EFFECT OF CHLORPYRIFOS APPLICATION AT DIFFERENT GROWTH STAGES ON INSECT PESTS' INCIDENCE, DAMAGE AND YIELD OF TOMATO (*Solanum lycopersicum* L) and OKRA (*Abelmoschus esculentus* L)

BY

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KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOG, KUMASI, GHANA

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IN PARTIAL FULFILMENT OF THE REQUIRMENT FOR THE AWARD OF M.Sc. CROP PROTECTION (ENTOMOLOGY)

JUNE, 2014

DECLARATION

I hereby declare that this thesis is my own work towards the Master of Science degree (Entomology) and to the best of my knowledge, it contains no material previously published by another person or material which has been accepted for the award of any other degree of the University, except where due acknowledgment has been made in the text.

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ABSTRACT

Field studies were conducted at the Plantation Crops Section of the Department of Crop and Soil Sciences (KNUST), Kumasi in the major and minor planting seasons of 2013 to evaluate the effect of Chlorpyrifos applications at different growth stages of okra (*Abelmoschus esculentus* L) and tomato *(Solanum lycopersicum* L) for the management of insect pests of the two crops. The treatments were: Chlorpyrifos at 1.5 ml / 0.5 l of water applied (i) at the vegetative stage of the crops (sprayed vegetative), (ii) at the reproductive growth stage of the crops (starting at 50 % flowering of the crops – sprayed reproductive) and (iii) throughout the crops' growth period (sprayed throughout). A control plot that received only water was also maintained. In both seasons, significantly ($P < 0.05$) less number of *Bemisia tabaci* Gennadius and *Thrips tabaci* (Linderman) were collected from the insecticide treated tomato plots than the untreated control plots, but no significant difference was observed among the treatments in the aggregations of *Aphis gossypii* (Glover) and *Helicoverpa armigera* (Hubner). With respect to okra, significantly ($P < 0.05$) fewer *T. tabaci*, *B. tabaci*, *A. gossypii* and *Podagrica* spp. were collected from the sprayed throughout plots than the other treatment plots, in the major season. Similar results were obtained in the minor season. Over 99 % of the *Podagrica* species collected on okra were *P. uniformis* (Jacoby). Chlorpyrifos application in the sprayed throughout plots significantly ($P < 0.05$) reduced damage to tomato fruits in the major season but not in the minor season. Tomato fruits from the sprayed vegetative and sprayed reproductive plots had comparable damage as the fruits from untreated control plots. Chlorpyrifos application also significantly ($P < 0.05$) increased yield of tomato from the sprayed throughout plots in both seasons. Significantly ($P < 0.05$) less per cent defoliation was recorded on the insecticide-treated plots than the untreated control

plots in both seasons. However, significant increase in yield of okra was obtained from only the sprayed throughout plots, but no significant differences were obtained in the number of damaged okra fruits. The best protection to the crops against the insect pests was obtained from weekly applications of chlorpyrifos throughout the entire growth period of the crops (sprayed throughout plots).

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CHAPTER 1

1.0 Introduction

Vegetables production in Ghana is an all-year-round agricultural activity of small-scale farmers. It has a great potential to increase the income level and standard of living of growers (Obeng-Ofori and Ankrah, 2002; Afreh-Nuamah, 1996). Tomato (*Solanum lycopersicum* L) and okra (*Abelmoschus esculentus* L) are important sources of nutrients in the diet of most families in Ghana and are therefore cultivated extensively in the country (Norman, 1992; Sinnadurai, 1992).

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 crop is a good source of vitamins A, B and C. It is also an important source of income to both producers and retailers in Ghana. Demand for tomato in Ghana is high, therefore, production is all-year-round under rain-fed conditions in the wet seasons and under irrigation in the dry seasons (Bonsu, 2002). However, yield values are low. The average yield for the country stands at 10 tons per hectare, and the low yield is attributed to diseases, insect-pests and environmental factors such as temperature and humidity (Bonsu, 2002).

Tomato is attacked by insect pests such as, whiteflies, *Bemisia tabaci* (Gennadius), cotton aphids, *Aphis gossypii* (Glover) and American bollworm, *Helicoverpa armigera* (Hubner). Aphids prefer to attack the tender shoots and the young leaves of the host plant, but they can also exist on older leaves. Apart from removing plant nutrients, whiteflies transmit a number of disease causing viruses including Tomato Yellow Leaf Curl Virus (TYLCV) which adversely affect tomato cultivation in Ghana (Horna *et al*., 2008).

Helicoverpa armigera attacks the riped and pre-riped fruits, contaminating them with frass and exposing them to fungi and bacteria (Burgstaller and Hassan, 1984).

Okra is a major vegetable crop in many countries (Bisht and Bhat, 2006). Okra fruit is principally consumed fresh or cooked and is a major source of vitamins A, B, and C, minerals such as iron and iodine but it is reportedly low in sodium, saturated fat and cholesterol (Shehaya *et al*., 1984). Cultivation of okra in Nigeria and Ghana is usually done as mixed cropping. Okra can be grown on a wide range of soils, but high yields are obtained when grown in well drained fertile soils with adequate organic matter (Temikotan *et al*, 2007).

Insect pests' infestation is one of the major factors counting against cultivation of okra in Ghana and Nigeria. The crop is known to share the same broad pest spectrum with cotton and hibiscus (Hill and Waller, 1988). Among the insect pests, *Podagrica* species are known to cause economic damage. According to Fasunwon and Banjo (2010), *Podagrica* species attack the lamina of the foliage and matured leaves of the okra plant which results in the reduction of the photosynthetic ability of the crop leaves. The insect is also responsible for the transmission of mosaic virus which can reduce yields by 20 – 50 %. Aphids and thrips are the other major insect pests of both tomato and okra and they suck plant sap causing various diseases (Fanjimi and Fanjimi, 2010). With piercing and sucking mouthparts, whiteflies are able to feed effectively on plant sap causing okra leaf curl disease.

In view of the high incidence of insect pests on tomato and okra plants, farmers tend to apply chemicals for their control (Ogemah, 2003). Vegetable farmers in Ghana rely heavily on the use of pesticides (Dinham, 2003). Even though insecticides have proven to be highly effective in protecting vegetable crops under extreme pressure from insect pests (Cooper and Dobson, (2007), the indiscriminate and widespread use of synthetic insecticides in vegetable cultivation usually has resulted in insecticide resistance development (Odhiambo, 2010; Wintuma, 2009; Owusu and Yeboah, 2007).

Many of these insecticides applications do not yield the desired control but their aggregate cost increase the production cost of farmers resulting in loss of revenue. One way to reduce this loss is to resort to judicious and timely application of insecticides to achieve desirable control with minimal pesticide application.

Therefore, the need to determine the appropriate time and stages of the plant at which insecticides should be applied to ensure management of insect pests of crops while using optimal dosages of the insecticides. It is in this light that this study with the objective to determine the effect of Chlorpyrifos application at different growth stages on insect pests of tomato and okra was undertaken

The specific objectives of the study were to;

i. Identify insect pests of tomato and okra
ii. Determine the effect of time of application of Chlorpyrifos on insect pests' incidence and damage on tomato and okra
iii. Assess the effect of Chlorpyrifos application on the yield of tomato and okra

CHAPTER 2

LITERATURE REVIEW

2.1 Tomato (*Solanum lycopersicum* L)

Tomato is one of the most commonly grown vegetables in the world (Peralta and Spooner, 2007). Its cultivation is widely spread throughout Africa (Obeng-Ofori *et al*., 2007; Norman 1992). Tomato fruits are regarded as prominent "protective food" (Alam *et al*., 2007). In Ghana, tomato forms a very essential part of human food (Osei *et al*., 2008; Beecher, 1998) and is consumed in diverse ways. It is consumed as fresh food and as an ingredient in many dishes, sauces, drinks and salad (Alam *et al*., 2007). Based on these nutritive facts, it forms a very important component of food consumed in Ghana (Tambo and Gbemu, 2010).

2. 2 World Tomato Production

Cultivated tomato is the second most consumed vegetable after potato (FAOSTAT, 2005) and categorically the most popular garden crop. It is frequently grown around the world and establishes a major agricultural industry. According to USDA (2005), it is the third greatest economically important vegetable grown in US (with a total farm value of $2.062 billion) after potato ($2.564 billion) and lettuce ($2.064 billion). Major tomato producing countries in descending order are China, USA, India, Turkey, Egypt, and Italy (http://faostat.fao.org). Other leading countries are Spain, Brazil, Iran, Mexico, Greece, and Russia. China accounts for more than one–quarter of the world's tomato land. Egypt and India together account for more than one-fifth of the world total; Turkey and Nigeria are the other major tomato producing countries. Asia and Africa account for about 79 % of the overall tomato area with about 65 % of world yield (FAO, 2008).

2.2.1 Tomato Production in Ghana

Ghana's commitment to the tomato sector has its roots in the 1960s when three large tomato processing plants were established in the country (Robinson and Kolavalli, 2010). These were the GIHOC cannery at Nsawam (Eastern Region), Pwalugu Tomato Factory at Pwalugu (Upper East Region), and the GIHOC Tomato Cannery -TOMACAN at Wenchi. These enterprises, all built by a Yugoslavian company in 1967 and set up as part of President Nkrumah's government's overall development plan for Ghana dominated the food processing industry. By the late 1980s, a combination of structural reforms promoted by the World Bank and IMF, frequent breakdowns in the face of lack of spare parts and obsolete machinery coupled with technical incompetence and poor financial management and marketing, resulted in the closure of these factories (Ablorh-Odjidia, 2003).

According to Robinson and Kolavalli (2010), tomato production appears to be falling since 2000 in spite of report by Ellis *et al.* (1998) that an average three times a year cultivation of tomato occur in Ghana. The tomato sector in Ghana has failed to reach its potential, in terms of achieving yields similar to other countries (Robinson and Kolavalli (2010).

In spite of government interventions that included the establishment or restoration of a number of tomato processing plants in recent times, farmers do not only refuse to grow the right quality (as they still prefer planting local varieties) but also, most importantly, they do not produce the right quantity for commercial agro processing. Robinson and Kolavalli (2010) reported that average yields in Ghana remain low, typically, less than ten tons per hectare and that, due to production seasonality, high perishability, poor market access and competition from imports, some farmers are unable to sell their tomatoes, which are left to rot in their fields. In the midst of this situation, they upheld that yet other farmers in Ghana have achieved higher tomato yields culminating in higher profits.

2.3 Okra (*Abelmoschus esculentus* (L) Moench)

Okra belongs to Malvaceae. The fruit is a green capsule containing numerous white seeds when immature (Jesus *et al*., 2008) and the flowers and upright plants give okra an ornamental value (Duzyaman, 1997). The okra fruit can be classified based on the shape as angular or circular (Mota *et al*., 2005). Okra is a warm-season crop that is considered to have originated from India (Rao, 1985) and is cultivated in many parts of the world, including West Africa, India, Southeast Asia, the southern United States, Brazil, Turkey and northern Australia (Duzyaman, 1997). Okra has a high nutritional value and grows very quickly in temperatures which lends its production to more tropical parts of the world (Costa *et al*., 1981). Okra seeds are a source of oil and protein and are also used as a coffee substitute, while ground okra seeds have been used as a substitute for aluminum salts in water purification (Camciuc *et al*., 1998).

2.3.1 World okra production

Okra is a potential export item in the Middle East, Thailand, Japan and the Philippines (Siemonsma and Piluck, 1993). 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 and Hamon, 2000). It is an economically important vegetable crop grown in tropical and sub-tropical parts of the world. This crop is suitable for cultivation on large commercial farms. It is grown commercially in India, Turkey, Western Africa, Brazil, Ghana, Ethiopia and the Southern United States. India ranks first in the world with 3.5 million tonnes which is 70 % of the total world (FAOSTAT, 2008).

2.3.2 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 0-10 °C at 90 % relative humidity. Those held at 2-13 °C lasted for only four to six days and deteriorated rapidly on exposure to higher temperatures (20-26 °C) (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 “take-away” 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).

2.3.3 Climate and soils of both tomato and okra

Tomato is a cool season crop flourishing best in the winter months, but it can be grown throughout the year in different parts of the country, provided that the temperature is suitable for tomato fruit set while okra is warm season crop growing best during summer with irrigation or during rainy season, but can be grown all-year-round in tropical, subtropical and temperate zones. It thrives in a wide range of soils as long as they are well drained (Sharafel, 1963*)*.

