KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF AGRICULTURE AND RENEWABLE NATURAL RESOURCES

DEPARTMENT OF CROP AND SOIL SCIENCES

EVALUATION OF INSECTICIDES AND FUNGICIDES FOR THE MANAGEMENT OF INSECT PESTS AND DISEASES OF TOMATO (*Solanum lycopersicum* L.)

A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DAGREE OF MASTER OF SCIENCE IN CROP PROTECTION (ENTOMOLOGY)

BY

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DECLARATION

I, Garmonyou Aloysius Sam hereby declare that this submission is my own work towards the Master of Science 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 any institution, except where due acknowledgement has been made in the text.

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DEDICATION

This work is fervently dedicated to my Lord and Saviour, Jesus Christ, and also to my beloved parents Mr. Samuel C. B. Sam and Mrs. Etta W. Sam, through whose enthusiasm and inspirations have brought me this far.

ABSTRACT

Studies comprising a survey conducted in Agogo in the Ashanti region to gather information on farmers' perceptions on tomato production and field experiments conducted in 2012 and 2013 at the Plantation Crops Section of the Department of Crop and Soil Sciences of the Kwame Nkrumah University of Science and Technology, (KNUST) were undertaken to evaluate the efficacy of two insecticides (Lambda Super and Cymethoate) and two fungicides (Shavit F and Kocide 2000) for the management of insect pests and diseases of tomato. Results from the survey showed that males dominate tomato production in Agogo. Majority (74.3 %) of the farmers aged between 31 – 50 years and most of them had no formal education. Majority of them obtained their seeds from agrochemical shops. The survey also revealed that whiteflies, *Bemisia tabaci* (Gennadius); Thrips, *Thrips tabaci* (Lindeman); Aphids, *Aphis gossypii* (Glover); and Tomato fruitworm, *Helicoverpa armigera* (Hubner) were the most important insect pests that attack tomato in the area. Septoria leaf spot, Blight, Fusarium wilt and rot were identified by farmers as the major diseases of that affect tomato. About 45.7 % of the farmers reported that pesticides were not effective, with 48.6 % of them reporting of their effectiveness. The field experiments had the following treatments: Lambda Super 2.5 EC (Lambda-cyhalothrin a.i.) at 1.5 ml / 0.5 L of water; Cymethoate Super EC (Cypermethrin & Dimethoate a.i.) at 0.25 ml / 0.5 L of water; Control, (water only); Shavit F 71.5 WP (Folpet + Triadimenol a.i.) at 6.25 g / 2.5 L of water and Kocide 2000 (Copper Hydroxide a.i.) at 100 g / 15 L of water.

In the experiment in 2012, there were no significant differences among the insecticide - treated plots and the control with respect to the densities of *B. tabaci*, *A. gossypii*, *Liriomyza* sp. and *H. armigera*. Cymethoate recorded significantly lower number of *T. tabaci* than the control. In the experiment in 2013, the control plots recorded significantly more aggregations of *B. tabaci*, *H. armigera* and *A. gossypii* than the Lambda Super and Cymethoate treated plots. There were no significant differences in the number of leaf miners, *Liriomyza* sp. and *T. tabaci* in the insecticides treated plots. In the experiment in 2012, there were no significant differences among fungicide treatments with respect to Blight, Fusarium wilt, Leaf mould and Tomato Yellow Leaf Curl Virus (TYLCV) disease. Significant difference was however observed in Septoria leaf spot between treatments. In the experiment in 2013, there were no significant differences among fungicide treatments with respect to the diseases. There were no significant differences among the insecticides and fungicides treatments with respect to number of fruits plant^{-1}, mean fruits weight plant^{-1}, mean % damaged fruits and mean yield (kg ha^{-1}). No significant difference was observed among treatments with respect to mean shoot dry weight. The implications of these results were discussed.

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CHAPTER ONE

1.0. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) belongs to the family Solanaceae and it is one of the most important vegetable crops cultivated worldwide (Naika *et al*., 2005; Alam *et al*., 2007). In Ghana, tomato contributes about 61.8 % to the agricultural GDP (MoFA, 2010). It is consumed in many ways (raw or processed form), and this has played a major role in its rapid and widespread adoption as an important food component in Ghana (Norman, 1992; Horna *et al*., 2006; Asare-Bediako *et al*., 2007). Tomato contributes to a healthy, well-balanced diet. It is rich in vitamins and minerals, essential amino acids, sugar and dietary fibres as well as phytonutrients such as lycopene, an antioxidant, which fights the free radicals that can interfere with normal cell growth and activities (Beecher, 1998).

Tomato production in Ghana is mainly a smallholder activity, and its distribution throughout the year is markedly seasonal with a few large scale ventures at designated irrigation sites (FAO, 2005). According to Clottey *et al*. (2009), tomato production provides employment and generates income for the rural and urban folks. Tomato yields in the tropics vary widely, ranging from 1 to 23 mt / ha compared with the temperate, where yields of 10 to 22 mt / ha are realized (Maerere *et al*., 2010). In Ghana, however, average yield of tomato ranged from 7.5 to 15 mt / ha in the early 2000s, and the annual national volume of tomato rarely reaches 90,000 mt (Adu-Dapaah and Oppong-Konadu, 2002; Integrated Social Development Center (ISODEC), 2004; Obeng-Ofori *et al*., 2007). The highest and lowest annual production levels ever recorded in Ghana were 213,000 mt and 35,800mt in 1995 and 1997, respectively (Adu-Dapaah and Oppong-Konadu, 2002). Moreover, tomato production has intensified over the years; however, yields continue to be low due to several production constraints such as insect pests, diseases, and other environmental factors (Norman, 1992; Blay, 2005; Osei *et al*., 2010). The major economically important insect pest species of the crop belong to the insect orders of Diptera, Hemiptera, Lepidoptera and Orthoptera. Among these are the whitefly, (*Bemisia tabaci*) Gennadius, leaf miners, (*Liriomyza* sp.), thrips, (*Thrips tabaci*) Lindeman, cotton aphids, (*Aphis gossypii*) Glover, tomato fruitworm, (*Helicoverpa armigera*) Hubner according to (Obeng-Ofori *et al*., 2007; Enomoto, 2008).

Additionally, some important diseases of economic concern such as Septorial leaf spot caused by (*Septoria lycopersici*), Early blight by (*Alternaria solani*), Late blight by (*Phytophthora infestans*), Anthracnose by (*Colletotrichum lindemuthianum*) and, (*Pythium* spp.), Bacterial wilt by (*Pseudomonas solanacearum*), Fusarium wilt by (*Fusarium oxysporum* f. *Lycopersici*), Sclerotium wilt and fruit rot and wilt by (*Sclerotium rolfsii*), Blossom-end rot (non-infectious), Soft rot by (*Erwinia carotovora*), tomato spotted wilt by Tomato Spotted Wilt Virus (TSWV), tomato yellow leaf curl by Tomato Yellow Leaf Curl Virus (TYLCV), Tomato mosaic by Tobacco Mosaic Virus (TMV) and root knot nematode (*Meloidogyne* spp.), etc. are known factors limiting tomato production worldwide according to (Norman, 1992; Obeng-Ofori *et al*., 2007; Enomoto, 2008; Offei *et al*., 2008).

Pesticide application is the most effective way of controlling insect pests, diseases and weeds. They are known to increase yield tremendously as these chemicals act on pests that destroy agricultural produce when used judicially (Graham-Bryce, 1981). Tomato farmers in many parts of the world and, Ghana in particular, rely entirely on the use of pesticides to manage insect pests and diseases. According to Horna *et al*. (2008) and

Gianessi (2009), fresh tomato yield losses in Ghana can be as high as 64 % without the use of insecticides.

1.1 Problem Statement and Justification of the Study

The high susceptibility of tomato cultivars to insect pests and diseases has caused farmers to obtain low yields (Bonsu, 2002).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; Gianessi, 2009), the indiscriminate and widespread use of synthetic insecticides in vegetable cultivation usually has resulted in insecticide resistance development (Owusu and Yeboah, 2007; Wintuma, 2009; Odhiambo *et al*., 2010). On the other hand, it has been established that farmers limited knowledge on appropriateness of pesticides to use, timely application, and the quantity to apply have led to low yield and undesirable accumulation in food. Because of the critical role pesticides play in vegetable crop production, there is a need to evaluate some of the most common ones used by farmers in order to provide useful information for effective management of insect pests and diseases for increased yield of tomato.

1.2. Main Objective

The main objective of this study was to assess the efficacy of insecticides and fungicides for the management of insect pests and diseases of tomato.

1.3. Specific Objectives

The specific objectives were to;

i) determine farmers' perceptions about pesticides, insect pests and diseases of tomato

ii) identify insect pests and diseases of tomato in the study area (Kumasi)

iii) determine the efficacy of Lambda Super and Cymethoate against insect pests of tomato

iv) determine the efficacy of Shavit F and Kocide 2000 against major diseases of tomato and

v) determine the effects of the insecticides and fungicides on yield of 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 (Obeng-Ofori *et al*., 2007; Norman, 1992) and it is a very important crop used in many recipes and for different products. Through domestication, research and breeding activities by scientists worldwide, have resulted in modern tomato varieties (mostly hybrids) with all shapes, colours and sizes.

Tomato belongs to the Solanaceae family, which includes more than 3000 species with eggplant, pepper and potato (Knapp, 2002). Although the crop requires a relatively cool, dry climate for high yield and better quality (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*., 2004; Obeng-Ofori *et al*., 2007). It also contains lycopene, an antioxidant that reduce 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.

2.1.1. World Tomato Production

Tomato ranks second in priority after potato in the world. The major tomato growing countries are China, India, USA, Turkey, Egypt and Italy. It is grown on more than 5 million hectares with a production of nearly 129 million tons. However, China is the world's top tomato grower, accounting for more than one-quarter 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. In spite of the above, Asia and Africa account for about 79 % of the global tomato area, with about 65 % of world output (FAO, 2008).

2.1.2. Tomato Production in Ghana

Tomato is a relatively short duration vegetable crop that is grown both for fresh market and for processing. The total land area utilized for tomato production in Ghana increased from 28,400 hectares in 1996 to 37,000 hectares in 2000 (GIPC, 2001). 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*., 2007). 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-Ofori *et al*., 2007; Ntow *et al*., 2006). Some important tomato varieties cultivated in Ghana include Wosowoso, Rasta, Heinz 135, Roma VFN, Power and Petomech (Norman, 1992; Blay, 2005; Obeng-Ofori *et al*., 2007).

Tomato is grown throughout the year in Akumadan. Generally, there are three tomato-growing seasons (March – May, July – September and September – Nov), 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*., 2006).

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 metric tonnes (Adu-Dapaah and Oppong-Konadu, 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 about two decades of the closure of the two state owned tomato-processing factories, namely, Wenchi and the Pwalugu tomato factories, Ghana now has the Wenchi tomato processing factory as the only large-scale producer of processed tomato products in the country (ISODEC, 2004).

Tomatoes are 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, which may increase the susceptibility of the crops to infection by pathogens.

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*., 2007). 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*., 2007).

2.1.3. Pesticide Use in Tomato Cultivation

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 (National Academy of Science (NAS), 2000; Cooper and Dobson, 2007). The annual pesticide usage in Akumadan was estimated at 500 t, of which 4 % are made up of organochlorine compounds (Ntow, 2001). 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*., 2006; 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-trichloro-ethane (DDT), lindane and endosulfan (Kotey *et al*., 2008).

