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MANAGEMENT OF INSECT PESTS OF TOMATO (*Solanum lycopersium* L.) and OKRA (*Abelmoschus esculentus* L.) USING KARATE (lambda cyhalothrin) WITH ALATA SAMINA

BY

EDDIE ZORKPO ZOMONWAY (BSc. Hons. General Agriculture)

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EDDIE ZORKPO ZOMONWAY (BSc. Hons. General Agriculture)

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In Partial Fulfillment of the Requirements for the Degree

Of

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DECLARATION

I, Eddie Zorkpo Zomonway, do hereby declare that this submission is my own work towards the Master of Philosophy Degree in Crop Protection (Entomology) and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the university, except where due acknowledgement has been made in the text.

Eddie Zorkpo Zomonway	……………………………	…………..………
PG-1219413	Signature	Date

Certified by:

Dr. Enoch A. Osekre	……………………………	…………..………
Supervisor	Signature	Date

Dr. Enoch A. Osekre	……………………………	…………..………
Head of Department	Signature	Date

ABSTRACT

Field experiments were conducted in 2014 at the Plantation Crops Section of the Department of Crop and Soil Sciences of the Kwame Nkrumah University of Science and Technology (KNUST), to evaluate the effect of karate (lambda-cyhalothrin) with 1% and 2% of alata samina on tomato (*Solanum lycopersicum* L.) and okra (*Abelmoschus esculentus* L.) for the management of insect pests of the two crops. A control plot that received only water was also maintained. Two species of *Podagrica*, *P. sjostedti* (Jacoby) and *P. uniformis* (Jacoby), *Aphis gossypii* (Glover) and *Thrips tabaci* (Linderman) were collected on okra. In both seasons, karate, karate + 1% and karate + 2% alata samina significantly ($P < 0.05$) reduced the aggregations of the insects than the control. *A. gossypii, T. tabaci,* and *B. tabaci* Gennadius were collected from the tomato plots. Karate, karate + 1% and 2% alata samina significantly reduced aggregations of the insects as compared to the untreated plots. Significantly ($P < 0.05$) less number of *Bemisia tabaci* aggregated on the karate + 2% alata samina treatment plots in the major and minor cropping seasons. With regard to okra, significantly ($P < 0.05$) fewer *T. tabaci*, *A. gossypii* and *Podagrica* spp. were collected from the plots that received applications containing karate, in the major season. Similar results were obtained in the minor season for *T. tabaci* and *A. gossypii* but, significantly fewer *Podagrica* spp. were collected on the karate + 2% alata samina treatment plots. Application of karate + 2% alata samina significantly ($P < 0.05$) reduced damage to tomato fruits compared to fruits on the untreated control plots in both the major and minor seasons. Significantly ($P < 0.05$) less percent defoliation was recorded on the karate-treated plots than the untreated control plots in both seasons. Karate + 2% alata samina application also significantly ($P < 0.05$) increased yield of tomato in both seasons. Significant increase in yield of okra was obtained from the karate + 2% alata samina plots, but no significant differences were obtained in the number of damaged okra fruits. The best protection of the crops against the insect pests was obtained from weekly applications of karate + 2% alata mixture.

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DEDICATION

This project is dedicated to my father, Mr. Mesa G. Zomonway, my late mother Mrs. Helena D. Zomonway, who did not live long to see her dream come true. "May her soul rest in perfect peace" and my girlfriend Miss Georgina Donkor and finally to my siblings especially Mr. T. Jimmy Zomonway, his lovely children Jimmy Saye Zomonway Jr. and Helena Kou Leela Zomonway.

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CHAPTER ONE

1.0 INTRODUCTION

Okra (*Abelmoschus esculentus* L.) and tomato (*Solanum lycopersicum* L.) are among the most important vegetables in Ghana. Rich in nutrients, okra and tomato supply vital vitamins, minerals, and dietary fiber to the human diet. The production of these crops has great potential to increase the income level and the standard of living of growers (Afreh-Nuamah 1996; Obeng-Ofori and Ankrah, 2002). In Ghana, farmers in Brong-Ahafo, Ashanti, Northern, Volta, Greater Accra and Central are the bulk producers in terms of tonnage (NARP, 1993).

The world okra production, as of 2007, was estimated at 4.8 million tons with India leading the production by 70%, followed by Nigeria (15%), Pakistan (2%), Ghana (2%), Egypt (1.7%) and Iraq (1.7%) (Gulsen *et al*., 2007). Okra is a major vegetable crop grown in Ghana and many countries around the world (Bisht and Bhat, 2006). Okra fruit is principally consumed fresh or cooked and is a major source of vitamin A, B, and C and minerals such as iron and iodine, but it is reportedly low in sodium, saturated fat and cholesterol (Shehaya *et al*., 1984). The crop is widely cultivated throughout the year in the tropics.

Demand for vegetables in Ghana is very high and therefore, production is all-yearround, under rain-fed condition in the wet seasons and under irrigation in the dry season (Bonsu, 2002). Tomato is normally used in large quantities compared to other vegetables (Ellis *et al*., 1998). However, in most West African countries, it is produced mainly for domestic consumption (Norman, 1992).

The yield of vegetables is low, due to diseases, insect-pests and some environmental factors such as low humidity or high temperature (Bonsu, 2002). Tomato is attacked by insect-pests such as whiteflies, *Bemisia tabaci* (Gennadius), Aphid, *Aphis gossypii* (Glover) and the American bollworm, *Helicoverpa armigera* (Hubner). Aphids attack the tender shoots and the young leaves of the host plant, but they can exist on older leaves. *B. tabaci* transmits a large number of diseases to crop plants. According to Graham-Bryce, (1981), pesticide application is the best and most effective way of controlling insect pests of vegetables in Ghana. They are known to increase yield tremendously as these chemicals destroy the nervous system of their target insect pest.

The use of insecticides is usually the first tactic used to manage these insect pests on vegetable crops. Intensive pesticide use on okra and tomato increases the cost of production, making these vegetables expensive for poor consumers. Additionally, the indiscriminate and widespread use of synthetic insecticides in vegetables cultivation has resulted in insect building resistance against the insecticides (Odhiambo, 2010, Owusu and Yeboah, 2007; Wintuma, 2009).

Karate (a. i. lambda cyhalothrin) is the insecticide of choice of most vegetable farmers and is widely used in Ghana. Recent studies have shown some resistance by some of these insects to this insecticide and farmers try to manage this problem by using more dosage and frequencies than the recommended rate. Some agricultural adjuvants increase pesticide efficacy, are toxic to certain species, or increase the toxicity of pesticides (Mangan and Moreno, 2001; Sharma and Singh, 2001; Stark and Walthall, 2003). Locally manufactured soaps such as alata samina, from plant products may serve as an adjuvant in complementing or increasing the effectiveness of the insecticide. According to Owusu and Yeboah, (2007), easily available locally, inexpensive, non-toxic plant products which possess insecticidal, antifeedant or repellent properties have been identified.

It is based on this backdrop that this study with the objective to assess the efficacy of karate in Alata samina for the management of insect-pests on okra and tomato, was undertaken.

1.1 Specific Objectives

The specific objectives were to determine the effect of karate in alata samina on the

i) incidence of insect-pests of okra and tomato, ii)
damage caused by insect-pests of the two crops, and

iii) yield of okra and tomato

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Tomato (*Solanum lycopersicum* L.)

Tomato (*Solanum lycopersicum* L.) is one of the most important and popular vegetables in the world (Peralta and Spooner, 2007). Its cultivation is widely spread throughout Africa (Norman, 1992; Obeng-Ofori *et al.*, 2002) and it is a very important crop used in many recipes and for different products. Through domestication, research and breeding activities by scientists worldwide, modern tomato varieties (mostly hybrids) with all shapes, colours and sizes have been developed.

Tomato belongs to the Solanaceae family, which includes more than 3000 species including eggplant, pepper and potato (Knapp, 2002). Although the crop requires a relatively cool, dry climate for high yield and better quality fruits (Nicola *et al*., 2009), it is adapted to a wide range of climatic conditions from temperate to hot and humid tropical (Naika *et al*., 2005). Tomato contains nutrients such as vitamins A and C, potassium, phosphorus, magnesium, and calcium (Kabelka *et al*., 2009; Obeng-Ofori *et al*., 2002). It also contains lycopene, an antioxidant that reduces the risk of cancer (Miller, 2002). According to Ellis *et al*. (1998), in Ghana, however, tomato is almost an obligatory ingredient in the daily diets of people across all regions. Compared to other vegetables used in Ghana, tomato is normally used in large quantities.

2.2 World Tomato Production

The major tomato growing countries are China, India, USA, Turkey, Egypt and Italy. It is grown on more than five million hectares with a production of nearly 129 million tons. China is the world's top tomato grower, accounting for more than onequarter of the world's tomato acreage. Egypt and India together account for more than one-fifth of the world total; Turkey and Nigeria are the other major tomato producing countries (FAO, 2008). Asia and Africa account for about 79% of the global tomato area, with about 65% of world output (FAO, 2008).

2.3 Tomato Production in Ghana

Tomato is a relatively short duration vegetable crop that is grown both for fresh market and for processing. Major tomato - growing communities include Akumadan and Wenchi in the Ashanti Region and the Brong Ahafo regions, respectively (ISODEC, 2004). Other tomato production areas include Tono, Vea and Navrongo in the Upper East region, Mankesim and Okyereko in the Central region, Afram Plains in the Eastern region, Ada in the Greater Accra region and the Keta-Akatsi areas of the Volta region (Norman, 1992; ISODEC, 2004; Obeng- Ofori *et al*., 2002). Tomato cultivation

is predominantly rain-fed in Ghana. However, there are few irrigation facilities for dry season production in the Akumadan, Tono, Vea and Navrongo areas (Obeng-Oforl *et al*., 2002; Ntow *et al*., 2008). Some important tomato varieties cultivated in Ghana include Wosowoso, Rasta, Heinz 135, Roma VFN, Power and
Petomech (Blay, 2005; Norman, 1992; Obeng-Ofori *et al*., 2002).