2.3.4 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 the younger pod two to three days 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, 1986).

2.3.5 Common pests of Tomato and okra

Tomato and okra plants are subject to infestation by sucking insects, notably whiteflies (*B. tabaci*) (Homoptera: Aleyrodidae), cotton aphid, *A. gossypii* (Homoptera: Aphididae) and Thrips, *T. tabaci* (Thysanoptera, Thripidae). American bollworm (*H. armigera*) attacks the riped and pre-riped fruits of tomato, contaminating them with frass and exposing them to fungi and bacteria. The pest also prefers the reproductive parts of the okra plant, including buds, flowers and fruits. Leaf miner, *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae) attacks tomato leaves causing various losses. On the other hand, okra plants are 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).

2.3.6 Life cycles of important insect pests of Tomato and Okra

2.3.6.1 Life cycle of whiteflies

Life cycle of insects is the changes that take place in the reproductive system from the egg to adult stage. 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. Eggs are tiny (about 0.2 mm long) and pear-shaped. 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. Hatching occurs after 5-10 days at 30 °C depending on species, temperature and humidity (Martin, 1999). 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).

2.3.6.2 Life cycle of flea beetles

Schmutterer (1969) reported that the female flea beetle lays its small yellow eggs into the soil at the base of the host plant. The larva hatches after 7–11 days and feed for a period of 11-28 days on the rootlets. Pupation takes place in the soil and the adults emerge after 10-17 days from the pupa. There are many generations in the season. The adult remains after rain on the host plant for as long as they can find suitable food. Bird (1948) described the larvae as white in colour, with dark head, and feeds mainly on the fine roots and root hairs, but sometimes attacks the surface of the main root.

2.3.6.3 Life cycle of thrips

The metamorphosis is incomplete (hemimetabolous) but can be regarded as complete (holometabolous) too. The female lays about 50 white bean-shaped eggs by means of its ovipositor, in the tissue of host plants. The nymphs hatch after an incubation period of a few days and the two nymphal instars pass within a short time. The first and second instars resemble the adults in appearance and habits, but have no wing pads. The two following instars are called pre-pupa and pupa. They possess distinct wing pads, do not feed and are inactive. Pupation takes place either on the host plant, on debris on the ground or in the soil about as long as the nymphal period. The short life cycle enables the pest to develop a number of generations per year and to build up its populations in the favourable conditions (Burgstallar and Hassan, 1984).

2.3.6.4 Life cycle of Aphids

No sexual forms of Aphids species are known in the tropics so reproduction is most probably exclusively parthenogenetic. Many generations occur during the year; only three to five days at 28-30 °C and 10-12 days at 25-28 °C are required to complete the development from the first nymphal instar to the adult. The number of nymphs, which are produced by one female under favourable conditions may reach 150 (Schmutterer, 1969).

2.3.7 Ecology of these insect pests

2.3.7.1 Ecology of whiteflies

High RH (80-90 %), coupled with relatively high temperature (36-38 ºC) were found to favour the development of whiteflies resulting in a sharp increase in their population during September-October.

2.3.7.2 Ecology of flea beetles

Schmutterer (1969) recorded flea beetles from Saudi Arabia, Africa and other parts of the world. In Sudan the flea beetle was recorded from northern Khartoum, and Equatorial states. The pest seems to be most common in irrigated areas such as the Gezira. 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. Okra plants in gardens are also badly infested and injured by the cotton flea beetle.

2.3.7.3 Ecology of Aphids

Sharafel (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.

2.3.8 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 (Ahmed *et al*., 2007; Obeng-Ofori and Sackey, 2003). These insects also transmit the okra mosaic virus which causes significant yield losses (Vanlommel *et al*., 1996). Young plants are thus either badly stunted in growth or destroyed and on older plants a typical shot-hole effect is caused on the leaves. Okra plants in gardens are also badly infested and injured by the flea beetle. Insect pests such as *L. trifolii* cause considerable damage to tomato and other crops worldwide. According to Johnson (1987), leaf mining species can cause serious crop losses to the extent that daily pesticides application over two to five months is required to control *L. trifolii* on tomato plant.

2.3.9 Fruitworm (Helicoverpa *armigera*)

Helicoverpa armigera is a polyphagous pest with host range of over 360 plant species including cultivated crops of economic importance worldwide (Duraimurugan and Regupathy, 2005). The most important crop hosts include tomato, cotton, pigeon pea, sorghum and cowpea (Lammer and MacLeod, 2007). Factors enhancing the ability of this insect pest to attain a key pest status include its high polyphagy, mobility, facultative diapause, high fecundity, propensity to develop resistance to insecticides and larval feeding habit (Wakil *et al*., 2010; Fitt, 1989). The insect may feed on volunteer plants and many weed species, and migrates to tomato and pepper after the plants begin flowering. Female adults lay oval, heavily ridged eggs individually on leaves, especially those immediately below the uppermost flowers in the upper canopy. Larvae prefer to bore into small, green fruits, but may feed on buds, flowers or stems if fruits are not present. Larvae may complete their development inside a single fruit or may move to other fruits. Mature larvae drop to the soil and form a cell two to four units deep and pupate inside. The egg-to-adult period lasts about 30 days (Capinera, 2000).

2.3.10 Tomato fruitworm

The tomato fruitworm has a very wide host range. Many common weeds serve as larval hosts. Larvae bore deeply into fruits, usually at or near the calyx. Infested fruits are unmarketable and usually rot due to invasion by secondary microorganisms (Capinera, 2000). Insecticides usually are applied when the action threshold is reached. Insecticide applications usually are timed to control eggs and larvae. Once larvae enter fruit, they are less reachable to insecticides and are more difficult to control (Flint, 1998).

2.3.11 Pesticide Used in Tomato and Okra Cultivation

In most tomato and okra production systems, farmers almost exclusively rely on the use of pesticides to control insect pests and diseases (Gianessi, 2009; Berlin and Eitrem, 2005; Biney, 2001). Although chemical pesticides protect crops and improve farm yield, there are increased concerns about their possibly hazardous residues and their effects on the ecosystem (National Academy of Science) (Cooper and Dobson, 2007; NAS, 2000). The annual pesticide usage in Akumadan was projected at 500 tons of which 4 % are made up of organochlorine compounds (Ntow, 2001). Out of the several pesticide formulations used by vegetable 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 (Wintuma, 2009; Obuobie *et al*., 2006; Ntow *et al*., 2006; Biney, 2001). 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-trichloro-ethane (DDT), lindane and endosulfan (Kotey *et al*., 2008).

2.3.12 Chlorpyrifos – common insecticide in Ghana

Chlorpyrifos is a broad-spectrum insecticide, acaricide and nematicide. It is used on food and feed crops, cattle ear tags, wood treatments and to control public health pests such as mosquitoes and fire ants (Washington DC, 2006). Chlorpyrifos is a non-systemic insecticide designed to be effective by direct contact, ingestion, and inhalation (Tomlin, 2006).

2.3.13 Mode of action of Chlorpyrifos

Chlorpyrifos kills insects upon contact by affecting the normal function of the nervous system (Washington DC, 1999). It affects the nervous system by inhibiting the breakdown of acetylcholine (ACh), a neurotransmitter. When insects are exposed, chlorpyrifos binds to the active site of the cholinesterase (ChE) enzyme, which prevents breakdown of ACh in the synaptic cleft. The resulting accumulation of ACh in the synaptic cleft causes overstimulation of the neuronal cells, which leads to neurotoxicity and eventually death (Pope and Karanth, 2000; Atlanta, 1997).

Chlorpyrifos has a short residual life on plant foliage and fruits, but is effective for several weeks on soil, polluted water, wood and concrete (FAO/WHO, 1972).

CHAPTER 3

MATERIALS AND METHODS

3.1. Experimental location

The experiment was conducted at the plantation crops section of the Department of Crop and Soil Sciences of the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi.

The study was done in the major season and repeated in the minor which lasted from mid-May to mid-September and late September to late December 2013, respectively.

3.2. Source of seeds

The tomato variety used was CRI-POO and that of okra was "Asontem". These were obtained from the Crops Research Institute of the Council for Scientific and Industrial Research (CSIR-CRI), Kwadaso, Kumasi. CRI-POO and Asontem are locally improved open pollinated varieties and both are susceptible to insect pests and diseases of the respective crops.

3.3 Nursery preparation

Nursery beds were prepared and heat sterilized by burning of plant debris on the seed beds to reduce infections. Tomato seeds were sown on raised beds which measured 3 m x 2 m (6 m^2). Okra seeds were sown directly.

3.4 Land preparation.

Herbicide (Nwura-wura) at 1.5 ml / 15 l of water was applied three weeks before ploughing. The land was ploughed and harrowed with a tractor to allow smooth root penetration. Prior to the preparation of the land, soil analysis was done (Appendix 1).

3.5 Field layout and experimental design.

The experimental fields for both tomato and okra were separately laid in a randomly complete block design (RCBD) with four treatments. Each treatment was replicated four times in four blocks. The experimental fields for both okra and tomato measured 25 m x 25 m (625 m^2). Each treatment plot measured 5 m x 5 m with 1 m alley.

3.6 Treatments

Tomato field

Dursban (a. i. Chlorpyrifos) at 1.5 ml / 0.5 l water per plot was applied weekly on tomato at the following times:

1. Vegetative growth period of the crop (from three weeks after transplanting to 50 % flowering) – Sprayed vegetative stage only
2. Reproductive growth period of the crop (starting at 50 % flowering until first harvest of the fruits) – Sprayed reproductive stage only
3. Throughout the entire growth period of the crop – Sprayed throughout
4. Control (water - with no insecticide application)

Okra field

Dursban (a. i. chlorpyrifos) at 1.5 ml / 0.5 l water per plot was applied weekly on okra at the following times:

1. Vegetative growth period of the crop (from four weeks after sowing to 50 % flowering) – Sprayed vegetative stage only
2. Reproductive growth period of the crop (starting at 50 % flowering until first harvest of the fruits) – Sprayed reproductive stage only
3. Throughout the entire growth period of the crop – Sprayed throughout
4. Control (water – with no insecticide application)

The insecticide solution was applied weekly in the morning immediately after taking data; and application started three weeks after transplanting tomato seedling and four weeks after sowing okra seeds.

3.7 Transplanting of Tomato seedling

Tomato seedlings were transplanted on 26th June, 2013 during the major season and 27th September, 2013 during the minor season, at a spacing of 0.5 m x 1 m. Healthy seedlings were transplanted one per hill. Each plot contained five rows of plants with each row having 10 plants giving a total of 50 plants per plot. Replacement of dead seedlings as a result of transplanting shocks was carried out three days after transplanting.

3.8 Sowing of Okra seeds

The sowing of okra seeds was done on 21st June, 2013 and 11th October, 2013 in the major and minor seasons, respectively. Prior to the sowing, the seeds were soaked in water overnight to facilitate germination. The seeds were sown two per hill at about 3 cm depth with a hoe at the planting spacing of 0.5 m by 1 m, and later thinned to one plant per hill. Each plot contained five rows of plants with each row having 10 plants giving a total of 50 plants per plot.

3.9 Cultural practices

Manual weeding was done at three weeks interval throughout the period of the experiment for both crops. The fields were irrigated as and when necessary. NPK (15-15-15) fertilizer was applied in two splits. The first dose was applied three weeks after transplanting of tomato and three weeks after sowing of okra at a rate of 10 g per plant while Urea (46 % N) was applied at the rate of 2.2 g per plant as the second dose three weeks after the first application.

3.10 Sampling of Insect Pests on Tomato and Okra

On a weekly basis, starting two weeks after seedling emergence in okra and after transplanting of tomato seedling, sampling for insects began. Sampling for whiteflies involved visual examination with the help of magnifying lens of five randomly selected plants from the two middle rows. Number of insects present on five randomly selected plants per plot was counted. Sampling was done in the morning between 0800 and 1000 h when the insects were less active and the number of each species was recorded separately. In addition, three leaves from the upper and lower canopies of tomato were collected and put in a high density polyethylene bottle containing 70 % ethyl alcohol. They were later transported to the insectary for processing, identification and counting using a stereo-microscope. Sampling was done for ten weeks on the tomato plants. The same procedure was followed to sample insects on okra. Sampling was done for nine weeks on the okra plants.