2.2. Insect Pests of Tomato

Several kinds of insect pests attack tomato both in the nursery and on the field (Norman, 1992; Blay, 2005; AVRDC, 2007). The most commonly occurring insect pests include whiteflies (*Bemisia tabaci*); Thrips (*Thrips tabaci*); Aphids (*Aphis gossypii*) and tomato fruitworm (*Helicoverpa armigera*). These insect pests are considered important based on their economic impacts on tomato production worldwide (Lammer and MacLeod, 2007; Enomoto, 2008; Gianessi, 2009).

2.2.1. Whiteflies, *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae)

The whitefly is widely distributed in tropical and subtropical regions, and in greenhouses. *B. 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. The whitefly is a soft-bodied, moth-like fly. The wings, however, is 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 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).

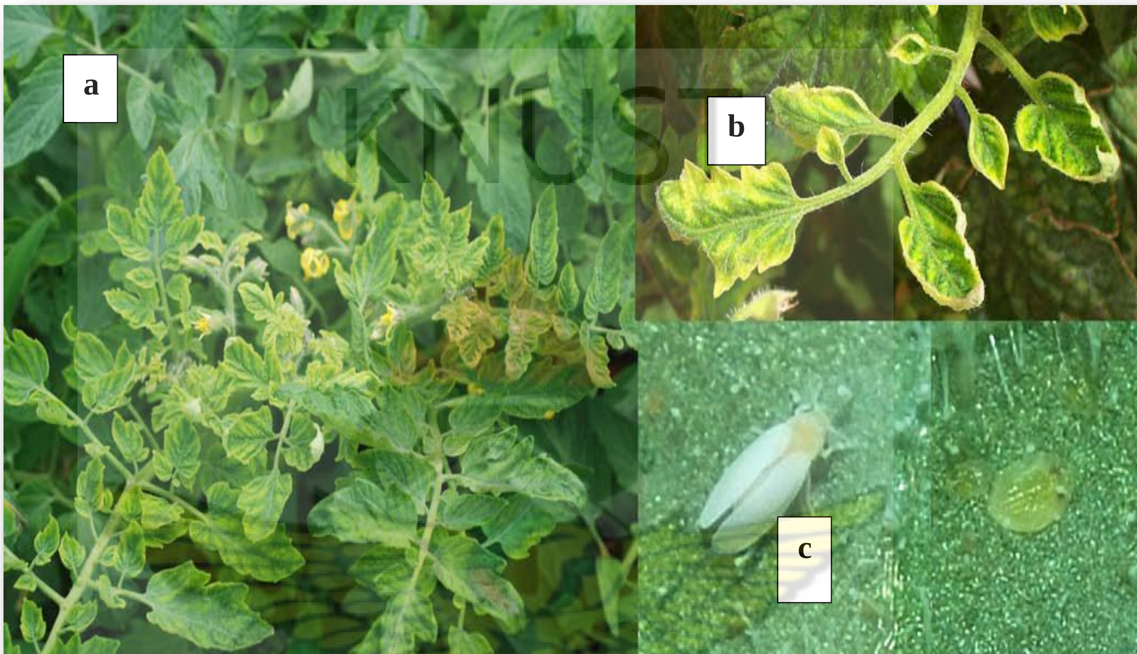

Plate 2.1: Whitefly, *B. tabaci* and tomato plant showing TYLCV disease c = whitefly, a, b = TYLCV disease

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 e*t al*., 1995). Whitefly transmitted viruses are among the most serious viral diseases on plants, often resulting in total crop losses as limiting factors. 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 stage; mainly affected parts are the leaves (Legg *et al*., 2003).

2.2.2. Tomato Fruitworm, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae)

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 (Fitt, 1989; Wakil *et al*., 2010). The extent of damage to crop and the consequent losses in yield due to this pest vary considerably between crops, regions and locations, and between seasons (Fitt, 1989; Lammer and MacLeod, 2007; Wakil *et al*., 2010). Fruit formation is adversely affected when the larvae feed on flower buds and flowers. As reported by Talekar (1998) and Gianessi (2009), the larvae bore holes into fruits when feeding and these not only serve as exit holes but are also used as entry points for pathogenic pests which give rise to fruit rot.

2.2.3. 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 areal 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). Losses incur because sucking of tomato crop is insurmountable. 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 chlorophillus tissues, suppresses tomato flowers to bloom and makes the mature fruits unfit to consume. 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 infection 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 well - known are lady beetle adults and larvae, 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. Selective insecticides 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.

2.2.4. Thrips, *Thrips tabaci* (Lindeman) (Thysanoptera: Thripidae)

Thrips are important pests of several crops in most parts of the world. It is very small ranging from 0.5 to 1.2 mm in size. The form of the thrips body is elongated, elliptical and slender. Their eyes have darker coloration and are easy to see. Immature thrips have short antennae. The difference between immatures 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).

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).

In most cases thrips are not a problem in the rainy season because the rain washes the tiny insects 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 use pesticides as little as possible to avoid unfriendly conditions with the environment (Hoffmann *et al*., 1996).

2.2.5. Efficacy of Insecticides on Insect Pests

Chemical control using broad spectrum insecticides such as aldicarb and acephate, is the most commonly used and recommended management approach (Greenberg *et al*., 2009; Herbert *et al*., 2011). There are concerns, however, regarding the toxicity of these insecticides to beneficial species, the development of resistance, and in some cases, the lack of efficacy (Zhao *et al*., 1995; Allen *et al*., 2005). These concerns have led to the development of new insecticides which have different modes of action, greater host specificity, and less toxicity to beneficially important species (Isayama *et al*., 2005; Bruck *et al*., 2009). Cyantraniliprole (DuPont Crop Protection, Wilmington, DE) is a novel insecticide that has been shown to reduce thrips feeding injury and tomato spotted wilt virus transmission (*Bunyaviridae Tospovirus*) by tobacco thrips, *Frankliniella fusca* (Jacobson and Kennedy, 2011). Cyantraniliprole is an anthranilic diamide insecticide that acts as an agonist targeting ryanodine receptors in insects affecting calcium release during muscle contraction (IRAC Group 28) (Cordova *et al*., 2006; Sattelle *et al*., 2008). Insects treated with cyantraniliprole exhibit rapid feeding cessation, muscle paralysis, and ultimately death. Chlorantraniliprole, a similar chemical to cyantraniliprole, has demonstrated tremendous efficacy against a variety of lepidopteran pests, whiteflies, and beetles. It has demonstrated excellent efficacy against Colorado potato beetle in the field (Kuhar *et al*., 2010). Cyantraniliprole, like chlorantraniliprole, is also xylem-mobile for root uptake providing systemic control of insect pests.

The most common management strategy for thrips is chemical control using broad - spectrum (carbamate, organophosphate or pyrethroid) insecticides (Olsen *et al*., 2006; Greenberg *et al*., 2009; Toews *et al*., 2010; Herbert *et al*., 2011). This approach has also been shown to lead to outbreaks of secondary pests, toxicity to beneficial species, development of resistance in the target insect, and potential toxicity for the applicator (Zhao *et al*., 1995; Allen *et al*., 2005; Herron *et al*., 2008). These concerns have led to the development of new insecticides that have stronger target specificity, reduced toxicity for both beneficial insects and human applicators, and new modes of action reducing the potential for resistance development (Isayama *et al*., 2005; Bruck *et al*., 2009; Cameron *et al*., 2009).

Mathirajan *et al*. (2000) also reported that Lambda – cyhalothrin applied at the rate of 30 g a.i ha^{-1} was more effective against shoot and fruit borer on brinjal than endosulfan and fenvalerate.

Plate 2.2: PO34 Tomato Fruits harvested, 2012

2.3. Diseases of tomato

Tomatoes are injured by pathogenic diseases caused by fungi, bacteria, and viruses, as well as abiotic diseases, such as catfacing and blossom end rot, which are caused by environmental and physiological disorders. Pathogenic diseases develop through soil-borne and above-ground infections and, in some instances, are transmitted through insect feeding. Major tomato diseases include those that attack the root system (fusarium wilt, bacterial wilt, nematodes, rhizoctonia), above-ground stems and foliage (Early blight, Late blight, Septoria leaf spot, Bacterial canker), and fruit (Bacterial spot, Bacterial speck, Anthracnose). Thus, a disease-control program is important at each stage of growth. Fusarium wilt, one of the most damaging soil - borne diseases of tomatoes, also attacks more than 200 other plant species, including potato, pepper, eggplant, strawberry, watermelon, and radish (Gleason and Edmunds, 2006).

2.3.1. Late Blight (*Phytophthora infestans*) of Tomato

Late blight is caused by *Phytophthora infestans*, and is a serious plant disease that mainly attacks potatoes and tomatoes worldwide (Agrios, 2005). It can be found on other crops, weeds and ornamentals in the Solanaceae. It is most common in wet weather. Daytime temperatures between 16 and 21 °C, night temperatures between 10 and 16 °C, and relative humidity about 100 % are the ideal conditions for infection and spread of late blight disease. Predisposing factors include cool, wet weather and high relative humidity, densely planted crops of tomato (Agrios, 2005). *P. infestans* is still a difficult disease to control today by ordinary methods. However, fungicides for the control of tomato blight are normally only used in a preventative manner.

2.3.2. Fusarium Wilt, *Fusarium oxysporum* f. sp. *Lycopersici*

Fusarium oxysporum f. sp. *lycopersici* is a highly destructive pathogen of both greenhouse and field grown tomatoes in warm vegetable production areas. The disease is characterised by wilted plants, yellowed leaves and minimal or absent crop yield.

There may be a 30 – 40 % yield reduction in tomato as a result of its attack (Kirankumar *et al*., 2008). The Fusarium wilt fungus infects plants through the rootlets, invading the xylem and eventually extending throughout the plant. Individual branches and associated leaves on plants infected with *Fusarium* become yellow and wilt. Sometimes only one branch or one side of the plant is affected, creating a yellow flag effect. Infected plants usually die. A dark brown vascular discoloration extends far up the stem. Symptoms often first appear during fruit sizing (Davis, 2012).

Fusarium wilt can greatly reduce yields in fields with a high incidence of Fusarium. The fungus survives for many years in the soil as spores. Long distance spread is by seed, transplants, and soil on farm machinery (Davis, 2012). The disease is favoured by warm weather. The fungus only infects tomato but exists as three races but Race 1 is widespread. There is no cure for Fusarium and since it persists in the soil for years, it can be very hard to eradicate.

The use of resistant tomato varieties is one of the best method to control the pathogen. Resistant varieties are common for Race 1, and many are also resistant to Race 2. A few varieties are resistant to all three races. The spread of infested soil by cleaning farm equipment should be limited. Avoidance of root knot nematode infestations can reduce Fusarium wilt because nematode feeding can overcome the plant resistance to the disease. Rotation out of tomatoes for several years reduces inoculum level, although *Fusarium* is long-lived (Davis, 2012).

Plate 2.3: Tomato leaf showing Early Blight Symptom

Plate 2.4: Tomato plant showing symptom of Fusarium wilt

2.3.3. Leaf mould (*Clasdosporium fulvum*)

Leaf mould caused by *Clasdosporium fulvum* is a serious fungal disease of worldwide concern, especially in the wet season. It is most severe in the forest zone (Obeng – Ofori *et al*., 2007). The older leaves develop large yellow chlorotic spots, turn reddish brown mould and may become blackened. The disease results in premature leaf drop and therefore lead to reduction in yield (Obeng – Ofori *et al*., 2007). However, early planting, avoidance of damp and humid areas minimize its potency. Other ways of control are by planting resistant varieties and spraying suitable fungicides such as Dithane M-45 and cuprous oxide (Obeng – Ofori *et al*., (2007).

