FAO/WHO (1986) reported deltamethrin levels in tomato of 0.2800 mg/kg (See Appendix XX), which was higher than the deltamethrin residue levels of the tomatoes samples analysed from the rural area during both the dry and wet seasons with a mean of 0.0800 mg/kg and 0.0042 mg/kg respectively.

4.4 Levels of deltamethrin in vegetable samples from both urban and rural areas during the dry season

The results obtained from the vegetable samples from both urban and rural areas during the dry season are shown in Table 4.2 and Figure 4.2.
Table 4.2 Mean residue levels of deltamethrin in mg/kg in the vegetable samples analysed from the urban and rural areas during the dry season (Mean ± SD, n=10)

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Urban area</th>
<th>Rural area</th>
<th>t (8, 0.05)</th>
<th>t calculated</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kales</td>
<td>0.2000±0.1000</td>
<td>0.1200±0.0300</td>
<td>2.31</td>
<td>0.13</td>
<td>Not significant</td>
</tr>
<tr>
<td>Cabbage</td>
<td>0.0700±0.0200</td>
<td>0.1400±0.0800</td>
<td>2.31</td>
<td>1.90</td>
<td>Not significant</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0.1100±0.0400</td>
<td>0.0800±0.1300</td>
<td>2.31</td>
<td>0.52</td>
<td>Not significant</td>
</tr>
</tbody>
</table>

Figure 4.2 Graphical presentation of the mean residue levels of deltamethrin in the samples analysed from the urban and rural areas during the dry season

From Table 4.2 and Figure 4.2 the mean residue levels of deltamethrin in kales samples analysed from the urban areas of 0.2000 mg/kg was higher than that from the rural areas of 0.1200 mg/kg during the dry seasons. However, the difference was not significant (t (8, 0.05) = 2.31 and t calculated = 0.13). The two deltamethrin mean residue levels obtained are below the MRLs accepted by the FAO/WHO (1996) of 0.5 mg/kg, but higher than the ADI accepted by the FAO/WHO (1996) of 0.05 mg/kg.

Comparing the deltamethrin mean residue levels in cabbage samples analysed from the urban areas of 0.0700 mg/kg and those from the rural areas which was 0.1400 mg/kg during the dry season, it was observed that, those from the rural areas had higher
concentrations, than for urban areas. The difference between the two means was not significant \( t_{(8, 0.05)} = 2.31 \) and \( t_{\text{calculated}} = 1.90 \). The two levels are higher than the ADI by FAO/WHO (1996) \( (0.05 \text{ mg/kg}) \), but are less than the MRLs \( (0.5 \text{ mg/kg}) \) by the FAO/WHO (1996).

Comparing the deltamethrin mean residue levels of tomato samples from the urban areas which was \( 0.1100 \text{ mg/kg} \) with the ones analysed from the rural areas with level of \( 0.0800 \text{ mg/kg} \) during the dry season, we find that those from the urban areas still had higher residue levels than the ones from the rural areas. Again no significant difference exists between the two mean residue levels \( t_{(8, 0.05)} = 2.31 \) and \( t_{\text{calculated}} = 0.52 \). The two levels are higher than the ADI by the FAO/WHO (1996) of \( 0.05 \text{ mg/kg} \) but lower than the MRLs by FAO/WHO (1996) of \( 0.5 \text{ mg/kg} \).

### 4.5 Levels of deltamethrin in vegetable samples from both urban and rural areas during the wet season

The results obtained from the vegetable samples from both urban and rural areas during the wet season are shown in Table 4.3 and Figure 4.3

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Urban area</th>
<th>Rural area</th>
<th>( t_{(8, 0.05)} )</th>
<th>( t_{\text{calculated}} )</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kales</td>
<td>0.0400±0.0001</td>
<td>0.1100±0.0080</td>
<td>2.31</td>
<td>7.00</td>
<td>Significant</td>
</tr>
<tr>
<td>Cabbages</td>
<td>0.0200±0.0070</td>
<td>0.0012±0.0016</td>
<td>2.31</td>
<td>5.90</td>
<td>Significant</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0.0080±0.0500</td>
<td>0.0042±0.0075</td>
<td>2.31</td>
<td>0.17</td>
<td>Not significant</td>
</tr>
</tbody>
</table>
Figure 4.3 Graphical presentation of the mean residue levels of deltamethrin in the samples analysed from the urban and rural areas during the wet season

It can be seen from Table 4.3 and Figure 4.3 that the deltamethrin residues levels in kales analysed from urban areas of 0.0400 mg/kg were lower than those of kales from rural area of 0.1100 mg/kg during the wet season. The difference between the two means was statistically significant ($t_{(8, 0.05)} = 2.31$ and $t_{\text{calculated}} = 7.00$).

Considering the cabbage samples analysed from the urban and rural areas during the wet season, we find that those from the urban areas had a higher concentrations of deltamethrin of 0.0200 mg/kg than those from the rural areas, which had a deltamethrin residue level of 0.0012 mg/kg (Table 4.3 and Figure 4.3). The two means were significantly different ($t_{(8, 0.05)} = 2.31$ and $t_{\text{calculated}} = 5.90$). This indicates that consumers in urban areas were exposed to higher levels of pesticides residues in cabbage than those in the rural areas. Comparing them with the ADI and MRLs recommended by FAO/WHO (1996), both had levels that were less than the MRLs of 0.5 mg/kg, but those from the urban areas had residue levels higher than the ADI (0.05 mg/kg) unlike the ones from the rural areas, which had less levels than the ADI.
From Table 4.3 and Figure 4.3 the tomato samples analysed from the urban areas had a higher concentration of deltamethrin levels of 0.0080 mg/kg than those from the rural areas, which had a deltamethrin residue level of 0.0042 mg/kg. There was no significant difference between the two means ($t_{(8, 0.05)} = 2.31$ and $t_{\text{calculated}} = 0.17$). This may be because the farmers who provide tomatoes in both the urban and rural areas did not apply much deltamethrin in the tomatoes since it was during the wet season.

4.6 Mean residue levels of lambda-cyhalothrin in vegetable samples from urban areas (dry and wet seasons)

The analysis of lambda-cyhalothrin was done on vegetable samples obtained from the urban area during the dry and wet seasons. Appendices XVIII and XIX gives the raw data of the lambda-cyhalothrin levels in the vegetables analysed from the urban area during the dry and wet seasons. Five samples of each vegetable type were analysed in duplicate during the dry season and also during the wet season making a total of 60 samples as shown in Figure 3.0.

From Appendices XVIII and XIX, it can be seen that the samples analysed from the urban areas during the dry season had higher residue levels of lambda-cyhalothrin than those analysed during the wet season. During the wet season almost all the samples had undetectable levels of lambda-cyhalothrin as per Appendix XIX, implying that could be during the wet seasons farmers rarely apply pesticides on vegetables or may be because the farmers might not have waited for the elapse time before harvesting their vegetables during the dry season. Although the lambda-cyhalothrin residues were higher during the dry season than during the wet season it can still be seen form Appendix XVIII, that
some samples had much higher residue levels of lambda-cyhalothrin than others. For instance, S₂ of tomato samples had residue level of 0.4800 mg/kg, whereas, S₄ of kales and S₁ of cabbage samples had a much lower level each of 0.0200 mg/kg. This could be because the tomato growers did not wait for the elapse time before harvesting their vegetables or they did not follow the manufacturers instructions properly before and after applying the lambda-cyhalothrin on their vegetables.

The lambda-cyhalothrin mean residue levels of samples S₁ - S₅ from the raw data in Appendices XVIII and XIX are as shown in Table 4.4 and Figure 4.4.

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Dry season</th>
<th>Wet season</th>
<th>t (0.05)</th>
<th>t calculated</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kales</td>
<td>0.0300±0.0100</td>
<td>0.0040±0.0090</td>
<td>2.31</td>
<td>4.30</td>
<td>Significant</td>
</tr>
<tr>
<td>Cabbage</td>
<td>0.1100±0.1000</td>
<td>0.0040±0.0090</td>
<td>2.31</td>
<td>2.36</td>
<td>Significant</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0.3400±0.1100</td>
<td>ND</td>
<td>2.31</td>
<td>6.94</td>
<td>Significant</td>
</tr>
</tbody>
</table>

From Table 4.4 the mean residue levels of the lambda-cyhalothrin in the samples obtained from the urban areas, ranged from 0.0300 mg/kg to 0.3400 mg/kg during the dry seasons, with tomatoes having the highest and kales the lowest, and from undetectable level to 0.0040 mg/kg during the wet season, kales and cabbage having almost the same and the tomatoes with the least.

From Table 4.4 it can be seen that the mean residue levels of lambda-cyhalothrin in the samples analysed during the dry season were higher than those analysed during the wet season. A graphical presentation of this is shown in Figure 4.4, with tomatoes having the
highest mean residue levels of lambda-cyhalothrin than either cabbage or kales and kales having the least levels.

![Graphical presentation of mean residues levels of lambda-cyhalothrin in samples analysed from the urban area](image)

**Figure 4.4 Graphical presentation of mean residues levels of lambda-cyhalothrin in samples analysed from the urban area**

### 4.6.1 Lambda-cyhalothrin residue levels in kales from urban areas

From Table 4.4 and Figure 4.4, during the dry season, the lambda-cyhalothrin mean residue of 0.0300 mg/kg was higher than that found during the wet season of 0.0040 mg/kg in the kale samples from the urban areas. There was a significant difference between the two mean lambda-cyhalothrin residue levels ($t_{(8, 0.05)} = 2.31$ and $t_{\text{calculated}} = 4.30$). Therefore, during the dry season farmers were exposed to higher levels of pesticide residues from kales than during the wet season. The levels during the dry season were more than the FAO/WHO’s ADI of 0.02 mg/kg but less than the FAO/WHO’s MRLs of 0.2 mg/kg (FAO/WHO, 1996).

