IMPACT OF DIFFERENT LEVELS OF NITROGEN IN LIQUID FERTILIZER (SIDALCO) ON THE POPULATION DYNAMICS AND WITHIN PLANT DISTRIBUTION OF *Aphis gossypii* AND *Thrips palmi* AND YIELD OF EGGPLANT

BY

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NOVEMBER, 2013

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

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SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF CROP AND SOIL SCIENCES

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A THESIS SUBMITTED TO THE DEPARTMENT OF CROP AND SOIL SCIENCES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI - GHANA, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE CROP PROTECTION (ENTOMOLOGY)

NOVEMBER, 2013

DECLARATION

I, Foster Appiah Baah, hereby declare that, except for other people's work which have been duly acknowledged, this thesis is as a result of my own effort and it has neither in part nor in whole been submitted elsewhere for the award of a degree

FOSTER APPIAH BAAH ……………………….. …………………………

PG 4239210 Signature Date

Student

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Supervisor Signature Date

Certified by

DR. CHARLES KWOSEH ……………………….. …………………………

Head of Department Signature Date

DEDICATION

This dissertation is dedicated to the Omnipresent God, who knew me and my assignment even before I was conceived.

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I am not certain I can ever say how much I owe my wife, Mrs. D. Appiah Baah. For now I hope it is enough to say thank you. Your love, encouragement, financial support and unflinching support have bought me this far. God richly bless you.

Jehovah God into your hands I finally commit this research work, may your name be glorified.

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ABSTRACT

Increased use of Sidalco liquid fertilizer by vegetable farmers has attracted the attention of researchers. However, very little literature on the impact of this fertilizer on the aggregation patterns of some common but important insect pests of these crops is available, necessitating this work. The objective of the study was to evaluate the impact of different levels of Nitrogen in liquid fertilizer (Sidalco NPK) on the population dynamics and within plant distribution of *Aphis gossypii* (Glover) (Hemiptera: Aphididae) and *Thrips palmi* Karny (Thysanoptera: Thripidae) in eggplant (*Solanum melongena* L). The research was conducted in both the major (April - July) and minor seasons (August - October) of 2011 at the Plantation section of the Department of Crop and Sciences, Kwame Nkrumah University of Science and Technology, Kumasi. Eggplant variety (Oforiwaa), was used for this study and the treatments were; (i) Sidalco liquid fertilizer (NPK 10:10:10) + 1 % sulphate of ammonia solution, and (ii) Sidalco liquid fertilizer (NPK 10:10:10) + 0.5 % sulphate of ammonia solution and (iii) Sidalco liquid fertilizer (NPK 10:10:10) and these were applied directly on leaves, weekly for eight weeks. An untreated control was also maintained. Generally, even though low densities of both insects were collected in both seasons, a higher number of *A. gossypii* was collected in the major season than in the minor season whilst *T. palmi* population was higher in the minor season than in the major season. Significantly ($P < 0.05$) more *A. gossypii* aggregated in the lower canopy than in the upper canopy in both major and minor seasons. Similarly more *T. palmi* was collected in the upper canopy than the lower canopy in both the major and minor seasons. Furthermore, plots with the highest doses of N recorded the highest number of *A. gossypii* and *T. palmi* in both seasons. The respective densities of each of the two insects also correlated positively with the density of ladybird beetles. The plots with the highest doses of N recorded the highest yield in both seasons despite the increased aphids and thrips population.

CHAPTER ONE

1.0 INTRODUCTION

The eggplant (*Solanum melongena* L.) is a tropical and subtropical plant belonging to the family Solanaceae, which grows in high temperatures and can produce up to 15 kg of fruits per plant (Filgueira, 2000). Though often egg shaped, there are many varieties which come in shapes ranging from round, flat, to fusiform. They could also come in various colours, ranging from pink, white, yellow, lavender, black or navy blue, stripped or unstripped. They taste from bland to sweet or slightly bitter, and is used in preparation of stews (Filgueira, 2000).

The nutritional qualities of eggplant are not as good as those of tomato; the edible part of the fruit represents around 96 % of the total weight. It contains per 100 g, 92 g water, 1.6 g protein, 7.7 g carbohydrates (including 1 g cellulose), 22 mg calcium, 0.9 mg iron, 0.08 mg thiamine, 0.07 mg riboflavin, 0.7 mg niacin and 6 mg carbon. The energy value of eggplant is 108 kl (26 k cal)/100 g (Norman, 1992).

Eggplant cultivation in Ghana is done in many ecological zones by subsistence farmers. Mono-cropping is practiced in commercial farms but peasant farmers may intercrop it with pepper, okra and other crops. The crop may also be found in backyard gardens either monocropped or intercropped. Produce from backyard gardens is largely for home consumption.

Almost every household in Ghana consumes eggplant fruit (garden egg) in the form of soup or stew daily. It is the boiled fruit which is used in the preparation of soup or stew.

The importance of cultivating vegetables has extensively increased year after year, due to their economic value. However, most of these agricultural crops are subjected to attack by many piercing and sucking insect pests such as aphids, whiteflies and thrips (El-Khawas, 2005). Absorption of nutrients by plants is not a function limited to the root system. Foliar nutrition is ideally designed to provide many elements to a crop that may be limiting production at a time when nutrient uptake from the soil is inefficient or nonexistent (Hiller, 1995).

Several studies have been done on fertilizer supply through the leaves and on viable fertilization alternatives on a number of nutrients like potassium (Weir, 1998), boron (Shaaban *et al*., 2006), phosphorus (Ekelof, 2007) and silicon (Buck *et al*., 2008) using lower amounts that would provide the needed nutrient or else stimulate its beneficial effects (Elwan, 2010). These studies emphasize the emerging importance of foliar fertilizers in the face of certain problems associated with excessive use of fertilizers applied to the soil. Certainly the seeming advantages of the use of foliar fertilizers such as the smaller fertilizer use (since foliar fertilization consists of supplying small amounts of nutrients directed to the leaves), lower cost, ease of application, good quality of fertilizers used and fertilizers readily soluble in water (Buck *et al*., 2008) should be explored. It appears extensive use of foliar fertilizers would take centre stage in Agriculture sooner than later.

The behavioural variations in insects on different host plants emphasize the need to study the population dynamics of thrips and aphids on various crops to help determine how host plant architecture and plant phenology as affected by liquid N application impact the within-plant distribution of aphids and thrips.

Additionally, quantifying the within-plant distribution of thrips is important for the development of reliable and cost effective sampling protocols (Atakan *et al*., 1996), and would allow accurate estimation of the abundance and subsequent control of thrips in the crop (Osekre *et al*., 2007).

Several researchers have worked on population of aphids and thrips on some crops. However, the distribution of these pests within eggplant and seasonal fluctuation of their numbers as affected by liquid fertilizer is yet to be investigated. It is against this background that this research was carried out with the objective to determine the effect of different levels of N in liquid fertilizer (Sidalco) on the aggregation and distribution of *Aphis gossypii* (Glover) and *Thrips palmi* Karny within eggplant.

The specific objectives of this research were to determine the impact of different levels of N liquid fertilizer (Sidalco) on the;

I. population dynamics of *A. gossypii* and *T. palmi* on eggplant
II. distribution of the insects within eggplant
III. distribution of the ladybird beetles (a generalist predator) in eggplant
IV. yield of eggplant

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 History and origin of eggplant

Eggplant (*S. melongena*), also called garden eggs or aubergine or guinea squash, originated from India and was introduced into southern Europe in the middle ages by the Arabs and then distributed in Africa by the Persians. Its cultivation in the Northern Sahara dates back more than 500 years. The terms eggplant and aubergine are common in Europe and United States. The word garden egg is used only in West Africa, where it is used in the preparation of certain traditional dishes. In South and South East Asia, it is termed 'brinjil' (Raemaekers, 2001).

2.2 Structure and botany of eggplant

S. melongena is a perennial woody herb which attains a height of about 1.5 m. It is usually grown as an annual. It has vigorous tap root with extensively branched root system that may extend to a depth of 75 - 90 cm in the soil. The stem is hairy and occasionally spiny. The leaves are alternate, simple, oval and hairy with lobed margins. The lamina is 7 to 25 cm long and 5 to 15 cm wide. The length of the petiole ranges between 2 to 10 cm (Tindall, 1983).

Eggplant is unaffected by photoperiod. It is autogamous but a fairly high percentage of cross-pollination may occur (0-48 %), depending on insect activity. The large purplish flowers are hermaphroditic. They appear in the axils of the leaves. The fruit is a berry without cavity and has a spiny or smooth calyx at the proximal end. Eggplant comes in a wide variety of forms of fruit (round, ovoid, pear-shaped or elongated) and colours (white, mauve, streaked violet or uniform) (Raemaekers, 2001).

The green or white mesocarp (flesh) contains small seeds (150 - 300) which represent around 0.8- 4 % of total weight of fruits. If stored under favourable conditions, the seeds retain viability for about four years (Raemaekers, 2001).

2.3 Climate and growth requirements of eggplant

Eggplant grows best in regions below 800 m in altitude where the temperature remains relatively high throughout the entire cycle. It requires much more heat than tomato or hot pepper. Optimum growth is obtianed when the temperature is between 25 ^{o}C and 35 ^{o}C in the daytime and 20 ^{o}C – 27 ^{o}C during the night. The plant is also well suited to humid tropical climate. A well drained fertile soil rich in organic matter with pH between 5.5 and 6.8 is desirable for good production. For early cultivars, a sandy loam soil is preferable. For local garden egg types, clay loams are ideal (Raemaekers, 2001).

2.3.1 Eggplant production in the world

Eggplant is well regarded among the vegetables increasingly sought by consumers, whose demand for food with potential health promoting effects, such as disease prevention, is escalating. It is said that eggplant fruits associate good nutritional value (Ribeiro *et al*., 1998) and therapeutic properties (Reis *et al*., 2007).

The area in Brazil occupied with eggplant crops ranges from 1,300 to 1,500 ha (Antonini *et al*., 2002; Reis *et al*., 2007). The largest cultivated areas are located in the States of São Paulo, Rio de Janeiro, and Paraná (Filgueira, 2003).

According to FAO in 2010, production of eggplant is highly concentrated, with 90 % of output coming from five countries**.** China is the top producer (58.55 % of world output) and India is second (25.24 %), followed by Egypt, Iran and Turkey. More than 4,000,000 acres (1,600,000 ha) are devoted to the cultivation of eggplant in the world (FAO, 2010).

2.3.2 Eggplant production in Ghana

Both local and exotic varieties of eggplant are grown in Ghana mainly for local consumption. Eggplant is cultivated mainly in the forest, derived and coastal savanna zones in Ghana (Norman, 1992). Commercial production is centred mainly in Brong-Ahafo, Ashanti, Central, Volta, Eastern and Greater Accra regions of Ghana.

Some specific areas of commercial production include Amantin, Atebubu and Techere in Brong-Ahafo region, Ejura and Akumadan in Ashanti region, Mankesim and Swedru in Central region, Ada, Sege and Dodowa in Greater Accra region and Asesewa in the Eastern region. Exotic varieties are however, produced in backyard gardens as well as market gardens by peri-urban market gardeners mainly for expatriate market (Tweneboah, 1998).

2.4 Insect pests of eggplant

Like many other economic crops, eggplant suffers from serious losses due to damage caused by various species of insects. The leaves, stem, fruits and roots are all attacked (Frempong, 1973). The crop is attacked by a number of insect pests at various stages of the plant development.