2.3.4. Tomato Yellow Leaf Curl (Bigeminivirus, TYLCV)

Tomato Yellow Leaf Curl Virus (TYLCV) is a very destructive disease transmitted by *B. tabaci* (whiteflies). Early and severe infection can cause total crop failure as most of the flowers abort. Disease symptoms include stunting and yellowing with curled leaves showing veinal clearing and interveinal chlorosis (Obeng – Ofori *et al*., 2007). There are no synthetic chemicals available to control viral diseases. Control is therefore preventive and cultural such as planting of resistant varieties, removal and destruction of infected plants, destruction of alternative host plants and control of insect vectors (whiteflies).

2.3.5. Septoria leaf spot (*Septoria lycopersici*)

Septoria leaf spot is a fungal disease caused by *Septoria lycopersici* and is distributed throughout the world. It is very common where tomatoes are grown continuously for years, especially in the wet season (Obeng – Ofori *et al*., 2007). Septoria leaf spot over - season on infected tomato debris and other solanaceous weed hosts such as horsenettle between crops (Jones *et al*., 1991). Tomato plants become infected during the production season when infested soil carrying inoculum (spores) is splashed onto lower leaves during rainfall and overhead irrigation. Periods of high relativity, high temperatures, and leaf wetness favour the development of Septoria leaf spot during the production season (Jones *et al*., 1991). Septoria leaf spot is controlled by the use of healthy disease – free seed dusted with fungicides, regular weeding to destroy alternative hosts, removal of crop debris, crop rotation with non – host crops, early planting of resistant varieties and spraying with a suitable fungicides (Obeng – Ofori *et al*., 2007).

2.3.6. Efficacy of Fungicides on Diseases

Chemical control of tomato fusarium wilt *in vitro* and glasshouse was examined repeatedly. Fungicides including benomyl, captafol, imazalil, thiram, and prochloraz - Mn, provided inconsistent control of Fusarium crown and root rot on tomatoes, leaving problematic residues in fruit tissues (Marois and Mitchell 1981; Jarvis 1988, 1992; Hartman and Fletcher 1991). Also application of methyl bromide and chloropicrin reduced Fusarium crown and root rot of tomato (Mc Govern and Vavrina, 1998).

Mandal and Sinha (1992) found out that such compounds as copper chloride, ferric chloride, manganese sulfate, controlled *Fusarium oxysporum* f. sp. *lycopersici* by inducing resistance in susceptible tomato plants. El-Shami *et al*. (1993) reported that Vitavax (carboxin)-thiuram or Vitavax-captan, applied as fungicidal seed treatment, were effective in controlling Fusarium wilt disease so that, Vitavax-captan gave better disease control than Vitavaxthiuram. The effect of mixture of metamidoxime and copper oxychloride on *F. oxysporum* f. sp. *lycopersici* was tested *in vitro*, and the results showed that these fungicides had a strong synergistic effect and could be used as a basis for a new product to control tomato diseases (Nedelcu and Alexandri, 1995). In addition, it was demonstrated that Thiram and Topsin-M were the most effective at 800 mg/g soil, reducing populations of *F. oxysporum* f. sp. *lycopersici* by 83.4 % after 45 days (Dwivedai *et al.* 1995).

2.4.0. Pesticides Used as Treatments and their Mode of Action

2.4.1. Lambda Super 2.5 EC (Lambda-cyhalothrin a.i.)

Lambda-cyhalothrin is an organic compound that is used as a pesticide. It is a pyrethroid, a class of man-made insecticide 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 cotton and vegetables. Lambda-cyhalothrin is a mixture of isomers of cyhalothrin. Brand names include Karate, Kung-fu, Matador, and Demand CS, Charge, Excaliber, Grenade, Hallmark, Icon, OMS 0321, PP321, Saber, Samurai, and Sentinel.

2.4.2. Mode of Action of Lambda-cyhalothrin

Pyrethroids, including lambda-cyhalothrin, disrupt the functioning of the nervous system in 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 studies, 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 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 (NPIC, 2012). The LD_{50} of Lambda-cyhalothrin is 79–56 mg/kg (rats, oral)

2.4.3. Cymethoate Super EC (Cypermethrin + Dimethoate a.i.)

An insecticide and acaricide of moderate mammalian toxicity which is used in housefly control and against a broad range of agricultural insect and mite pests. It is active after metabolism, both as a contact and as a systemic insecticide. It is readily absorbed by the gastrointestinal tract and to a lesser extent through the intact skin and by inhalation.

2.4.4. Mode of Action of Cypermethrin + Dimethoate

It acts as a cholinesterase inhibitor after metabolism. Oral dimethoate is bio-transformed in the liver microsomes by conversion into its oxygen analogue, which is the active form, by hydrolysis of the methyl ester group, and by removal of the methyl-amido group. It has an Oral LD_{50} of 500-600 mg/kg (pure dimethoate) and about 150 mg/kg (technical product) which is recommended for classification purposes, and a Dermal LD_{50} of 353 mg / kg.

2.4.5. Kocide 2000 (Copper Hydroxide a.i.)

Kocide 2000 is a contact fungicide that contains 53.8 % copper hydroxide active ingredient. It treats symptomatically and belongs to the toxicity class III, which is strightly hazardous.

2.4.6. Mode of Action of Copper Hydroxide

Kocide 2000 has a superior dry flowable formulation with smaller particle size. It acts as a protectant and has a contact action. Once applied, Kocide 2000 particles stick to foliar surfaces and acts as copper ion reservoirs. As the copper slowly dissolves in the presence of water, copper ions are continuously released to form a protection barrier against infection providing multi-site activity.

2.4.7. Shavit F 71.5 WP (Folpet + Triadimenol a.i.)

Shavit F is a broad spectrum, systemic triazole fungicide with preventive, curative and eradicative properties. Shavit is quick acting and exhibits long residual effect. Shavit is effective as a foliar treatment against powdery mildew, rust and leaf spot diseases in cereals, coffee, deciduous fruit, grapes, ornamentals and vegetables. It is especially suited as a seed treatment technology to control seed - borne and leaf diseases in cereals.

2.4.8. Mode of Action of Folpet + Triadimenol

Shavit F is a fungicide which combines the systemic properties of triadimenol with the contact properties of folpet. Triadimenol belongs to the family of triazole fungicides and as such, is an inhibitor of biosynthesis of ergosterol. Triadimenol moves upwards the vascular system and is distributed to give full protection of new growth. Folpet acts as a protectant and has contact action. It binds to sulfur-hydrogen bonds, interfering with the respiration process in fungi. Shavit F is available as a wettable powder formulation, containing 70 % folpet + 1.5 % triadimenol. Rat oral LD_{50} mg / kg (> 2000), rat dermal LD_{50} [mg / kg] (> 2000) and rat inhalation LC_{50} mg / l / 4h (> 1.31).

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. Composition of the Study

The study comprised of field survey and field experiments. The field survey was conducted in 2012 to identify constraints and other related problems encountered by tomato farmers in Agogo. Questionnaires were designed and administered to 35 tomato farmers randomly selected from the area. The field experiments were carried out to identify insect pests and diseases of tomato and to evaluate the efficacy of two insecticides and two fungicides for the management of insect pests and diseases, respectively.

3.2. Survey: to assess tomato production systems, perceptions and constraints associated with production.

Agogo is a major tomato production area in Ghana. The 35 randomly selected tomato farmers were interviewed on their demographic characteristics, cultural practices, sources of seeds and cultivars used, and problems encountered in tomato production as well as solutions (Appendix I).

3.3.0. Field experiment

The field experiment was conducted for the identification of insect pests and diseases and the evaluation of insecticides and fungicides for their management.

3.3.1. Experimental Locations

The study was conducted at the Plantation Crops Section of the Department of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology (KNUST).

The first and second growing seasons lasted from mid-August to mid-November 2012 and from January to April 2013, respectively. The major dry season covers mid-November to the end of February or mid-March. Average annual rainfall ranges from 1000 mm to 1500 mm. The soil texture is sandy loam. Rainfall, temperature and humidity recorded during the study were 5.8 mm, 25.7 ºC, 88.4 % in the minor season in 2012 and 1.20 mm, 24.1 ºC, and 73.7 % in the early part of 2013 (KNUST-DAE, 2013).

3.3.2. Tomato Accession and Source of Seeds

The tomato used was PO34 and the seeds were collected from the Crops Research Institute of the Council for Scientific and Industrial Research (CSIR – CRI), Kwadaso, Kumasi. P034 (plant number 34) is a local improved open pollinated accession, susceptible to insect pests and diseases of tomato.

3.3.3. Nursery Preparation

Nursery beds were prepared and heat sterilized by burning of plant debris on the seed beds. Seeds were sown on raised beds which measured 3 m x 2 m (6 m^2). All recommended cultural practices were carried out, as and when necessary.

3.3.4. Land Preparation and Soil Analysis

The experimental area was cleared and burnt. The land was ploughed and disc-harrowed to fine tilt with a tractor to allow smooth root penetration. Prior to the preparation of the land, soil samples were randomly collected from the area at a depth of 0 - 15 cm and analyzed for its characteristics (Appendix 2).

3.3.5. Field Experimental Layout and Design

The experimental fields were laid in a randomized complete block design (RCBD) with five treatments. Each treatment was replicated four times (four blocks). The experimental field measured 46 m x 28 m (1288 m^2). Each treatment plot measured 5 m x 5 m, with 1.5 m alley between each plot and 2 m alley between blocks. Five ridges were constructed to a height of 40 cm in each plot to provide support to the plant.

3.3.6. Transplanting of Seedlings and Cultural Practices

Seedlings were transplanted onto the field at a spacing of 1 m x 0.5 m. Uniform seedlings were selected and planted one per hill. Each plot contained five rows with 10 plants per row, giving a total of 50 plants per plot.

Replacement of dead seedlings as a result of transplanting shocks was carried out one week after transplanting. The field was irrigated as and when necessary since the rainfall pattern was erratic. Regular hoeing to control weeds was done. NPK (15-15-15) fertilizer was applied in two splits.

The first dose was applied three weeks after transplanting at a rate of 30-30-30 kg / ha, where 0.01 kg / ha (10 g) per plant was applied. The second split, Urea (46 % N) was used at six weeks after transplanting as side dressing at a rate of 20 kg N / ha (2.17×10^{-3} kg / ha or 2.2 g per plant.

3.3.7. Pesticide Treatments and their Application

The treatments used were calculated as advised by the manufacturers' recommendation. The treatments were as follows:

1. Lambda Super 2.5 EC (Lambda-cyhalothrin), 1.5 ml / 0.5 l of water
2. Cymethoate Super EC (Cypermethrin & Dimethoate), 0.25 ml / 0.5 l of water
3. Control (sprayed with water only)
4. Shavit F 71.5 WP (Folpet + Triadimenol), 6.25 g / 2.5 l of water
5. Kocide 2000 (Copper Hydroxide), 1 sachet (100 g) / 15 l of water

Application of treatments was done using separate knapsack sprayers (CP 15) for insecticides and fungicides at two weeks interval, starting three weeks after transplanting.

3.4.0. Data Collection

3.4.1. Sampling of Insect Pests

Sampling of insect pests was carried out three weeks after transplanting before treatments were applied. The three inner rows of each treatment plot were used for the sampling. Five plants were selected at random from each plot every week to sample for insect pests.

Sampling for very active insects involved visual examination with the aid of a magnifying lens of each plant. In addition, three leaves from both the upper and lower canopies were collected and put in high density polyethylene bottles containing diluted liquid soap (detergent). These were later transported to the insectary for processing, counting and identification using a stereo microscope. Sampling was done for nine weeks.

3.4.2. Scoring of disease Symptoms, Severity and Incidence

Scoring was done using a score guide (scale) with pictures that clearly illustrate the symptoms of diseases on tomato (CSIR-CRI, Kumasi, Ghana). Additionally, plant samples showing the symptoms of diseases per treatment were collected and taken to the Pathology Laboratory, Department of Crop and Soil Sciences for culturing and further identification. Initial scoring of disease symptoms were carried out at three weeks after transplanting before treatments application.