No work has been reported on the analysis of lambda-cyhalothrin in vegetables, except in cow tissue (Sapiets *et al.*, 1985) (See Appendix III). Lambda-cyhalothrin residues in cow tissue ranged from 0.0100 mg/kg to 7.900 kg/kg (Sapiets, 1985).
4.6.2 Lambda-cyhalothrin mean residue levels in cabbages from urban areas

As shown in Table 4.4 and Figure 4.4 the cabbage samples analysed from urban area had lambda-cyhalothrin mean residue level of 0.1100 mg/kg during the dry season, which was higher than those obtained during the wet season of 0.0040 mg/kg. This also shows that vegetable consumers were exposed to high levels of pesticides in vegetables during the dry season. Thus, there is a significant difference between the two mean residue levels \( t_{(8, 0.05)} = 2.31 \) and \( t_{\text{calculated}} = 2.36 \). The samples analysed during the dry season had higher levels of lambda-cyhalothrin residues than the ADI of 0.02 mg/kg (FAO/WHO, 1996) and less level than the MRLs of 0.2 mg/kg (FAO/WHO, 1996). On the other hand the mean residues levels of the samples analysed during the wet season were less than both ADI of 0.02 mg/kg and MRLs of 0.2 mg/kg (FAO/WHO, 1996).

4.6.3 Lambda-cyhalothrin levels in tomatoes from urban areas

As shown in Table 4.4 and Figure 4.4 the tomato samples analysed from the urban areas during the dry season had mean residue levels of lambda-cyhalothrin of 0.3400 mg/kg, which was higher than the undetectable level obtained during the wet season. There was therefore a significant difference between the two mean residue levels \( t_{(8, 0.05)} = 2.31 \) and \( t_{\text{calculated}} = 6.94 \). The dry season tomatoes samples from the urban areas had residue levels, which were higher than both ADI of 0.02 and MRLs of 0.2 mg/kg (FAO/WHO, 1996). The ones analysed during the wet season on the other hand had non-detectable levels of lambda-cyhalothrin, implying that may be farmers rarely apply lambda-cyhalothrin on vegetables during the wet seasons.
4.7 Mean residue levels of lambda-cyhalothrin in vegetable samples analysed from the rural area during the dry and wet seasons

Lambda-cyhalothrin was also analysed on vegetable samples obtained from the rural area during the dry and the wet seasons. Appendices XX and XXI gives the raw data of the lambda-cyhalothrin levels in the vegetables analysed from the rural area during the dry and wet season. Five samples of each vegetable type were analysed in duplicate during the dry season and also during the wet season making a total of 60 samples as shown in Figure 3.0.

From the raw data in Appendices XX and XXI, it can be seen that the samples analysed from the rural areas during the dry season had higher residue levels of lambda-cyhalothrin than those analysed during the wet season. During the wet season almost all the samples had undetectable levels of lambda-cyhalothrin as per Appendix XXI, implying that during the wet seasons, farmers rarely apply pesticides on vegetables or may not have followed the manufacturers’ instruction. Although most of the vegetable samples from the rural area during the dry season as in Appendix XX, had some lambda-cyhalothrin detected, we still note that some of the levels were much higher than the others. For example S₃ of cabbage had residue level of 0.0800 mg/kg, which was much higher than S₂ of tomatoes, which had residue level of 0.0005 mg/kg. This could be because the cabbage farmers had harvested them before the elapse time, or could be they did not follow the instructions given by the manufacturers during application.

The lambda-cyhalothrin mean residue levels of samples S₁ - S₅ from the raw data in Appendices XX and XXI are as shown in Table 4.5 and Figure 4.5.
Table 4.5 Mean residue levels of lambda-cyhalothrin in mg/kg in the samples from the rural areas during the dry and wet seasons (Mean ± SD, n=10)

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Dry season</th>
<th>Wet season</th>
<th>( t_{(8, 0.05)} )</th>
<th>( t_{\text{calculated}} )</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kales</td>
<td>0.0130±0.0200</td>
<td>0.0018±0.0040</td>
<td>2.31</td>
<td>1.20</td>
<td>Not significant</td>
</tr>
<tr>
<td>Cabbages</td>
<td>0.0500±0.0300</td>
<td>0.0050±0.0400</td>
<td>2.31</td>
<td>2.00</td>
<td>Not significant</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0.0500±0.0400</td>
<td>0.0020±0.0045</td>
<td>2.31</td>
<td>2.67</td>
<td>Significant</td>
</tr>
</tbody>
</table>

The mean residue levels of lambda-cyhalothrin in the samples obtained from the rural areas, ranged between 0.0130 mg/kg and 0.0500 mg/kg during the dry seasons, and between 0.0018 mg/kg and 0.0050 mg/kg during the wet season. The results are as shown in the Tables 4.5. Cabbage and tomatoes had higher levels of lambda-cyhalothrin than kales.

From Table 4.5 it can be seen that the mean residue levels of lambda-cyhalothrin in the samples analysed during the dry season were higher than those analysed during the wet season. The graphical presentation of this is shown in Figure 4.5.

![Graphical presentation of mean residue levels of lambda-cyhalothrin in samples analysed from the rural areas during the dry and wet seasons](image)
4.7.1 Levels of lambda-cyhalothrin in kales from rural area

During the dry season, the lambda-cyhalothrin mean residues levels of 0.0130 mg/kg were higher than the residues found during the wet season of 0.0018 mg/kg (Table 4.5 and Figure 4.5) in the kale samples analysed from the rural areas. However, there was no significant difference between the two mean residues levels \((t_{(8, 0.05)} = 2.31\) and \(t_{\text{calculated}} = 1.20\)). The two levels were less than the ADI by FAO/WHO (1996) of 0.02 mg/kg and still they were both less than the MRLs by FAO/WHO (1996) of 0.2 mg/kg.

4.7.2 Levels of lambda-cyhalothrin in cabbage from rural area

Looking at the results of lambda-cyhalothrin for cabbage samples from rural areas, it was found that they had higher mean residue levels of 0.0500 mg/kg during the dry season than during the wet season which was 0.0050 mg/kg (Table 4.5 and Figure 4.5). There was no significant difference between the two lambda-cyhalothrin mean residue levels \((t_{(8, 0.05)} = 2.31\) and \(t_{\text{calculated}} = 2.00\). The samples analysed during the dry season had higher levels of residues than the ADI of 0.02 mg/kg and less level than the MRLs of 0.2 mg/kg (FAO/WHO, 1996). On the other hand the residues during the wet season were found to be less than the ADI of 0.02 mg/kg and still less level than the MRLs of 0.2 mg/kg (FAO/WHO, 1996).

4.7.3 Lambda-cyhalothrin in tomatoes from rural area

The tomato samples analysed from the rural areas during the dry season had higher residues levels of lambda-cyhalothrin of 0.0500 mg/kg than those analysed during the wet season of 0.0020 mg/kg (Table 4.5 and Figure 4.5). There was a significant
difference between the two mean residue levels \((t_{(8, 0.05)} = 2.31\) and \(t_{\text{calculated}} = 2.67\)). The tomato samples analysed from the rural area during the dry season had higher residue level than the ADI of 0.02 but are less than the MRLs of 0.2 mg/kg (FAO/WHO, 1996). On the other hand the residues determined during the wet season were less than both the ADI of 0.02 mg/kg and MRLs of 0.2 mg/kg (FAO/WHO, 1996).

4.8 Levels of lambda-cyhalothrin in vegetable samples from both urban and rural areas during the dry season

The results that were obtained from the three vegetable samples from both urban and rural areas during the dry season are shown in Table 4.6 and Figure 4.6.

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Urban area</th>
<th>Rural area</th>
<th>(t_{(8, 0.05)})</th>
<th>(t_{\text{calculated}})</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kales</td>
<td>0.0300±0.0100</td>
<td>0.0130±0.0200</td>
<td>2.31</td>
<td>1.70</td>
<td>Not significant</td>
</tr>
<tr>
<td>Cabbages</td>
<td>0.1100±0.1000</td>
<td>0.0500±0.0300</td>
<td>2.31</td>
<td>1.30</td>
<td>Not significant</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0.3400±0.1100</td>
<td>0.0500±0.0400</td>
<td>2.31</td>
<td>1.30</td>
<td>Not significant</td>
</tr>
</tbody>
</table>

Table 4.6 Mean residue levels of lambda-cyhalothrin in mg/kg in the samples from the urban and rural areas during the dry season (Mean ± SD, n=10)

Figure 4.6 Graphical presentation of the mean residue levels of lambda-cyhalothrin in the samples analysed from the urban and rural areas during the dry season
Comparing the lambda-cyhalothrin mean residues levels in kales samples analysed from the urban areas with those analysed from the rural areas (See Table 4.6 and Figure 4.6) during the dry season, it was observed that the mean residue levels from the rural areas which were 0.0130 mg/kg were less than those from the urban areas of 0.0300 mg/kg. But there was no significant difference between the two mean residue levels ($t_{(8, 0.05)} = 2.31$ and $t_{\text{calculated}} = 1.70$). The kales samples analysed from the both the urban and rural areas had higher residue levels than the ADI of 0.02 mg/kg and lower residue levels than the MRLs of 0.2 mg/kg (FAO/WHO, 1996).