These insect pests include; *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae)**,** *Spodoptera exigua* (Hübner) (Lepidoptera: Noctuidae), *Leucinodes orbonalis* F (Lepidoptera: Pyraustidae), *Scapteriscus abbreviates* Scudder (Orthopthera: Gryllotalpidae), *Zonocerus variegatus* L. (Orthoptera: Pyrgomorphidae), *Aphis gossypii* (Glover) (Hemiptera: Aphididae) and *Thrips palmi* Karny (Thysanoptera: Thripidae).

2.4.1 Aphids and Thrips pests of eggplant

Among important pests of this crop are *Aphis gossypii* (Glover) (Hemiptera: Aphididae) and the *Thrips palmi* Karny (Thysanoptera: Thripidae) (Etienne *et al*., 1990; Hosoda *et al*., 1993).

A. gossypii, normally appears at the end of the season when growers are not actively spraying. They feed by injecting their sharp, hollow mouthparts into plant tissue, and sucking out phloem exudate. Female aphids reproduce asexually, giving birth to live young that develop rapidly. Undisturbed, adults remain sedentary, continuing to give birth to more asexually reproducing adults. It is one of the most widespread species of aphids, and displays a large range of host-plants, covering very different families. This impressive behaviour made it a major pest of numerous crops (Fuchsberg *et al.*, 2007). Like other soft bodied insects such as leafhoppers, mealybugs, and soft scales, aphids produce honeydew. Copious amounts of honeydew, sweet and watery excrement, may be produced. Honeydew serves as a medium on which sooty mould grows. Sooty mould blackens the leaf and decreases photosynthetic activity (Elmer and Brawner, 1975). Gomez *et al*. (2006) reported that damage by aphids is due to consumption of phloem sap, and then the excretion of honeydew, which composed of large amounts of carbohydrates that are lost from aphid-infested plants and covers the leaves.

Photosynthesis reduction may be due to unbalanced chlorophyll biosynthesis (as result of alteration in mineral nutrition and degradation as result of degradative enzymes) (Wang *et al.*, 2004). On the other hand, carotenoids showed a significant increase as a protective agent, playing an essential role in resistance to aphids (Leszcynski *et al.*, 1989). Aphid attack causes severe damage to eggplant by feeding on sap, rolling leaves, and secreting honeydew (Hosoda *et al*., 1993; Gallo *et al*., 2002). Aphids are found in groups on the under- surface of young leaves.

When numbers increase they can move to upper leaf surfaces, stems and flowers. Aphids, in particular the cotton aphid, can become important pests in the cool dry season (Hosoda *et al*., 1993).

Eggplants when severely attacked by thrips present leaves with silvery appearance and deformed fruits. Thrips attack eggplant mostly during the dry season. They cause browning of leaves, especially on the lower leaf surface. In severe cases, the entire leaf dries.

Thrips feeding on fruits causes scarring, irregular discoloration and deformation, which reduce the market value of fruits (Gallo *et al*., 2002). A moderate to serious cotton aphid infestation generally results in mild to severe crinkling and cupping of leaves, often significantly inhibiting leaf development. Even mild to moderate damage can cause reduction in plant vigour with loss of yield. In severe cases aphid infestations can cause stunted plants and shedding of leaves and fruits.

2.4.2 Biology and damage of *A. gossypii*

Aphis gossypii are polymorphic with considerable variation in both size and colour (Rosenheim *et al*., 1995). It has a very complex and variable life cycle. Usually the larval development of aphids is a rapid process (Minks and Harrewijn, 1989).

During ideal conditions this process can take as little as three days. In the southern plains and throughout the cotton belt the aphid population is primarily composed of females with relatively few males (Slosser *et al*., 1989). Female cotton aphids reproduce asexually through parthenogenesis (Minks and Harrewijn, 1989). In the northern portions of the United States, the cotton aphid is holocyclic, reproducing sexually and laying eggs (Slosser *et al*., 1989). The aphid can display sexual and parthenogenetic forms, polymorphism, hibernation and aestivation, winged and wingless forms, migrant and non-migrant forms, and often display all forms in one annual cycle (Kring, 1959).

At what was determined to be the optimal temperature of 27.5 ^{o}C, aphids reached maturity in five days (Ebert and Cartwright, 1997). Drees (1999) reported that the reproductive period of cotton aphids was approximately three weeks and the average life span of an adult cotton aphid was approximately one month. Female cotton aphids have the capability of producing 85 offspring in a lifetime (Slosser *et al.*, 1989; Drees, 1999; Freeman and Smith, 1999).

At this reproduction level, an average number of 2.85 larvae per day would be produced (Akey and Butler, 1989). In most cases aphids, have four larval instars (Minks and Harrewijn, 1989). These instars last from a few hours to several days (Minks and Harrewijn, 1989). When the stadium for each instar is complete, the aphid will moult, shedding its exoskeleton and increasing its size (Borror *et al.*, 1989). The first three instars are generally around the same length of time, with the fourth lasting slightly longer (Minks and Harrewijn, 1989). Aphid becomes an adult after the fourth moult. After this moult the pre-reproductive adult may take as long as three days to begin reproduction (Minks and Harrewijn, 1989).

Both adult and the larvae of the cotton aphids have stylet mouthparts which they use to suck the fluids out of individual cells of host plants (Auclair, 1963). Aphids have a specialized digestive system which allows the insect to filter out unwanted liquids, digest only necessary amino acids and sugars, and excrete unwanted substances as sticky liquid called honeydew (Chapman, 1982). This system allows the aphids to ingest up to 133 % of their body weight in one hour (Slosser *et al*., 1989). The honeydew falls to the tops of leaves and, in the case of late season aphid infestations, onto open bolls underneath the feeding aphids. Cotton aphid honeydew contamination causes significant problems in lint processing at the gin and the textile mill (Slosser *et al.*, 1989; Ebert and Cartwright, 1997). Honeydew also creates a habitat for a black fungus known as "sooty mould" that develops on the plant. Aphid honeydew during the growing season may results in the inhibition of photosynthesis and can cause reduced yield and fibre quality.

Cotton aphids prefer to feed on younger stems, fruit, and leaves (Freeman and Smith, 1999). The underside of newer leaves hosts the highest population of aphids. When aphid overcrowding occurs, some aphids may be found on the upper surface of the leaves. The cotton aphid can be a serious pest of cotton, often developing into large populations of up to several hundreds per leaf.

2.4.3 Biology and damage of *T. palmi*

The life stages of Thrips include an egg, larva I, larva II, pupa I, pupa II, and adult. Developmental times at optimal temperatures of eggs, larvae, and pupae are about 6, 5, and 5 days, respectively, for each species (Reitz, 2008; Tsai *et al*., 1996). The adults of all species feed on flower tissues and pollen. Pollen feeding greatly increases the number of eggs produced. Development of Thrips is slower at cool temperatures.

The minimum temperature required is about 10^{o} C. About 30 to 40 days are necessary for a complete generation during the winter in northern Florida (Toapanta *et al*., 1996, 2001). Generations develop more rapidly as the temperatures increase in the spring, and populations become very abundant in the near absence of natural enemies in the early spring in northern Florida (Northfield *et al*., 2008). Population numbers decline greatly in summer and fall as natural enemies become important factors affecting their abundance. Plant species that serve as reproductive hosts vary with each individual species of thrips (Paini *et al*., 2007, Northfield *et al*., 2008). Adults also commonly feed in the flowers of plants that are not reproductive hosts. Eggplants when severely attacked by thrips present leaves with small size and silver appearance and deformed fruits. Adults of eastern flower thrips, Florida flower thrips, western flower thrips and melon thrips aggregate in flowers, while larvae of these species are found in flowers and on fruits (Hansen *et al*., 2003). Thrips attack eggplant mostly during the dry season. They cause browning of leaves, especially on the lower leaf surface. In severe cases, the entire leaf dries. Thrips feeding on fruits causes scarring, irregular discoloration and deformation, which reduce the market value of fruits (Gallo *et al.*, 2002).

2.4.4 Natural Enemies of *A. gossypii* and *T. palmi*

Aphids have a number of natural enemies, including ladybird beetles, aphid lions, hover flies, and parasitic wasps. If foliar sprays are needed to manage aphids, thorough coverage of all the plant surfaces is essential, as aphids tend to prefer the underside of leaves.

Many kinds of predaceous arthropod groups help to suppress thrips populations. Minute pirate bugs (Family Anthocoridae) are the most important predators of thrips (Funderburk *et al.*, 2000). Species of anthocorids occur nearly worldwide. Hulshof *et al.* (2003) noted that biological control of thrips is not easily achieved, and its success depends on the crop.

The species *Orius insidiosus* (Say) occurs throughout eastern North America, Central America and the Caribbean, and South America. *Orius pumilio* (Champion) also occurs with *O. insidiosus* (Say) in central and southern Florida (Shapiro *et al.*, 2009). Other thrips predators include big-eyed bugs (Family Lygaeidae), damsel bugs (Family Nabidae), lacewings (Family Chrysopidae), predatory thrips (primarily in the family Aeolothripidae), and predatory mites (Family Phytoseiidae).

2.5 Effect of fertilization on plant growth

Fertilizers are a major input for increased agricultural productivity. For instance, N fertilization increases aphid infestation on winter wheat. N is an essential plant nutrient.

It is the nutrient that is most commonly deficient in soils, contributing to reduce crop yields throughout the world (Van and Hartley, 2000).

Chemical fertilizers are compounds given to plants to promote growth, and are usually applied either through the soil for uptake by plants, or by foliar feeding, for uptake through leaves.

One of the ways of increasing the nutrient status is by boosting the soil nutrient content either using organic materials such as poultry manure, animal waste, compost or inorganic fertilizers (Dauda *et al*., 2005). Fertilizers in general are one of the major inputs for increased agricultural productivity.

The application of nitrate as soil amendment offers crop plant the leverage to produce foliage with large surface area. N in the soil is absorbed by the plant in the form of nitrate and ammonium ions, and is used by plants to synthesize amino acids, proteins and other complex nitrogenous compounds like chlorophyll.

Adequate supply of N is associated with high photosynthetic activity, vigorous vegetative growth and a dark green colour of the leaves (John *et al*., 2004). Agronomically, the most cardinal reason, for applying nitrates to soil is to increase leaf area which invariably increases sunlight interception for a higher rate of photosynthesis (Varela and Seif, 2004).

Nitrogen is important for plant growth partly due to its influence on leaf area index and consequently light interception (Jones 1992; Grindlay, 1997). The main effect of N fertilization is an increase in leaf area index leading to increased light interception and dry matter production in crops such as eggplant (*Solanum melongena* L.) (Rosati *et al*., 2001), lettuce (*Lactuca sativa* L. ‘Vegas’) and lucerne (*Medicago sativa* L.) (Lemaire *et al*., 2005).

In lucerne, a linear relationship has been shown between shoot N content and leaf area irrespective of the growing conditions (Lemaire *et al*., 2005).

Lawlor (2002) and Ulukan (2008) have underscored the importance of N for vegetative growth in plants. Leaf growth is substantially affected by N and the response is more pronounced under increasing N supply when N is limiting (Lawlor, 2002).

Leaf N concentration is an important physiological parameter that indicates the plant N status. This could be measured through N content on a dry weight basis or on a leaf area basis. A good correlation has been shown between chlorophyll content and leaf N.

Demotes-Mainard *et al*. (2008) have shown that the leaf N content correlates well with the leaf chlorophyll content, hence a low leaf N content as occurs during N deficiency leads to reduced photosynthesis resulting in lower biomass accumulation (Zhao *et al*., 2005).

Zhang *et al*. (2007) found that applying the equivalent of 5 g N/plant to maize in soil with about 0.096 % total N increased mature dry matter weight by 9 – 26 % compared to plants that received no N depending on variety and soil moisture. Liptay and Nicholls (1993) found that tomato seedlings grown with high N levels had enhanced root growth after transplanting.