Tomato is grown throughout the year in Akumadan. Generally, there are three tomato growing seasons (March - May, July - September and September - November), but the crop can be cultivated up to four seasons on marshy land along streams and under irrigation conditions during the dry season between December and March (Ntow *et al*., 2008). According to Adu-Dapaah and Oppong-Konadu (2002), the lowest and highest annual production levels ever recorded in Ghana were 35,800 and 213,000 metric tonnes in 1995 and 1997, respectively. Currently, the annual volume of production in Ghana rarely reaches 90,000 Mt (Adu-Dapaah and OppongKonadu, 2002). Production levels of fresh and processed tomato in Ghana are inadequate in meeting the ever-increasing domestic demand as evidenced by the increasing influx of imported processed tomato paste as well as the importation of fresh tomato from neighbouring Burkina Faso (ISODEC, 2004; Horna *et al*., 2008). After the closure of the two state-owned tomato-processing factories, the Wenchi tomato processing factory is the only large-scale producer of processed tomato products in the country (ISODEC, 2004).

Tomato is perishable and as such proper post-harvest handling of the commodity is critical for ensuring longer shelf-life. It was reported by Ofuso-Anim (2008), that post - harvest losses in fresh crops are primarily due to mechanical damage resulting from unsatisfactory handling, physiological processes such as ripening, wilting and senescence (Davis *et al*., 2012). Considerable post-harvest losses of tomato fruits in Ghana have been attributed to high temperature and relative humidity as well as unsatisfactory handling during transport and storage (Obeng-Ofori *et al*., 2002). Fruits are usually packed in baskets, cardboard boxes and wooden crates and transported over long distances, especially from the northern parts of Ghana to the attractive markets in the south (Norman, 1992; ISODEC, 2004; Obeng-Ofori *et al*., 2002).

2.4 Pesticide Use in Okra and Tomato Cultivation in Ghana

In most tomato production systems, farmers almost entirely rely on the use of pesticides to combat insect pests and diseases (Biney, 2001; Berlin and Eitrem, 2005; Gianessi, 2009). Although, chemical pesticides safeguard crops and improve farm productivity, there are increased concerns about their potentially dangerous residues and their effects on the ecosystem (NAS, 2000; Cooper and Dobson, 2007). The annual pesticide usage in Akumadan was estimated at 500 tons, of which 4% are made up of organochlorine compounds (Ntow, 2008).

Out of the several pesticide formulations used by tomato farmers in the Upper East region of Ghana, Biney (2001) found that only two of these formulations were registered for use in Ghana. Studies in Ghana suggest that some farmers mix cocktails of two or more insecticides including obsolete insecticides (Biney, 2001; Obuobie *et al*., 2006; Ntow *et al.*, 2008; Wintuma, 2009). It has been observed that the lower cost and effectiveness of most banned insecticides are key factors that make most banned pesticides attractive and affordable to resource-poor smallholder farmers in Africa (Williamson, 2003). Some of the restricted or banned pesticides still being used on vegetable crops in Ghana include Dichloro-diphenyl-trichloroethane (DDT), lindane and endosulfan (Kotey *et al.*, 2008).

2.5 Origin and Botany of Okra

Okra (*Abelmoschus esculeutus* L.) has its origin in West Africa (Joshi *et al*., 1974; Kochhar, 1986). It is currently grown on a large scale in Africa, especially in the Sudan, Egypt and Nigeria (Joshi *et al*., 1974). It is also very important in other tropical regions including Asia, Central and South Americas. Okra is a warm-season annual herbaceous vegetable crop grown primarily for immature fruits used in soups and stews. The Nile basin seems to have been the route by which this plant spread throughout North Africa, the eastern Mediterranean, Asia Minor and to India. There are a number of varieties, both wild and cultivated, including *A. esculentus, A. caillei, A. moschatus, A. manihot, A. ficulneas and A. tetraphyllus*. Two species in the genus *Abelmoschus* are cultivated *A. manihot* L. and *A. moschatus* L. (Stevels, 1988; Siemousma, 1991).

Okra is an amphidiploid-having a complete diploid set of chromosome derived from each parent (Siemonsma, 1982) with varieties displaying a tremendous variation in plant size, shape, fruit type and colour. Okra seed is also similar in size to soybeans and can be handled with most of the same equipment (Martin, 1982). Okra plant is a semi woody, fibrous herbaceous annual with an indeterminate growth habit (Nonnecke, 1989). The plant form a deeply penetrating taproot with dense shallow feeder roots reaching out in all direction in the upper 45 cm of the soil. The seeds are dicotyledonous and they vary in shape; roundness, kidney or spherical with epigeal germination (Hamon *et al*., 1991; Ariyo, 1993).

The Monoic flowers of Okra are self-compatible (Martin, 1983; Hamon *et al*, 1991). About 35-60 days after emergence, the plant begins to flower and the flower remains open for a day. It is mainly self-fertilized. Harvesting is commended at least every other day for size and quality (Ramu, 1976). About 35-40 days are required from anthesis to seed maturity. If fruits are allowed to mature, plant growth declines and few flowers develop, but with continuous harvesting, the plant continues to set fruit (Purewal and Rhandhaug, 1947). Fruits are harvested four to seven days after the flower has opened, and the fruit are not fibrous.

The rate of allogamy differs according to varieties and ecological conditions (Hamon *et al*., 1991). Okra has alternate palmate broad leaves and the flowers have fine large yellow petals with a large purple area covering the base. The fruit, which is harvested immature, are pale green, green or purplish fruit and in many cultivars are ridged (Hamon *et al*., 1991). When mature, they are dark brown dehiscent or indehiscent capsules. Fruit shapes range from round to ridged and short to long (Siemonsma, 1982). The plant and fruits may have small spines on them that create allergies in some people (Ariyo, 1993; Duzyaman, 1997).

2.6 Environmental Requirements of Okra

Okra is a warm season crop, growing best between the minimum and maximum mean temperatures of 18^{o}C (65^{o}F) and 35^{o}C (95^{o}F), respectively (Martin, 1982). In recent years there has been interest in growing it as a protected crop in heated greenhouse in Northern Europe (Buchholz *et al*., 2006). Optimum temperature requirements range from 21^{o} to 30^{o}C (Martin, 1982). It can be grown in a wide range of soil types provided the drainage is good.

It is intolerant of wet and poorly drained and acidic soils (Incalcaterra and CuratoLo, 1997). Okra does not do well in tight, water logged soils, but will tolerate a soil pH range from 6.0 to 7.5 (Incalcaterra and Curato-Lo, 1997). The addition of lime or dolomite may be necessary during soil preparation to bring the pH to about 6.0 to 6.5 (Incalcaterra and Curato-Lo, 1997). Optimum soil temperature for seed germination is 24^{o}C-32^{o}C (75^{o}-90^{o}F) (Martin, 1982). Germination is poor at 20^{o}C (68^{o}F). Short day-length stimulates flowering of most cultivars (Martin, 1982).

Flowering begins at a very early stage of growth at day lengths of less than 11 h; under long days, the flower buds tend to abort (Lutz and Hardenburg, 1966). Germination will take 5-14 days (Hamon *et al*., 1991). Okra is best eaten just after it is picked but it can be stored for several days. Okra will keep for 7-10 days if kept at 45-50^{o}C with a relative humidity of 90-95% (Martin, 1982). Okra is very sensitive to ethylene gas, and therefore not recommended to be stored with vegetables and fruits that give off ethylene gas such as apples and pears (Lutz and Hardenburg, 1966).

2.7 Okra Nutritional Information

2.7.1 Nutritional value and Health Benefits

Okra is a repository of valuable nutrients (Table 2:1) (Candlish *et al*., 1987; Grubben *et al*., 1977). Nearly half of which is soluble fiber in the form of gums and pectins. Soluble fiber helps to lower serum cholesterol, reducing the risk of heart disease (Brown *et al*., 1999).

The other half is insoluble fiber which helps to keep the intestinal tract healthy, decreasing the risk of some forms of cancer, especially colorectal cancer (Schneeman, 1998). Nearly 10% of the recommended levels of vitamin B6 and folic acid are also present in a half cup of cooked okra (Hamon and Charrier, 1997).

Table 2.1. Nutritive value of Okra fruit

VARIABLE	**CONTENT (%)**
Dry matter	10.4
Moisture	85.5
Protein	1.8
Starch	0.52
Cellulose	0.98
Lignin	0.52
Calcium	0.09
Iron	0.001
Carotene	0.0001
Thiamin	0.00007
Riboflavin	0.00008
Niacin	0.0008
Vitamin	0.13

Source: (Grubben *et al*., 1977, Candlish *et al*., 1987)

2.8 World okra production

Okra is a potential export crop in the Middle East, Thailand, Japan and the Philippines (Siemonsma, 1982). The world production of okra as fresh vegetable is estimated at six million tonnes per year. In West and Central Africa, production figures are estimated at between 500,000 to 600,000 tonnes annually (Siemonsma, 1982). It is an economically important vegetable crop grown in tropical and subtropical parts of the world. This crop is suitable for cultivation on large commercial farms. It is grown commercially in India, Turkey, Nigeria, Brazil, Ghana, Ethiopia and the Southern

United States. India ranks first in the world with 3.5 million tonnes which is 70% of the world's total (FAOSTAT, 2008).

2.8.1 Okra production in Ghana

The average yield of okra is between 1.5 to 4.5 tons/ha (SRID-MOFA, 2007). Despite its importance, the crop, like all other fresh vegetables, has a problem of short shelf-life. The fresh fruits remain in usable quality for eight to ten days if held at 0-10ºC at 90% relative humidity (Chauhan, 1972). Those held at 2-13ºC lasted for only four to six days and deteriorated rapidly on exposure to higher temperatures (20-26ºC) (Yamaguchi, 1983). Large quantities of okra fruits produced during the main production season are usually left to deteriorate, as they cannot be kept longer. Producers are forced under the circumstances to give their commodities out at "takeaway" prices. In certain situations market women have no alternative than to throw away the okra fruits in the market. Many growers depend mostly on daily sales for their income and hence are forced to accept a lower price under such situations of glut (FAO, 1988).

2.8.2 Harvest of tomato and okra

Tomato first harvest is ready in 10-12 weeks after transplanting. The harvest period continues for 8-10 weeks. Tomatoes are harvested ripe for the local market. Okra matures in 45-50 days after sowing. The harvest season continues for one to two months. Only younger pods of two to three days old after flowering are desired in the market, as the older ones become tough and woody. More frequent harvest, for example, every three days, results in more yields, a longer picking period and better quality produce (Sharafel-Din, 1986).