A comparison of lambda-cyhalothrin mean residue levels of cabbage from the samples analysed from the urban areas with those analysed from the rural areas (Table 4.6 and Figure 4.6) during the dry season, those from the urban areas with a mean residue level of 0.1100 mg/kg level of lambda-cyhalothrin were higher than the ones from the rural areas which was 0.0500 mg/kg. There was no significant difference between the two mean residue levels ($t_{(8, 0.05)} = 2.31$ and $t_{\text{calculated}} = 1.30$). The two residues were higher than the ADI of 0.02 mg/kg but they are both less than the MRLs of 0.2 mg/kg (FAO/WHO, 1996).

The comparison of the tomato samples analysed from urban areas with those analysed from the rural areas during the dry season (Table 4.6 and Figure 4.6), show that the samples from the urban areas had higher lambda-cyhalothrin mean residue levels of 0.3400 mg/kg than those from rural areas which was 0.0500mg/kg. There was therefore no significant difference between the two mean residue levels ($t_{(8, 0.05)} = 2.31$ and $t_{\text{calculated}} = 1.70$).
The mean residue levels of tomato samples analysed from both urban and rural areas are higher than those of ADI of 0.02 mg/kg but less than the MRLs of 0.2 mg/kg (FAO/WHO, 1996).

4.9 Levels of lambda-cyhalothrin in vegetable samples from both urban and rural areas during the wet season

The results that were obtained from the vegetable samples obtained from both urban and rural areas during the wet season are as shown in 4.7 and Figure 4.7.

<table>
<thead>
<tr>
<th>Vegetables</th>
<th>Urban area</th>
<th>Rural area</th>
<th>t_{calculated}</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kales</td>
<td>0.0040±0.0900</td>
<td>0.0018±0.0040</td>
<td>2.31</td>
<td>0.50</td>
</tr>
<tr>
<td>Cabbages</td>
<td>0.0040±0.0900</td>
<td>0.0050±0.0400</td>
<td>2.31</td>
<td>0.06</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>ND</td>
<td>0.0020±0.0045</td>
<td>2.31</td>
<td>0.100</td>
</tr>
</tbody>
</table>

ND- Not Detected

Figure 4.7 Graphical presentation of the mean residue levels of lambda-cyhalothrin in the samples analysed from the urban and rural areas during the wet season

A comparison of kales samples analysed for lambda-cyhalothrin from the urban areas with those analysed from the rural areas (Table 4.7 and Figure 4.7) during the wet season,
showed that still those from the urban areas with a mean of 0.0040 mg/kg were higher than those from the rural areas, with a mean of 0.0018 mg/kg residue concentrations. However, here was no significant difference between the two mean residue levels \( t_{(8, 0.05)} = 2.31 \) and \( t_{\text{calculated}} = 0.50 \). The mean residue levels of the samples were less than the ADI of 0.02 mg/kg and also less than the MRLs of 0.2 mg/kg (FAO/WHO, 1996).

It was observed that cabbage samples analysed from the urban areas with lambda-cyhalothrin residue level of 0.0040 mg/kg compared with those analysed from the rural areas with mean residue levels of 0.0050 mg/kg (Table 4.7 and Figure 4.7), during the wet season, the ones from the urban areas had the higher mean residue levels than those from the rural areas. There was no significant difference between the two mean residue levels \( t_{(8, 0.05)} = 2.31 \) and \( t_{\text{calculated}} = 0.06 \). The samples analysed from both the urban and rural areas had less mean residue levels than both the ADI of 0.02 mg/kg and MRLs of 0.2 mg/kg (FAO/WHO, 1996) respectively. Considering the residues levels of the samples from the rural areas it was found that they are also less than both the ADI of 0.02 mg/kg and MRLs of 0.2 mg/kg (FAO/WHO, 1996).

If the levels of lambda-cyhalothrin tomato samples analysed from the urban areas were compared with those from the rural area (Table 4.7 and Figure 4.7) during the wet season, it was observed that those of the rural area with a mean of 0.0020 mg/kg were slightly higher than those obtained from the urban areas which were undetectable. There was no significant difference between the two mean residue levels \( t_{(8, 0.05)} = 2.31 \) and \( t_{\text{calculated}} = 1.00 \). The lambda-cyhalothrin mean residue level of the samples analysed from the urban
area was un-detectable while as those analysed from the rural areas were all less than both the ADI of 0.02 mg/kg and MRLs of 0.2 mg/kg (FAO/WHO, 1996). The results indicate that vegetables grown during wet season do not pose any threat as far as lambda-cyhalothrin pyrethroid is concerned for both urban and rural dwellers.

4.10 Kale samples from the experimental garden

Kales were planted in an experimental garden at the University, which was divided into two portions; one portion was sprayed with deltamethrin and the other with lambda-cyhalothrin. The two pyrethroids (deltamethrin and lambda-cyhalothrin) were prepared for spraying according to the manufacturer’s instructions. The application was done after every seven days as per the manufacturer’s instructions for three times. Samples from each portion were analysed in duplicate per day for five consecutive days after each application for each pyrethroid. The analysis was done during the dry and wet seasons. According to the manufacturers instructions the elapse time for deltamethrin is 1 day and that for lambda-cyhalothrin is 3 days.

4.10.1 Deltamethrin mean residue levels of the kale samples from experimental garden during the dry and wet seasons

The kale samples from the portion that was sprayed with deltamethrin were picked and analysed in five consecutive days. One sample was analysed in duplicate per day for five consecutive days after each application. The application and the analysis were done during the dry and wet seasons making a total of 60 samples analysed for deltamethrin during the dry and the wet seasons. The raw data of the analysis is shown in Appendices XXII and XXIII.
As can be seen from Appendices XXII and XXIII the deltamethrin residue levels increased after each subsequent application from day one to day five. For example day one after the 1st application during the dry season had residue level of 0.0900 mg/kg while day one after the 3rd application had residue levels of 0.1200 mg/kg (See Appendix XXII). This is because some residues were still remaining on the kales during the next application. It was also found from Appendices XXII and XXIII that after each application the deltamethrin residue levels decreased from day one to five day five. For instance, after the 2nd application during the wet season day one had deltamethrin residue level of 0.1000 mg/kg and day five had levels of 0.0096 mg/kg (See Appendix XXIII). This may be due to degradation and wash off of deltamethrin by the rainwater.

The mean residue levels of deltamethrin from Appendices XXII and XXIII are therefore shown in Table 4.8 and Figure 4.8.

Table 4.8 Mean residue levels of deltamethrin in kales in mg/kg between days 1-5 after application during the dry and wet seasons (Mean ± SD, n=6)

<table>
<thead>
<tr>
<th>Day</th>
<th>Dry season</th>
<th>Wet season</th>
<th>t (4, 0.05)</th>
<th>t calculated</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.1100±0.0050</td>
<td>0.1000±0.0020</td>
<td>2.78</td>
<td>3.22</td>
<td>Significant</td>
</tr>
<tr>
<td>2</td>
<td>0.0600±0.0030</td>
<td>0.0600±0.0020</td>
<td>2.78</td>
<td>0.00</td>
<td>Not significant</td>
</tr>
<tr>
<td>3</td>
<td>0.0500±0.0040</td>
<td>0.0400±0.0020</td>
<td>2.78</td>
<td>3.88</td>
<td>Significant</td>
</tr>
<tr>
<td>4</td>
<td>0.0400±0.0030</td>
<td>0.0200±0.0040</td>
<td>2.78</td>
<td>6.93</td>
<td>Significant</td>
</tr>
<tr>
<td>5</td>
<td>0.0200±0.0030</td>
<td>0.0100±0.0020</td>
<td>2.78</td>
<td>4.80</td>
<td>Significant</td>
</tr>
</tbody>
</table>
It can be seen from Table 4.8 and Figure 4.8 that the deltamethrin residue levels analysed in the kale samples from the experimental garden decreased from day 1 to day 5 during both the dry and the wet seasons. This could be because of the degradation of deltamethrin as the days increased or/and also due to the effect of wash off by the rainwater during the wet season. For instance during the dry season, the deltamethrin residue levels decreased from 0.1100 mg/kg to 0.0200 mg/kg between day 1 and day 5.

There was a significant difference between most of the deltamethrin residue levels obtained from the kales in the experimental garden during the dry and wet seasons on the corresponding days, except on the second day where the residues levels were equal (Table 4.8). For instance on day one the deltamethrin residue level was 0.1100 mg/kg during the dry season and 0.1000 mg/kg during the wet season. The deltamethrin residues were significantly higher during the dry season than during the wet season ($t_{(4, 0.05)} = 2.78$ and $t_{\text{calculated}} = 3.22$). Therefore, it can be concluded that during the dry season consumers
were exposed to significantly higher levels of deltamethrin in vegetables than during the wet season, as it was the case in the samples analysed from the markets. This may be as result of wash off of the deltamethrin from the vegetables by rainwater.

4.10.2 Lambda-cyhalothrin mean residue levels of the kale samples from the experimental garden during the dry and wet seasons

The kale samples sprayed with lambda-cyhalothrin were also picked randomly from the experimental garden and analysed during both the dry and the wet seasons. The results are shown in Appendices XXIV and XXV.