2.5.1 Effect of fertilization on insect pests population

There is some evidence that application of synthetic fertilizers reduce the resistance of crop plant to insect pest, hence the application of N fertilizer significantly increases the incidence of pests and diseases (Yardim and Edwards, 2003). The form of these inputs can influence pest populations in various agro-ecosystems, depending on the kind of fertilizers used, the crops grown, and the insect pests present. However, excessive nutrient application can also lead to pest problems by increasing the reproduction, longevity and overall fitness of certain pests (Jahn, 2004).

Extensive use of inorganic fertilizer has a depressing effect on yield, reducing number of fruits, and also delaying and reducing fruit setting which subsequently delays ripening and leads to heavy vegetative growth (Aliju *et al*., 1992).

2.5.2 Effect of N on insect pests population

N may influence semio-chemicals and nutritional values of plants and also behavioural characteristics of the herbivores (Herms, 2002; Hunt *et al*., 1992). In host plants the N content is generally considered as an indicator of food quality and affecting host selection by herbivores (Jansson and Smilowitz, 1986).

It has been noted that a high rate of N fertilizer significantly increased the number of egg masses deposited by Asian corn borer, *Ostrinia furnacalis* (Guenee), on maize leaves (Kalule and Wright, 2002). N was found to modify the plant nutrition and reduce the resistance against aphids in cotton (Kasyab and Batra, 1987) and Coleopterans and Lepidopterans in tomato (Eigenbrode and Pimentel, 1988).

The protein content of the leaves linearly increased with the increase in the level of N applied to plants and the number of eggs of *Bemisia argentifolii* (Gennadius) on Poinsettias. (Bentz *et al*., 1995). Herbivorous fly when exposed to crop plant with N content preferred to feed and oviposit on high plants, whereas flies exposed to plants with low N content showed no preference (Phelan *et al*., 1995).

Adequate supply of N is associated with high photosynthetic activity, vigorous vegetative growth and a dark green colour of the leaves (John *et al*., 2004). However, N is partitioned in the crop in the form of phenols and amino acids (protein), making the foliage extremely succulent and therefore becoming susceptible to both diseases and pests incidence

(Youdeowei, 2002). It is hypothesized that increases in N levels in plants can enhance populations of host invertebrate herbivores (Patriquin *et al*., 1988; White, 1984).

Such increases in populations of insect pests on their host-plants in response to higher N levels can result from various mechanisms, depending on the insect species and host plants. For instance, some changes in N content in Poinsettias grown with ammonium nitrate stimulated the fecundity of the whitefly *Bemisia tabaci* (Gennadius) and attracted more individuals to oviposit on them (Bentz *et al*., 1995). The substances known to influence pest activity include sugars, enzymes, phenols and alkaloids (Palaniapan and Annadurai, 1999).

When nutrients are made available to crop plants in the required quantities, they aid in the formation of these substances that impart resistances/tolerance to insect pests. N fertilization may decrease plant resistance to insect pests by improving the nutritional quality of host plants and reducing the secondary metabolite concentrations (Herms, 2002).

Barbour *et al*. (1991), investigating interactions between fertilizer regimes and host-plants resistance in tomatoes, showed that the survival of Colorado potato beetles to adult emergence increased with larger amounts of fertilizer, and was related to decreases in trichome and lamellar-based beetle resistance, in response to the improved nutritional quality of the host plant.

In addition to increases in the survival rates of Colorado potato beetles from the first instar to adults in tomatoes receiving large amounts of the element, N could also cause significantly faster insect development and increased pupa biomass (Hunt *et al*., 1992).

Several authors have mentioned that high N levels were associated with aphids and thrips infestations on lettuce, tomato and cotton (Kennedy, 1958; Brodbeck *et al*., 2001; Cisneros and Godfrey, 2001; Nevo and Coll, 2001).

An excess of N can lead to higher accumulations of amino acid which in turn can cause higher attack rates by sucking insects (Jansson and Smilowitz, 1986).

According to Marschner (1995), excess of N and deficiency of K can increase the accumulation of amino acids, allowing the increase in sucking insect population on plants.

2.6 Effect of plant density on insect pests

The effect of plant density on insect pest abundance is varied and complex. Dense planting change crop growth, development, and microclimate which impact on insect pests and their natural enemies (Litsinger and Ruhendi, 1984). Dense planting in rice farming for example, increases population of planthoppers, leaf folders, and leafhoppers while root aphids, root weevils and leaf beetles may become less abundant. Sparse planting encourages weed growth which indirectly has effect on insect pests' abundance (Litsinger and Ruhendi, 1984).

2.7 Population dynamics of Aphids and Thrips in response to N application

Understanding the population dynamics of a crop pest is of fundamental importance to the management of crop infestations. It was reported that N applications increased the rate of population growth of green peach aphid on potatoes and the growth was positively correlated with the concentrations of amino acids in the leaves (Jansson and Smilowitz, 1986).

Over-fertilization above recommended rates of N in an attempt to optimize production results in an increase in the numbers of all species of thrips and an increased incidence of tomato spotted wilt virus (Baez *et al*., 2011). This is due to an increased level of aromatic amino acids in over-fertilized plants that attract western flower thrips and increase their rate of reproduction. Although little is known of the nutritional ecology of thrips, Brodbeck *et al*. (2001) manipulated nitrogen content of plants through fertilization, and found that the peak abundance of *F. occidentalis* adults in tomato flowers is positively correlated with the concentration of the primary aromatic amino acid, phenylalanine, in the flowers.

This correlation was most pronounced for females. Higher rates of nitrogen fertilization also result in higher populations of *F. occidentalis* in chrysanthemums (Schuch *et al*., 1998).

This phenomenon may be critically important to the management of thrips because southeastern America tomato growers frequently apply unnecessarily high rates of nitrogen fertilizer to tomato crops (Castro *et al*., 1993), which may then induce higher populations of serious pests.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Site and Location

The research was carried out at the Department of Crop and Soil Sciences' experimental site (Plantation) of the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana. The area lies at altitude 261.4 MSL, Latitude 06 ^{o} 41'N and Longitude 01 ^{o} 33' W, (Ghana Meteorological Service, 2011). The duration of the experiment was April to October, 2011.

3.2 Climatic conditions of study site

The area lies within semi-deciduous forest zone with bimodal rainfall. The major season spans from April-July and the minor season from August-October. The mean highest and lowest monthly temperatures for the area are 33.3 and 21.7 ^{o}C, respectfully. The mean highest and lowest monthly rainfalls are 241.6 and 71.5 mm, respectively (Ghana Meteorological Service, 2011).

3.3 Preparation of Experimental Field

The experimental plot was slashed, ploughed and harrowed to a fine tilt and divided into four blocks, and each measured 31.0 m by 10.0 m. Each block was divided into four treatment plots with each measuring 10.0 m x 7.0 m, with an alley of 1.0 m between them. Between each of the four blocks was an alley of 2.0 m. Thus the total plot size of the experimental site was 1,426 m^2.

3.4 Soil Routine Analysis

The initial soil test was done to ascertain the soils' nutrient status before the research was undertaken. The various parameters examined are described below:

3.4.1 Soil pH

This was determined using the glass electrode HT 9017 pH meter in a 1: 2: 5 soil to distilled water (soil: water) ratio. The pH of the soil was found to be 6.07.

3.4.2 Soil Organic Carbon

The modified Walkley and Black procedure as described by Nelson and Sommers (1982) was used to determine organic C.

3.4.3 Total nitrogen

The macro Kjeldahl method involving digestion and distillation as described in Soil Laboratory Staff (1984) was used for the determination of total N of the soil.

3.4.4 Available Phosphorus

The readily acid-soluble forms of P were extracted with Bray No. 1 solution (HCl: NH_4F mixture) (Bray and Kurtz, 1945; Olsen and Sommers, 1982). P in the sample was determined on a spectrophotometer by the blue ammonium molybdate with ascorbic acid as a reducing agent.

3.4.5 Extraction of exchangeable cations

Ca, Mg, K and Na in the soil were determined in 1.0 M ammonium acetate (NH_4OAc) extract (Black, 1986). A 10 g sample was transferred into a leaching tube and leached with a 250 ml of buffered 1.0 M ammonium acetate (NH_4OAc) solution at pH 7.

3.5 Eperimental Design and Treatement Allocation

The experiment was arranged in a randomized complete block design with four replications. There were four treatments;

T1: Control (No Fertilizer Application)

T2: SLF (NPK 10:10:10) + 1 % Sulphate of Ammonia

T3: SLF (NPK 10:10:10) + 0.5 % Sulphate of Ammonia

T4: SLF (NPK 10:10:10)

Each treatment was allocated to each of the plots within a block. There were four blocks.

Sidalco liquid fertilizer, manufactured by "Eagle Media House Ltd", UK was chosen for this research because it is a new product being promoted for use on crops, especially vegetables for increased yield, and that was also why eggplant was chosen.

3.6 Source and Variety of Seeds

Eggplant variety (Oforiwaa) which is popular in most local communities and early maturing was obtained from the Horticulture Department of the Crops Research Institute of the Council for Scientific and Industrial Research (CSIR – CRI), Fumesua, Kumasi.

3.7 Planting and other Agronomic Practices

3.7.1 Preparation of Nursery

The seeds were sown in a raised seedbed with friable soil in rows 10 cm apart. The seeds were spaced well to make transplanting easier. Before sowing an application of 3 to 5 kg of good compost per m^2 was incorporated into the nursery seedbed.

Redomil fungicide solution was mixed with the soil as pre- disinfectant and also applied to the seedlings on the nursery bed to prevent damping-off disease.

3.7.2 Transplanting of Seedlings

The seedlings transplanted after four weeks to the main field at one seedling per hill with 1.0 m inter - and intra - row spacing.

3.7.3 Cultural Practices

All agronomic practices were employed as and when needed. Weeds were controlled by the use of a hoe at 14, 28, 42 and 56 days after transplanting (DAT).

3.8 Application of Treatments

The sources of the N-fertilizers were NPK (10:10:10) in Sidalco liquid fertilizer and Sulphate of ammonia solution (1 % and 0.5 %). The NPK was applied two weeks after transplanting after which the Sulphate of Ammonia was added two days later, and this was repeated weekly for eight weeks. A knapsack sprayer was used to apply the treatments.

3.9 Data Collection

3.9.1 Insects' Data

Insect samples were taken from the three middle rows starting at two weeks after transplanting and continued weekly for eight weeks. Sampling of insects was between 0800 and 1000 h when insects were less active.

At the three - leaf stage when sampling began, the above - ground part of the plants were cut and quickly put into high density polyethylene plastic containers containing 70 % ethanol. This continued for three subsequent weeks. After the 4th week, the plant canopy was partitioned into upper and lower canopies and samples taken from the two canopies.

Five plants were randomly sampled for each treated plot. For each plant a leaf from each canopy level was cut into the plastic containers containing 70 % ethanol.

Samples from the buds and flowers were collected as and when they appeared. The samples were transported to the laboratory for identification using observable external characteristics after which the insects were separated from the ethanol solution to be counted and recorded with the aid of a stereomicroscope. No insecticides were applied to the plants and the experiment was undertaken in both the major and minor seasons.

3.9.2 Agronomic Data

The growth and yield components were recorded.

3.9.3 Plant Height

Plant height was recorded from five randomly selected plants from each plot and tagged. The plants from which measurement were taken were randomly selected from the plants which were not used to sample insects. The height was measured 2 cm from the base of the plants to the crown or the terminal point of the plant with the aid of a tape measure. Collection of this data began immediately after the application of the first treatments. It was carried out weekly for a period of eight weeks.

3.9.4 Number of Leaves

The leaves of the plants whose plant height were taken were also counted on weekly basis for a period of eight weeks. The means of the leaves of five randomly selected plants were recorded.