The Disease Severity Scale (CSIR-CRI, Kumasi, Ghana) used is interpreted below:

1 = No disease symptom expression on tomato plant (No disease)

2 = Disease symptom expression on at least a single leaf of tomato plant to cover 1-25 % of the total leaf (ves) area (Slight infection)

3 = Disease symptom expression on leaf to cover 26-50 % of the total leaf (ves) area of tomato plant (Moderate infection)

4 = Disease symptom expression on leaf and tissues to cover 51-75 % of the total leaf (ves) area of tomato plant where at most a single fruit is assessed as yield (Severe infection)

5 = Disease symptom expression on leaf and tissues to cover 76-100 % of the total leaf (ves) area causing complete death of tomato plant to the point of no recovery or no yield attained (Very severe infection).

Disease incidence was however, assessed by counting the number of infected plants, expressed over the total number of plants.

3.5.0. Yield and Yield Components Assessments

The following parameters were taken:

- Number of fruits per plant
- Weight of fruits per plant
- % damaged fruits per plant
- Yield (kg ha^{-1})

In assessing damage, any fruit with any blemish was considered damaged.

3.5.1. Data Analysis

All count data were transformed using square root transformation and percentages by arc sin transformation. The data were subjected to Analysis of Variance (ANOVA) using SAS software, version (8.2). Treatment means were separated using Tukey at 5 % probability.

CHAPTER FOUR

4.0. RESULTS

This chapter presents the results of the data collected from a field survey conducted in Agogo area to assess farmers' tomato production systems, perceptions on constraints and other related problems encountered during tomato cultivation. It also covers field experiments that were carried out at the Plantation Crops Section of the Department of Crop and Soil Sciences, KNUST, Kumasi.

4.1. Assessment of Farmers' Tomato Production Systems, Perceptions on Constraints and other related Problems encountered by Tomato Farmers in Agogo

4.1.1. Socio – Demographic Characteristics of Respondents

There was a clear dominance of male producers (82.9 %) as against female producers (17.1 %). The results show that majority (74.3 %) of the farmers were within the age range of 31 – 50 years, while 5.7 % constituted above 50 years (Figure 4.1). Additionally, the majority (71.4 %) had no formal education, while the rest had basic education (Figure 4.2).

Figure 4.1. Age Pattern of Tomato Farmers in Agogo, Ashanti region

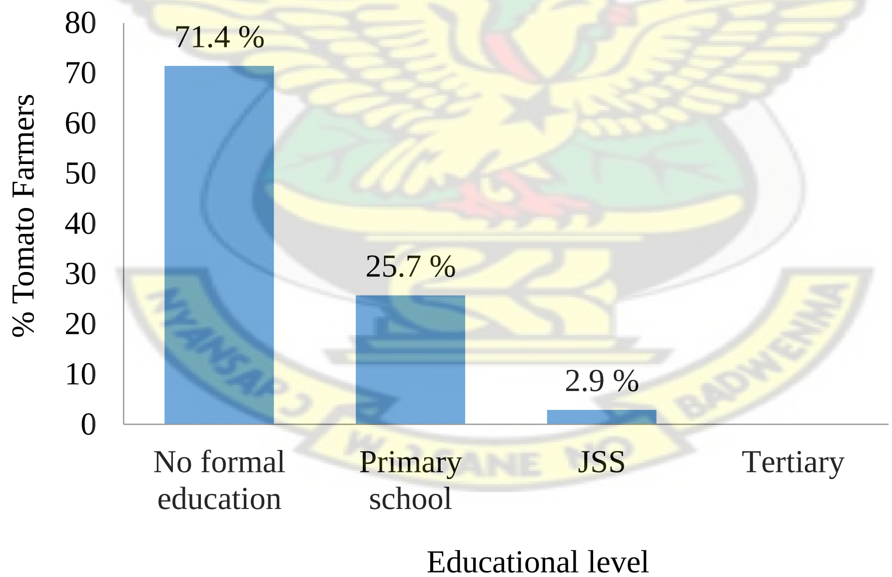

Figure 4.2. Percentage distribution of farmers based on level of education in Agogo, Ashanti region

4.1.2. Farming practices

Experiences in years of cultivation of tomato amongst farmers varied. The majority (31.4 %) of the farmers have been producing the crop since the last ten years (Figure 4.3). (22.9 %) of the farmers were between 0 - 5 and 11 - 15 years, whereas (2.9 % and 20 %) were between 16 – 20 and above 20 years, respectively.

Most (77.1 %) of them obtained their seeds from agrochemical shops, and majority (71.4 %) depended solely on Power seed variety (Table 4.1). About 22.9 % of the farmers obtained their planting materials from both agrochemical shop and from own saved - seeds (Table 4.2.). The most commonly grown tomato varieties in Agogo included Power (71.4 %), being the most dominant, Power and Petomech (22.9 %) and Power, Petomech and Burkina (5.7 %) varieties (Table 4.1).

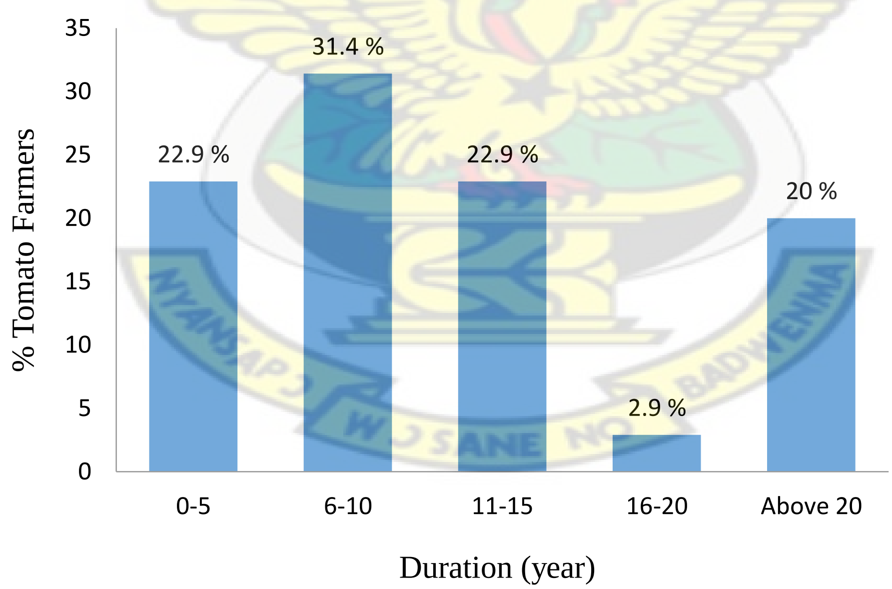

Figure 4.3. Experience of respondents in tomato production in Agogo, Ashanti region

Table 4.1. Distribution of tomato farmers with respect to source of seeds and seed varieties used in Agogo, Ashanti region, 2012

Variable	Percentage of tomato farmers
A) Source of planting seeds	
Agrochemical shop	77.1
Agrochemical shop and farmer saved - seeds	22.9
B) Variety of tomato	
Power	71.4
Power and Petomech	22.9
Power, Petomech and Burkina	5.7

4.1.3. Problems Encountered in tomato production by tomato farmers in Agogo

Majority (48.6 %) of the farmers reported inadequate rainfall, insect pests and diseases as the major hindrance to tomato production in the area. About 22.9 % of the farmers reported inadequate rainfall as their major constraint. Again, 14.3 % accounted for insect pests and diseases; whereas 8.6 % and 5.7 % were recorded for only diseases and only insect pests, respectively. Other factors mentioned were; transportation difficulty, high cost and inadequate funding (purchase of seeds, pesticides, and fertilizer) (Table 4.2).

4.1.3.1. Insect Pests, Diseases and their Management in Tomato Farms in Agogo

The major insect pests reported by farmers to pose a threat to tomato production included caterpillars, cricket, millipede, cotton aphids, whiteflies and thrips (Table 4.3). Some of the major tomato diseases reported included black spot, blight, Fusarium wilt and tomato fruit rot (Table 4.4). Application of insecticides and fungicides, according to the farmers, was the only strategy employed for the management of pests and diseases. The commonly used insecticides Lambda (Lambda cyhalothrin); kombat (Quinalphos); Cymethoate (Dimethoate and Cypermethrin); PAWA (Lambda cyhalothrin); Karate (Lambda cyhalothrin); Confidor (Imidacloprid) and Sunpyrifos (Chlorpyrifos – ethyl); and fungicides Dithane (Mancozeb); Topsin (Thiophanate – methyl); Kocide (Copper Hydroxide); Ridomil (Mefenoxam); Funguran (Copper Hydroxide); and Champion (Copper Hydroxide); were among the insecticides and fungicides used. However, 45.7 % of the farmers reported that these insecticides and fungicides were not effective in controlling insect pests and diseases (Table 4.2). About 48.6 % also reported that they were effective whereas 5.7 % indicated that they were very effective.

Table 4.2. Percentage distribution of constraints to tomato production and effectiveness of pesticides used among tomato farmers in Agogo, Ashanti region, 2012

Variable	Percentage of Respondents
A) **Problems**	
Inadequate rainfall	22.9
Insect pests	5.7
Diseases	8.6
Insect pests and diseases	14.3
Inadequate rainfall, pests and diseases, and others	48.6
B) **Pesticides evaluation**	
Very effective	5.7
Effective	48.6
Ineffective	45.7

Table 4.3. Percentage distribution of Tomato Farmers with respect to insect pests in Agogo, Ashanti, 2012

Insect	Percent of Respondents
Caterpillar	2.9
Cricket	2.9
Millipede and cricket	2.9
Caterpillar and cricket	28.6
Aphids, whitefly, caterpillar, thrips cricket	48.6
Caterpillar, cricket and aphids	8.6
Caterpillar, cricket and whitefly	5.7

Table 4.4. Percentage distribution of Tomato Farmers with respect to diseases in Agogo, Ashanti region, 2012

Disease	Percent of respondents
Black spot	51.4
Blight	2.9
Black spot, rot, Fusarium wilt, blight	5.7
Black spot and blight	11.4
Black spot, rot, blight and Fusarium	28.6

4.2.0. Field Experiment: Identification of insect pests and diseases and evaluation of insecticides and fungicides for their management.

4.2.1. Insect Pests collected in 2012

There was no significant difference (P > 0.05) in *B. tabaci* (Whiteflies) densities between treatments (Table 4.5). Also, *Liriomyza* sp. (leaf miner), *A. gossypii* (aphids) and *H. armigera* (tomato fruitworm) densities showed no significant differences (P > 0.05) between the treatments (Table 4.5). However, significant differences (P < 0.05) were observed in *T. tabaci* densities between treatments (Table 4.5). Cymethoate recorded significantly (P < 0.05) lower number of *T. tabaci* than the control (Table 4.5). There was no significant difference between *T. tabaci* densities in Lambda Super and Cymethoate and between Lambda Super and control (Table 4.5).

4.2.1.1. Insect Pests collected in 2013

There were significant differences (P < 0.05) between treatment means with respect to the densities of *B. tabaci*, *H. armigera* and *A. gossypii* (Table 4.6). The control plots recorded significantly (P < 0.05) more aggregations of the insects than the Lambda Super and Cymethoate treated plots. There was no significant difference (P > 0.05) in their densities between Lambda Super and Cymethoate treated plots. There was no significant differences (P > 0.05) in the number of leaf miners (*Liriomyza* sp) and *T. tabaci* in the insecticides treated plots.