2.9 Common pests of Tomato and okra

Tomato and okra plants are subject to infestation by sucking insects, notably whiteflies (*B. tabaci*) (Hemiptera: Aleyrodidae), cotton aphid, *A. gossypii* (Hemiptera: Aphididae) and Thrips, *T. tabaci* (Thysanoptera: Thripidae). These attack the riped and pre-riped fruits of tomato, contaminating them with frass and exposing them to fungi and bacteria. *Thrips tabaci* prefers the reproductive parts of the okra plant, including buds, flowers and fruits. Okra plants are also attacked by flea beetles *Podagrica uniformis* **(**Jacoby) *and P. sjostedti* (Jacoby) (Coleoptera: Chrysomelidae) and can cause damage by feeding on the leaves. If more than two and three individuals appear per seedling, chemical control measures need to be initiated (Schmutterer, 1961).

Plate 2.1: A. Aphids, *A. gossypii* and B. Whiteflies, *B. tabaci*

Source :(http://www.nbcnews.com).

2.10 Morphology or Biology of Whitefly

The whitefly is a soft-bodied, moth-like fly. The wings, however, are covered with powdery wax and the body is light yellow in colour. The adult males are slightly smaller in size than the females. The adults live for one to three weeks. The females mostly lay eggs near the veins on the lower surface of tomato leaves. They prefer hairy leaf surfaces to lay more eggs and each female can produce as many as 300 eggs in its lifetime. Eggs are tiny (about 0.2 mm long) and pear-shaped, and vertically attached to the leaf surfaces through a pedicel. Newly laid eggs are white and later turn to brown meanwhile, hatching occurs after 5-10 days at 30°C depending on species, temperature and humidity (Martin, 1999). *Bemisia tabaci* is highly polyphagous and is known to feed on several vegetables including tomato, eggplant, pepper and okra and weeds. Additionally, hot, dry conditions favour the whitefly, and heavy rains drastically reduce population build-up. The pest is active during the day and settles on lower leaf surfaces at night (Martin, 1999).

Damage by this pest is direct by feeding on the host. Both the adults and nymphs suck the plant sap and reduce the vigour of the plant (Martin, 1999; Perring, 2001). Additionally, in severe infestations, the leaves turn yellow and drop off. With increased populations, they secrete large quantities of honeydew, which favour the growth of sooty mould on leaf surfaces and reduce the photosynthetic efficiency of the plants (Brown *et al.,* 1995). The honeydew also contaminates the marketable part of the plant, reducing its market value. However, damage is also indirect as vectors of viral diseases. *Bemisia tabaci* transmits viral diseases on cassava, cotton, tobacco, tomato, beans, chillies, and sweet potatoes (Brown *et al*., 1995). Whitefly transmitted viruses are among the most serious viral diseases on plants, often resulting in total crop losses. As reported by Legg *et al.* (2003), whitefly is the vector of a range of leaf curl disease - inducing viruses in Africa, including the tomato yellow leaf curl virus, the cassava mosaic virus, the cowpea mild mottle virus, and the water melon chlorotic stunt virus, among others. Affected plant stages are the seedling, vegetative growing stage and flowering stages; mainly affected parts are the leaves (Legg *et al.*, 2003).

2.11 Life cycle of whiteflies

According to Schmutterer (1969), whiteflies are known to reproduce bisexually or parthenogenetically, and hence numerous generations can occur during the year. Both adults and nymphs suck the plant sap. They stand upright on the leaves, being anchored at the broad end by a short stalk inserted into the leaf. They are laid usually in arcs or circles, on the undersides of young leaves. Eggs are whitish in colour when first laid, but gradually turn brown. Some whiteflies deposit large quantities of wax around the eggs in the form of a loose spiral like a fingerprint (Davis *et al*., 2012). On hatching, the first instar nymph is flat, oval and scale-like, and greenish-white in colour and is the only mobile nymphal stage. It moves to a suitable feeding location on the lower leaf surface where it settles. It moults, losing the legs and antennae, and cannot move throughout the remaining immature stages. The first three nymphal stages last two to four days. Many species produce large quantities of waxy secretions around the margins and the dorsal surface of the nymph (Martin, 1999).

2.12 Aphids, *Aphis gossypii* Glover (Hemiptera: Aphididae)

Aphids or plant lice are one of the most common polyphagous insect pests (Berlandier and Sweetingham, 2003). Detection of the field damage of tomato aphids' population in relation to crop phenology and climatic condition is considered as a prime requisite for the execution of the subsequent crop protection package in view of modern IPM practices. According to Cruz and Bernardo (1971) and Contagelo *et al.* (1971), the pest affects almost all the aerial parts of the tomato plant from the early growth stages till the fruit maturation stage. Feeding often results in stunting, curling or yellowing of plant green foliage (Berlandier and Sweetingham, 2003). Severe infestations may exterminate the plant totally (Sharma and Bhatnagar, 2004).

Way *et al.* (1954) documented that the damage done by aphids reduce seed viability and food value of bean. Severe infestation causes necrosis to the plant chlorophyllus tissues, suppresses tomato flowers to bloom and makes the mature fruits unfit to for consumption. Aphids transmit viruses from plant to plant on certain vegetable and ornamental plants. Although losses can be great, minimizing them through the control of aphids is difficult because infestation occurs even when aphid numbers are very low. It takes a few minutes for the aphid to transmit the virus while it takes a much longer time to kill the aphid with an insecticide.

Natural enemies can be very important in the control of aphids. The most wellknown are adult and larva ladybird beetles, lacewing larvae, and syrphid fly larvae. Before planting vegetables, surrounding areas should be checked for sources of aphids and be removed. Aphids often build up on weeds, moving onto crop seedlings after they are planted. Aphids should be removed on transplants before planting, and localized aphids population on a few curled leaves or new shoots, should be pruned out. In some situations, ants tend aphids and feed on the honeydew aphids excrete. At the same time, they protect the aphids from natural enemies. A band of sticky material, for example Tanglefoot, is usually placed around the trunk to prevent ants from getting up.

Many pesticides are available to control aphids. Materials such as oils and soaps are safer to use where children and pets may be present, and may provide more effective long term control because they do not kill the natural enemies of the aphids.

2.13 Ecology of Aphids

Sharafel-Din (1986) reported about the variation in aphid incidence from one area to another and, from season to season in the same area, depending on a number of biotic and abiotic factors. El Khidir (1960) found that the insect's population dropped when local temperatures dropped between January and February while increase in temperature during April and May, produced higher pest infestation.

2.13.1 *Thrips tabaci* (Lindeman) (Thysanoptera: Thripidae)

Thrips are important pests of several crops in most parts of the world. They are elongated, elliptical and slender small insects ranging from 0.5 to 1.2 mm in size. Their eyes have darker coloration and are easy to see. Immature thrips have short antennae. The difference between immature and adults is that immatures do not have wings, so they cannot fly. They have a wide host range including cabbage, cotton, celery, tomatoes, beans, cucumber and pineapple. The economic threshold is three thrips per green leaf. In other parts, the recommended economic threshold is 20% of the plants infested with thrips (Hoffmann *et al.*, 1996).

In most cases thrips are not a problem in the rainy season because the rain washes them from the plant. At the end of the hot dry season, thrips populations are at their maximum. In some places, it is better not to plant under these conditions because thrips control is almost impossible (Hoffmann *et al.*, 1996). Good sanitation practices and planting of resistant cultivars that have a more open growth characteristic are recommended. Because of severe pesticide resistance problems around the globe, it is very important to minimize pesticides use to avoid unfriendly conditions with the environment (Hoffmann *et al.*, 1996). There are several natural enemies that help in the control of thrips. Unfortunately, none of them alone can reduce the thrips populations to a low, non-economical density. Also, the intensive use of pesticides limits natural enemies' activity (Hoffmann *et al.*, 1996).

2.13.2 Ecology of flea beetles (*Podagrica* spp.)

Schmutterer (1969) recorded flea beetles from Saudi Arabia, Africa and other parts of the world. The main host plants of flea beetles are the members of Malvaceae such as cotton and okra. The most serious damage is caused to young seedlings. They cause damage of economic importance by feeding on the leaves. Seedling are either badly stunted in growth or destroyed and on older plants, a typical shot-hole effect is caused on the leaves.

2.13.3 Damage caused by insect pests on okra and tomato

Insect pests of tomato and okra usually suck plant nutrients and transmit a number of viruses that cause diseases such as leaf curl (Osei *et al*., 2010). Wilting and shedding of leaves, fruits and branches are symptoms associated with very heavy infestation of such insects, which may result in a decrease in yield.

In West-Africa, okra is attacked by flea beetles *P. uniformis* and *P. sjostedti* which are responsible for heavy defoliation (Odebiyi, 1980). Heavy yield losses are reported in Nigeria and Ghana (Obeng-Ofori and Sackey, 2003; Ahmed *et al*., 2007).

These insects also transmit the okra mosaic virus which causes significant yield losses (Vanlommel *et al*., 1996). Okra plants in gardens are badly infested and injured by flea beetle.

2.14 Karate (a. i. lambda cyhalothrin) - Common pesticide use in Ghana Lambda cyhalothrin is a pyrethroid, a class of man-made insecticides that mimic the structure and insecticidal properties of the naturally occurring insecticide pyrethrum which comes from the flower of chrysanthemum. Synthetic pyrethroids, such as lambda cyhalothrin, are often preferred as an active ingredient in insecticides because they remain effective for longer periods of time. It is a colourless solid, although samples can appear beige, with a mild odour. It has a low water solubility and is non-volatile. It is used to control insects in vegetables and cereals. Brand names include Karate, Kung-fu, Matador and Demand CS, Charge, Excaliber,
Grenade, Hallmark.

2.15 Mode of Action of Lambda cyhalothrin

Lambda cyhalothrin like other pyrethroids, disrupt the functioning of the nervous system of an organism. By disrupting the nervous system of insects, Lambda cyhalothrin may cause paralysis or death. Temperature influences its effectiveness. It is highly toxic to many fish and aquatic invertebrate species. Binding of Lambda cyhalothrin to soil and sediment reduces exposure and may lessen the risk to fish. Lambda cyhalothrin is also highly toxic to bees, although field studies found few effects. In laboratory research, alkaline water degraded Lambda cyhalothrin with an approximate half-life of seven days, but at neutral and acidic conditions degradation did not occur. Sunlight accelerates its degradation in water and soil. The half-life of lambda cyhalothrin on plant surfaces is five days. Lambda cyhalothrin has a low potential to contaminate ground water due to its low water solubility and high potential to bind to soil (NAS, 2000).