3.11 Defoliation on okra

Five plants were randomly selected in each of the plots at every sampling time for data on defoliation by *Podagrica* species on okra. Percent leaf defoliation and the number of holes made on the leaves of the sampled plants were recorded as damage done to the plants by the insects. For the estimation of the percentage defoliation, the leaves were critical examined and section of the leaves that had lost virtually the photosynthetic portions (scarified leaves or holes) through the feeling habits of *Podagrica* species were considered as defoliated, and the percentage defoliation then estimated.

3.12 Yield and Yield Components Assessment in Tomato and Okra

Tomato fruits were harvested after every two days and weighed. Damaged and healthy fruits were weighed separately on a scale and recorded. 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 taken. The same procedure was followed to calculate the yield of okra.

3.13 Data Analysis

Insect data were transformed using square root transformation and data in percentages arcsine transformed. The data was analysed using analysis of Variance (ANOVA) using SAS (9) 2010. Treatment means were separated using Tukey at 5 % probability.

CHAPTER 4

RESULTS

4.1 Insect Pests Collected

Five species of insect pests were collected from the experimental field. These were whiteflies; *B. tabaci*, aphids; *A. gossypii*, thrips *T. tabaci*, flea beetles, *Podagrica uniformis* and *P. sjostedti* and also tomato fruit borer *H. armigera.*

4.1.1 Insect pests collected on tomato in the major season

There were significant (P < 0.05) differences between treatments means with respect to the densities of *B. tabaci* and *T. tabaci* (Table 4.1). Significantly (P < 0.05) more of these insects were collected on the untreated, control plots than the insecticide-treated plots. *A. gossypii* densities showed no significant difference (P > 0.05) among the treatments (Table 4.1). Significantly fewer *B. tabaci* were collected from the plots that received insecticide application during the reproduction stage than that which received insecticide application during the vegetative growth period only. Plots that received insecticide application throughout the growth period received significantly (P < 0.05) less number of *B. tabaci* than the other insecticide treatment plots.

Significantly (P < 0.05) more *T. tabaci* were recorded in the control plots than the insecticide treated plots. However, there were no significantly differences in the densities of the insect between the insecticide-treated plots (Table 4.1). No significant differences were observed among the treatments in the mean number of *H. armigera*.

Table 4.1: Mean number (± SEM) of insect pests collected on tomato, *Solanum lycopersicum* as affected by chlorpyrifos applications in the major season in 2013.

	Mean number of insect per plant			
Treatment	*B. tabaci*	*T. tabaci*	*A. gossypii*	*H. armigera*
Sprayed throughout	1.22 ± 0.06 [d]	0.05 ± 0.01 [b]	0.14 ± 0.02 [a]	0.01 ± 0.01[a]
Sprayed vegetative	1.84 ± 0.08 [b]	0.06 ± 0.01 [b]	0.14 ± 0.02 [a]	0.01 ± 0.01 [a]
Sprayed reproductive	1.54 ± 0.06 [c]	0.05 ± 0.01 [b]	0.11 ± 0.02 [a]	0.02 ± 0’01 [a]
Control	2.55 ± 0.10 [a]	0.27 ± 0.03 [a]	0.13 ± 0.03 [a]	0.06 ± 0.10 [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 season

There were significant ($P < 0.05$) differences among treatment means with respect to the densities of *B. tabaci* but not with respect to *T. tabaci* (Table 4.2). The control plots recorded significantly ($P < 0.05$) more aggregation of *B. tabaci* and *T. tabaci* than the insecticide-treated plots. There were no significant ($P > 0.05$) differences among the treatments with respect to the number of *A. gossypii*, and also, no significant differences were observed in the aggregation of *T. tabaci* among the insecticide-treated plots (Table 4.2)

Table 4.2: Mean number (± SEM) of insect pests collected on tomato, *Solanum lycopersicum* as affected by chlorpyrifos applications in the minor season in 2013.

	Mean number of insect per plant		
Treatment	*B. tabaci*	*T. tabaci*	*A. gossypii*
Sprayed throughout	0.49 ± 0.04 [c]	0.21 ± 0.03 [b]	0.09 ± 0.02 [a]
Sprayed vegetative	0.95 ± 0.06 [b]	0.35 ± 0.04 [b]	0.07 ± 0.02 [a]
Sprayed reproductive	0.64 ± 0.05 [c]	0.24 ± 0.03 [b]	0.09 ± 0.02 [a]
Control	1.33 ± 0.07 [a]	0.67 ± 0.06 [a]	0.11 ± 0.03 [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 season on okra

There were significant (P < 0.05) differences among treatment means with respect to the densities of *B. tabaci*, *Podagrica* spp., but not with respect to *T. tabaci* and *A. gossypii* (Table 4.3). Higher densities of *B. tabaci* and *Podagrica* spp. were significantly recorded on the control and sprayed reproductive plots than the sprayed vegetative plots (Table 4.3). Significantly (P < 0.05) more *T. tabaci* were recorded from the control plots than those plots that received chlorpyrifos applications. Significant (P < 0.05) more *A. gossypii* were recorded on the control and the sprayed vegetative plots than the sprayed reproductive and the sprayed throughout plots.

Table 4.3: Mean number (± SEM) of insect pests collected on okra, *Abelmoschus esculentus* as affected by chlorpyrifos applications in the major season in 2013.

	Mean number of insect per plant			
Treatment	*B. tabaci*	*Podagrica* spp.	*T. tabaci*	*A. gossypii*
Sprayed throughout	0.45 ± 0.04 [c]	1.05 ± 0.06 [c]	0.03 ± 0.01 [b]	0.76 ± 0.012 [c]
Sprayed vegetative	0.93 ± 0.06 [b]	1.55 ± 0.07 [b]	0.14 ± 0.02 [b]	1.49 ± 0.19 [ab]
Sprayed reproductive	1.32 ± 0.07 [a]	2.35 ± 0.07 [a]	0.08 ± 0.02 [b]	0.98 ± 0.012 [bc]
Control	1.55 ± 0.10 [a]	2.57 ± 0.08 [a]	0.39 ± 0.06 [a]	2.0 3 ± 0.22 [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 pest collected in the minor season on okra

There were no significant differences (P < 0.05) among treatment means with respect to the densities of *A. gossypii* (Table 4.4). The control plots had significantly (P < 0.05) more *B. tabaci, A. gossypii* and *Podagrica* spp. than the sprayed throughout plots. There were no significant differences among the sprayed vegetative, sprayed reproductive and control plots with respect to the densities of *B. tabaci*. But significant differences were observed between sprayed throughout and the other plots with respect to the densities of *Podagrica* spp. Significantly (P < 0.05) more *A. gossypii* were recorded in the control plots than the sprayed throughout plots.

Table 4.4: Mean number (± SEM) of insect pests collected on okra, *Abelmoschus esculentus* as affected by chlorpyrifos applications in the minor season in 2013.

	Mean number of insect per plant		
Treatment	*B. tabaci*	*Podagrica* spp.	*A. gossypii*
Sprayed throughout	0.76 ± 0.04 [b]	0.67 ± 0.06 [b]	0.17 ± 0.04 [b]
Sprayed vegetative	1.01 ± 0.07 [ab]	1.05 ± 0.07 [a]	0.24 ± 0.04 [ab]
Sprayed reproductive	0.81 ± 0.06 [b]	1.07 ± 0.06 [a]	0.30 ± 0.06 [ab]
Control	1.17 ± 0.08 [a]	1.27 ± 0.07 [a]	0.41 ± 0.06 [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 season

In the major season, significant ($P < 0.05$) differences were recorded between the insecticide- treated plots and the untreated control plots with respect to percent defoliation of okra plants, but no significant differences were obtained among the insecticide treatments at 28 and 42 days after planting (Table 4.5). There were no significant ($P < 0.05$) differences in the percent defoliation among the sprayed throughout and sprayed reproductive treatments at 35 DAP.

Table 4.5: Mean percent defoliation of okra, *Abelmoschus esculentus* plants by *Podagrica* spp, as affected by chlorpyrifos applications in the major season in 2013.

	Mean percent defoliation *Podagrica* spp		
Treatment	28 DAP	35 DAP	42 DAP
Sprayed throughout	7.8 ± 0.6 [b]	5.5 ± 0.2 [c]	6.8 ± 0.6 [b]
Sprayed vegetative	9.4 ± 0.3 [b]	8.6 ± 0.4 [b]	8.6 ± 0.4 [b]
Sprayed reproductive	9.2 ± 0.3 [b]	6.0 ± 0.3 [c]	7.0 ± 0.5 [b]
Control	16.7 ± 0.9 [a]	15.8 ± 0.9 [a]	15.4 ± 0.8 [a]

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

4.1.6 Aggregation of *Podagrica* species on okra plants in the minor season

In the minor season, no significant differences were recorded in the percent defoliation of okra plants by *Podagrica* species at 28 DAP but there were significant differences among the treatments at 35 and 42 DAP. Significantly more defoliation was recorded on the plants in the control plots than the insecticide-treated plots at 42 DAP but not at 28 and35 DAP (Table 4.6).

Table 4.6: Mean percent defoliation by *Podagrica* spp on okra plant, *Abelmoschus esculentus* as affected by chlorpyrifos applications in the minor season in 2013.

	Mean percent defoliation		
Treatment	28 DAP	35 DAP	42 DAP
Sprayed throughout	10.6 ± 0.4 [a]	9.8 ± 0.6 [b]	8.1 ± 0.2 [c]
Sprayed vegetative	11.2 ± 0.7 [a]	10.2 ± 0.5 [b]	9.8 ± 0.6 [b]
Sprayed reproductive	10.1 ± 0.5 [a]	13.9 ± 0.8 [a]	8.2 ± 0.4 [cb]
Control	10.1 ± 0.6 [a]	14.3 ± 1.2 [a]	19.6 ± 0.2 [a]

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

4.1.7 Defoliation of okra plants in the major and minor season

More defoliation was caused by *Podagrica* species in the minor season as compared to the major season but not for the control (Table 4.7).

Table 4.7: Mean percent defoliation by *Podagrica* spp. on okra plant, *Abelmoschus esculentus* as affected by chlorpyrifos applications in the major and minor seasons in 2013.

	Mean percent defoliation	
Treatment	Major season	Minor season
Sprayed throughout	6.7 ± 0.3 [c]	9.5 ± 0.3 [b]
Sprayed vegetative	8.9 ± 0.2 [b]	10.4 ± 0.3 [b]
Sprayed reproductive	7.4 ± 0.2 [c]	10.7 ± 0.4 [b]
Control	15.9 ± 0.5 [a]	14.7 ± 0.6 [a]

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

Plate 4.1: Fruit of okra and defoliated leaves

4.2. Insect Pests Population Dynamics as influenced by insecticide Application on tomato.

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

The population of *B. tabaci* was < 1 per tomato plant when the insecticide application began but this increased above one per plant in all the treatments throughout the second and third weeks of insecticide application (Figure 4.1). There was a sharp drop in the aggregation of this insect by the fourth week before increasing steadily in all the treatments throughout August. However, *B. tabaci* population in the control remain consistently above two per plant throughout August and September. The lowest densities of *B. tabaci* was recorded in the sprayed throughout plots throughout August and September.