From Appendices XXIV and XXV, it was observed that lambda cyhalothrin residue levels decreased from day 1 to day 5 after each application during both the dry and wet seasons. For instance lambda-cyhalothrin residue levels decreased from 0.0280 mg/kg to 0.0038 mg/kg between the 1st and the 5th day after the first application during the wet season (Appendix XXV). This could be due to wash off by the rainwater. On the other hand it was observed from Appendices XXIV and XXV that lambda-cyhalothrin increased after subsequent applications on the corresponding days during both the dry and wet seasons. For example the residues increased from 1.7600 mg/kg to 1.8100 mg/kg between 1st and the 3rd application during the dry season (Appendix XXIV).

The lambda-cyhalothrin mean residue levels of kale samples obtained during the 1st-3rd applications between days 1-5 for each application from Appendices XXIV and XXV are shown in Table 4.9 and Figure 4.10.
Table 4.9 Mean residue levels of lambda-cyhalothrin in kale samples in mg/kg between days 1-5 after application during the dry and wet seasons (Mean ± SD, n=6)

<table>
<thead>
<tr>
<th>Day</th>
<th>Dry season</th>
<th>Wet season</th>
<th>t(calculated)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.8000±0.0400</td>
<td>0.0300±0.0030</td>
<td>2.78</td>
<td>61.46 Significant</td>
</tr>
<tr>
<td>2</td>
<td>0.9000±0.0500</td>
<td>0.0200±0.0030</td>
<td>2.78</td>
<td>30.45 Significant</td>
</tr>
<tr>
<td>3</td>
<td>0.5000±0.0200</td>
<td>0.0100±0.0020</td>
<td>2.78</td>
<td>42.24 Significant</td>
</tr>
<tr>
<td>4</td>
<td>0.1480±0.0200</td>
<td>0.0070±0.0002</td>
<td>2.78</td>
<td>12.21 Significant</td>
</tr>
<tr>
<td>5</td>
<td>0.1400±0.0200</td>
<td>0.0040±0.0002</td>
<td>2.78</td>
<td>11.77 Significant</td>
</tr>
</tbody>
</table>

Figure 4.9 Mean residue levels for lambda-cyhalothrin kales samples planted in the experimental garden between days 1-5 after application during the dry season

As can be seen from Table 4.10 and Figure 4.10 the lambda-cyhalothrin residue levels analysed in kale samples from the garden decreased from day 1 to day 5 during both the dry and wet seasons. This could be because of the degradation of lambda-cyhalothrin as the days increased or/and also may be due to the effect of wash off by the rainwater during the wet season. For instance during the wet season (Table 4.10), the lambda-cyhalothrin residue levels decreased from 0.0300 mg/kg to 0.0040 mg/kg between day 1 and day 5. There was a significant difference between the lambda-cyhalothrin residue...
levels obtained in all the kale samples from the experimental garden during the dry and wet seasons on the corresponding days (Table 4.10). For instance on day two the lambda-cyhalothrin residue levels was 0.9000 mg/kg during the dry season and 0.0200 mg/kg during the wet season. This shows that during the dry season the residues were significantly higher than during the wet \( t_{(4, 0.05)} = 2.78 \) and \( t_{\text{calculated}} = 61.46 \). Therefore, during the dry season consumers were exposed to significantly higher levels of deltamethrin in kales than during the wet season. This may be as a result of wash off of the deltamethrin from the vegetables by rainwater.

![Figure 4.10 Mean residue levels for lambda-cyhalothrin in kales samples planted in the experimental garden between days 1-5 after application during the wet season](image)

**Figure 4.10 Mean residue levels for lambda-cyhalothrin in kales samples planted in the experimental garden between days 1-5 after application during the wet season**

### 4.11 Comparison of the mean residue levels of the pyrethroids (deltamethrin and lambda-cyhalothrin) analysed from the kale samples in the experimental garden with those of the kale samples analysed from urban and rural areas during the dry and wet seasons

There was need to compare the mean residue levels in the kales samples analysed from both urban and rural areas during the dry and the wet seasons with the kales samples obtained from the experimental garden. The idea of the experimental garden was to
investigate whether the kales growers in both the urban and the rural follow the manufacturers' instructions before and after applying the pyrethroids on their kales.

4.11.1 Comparison of the pyrethroids levels in kales from the urban areas and the experimental garden samples during the dry season

From Table 4.8 the mean residue levels of deltamethrin in the kales during the dry season ranged from 0.1100 to 0.0200 mg/kg in the five days. Deltamethrin has an elapse time of 1 day, which means one can harvest the kales as from the second day after application. The second day had a mean residue level of 0.06 mg/kg (Table 4.8). The results for deltamethrin mean residues levels in kale samples analysed from the urban areas during the dry season as indicated in Table 4.0 in the study was 0.200 mg/kg. There was a significant difference between the two mean residue levels ($t_{(6, \, 0.05)} = 2.57$ and $t_{\text{calculated}} = 3.18$). The deltamethrin mean residue levels obtained from urban areas for kales during the dry season therefore, were significantly higher than those obtained from experimental garden. This indicated that may be most of the farmers who supply kales to the urban areas do not really wait for the elapse time required before harvesting the kales or they apply more than is expected. The concentration of 0.2 mg/kg exceeds the concentration of 0.1300 mg/kg recommended by the manufacturers, which suggests that the farmers do not really follow the instructions. Generally, even after the elapse time is over we find that there are some residues of deltamethrin in the kales. It is therefore clear that even after the elapse time people are not 100 % protected from the effects of pesticides, and therefore if possible an alternative to pesticides use on vegetables should be considered.
The lambda-cyhalothrin mean residues levels in the experimental garden decreased from 1.800 to 0.1400 mg/kg in the five days during the dry season (Table 4.10). The elapse time for lambda-cyhalothrin is 3 days, according to the manufacturer’s instructions, which means one can harvest the kales as from the fourth day after application. The mean residue level on the fourth day was 0.1480 mg/kg (Table 4.10). Therefore if we compare this with results for the lambda-cyhalothrin in the kales analysed from the urban areas during the dry season of 0.0300 mg/kg (Table 4.4 and Figure 4.4), we find that there was a significant difference between the two mean residue levels ($t_{(6,0.05)} = 2.57$ and $t_{\text{calculated}} = 3.92$). Thus, the lambda-cyhalothrin mean residue level in kales analysed from the urban areas during the dry season was significantly lower than that obtained from the experimental garden.

4.11.2 Comparison of the pyrethroids levels in kales from the urban areas and the experimental garden kale samples during the wet season

During the wet season, most vegetable growers rarely spray their vegetables. This was confirmed by the fact that the results obtained from the experimental garden sprayed with deltamethrin during the wet season ranged between 0.1000 and 0.0100 mg/kg (Table 4.8) most of which were higher than the results obtained in kales samples analysed from the urban area during the wet season (0.0400 mg/kg) (Table 4.0 and Figure 4.0). On the second day, which is the recommended time for harvesting the kales after the application, the deltamethrin residue level was 0.0600 mg/kg (Table 4.8). It is clear that on the second day the mean residue level of 0.0600 mg/kg was higher than the mean residue level obtained from the kales from the urban areas of 0.0400 mg/kg during the wet seasons.
There was a significant difference between the two mean residue levels \( t_{(6,0.05)} = 2.57 \) and \( t_{\text{calculated}} = 69.9 \).

Considering the lambda-cyhalothrin residues levels for the kales analysed from the control garden, which ranged between 0.0300 and 0.0040 mg/kg after 5 days (Table 4.10), the mean residue level of the kales analysed from the urban areas during the wet season were also very low (0.0040 mg/kg) from Table 4.4 and Figure 4.4. On the fourth day (that is, when the kales are supposed to be harvested after application), the mean residue level of lambda-cyhalothrin was 0.0070 mg/kg. This was higher than the mean residue level of the lambda-cyhalothrin in the kales obtained from the urban areas during the wet season of 0.0040 mg/kg. There was no significant difference between the two mean residue levels \( t_{(6,0.05)} = 2.57 \) and \( t_{\text{calculated}} = 0.75 \). In both cases still we find that after the elapse time there are still some residues left in the vegetables.

### 4.11.3 Comparison of the pyrethroids levels in kale samples from the rural area and the experimental garden kale samples during the dry season

From the experimental garden results we find that the deltamethrin mean residues levels between day 1 and day 5 after application ranged between 0.1100 and 0.0200 mg/kg (Table 4.8 Figure 4.8). These values are all lower than the values obtained in rural areas during the dry season (0.1200 mg/kg) as per Table 4.1. On the second day the mean residue level of the deltamethrin analysed in kales from the experimental garden was 0.0600 mg/kg (Table 4.8 Figure 4.8), which was much less the mean residue level of kales from the rural areas during the dry season of 0.12 mg/kg (Table 4.5 and Figure 4.5).
There was a significant difference between the two mean residue levels ($t_{(6, \, 0.05)} = 2.57$ and $t_{\text{calculated}} = 11.4$).

4.11.4 Comparison of the pyrethroids levels in kales from the rural area and the experimental garden kale samples during the wet season

The mean residue levels of deltamethrin recovered in kales samples from the rural areas during the wet season was 0.1100 mg/kg (Table 4.1 and Figure 4.1). The deltamethrin residue levels recovered from the experimental garden during the wet season ranged between 0.100 and 0.0100 mg/kg as per Table 4.8. On the second day the deltamethrin mean residue level for the control sample was 0.0600 mg/kg, which was lower than the mean residue levels of the kales samples from the rural areas during the wet season of 0.1100 mg/kg. There was a significant difference between the two mean residue levels ($t_{(6, \, 0.05)} = 2.57$ and $t_{\text{calculated}} = 13.9$).