2.16 Alata Samina, its basic ingredients, its usage and its Origins.

The basic ingredients used in alata samina (black soap) are red palm oil or coconut oil, ash from roasted plantain peels, roasted cocoa pods (or black soap) and salt. For centuries, Ghanaians have used alata samina to help relieve acne, oily skin, clear blemishes, rashes, and various other skin issues. It has its origins from the Yoruba tribe in Nigeria. The soap is a soft dark coloured lumpy block. It dissolves faster than commercial cold press soap.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental location

The experiment was carried-out at the plantation crops section of the Department of Crop and Soil Sciences of the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi with Latitude and Longitude of (N 5.676252º, W 1.566939º). The study was done in the major and minor seasons which lasted from July to August and September to December 2014, respectively. The mean average rainfall received during the major season (July-August) was 145.2 mm and the minor season (September-December) was 104.56 mm, also the relative humidity recorded in both the major and minor seasons are 86.4% and 78.5%, while the minimum and maximum temperature recorded in the major season were 21.6 and 29.1^{o}C, and the minor season experienced 21.8 and 31.0^{o}C, respectively.

3.2 Source of seeds

Petomech tomato and Clemson okra varieties were used for the experiments. These were obtained from the Crops Research Institute of the Council for Scientific and Industrial Research (CSIR-CRI), Kwadaso, Kumasi. These varieties were selected based on their susceptibility to field insect pests.

3.3 Nursery preparation

Plant debris from field clearing was burnt on the Nursery beds as a means of sterilizing the soil to reduce soilborne diseases. Tomato seeds were nursed on raised beds with dimensions 3 m x 2 m (6 m^2). Okra seeds were planted directly, three seeds per hole and later thinned to one seedling per hill after emergence.

3.4 Land preparation

Three weeks before ploughing the experimental site with a tractor, herbicide, Nwurawura (Glyphosate) at the rate of 1.5 ml/ 15 *l* of water was sprayed. Prior to the preparation of the land, soil samples were taken for analysis.

3.5 Field layout and experimental design

The experimental fields for tomato and okra were laid out separately with each measuring 5 x 5 m with 1 m alley between them. Total field area was 25 x 25 m (625 m^2). A randomized complete block design (RCBD) with four replications was used.

3.6 Treatments

The treatments for both tomato and okra were:

1. Lambda Only (Dosage recommended) as 36 ml /15*l* of water
2. Lambda mixed with 1% Alata Samina
3. Lambda mixed with 2% Alata Samina
4. Control (water - with no insecticide application)

A trial experiment had shown that 1% alata samina was not effective in reducing insect pests numbers on the two crops, okra and tomato, so this treatment was not included in the main experiment.

Treatment applications were started three and four weeks for tomato and okra respectively after planting. Weekly applications of the treatments were done after field sampling.

3.7 Transplanting of Tomato seedling

Healthy seedlings were transplanted on 3rd June, 2014 during the major season and 20th September, 2014 during the minor season. Seedlings were planted one per hill at a spacing of 0.5 m x 1 m. Each plot had a total of 50 plants with each row having 10 plants. Dead seedlings as a result of transplanting shocks were replaced three days after transplanting.

3.8 Sowing of Okra seeds

Okra seeds were sown on 6th June, 2014 and 29th September, 2014 in the major and minor seasons, respectively. Seeds were soaked in tap water overnight to soften the seed coat which accelerated germination. Seeds were sown three per hill at a spacing of 0.5 m x 1 m. Plants were later thinned to one per hill after emergence. A total of 50 plants were in each plot of 10 plants per row.

3.9 Cultural practices

Weeds were managed every three weeks by manual weeding using a hoe and cutlass. NPK, 15-15-15 fertilizer was applied as the first split at a rate of 10 g per plant three weeks after transplanting for tomato and three weeks after sowing for okra. The second split was urea (46 % N) at 2.2 g per plant three weeks after NPK application.

3.10 Sampling of Insect Pests

Field sampling for insects was done on weekly basis; it began two weeks after seedling emergence for okra and two weeks after transplanting for tomato plants. For whiteflies sampling, visual examination and counting with the aid of a magnifying hand lens was done on five randomly selected plants from the middle rows on the field while for

Podagrica spp., aphids and thrips, three leaves from the plant were picked and put into a plastic container containing liquid soap. Samples were transported to the insect laboratory for identification and counting using a stereomicroscope and tally counter. Sampling was carried out for 10 weeks for both okra and tomato. Sampling was done between 0800 and 1000 h.

3.11 Defoliation of okra

Five randomly selected plants from each plot were sampled for percent defoliation by *Podagrica* spp. on okra. For the estimation of percentage defoliation, critical observation of leaves was made and sections of the leaves that had lost virtually all the photosynthetic sites were observed. Percentage defoliation was calculated as follows:

$$\text{Defoliation (\%)} = \left[\frac{\text{(Total number of leaves defoliated)}}{\text{(Total number of leaves in a sample)}}\right] \text{x } 100$$

Source: (Grubben *et al*., 1977, Candlish *et al*., 1987)

Plate 3.1: Defoliated leaves of okra

3.12 Yield and Yield Components Assessment in Tomato and Okra

Tomato fruits were harvested after every two days and weighed with an electronic scale. Insect damaged and healthy fruits were also assessed. Any fruit with any blemish or injury apparently caused by insects, was considered damaged and the number was expressed over the total number of fruits to obtain the percent damaged. The yield data was also assessed by recording the weight of fruits and expressed in kg/ha. The same procedure was followed to calculate the yield of okra.

3.13 Data Analysis

Insect data were transformed and percentage data were transformed using square root and arcsine transformation, respectively. The data was analysed using Analysis of Variance (ANOVA) with SAS (9) 2010. Tukey's procedure was used for mean separation at 5%.

4 CHAPTER FOUR

RESULTS

4.1 Insect Pests Collected

Whiteflies; *B. tabaci*, aphids; *A. gossypii*, thrips; *T. tabaci*, and flea beetles; *Podagrica* spp. were the insect pests collected and identified from the experimental fields.

4.1.1 Insect pests collected on tomato in the major cropping season

Significantly ($P < 0.05$) more *T. tabaci* and *A. gossypii* were collected on the untreated, control plots than the insecticide-treated plots. Significantly ($P < 0.05$) fewer *B. tabaci* were collected from the plots that received Karate with 2% alata samina than the other treatments (Table 4.1).

Table 4.1: Mean number of insect pests collected on tomato, *Solanum lycopersicum* as affected by the various treatments in the major cropping season in 2014

Treatment	Mean number (± SEM) of insect per leaf		
	T. tabaci	*A. gossypii*	*B. tabaci*
Karate	0.76 ± 0.06 [b]	0.77 ± 0.06 [b]	2.38 ± 0.04 [a]
Karate + 1% Alata samina	0.61 ± 0.04 [b]	0.61 ± 0.04 [b]	2.37 ± 0.04 [a]
Karate + 2% Alata samina	0.61 ± 0.04 [b]	0.61 ± 0.04 [b]	1.83 ± 0.02 [b]
Control	2.63 ± 0.03 [a]	2.52 ± 0.04 [a]	2.45 ± 0.04 [a]

Means with the same letter(s) in a column are not significantly different from each other ($P < 0.05$, according to Tukey)

4.1.2 Insect pests collected on tomato in the minor cropping season

Karate with 2% alata samina treated plots harboured significantly ($P < 0.05$) fewer *B. tabaci* on other treatments. *B. tabaci* than, the karate + 1% alata samina and the control plots were not significantly different from each other and they were more than all the other plots. Significantly ($P < 0.05$) more *T. tabaci* and *A. gossypii* inhabited the control plots than the karate treated plots (Table 4.2).

Table 4.2: Mean number of insect pests collected on tomato, *Solanum lycopersicum* as affected by the various treatments in the minor cropping season in 2014

	Mean number (± SEM) of insect per leaf		
Treatment	*T. tabaci*	*A. gossypii*	*B. tabaci*

Karate	0.69 ± 0.05 [b]	0.72 ± 0.05 [b]	2.05 ± 0.05 [b]
Karate + 1% Alata samina	0.66 ± 0.04 [b]	0.65 ± 0.04 [b]	2.21 ± 0.05 [a]
Karate + 2% Alata samina	0.64 ± 0.04 [b]	0.60 ± 0.04 [b]	1.77 ± 0.03 [c]
Control	2.14 ± 0.06 [a]	2.12 ± 0.05 [a]	2.31 ± 0.04 [a]

Means with the same letter(s) in a column are not significantly different from each other ($P < 0.05$, according to Tukey)

4.1.3 Insect pests collected in the major cropping season on okra

Significantly ($P < 0.05$) more densities of *A. gossypii*, *T. tabaci* and *Podagrica* spp. were collected on the control plots than the karate treated plots (Table 4.3).

Table 4.3: Mean number of insect pests collected on okra, *Abelmoschus esculentus* as affected by the various treatments in the major cropping season in 2014

	Mean number (± SEM) of insect per leaf		
Treatment	*T. tabaci*	*A. gossypii*	*Podagrica* spp.
Karate	0.68 ± 0.05 [b]	0.65 ± 0.04 [b]	2.34 ± 0.06 [b]
Karate + 1% Alata samina	0.58 ± 0.04 [b]	0.61 ± 0.04 [b]	2.26 ± 0.05 [b]
Karate + 2% Alata samina	0.57 ± 0.04 [b]	0.60 ± 0.04 [b]	1.74 ± 0.04 [b]
Control	2.59 ± 0.03 [a]	2.38 ± 0.04 [a]	2.38 ± 0.05 [a]

Means with the same letter(s) in a column are not significantly different from each other ($P < 0.05$, according to Tukey)

4.1.4 Insect pests collected on okra in the minor cropping season

Significantly (P < 0.05) less number of *T. tabaci* and *A. gossypii* were collected from the karate, karate + 1% alata samina and karate + 2% alata samina plots than the control plots. With respect to *Podagrica* spp., only the karate + 2% alata samina plots harboured significantly (P < 0.05) less number of the insect (Table 4.4).