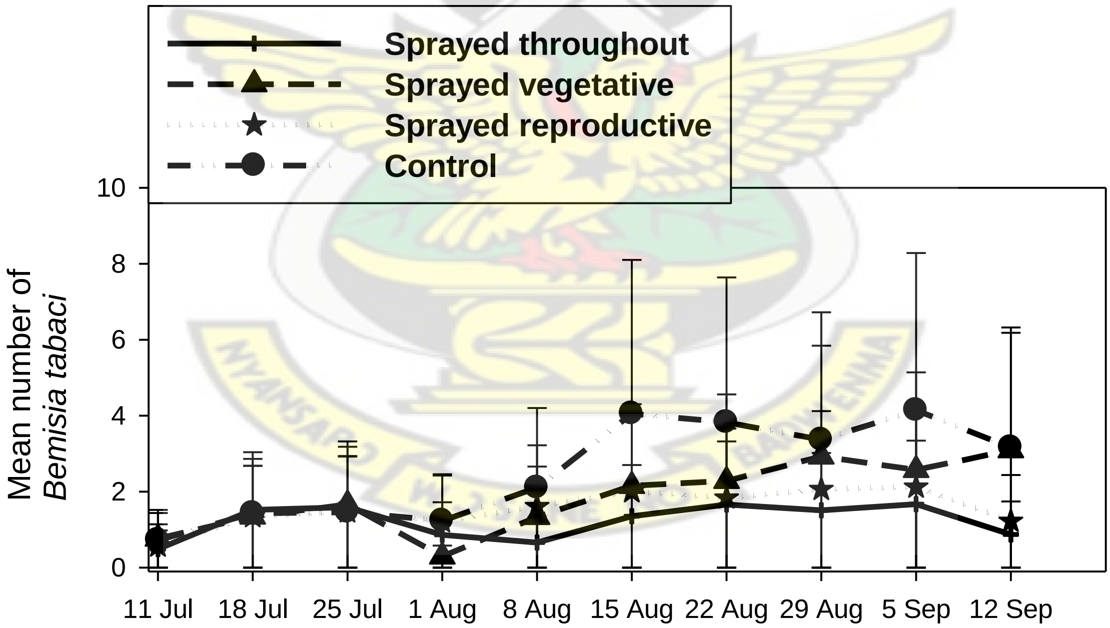

Figure 4.1: Mean number of *Bemisia tabaci* on tomato, *Solanum lycopersicum* plant as influenced by chlorpyrifos application in the major season in 2013.

4.2.2 Whiteflies (*B. tabaci*) population dynamics in the minor season

In the minor season, the population of *B. tabaci* was also < 1 per tomato plant in the insecticide treated plots up to the 5th week (19th November) of insecticide application. Similarly, the lowest densities of *B. tabaci* was recorded in the sprayed throughout plots throughout the seven weeks of insecticide application as in the major season (Figure 4.2). The densities of *B. tabaci* peaked at about three per plant in the control plots on 26th November before declining the following week.

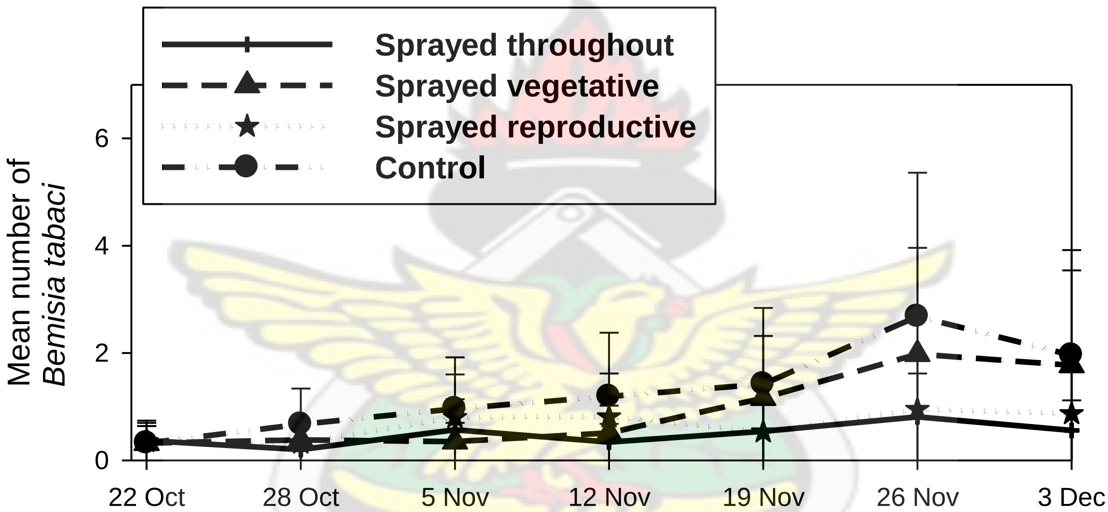

Figure 4.2: Mean number of *Bemisia tabaci* per tomato, *Solanum lycopersicum* plant as influenced by insecticide application in the minor season in 2013.

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

The densities of *T. tabaci* were consistently low (< 0.5 per plant) in all the plots until the end of August (Figure 4.3). There was a drop in the aggregation of this insect in the second week in all the insecticide-treated plots and remained low throughout until 5th September, when its density increased to about 1 per plant in the untreated, control

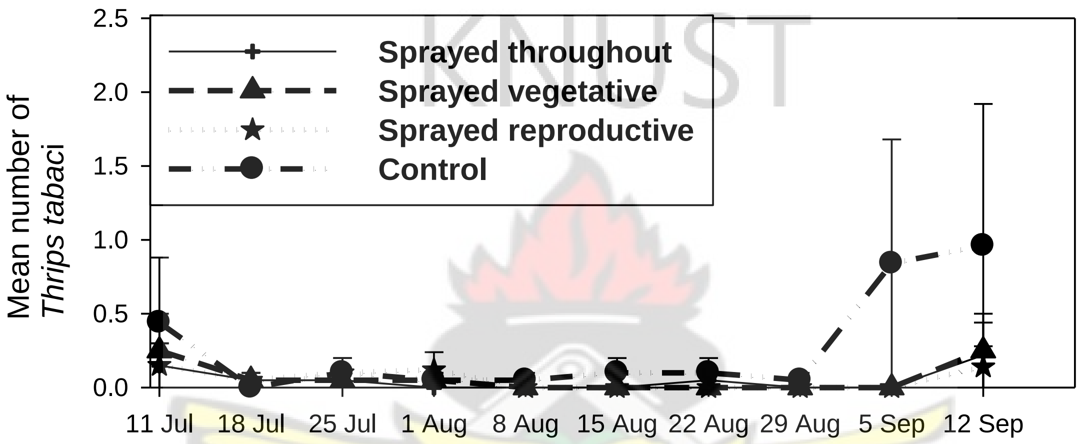

Figure 4.3: Mean number of *Thrips tabaci* per tomato, *Solanum lycopersicum* plant as influenced by chlorpyrifos application in the major season in 2013.

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

The densities of *T. tabaci* in all the plots were low in the minor season when the insecticide application began. Its number continued to be low in the sprayed throughout and sprayed reproductive plots but gradually increased above one per tomato plant in the last two weeks in the sprayed vegetative and control plots (Figure 4.4) In all treatments including the number of T tabaci increased after 5 weeks (19th Nov) but not for sprayed throughout and decreased thereafter.

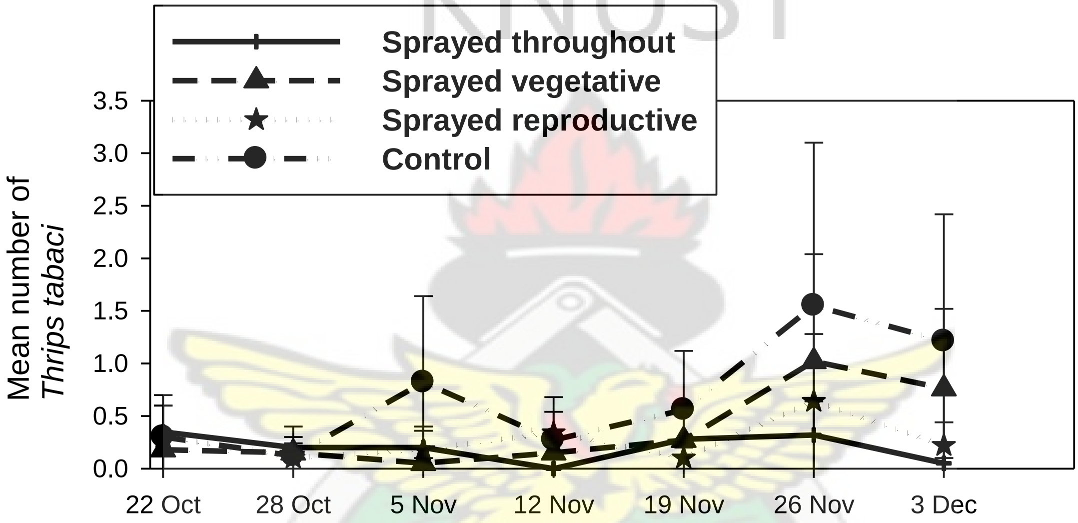

Figure 4.4: Mean number of *Thrips tabaci* per tomato, *Solanum lycopersicum* plant as influenced by chlorpyrifos application in the minor season in 2013.

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

The density of *A. gossypii* was one per tomato plant when the insecticide application began, but increased in the 2nd week and dropped in the 3rd week in all the treatments. *A gossypii* aggregations were similar in the sprayed vegetative and sprayed reproductive plots and peaked above 0.4 per tomato plant on 5th September 2014 (Figure 4.5). After the third week of chlorpyrifos application, *A. gossypii* fluctuated week after week until after 22nd August 2014.

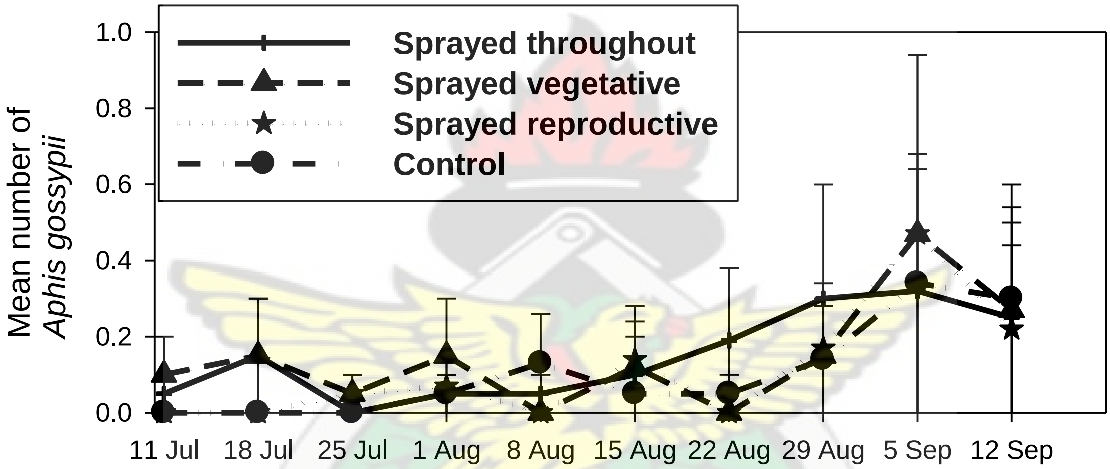

Figure 4.5: Mean number of *Aphis gossypii* per tomato, *Solanum lycopersicum* plant as influenced by chlorpyrifos application in the major season in 2013.

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

Aggregation of *A. gossypii* started above 0.4 per tomato plant in the sprayed throughout plots, 0.2 in the cotrol plots and sprayed reproductive plots and < 0.1 in the sprayed vegetative plots when the insecticide application began in the minor season. Densities of *A. gossypii* dropped below 0.4 for the 2nd week in all the treatments throughout the minor season (Figure 4.6).

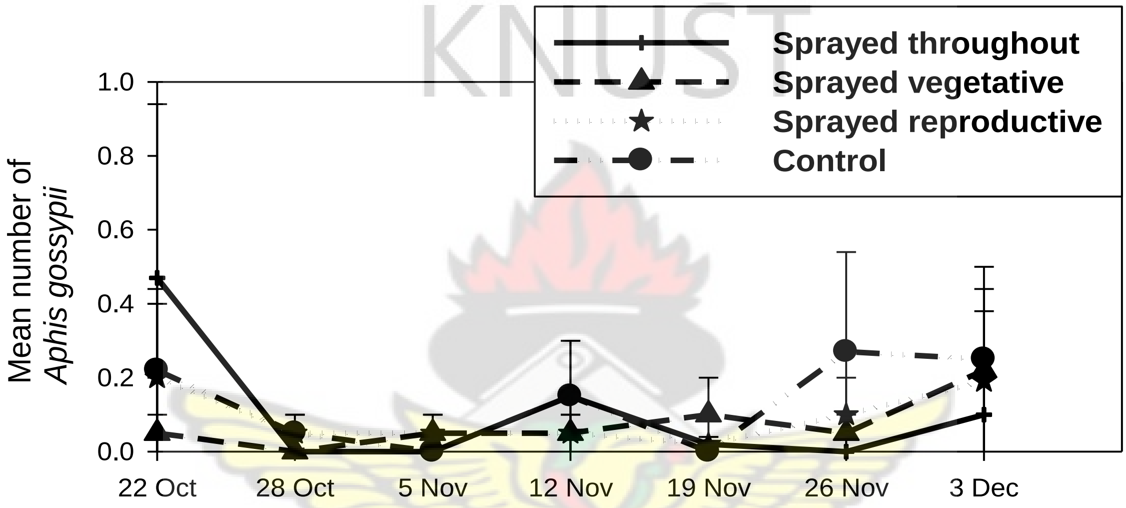

Figure 4.6: Mean number of *Aphis gossypii* per tomato, *Solanum lycopersicum* plant as influenced by chlorpyrifos application in the minor season in 2013.