On the other hand the lambda-cyhalothrin residue in the kales samples from the rural areas during the wet seasons was 0.0018 mg/kg (Table 4.5 and Figure 4.5). The lambda-cyhalothrin mean residue levels for the experimental garden ranged between 0.03 and 0.004 mg/kg (Table 4.10 and Figure 4.13). Since the kales are supposed to be harvested 3 days after application, one can use them as from the fourth day. We therefore find that on the fourth day the mean residue level for the lambda-cyhalothrin from the control sample was 0.0070 mg/kg, which was much higher than the mean residue level in the kales samples from the rural areas during the wet season (0.0018 mg/kg). There was a significant difference between the two mean residue levels ($t_{(6, \, 0.05)} = 2.57$ and $t_{\text{calculated}} = 2.91$). The kales samples from the experimental garden contained more mean residue
level (0.0070 mg/kg) than the kales sample from the rural area during the wet season (0.0018 mg/kg). This might imply that rural farmers don’t often use pesticides during the wet seasons.

4.12 Summary

In summary, the current study was carried out on the analysis of deltamethrin and lambda-cyhalothrin in vegetables from both the urban and the rural areas during the dry and the wet seasons. The results obtained showed that most of the vegetables consumed during the dry season had significantly higher mean residue levels of deltamethrin and lambda-cyhalothrin than those consumed during the wet season in both urban and rural areas. The high levels during the dry season may be as a result of some farmers failing to follow the manufacturer’s instructions before and after applying the pesticide.

Table 4.10 Mean residue levels of deltamethrin in mg/kg in the vegetable samples analysed from both the urban and rural areas during the dry and wet seasons

<table>
<thead>
<tr>
<th>Area Sample</th>
<th>Urban Dry season</th>
<th>Wet season</th>
<th>Rural Dry season</th>
<th>Wet season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kales</td>
<td>0.2000±0.0100</td>
<td>0.0400±0.0001</td>
<td>0.1200±0.0300</td>
<td>0.1100±0.0080</td>
</tr>
<tr>
<td>Cabbage</td>
<td>0.0700±0.0200</td>
<td>0.2000±0.0070</td>
<td>0.1400±0.0800</td>
<td>0.0012±0.0016</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0.1100±0.0400</td>
<td>0.0080±0.0500</td>
<td>0.0800±0.1300</td>
<td>0.0042±0.0075</td>
</tr>
</tbody>
</table>
The deltamethrin mean residue levels in all the vegetable samples that were analysed from both urban and rural areas during the dry and wet seasons, ranged between 0.0042 and 0.2000 mg/kg, with kales having the highest mean residue level and cabbage having the lowest mean residue level (Table 4.10).

Table 4.11 Mean residue levels of lambda-cyhalothrin in mg/kg in the vegetable samples analysed from both the urban and rural areas during the dry and wet seasons

<table>
<thead>
<tr>
<th>Area</th>
<th>Urban Dry season</th>
<th>Wet season</th>
<th>Rural Dry season</th>
<th>Wet season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kales</td>
<td>0.0300±0.0100</td>
<td>0.0040±0.0090</td>
<td>0.0130±0.0200</td>
<td>0.0018±0.0040</td>
</tr>
<tr>
<td>Cabbage</td>
<td>0.1100±0.1000</td>
<td>0.0040±0.0090</td>
<td>0.0500±0.0300</td>
<td>0.0012±0.0400</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0.3400±0.1100</td>
<td>ND</td>
<td>0.0500±0.0400</td>
<td>0.0020±0.0045</td>
</tr>
</tbody>
</table>

ND– Not Detected

As observed from Table 4.11 the lambda-cyhalothrin mean residue levels in all the vegetable samples that were analysed from both urban and rural areas during the dry and wet seasons, ranged from non-detectable level to 0.3400 mg/kg. In this case tomatoes had the highest mean residue level during the dry season and the same tomatoes had non-detectable level during the wet season.

It was also found that most of the vegetables from urban areas had higher residue levels of deltamethrin and lambda-cyhalothrin than those from the rural areas during both the dry and wet seasons, although the differences for most of them were not statistically
significant. From a personal communication with the farmers, it was found that most of the vegetables consumed in the urban areas were produced in large-scale farms (so that the large-scale farmers can provide in large quantities to the urban areas), while the vegetables sold in the rural areas were mostly from small-scale farms. Therefore, the high levels of the pyrethroids (deltamethrin and lambda-cyhalothrin) in the vegetables consumed in the urban areas may be as a result of farmers in the large-scale farms selling the vegetables before the elapse time in case they find a ready market. It was also believed that the large-scale farmers are not very careful when handling the pesticides on the vegetables since they mainly produce them for commercial purposes rather than for their own consumptions. Those who provide vegetables to the people in the rural areas mostly grow these vegetables also for their own consumptions and hence are believed to follow the manufacturer’s instructions better than the large-scale farmers.

The study also dealt with analysis of both deltamethrin and lambda-cyhalothrin in kale samples that were obtained from the experimental garden. The analysis in this case was also done during the dry and wet seasons.
### Table 4.12 Mean residue levels of deltamethrin in kale samples in mg/kg between days 1-5 after application during the dry and wet seasons (Mean ± SD, n=6)

<table>
<thead>
<tr>
<th>Day</th>
<th>Dry season</th>
<th>Wet season</th>
<th>$t$ (4, 0.05)</th>
<th>$t_{calculated}$</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.1100±0.0050</td>
<td>0.1000±0.0020</td>
<td>2.78</td>
<td>3.22</td>
<td>Significant</td>
</tr>
<tr>
<td>2</td>
<td>0.0600±0.0030</td>
<td>0.0600±0.0020</td>
<td>2.78</td>
<td>0.00</td>
<td>Not significant</td>
</tr>
<tr>
<td>3</td>
<td>0.0500±0.0040</td>
<td>0.0400±0.0020</td>
<td>2.78</td>
<td>3.88</td>
<td>Significant</td>
</tr>
<tr>
<td>4</td>
<td>0.0400±0.0030</td>
<td>0.0200±0.0040</td>
<td>2.78</td>
<td>6.93</td>
<td>Significant</td>
</tr>
<tr>
<td>5</td>
<td>0.0200±0.0030</td>
<td>0.0100±0.0020</td>
<td>2.78</td>
<td>4.80</td>
<td>Significant</td>
</tr>
</tbody>
</table>

As can be observed from Table 4.12, the deltamethrin mean residue level in the kale samples analysed from the experimental garden decreased from day 1 to day 5. The decrease followed the 1st order model when the logarithm of the mean residue levels was plotted against the days.

### Table 4.13 Mean residue levels of lambda-cyhalothrin in kale samples in mg/kg between days 1-5 after application during the dry and wet seasons (Mean ± SD, n=6)

<table>
<thead>
<tr>
<th>Day</th>
<th>Dry season</th>
<th>Wet season</th>
<th>$t$ (4, 0.05)</th>
<th>$t_{calculated}$</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.8000±0.0400</td>
<td>0.0300±0.0030</td>
<td>2.78</td>
<td>61.46</td>
<td>Significant</td>
</tr>
<tr>
<td>2</td>
<td>0.9000±0.0500</td>
<td>0.0200±0.0030</td>
<td>2.78</td>
<td>30.45</td>
<td>Significant</td>
</tr>
<tr>
<td>3</td>
<td>0.5000±0.0200</td>
<td>0.0100±0.0020</td>
<td>2.78</td>
<td>42.24</td>
<td>Significant</td>
</tr>
<tr>
<td>4</td>
<td>0.1480±0.0200</td>
<td>0.0070±0.0002</td>
<td>2.78</td>
<td>12.21</td>
<td>Significant</td>
</tr>
<tr>
<td>5</td>
<td>0.1400±0.0200</td>
<td>0.0040±0.0002</td>
<td>2.78</td>
<td>11.77</td>
<td>Significant</td>
</tr>
</tbody>
</table>

The lambda-cyhalothrin mean residue level in the kale samples analysed from the experimental garden also decreased from day 1 to day 5 (Table 4.13). The decrease
followed the 1st order model when the logarithm of the mean residue levels was plotted against the days.

It was found that the kale samples analysed from the urban and rural areas had higher deltamethrin mean residue levels than those analysed from the experimental garden during the dry season. It was also found that the kale samples analysed from the urban areas had significantly lower deltamethrin mean residue levels than those from the experimental garden during the wet season, whereas, those analysed from the rural areas had significantly higher deltamethrin mean residue levels than those from the experimental during the same season. On the other hand it was observed that most of the kale samples analysed from both urban and rural areas had significantly lower lambda-cyhalothrin mean residue levels than those from the garden during the two seasons. This indicate that probably the farmers did not follow the manufacturer’s instructions when applying the deltamethrin on kales, unlike when applying the lambda-cyhalothrin, or may be farmers made use of deltamethrin more than the lambda-cyhalothrin.