Table 4.4: Mean number of insect pests collected on okra, *Abelmoschus esculentus* as affected by the various treatments in the minor cropping season in 2014

	Mean number (± SEM) of insect per leaf		
Treatment	*T. tabaci*	*A. gossypii*	*Podagrica* spp.
Karate	0.64 ± 0.05 [b]	0.58 ± 0.05 [b]	2.48 ± 0.04 [a]
Karate + 1% Alata samina	0.61 ± 0.05 [b]	0.67 ± 0.04 [b]	2.38 ± 0.04 [a]
Karate + 2% Alata samina	0.63 ± 0.04 [b]	0.65 ± 0.03 [b]	1.59 ± 0.03 [b]
Control	2.67 ± 0.03 [a]	2.61 ± 0.03 [a]	2.49 ± 0.04 [a]

Means with the same letter(s) in a column are not significantly different from each other (P < 0.05, according to Tukey)

4.1.5 Defoliation of okra plants in the major cropping season

Significant differences (P < 0.05) were recorded between karate treated plots and the control plots with respect to percent defoliation of leaves of okra plants in the major cropping season. Also, significant differences were recorded between treatment means of the karate + 1% alata samina and karate + 2% treated plots after 25 DAP, 39 DAP, 46 DAP and 53 DAP. There were no significant differences (P > 0.05) in percent defoliation between the karate only and karate + 2% alata samina on each sampling day (Table 4.5).

4.1.6 Defoliation of okra plants in the minor cropping season

Similar results obtained in the major cropping season were recorded in the minor cropping season (Table 4.6).

Table 4.5: Mean percent defoliation of okra, *Abelmoschus esculentus* plants by *Podagrica* spp., as affected by the treatment applications in the major cropping season in 2014

	Mean percent defoliation (±SEM)				
Treatment	**25 DAP**	**32 DAP**	**39 DAP**	**46 DAP**	**53 DAP**
Karate	6.00 ± 0.39^{bc}	6.00 ± 0.33^{b}	6.00 ± 0.36^{bc}	6.00 ± 0.29^{bc}	26.00 ± 0.97^{bc}
Karate + 1% Alata samina	7.00 ± 0.42^{b}	7.00 ± 0.46^{b}	8.00 ± 0.61^{b}	8.00 ± 0.62^{b}	32.00 ± 1.4^{b}
Karate + 2% Alata samina	5.00 ± 0.21^{c}	5.00 ± 0.24^{b}	5.00 ± 0.28^{c}	5.00 ± 0.41^{c}	26.00 ± 0.65^{c}
Control	15.00 ± 0.79^{a}	17.00 ± 0.10^{a}	17.00 ± 0.10^{a}	18.00 ± 0.88^{a}	76.00 ± 3.1^{a}

Means with the same letter(s) in a column are not significantly different from each other ($P < 0.05$, according to Tukey)

Table 4.6: Mean percent defoliation of okra, *Abelmoschus esculentus* plants by *Podagrica* spp., as affected by the treatment applications in the minor cropping season in 2014

	Mean percent defoliation (±SEM)				
Treatment	**25 DAP**	**32 DAP**	**39 DAP**	**46 DAP**	**53 DAP**
Karate	6.00 ± 0.42 [bc]	6.00 ± 0.46 [b]	6.00 ± 0.34 [bc]	6.00 ± 0.37 [bc]	26.00 ± 0.10 [bc]
Karate + 1% Alata samina	7.00 ± 0.37 [b]	7.00 ± 0.48 [b]	7.00 ± 0.52 [b]	7.00 ± 0.49 [b]	30.00 ± 0.10 [b]
Karate + 2% Alata samina	5.00 ± 0.28 [c]	5.00 ± 0.35 [b]	5.00 ± 0.36 [c]	5.00 ± 0.41 [c]	21.00 ± 0.85 [c]
Control	17.00 ± 0.75 [a]	18.00 ± 0.10 [a]	17.00 ± 0.89 [a]	18.00 ± 0.11 [a]	81.00 ± 0.29 [a]

Means with the same letter(s) in a column are not significantly different from each other ($P < 0.05$, according to Tukey)

4.2 Insect Pests Population Dynamics as influenced by treatment applications on tomato

4.2.1 Whiteflies (*B. tabaci*) population dynamics in the major season

B. tabaci population in the karate only, karate + 1% alata samina and control plots were consistently above two per leaf through 3rd July to 21st August. *B. tabaci* population in the karate + 2% alata samina peaked at slightly at above two per leaf on 31st July and dropped after that day (Figure 4.1).

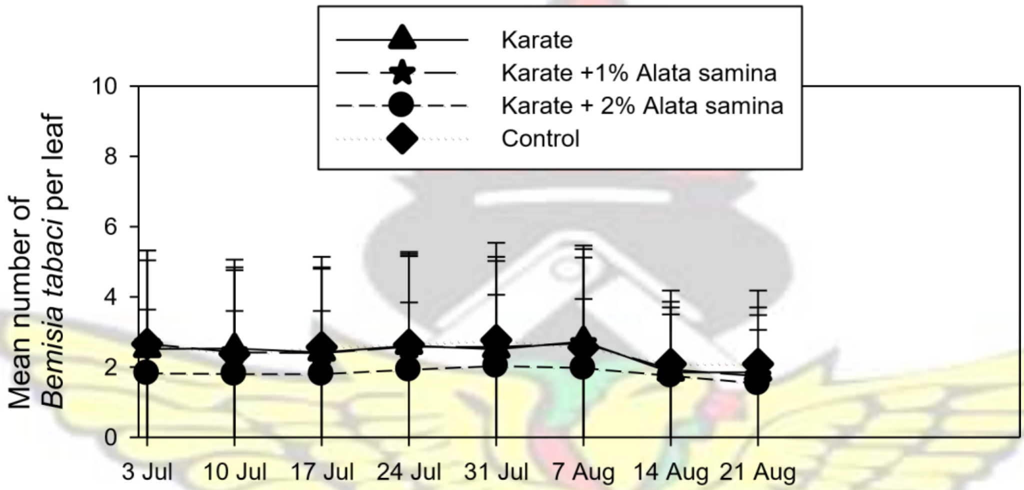

Figure 4.1: Mean number of *Bemisia tabaci* on tomato, *Solanum lycopersicum* plant as influenced by treatment applications in the major cropping season in 2014

4.2.2 Whiteflies (*B. tabaci*) population dynamics in the minor cropping season In the minor season, *B. tabaci* numbers was about two per tomato leaf in all the treated plots. The control plots harboured population densities > 2 per leaf throughout the study period (Figure 4.2).

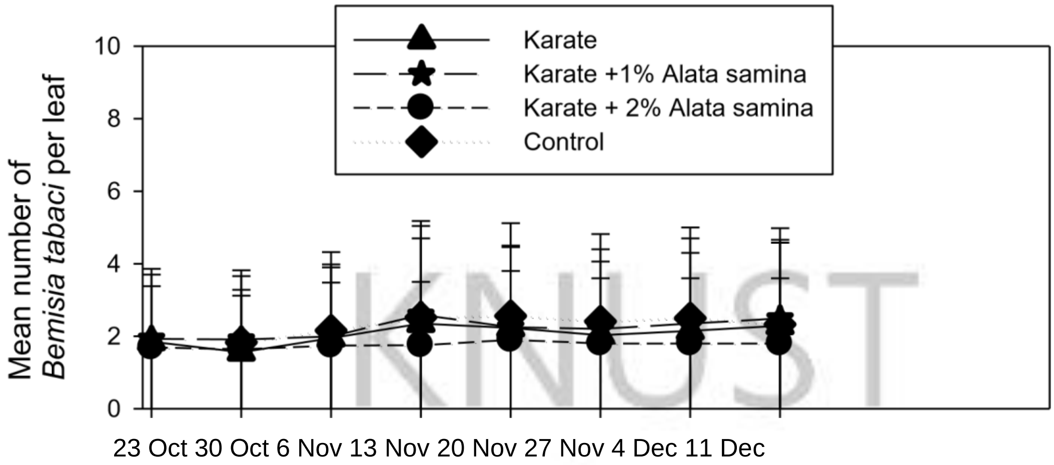

Figure 4.2: Mean number of *Bemisia tabaci* per tomato, *Solanum lycopersicum* plant as influenced by treatment applications in the minor cropping season in 2014

4.2.3 Thrips (*T. tabaci*) population dynamics in the major cropping season

In Figure 4.3, the densities of *T. tabaci* was consistently low (< 1 per tomato leaf) in all karate treated plots almost throughout the study period. Densities of the insect in the karate only treated plots increased to one per leaf in the 3rd week and decreased again in the subsequent weeks. On the other hand, *T. tabaci* population in the control plots remained consistently above two per tomato leaf throughout July and August.

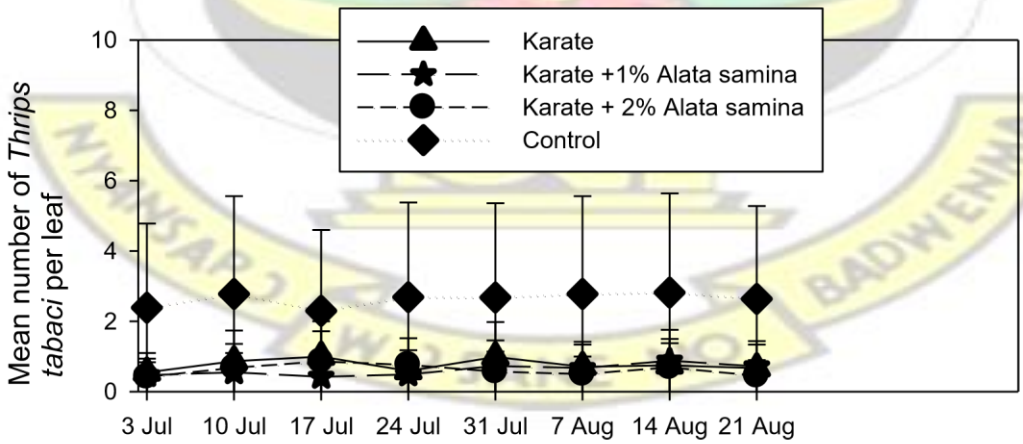

Figure 4.3: Mean number of *Thrips tabaci* per tomato, *Solanum lycopersicum* plant as influenced by the various treatment in the major cropping season in 2014

4.2.4 Thrips (*T. tabaci*) population dynamics in the minor cropping season

Similar to the population densities of *T. tabaci* in the major cropping season, its number progressively increased on the control plots in the minor season with slight dips on 6th November and 4th December. Its numbers on the other treatment plots hovered around 1 per leaf throughout the period (Figure 4.4).