Table 4.5. Mean number (± SEM) of insect pests collected on tomato as affected by insecticide treatments in the first planting (minor season) in 2012 in Kumasi

	Mean number of insects per plant				
Treatment	*B. tabaci*	*Liriomyza* sp	*T. tabaci*	*A. gossypii*	*H. armigera*
Lambda Super EC (Lambda-cyhalohrin)	1.30 ± 0.08 [a]	0.10 ± 0.26 [a]	0.32 ± 0.06 [ab]	0.19 ± 0.03 [a]	0.05 ± 0.06 [a]
Cymethoate (Cypermethrin + Dimethoate)	1.35 ± 0.08 [a]	0.09 ± 0.02 [a]	0.24 ± 0.04 [b]	0.17 ± 0.02 [a]	0.08 ± 0.02 [a]
Control (Water)	1.50 ± 0.07 [a]	0.06 ± 0.02 [a]	0.47 ± 0.06 [a]	0.25 ± 0.03 [a]	0.13 ± 0.03 [a]

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

Table 4.6. Mean number (± SEM) of insect pests collected on tomato as affected by insecticide treatments in the second planting in 2013 in Kumasi

	Mean number of insects per plant				
Treatment	*B. tabaci*	*Liriomyza* sp	*T. tabaci*	*A. gossypii*	*H. armigera*
Lambda Super EC (Lambda-cyhalohrin)	0.86 ± 0.08 [b]	0.00 ± 0.00 [a]	0.00 ± 0.00 [a]	0.07 ± 0.02 [b]	0.12 ± 0.03 [b]
Cymethoate (Cypermethrin + Dimethoate)	0.99 ± 0.88 [b]	0.03 ± 0.01 [a]	0.00 ± 0.00 [a]	0.06 ± 0.02 [b]	0.15 ± 0.04 [ab]
Control (Water)	1.56 ± 0.09 [a]	0.00 ± 0.00 [a]	0.03 ± 0.01 [a]	0.27 ± 0.06 [a]	0.33 ± 0.06 [a]

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

4.3.0. Insect Pest Population Dynamics as Influenced by Insecticide Treatments

4.3.1. Whiteflies (*B. tabaci*)

The population of *B. tabaci* increased steadily in all the insecticide - treated plots and the control in October and comparatively reduced in November (Figure 4.4) with the control plots recording higher numbers in the sample dates except the last sampling in November. There were four spray applications in the minor season (2012). The mean number of *B. tabaci* at the beginning of the spray regime was about two per plant but reduced to about one by the end of the season (Figure 4.5.). After the 1st, 2nd and 3rd spray applications, *B. tabaci* number generally reduced with an exception of the control which recorded slightly higher number after the first spray applications.

In the second planting in early 2013, before application treatments, *B. tabaci* number was between one and 1.5 per plant in the insecticides - treated plots but more than 1.5 per plant in the control (Figure 4.5.). There were three spray applications in 2013. After the 1st spray applications, *B. tabaci* number reduced in all the insecticides - treated plots. However, the control recorded the highest mean number of about two per plant, and later reduced to about one before the 2nd spray applications. After the 2nd spray applications. *B. tabaci* density reached its peak in April. *B. tabaci* number reduced drastically after the 3rd spray applications in all treatments including the control, recording a mean value of about one per plant in the control with the rest of the treatments recording below one per plant.

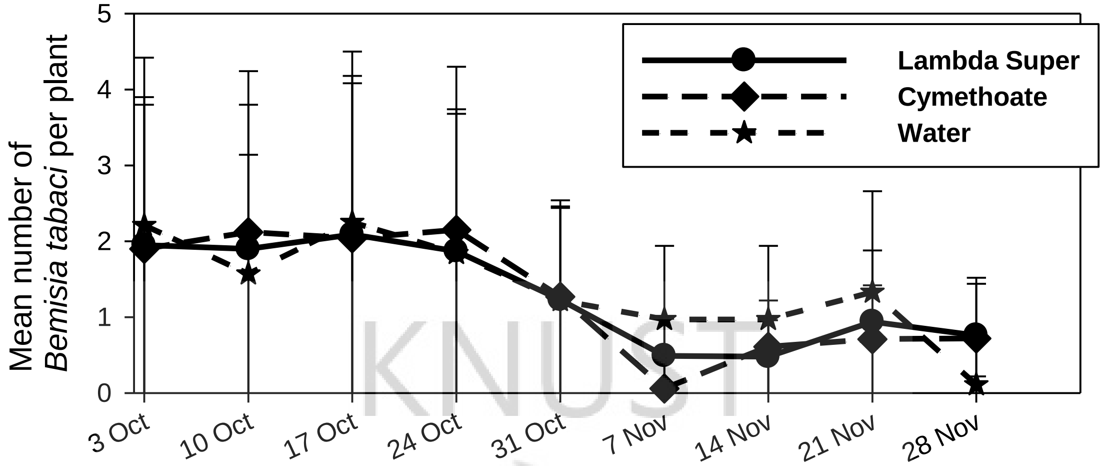

Figure 4.4: Mean number of *B. tabaci* per plant as influenced by treatments application in the first planting in the minor season in 2012

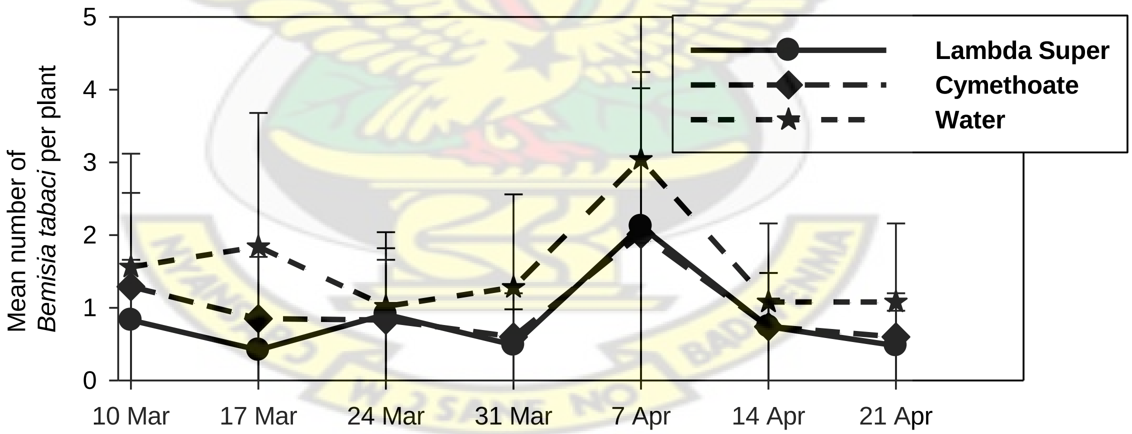

Figure 4.5: Mean number of *B. tabaci* per plant as influenced by treatments application in the second planting in 2013.

4.3.2. Thrips (*T. tabaci*)

The first data taken at the beginning of the experiment recorded virtually no thrips. This increased to a peak of about 1.5 per plant in the 3rd week (Figure 4.6). After a month into the experiment, till the end, thrips numbers reduced in all the treatments plots.

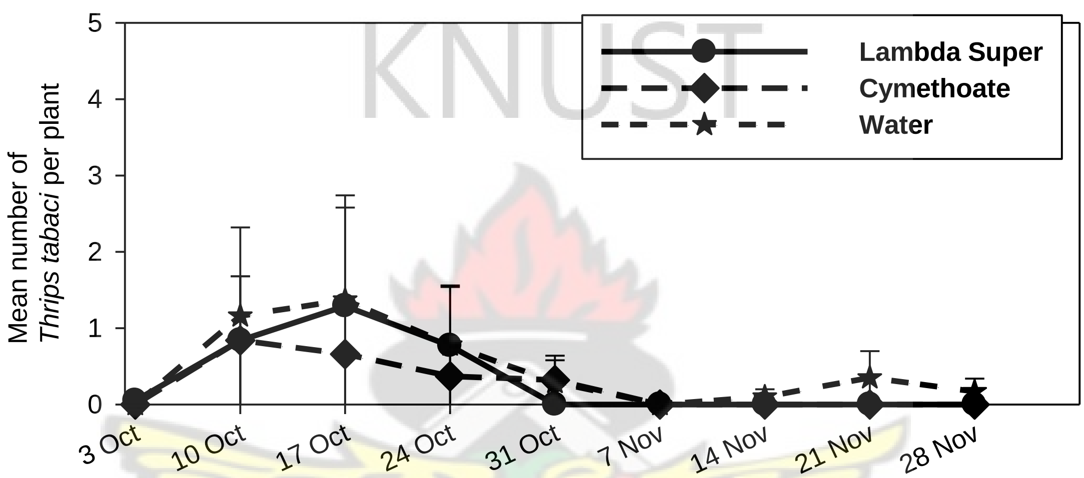

Figure 4.6: Mean number of *T. tabaci* per plant as influenced by treatments application in the first planting in minor season in 2012

4.3.3. Aphids (*A. gossypii*)

Aphids' number was below a mean of one per plant throughout the experimental two planting times in 2012 and 2013 (Figures 4.7 and 4.8). Its population recorded peaks of 0.75 per plant on March 17 and April 14 in the control in 2013. Due to the low number of aphids, the effects of the various treatments were not very clear; though reduced numbers were observed after spray applications.

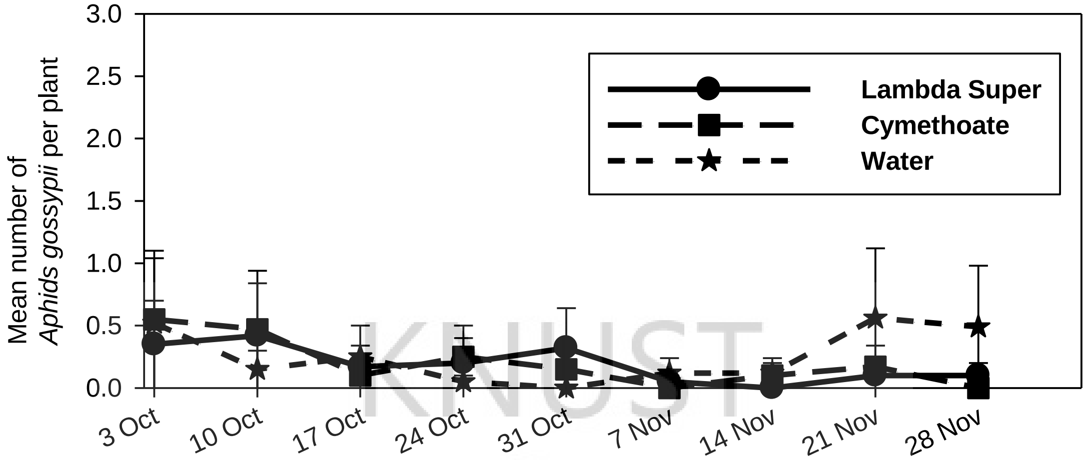

Figure 4.7: Mean number of *A. gossypii* per plant as influenced by treatments application in the first planting in the minor season in 2012

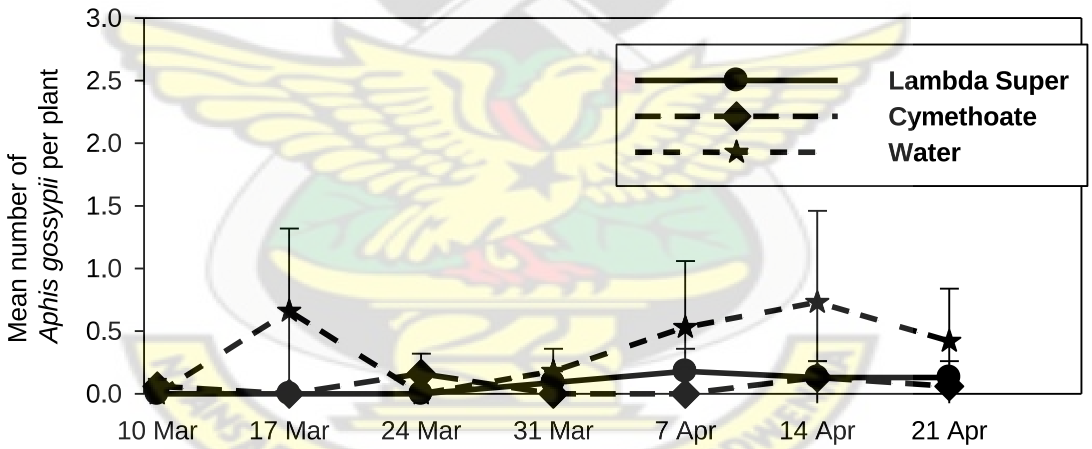

Figure 4.8: Mean number of *A. gossypii* per plant as influenced by treatments application in the second planting in 2013.