3.9.5 Determination of Leaf Area

The harvested leaves were brought to the laboratory and leaf areas determined. The leaves were placed in wet foam or in a moist towel. The main idea was to keep the leaves not to shrivel up and contort. To determine fresh leaf area, leaves were flattened between Perspex sheets with a scale bar and photographs were taken with a white background.

The leaf areas were calculated from digital photographs of the scanned leaves (images) with the program image J (Rasband, 2011). The mean of the leaf areas were determined and recorded.

3.9.6 Yield

Harvesting of matured fruits started eight weeks after transplanting and it was done five days interval for four consecutive weeks. Harvested fruits of each treatment were counted and weighed in the laboratory using an electronic weighing scale.

3.9.7 Determination of plant N

In order to determine the N levels in the plant, leaves were sampled from each treatment plot into labelled plastic containers to determine the N content using macro Kjeldahl method involving digestion and distillation as described in Soil Laboratory Staff (1984).

3.10 Data Analysis

Data for each season were subjected to analysis of variance [ANOVA] using SAS (9.0) GLM procedure (SAS institute, 2010). For the insects, data were pooled over date and data for each season transformed using square – root transformation to normalise the distribution of the insect population and separate analyses performed for each season. Analyses of the data for the two canopy leaves (upper and lower) were run separately.

Tukey's procedure was used for mean separation for the insect data analysis and Fisher's least significant difference (lsd) used to separate the means of the agronomic data at 5 % probability level.

The plant data (height, length, weight, etc) and soil data recorded throughout the experiment were subjected to analysis of variance using Genstat Windows Software Pack (9^{th} edition).

CHAPTER FOUR

4.0 RESULTS

4.1 Soil Routine Analysis

The results of the initial soil analysis of the experimental site are shown in Table 4.1. The initial % N recorded was low. The pH was 6.07 and the texture of the soil was sandy loam.

Table 4.1 Initial nutrient content of the soil

Constituent	Amount
Organic Carbon	1.04 %
Total Nitrogen	0.09 %
Organic Matter	1.79 %
Calcium/100 g of Soil	4.01
Magnesium/100 g of Soil	2.40
Potassium/100 g of Soil	0.09
Sodium/100 g of Soil	0.21

4.2.1 *A. gossypii* population dynamics in response to N application in major season of 2011

The highest densities of *A. gossypii* were recorded on the Treatment 2 (Sidalco liquid fertilizer, SLF + 1 % Sulphate of Ammonia) plots with two peaks of 4.01 and 4.98 per leaf on 9th June and 23rd June, 2011 respectively. The plot treated with SLF + 0.5 % Sulphate of Ammonia (Treatment 3) recorded a gradual increase of *A. gossypii* and peaked at 3.56 per leaf on 9th June and 3.59 per leaf on 30th June.

The population of the insect in the Sidalco liquid fertilizer treated plots (Treatment 4) recorded a peak of 3.50 per leaf on 9th June before declining thereafter. The control plots (Treatment 1) however, recorded a peak of 1.72 per leaf on 9th June and 1.51 per leaf on 30th June (Fig. 4.1).

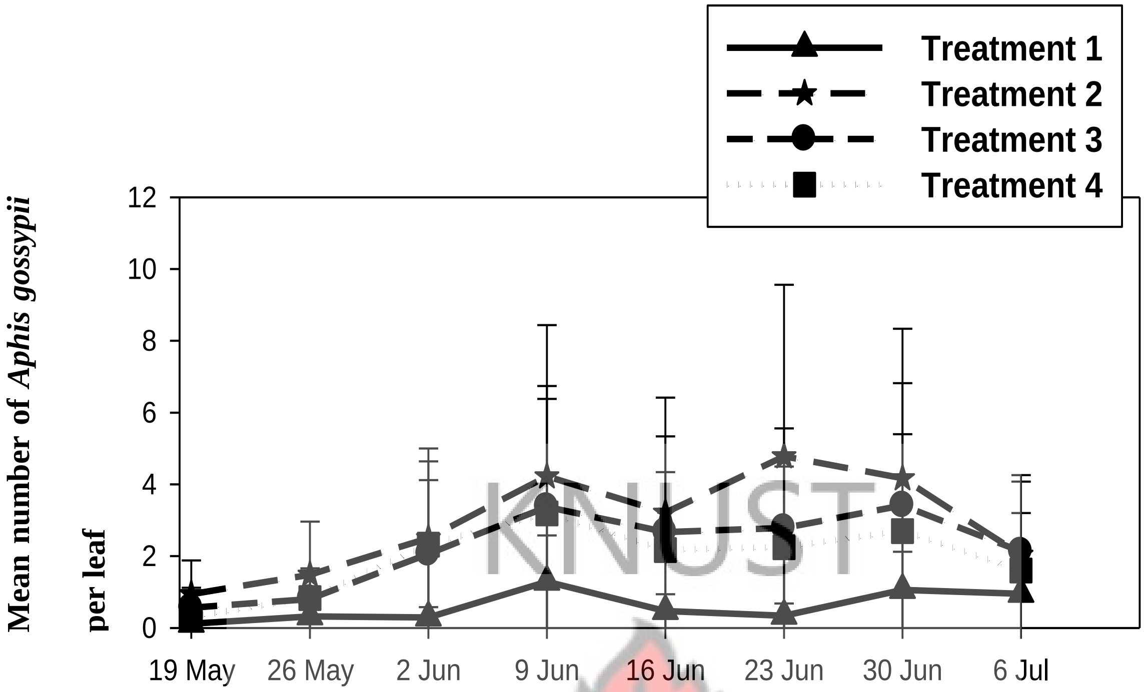

Figure 4.1 Mean densities (±SEM) of *Aphis gossypii* per eggplant leaf in fertilizer treatments from May to July (Major season).

Treatment 1 = Control; Treatment 2 = Sidalco liquid fertilizer + 1 % sulphate of ammonia; Treatment 3 = Sidalco liquid fertilizer + 0.5 % sulphate of ammonia; Treatment 4 = Sidalco liquid fertilizer only.

4.2.2 *A. gossypii* population dynamics in response to N application in minor season of 2011

Mean densities of *A. gossypii* in the minor season were lower than that recorded in the major season.

The density *A. gossypii* increased steadily and peaked at 3.89 per leaf on 15th September and declined thereafter in the Treatment 2 plots (Sidalco liquid fertilizer, SLF + 1 % Sulphate of Ammonia).

The density of insects in the Treatment 3 plots (SLF + 0.5 % Sulphate of Ammonia) also followed a steady increase and peaked at 2.96 per leaf on 22nd September and declined thereafter. Densities of *A. gossypii* in Treatment 4 (Sidalco liquid fertilizer treated plots) peaked at 2.68 per leaf on 22nd September and also declined thereafter. The control plots (Treatment 1) recorded a steady increase and peaked at 1.66 per leaf on 6th October only to decline thereafter (Fig. 4.2).

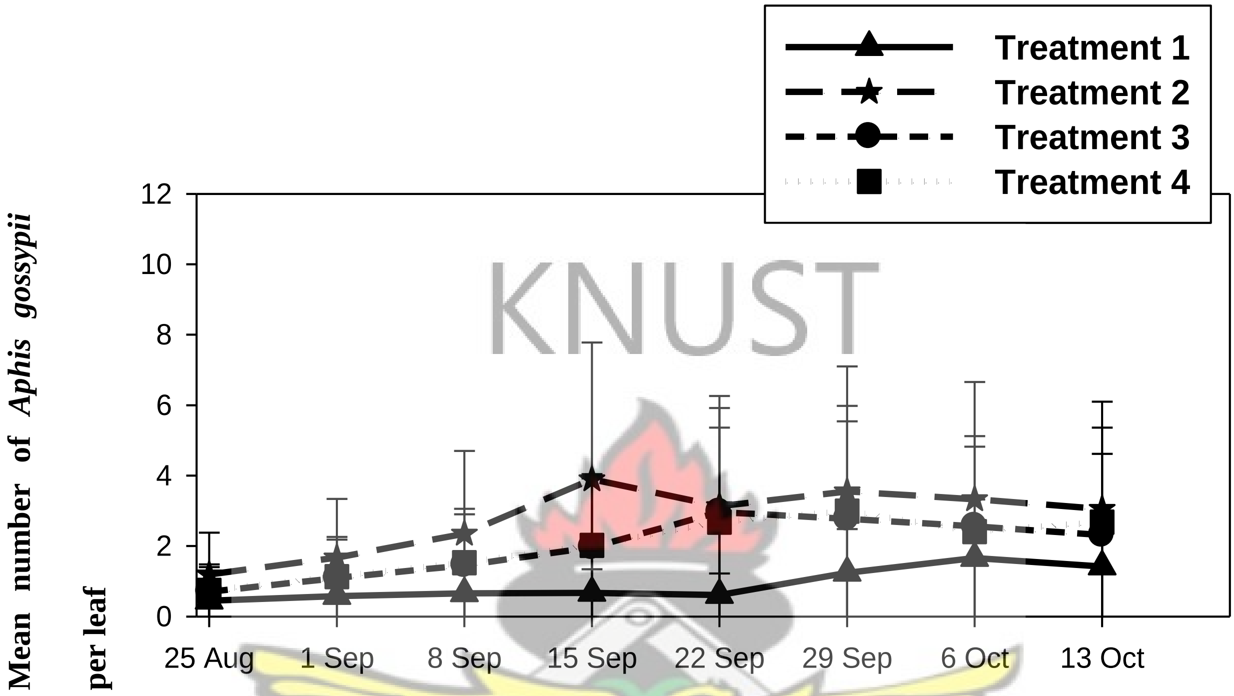

Figure 4.2 Mean densities (±SEM) of *Aphis gossypii* per eggplant leaf in fertilizer treatments from August to October (Minor season).

Treatment 1 = Control; Treatment 2 = Sidalco liquid fertilizer + 1 % sulphate of ammonia; Treatment 3 = Sidalco liquid fertilizer + 0.5 % sulphate of ammonia; Treatment 4 = Sidalco liquid fertilizer only.

4.3.1 *T. palmi* population dynamics in response to N application in major season of 2011

Generally, mean densities of *T. palmi* were very low. The peak density of *T. palmi* was recorded on 16th June for all treatments (Fig. 4.3).

Whilst the control plots (Treatment 1) recorded a peak of 1.02 per leaf, 1.87, 1.59 and 0.89 of *T. palmi* per leaf were respectively recorded in the Treatment 2 (Sidalco liquid fertilizer, SLF + 1 % Sulphate of Ammonia), Treatment 3 (Sidalco liquid fertilizer, SLF + 0.5 % Sulphate of Ammonia) and Treatment 4 plots (Sidalco liquid fertilizer). Treatment 2 plot recorded another high density of 1.82 per leaf on 30th June whilst treatment 3 also recorded a density of 1.53 per leaf on 6th July.