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

Aggregations of *Podagrica* spp. were low (< 0.1) when the insecticide application began, but increased above two per plant in all the treatments up to the 4th week of insecticide application (Figure 4.7). Their densities dropped below two per okra plant in the sprayed throughout and sprayed vegetative plots throughout the major season. However, their aggregations in the sprayed reproductive and the control, remained above two per plant throughout the rest of the season (Figure 4.7).

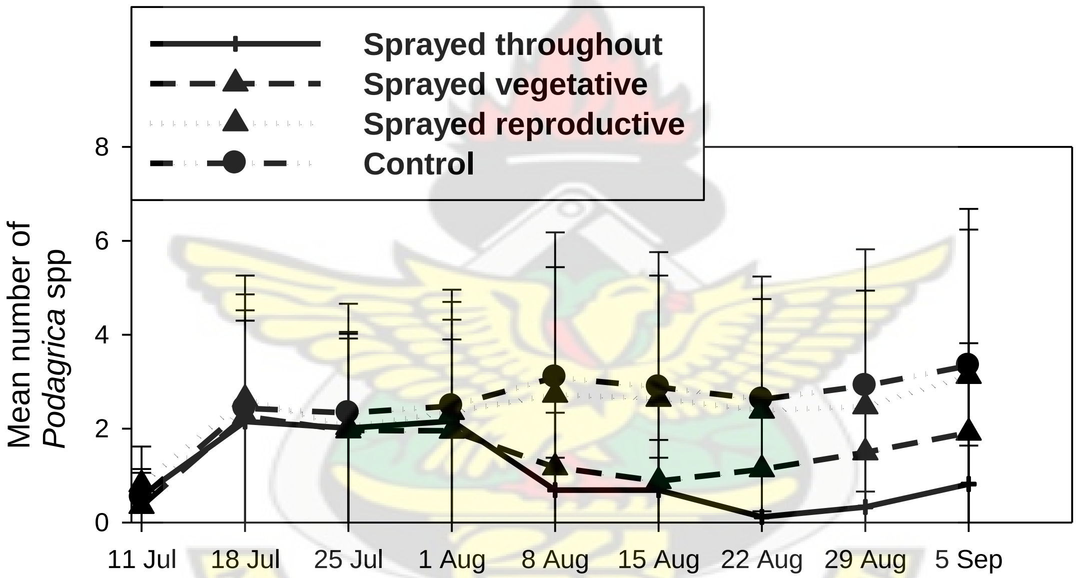

Figure 4.7: Mean number of *Podagrica* spp per okra, *Abelmoschus esculentus* plant as affected by chlorpyrifos application in the major season in 2013.

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

The densities of *Podagrica* spp. were also < 1 per okra plant when the insecticide application began in the minor season. Their densities in the sprayed throughout, sprayed vegetative and sprayed reproductive plots hovered around one per plant throughout the growth season while the control plots had above one per plant and peaked at two per plant on 5th December (Figure 4.8).

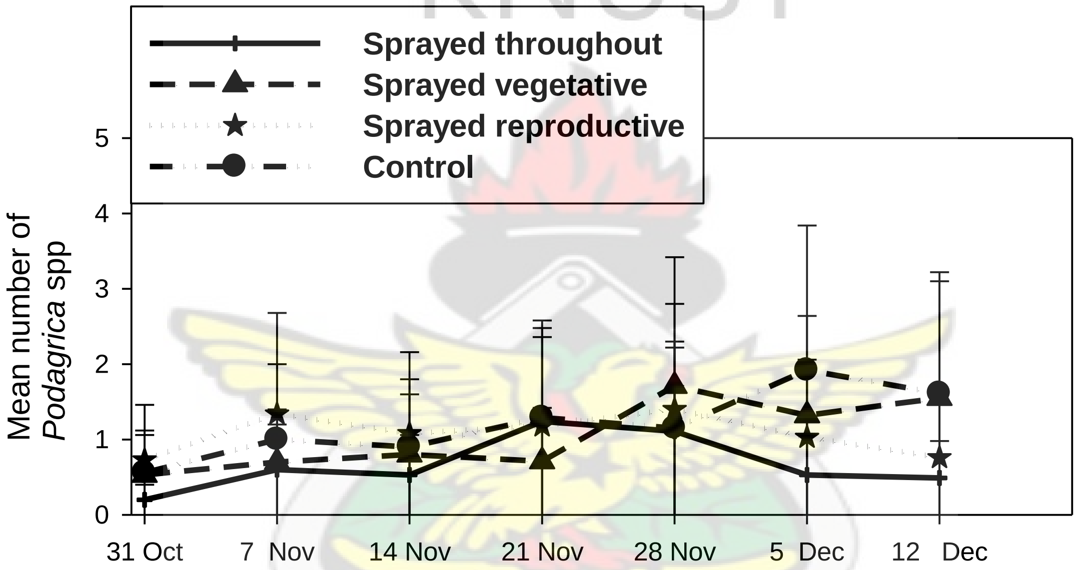

Figure 4.8: Mean number of *Podagrica* spp per okra, *Abelmoschus esculentus* plant as affected by chlorpyrifos application in the minor season in 2013.

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

The densities of *T. tabaci* remained low throughout the season in all the treatment plots (Figure 4.9). There was a sharp increase in the aggregation of the insect in the control, recording above one per plant in the last week.

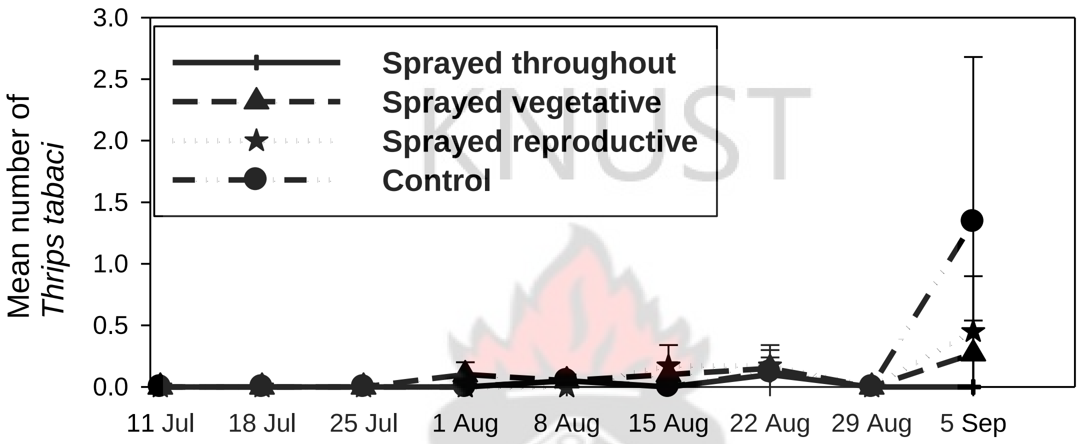

Figure 4.9: Mean number of *Thrips tabaci* per okra, *Abelmoschus esculentus* plant as affected by chlorpyrifos application in the major season in 2013.

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

Similarly, the aggregation of *A. gossypii* remained low until after the 22nd August 8th week when the number increased above two per plant in almost all the treatments. *A. gossypii* densities in the sprayed throughout, sprayed reproductive, and the control plots dropped below one per plant while those in the sprayed vegetative increased to four per plant by the 5th September the end of the experiment (Figure 4.10).

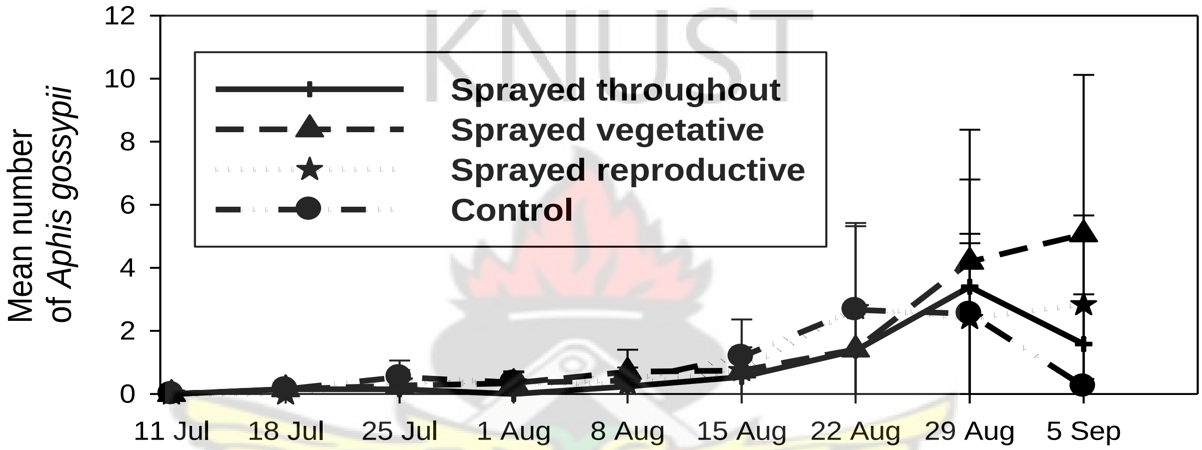

Figure 4.10: Mean number of *Aphis gossypii* per okra, *Abelmoschus esculentus* plant as affected by chlorpyrifos application in the major season in 2013.

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

The densities of *A. gossypii* were < 0.5 per okra plant in the sprayed reproductive and control plots and < 0.4 in the sprayed throughout and the sprayed vegetative plots. Their densities increased in the sprayed throughout plots to 0.5 in the second week and dropped by the fourth week of insecticide application and continued to be low throughout the season. *A. gossypii* densities in the sprayed vegetative plots continued to be low through to 5th December before increasing to 0.5 per plant. Their densities in the sprayed reproductive plots were low but increased above 0.5 and dropped again on 5th December. Its density was also low in the Control plots increased steadily until 5th December when it dropped (Figure 4.11).

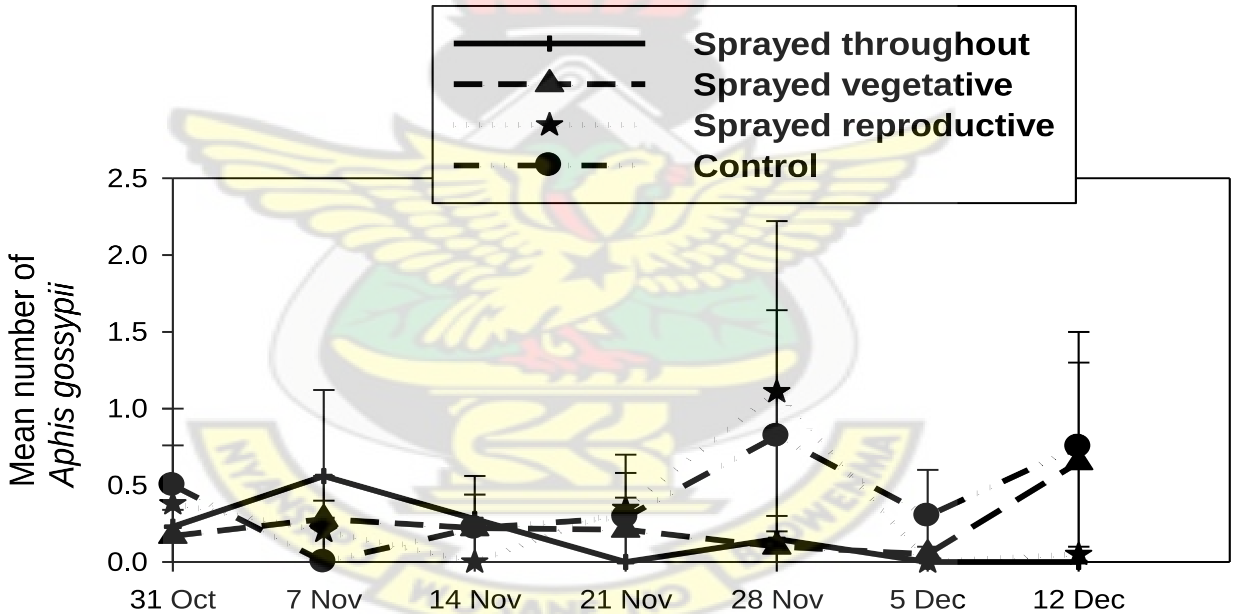

Figure 4.11: Mean number of *Aphis gossypii* per okra, *Abelmoschus esculentus* plant as influenced by chlorpyrifos application in the minor season in 2013.