4.3.4. Tomato Fruitworm (*H. armigera*)

H. armigera numbers were very low before 2nd spray application (Figure 4.9.). The results revealed that the first application of treatments were effective in reducing *H. armigera* number. However, its densities increased after the 3rd spray application, with the control plots recording higher densities.

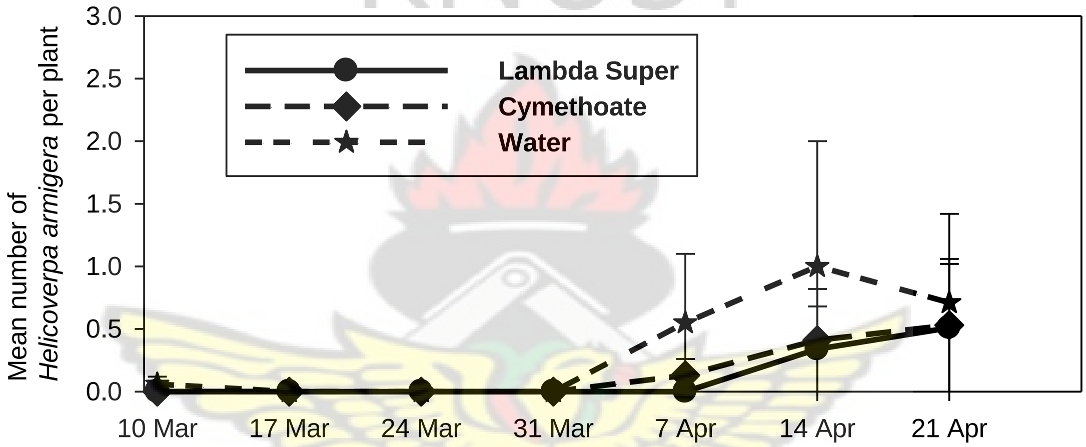

Figure 4.9: Mean number of *H. armigera* per plant as influenced by treatments application in the second planting in 2013

4.4.0. Disease Incidence and Severity in the First Planting in the Minor Season in 2012

Before application of treatments, there were significant differences (P < 0.05) between the fungicide treatments in the incidence of blight disease, with the untreated control and Shavit F treated plots recording significantly (P < 0.05) higher incidence of the disease than the plots treated with Kocide 2000 three weeks after transplanting (Table 4.7).

However, there was no significant (P > 0.05) difference in the incidence of the disease in the control and the Shavit F plots. There were differences in the severity of the disease among the treatments.

With respect to Septoria leaf spot, the Kocide 2000 treated plots recorded higher incidence than the control and the Shavit F treated plots but no significant difference (P > 0.05) was recorded between the control and the Shavit F treated plots (Table 4.7). There were no much variations in the severity of the disease among the treatments. There were no significant differences (P > 0.05) in the incidence of leaf mould between the treatments but variations were observed in the severity of the disease among the treatments (Table 4.7). For Fusarium wilt, significantly higher incidence was recorded in the control plots than the Shavit F and Kocide 2000 treated plots but there was no significant difference (P > 0.05) between the Kocide 2000 and Shavit F treated plots. Also, variations were observed among the treatments in the severity of the disease. Significantly more incidence of TYLCV was recorded in the control plots than the Kocide 2000 and Shavit F plots and severity of the disease followed a similar trend.

Five weeks after transplanting, apart from Septoria leaf spot for which significantly higher incidence was recorded in the control and Shavit F treated plots than the Kocide 2000 treatments, no significant differences (P > 0.05) were observed in the incidence of the other diseases with respect to the treatments (Table 4.8). Although the fungicides treated plots were the same as the control, apart from leaf mould and TYLCV, Kocide 2000 did better in suppressing disease incidence of blight, Septoria leaf spot and Fusarium wilt than Shavit F and the control.

Variations were however observed in the severity of the diseases with respect to the treatments (Table 4.8).

At seven weeks after transplanting, no significant differences (P > 0.05) were observed in the incidence of the diseases with respect to the treatments (Table 4.9). However, the fungicides (Shavit F and Kocide 2000), except for Leaf mould and TYLCV, did not significantly suppress the disease incidence of blight, Septoria and Fusarium wilt. Variations were however observed in the severity of the diseases with respect to the treatments (Table 4.9).

Table 4.7: Disease Incidence and Severity Scored before Fungicides Treatments Application on PO34 Tomato three weeks after transplanting in the first planting season in the minor season in 2012 in Kumasi

	% Disease Incidence / Treatment			Disease Severity / Treatment		
Disease	Control	Shavit F	Kocide 2000	Control	Shavit F	Kocide 2000
Blight	27.11 ± 2.8 [a]	15.92 ± 4.0 [a]	5.76 ± 2.1 [b]	4	3	4
Septoria leaf spot	10.04 ± 2.1 [a]	10.04 ± 4.6 [a]	13.59 ± 4.6 [a]	4	4	4
Fusarium wilt	16.0 ± 2.1 [a]	1.50 ± 0.8 [b]	0.7 ± 0.7 [b]	5	4	5
Leaf mould	10.8 ± 3.5 [a]	4.2 ± 1.7 [a]	2.5 ± 1.6 [a]	4	3	3
TYLCV	29.6 ± 1.5 [a]	9.2 ± 1.4 [b]	16.8 ± 2.5 [b]	4	3	3

Values with the same letter (s) in a row are not different significantly from one another ($P < 0.05$, Tukey Test)

1 = No disease symptom expression on tomato plant (No disease)
2 = Disease symptom expression on at least a single leaf of tomato plant to cover 1-25 % of the total leaf (ves) area (Slight infection)
3 = Disease symptom expression on leaf to cover 26-50 % of the total leaf (ves) area of tomato plant (Moderate infection)
4 = Disease symptom expression on leaf and tissues to cover 51-75 % of the total leaf (ves) area of tomato plant where at most a single fruit is assessed as yield (Severe infection)
5 = Disease symptom expression on leaf and tissues to cover 76-100 % of the total leaf (ves) area causing complete death of tomato plant to the point of no recovery or no yield attained (Very severe infection)

Table 4.8: Disease Incidence and Severity Scored after Fungicides Treatments Application on PO34 Tomato five weeks after transplanting in the First Planting Season in the Minor Season in 2012 in Kumasi

	% Disease Incidence / Treatment			Disease severity / Treatment		
Disease	Control	Shavit F	Kocide 2000	Control	Shavit F	Kocide 2000
Blight	44.7 ± 2.6 [a]	44.9 ± 9.6 [a]	33.2 ± 5.6 [a]	4	3	3
Septoria leaf spot	65.5 ± 4.4 [a]	65.5 ± 4.7 [a]	39.6 ± 7.6 [b]	5	4	4
Fusarium wilt	10.8 ± 3.5 [a]	1.7 ± 0.7 [a]	0.7 ± 0.7 [a]	5	2	2
Leaf mould	10.1 ± 3.2 [a]	2.5 ± 1.6 [a]	3.2 ± 1.4 [a]	3	2	2
TYLCV	32.4 ± 4.2 [a]	15.1 ± 2.9 [a]	31.9 ± 6.3 [a]	5	4	4

Values with the same letter (s) in a row are not different significantly from one another ($P < 0.05$, Tukey Test)

1 = No disease symptom expression on tomato plant (No disease)
2 = Disease symptom expression on at least a single leaf of tomato plant to cover 1-25 % of the total leaf (ves) area (Slight infection)
3 = Disease symptom expression on leaf to cover 26-50 % of the total leaf (ves) area of tomato plant (Moderate infection)
4 = Disease symptom expression on leaf and tissues to cover 51-75 % of the total leaf (ves) area of tomato plant where at most a single fruit is assessed as yield (Severe infection)
5 = Disease symptom expression on leaf and tissues to cover 76-100 % of the total leaf (ves) area causing complete death of tomato plant to the point of no recovery or no yield attained (Very severe infection)

Table 4.9: Disease Incidence and Severity Scored after Fungicides Treatments Application on PO34 Tomato seven weeks after transplanting in the First Planting Season in the Minor Season in 2012 in Kumasi

	% Disease Incidence / Treatment			Disease severity / Treatment		
Disease	Control	Shavit F	Kocide 2000	Control	Shavit F	Kocide 2000
Blight	63.1 ± 6.6 [a]	67.2 ± 8.9 [a]	69.1 ± 8.3 [a]	4	4	3
Septoria leaf spot	28.2 ± 3.6 [a]	42.8 ± 9.2 [a]	40.1 ± 2.6 [a]	4	3	4
Fusarium wilt	0.7 ± 0.7 [a]	2.5 ± 0.6 [a]	3.2 ± 0.8 [a]	5	3	2
Leaf mould	2.2 ± 0.7 [a]	0.0 ± 0.0 [a]	1.7 ± 1.7 [a]	3	1	2
TYLCV	38.7 ± 5.9 [a]	22.5 ± 8.7 [a]	24.8 ± 6.8 [a]	5	4	4

Values with the same letter (s) in a row are not different significantly from one another ($P > 0.05$, Tukey Test)

1 = No disease symptom expression on tomato plant (No disease)
2 = Disease symptom expression on at least a single leaf of tomato plant to cover 1-25 % of the total leaf (ves) area (Slight infection)
3 = Disease symptom expression on leaf to cover 26-50 % of the total leaf (ves) area of tomato plant (Moderate infection)
4 = Disease symptom expression on leaf and tissues to cover 51-75 % of the total leaf (sve) area of tomato plant where at most a single fruit is assessed as yield (Severe infection)
5 = Disease symptom expression on leaf and tissues to cover 76-100 % of the total leaf (ves) area causing complete death of tomato plant to the point of no recovery or no yield attained (Very severe infection)

4.4.1. Disease Incidence and Severity in the second planting in 2013

Three weeks after transplanting, no significant differences (P < 0.05) were observed in the incidence of the diseases with respect to all the treatments (Table 4.10). Kocide 2000 treated plots recorded the highest mean (28.9) followed by the control (27.5) and the least being recorded in Shavit F (24.1) in disease incidence of blight. Shavit F recorded the least (7.6) disease incidence in Septoria leaf spot, followed by Kocide 2000 (10.0) and the highest mean was recorded in the control (16.7). The control recorded the least (1.0) disease incidence in Fusarium wilt followed by Shavit F (2.3) and Kocide 2000 recorded the highest (4.3). The highest disease incidence of Leaf mould was recorded in the control (7.7) and the least (1.0) in Kocide 2000 - treated plot followed by Shavit F (4.6). Kocide 2000 recorded the highest (35.4) disease incidence in TYLCV followed by Shavit F (13.7) and the least was recorded in the control (9.0). Meanwhile, the same trend was recorded for Collar rot. Variations were however observed in the severity of the diseases with respect to the treatments (Table 4.10).