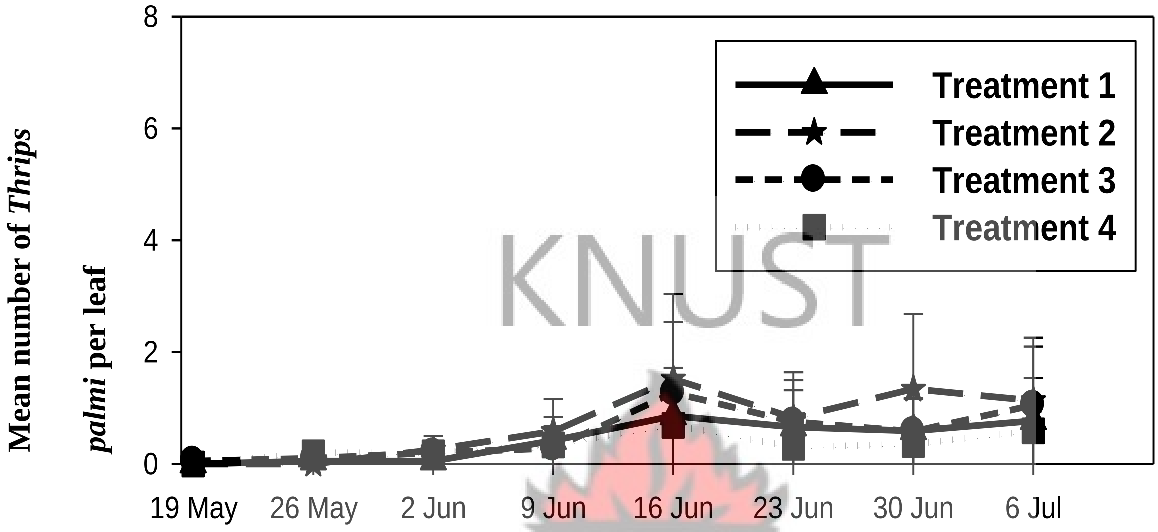

Figure 4.3 Mean densities (±SEM) of *Thrips palmi* per eggplant leaf in fertilizer treatments from May to July (Major season).

Treatment 1 = Control; Treatment 2 = Sidalco liquid fertilizer + 1 % sulphate of ammonia; Treatment 3 = Sidalco liquid fertilizer + 0.5 % sulphate of ammonia; Treatment 4 = Sidalco liquid fertilizer only.

4.3.2 *T. palmi* population dynamics in response to N application in minor season of 2011

Mean densities of *T. palmi* for Treatment 2 (Sidalco liquid fertilizer, SLF + 1 % Sulphate of Ammonia) recorded peaks of 2.01, 2.07 and 2.20 per leaf on 8th September, 15th September and 29th September, respectively, before it declined thereafter.

Treatment 3 (Sidalco liquid fertilizer, SLF + 0.5 % Sulphate of Ammonia) also recorded its peak density of 1.70 per leaf on 22nd September and declined thereafter. Peak densities of 0.85 and 1.07 per leaf were recorded on 15th September for Treatment 1 (control plots) and Treatment 4 (Sidalco liquid fertilizer), respectively, and also recorded 1.37 and 1.48 per leaf on 6th October (Fig. 4.4).

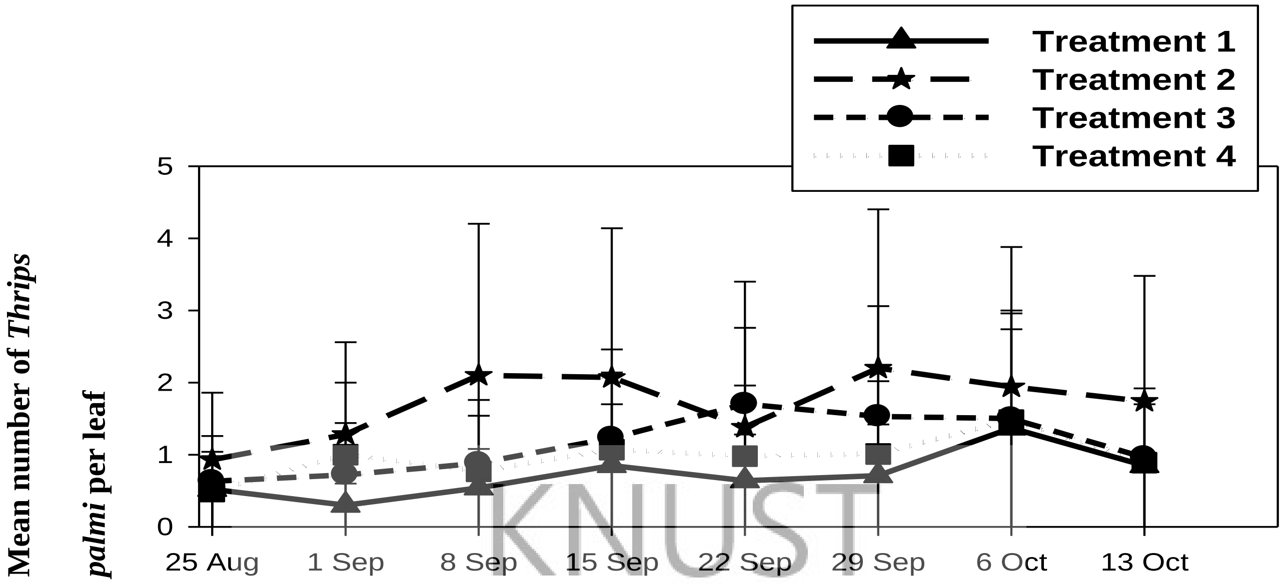

Figure 4.4 Mean densities (±SEM) of *Thrips palmi* per eggplant leaf in fertilizer treatments from August to October (Minor season).

Treatment 1 = Control; Treatment 2 = Sidalco liquid fertilizer + 1 % sulphate of ammonia; Treatment 3 = Sidalco liquid fertilizer + 0.5 % sulphate of ammonia; Treatment 4 = Sidalco liquid fertilizer only.

4.4.1 Population dynamics of Ladybird (*Epilachna chrysonilia*) and *A. gossypii* in response to N application in major season of 2011

Generally mean densities of the ladybird beetle (*E. chrysonilia*), a predator, were lower than the mean densities of the prey in all the N treated plots.

A. gossypii reached its peak density per leaf a week before the peak population of the predator on the control plots. Prey population density declined to 0.87 per leaf whereas that of the predator declined slightly by the eighth week.

A. gossypii population attained a peak density per leaf a week after the peak population of the predator in the Treatment 4 plots (Sidalco liquid fertilizer). By the eighth week, the prey population density declined to 1.98 per leaf whereas that of the predator recorded a marginal increase. Mean densities of the prey peaked four weeks before the peak population of the predator in the Treatment 3 plots (Sidalco liquid fertilizer, SLF + 0.5 % Sulphate of Ammonia). The mean densities of the prey declined to 2.01 when the predator population increased slightly by the last sample week. The Treatment 4 (Sidalco liquid fertilizer) recorded a peak density of *A. gossypii* three weeks before the peak population of the predator. Population of the prey reduced to 1.45 per leaf with *E. chrysonilia* attaining 0.79 per leaf (Fig. 4.5).

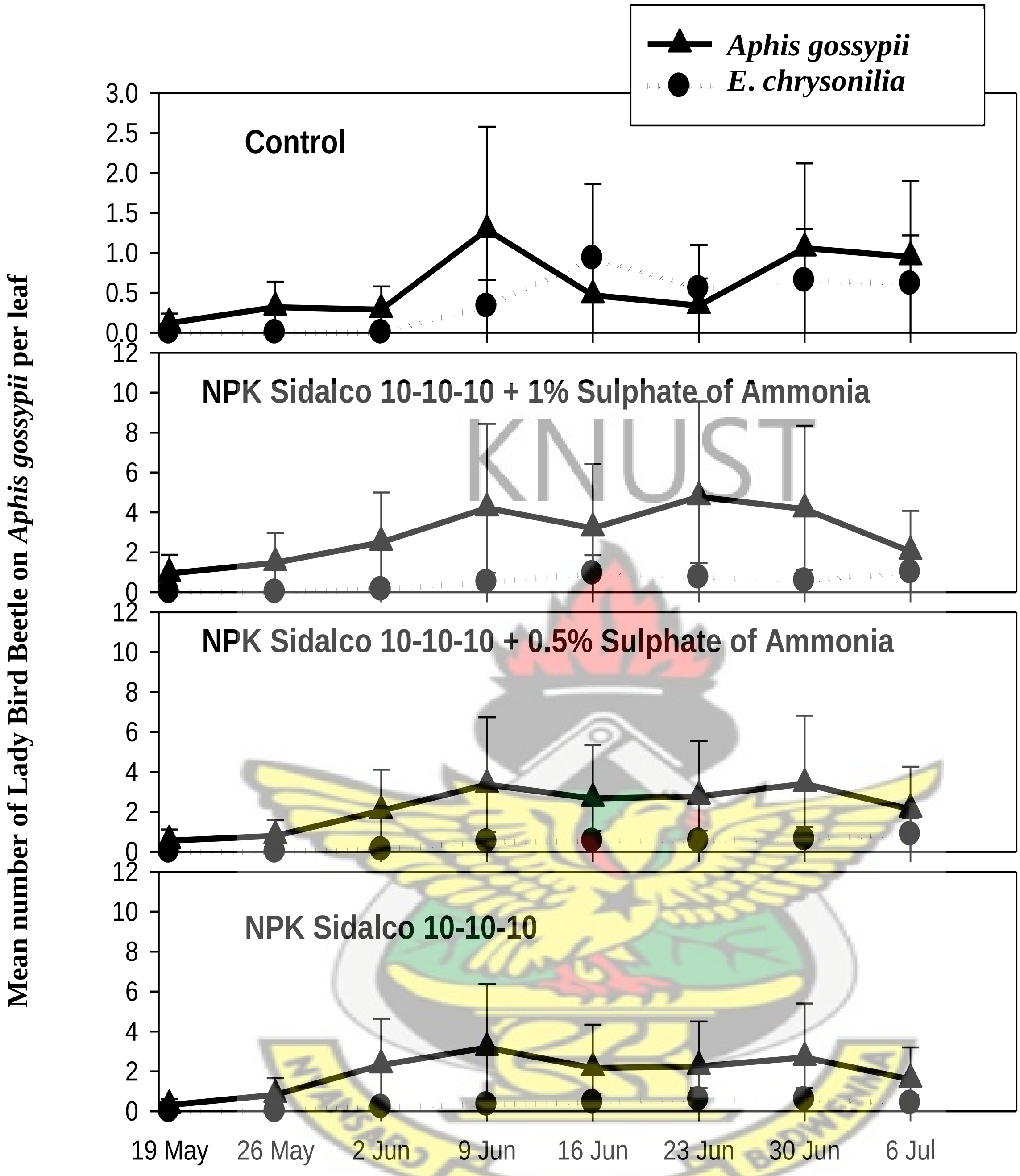

Figure 4.5 Mean densities (±SEM) of *E. chrysonilia* and *A. gossypii* per eggplant leaf in fertilizer treatments from May to July (Major season).

Treatment 1 = Control; Treatment 2 = Sidalco liquid fertilizer + 1 % sulphate of ammonia; Treatment 3 = Sidalco liquid fertilizer + 0.5 % sulphate of ammonia; Treatment 4 = Sidalco liquid fertilizer only.

4.4.2 Population dynamics of Ladybird (*Epilachna chrysonilia*) and *A. gossypii* in response to N application in minor season of 2011

Generally mean densities of *E. chrysonilia* were lower than the mean densities of the *A. gossypii* population. In the control, mean densities of the prey peaked simultaneously with the predator population at 1.75 and 1.01 per leaf, respectively, which declined to 1.42 and 0.79 per leaf by the eighth week. The population dynamics of the *A. gossypii* and *E. chrysonilia* followed a similar pattern in the Treatments 2 (Sidalco liquid fertilizer, SLF + 1 % Sulphate of Ammonia), Treatment 3 (Sidalco liquid fertilizer, SLF + 0.5 % Sulphate of Ammonia) and Treatment 4 plots (Sidalco liquid fertilizer) (Fig. 4.6).