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

The densities of *B. tabaci* were one per okra plant when the insecticide application began, but dropped gradually in the 4th and 5th weeks in all the treatments. *B. tabaci* densities remained low in the sprayed throughout plots up to the end of the season while sprayed vegetative and sprayed reproductive plots had two of the insects per plant by the end of the studies (Figure 4.11).

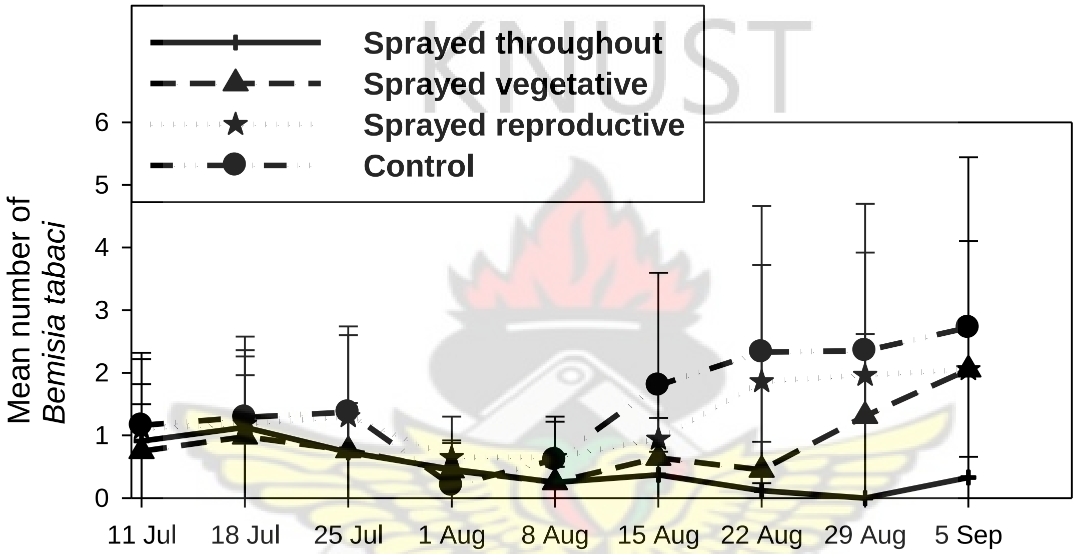

Figure 4.12: Mean number of *Bemisia tabaci* per okra, (*Abelmoschus esculentus*) plant as influenced by chlorpyrifos application in the major season in 2013.

4.4.5 Whiteflies (*B. tabaci*) population dynamics in the minor season

The densities of *B. tabaci* was < 1 per plant in the first and the second week of insecticide application, but increased to one per plant in the 3rd and 4th weeks in all the treatments. Their aggregations in the sprayed throughout and sprayed vegetative plots increased to two per plant on 28th November and dropped in the last week. Their aggregations in the sprayed reproductive plots also dropped below one per plant at the end of the insecticide application period. Control plots recorded above one per plant till the end of the season (Figure 4.12)

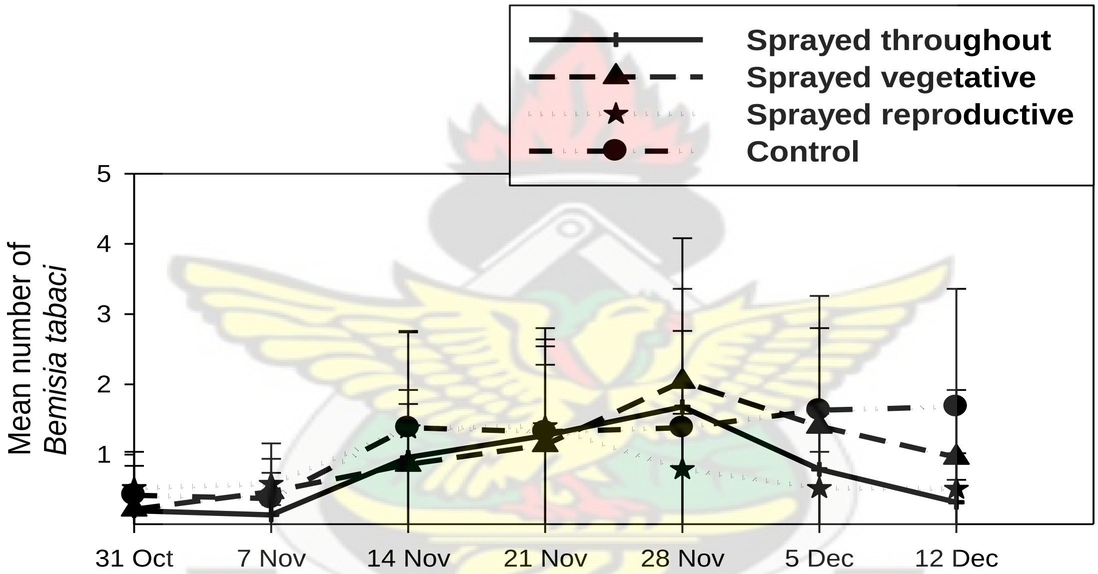

Figure 4.13: Mean number of *Bemisia tabaci* per okra, *Abelmoschus esculentus* plant as influenced by chlorpyrifos application in the minor season in 2013.

4.4.6 Yield and percent damaged fruits of CRI-POO tomato as affected by various treatments in the major and minor seasons.

In the major season, there were no significant differences were observed among the treatments in the mean percent damaged fruits, No significant ($P > 0.05$) differences were also observed between the sprayed vegetative and control plots (Table 4.5). The mean percent damaged fruits ranged from 11.7 to 22.3 %. More fruit yield was recorded in the sprayed throughout plots than the other plots. The mean yield range from 2954.8 to 4066.8 kg / ha in the major season (Table 4.8).

In the minor season, there were no significant ($P > 0.05$) differences obtained among the treatments in the mean percent damaged fruits (Table 4.5). There were also no significant ($P > 0.05$) differences among the insecticide- treated plots with respect to harvested fruits yield. They were significantly different from the control plots. The mean yield ranged from 1230.5 to 1791.8 kg / ha (Table 4.5).

Table. 4.8: Percent damaged fruits and yield of tomato as affected by chlorpyrifos applications in the major and minor season, 2013.

	Major season		Minor season	
Treatment	Mean % Damaged fruit	Yield (kg/ha)	Mean % Damaged fruit	Yield (kg/ha)
Sprayed throughout	11.7 ± 0.8 [b]	4066.8 ± 162.8 [a]	15.55 ± 2.4 [a]	1791.8 ± 127.9 [a]
Sprayed vegetative	18.1 ± 0.3 [ab]	3229.0 ± 169.4 [b]	19.2 ± 2.3 [a]	1709.1 ± 81.7 [a]
Sprayed reproductive	12.9 ± 1.3 [b]	2768.3 ± 148.7 [b]	12.0 ± 2.2 [a]	1746.1 ± 38.6 [a]
Control	22.3 ± 2.5 [a]	2954.8 ± 162.1[b]	15.7 ± 2.0 [a]	1230.5 ± 65.9 [b]

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 damaged fruits and yield of Okra (Asontem) as affected by various treatments in the minor season.

There were no significant (P < 0.05) differences in the mean percent damaged fruits among the sprayed throughout, and sprayed vegetative and control. More yield was significantly obtained in the sprayed reproductive than from the untreated control and sprayed throughout. However, there was no significant differences between the sprayed reproductive and sprayed reproductive plots. The mean yield ranged from 314.5 to 411.2 (kg / ha) (Table 4.6).

Table 4.9: Percent damaged fruits and yield of okra, *Abelmoschus esculentus* as affected by chlorpyrifos application in the minor season, 2013

Treatment	Mean % damaged fruits	Yield (kg / ha)
Sprayed throughout	16.8 ± 3.5 [a]	263.0 ± 28.5 [b]
Sprayed vegetative	36.2 ± 6.2 [a]	344.0 ± 16.4 [ab]
Sprayed reproductive	16.6 ± 3.6 [a]	411.2 ± 21.8 [a]
Control	30.0 ± 1.2 [a]	314.5 ± 20.4 [b]

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

Plate 4.2: Harvested okra fruits

Plate 4.3: Harvested tomato fruits

CHAPTER 5

DISCUSSION

5.1 Use of chlorpyrifos to manage insect pests of tomato and okra

Pesticides are used to control insect pests, diseases and weeds in agriculture. They are known to increase yield as they act on pests that destroy agricultural produce. The behaviour of a pesticide in the environment depends on its stability, physico-chemical properties, the nature of the medium into which it is applied, the organisms present in the soil, and the prevailing climatic conditions (Graham-Bryce, 1981).

The weekly applications of Chlorpyrifos at the rate of 1.5 ml in 0.5 l of water on tomato supressed *B. tabaci* and *T. tabaci* aggregations in the insecticide-treated plots. The density of *B. tabaci* in the first week was low (< 1 per plant) but increased in all the treatment plots in the second and third weeks but dropped sharply thereafter (Figure 4.1). *B. tabaci* and *T. tabaci* aggregations increased steadily when insecticide applications were stopped in the sprayed vegetative plots.

In the minor season, *B. tabaci* density was below one per tomato plant in all the treatment plots throughout the study period. More *T. tabaci* and *A. gossypii* were collected on tomato in the major season than in the minor season. However, comparable numbers of *B. tabaci* were collected on the crop in both seasons (Table 4.1 and 4.2). Environmental conditions may have played a role in the occurrence of low numbers of *T. tabaci*, *A. gossypii* and *H. armigera* in the minor season when relatively less amount of rainfall was recorded in addition to low relative humidity. This is being suggested as similar results and reasons had been reported by other researchers. Mailhot *et al.* (2007) reported that the effectiveness of the insecticides they used varied across seasons and years they conducted their studies on cotton.

Generally, low aggregations of the insects were recorded during the later weeks of the studies irrespective of insecticide applications. Typically, as plants grow in space and time, insects are presented with more hiding places to escape from both predators and insecticide spray droplets. Martin (1999) reported that dense canopies provide a favourable environment for both nymph and adult whiteflies to cluster in large numbers on the underside of leaves.

The sprayed throughout and sprayed reproductive plots had significantly less number of *B. tabaci* than the sprayed vegetative plots, with the untreated, control plots receiving the highest aggregation of the insect. According to Serra (1992) and Serra and Schmutterer (1993), Sumicidin effectively reduced the number of whiteflies in their studies on tomato.

The density of *T. tabaci* in the major season was < 0.5 per plant, but this dropped by the second week and continued to be low in all the insecticide-treated plots till the end of the studies (Figure 4.3). The sprayed throughout plots had comparable numbers of the insect to that of the sprayed reproductive plots (Table 4.5) and the usual early occurrence of *T. tabaci* in a plant's growth may account for this observation. Nevertheless, it can be inferred from these results that chlorpyrifos application was effective in reducing the aggregations of *B. tabaci* and *T. tabaci*.

Sam *et al*. (2014) conducted a similar experiment using Lambda–cyhalothrin at the same dosage as that used in the present study (1.5 ml / 0.5 litre of water per plot) and reported that lambda–cyhalothrin significantly reduced *B. tabaci*, *A. gossypii* and *H. armigera* numbers but had no adverse effect on *T. tabaci*, and these results were to what were obtained in the present study, in which chlorpyrifos applications did not have any significant effect on the aggregation of *T. tabaci* but achieved effective control of *B. tabaci*. Osekre *et al*. (2009) reported that Lambda–cyhalothrin application had no adverse effect on the population of *Frankliniella* thrips and explained that these thrips species had developed resistance to insecticide applications. Schmutterer (1995) concluded that some thrips species can be controlled by early insecticide application on tomato and other vegetable crops. Based on the results obtained in the present study, *T. tabaci* appears not to have developed some resistance to chlorpyrifos. It can be explained that differences in the mode of action or the classes of the insecticides used may account for these differences in the effect of these insecticides on the insects. Lambda cyhalothrin is a synthetic pyrethroid whilst chlorpyrifos is an organophosphate, with a different mode of action on insects.