Five weeks after transplanting, apart from TYLCV for which significantly higher (24.9) incidence was recorded in the control plots than the Shavit F and Kocide 2000 treated plots, where Shavit F recorded the least (0.00) no significant differences were observed in the incidence of the other diseases with respect to the treatments (Table 4.11). Although no significant differences (P > 0.05) were observed in the incidence of the disease between these two fungicide-treated plots, Kocide 2000 recorded the least (11.4) disease incidence followed by the control in blight. With respect to Septoria leaf spot, the least disease incidence was recorded in Shavit F (10.0) followed by the control. Shavit F and Kocide 2000 recorded the disease incidence of (0.00) and the control (3.3) in Fusarium wilt. Also, (0.00) disease incidence was recorded for Shavit F and the control in Leaf mould as well as (1.0) as in Kocide 2000. Kocide 2000 however recorded the highest (11.2) disease incidence in Collar rot followed by the control and Shavit F respectively. Differences were however observed in the severity of the diseases with respect to the treatments (Table 4.11).

After seven weeks, no significant differences were observed in the incidence of the diseases with respect to the treatments. Also, variations were however observed in the severity of the diseases with respect to the treatments (Table 4.12).

Table 4.10: Disease Incidence and Severity Scored before Fungicides Treatments Application on PO34 Tomato three weeks after transplanting in the Second Planting in 2013 in Kumasi

	% Disease Incidence / Treatment			Disease Severity / Treatment		
Disease	Control	Shavit F	Kocide 2000	Control	Shavit F	Kocide 2000
Blight	27.5 ± 6.3 [a]	24.1 ± 4.8 [a]	28.9 ± 7.1 [a]	3	3	3
Septoria leaf spot	16.7 ± 3.4 [a]	7.6 ± 1.9 [a]	10.0 ± 1.7 [a]	3	2	3
Fusarium wilt	1.0 ± 0.2 [a]	2.3 ± 1.9 [a]	4.3 ± 1.7 [a]	4	3	2
Leaf mould	7.7 ± 3.3 [a]	4.6 ± 2.3 [a]	1.0 ± 0.8 [a]	3	2	2
TYLCV	9.0 ± 2.2 [a]	13.7 ± 3.7 [a]	35.4 ± 4.1 [a]	3	2	4
Collar rot	2.3 ± 1.6 [a]	10.1 ± 3.8 [a]	16.8 ± 3.2 [a]	2	5	4

Values with the same letter in a row are not different significantly from one another ($P > 0.05$, Tukey Test)

1 = No disease symptom expression on tomato plant (No disease)
2 = Disease symptom expression on at least a single leaf of tomato plant to cover 1-25 % of the total leaf (ves) area (Slight infection)
3 = Disease symptom expression on leaf to cover 26-50 % of the total leaf (ves) area of tomato plant (Moderate infection)
4 = Disease symptom expression on leaf and tissues to cover 51-75 % of the total leaf (ves) area of tomato plant where at most a single fruit is assessed as yield (Severe infection)
5 = Disease symptom expression on leaf and tissues to cover 76-100 % of the total leaf (ves) area causing complete death of tomato plant to the point of no recovery or no yield attained (Very severe infection)

Table 4.11: Disease Incidence and Severity Scored after Fungicides Treatments Application on PO34 Tomato five weeks after transplanting in the Second Planting in 2013 in Kumasi

	% Disease Incidence / Treatment			Disease Severity / Treatment		
Disease	Control	Shavit F	Kocide 2000	Control	Shavit F	Kocide 2000
Blight	14.4 ± 2.5 [a]	18.9 ± 3.4 [a]	11.4 ± 3.2 [a]	3	2	3
Septoria leaf spot	11.0 ± 2.4 [a]	10.0 ± 2.3 [a]	12.4 ± 1.8 [a]	3	3	3
Fusarium wilt	3.3 ± 0.8 [a]	0.0 ± 0.0 [a]	0.0 ± 0.0 [a]	5	1	1
Leaf mould	0.0 ± 0.0 [a]	0.0 ± 0.0 [a]	1.0 ± 0.02 [a]	1	1	2
TYLCV	24.9 ± 4.0 [a]	0.0 ± 0.0 [a]	9.0 ± 2.2 [a]	4	1	2
Collar rot	9.0 ± 3.2 [a]	9.1 ± 2.6 [a]	11.2 ± 2.1 [a]	5	2	2

Values with the same letter (s) in a row are not different significantly from one another ($P > 0.05$, Tukey Test)

1 = No disease symptom expression on tomato plant (No disease)
2 = Disease symptom expression on at least a single leaf of tomato plant to cover 1-25 % of the total leaf (ves) area (Slight infection)
3 = Disease symptom expression on leaf to cover 26-50 % of the total leaf (ves) area of tomato plant (Moderate infection)
4 = Disease symptom expression on leaf and tissues to cover 51-75 % of the total leaf (ves) area of tomato plant where at most a single fruit is assessed as yield (Severe infection)
5 = Disease symptom expression on leaf and tissues to cover 76-100 % of the total leaf (ves) area causing complete death of tomato plant to the point of no recovery or no yield attained (Very severe infection)

Table 4.12: Disease Incidence and Severity Scored after Fungicides Treatments Application on PO34 Tomato seven weeks after transplanting in the Second Planting in 2013 in Kumasi

	% Disease Incidence / Treatment			Disease Severity / Treatment		
Disease	Control	Shavit F	Kocide 2000	Control	Shavit F	Kocide 2000
Blight	31.5 ± 2.0 [a]	28.3 ± 1.0 [a]	12.5 ± 3.4 [a]	3	3	2
Septoria leaf spot	13.4 ± 1.8 [a]	17.8 ± 2.8 [a]	2.3 ± 0.6 [a]	4	3	2
Fusarium wilt	1.0 ± 0.6 [a]	3.3 ± 0.8 [a]	4.3 ± 0.8 [a]	2	3	3
Leaf mould	2.3 ± 0.3 [a]	2.3 ± 0.3 [a]	0.0 ± 0.0 [a]	3	2	1
TYLCV	21.1 ± 1.0 [a]	12.0 ± 2.9 [a]	14.3 ± 2.9 [a]	4	3	3
Collar rot	13.6 ± 5.6 [a]	18.4 ± 8.3 [a]	1.0 ± 1.0 [a]	4	3	2

Values with the same letter (s) in a row are not different significantly from one another ($P > 0.05$, Tukey Test)

1 = No disease symptom expression on tomato plant (No disease)
2 = Disease symptom expression on at least a single leaf of tomato plant to cover 1-25 % of the total leaf (ves) area (Slight infection)
3 = Disease symptom expression on leaf to cover 26-50 % of the total leaf (ves) area of tomato plant (Moderate infection)
4 = Disease symptom expression on leaf and tissues to cover 51-75 % of the total leaf (ves) area of tomato plant where at most a single fruit is assessed as yield (Severe infection)
5 = Disease symptom expression on leaf and tissues to cover 76-100 % of the total leaf (ves) area causing complete death of tomato plant to the point of no recovery or no yield attained (Very severe infection)

4.5.0. Yield of PO34 Tomato as Affected by various Treatments in 2012

No significant differences ($P > 0.05$) were observed in the number of fruits per plant, percent fruit damage, mean fruit weight per plant and yield among the control and the insecticides treated plots (Tables 4.13). Similar results were obtained in the fungicide treated plots (Table 4.14). Number of fruits ranged from 10.8 to 13.6. Percent damage fruits ranged from 30.2 to 41.9. Also, mean fruit weight ranged from 117.7 – 152.9. However, the over – all yield per treatment ranged from 6832 to 8814 (kg ha^{-1}) (Table 4.13).

Similarly, No significant differences ($P > 0.05$) were observed in the number of fruits per plant, percent fruit damage, mean fruit weight and yield among the control and the fungicides – treated plots. (Table 4.14)

4.5.1. Shoot Dry Weight

No significant differences ($P > 0.05$) were observed in the mean shoot dry weights as affected by the various treatments in the second planting in 2013. (Table 4.15). Similar results were obtained in the fungicides treated plots (Table 4.16).

Table 4.13. Yield, yield components and mean damaged fruits as Affected by Insecticides - treated PO34 Tomato in the First Planting in the Minor Season in 2012 in Kumasi

Treatment	Mean No. of fruits $plant^{-1}$ (g)	Mean % Damaged fruits	Mean Fruit weight $plant^{-1}$ (g)	Mean Yield (kg ha^{-1})
Lambda Super EC	13.6 ± 1.5 [a]	30.2 ± 6.3 [a]	152.9 ± 30.9 [a]	8814 ± 1142.5 [a]
Cymethoate	12.3 ± 0.2 [a]	33.6 ± 4.7 [a]	145.6 ± 19.9 [a]	8730 ± 209.6 [a]
Control (Water)	10.8 ± 1.0 [a]	41.9 ± 7.1 [a]	117.7 ± 14.7 [a]	6832 ± 956.6 [a]

Means with the same letter in a column are not significantly different from each other at (P > 0.05, Tukey Test)

Table 4.14. Yield, yield components and mean damaged fruits as Affected by Fungicides - treated PO34 Tomato in the First Planting in the Minor Season in 2012 in Kumasi

Treatment	Mean No of fruits plant^{-1} (g)	Mean % Damaged fruits	Mean Fruit weight plant^{-1} (g)	Mean Yield (kg ha^{-1})
Shavit F	11.0 ± 1.2 ^{a}	40.0 ± 9.5 ^{a}	123.2 ± 16.0 ^{a}	7393 ± 680.3 ^{a}
Kocide 2000	10.7 ± 0.4 ^{a}	42.1 ± 9.8 ^{a}	116.1 ± 8.4 ^{a}	6964 ± 394.4 ^{a}
Control (Water)	10.8 ± 1.0 ^{a}	41.9 ± 7.1 ^{a}	117.7 ± 14.7 ^{a}	6832 ± 956.6 ^{a}

Values with the same letter in a column are not significantly different from each other ($P > 0.05$, Tukey Test)

Table 4.15. Shoot Dry Weight as Affected by Insecticides - treated PO34 Tomato in the Second Planting in 2013 in Kumasi

Treatment	Mean shoot Dry weight (g)
Lambda Super EC	4.95 ± 0.7 [a]
Cymethoate	4.46 ± 0.8 [a]
Control (Water)	3.34 ± 0.5 [a]

Values with the same letter in a column are not significantly different from each other ($P > 0.05$, Tukey Test)

Table 4.16. Shoot Dry Weight as Affected by Fungicides - treated PO34 Tomato in the Second Planting in 2013 in Kumasi

Treatment	Mean Shoot dry weight (g)
Shavit F	4.57 ± 0.6 [a]
Kocide 2000	4.34 ± 1.1 [a]
Control (Water)	3.34 ± 0.5 [a]

Means with the same letter in a column are not significantly different from each other (P > 0.05, Tukey Test)

CHAPTER FIVE

6.0. DISCUSSION

5.1. Survey: Assessment of farmers' tomato production systems, perceptions on constraints and other related problems encountered in Agogo area.

5.1.1. Farmers' Perceptions

Results from the survey revealed that males dominate tomato production in Agogo. This may be due to the difficulties encountered in tomato production as it is labour intensive. Majority (74.3 %) of the farmers were between the age range of 31 – 50 years. This shows that most of the tomato farmers are middle-aged, which gives a message that efforts should be made to entice the youth to take up farming in order to sustain tomato production. It is also possible that because most of the farmers are illiterate, their children are leaving the farm work and migrating to the big towns and cities to seek greener pastures.