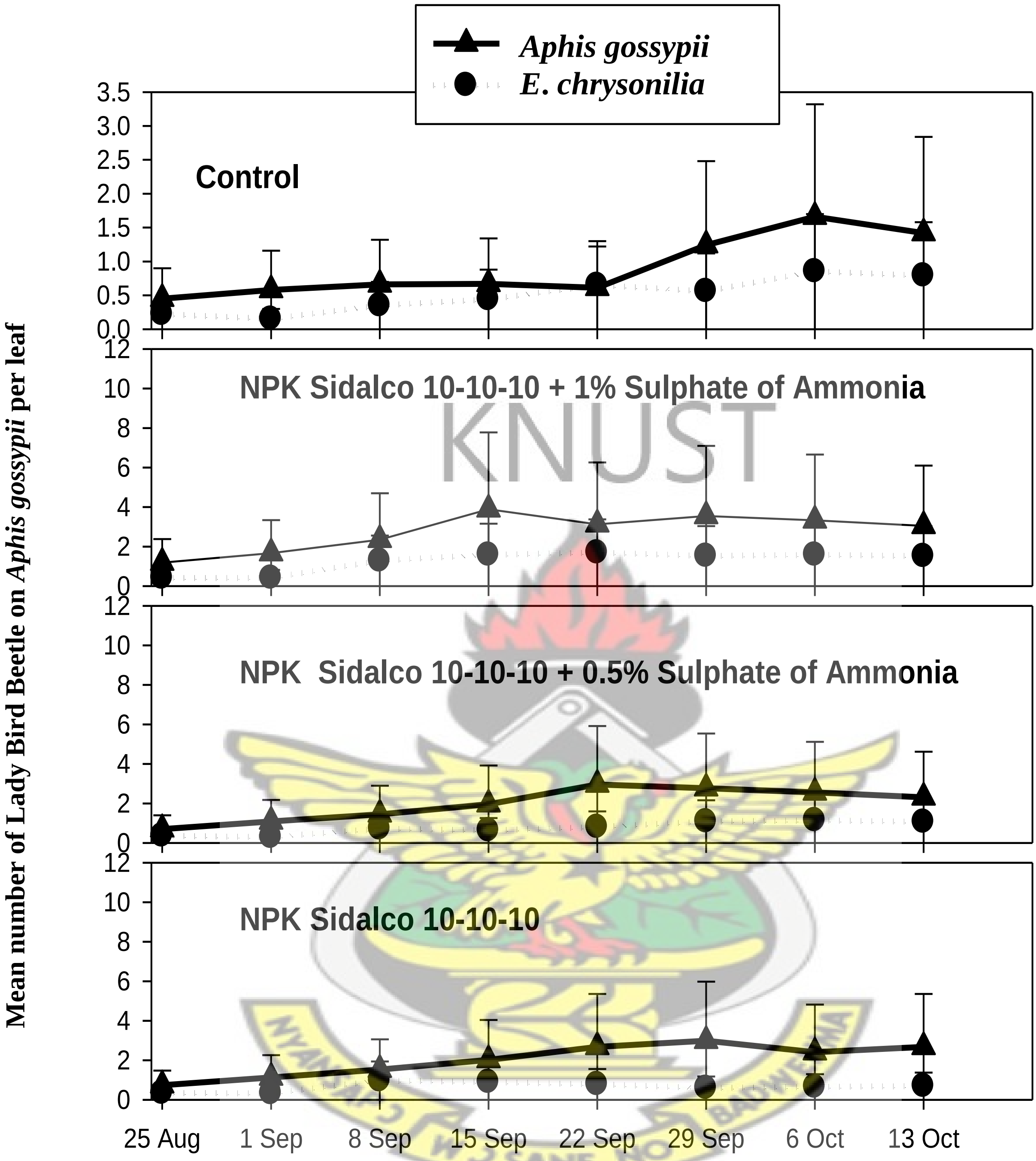

Figure 4.6 Mean densities (±SEM) of *E. chrysonilia* and *A. gossypii* per eggplant leaf in fertilizer treatments from May to July (Minor season).

Treatment 1 = Control; Treatment 2 = Sidalco liquid fertilizer + 1 % sulphate of ammonia; Treatment 3 = Sidalco liquid fertilizer + 0.5 % sulphate of ammonia; Treatment 4 = Sidalco liquid fertilizer only.

4.5.1 Population dynamics of Ladybird (*Epilachna chrysonilia*) and *T. palmi* in response to N application in major season of 2011

T. palmi reached its peak density simultaneously with the population of *E. chrysonilia* in the Treatment 1 (control plots). In the Treatment 2 plots (Sidalco liquid fertilizer, SLF + 1 % Sulphate of Ammonia), population of the prey, *T. palmi* peaked four weeks before the peak of the predator, *E. chrysonilia* was reached. The mean densities of *T. palmi* declined to 1.21 per leaf whereas that of *E. chrysonilia* increased to 1.00 per leaf by the eighth week after declining in the sixth and seventh sample weeks.

Population of the prey, *T. palmi* also peaked four weeks before the peak population of the predator, *E. chrysonilia* in the Treatment 3 plots (Sidalco liquid fertilizer, SLF + 0.5 % Sulphate of Ammonia). Both prey and predator population increased to 1.13 and 1.10 per leaf, respectively, in the eighth week.

Mean densities recorded in the Treatment 4 plots (Sidalco liquid fertilizer) for the prey, *T. palmi* reached its peak a week before the peak of predator, *E. chrysonilia*. Prey population increased to 0.87 per leaf whilst the predator population declined to 0.51 per leaf by the eighth week (Fig. 4.7).

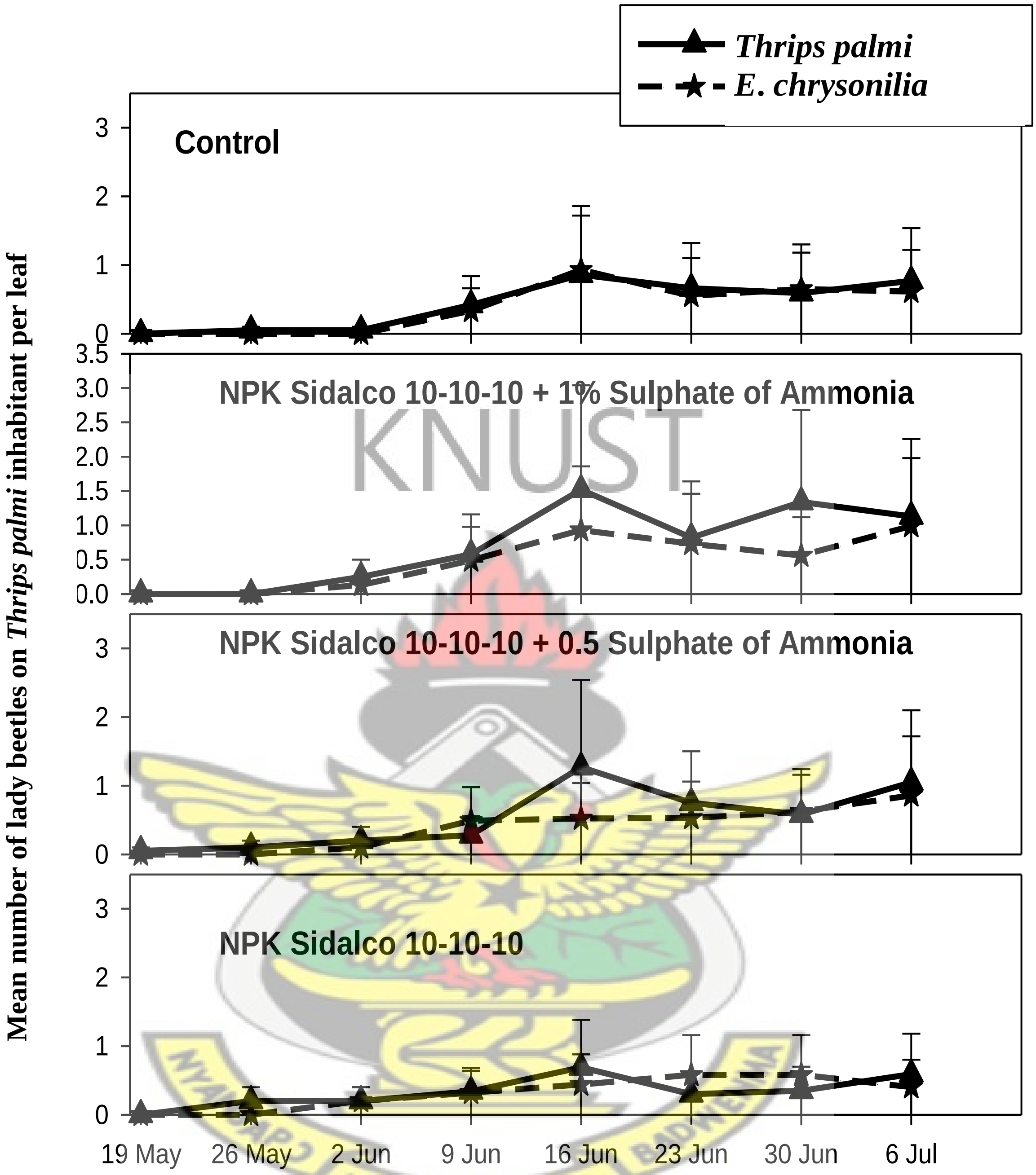

Figure 4.7 Mean densities (±SEM) of *E. chrysonilia* on *T. palmi* per eggplant leaf in fertilizer treatments from May to July (Major season).

Treatment 1 = Control; Treatment 2 = Sidalco liquid fertilizer + 1 % sulphate of ammonia; Treatment 3 = Sidalco liquid fertilizer + 0.5 % sulphate of ammonia; Treatment 4 = Sidalco liquid fertilizer only.

4.5.2 Population dynamics of Ladybird (*Epilachna chrysonilia*) and *T. palmi* in response to N application in minor season of 2011

T. palmi, reached its peak density simultaneously with the population of *E. chrysonilia* in the seventh week in the control plots. Both densities declined by the eighth week to 0.85 and 0.79 per leaf, respectively.

In the Treatment 2 plots (Sidalco liquid fertilizer, SLF + 1 % Sulphate of Ammonia), population of the prey peaked a week after the peak population of the predator. The mean densities of *T. palmi* declined to 1.74 per leaf whereas population of *E. chrysonilia* recorded slight decrease by the eighth week.

Mean densities recorded in the Treatment 3 plots (Sidalco liquid fertilizer, SLF + 0.5 % Sulphate of Ammonia) show that *T. palmi* peaked two weeks before the peak population of the predator, *E. chrysonilia* whereas in the Treatment 4 plots (Sidalco liquid fertilizer), *T. palmi* reached its peak five weeks after the peak attained by the predator, *E. chrysonilia* (Fig. 4.8).