There were still some residues of deltamethrin and lambda-cyhalothrin detected in kales planted in the experimental garden even after waiting for the recommended time by the manufacturers. This showed that even after waiting for the elapse time vegetables still contain some residues and therefore can never be 100 % free from the pesticides. It was also found that most of the residues of the deltamethrin and lambda-cyhalothrin obtained from the vegetable samples analysed from the urban and rural areas exceeded the ADI but most of them were less than the MRLs by FAO/WHO (1996).
4.13 CONCLUSION AND RECOMMENDATIONS

4.13.1 Conclusion

The results of the present study showed that:-

i. Most of the vegetables consumed during the dry season had significantly higher mean residue levels of deltamethrin and lambda-cyhalothrin than those consumed during the wet season in both urban and rural areas.

ii. Most of the vegetables from urban areas had high residue levels of deltamethrin and lambda-cyhalothrin than those from the rural areas during the dry and wet season, although the differences for most of them were not statistically significant.

iii. There were low residue levels of both deltamethrin and lambda-cyhalothrin during the wet seasons for vegetables obtained from both the urban and rural areas, which could be due to either the wash off of the pesticides by the rainwater or low application of pesticides on vegetables during the wet season.

iv. There were some residues of deltamethrin and lambda-cyhalothrin detected in kales planted in the experimental garden even after waiting for the recommended time.

v. Most of the pyrethroids residues of the vegetable samples analysed from both the urban and the rural areas during the dry and the wet seasons exceeded the WHO’s ADI.

vi. Most of the pyrethroids residues of the vegetable samples analysed from both the urban and the rural areas during the dry and the wet seasons residues were less than the WHO’s MRLs.
4.13.2 Recommendations

4.13.2.1 Recommendations from the present study

From the results the following recommendations have been made:

i. People in both urban and rural areas should be encouraged to thoroughly wash vegetables before use to minimize consumption of pesticide residues.

ii. The public should be sensitized on the dangers of pesticides to their health.

iii. Farmers should be advised to carefully follow the manufacturers’ instructions or specifications before and after applying the pyrethroids and other pesticides on their vegetables.

iv. People should be encouraged to avoid using pesticides where necessary or to use alternative methods of pest control, for example the biological methods of pesticides control.

4.13.2.2 Recommendations for further research

The results of the present study have observed gaps in the following areas, which need to be filled:

i. Vegetables from other parts of the country be analysed for the pesticides residue levels.

ii. Other vegetables, grains and fruits be analysed for pesticides.

iii. Histological studies on the effects of pesticides be done. This can be done by dosing some study animals with pesticides and then investigating their behavior and how these pesticides affect them.

iv. Long-term study of the effects of deltamethrin and lambda-cyhalothrin be done.
v. Experimental studies for other vegetables and pesticides be carried out.
REFERENCES


REFERENCES


APPENDICES

Appendix I The six active ingredients of pyrethrum

<table>
<thead>
<tr>
<th>The pyrethrins</th>
<th>R</th>
<th>( R' )</th>
<th>Empirical formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrethrin I</td>
<td>-CH(_2)-CH=CH-CH=CH(_2)</td>
<td>-CH(_3)</td>
<td>C(<em>{12})H(</em>{28})O(_3)</td>
</tr>
<tr>
<td>Pyrethrin II</td>
<td>-CH(_2)-CH=CH-CH=CH(_2)</td>
<td>-COOCH(_3)</td>
<td>C(<em>{22})H(</em>{28})O(_5)</td>
</tr>
<tr>
<td>Cinerin I</td>
<td>-CH(_2)-CH=CH-CH(_3)</td>
<td>-CH(_3)</td>
<td>C(<em>{20})H(</em>{28})O(_3)</td>
</tr>
<tr>
<td>Cinerin II</td>
<td>-CH(_2)-CH=CH-CH(_3)</td>
<td>-COOCH(_3)</td>
<td>C(<em>{21})H(</em>{28})O(_5)</td>
</tr>
<tr>
<td>Jasminol I</td>
<td>-CH(_2)-CH=CH-CH(_2)-CH(_3)</td>
<td>-CH(_3)</td>
<td>C(<em>{21})H(</em>{30})O(_3)</td>
</tr>
<tr>
<td>Jasminol II</td>
<td>-CH(_2)-CH=CH-CH(_2)-CH(_3)</td>
<td>-COOCH(_3)</td>
<td>C(<em>{22})H(</em>{30})O(_5)</td>
</tr>
</tbody>
</table>
## Appendix II Technical grade active ingredient (TGAI) identification

<table>
<thead>
<tr>
<th>Active substance</th>
<th>Lambda-cyhalothrin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical name:</td>
<td>A reaction product containing equal quantities of (S)-α-cyano-3-phenoxybenzyl (Z)-(1R, 3R)-3-(2-chloro-3, 3,3-trifluoropropenyl)-2,2-dimethylcyclopropanecarboxylate and (R)-α-cyano-3-phenoxybenzyl (Z)-(1S, 3S)-3-(2-chloro-3, 3,3-trifluoropropenyl)-2,2-dimethylcyclopropanecarboxylate</td>
</tr>
<tr>
<td>1. International Union of Pure and applied Chemistry (IUPAC)</td>
<td></td>
</tr>
<tr>
<td>2. Chemical abstract Services (CAS)</td>
<td>[1α(s'),3α(z)]-(±)-cyano-(3-phenoxyphenyl)methyl3-(2-chloro-3,3,3-trifluoro-1-propenyl)-2,2-dimethylcyclopropanecarboxylate</td>
</tr>
<tr>
<td>CAS number</td>
<td>91465-08-6</td>
</tr>
<tr>
<td>Molecular formula</td>
<td>C_{23}H_{19}ClF_{3}NO_{3}</td>
</tr>
<tr>
<td>Molecular weight</td>
<td>449.9</td>
</tr>
<tr>
<td>Structural formula</td>
<td><img src="image" alt="Structural formula" /></td>
</tr>
<tr>
<td>Nominal purity of active</td>
<td>85.5% (limits 82.9-88.1%)</td>
</tr>
<tr>
<td>Registration number</td>
<td>24567</td>
</tr>
<tr>
<td>Identity of relevant impurities Of toxicological, environmental or other significance</td>
<td>The technical grade active ingredient Lambda-cyhalothrin does not contain any impurities or microcontaminants known to be toxic substances management policy (TSMP) Track-1 substances.</td>
</tr>
</tbody>
</table>
### Appendix III Lambda-cyhalothrin residues (mg/kg) in cow tissues

<table>
<thead>
<tr>
<th>Dietary feeding rate (mg/kg)</th>
<th>Abductor muscle</th>
<th>Pectoral muscle</th>
<th>Subcutaneous fat</th>
<th>Peritoneal fat</th>
<th>Liver</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.01-0.21</td>
<td>0.07-0.50</td>
<td>&lt;0.01-0.03</td>
</tr>
<tr>
<td>5.0</td>
<td>0.01-0.03</td>
<td>0.03-0.07</td>
<td>0.44-0.81</td>
<td>0.95-1.8</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>25.0</td>
<td>0.08-0.14</td>
<td>0.02-0.41</td>
<td>1.3-4.6</td>
<td>3.9-7.9</td>
<td>0.06-0.10</td>
</tr>
<tr>
<td>25.0 + 14-day recovery period</td>
<td>&lt;0.01-0.05</td>
<td>&lt;0.01-0.03</td>
<td>0.03-1.1</td>
<td>0.47-2.6</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Control</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01-0.02</td>
<td>&lt;0.01-0.07</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

*Source: Sapiets et al., 1985*
Appendix IV The metabolic pathways for cyhalothrin in mammals

Source: Harrison, 1984
## Appendix V Acute toxicity of lambda-cyhalothrin to fish

<table>
<thead>
<tr>
<th>Species</th>
<th>Weight</th>
<th>Test substance and vehicle</th>
<th>Temperature (°C)</th>
<th>96-hours LC50 (µg/litre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainbow trout (<em>Salmo gairdneri</em>)</td>
<td>0.32-1.37</td>
<td>Technical cyhalothrin dispersed via acetone</td>
<td>12</td>
<td>0.54</td>
</tr>
<tr>
<td></td>
<td>0.30-1.48</td>
<td>Technical lambda-cyhalothrin dispersed via acetone</td>
<td>12</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>0.99-2.32</td>
<td>Lambda-cyhalothrin 2.5% EC dispersed in water</td>
<td>16</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>1.28-4.78</td>
<td>Lambda-cyhalothrin 13% EC dispersed in water</td>
<td>12</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>0.87-4.09</td>
<td>Lambda-cyhalothrin 5% EC dispersed in water</td>
<td>16</td>
<td>0.93</td>
</tr>
</tbody>
</table>

Source: Yamauchi *et al.*, 1984
Appendix VI Technical grade active ingredient (TGAI) of deltamethrin

<table>
<thead>
<tr>
<th>REG.NO.</th>
<th>52918-63-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>FORMULA</td>
<td>C\textsubscript{22}H\textsubscript{19}Br\textsubscript{2}NO\textsubscript{3}</td>
</tr>
</tbody>
</table>
| ACTIVITY      | Insecticides (pyrethroid ester insecticides)  
                The name "decamethrin" was originally proposed for this compound and was used in the literature, but was rejected because of a conflict with a trademark. |
| STRUCTURE     | ![Chemical Structure](image) |
Appendix VII The eight stereoisomers of deltamethrin isomer

1. (1R, trans) (1)
2. (1R, trans) (2)
3. (1R, cis) (3)
4. (1R, cis) (4)
5. (1S, trans) (5)
6. (1S, trans) (6)
7. (1S, cis) (7)
8. (1S, cis) (8)
Appendix VIII Some physical and chemical properties of deltamethrin

<table>
<thead>
<tr>
<th>Physical state</th>
<th>Crystalline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>Colorless</td>
</tr>
<tr>
<td>Odor</td>
<td>Odorless</td>
</tr>
<tr>
<td>Density (20 °C)</td>
<td>0.5 g/cm³</td>
</tr>
<tr>
<td>Relative molecular mass</td>
<td>505.24</td>
</tr>
<tr>
<td>Melting point (°C)</td>
<td>98-101</td>
</tr>
<tr>
<td>Boiling point</td>
<td>Decomposes above 300 °C</td>
</tr>
<tr>
<td></td>
<td>&lt; 0.002 mg/litre</td>
</tr>
<tr>
<td>Water solubility (20 °C)</td>
<td>Practically insoluble</td>
</tr>
</tbody>
</table>
Appendix IX The degradation pathways of deltamethrin in soil