Ghanaian vegetable farmers use lambda–cyhalothrin far more than chlorpyrifos (Sam *et al*., 2014) and this could explain the seeming resistance of the insects to the former, irrespective of application regime used. Other researchers have also reported reduced adverse effects of lambda-cyhalothrin on other species of thrips (Hassen *et al*., 2003; Reitz *et al.*, 2003; Funderburk *et al*., 2002).

No significant differences were observed for *H. armigera* among the treatment plots in the minor season only for the 28 DAP, however minimal difference were observed for 35 and 42 DAP (Table 4.6). Mathirajan *et al*. (2000) had reported that lambda–cyhalothrin applied at the rate of 30 g a i ha $^{-1}$ significantly reduced the number of the shoot and fruit borer on brinjal than endosulfan and fenvalerate. However, Romeis *et al*. (1999) had reported that the management of *H. armigera* is very difficult in many crops, and Ahmed *et al*. (2009) also reported that the same insect showed some resistance to lambda-cyhalothrin in their work.

Chlorpyrifos application in the sprayed throughout plots significantly reduced the densities of the four insects pest species that attacked okra in both seasons; *B. tabaci*, *T. tabaci, A. gossypii* and *Podagrica* spp. Similarly, in a field trial of insecticide for the control of okra flea beetles, Egwuatu (1982) found carbofuran as the most effective against the insect.

Two species of flea beetle identified in the experimental were; *P. uniformis* and *P. sjostedti* but *P. uniformis* constituted over 99 % of their populations. Egwuatu (1982) found more *P. sjostedti* than *P. uniformis* in their field evaluation of insecticides for the management of pests of okra in Nigeria. It is unclear why *P. uniformis* dominated *P. sjostedti* in the area where this current work was undertaken. Some factors may be favouring *P. uniformis* in the area where the present study was undertaken but it appears agronomic practices and inherent competitiveness of *P. uniformis* favour it in the area.

Generally, the sprayed vegetative plots had comparable number of insects with that of the sprayed reproductive plots, suggesting that spraying during the former period of growth was not advisable unless very serious outbreak of any of the insect occurs.

In the major season, insecticide application throughout the growth stages of the plants significantly reduced tomato fruit damage. In the major season, insecticide application throughout and during only the reproductive stage of the plants, significantly reduced fruit damage but same protection could not be obtained in the minor season. Similarly, drier conditions during the minor season may have contributed to this observation.

The adverse effects of Chlorpyrifos applications on *Podagrica* species which resulted in reduced aggregations of the insects, also reflected in the level of damage they caused to okra leaves as the insecticide-treated plots had significantly less percent defoliation than the untreated control (Tables 4.5, 4.6 and 4.7). Consequently, there was increased yield in okra fruits in the insecticide-treated plots, especially in the sprayed throughout plots.

Chlorpyrifos application significantly increased yield of both crops in both seasons irrespective of the time of application and this can be attributed to the reduced insect pests' incidence in the insecticide treated plots. Generally, higher yield of tomato was recorded from each of the insecticide treatment plots in the major than the minor season. Higher rainfall and generally more favourable environmental conditions during the major season may have contributed to this.

Generally, chlorpyrifos applications reduced the insect pest species that were collected on both crops irrespective of the period of application of the insecticides, but judging from the overall performance of the insecticide application periods vis-à-vis the yield obtained, it can be concluded that the sprayed throughout regime gave the best protection to both crops.

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1. Conclusion

Insect pests identified during the studies on tomato and okra included *Bemisia tabaci*, *Thrips tabaci*, *Helicoverpa armigera* and *Aphis gossypii* while *Podagrica* species was found on okra only.

From the results of the study, it can be concluded that chlorpyrifos application was able to significantly reduce the densities of *Bemisia tabaci* and *Thrips tabaci* but not *Aphis gossypii* and *Helicoverpa armigera* on tomato in the sprayed throughout plots and increased the yield in the major and minor seasons. Similarly, chlorpyrifos application significantly reduced aggregations of these insects on okra plants and increased the yield in the sprayed throughout plots.

6.2. Recommendation

It is recommended that, Chlorpyrifos, if needed to be used for the management of insect pests, should be applied throughout the growing season on both tomato and okra.

REFERENCES

Ablorh-Odjidia, E. (2003). From Pwalugu to Cancun: Toward fair agricultural trade policies. Modern Ghana, September 29: 1-23.

Afreh-Nuamah, K. (1996). Effects of frequency of spraying of neem seed extracts on the lepidopterous pests of eggplant (*Solanum integrifolium* L). *Ghana Journal Agricultural* science 29: 65-69.

Ahmed, BI., Yusuf, S.R., Yusuf, A.U. and Aliyu, M (2007). Comparative efficacy of different concentrations of some promising insecticides for the control of *Podagrica* spp. (Coleoptera: Chrysomelidae) on okra (*Abelmoschus esculentus* (L.) Moench). *Global Journal Agricultural Sciences* 6: 31-34.

Ahmed, M., Arif, M. I. and Attique, M. R. (2009). Pyrethroid resistance of Helicoverpa armigera (Lepidoptera: Noctuidae) in Pakistan. *Bulletin of Entomological Research* 87 (4): 343 – 347

Alam, T., Tanweer, G. and Goyal, G.K. (2007). Stewart Postharvest Review, Packaging and storage of tomato puree and paste. Research article, Volume 3, Number 5, October2007, pp. 1-8(8). Publisher: Stewart Postharvest Solutions. DOI: 10.2212/spr.2007.5.1

Beecher, B. R. (1998). Nutrient content of tomatoes and tomato products. National Center for Biotechnology Information, U.S. National Library of Medicine. (Online).http://www .ncbi.nlm.nih.gov/pubmed/9605204.

Berlin, A. and Eitrem, S. (2005). Tomato diseases, quality, yield and pesticide use: A field study in Nicaragua. Sverigeslantbruks University, Nicaragua. 60.

Biney, P. M. (2001). Pesticide use patterns and residue levels in tomato in some selected production systems in Ghana. M. Phil thesis, University of Ghana. 127.

Bird, R. D. (1948). Flea Beetles. Processed Publication Series No. 83 Entomology Ottawa Canada.

Bisht, I. S. and Bhat, K.V. (2006). Chapter 5 Genetic Resources, Chromosome Engineering and Crop Improvement Okra (*Abelmoschus* sp.). pp. 149-185.

Bonsu, K. O. (2002). Yield improvement by transferring heat tolerant genes into a local tomato line 'Power'. *Ghana Journal of Horticulture* 1: 40-44.

Burgstaller, H. and Hassan, M. (1984) A Hand Book of vegetable production and vegetable pests and diseases in the Sudan. Khartoum 31

Capinera, J. L. (2000). Corn Earworm: *Helicoverpa* (*Heliothis) zea* (Boddie) (Lepidoptera Noctuidae) UF/ IFAS EENY-145, http://creatures.ifas.ufl.edu/veg/ corn_ earworm.htm.

Camciuc, M., M. Deplagne, G. and Vilarem, A. Gaset. (1998). Okra – *Abelmoschus esculentus* L. (Moench.) a crop with economic potential for set aside acreage in France. *Industrial Crops and Products* 7: 257–264

Cooper, J. and Dobson, H. (2007). The benefits of pesticides to mankind and their environment. *Crop Protection* 26: 1337-1348.

Costa, M. C. B., Oliveira, G. D. and Haag, H. P. (1981). Nutrição mineral de hortaliças - Efeito da omissão dos macronutrientes e do boro no desenvolvimento e na composição química de hortaliças. Nutrição mineral em hortaliças**.** Campinas: Fundação Cargil. 6: 257-276.

Dinham, B. (2003). Growing vegetables in developing countries for local urban population and export markets: problems confronting small-scale producers. *Pesticide Management Science* 59: 575-582.

Duraimurugan, P. and Regupathy, A. (2005). Synthetic pyrethroid resistance in field strains of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) in Tamil Nadu, South India. *American Journal of Applied Sciences* 2 (7): 1146-1149.

Duzyaman, E. (1997). Okra: Botany and Horticulture. *Horticulture Reviews* 21: 41-72

Egwuatu, R. I. (1982). Field trials with systemic and contact insecticide for the control of *Podagrica uniforma* and *P. sjostedti* (*Coleoptera: Chrysomelidae*) on okra.*Tropical Pest Management* 28 (2):115-121.

El Khidir, E. (1960). Morphological and biological studies on whiteflies in the Sudan._ M. Sc. Thesis, Faculty of Agriculture, University of Khartoum-Sudan

Ellis, W. O., Olympio, N. S., Mensah, E. P., Adu-Amankwa, A., Tetteh, Y. (1998). Postharvest problems of tomato production in Ghana - Field studies of some selected major growing areas in Ghana. *Journal of the Ghana Science Association* 1 (1): 55-59

Fajinmi, A .A. and Fajinmi O. B. (2010) Incidence of okra mosaic virus at different growth srages of okra plants (*Abelmoschus esculentus* L. Moench) under tropical condition. *Journal of General and Molecular Virology* 2 (1): 028- 031.

FAO/WHO (1972). Evaluations of some pesticide residues in food. FAO/AGP: 1972/M/9/1; WHO/1973, p. 190

Food and Agricultural Organization (FAO). (1988). Food loss prevention in perishables. FAO Agricultural services. Bulletin N P 43:1-6.

Food and Agricultural Organization (FAO) (2011). Food and Agriculture organization. 2008, FAOSTAT. http; /faostat, fao.org. {Accessed 31 December 2009)

Food and Agriculture Organization (2008). FAOSTAT. http; /faostat, fao.org.{accessed 31 December 2009 (2.1.1)

Food and Agriculture Organization. (2008). Physical and chemical characteristics from fruits of four okra cultivars.

FAOSTAT (2005). Food outlook, September 2005,www.fao.org/giews

FAOSTAT, (2008). (http://fao.org)

Fasunwon, B.T and Banjo, A.D. (2010). *Research Journal of Agriculture and Biological Sciences* 6: 283 – 288.

Fitt, G. P. (1989). The ecology of *Heliothis* species in relation to agro - ecosystems. *Annual Review of Entomology* 34: 17-52.

Flint, M.L. (Technical Editor). (1998). Integrated Pest Management for Tomatoes, Fourth Edition. Univ. Calif. State-wide Integrated Pest Management Project, Div. Agric. Natural Resources, Publication 3274

Funderburk, J. E., Stavisky, J., Tipping, C., Gorbet, D., Momol, M. T., and Berger, R. (2002). Infection of *Frankliniella fusca* (Thysanoptera: Thripidae) in peanut by the parasitic nematode *Thripinema fuscum* (Tylenchidae: Allantonemetidae). *Environmental Entomology* 31: 558 – 563.

Gianessi, L. (2009). The Benefits of insecticide use: Tomatoes. Crop Life Foundation, Washington, USA. 18.

Graham-Bryce, I. J. (1981). The behaviour of pesticides in soil. In *The Chemistry of Soil Processes.* (D. J. Greenland and M. H. B Hayes, (ed.) John Wiley and Sons Ltd.

Hansen, E. A., Funderburk, J. E., Stuart, R. R., Ramachandran, S., Eger, J. E., and Mcauslane, H. (2003). Within-plant distribution of *Frankliniella* species (Thysanoptera: Thripidae) and *Orius insidiosus* (Heteropera: Anthocoridae) in field pepper. *Environmental Entomology* 32: 1035 – 1044.

Hill, D. S and Waller J.M. (1988). *Pests and Diseases of Tropical Crops*, Logman, New York, 414 pp.

Horna, D., Smale M. and Falck-Zepeda, J. (2008). Assessing the potential economic impact of genetically modified crops in Ghana: Tomato, Garden Egg, Cabbage and Cassava. *PBS report*, pp. 3-20.