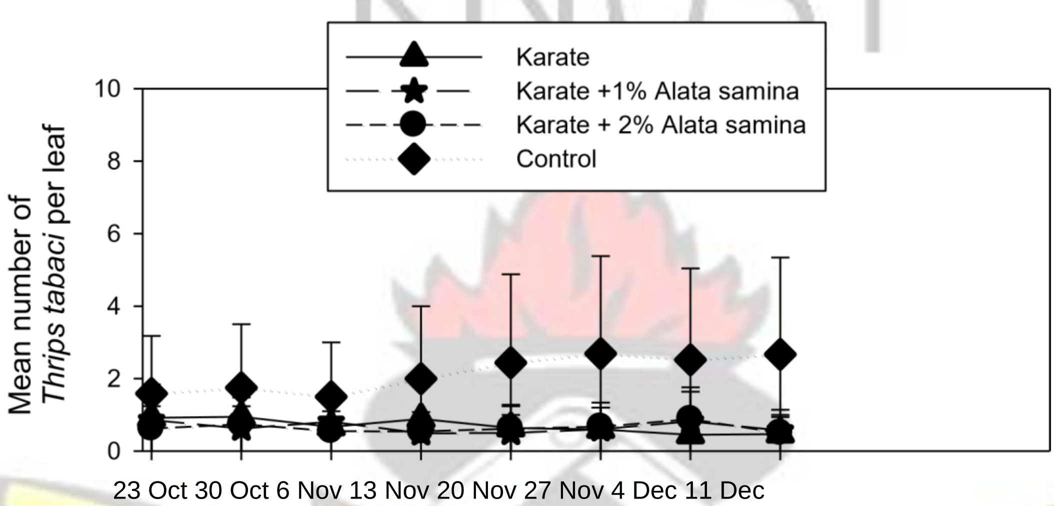

Figure 4.4: Mean number of *Thrips tabaci* per tomato, *Solanum lycopersicum* plant as influenced by the various treatment applications in the minor cropping season in 2014

4.2.5 Aphids (*A. gossypii*) population dynamics in the major cropping season

The density of *A. gossypii* hovered around one per tomato leaf in the karate treated plots but the control plots harboured densities of > 2 per tomato leaf from the 1st week (3rd July) to 7th week (21st August) (Figure 4.5).

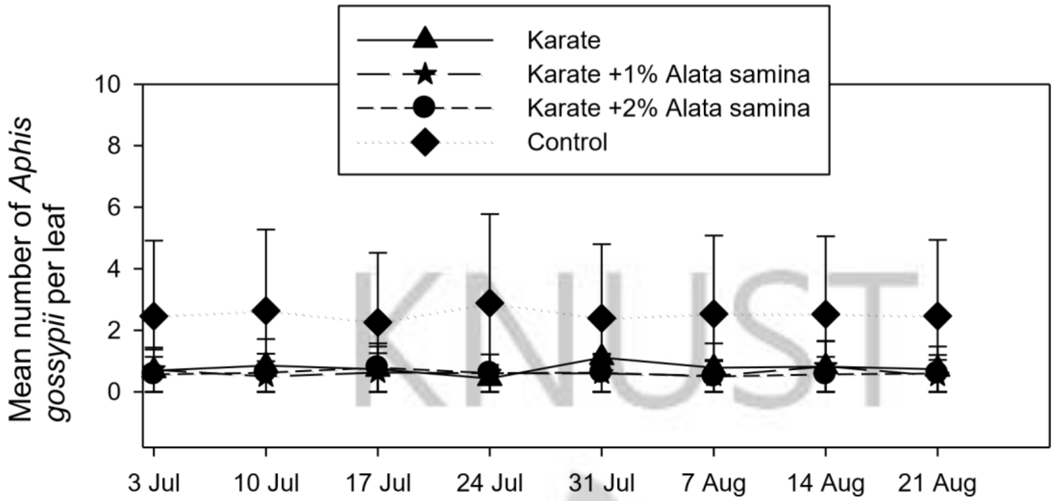

Figure 4.5: Mean number of *Aphis gossypii* per tomato, *Solanum lycopersicum* leaf as influenced by treatment applications in the major cropping season in 2014

4.2.6 Aphids *(A. gossypii)* population dynamics in the minor cropping season

Similarly, consistently low number of (< 1 per tomato leaf) *A. gossypii* was recorded on the karate treated plots throughout the study period whilst the control plots harboured densities > 2 per leaf beyond 13th November (Figure 4.6).

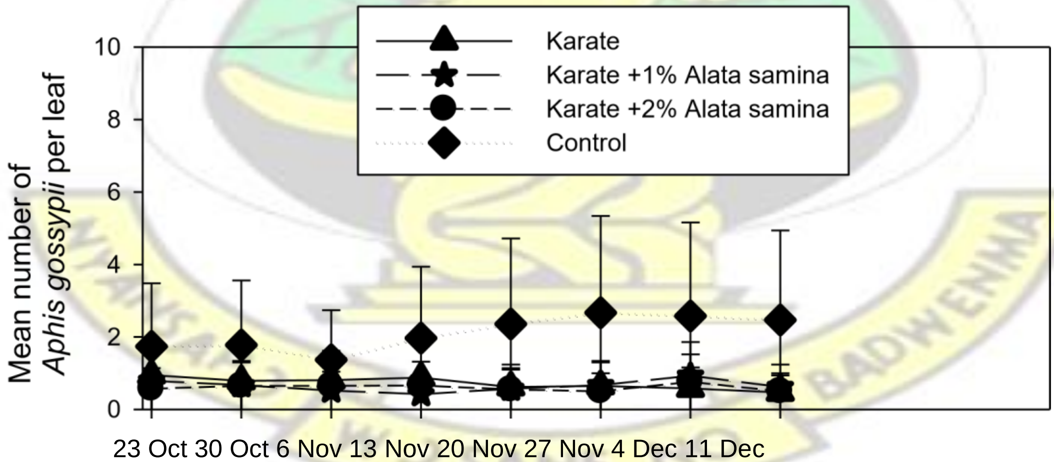

Figure 4.6: Mean number of *Aphis gossypii* per tomato, *Solanum lycopersicum* leaf as influenced by the various treatments in the minor cropping season in 2014

4.3 Flea beetle (*Podagrica* spp.) population dynamics in the major cropping season

Apart from the karate + 2% alata samina plots, > 2 of *Podagrica* spp. per leaf was recorded in all the other treatment plots throughout the study period (Figure 4.7).

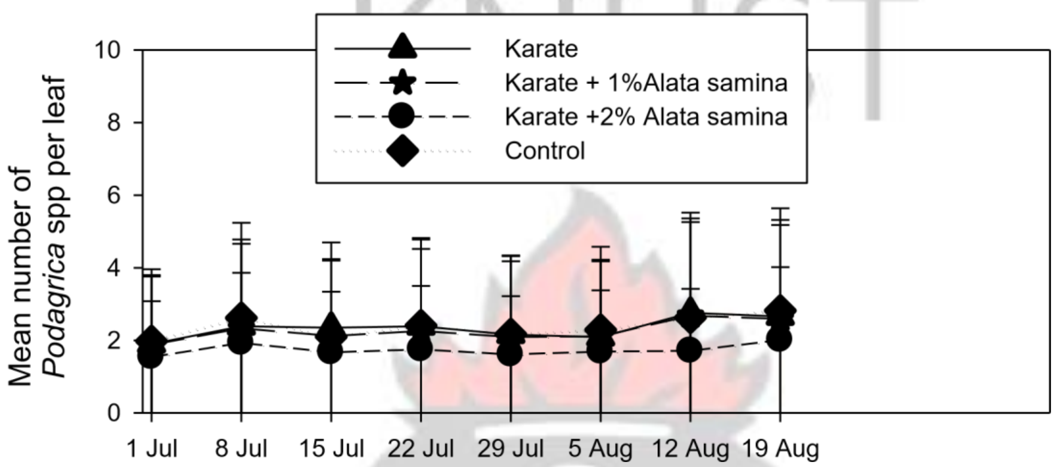

Figure 4.7: Mean number of *Podagrica* spp. per okra, *Abelmoschus esculentus* leaf as affected by various treatment applications in the major cropping season in 2014

4.4 Flea beetle (*Podagrica* spp.) population dynamics in the minor cropping season

Podagrica spp. density in the minor cropping season was about two per leaf on all the various treatment plots throughout the study period (Figure 4.8).

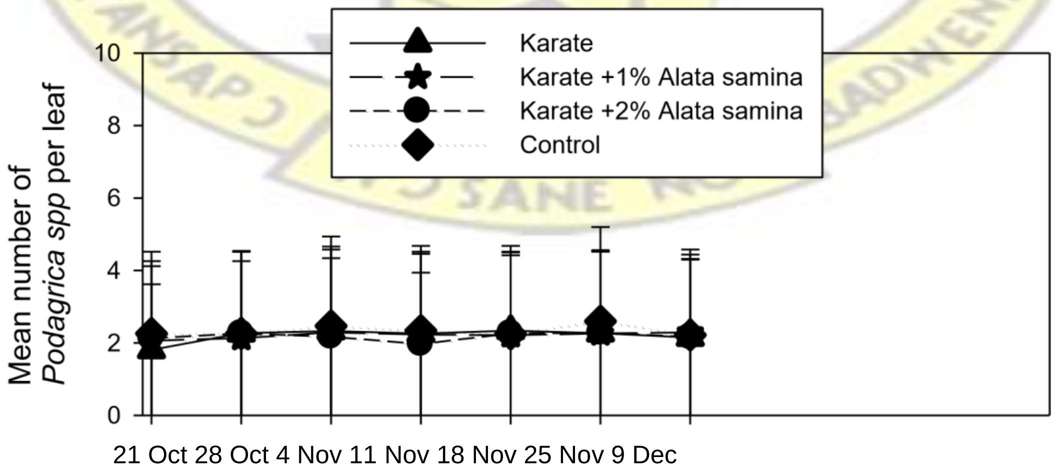

Figure 4.8: Mean number of *Podagrica* spp. per okra, *Abelmoschus esculentus* leaf as affected by the treatments in the minor cropping season in 2014

4.4.1 Thrips (*T. tabaci*) population dynamics in the major cropping season In Figure 4.9, *T. tabaci* density remained low (< 1 per okra leaf) in all karate treated plots when the treatment application began until the 7th week when karate only treated plots increased slightly above one per leaf. The control plots harboured densities of > 2 per leaf throughout the study period.