Source: Muir et al., 1985
Appendix X. Deltamethrin residues in lettuce and spinach in mg/kg from supervised trials

<table>
<thead>
<tr>
<th>Country</th>
<th>Crop</th>
<th>Year</th>
<th>Rate (g/ha)</th>
<th>Residues (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>Lettuce</td>
<td>1979</td>
<td>12.5</td>
<td>0.27 ± 0.150</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1980</td>
<td>12.5</td>
<td>0.12 ± 0.11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1981</td>
<td>14.0</td>
<td>0.06 ± 0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1982</td>
<td>12.0</td>
<td>0.18 ± 0.15</td>
</tr>
<tr>
<td></td>
<td>Spinach (leaf)</td>
<td>1978</td>
<td>17.5</td>
<td>0.47 ± 0.06</td>
</tr>
<tr>
<td>France</td>
<td>Lettuce</td>
<td>1979</td>
<td>12.5</td>
<td>0.40 ± 0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1980</td>
<td>17.5</td>
<td>0.60 ± 0.27</td>
</tr>
</tbody>
</table>

Source: FAO/WHO, 1986

Appendix XI Deltamethrin residues in leafy vegetables in mg/kg from supervised trials

<table>
<thead>
<tr>
<th>Country</th>
<th>Crop</th>
<th>Year</th>
<th>Rate of application</th>
<th>Residues (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Zealand</td>
<td>Cabbage</td>
<td>1980</td>
<td>10</td>
<td>0.02 ± 0.00</td>
</tr>
<tr>
<td></td>
<td>Broccoli</td>
<td>1980</td>
<td>10</td>
<td>0.06 ± 0.02</td>
</tr>
<tr>
<td>Canada</td>
<td>Broccoli</td>
<td>1983</td>
<td>20</td>
<td>0.40 ± 0.40</td>
</tr>
<tr>
<td></td>
<td>(immature head)</td>
<td>1983</td>
<td>10</td>
<td>0.075 ± 0.007</td>
</tr>
<tr>
<td></td>
<td>Brussels sprouts</td>
<td>1983</td>
<td>20</td>
<td>n.d</td>
</tr>
<tr>
<td></td>
<td>Cauliflower</td>
<td>1983</td>
<td>10</td>
<td>n.d</td>
</tr>
<tr>
<td></td>
<td>Cabbage (GRUNKOHL)</td>
<td>1983</td>
<td>13</td>
<td>0.19 ± 0.17</td>
</tr>
</tbody>
</table>

Source: FAO/WHO, 1986
Appendix XII Deltamethrin residues in fruiting vegetables in mg/kg from supervised trials

<table>
<thead>
<tr>
<th>Country</th>
<th>Crop</th>
<th>Year</th>
<th>Rate of application (mWk^-2)</th>
<th>Residues (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>Tomato</td>
<td>1979</td>
<td>12.5</td>
<td>0.28 ± 0.36</td>
</tr>
<tr>
<td>New Zealand</td>
<td>Tomato</td>
<td>1980</td>
<td>15</td>
<td>0.011 ± 0.002</td>
</tr>
<tr>
<td>Germany</td>
<td>Tomato</td>
<td>1980</td>
<td>18.90</td>
<td>0.01 ± 0.01</td>
</tr>
<tr>
<td></td>
<td>Spinach</td>
<td>1980</td>
<td>17.5</td>
<td>0.04 ± 0.03</td>
</tr>
<tr>
<td>South Africa</td>
<td>Tomato</td>
<td>1981</td>
<td>1.25</td>
<td>0.05 ± 0.00</td>
</tr>
<tr>
<td>Australia</td>
<td>Tomato</td>
<td>1981</td>
<td>25</td>
<td>0.25 ± 0.35</td>
</tr>
<tr>
<td>Denmark</td>
<td>Green peppers</td>
<td>1980</td>
<td>12.5</td>
<td>0.01 ± 0.00</td>
</tr>
<tr>
<td>France</td>
<td>Green peppers</td>
<td>1979</td>
<td>12.5</td>
<td>0.06 ± 0.04</td>
</tr>
</tbody>
</table>

Source: FAO/WHO, 1986
### Appendix XIII Pyrethroid insecticide residues in vegetables and fruits for the year 1997

<table>
<thead>
<tr>
<th>Vegetables and fruits</th>
<th>Total No of samples</th>
<th>Cypermethrin</th>
<th>Deltamethrin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Range mg kg⁻¹</td>
<td>No of samples</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>15</td>
<td>0.01-0.41</td>
<td>11 0.5</td>
</tr>
<tr>
<td>Cabbage</td>
<td>15</td>
<td>0.013</td>
<td>1 1.0 0.017 1 0.2</td>
</tr>
<tr>
<td>Cauliflower head</td>
<td>8</td>
<td>0.04-0.06</td>
<td>2 1.0</td>
</tr>
<tr>
<td>Cauliflower leaves</td>
<td>8</td>
<td>0.47-1.12</td>
<td>2 1.0</td>
</tr>
<tr>
<td>Lettuce</td>
<td>15</td>
<td>0.74</td>
<td>1 2.0</td>
</tr>
<tr>
<td>Watercress</td>
<td>16</td>
<td>0.02-0.97</td>
<td>2 0.003-0.097 3 0.5</td>
</tr>
<tr>
<td>Beans</td>
<td>16</td>
<td>0.013-0.27</td>
<td>5 0.5</td>
</tr>
<tr>
<td>Golden Squash (Patisson)</td>
<td>14</td>
<td>0.014</td>
<td>1 0.2</td>
</tr>
<tr>
<td>Mustard greens (Brede de Chine)</td>
<td>2</td>
<td>0.42</td>
<td>1 1.0</td>
</tr>
<tr>
<td>Chinese Cabbage (Petsai)</td>
<td>2</td>
<td>NDL</td>
<td>NDL</td>
</tr>
<tr>
<td>Pineapple (peel)</td>
<td>1</td>
<td>NDL</td>
<td>-</td>
</tr>
<tr>
<td>Pineapple (pulp)</td>
<td>1</td>
<td>NDL</td>
<td>-</td>
</tr>
<tr>
<td>Mandarin (peel)</td>
<td>1</td>
<td>NDL</td>
<td>0.215</td>
</tr>
<tr>
<td>Mandarin (pulp)</td>
<td>1</td>
<td>NDL</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: Lee and Seeneevassen, 1997

### Appendix XIV Raw data of deltamethrin residue levels in mg/kg of duplicate samples from the urban areas during the dry season, n=2

<table>
<thead>
<tr>
<th>Samples</th>
<th>S₁</th>
<th>S₂</th>
<th>S₃</th>
<th>S₄</th>
<th>S₅</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kales</td>
<td>0.0800±0.0050</td>
<td>0.3800±0.0300</td>
<td>0.1000±0.900</td>
<td>0.1900±0.0160</td>
<td>0.1900±0.0100</td>
</tr>
<tr>
<td>Cabbages</td>
<td>0.0700±0.0110</td>
<td>0.0800±0.0060</td>
<td>0.0400±0.0080</td>
<td>0.0700±0.0130</td>
<td>0.0700±0.0060</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0.1800±0.0400</td>
<td>0.1100±0.0100</td>
<td>0.1500±0.0050</td>
<td>0.1300±0.0140</td>
<td>ND</td>
</tr>
</tbody>
</table>

**Key:**
- S₁-S₅- Sample 1- sample 5
- ND- Not Detected
Appendix XV Raw data of deltamethrin residue levels in mg/kg of duplicate samples from the urban areas during the wet season, n=2

<table>
<thead>
<tr>
<th>Samples</th>
<th>S_1</th>
<th>S_2</th>
<th>S_3</th>
<th>S_4</th>
<th>S_5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kales</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>0.2000±0.0300</td>
<td>ND</td>
</tr>
<tr>
<td>Cabbages</td>
<td>ND</td>
<td>0.0500±0.0010</td>
<td>0.0300±0.0100</td>
<td>ND</td>
<td>0.0200±0.0010</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0.0400±0.0000</td>
<td>ND</td>
<td>0.0020±0.0002</td>
<td>ND</td>
<td>ND</td>
</tr>
</tbody>
</table>

Key:  
S_1-S_5- Sample 1- sample 5  
ND- Not Detected

Appendix XVI Raw data of deltamethrin residue levels in mg/kg of duplicate samples from the rural areas during the dry season n=2

<table>
<thead>
<tr>
<th>Samples</th>
<th>S_1</th>
<th>S_2</th>
<th>S_3</th>
<th>S_4</th>
<th>S_5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kales</td>
<td>ND</td>
<td>0.1300±0.0000</td>
<td>0.1300±0.0140</td>
<td>0.1600±0.0140</td>
<td>0.1700±0.0070</td>
</tr>
<tr>
<td>Cabbages</td>
<td>0.2000±0.0000</td>
<td>0.0400±0.0000</td>
<td>0.2000±0.0100</td>
<td>0.0600±0.0010</td>
<td>0.2000±0.0140</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0.3000±0.0100</td>
<td>0.0500±0.0014</td>
<td>0.0400±0.0000</td>
<td>ND</td>
<td>ND</td>
</tr>
</tbody>
</table>