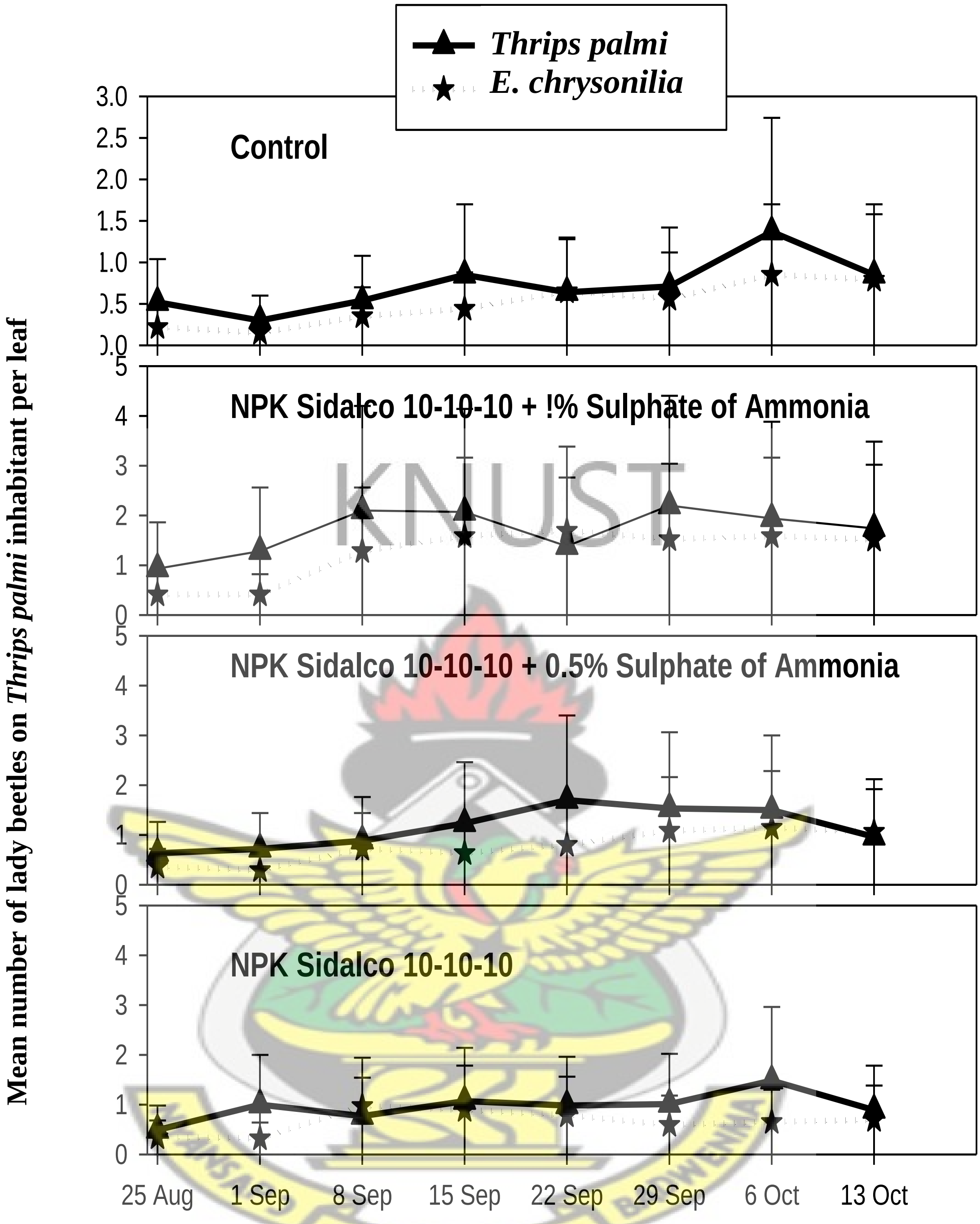

Figure 4.8 Mean densities (±SEM) of *E. chrysonilia* on *T. palmi* per eggplant leaf in fertilizer treatments from August to October (Minor season).

Treatment 1 = Control; Treatment 2 = Sidalco liquid fertilizer + 1 % sulphate of ammonia; Treatment 3 = Sidalco liquid fertilizer + 0.5 % sulphate of ammonia; Treatment 4 = Sidalco liquid fertilizer only.

4.6 Distribution of insect pest within eggplant

4.6.1 Distribution of *A. gossypii* (major season)

There were no significant differences in the densities of *A. gossypii* that aggregated in the lower and upper canopies of the control plots. However, there were significant differences ($P < 0.05$) in their numbers in the lower and upper canopies in all the N treated plots (Table 4.2).

Table 4.2: Mean (±SEM) distribution of *Aphis gossypii* per eggplant leaf in fertilizer treatments from May to July (major season), 2011

Canopy	Control	SLF + 1 % S A	SLF + 0.5 % S A	SLF
Lower	0.70 ± 0.11 a	3.66 ± 0.19 a	2.87 ± 0.16 a	2.27 ± 0.17 a
Upper	0.53 ± 0.11 a	1.82 ± 0.16 b	1.48 ± 0.15 b	0.97 ± 0.11 b

means with same letter(s) within a column are not significantly different ($p < 0.05$; tukey test).

[SLF = Sidalco Liquid Fertilizer ; S A = Sulphate of Ammonia]

4.6.2 Distribution of *A. gossypii* (minor season)

The control treatment, treatment 1 and treatment 2 (Sidalco liquid fertilizer, SLF + 1 % Sulphate of Ammonia) and Treatment 3 (Sidalco liquid fertilizer, SLF + 0.5 % Sulphate of Ammonia) showed no significant differences in the aggregation of the insect between the lower and upper canopies; while the Treatment 4 (Sidalco liquid fertilizer) recorded significantly ($P < 0.05$) higher number of *A. gossypii* in the upper canopy than that in the lower canopy (Table 4.3).

Table 4.3: Mean (±SEM) distribution of *Aphis gossypii* per eggplant leaf in fertilizer treatments from August to October (minor season), 2011

Canopy	Control	SLF + 1 % S A	SLF + 0.5 % S A	SLF
Lower	1.23 ± 0.13 a	3.27 ± 0.20 a	2.65 ± 0.19 a	3.19 ± 0.14 a
Upper	1.34 ± 0.12 a	3.37 ± 0.17 a	2.70 ± 0.14 a	2.39 ± 0.16 b

means with same letter(s) within a column are not significantly different ($p < 0.05$; tukey test).

[SLF = Sidalco Liquid Fertilizer ; S A = Sulphate of Ammonia]

4.6.3 Distribution of *T. palmi* (major season)

There were no significant differences in the densities of *T. palmi* in the Treatments 2 (Sidalco liquid fertilizer, SLF + 1 % Sulphate of Ammonia), Treatment 3 (Sidalco liquid fertilizer, SLF + 0.5 % Sulphate of Ammonia) and Treatment 4 (Sidalco liquid fertilizer); but significant difference were recorded in the control plots from the lower and upper canopies (Table 4.4).

Table 4.4: Mean (±SEM) distribution of *Thrips palmi* per eggplant leaf in fertilizer treatments from May to July (major season), 2011

Canopy	Control	SLF + 1 % S A	SLF + 0.5 % S A	SLF
Lower	0.40 ± 0.06 a	1.40 ± 0.11 a	0.85 ± 0.09 a	0.53 ± 0.08 a
Upper	0.75 ± 0.09 b	1.13 ± 0.12 a	0.89 ± 0.09 a	0.45 ± 0.06 a

means with same letter(s) within a column are not significantly different ($p < 0.05$; tukey test).

[SLF = Sidalco Liquid Fertilizer; S A = Sulphate of Ammonia]

4.6.4 Distribution of *T. palmi* (minor season)

Whereas there were no significant differences ($P < 0.05$) in the number of *T. palmi* was collected from the canopies in the control, treatment1 and Treatment 2 (Sidalco liquid fertilizer, SLF + 1 % Sulphate of Ammonia) and Treatment 4 (Sidalco liquid fertilizer), there were significant differences in Treatment 3 (Sidalco liquid fertilizer, SLF + 0.5 % Sulphate of Ammonia) (Table 4.5).

Table 4.5: Mean (±SEM) distribution of *Thrips palmi* per eggplant leaf in fertilizer treatments from August to October (minor season), 2011

Canopy	Control	SLF + 1 % S A	SLF + 0.5 % S A	SLF
Lower	0.89 ± 0.11 a	1.81 ± 0.17 a	1.17 ± 0.14 a	1.43 ± 0.12 a
Upper	1.11 ± 0.12 a	2.12 ± 0.15 a	1.67 ± 0.15 b	1.40 ± 0.14 a

means with same letter(s) within a column are not significantly different ($p < 0.05$; tukey test).

[SLF = Sidalco Liquid Fertilizer; S A = Sulphate of Ammonia]

4.7 Relationship between *A. gossypii* and *T. palmi* populations and % N in eggplant leaves

4.7.1 Relationship between *Aphis gossypii* population and % N in eggplant leaves (major season), 2011

There was a strong positive correlation between % N and aggregation of *A. gossypii* on the leaves in the major season with r value of 0.96. This shows the strong contribution N levels in the leaves to the abundance of aphids on eggplant (Fig. 4.9).

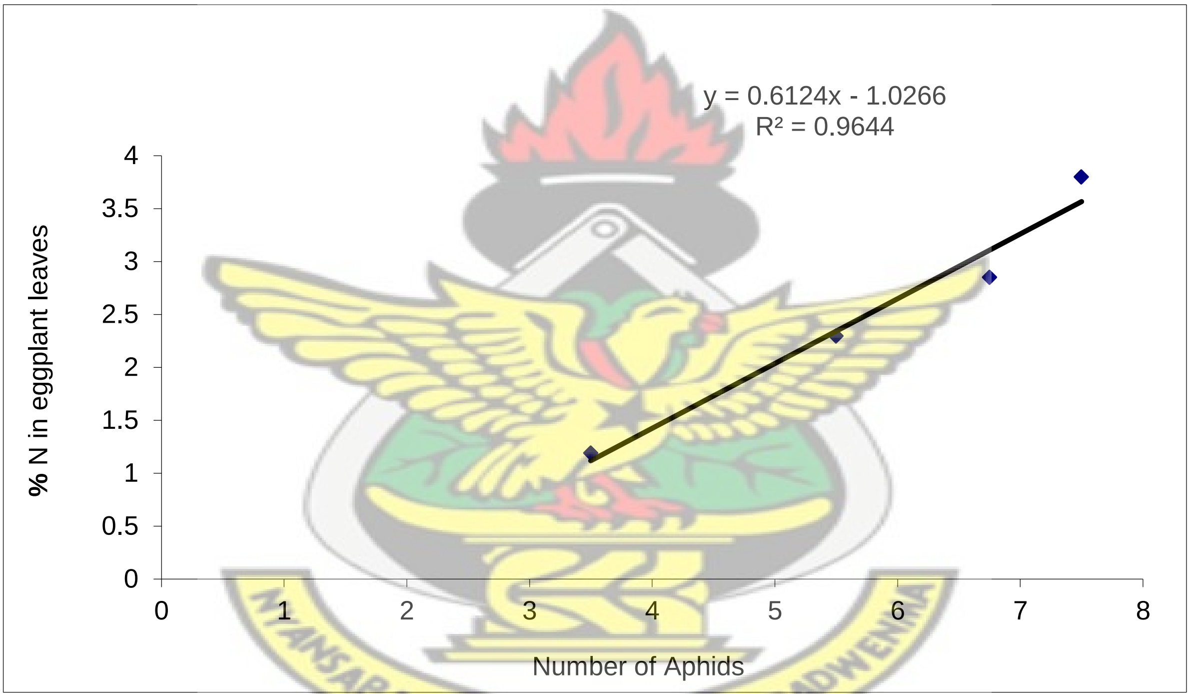

Figure 4.9: Relationship between number of *Aphis gossypii* and % N in the leaves of eggplant (major season)

4.7.2 Relationship between *Aphis gossypii* population and % N in eggplant leaves (minor season)

Strong positive correlations existed between % N and aggregation of *A. gossypii* on the leaves in the minor season with r value of 0.99. This shows the strong contribution of N level in the leaves to the abundance of aphids on eggplant (Fig. 4.10).