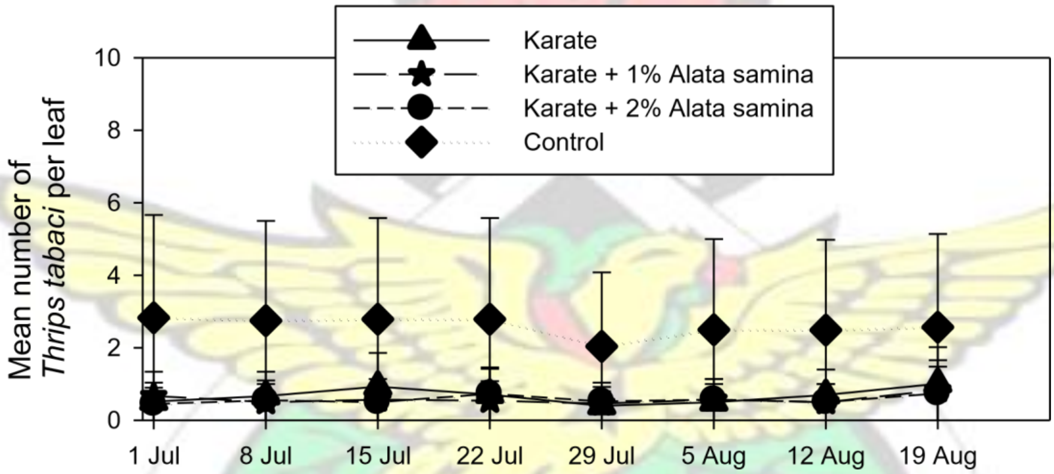

Figure 4.9: Mean number of *Thrips tabaci* per okra, *Abelmoschus esculentus* leaf as affected by treatment application in the major cropping season in 2014

4.4.2 Thrips (*T. tabaci*) population dynamics in the minor cropping season The density of *T. tabaci* in the minor cropping season was higher compared to the major season. Aside karate only treated plot which harboured density < 1 per leaf, the other treatments plots harboured densities > 1 per leaf throughout the growth period (Figure 4.10).

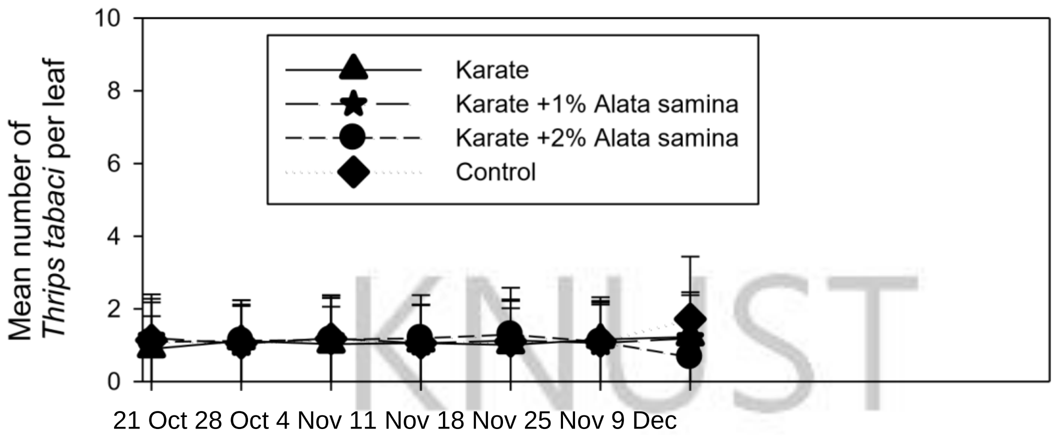

Figure 4.10: Mean number of *Thrips tabaci* per okra, *Abelmoschus esculentus* leaf as affected by treatment applications in the minor cropping season in 2014

4.4.3 Aphids (*A. gossypii*) population dynamics in the major cropping season

The density of *A. gossypii* was low (below one per okra leaf) throughout the study period in the karate treated plots in the major season. Its density in the control plots were above two per leaf in the 1st four weeks, decreased in the 5th week (29th July) and increased from the 6th week (Figure 4.11).

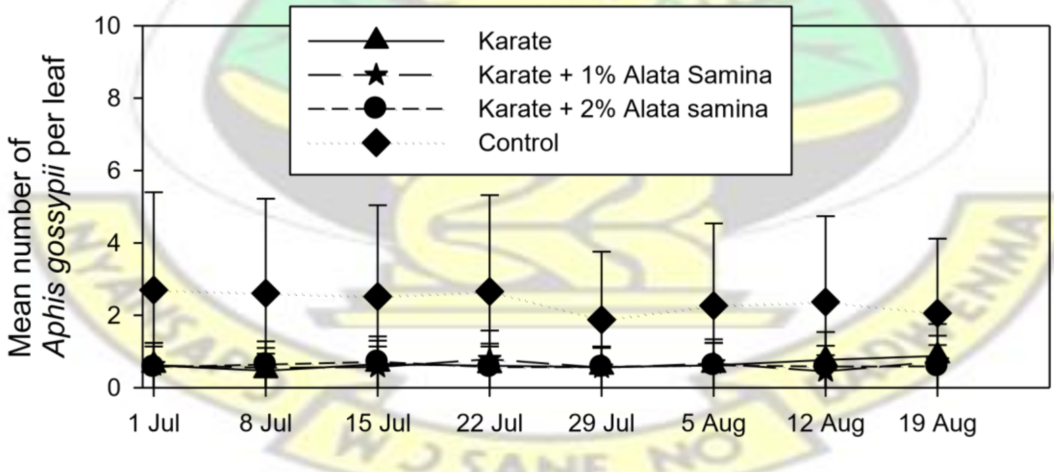

Figure 4.11: Mean number of *Aphis gossypii* per okra, *Abelmoschus esculentus* plant as affected by the treatment applications in the major cropping season in 2014

4.4.4 Aphids (*A. gossypii*) population dynamics in the minor cropping season The density of *A. gossypii* in the minor cropping season was higher compared to the major season with regards to the insecticide treated plots. Densities were above one per leaf throughout most of the weeks in all treatments. Karate + 1% alata samina treated plots harboured < 1 per leaf in the 1st week only while karate only and karate + 2% alata samina harboured < 1 per leaf in the 4th and 7th week, respectively (Figure 4.12).

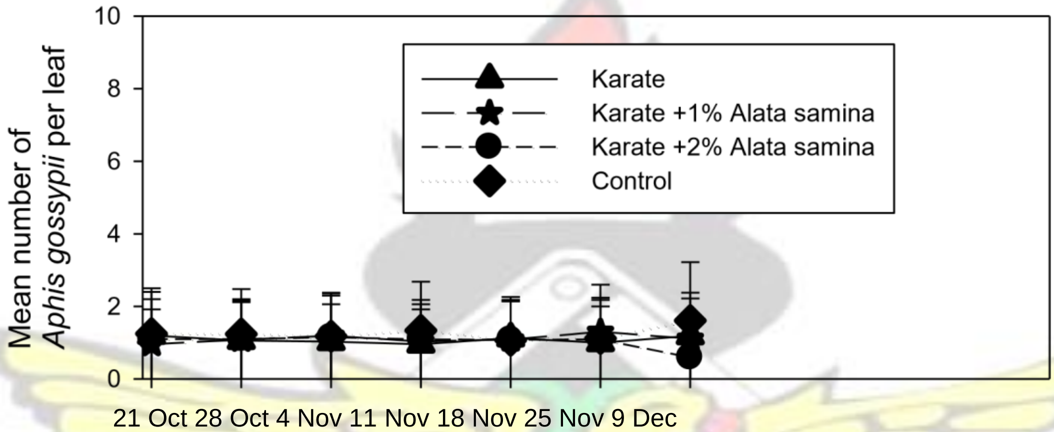

Figure 4.12: Mean number of *Aphis gossypii* per okra, *Abelmoschus esculentus* leaf as influenced by the various treatments in the minor cropping season in 2014

4.4.5 Yield, percent damaged and number of fruits of tomato as affected by various treatments in the major and minor cropping seasons

In the major season, there was significant ($P < 0.05$) difference between karate + 2% alata samina and the control with respect to mean percent damaged fruits. No significant differences were recorded between karate only, karate + 1% alata samina and the control plots. With respect to the mean number of fruits per plant, it was only in the karate only and the control treatments that no significant difference was observed. Significant differences were observed in the yield among the treatments (Table 4.7).

In the minor season, similar results were observed among the treatments in the percent damaged fruits and yield. No significant differences were observed among karate only and karate + 2% alata samina in the number of fruits per plant. There were significant differences observed between the control and the karate treatments (Table 4.7).

4.4.6 Yield, percent damaged and number of fruits of okra as affected by various treatments in the major and minor cropping seasons

Mean percent damaged okra fruits in the major season did not show significant ($P > 0.05$) differences among the treatments (Table 4.8). Apart from the karate only and the karate + 1% alata samina, there were significant ($P < 0.05$) differences in mean number of fruits per plant and the yield among the treatments.