Jesus, M. M. S., Carnelossi, M. A., Santos, G. S. F., Narain, N. and Castro, A. A. (2008). Inhibition of enzymatic browing in minimally processed okra. Rev. Cienc. Agron. 39(4): 524-530.

Johnson, P.N.T. (1987). Reduction of post-harvest losses of perishable crops in Ghana. Principles and Approaches. Accra, food Research Institute Mimeo

Kotey, D. A, Gbewenyo, W. S. K. and Afreh-Nuamah, K. (2008). High chlorpyrifos levels on vegetables in Ghana. *Pesticide News* 80: 4-6.

Lammer, W. and MacLeod, A. (2007). Report: Joint pest risk analysis for *Helicoverpa armigera* (Hubner). Plant Protection Service (NL) and Central Science Laboratory (UK). 18.

Mailhot, D. J., Marois, J. J., and Wright, D. L. (2007). Influence of flower thrips on Fusarium hardlock severity. *Plant Disease*. 91: 1423 – 1429.

Martin, N. A. (1999). Whitefly, Biology, identification and life cycle. *Crop and Food Research, Broadsheet* No. 91, February 1999, pp. 1-8.

Mathirajan, V. G., Natarajan, K., Kuttalam, S., Chadrasekaran, S. and Regupathy, A. (2000). Evaluation of lambda-cyhalothrin for the control of pod borers on red gram. *Annuals Plant Protection Sciences* 8(2): 246-247.

Mohamed-Ahmed, M.M. (2000). Studies on the control of insect pests in vegetables (okra, tomato, and onion) in Sudan with special reference to neem preparations. PhD Dissertation, University of Giessen, Germany.

Mota W.F., F.L. Finger., D. J. H. Silva., P. C. Correia., L. P. Firme and L. L. M. Neves. (2005). Physical and chemical characteristics from fruits of four okra cultivars. *Horticulture Brassica* 23 (3): 722-725.

NAS (2000). The future role of pesticide in USA Agriculture. National Academy press. 332.

Norman, J. C. (1992) Tropical vegetable crops. Arthur H. Stockwell Ltd. pp 107–110

Ntow, W. J., Gijzen, H. J., Kelderman, P. and Drechsel, P. (2006). Farmer perceptions and pesticide use practices in vegetable production in Ghana. *Pest Management Science* 62: 356-365.

Ntow, W. J. (2001). Organochlorine pesticides in water, sediment, crops, and human fluids in a farming community in Ghana. *Archives of Environmental Contamination Toxicology* 40: 557–563.

Obeng-Ofori, D. and Ankra, D. A. (2002). Effectiveness of Aqueous neem extract for the control of insect pests of cabbage, *Brassica oleracea var capitata* L, in the Accra plains of Ghana. *Agricultural and Food Science Journal of Ghana* 1 (1): 83–93.

Obeng-Ofori, D and Sackey, J. (2003). Field evaluation of non-synthetic insecticides for the management of insect pests of okra *Abelmoschus*

Obeng-Ofori, D., Danquah, E.Y. and Ofosu-Anim, J. (2007). Vegetable and Spice Crop Production in West Africa. City Printers Limited, pp. 53-65.

Obuobie, E., Keraita. B., Danso, G., Amoah, P., Cofie, O., Raschid-Sally, L. and Drechsel, P. (2006). Irrigated urban vegetable production in Ghana: Characteristics, benefits and risks. IWMI-RUAF-CPWF, Accra, Ghana. 150.

Odebiyi, J. A. (1980). Relative abundance and seasonal occurrence of *Podagrica* spp. (Coleoptera: Chrysomelidae) on okra in south Western Nigeria. *African Journal of Agricultural Science* 6:83-84.

Odhiambo J. A. O. (2010). Status of cotton aphid, *Aphis gossypii* Glover (Homoptera: Aphididae) resistance to insecticides in Southern Ghana. *Ghana Journal of Science* 47: 107 – 11.

Ogemah, V.K. (2003). Influence of derivatives of neem tree (*Azadirachta indica* A. Juss) on the Biology and Behaviour of Prostephanus truncatus (Horn) (Coleoptera: Bostrichidae) and its Predator, Teretrius ingrescens (Lewis) (Coleoptera: Histeridae), *Deutschen Nationalbibliografie*. Berlin, Germany, pp. 20-31.

Osei, M. K., Akromah, R., Shilh, S. L. and Green, S. K. (2010). Evaluation of Some tomato Germplasm for resistance to Tomato Yellow Leaf curl Virus disease (TYLCV) in Ghana. *Aspects Applied Biology* 96: 315-323

Osekre, E. A., Wright, D. L., Marois, J. J., and Funderburk, J. E. (2009). Flower inhabiting *Frankliniella* thrips (Thysanoptera: Thripidae), pesticides, and Fusarium hardlock in cotton. *Journal of Economic Entomology* 102: 887 – 896.

Owusu, E. O. and Yeboah, P. M. (2007). Status of cotton aphid, *Aphis gossypii* Glover (Homoptera: Aphididae) resistance to insecticides in Southern Ghana. *Ghana Journal of Science* 47: 107 – 11.

Peralta, I. E. and Spooner D. M**.** (2007). History, origin and early cultivation of tomato (Solanaceae). *In*: Razdan M.K. and Mattoo A.K. [ed.] Genetic Improvement of Solanceous Crops, Vol. 2. Enfield, USA: Science Publishers. p. 1-27

Pope, C. and Karanth, S. (2000). Carbosylesterase and A-Esterase Activities during Maturation and Aging: Relationship to the Toxicity of Chlorpyrifos and Parathion in Rats. *Toxicology Science* 58: 282-289.

Rao, P. U. (1985). Chemical composition and biological evaluation of okra (*Hibiscus esculentus*) seeds and their kernels. *Plant Foods for Human Nutrition* 35: 389-396.

Reitz, S. R., Yearby, E. L., Funderburk, J. E., Stavisky, J., Momol, M. T., and Olson, S. M. (2003). Intergrated management tactics for *Frankliniella* thrips (Thysanoptera: Thripidae) in field – grown pepper. *Journal of Economic Entomology* 96: 1201 – 1214

Robinson, J. Z. E. and Kolavalli, S. L. (2010). The Case of Tomato in Ghana-Marketing. (International Food Policy Research Institute - IFPRI). (Online) (2.1.2)

Romeis, J. T., Shanower, G., and Zebitz, C. P. W. (1999). *Trichogramma* egg parasitism on *Helicoverpa armigera* on pigeon pea and sorghum in Southern India. *Entomologia Experimentalis of Applicata* 90: 59 – 81.

Sam, G. A., Osekre, E. A., Mochiah, M. B. and Kwoseh, C. (2014) Evaluation of Insecticides for the Management of Insect Pests of Tomato (*Solanum lycopersicum* L.) Journal of Biology, Agriculture and Healthcare 4 (5); 49 - 52

Schmutterer, H. (1961). The most important pests of crops in the central rain lands of the Sudan and their Control. Anz. Schädlinge 34: 177-180.

Schmutterer, H. (1969). Pests of crops in Northeast and Central Africa with particular reference to the Sudan. Gustav. Fischer Verlag. Stuttgart. Portland. U.S.A.

Schmutterer, H. (ed.) (1995). The neem tree, *Azadirachta indica* A. Juss and other Meliaceous plants Sources of unique natural products for integrated pest management, medicines, industry and other purposes. VCH Publishers Inc., New York, USA, pp253

Serra, A. C. (1992). Untersuchungen zum Einsatz von Neemsamenextrakten im Rahmen integrierter Ansätze zur Bekämpfung von Tomatenschädlingen in der Dominikanischen Republik. Doctor, Thesis, Univ. of Giessen, Germany.

Serra, A. C. and Schmutterer, H. (1993). Die Bekämpfung der tabakmottenschillaus *Bemisia tabaci* Genn. Mit Niemextracten in Tomatenfeldern in der Dominkanischen yes Republik. Mitt. Dtsch. Ges. Allg. Angew. *Entomology* 8: 795-801.

Sharafel D. N. (1963). Biological and ecological studies on *A. gossypii* Glover (Aphididae: Hemiptera). MSc. Thesis, faculty of Agriculture, University of Khartoum Sudan.

Sharafel D. N. (1986). Investigation into the biology, ecology and control of the cotton aphid in the Sudan. Crop Pest Management in the Sudan; Proceeding of a symposium held in Khartoum. Feb. 1978. Min of Agric. And University of Khartoum, Khartoum Univ. Press, Khartoum pp. 68-71.

Shehaya, F. W., Alao, F. O., Adebayo T. A., Olaniran, O. A. and Akanbi, W. B. (1984). Preliminary Evaluation of the Insecticidal Potential of Organic Compost Extracts against Insect Pests of Okra (*Abemoschus esculentus (L.*) Moench). *Annual of Agricultural Science*, 21: 603 – 613.

Siemonsma, J. S. and Piluck, K. Eds. (1993). Vegetables. Plant Resources of South East Asia 8- 57-59

Siemonsma, J. S. and Hamon, S. (2002). *Abelmoschus caillei.* Record from Protabase. Plant Resources of Tropical Africa, p g 2-9 Wageningen, the Netherlands

Sinnadurai, S. (1992). Vegetable cultivation. Asempa Publishers pp. 166 – 171

SRID-MOFA (2007). Statistical Research and Information Directorate, Ministry of Food and Agriculture, (Ghana). Production Figures 2007, pp 56 – 57

Tambo, J. A. and Gbemu, T. (2010). Resource-use Efficiency in Tomato Production in the Dangme West District, Ghana. Conference on International Research on Food Security, Natural Resource Management and Rural Development. Tropentag, ETH Zurich, Swzld

Temikotan, T. and Akinyele B. O. (2007). Effect of Variation in Soil Texture on the Vegetative and Pod Characteristics of Okra (*Abelmoschus esculentus* (L.) Moench. *International Journal of Agricultural Research, 2: 165-169.*

Tomlin, C. D. S. (2006) *The Pesticide Manual, A World Compendium*, 14th ed.; British Crop Protection Council: Alton, Hampshire, UK, pp. 186-187.

USDA. (2005). World Agricultural outlook Board, MS 3812, 1400. Independence Ave., S. W., Washington, D. C. 20250-3812, phone: (202) 720-5715, email:dstallings@oce.usdu.gov.

Vanlommel, S., Duchateau L., Coosemans, J. (1996). The effect of okra mosaic virus and beetle damage on yield of four okra cultivar

Wakil, W., Ghazanfar, M. U., Kwon, Y. J., Qayyum, M. A. and Nasir, F. (2010). Distribution of *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae) in tomato fields and its relationship to weather factors. *Entomological Research* 40: 290-297.

Washington, DC. (1999). *Reregistration Eligibility Science Chapter for Chlorpyrifos Fate and Environmental Risk Assessment Chapter*; U.S. Environmental Protection Agency, Office of Prevention, Pesticides and Toxic Substances, Office of Pesticide Programs, Environmental Fate and Effects Division, U.S. Government Printing Office:

Washington, DC. (2006). *Reregistration Eligibility Decision (RED) for Chlorpyrifos*; U.S. Environmental Protection Agency, Office of Prevention, Pesticides and Toxic Substances, Office of Pesticide Programs, U.S. Government Printing Office

Williamson, S. (2003). Pesticide provision in liberalised Africa: Out of control? *Agricultural Research and Extension Network Paper* No. 126. 20.

Wintuma, A. S. (2009). Status of cotton aphid, *Aphis gossypii* Glover (Homoptera: Aphididae) resistance to insecticides in Southern Ghana. *Ghana Journal of Science* 47: 107 – 11.

Yamaguchi, M. A. S. (1983). World vegetables, principles production and nutritive value: pp 370. Publishers: Van Nostrand Reinhold. New York.

APPENDICES

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

Soil property	**Mean**
ORG. C (%)	1.52 (0.4)
Total N (%)	0.12 (0.01)
Available P (mg / kg soil)	6.9 (0.4)
Soil PH	5.8 (0.1)
Exchangeable cations (cmol kg /soil)	
Ca	5 (0.6)
Mg	2.6 (1.1)
K	0.1 (0.01)
Na	0.2 (0.01)
Al^{3+}	1.5 (0.1)
H	1.1 (0.1)

Mean with standard deviation in parenthesis ()

Appendix 2: Fruit of tomato CRI-POO

Appendix 3: Fruit of Okra Asontem