Majority of the farmers had no formal education. Poverty levels are high among farmers in Ghana and that may explain why education for the youth in farming areas is low. Due to illiteracy of most of the farmers, they find it difficult to read pesticide labels; the consequence of it being abuse and non – safe use of pesticides. It was interesting that 45.7 % of the respondents reported that the pesticides they used were ineffective and yet they continued to use them.

The ineffectiveness may be due to the lack of farmers' knowledge on the use of appropriate pesticides, the rate and the time of application.

The problem may be compounded by the fact that they applied cocktails of some of the pesticides (combination of active ingredients) which may have led to development of resistance in some insect species.

Majority of the farmers interviewed had been in tomato production for at last 10 years, and this is probably due to the fact that they consider tomato cultivation a more profitable venture than other crops. Most of them however, obtained their seed from agrochemical shops while some of them depended on their own saved – seeds. It may be because some of them cannot afford buying seeds from agrochemical shops and also believe that their own saved – seeds are more dependable.

Tomato has a long history as the most widely cultivated vegetable crop in Agogo, where farmers considered insect pest infestation and diseases as major constraints in the cultivation of tomato. As reported by the farmers, whiteflies (*B. tabaci*), crickets, Thrips (*T. tabaci*), Aphids (*A. gossypii*) and Caterpillars (*H. armigera*) were the most devastating insect pests affecting tomato in Agogo, confirming the findings of Biney (2001) who reported similar insect pests on the crop. The feeding behaviour of *H. armigera* larvae on the flower buds, flowers and fruits of tomato causes significant yield losses in cultivated host crops (Fitt, 1989; Wakil *et al*., 2010).

Diseases that were identified by tomato farmers in Agogo as major constraints to the production of tomato were Septoria leaf spot, blight, Fusarium wilt and rot. Fusarium wilt is difficult to control with pesticides because the causal agent is soil - borne. Effective fungicides to control soil borne pathogens are hard to come by and in areas where they are available, farmers cannot afford to buy because they are expensive.

Most of the pathogens are favoured by conducive weather conditions and can be difficult to control when symptoms are visible, so preventive measures are the best options to contain these diseases.

5.2.0. Experimental Field: Identification of insect pests and diseases of tomato, and evaluation of insecticides and fungicides for their management

5.2.1. Number of insect pests as affected by insecticides treatments

Pesticides are used in controlling insect pests, diseases and weeds in agriculture. They are known to increase agricultural production tremendously as these chemicals act on pests that destroy agricultural produce. However, according to Graham - Bryce (1981), the behaviour of a pesticide in the environment depends on its stability, physicochemical properties, the nature of the medium into which it is applied, the organisms present in the soil, and the prevailing climatic conditions.

From the results in experiment one in 2012, insects' population throughout the experiment were very low and this could be attributed to environmental factors which did not favour the activities of insects. Generally, the treatments did not have significant effect on some of the insects identified (Table 4.5). From Table 4.6, there were significant differences between the insecticide treatments and the control with respect to *B. tabaci*, *A. gossypii*, and *H. armigera*.

This means that the insecticides reduced the densities of some of the insects. The amount of Lambda – cyhalothrin applied in the present study was effective in reducing the numbers of *B. tabaci*, *A. gossypii*, and *H. armigera*. Mathirajan *et al*. (2000) reported that

Lambda – cyhalothrin applied at the rate of 30 g a.i ha^{-1} was more effective against shoot and fruit borer on brinjal than endosulfan and fenvalerate.

Similarly, Cymethoate (Cypermethrin + Dimethoate) applied in the present study was also effective in controlling *B. tabaci*, *A. gossypii*, and *H. armigera*.

Again, in the first experiment, both Lambda Super and Cymethoate did not significantly reduce the densities of *B. tabaci* (whiteflies), *Liriomyza* sp. (leaf miners), *A. gossypii* (aphids) and *H. armigera* (caterpillars) but in the second experiment in 2013, both insecticides significantly reduced the densities of whiteflies and aphids while Lambda Super significantly reduced the numbers of only the caterpillars. The insecticides appear not to have controlled *Liriomyza* sp. and *T. tabaci.* This could be as a result of the minimal occurrence of *T. tabaci* and *Liriomyza* sp. in the early part of the 2013 experiment. It is not clear why these differences in the effectiveness of the insecticides were obtained but, as indicated earlier, environmental factors may have played a role. This is being suggested because drier conditions were observed in the early part of 2013 when the experiment was conducted. Mailhot *et al*. (2007) found in their experiment on cotton that the effectiveness of the insecticides they used including lambda-cyhalothrin, varied across locations and years. Generally controlling some of these insects with insecticides has not been effective. Osekre *et al*. (2009) reported that controlling thrips with insecticides is difficult because of resistance to insecticides in some species and rapid recolonization of treated fields.

In their work on cotton, they reported higher numbers of adult *Frankliniella* thrips in lambda-cyhalothrin treated plots than the control plots. Similar results were recorded on other crops by Funderburk *et al*. (2002), Hansen *et al*. (2003) and Reitz *et al*. (2003).

It appears that the frequency of application of insecticides could contribute to significantly reduce the numbers of certain species of thrips. In the present study, the insecticides were applied once every two weeks and this application regime might not have been enough to significantly reduce the densities of some of the insects. Osekre *et al*. (2009) reported that they achieved control of some of the species of thrips they collected probably because they did weekly application of the insecticides. Romeis *et al*. (1999) had also 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.

The ineffectiveness of the insecticides might also be attributed to the evasive behaviour of some of the insects. Application of the insecticides in the early weeks of the experiment usually resulted in reduced densities of most of the insects collected but in the later weeks the densities of the insects began to rise again (Figures 4.4 and 4.5). As the plant grew the insects might have located more places to hide and might not have been reached by the insecticides applied. Whiteflies and Aphids, for example, were usually found on the underside of the tomato leaves and therefore become very difficult to get contact with insecticides when sprayed on the leaf.

Generally, phenological changes in the growth of the tomato plant in space and time have impact on the distribution of the insects as they are presented with more hiding places and difficult to reach by pesticides. Toapanta *et al*. (1996) noted that thrips aggregate and feed on leaves in the initial stage of the plant growth but shift to aggregate in the flowers when blooming begins; it is more difficult to reach them with pesticides when they aggregate in the flowers. The ineffectiveness of the insecticides used in this study seems to confirm what some of the tomato farmers indicated in the survey done as part of this study in respect of the effectiveness of the insecticides (Table 4.2).

5.2.2. Disease Incidence and Severity as Affected by Fungicides - treated plots on Tomato

Initially, disease incidence was low in the experimental plots before treatments application. However, there were significant differences among the treatments (Table 4.7). In Table 4.8, Shavit F and Kocide 2000 however, were not significantly different from the control in suppressing disease incidence except for Septoria leaf spot treated with Kocide 2000 that showed difference five weeks after transplanting. Shavit F and Kocide 2000 were ineffective in suppressing disease incidence even up to the seventh week after transplanting in the first planting in 2012. Similar results were observed in the second planting in 2013 with respect to the treatments.

Some infection of fungal diseases starts from the nursery as they are soil – borne. This could account for the ineffectiveness of Shavit F and Kocide 2000 to suppress the infection since the infection might have developed already before the treatments were applied.
The disease severity for three and five weeks after transplanting appeared to have reached a level that probably could affect yield that was why yield appeared not to have been increased in the fungicide treated plots. Shavit F and Kocide 2000 at seven weeks after transplanting did not suppress disease incidence in the fungicide treated plots.

5.2.3 Effect of the Insecticides and Fungicides Treatments on Tomato Yield

The insecticide and fungicide treatments did not significantly increase the yield of tomato. The treatments did not significant increase the number of fruits produced per plant, fruit weight, the yield and number of damaged fruits. The reasons for these are unclear but it may probably be due to the fact that the insecticide treatments did not consistently reduce the numbers of most of the insects whilst the fungicides too did not significantly suppress the incidence and severity of the diseases on the crop. Osekre *et al*. (2009) reported that the application of Lambda-cyhalothrin reduced thrips population and subsequently the yield of cotton was also increased significantly but the fungicide (Topsin) (Thiophanate-methyl a.i) treated plots recorded no significant increase in yield compared to the control. Similar results were reported by Mailhot *et al*. (2007). Disease incidence has a relationship with severity and the two impact yield in a negative way. Severity explains the point whether there would be a recovery or no recovery of the plant affected. From the findings of this study, Kocide 2000 and Shavit F appeared not to have significantly reduced incidence and severity of the disease for subsequent increase in yield.

CHAPTER SIX

6.0. CONCLUSION AND RECOMMENDATION

6.1. Conclusion

Majority (74.3 %) of the farmers were between the age range of 31 – 50 years (young adults) and most of them had no formal education. Most of them obtained their seeds from agrochemical shops while some of them depended on their own saved – seeds. The survey revealed that whiteflies (*Bemisia tabaci*), Crickets, Thrips (*Thrips tabaci*), Aphids (*Aphis gossypii*), and Tomato fruitworm (*Helicoverpa armigera*) were the most important insect pests that attack tomato in the area. Septoria leaf spot, blight, Fusarium wilt and rot were identified by farmers in Agogo as major diseases of economic importance in tomato production. About 45.7 % of the farmers reported that pesticides were not effective whereas 48.6 % of them said that they were effective.

The field study showed that *B. tabaci*, *T. tabaci*, *H. armigera*, *Liriomyza* sp., and *A. gossypii* were the most important insect pests that attack tomato in the study area (Kumasi). Similarly, Septoria leaf spot, Fusarium wilt, Leaf mould, Collar rot and Tomato Yellow Leaf Curl Virus (TYLCV) disease were the most important diseases that attack tomato in the study area (Kumasi).

Lambda Super and Cymethoate significantly reduced the densities of *B. tabaci*, *A. gossypii* and *H. armigera*. Insecticides treatments did not significantly increase yield.

Significant difference ($P < 0.05$) was observed between Kocide 2000 and the control with respect to Septoria leaf spot five weeks after transplanting in the experiment in 2012, but Shavit F was not different from the control. No significant difference was observed among the fungicides treated – plots in the experiment in 2013. Fungicide treatments also did not significantly increase yield.

In areas where these insects are predominant, farmers should not rely on Lambda and Cymethoate for their control. Farmers can however do weekly applications of these insecticides if they are the only ones available.

6.2. Recommendation

- It is therefore recommended that, due to the difficulty in controlling some fungal diseases when symptoms are visible, control measures should be taken as early as possible to prevent disease colonization.
- Further work can be done to evaluate weekly applications of the pesticides used.

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APPENDICES

Appendix I. **Survey: Assessment of Farmers' Tomato Production Systems, Perceptions on Constraints and other Related Problems Encountered in Agogo Ashanti Region**

Sample size: **about 35 farmers**

Farmer's name: ______________________ Sex: _____ Age: ____ No. of children: ____
Farm size: ____

Questionnaires

1. How long have you been cultivating tomato?
2. What is your source of planting materials?
3. What are the varieties used?
4. What are the problems you encountered during cultivation?
5. Do you have insect pest problems?
6. What are the insects and how do they cause damage to the plants?
7. What method do you use to control the insect pests?
8. What are the insecticides used?
9. What are some diseases that attack your crop and how do they affect the plants?
10. What chemicals do you use to control the diseases?
11. Where do you purchase the chemicals?
12. What are the names of the chemicals/fungicides used?
13. What are the chemicals (insecticides and fungicides) used previously and now?

14. What are the problems with the chemicals (previous & recent)?

15. What is the yield per hectare of your crop at the end of the growing season?

16. Education: Informal …… Primary ……. Secondary …… Tertiary ……

Appendix II. 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 ( )