Results similar to what were obtained in the major cropping season were observed in the minor cropping season with respect to the mean percent damaged fruits and the yield. Significant ($P < 0.05$) differences were obtained with respect to the number of fruits per plant (Figure 4.8)

Table 4.7: Yield, number of fruits plant^{-1} and mean damaged fruits as affected by the various treatment on tomato in the major and minor cropping seasons in 2014

	Major season			Minor season		
Treatment	Mean % Damaged fruit	Mean No. of fruits plant^{-1} (g)	Yield (kg/ha)	Mean % Damaged fruit	Mean No. of fruits plant^{-1} (g)	Yield (kg/ha)
Karate	11.25 ± 2.25 ^{ab}	4.79 ± 0.16 ^{c}	987.00 ± 26.24 ^{c}	7.06 ± 2.24 ^{ab}	2.01 ± 0.07 ^{c}	1966.00 ± 132.77 ^{c}
Karate + 1% Alata samina	10.67 ± 2.25 ^{ab}	6.63 ± 0.06 ^{b}	1191.00 ± 82.17 ^{b}	7.78 ± 2.68 ^{ab}	2.27 ± 0.09 ^{b}	2693.00 ± 35.37 ^{b}
Karate + 2% Alata samina	5.23 ± 0.27 ^{b}	9.38 ± 0.26 ^{a}	2095.00 ± 81.55 ^{a}	9.63 ± 0.26 ^{b}	3.12 ± 0.09 ^{a}	3703.00 ± 58.31 ^{a}
Control	12.15 ± 2.17 ^{a}	2.15 ± 0.26 ^{c}	418.00 ± 5.77 ^{d}	12.75 ± 2.19 ^{a}	1.03 ± 0.02 ^{d}	704.00 ± 136.71 ^{d}

Means with the same letter(s) in the column are not significantly different from each other ($P < 0.05$, according to Tukey)

Table 4.8: Yield, yield components and mean damaged fruits as affected by the various treatments on okra in the major and minor cropping seasons in 2014

	Major season			Minor season		
Treatment	Mean % Damaged fruit	Mean No. of fruits plant^{-1} (g)	Yield (kg/ha)	Mean % Damaged fruit	Mean No. of fruits plant^{-1} (g)	Yield (kg/ha)
Karate	8.80 ± 2.20 ^{a}	2.42 ± 0.09 ^{b}	917.00 ± 34.30 ^{b}	17.47 ± 5.54 ^{a}	2.11 ± 0.07 ^{c}	781.00 ± 54.85 ^{b}
Karate + 1% Alata samina	8.71 ± 3.12 ^{a}	2.66 ± 0.09 ^{b}	978.00 ± 40.87 ^{b}	13.86 ± 3.89 ^{a}	2.82 ± 0.14 ^{b}	955.00 ± 60.29 ^{b}
Karate + 2% Alata samina	6.17 ± 1.55 ^{a}	4.31 ± 0.21 ^{a}	1518.00 ± 78.05 ^{a}	10.93 ± 1.10 ^{a}	4.81 ± 0.10 ^{a}	1980.00 ± 95.17 ^{a}
Control	8.50 ± 2.14 ^{a}	1.19 ± 0.08 ^{c}	421.00 ± 12.04 ^{c}	12.91 ± 3.82 ^{a}	1.66 ± 0.08 ^{d}	487.00 ± 27.19 ^{c}

Means with the same letter(s) in the column are not significantly different from each other ($P < 0.05$, according to Tukey)

4.4.7 Percent marketable tomato fruits as affected by various treatments in the major and minor cropping seasons

Mean percent marketable tomato fruits in both major and minor cropping seasons did not show significant differences (Table 4.9).

4.4.8 Percent marketable okra fruits as affected by various treatments in the major and minor cropping seasons

In the major season, mean percent marketable okra fruits in the karate + 2% alata samina was significantly higher than that for the karate only and control plots. In the minor season, there were no significant differences (Table 4.10).

Table 4.9: Percent marketable fruits as affected by the various treatments on tomato in the major and minor cropping seasons in 2014

	Mean % marketable fruits	
Treatment	Major season	Minor season
Karate	88.03 ± 1.34 ^{a}	92.94 ± 1.34 ^{a}
Karate + 1% Alata samina	86.57 ± 4.43 ^{a}	93.48 ± 2.42 ^{a}
Karate + 2% Alata samina	94.77 ± 0.27 ^{a}	90.39 ± 2.63 ^{a}
Control	87.88 ± 2.16 ^{a}	91.29 ± 3.40 ^{a}

Means with the same letter(s) in the column are not significantly different from each other ($P < 0.05$, according to Tukey)

Table 4.10: Percent marketable fruits as affected by the various treatments on okra in the major and minor cropping seasons in 2014

	Mean % marketable fruits	
Treatment	Major season	Minor season
Karate	88.86 ± 1.62 [b]	86.37 ± 2.19 [a]
Karate + 1% Alata samina	93.66 ± 1.01 [ab]	86.67 ± 1.35 [a]
Karate + 2% Alata samina	96.44 ± 0.99 [a]	92.78 ± 2.12 [a]
Control	88.89 ± 2.07 [b]	79.33 ± 5.02 [a]

Means with the same letter(s) in the column are not significantly different from each other ($P < 0.05$, according to Tukey)

CHAPTER FIVE

5.0 DISCUSSION

5.1 Insect pest collected on tomato and okra in the major cropping season

As reported by Momo *et al*. (2014), *T. tabaci*, *A. gossypii*, *B. tabaci* and *Podagrica* spp. were insects identified on tomato and okra. The weekly applications of 1% alata samina, karate and its mixture with 1 and 2% concentration of alata samina on tomato and okra suppressed *T. tabaci* and *A. gossypii* aggregations.

However, Sam *et al*. (2014), reported low densities of *T. tabaci* in lambda-cyhalothrin treated plots. Also, Miller *et al*. (2005) reported 83 and 74% reduction in larvae and adult numbers, respectively, of *Frankliniella* spp. in cotton treated with lambdacyhalothrin alone. Other researchers have also reported adverse effects of lambdacyhalothrin on other species of thrips (Hansen *et al*., 2003; Reitz *et al.*, 2003; Funderburk *et al*., 2002). The control of these insects could be due to the weekly applications of insecticides. This application regime was recommended by Sam *et al*. (2014) reported a bi-weekly application of insecticides could not significantly reduce thrip numbers. Osekre *et al*. (2009) reported that the control of some of the species of thrips was achieved probably because they did weekly application of the insecticides.

Karate + 2% alata samina applications significantly ($P < 0.05$) reduced densities of *B. tabaci* and *Podagrica* spp. (Tables 4.1 and 4.4). Oladimeji and Kannike (2010) reported an 80% reduction in *Podagrica* spp. population at 3.75 ml/litre of lambdacyhalothrin. Higher densities of *B. tabaci* reported in this study could be due to resistance being developed by the insect against the insecticide as reported by Houndete *et al*. (2010). Aetiba and Osekre (2015) reported *B. tabaci* densities of more than two per eggplant leaf in both minor and major cropping seasons when eggplant and okra plots were treated with Lambda super. But the lower density (less than two per tomatoe plant) in karate + 2% alata samina treatment could be due to the fact that 2% alata samina increased the toxicity of karate. According to Nutsugah *et al*. (2007), alata samina applied as a mixture with thiophanate methyl and benomyl significantly reduced early and late leaf spot in peanut resulting in increased pod yields. Osekre *et al.* (2003) also reported 1% alata samina + 40 ml of cymethoate spray reduced insect pests incidence and damage to cowpea plants. The ineffectiveness of karate + 1% alata samina treatment to significantly lower *Podagrica* spp. and *B. tabaci* densities could be due to the concentration (1% alata samina) being low and therefore, could not have any adverse effect on the insects. This effect can also be deduced from the ineffectiveness of sole 1% alata samina to reduce aggregations of the insects in the trial experiment. It can be inferred that, alata samina alone cannot be applied or used as an insecticide, but can be used as an adjuvant with insecticides for increased toxicity when its concentration is increased to at least 2%.

5.2 Effect of insecticides treatment on okra leave damage (defoliation)

Continuous feeding by *Podagrica* spp. on okra leaves resulted in significantly ($P < 0.05$) higher defoliation of the plants in the untreated control plots compared to the treated plots in both major and minor cropping seasons (Table 4.5 and 4.6). Similar leaf defoliation was reported by Dabire-Binso *et al*. (2009) and Momo *et al*. (2014) when they used deltamethrin and chlorpyrifos, respectively. *Podagrica* spp. bore holes into the leaves and as a consequence, reduce the photosynthetic ability of the leaves. Therefore, may reduce okra yield (Dabire-Binso *et al*., 2009).

5.3 Effect of insecticide treatment on the yield of tomato in the major and minor cropping seasons

The insecticide treatments increased yield significantly in tomato in both major and minor cropping seasons. The treatments significantly increased the mean number of fruits produced per plant and yield. However, the mean percentage of damaged fruits compared to the control for karate and karate + 1% alata samina was not significantly different. But, karate + 2% alata samina significantly reduced the mean % damaged fruit as compared to the control (Table 4.7). Karate + 2% alata samina treatment produced the highest yield. This could be due to the effectiveness of the treatment in reducing the density of *B. tabaci* which is known to transmit the yellow leaf curl virus (TYLCV). This virus is known to cause severe yield losses in tomatoes.

5.4 Effect of insecticide treatment on yield of okra in the major and minor season

Insecticide treated plots produced significantly higher fruit number per plant and yield in this study (Table 4.8). According to Anaso (2003) and Thul *et al*. (2009), use of insecticide spraying enhances yield increase in okra. The untreated (control) plots produced significantly lower yield compared to the other treatments. According to Obeng-Ofori and Sackey (2003) and Ahmed *et al*. (2009), defoliation can significantly decrease yields in okra. This was evident in the report by Emosairue and Ukaegbu (1994) in one farmer's field. Flea beetle also transmit okra mosaic virus which causes yield loss (Vanlommel *et al*., 1996). From the study, karate + 2% alata samina treatment proved the most effective by producing significantly higher yield which may have resulted from the effectiveness of the treatment in significantly reducing densities of *Podagrica* spp. compared to the others in the minor season. No significant differences in all treatments for the major season (Table 4.3 and 4.4).

Overall, the insecticide treatments adversely affected the insects therefore, the population densities especially with karate + 2% alata samina treatment. It significantly reduced *B. tabaci* and *Podagrica* spp. densities and yield increased.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

From the results of the study, it can be concluded that karate + 2% alata samina treatment was able to significantly reduce the aggregations of *B. tabaci*. *T. tabaci* and *A. gossypii* on tomato in the major and minor cropping seasons. Similarly, karate + 2% alata samina treatment significantly reduced aggregations of *Bemisia tabaci*, *Thrips tabaci*, *Aphis gossypii* and *Podagrica* spp. on okra, increased the yield, but did not significantly reduce damage by *Podagrica* spp.

Karate + 2% alata samina treatment also significantly reduced the damaged fruit and increase the yield of tomato fruit as compared to the control.

6.2 Recommendations

- Karate + 2% alata samina mixture is recommended for the management of insect pests of okra and tomato.
- Further research should be carried out to determine the effect of other insecticides with alata samina on insect pests of other crops.

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APPENDICES

Appendix I. Descriptive statistics of the initial soil properties taken at the experimental site

Soil property	Value
ORG. C (%)	1.48
Total N (%)	0.11
Available P (mg / kg soil)	10.5
Soil PH	6.02
Exchangeable cations (cmol+ kg /soil)	
Ca	4.8
Mg	0.2
K	0.2
Na	1.5
Al^{3+}	1.5
H	1.1

% Sand = 82.4

% Silt = 7.5

% Clay = 11.1

Soil Texture was Sandy loam