Key:  
S_1-S_5- Sample 1- sample 5  
ND- Not Detected

Appendix XVII Raw data of deltamethrin residue levels in mg/kg of duplicate samples from the rural areas during the wet season

<table>
<thead>
<tr>
<th>Samples</th>
<th>S_1</th>
<th>S_2</th>
<th>S_3</th>
<th>S_4</th>
<th>S_5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kales</td>
<td>0.0800±0.0050</td>
<td>0.0300±0.0014</td>
<td>0.2000±0.0050</td>
<td>0.0400±0.0014</td>
<td>0.2000±0.0140</td>
</tr>
<tr>
<td>Cabbages</td>
<td>0.0030±0.0003</td>
<td>ND</td>
<td>0.0030±0.0001</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0.0175±0.0001</td>
<td>ND</td>
<td>0.0016±0.0000</td>
<td>0.0020±0.0000</td>
<td>ND</td>
</tr>
</tbody>
</table>

Key:  
S_1-S_5- Sample 1- sample 5  
ND- Not Detected

Appendix XVIII Raw data of lambda-cyhalothrin residue levels in mg/kg of duplicate samples from the urban areas during the dry season n=2

<table>
<thead>
<tr>
<th>Samples</th>
<th>S_1</th>
<th>S_2</th>
<th>S_3</th>
<th>S_4</th>
<th>S_5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kales</td>
<td>0.0390±0.0014</td>
<td>0.0430±0.0010</td>
<td>0.0086±0.0001</td>
<td>0.0200±0.0014</td>
<td>0.0400±0.0010</td>
</tr>
<tr>
<td>Cabbages</td>
<td>0.0200±0.0000</td>
<td>0.0700±0.0020</td>
<td>0.1500±0.0112</td>
<td>0.1000±0.0000</td>
<td>0.190±0.0050</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0.3400±0.0100</td>
<td>0.4800±0.0050</td>
<td>0.3000±0.0100</td>
<td>0.4100±0.0200</td>
<td>0.1800±0.0000</td>
</tr>
</tbody>
</table>

Key:  
S_1-S_5- Sample 1- sample 5
Appendix XIX Raw data of lambda-cyhalothrin residue levels in mg/kg of duplicate samples from the urban areas during the wet season

<table>
<thead>
<tr>
<th>Samples</th>
<th>S₁</th>
<th>S₂</th>
<th>S₃</th>
<th>S₄</th>
<th>S₅</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kales</td>
<td>ND</td>
<td>ND</td>
<td>0.0200±0.0000</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Cabbages</td>
<td>ND</td>
<td>ND</td>
<td>0.0200±0.0010</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
</tbody>
</table>

**Key:**  
S₁-S₅ - Sample 1- sample 5  
ND - Not Detected

Appendix XX Raw data of lambda-cyhalothrin residue levels in mg/kg of duplicate samples from the rural areas during the dry season

<table>
<thead>
<tr>
<th>Samples</th>
<th>S₁</th>
<th>S₂</th>
<th>S₃</th>
<th>S₄</th>
<th>S₅</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kales</td>
<td>0.0300±0.0014</td>
<td>0.0300±0.0020</td>
<td>ND</td>
<td>0.004±0.0001</td>
<td>0.0005±0.0000</td>
</tr>
<tr>
<td>Cabbages</td>
<td>0.0600±0.0070</td>
<td>0.0700±0.0020</td>
<td>0.0800±0.0000</td>
<td>0.0040±0.0001</td>
<td>0.0800±0.0000</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0.0024±0.0001</td>
<td>0.0005±0.0000</td>
<td>0.0800±0.0050</td>
<td>0.0700±0.0020</td>
<td>0.0500±0.0000</td>
</tr>
</tbody>
</table>

**Key:**  
S₁-S₅ - Sample 1- sample 5

Appendix XXI Raw data of lambda-cyhalothrin residue levels in mg/kg of duplicate samples from the rural areas during the wet season

<table>
<thead>
<tr>
<th>Samples</th>
<th>S₁</th>
<th>S₂</th>
<th>S₃</th>
<th>S₄</th>
<th>S₅</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kales</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Cabbages</td>
<td>0.0100±0.0010</td>
<td>ND</td>
<td>0.0100±0.0010</td>
<td>ND</td>
<td>0.0040±0.0000</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>ND</td>
<td>0.0100±0.0010</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
</tbody>
</table>

**Key:**  
S₁-S₅ - Sample 1- sample 5  
ND - Not Detected

Appendix XXII Raw data of deltamethrin residue levels in mg/kg of duplicate samples analysed between days 1-5 after the application during the dry season

<table>
<thead>
<tr>
<th>Day</th>
<th>1st application</th>
<th>2nd application</th>
<th>3rd application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0900 ± 0.0014</td>
<td>0.1100 ± 0.0200</td>
<td>0.1200 ± 0.0140</td>
</tr>
<tr>
<td>2</td>
<td>0.0500 ± 0.0020</td>
<td>0.0600 ± 0.0000</td>
<td>0.6500 ± 0.0000</td>
</tr>
<tr>
<td>3</td>
<td>0.0450 ± 0.0000</td>
<td>0.0500 ± 0.0014</td>
<td>0.0560 ± 0.0100</td>
</tr>
<tr>
<td>4</td>
<td>0.0380 ± 0.0014</td>
<td>0.0400 ± 0.0000</td>
<td>0.0420 ± 0.0014</td>
</tr>
<tr>
<td>5</td>
<td>0.0180 ± 0.0010</td>
<td>0.0190 ± 0.0010</td>
<td>0.0220 ± 0.0000</td>
</tr>
</tbody>
</table>
Appendix XXIII Raw data of deltamethrin residue levels in mg/kg of duplicate samples analysed between days 1-5 after the application during the wet season

<table>
<thead>
<tr>
<th>Day</th>
<th>1st application</th>
<th>2nd application</th>
<th>3rd application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0850 ± 0.0000</td>
<td>0.1000 ± 0.0000</td>
<td>0.1100 ± 0.0014</td>
</tr>
<tr>
<td>2</td>
<td>0.0560 ± 0.00190</td>
<td>0.0600 ± 0.0010</td>
<td>0.0640 ± 0.0010</td>
</tr>
<tr>
<td>3</td>
<td>0.0370 ± 0.0014</td>
<td>0.0410 ± 0.0010</td>
<td>0.0420 ± 0.0000</td>
</tr>
<tr>
<td>4</td>
<td>0.0180 ± 0.0000</td>
<td>0.0220 ± 0.0014</td>
<td>0.0240 ± 0.0014</td>
</tr>
<tr>
<td>5</td>
<td>0.0080 ± 0.0010</td>
<td>0.0096 ± 0.0000</td>
<td>0.0130 ± 0.0010</td>
</tr>
</tbody>
</table>

Appendix XXIV Raw data of lambda-cyhalothrin residue levels in mg/kg of duplicate samples analysed between days 1-5 after the application during the dry season

<table>
<thead>
<tr>
<th>Day</th>
<th>1st application</th>
<th>2nd application</th>
<th>3rd application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.7600 ± 0.0100</td>
<td>1.7900 ± 0.0140</td>
<td>1.8100 ± 0.0100</td>
</tr>
<tr>
<td>2</td>
<td>0.8700 ± 0.0140</td>
<td>0.8900 ± 0.0000</td>
<td>0.9200 ± 0.0140</td>
</tr>
<tr>
<td>3</td>
<td>0.4800 ± 0.0000</td>
<td>0.5000 ± 0.0140</td>
<td>0.5200 ± 0.0000</td>
</tr>
<tr>
<td>4</td>
<td>0.1450 ± 0.0010</td>
<td>0.1470 ± 0.0010</td>
<td>0.1510 ± 0.0010</td>
</tr>
<tr>
<td>5</td>
<td>0.1380 ± 0.0014</td>
<td>0.1390 ± 0.0014</td>
<td>0.1420 ± 0.0014</td>
</tr>
</tbody>
</table>

Appendix XXV Raw data of lambda-cyhalothrin residue levels in mg/kg of duplicate samples analysed between days 1-5 after the application during the wet season

<table>
<thead>
<tr>
<th>Day</th>
<th>1st application</th>
<th>2nd application</th>
<th>3rd application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0280 ± 0.0010</td>
<td>0.0300 ± 0.0014</td>
<td>0.0330 ± 0.0010</td>
</tr>
<tr>
<td>2</td>
<td>0.0180 ± 0.0014</td>
<td>0.0210 ± 0.0000</td>
<td>0.0220 ± 0.0014</td>
</tr>
<tr>
<td>3</td>
<td>0.0070 ± 0.0000</td>
<td>0.0090 ± 0.0010</td>
<td>0.0130 ± 0.0000</td>
</tr>
<tr>
<td>4</td>
<td>0.0069 ± 0.0001</td>
<td>0.0070 ± 0.0001</td>
<td>0.0071 ± 0.0001</td>
</tr>
<tr>
<td>5</td>
<td>0.0038 ± 0.0001</td>
<td>0.0041 ± 0.0000</td>
<td>0.0042 ± 0.0001</td>
</tr>
</tbody>
</table>
Appendix XXVI A plate showing tomatoes growing in a garden

Appendix XXVII A plate showing Researcher buying cabbages for the study at Githurai market (urban area)
Appendix XXVIII A plate showing Kales growing in a garden

Appendix XXIX A plate showing a farmer spraying kales with pesticide
Appendix XXX A plate showing the three types of vegetables analysed in the study (kales, cabbages and tomatoes)