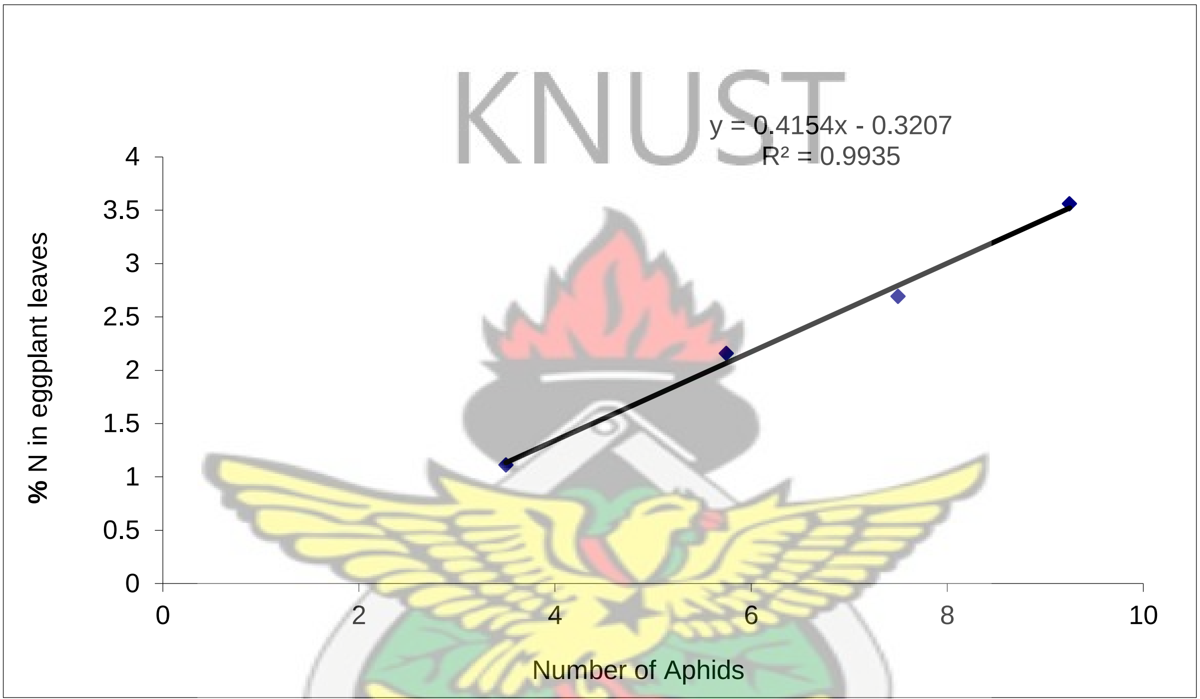

Figure 4.10: Relationship between number of *Aphis gossypii* and % N in the leaves of eggplant (minor season)

4.7.3 Relationship between *T. palmi* population and % N in eggplant leaves (major season)

There was also strong positive correlation between % N and aggregation of *T. palmi* on the leaves in the major season with r value of 0.75. (Fig. 4.11)

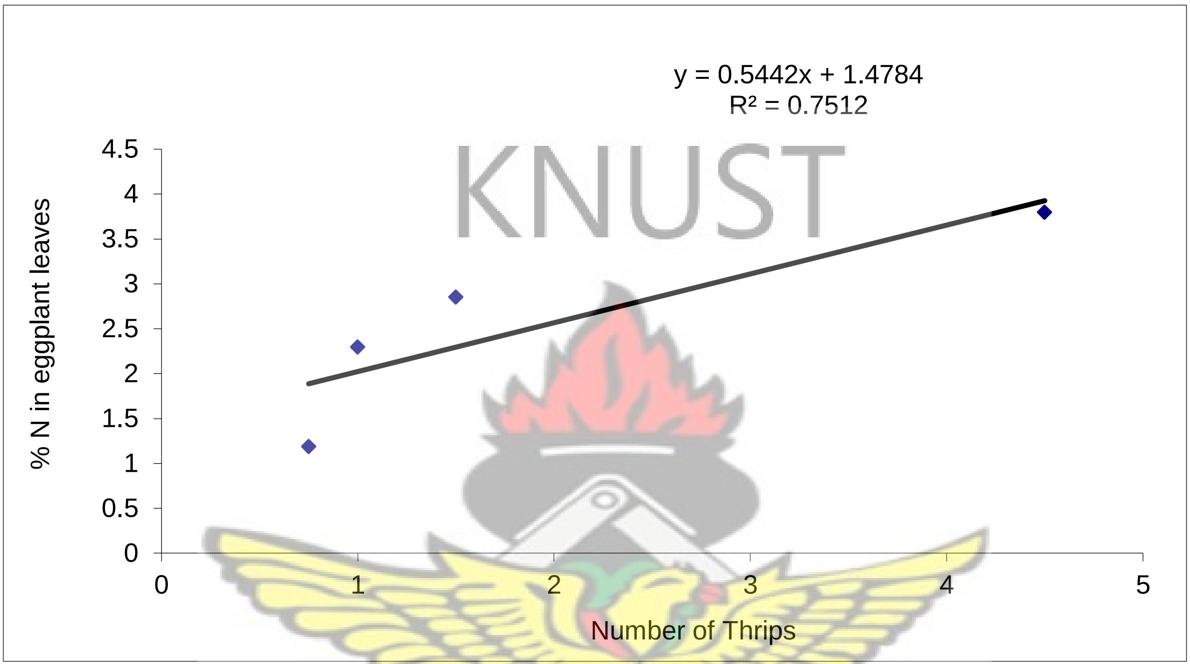

Figure 4.11: Relationship between number of *Thrips palmi* and % N in the leaves of eggplant (major season)

4.7.4 Relationship between *T. palmi* population and % N in eggplant leaves (minor season)

There was positive correlation between % N and aggregation of *T. palmi* on the leaves in the minor season with r value of 0.69. (Fig. 4.12).

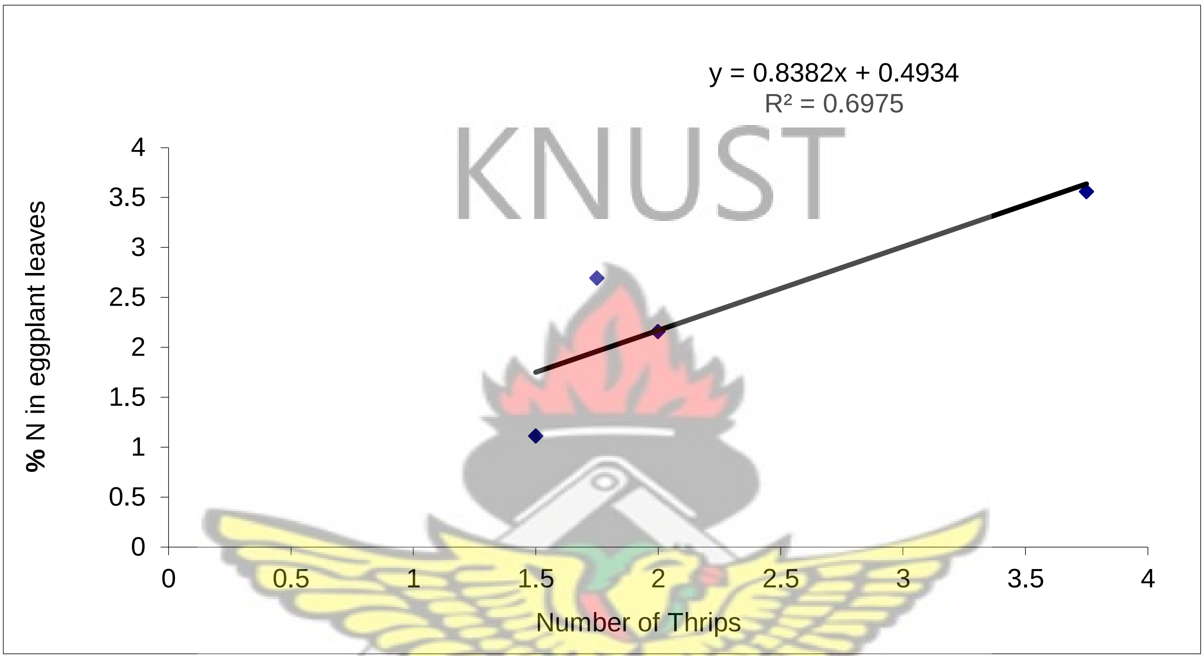

Figure 4.12: Relationship between number of *Thrips palmi* and % N in the leaves of eggplant (minor season)

4.8 Growth components and Yield as affected by N treatments (major season)

4.8.1 Plant Height

There were significant ($P < 0.05$) differences between the control and the N treatment plots in the major season. However, there were no significant differences in plant height between the N treatment plots (Table 4.6).

4.8.2 Leaf Area

There were significant ($P < 0.05$) differences between the control and the N treatment plots in the leaf area of the plants. The difference between the leaf area of the plants in the Treatment 2 (Sidalco liquid fertilizer, SLF + 1 % Sulphate of Ammonia) plots and that of Treatments 3 (Sidalco liquid fertilizer, SLF + 0.5 % Sulphate of Ammonia) and Treatment 4 (Sidalco liquid fertilizer) was significant. But there were no significant ($P < 0.05$) differences in the leaf area between the Treatments 3 and 4 plots (Table 4.6).

4.8.3 Number of fruits

There were significant ($P < 0.05$) differences between the control and treatment 2 (Sidalco liquid fertilizer, SLF + 1 % Sulphate of Ammonia) plots with respect to the number of fruits harvested. However, there were no significant ($P < 0.05$) difference between the control plots and Treatment 3 (Sidalco liquid fertilizer, SLF + 0.5 % Sulphate of Ammonia) and Treatment 4 (Sidalco liquid fertilizer) plots with respect to the number of fruits. There were also no significant ($P < 0.05$) differences between the Treatment 2 and 3 plots, but there were significant ($P < 0.05$) differences in the number of fruits between Treatment 2 and 4 plots (Table 4.6).

4.8.4 Yield

There were significant ($P < 0.05$) differences between the control and the N treatment plots with respect to fruit yield. There were also significant ($P < 0.05$) differences between the Treatment 2 (Sidalco liquid fertilizer, SLF + 1 % Sulphate of Ammonia), Treatment 3 (Sidalco liquid fertilizer, SLF + 0.5 % Sulphate of Ammonia) and Treatment 4 (Sidalco liquid fertilizer) plots. However, there were no significant ($P < 0.05$) differences between the Treatment 3 and 4 plots in the fruit yield (Table 4.6).

Table 4.6: The growth and yield parameters of eggplant treated with different levels of N in liquid fertilizer (major season), 2011

Treatment	Plant height (cm)	Leaf area (cm^2)	Mean no. of fruits /plot	Yield(kg/ha)	% Increase in yield
SLF + 1 % S A	73.2	378.0	303.0	402.8	35.7
SLF + 0.5 % S A	59.4	302.0	281.0	368.0	29.7
SLF	58.7	291.5	248.0	338.0	23.4
Control	41.6	175.2	253.0	258.8	–
Lsd (5%)	16.0	26.3	34.5	31.2	
CV (%)	8.1	5.9	5.1	4.2	

4.8.2 Growth components and Yield as affected by N treatments (minor season)

4.8.2.1 Plant Height

In the minor season there were significant ($P < 0.05$) differences between the control and the N treatment plots with respect to plant height. However, there were no significant ($P < 0.05$) differences in the plant heights between the N treatment plots (Table 4.7).

4.8.2.2 Leaf Area

There were significant ($P < 0.05$) differences between the control and the N treatment plots with respect to the leaf area. The difference in the leaf area between Treatment 2 (Sidalco liquid fertilizer, SLF + 1 % Sulphate of Ammonia) and Treatment 3 (Sidalco liquid fertilizer, SLF + 0.5 % Sulphate of Ammonia) plots were significant ($P < 0.05$). However, there were no significant differences between treatment 2 and treatment 4 (Sidalco liquid fertilizer) plots, with Treatments 3 and 4 plots also showing no significant differences in the leaf area (Table 4.7).

4.8.2.3 Number of fruits

There were significant ($P < 0.05$) differences between the control and the N treatment plots with respect to the number of fruits. There were also significant differences between all the N treatment plots (Table 4.7).

4.8.2.4 Yield

There were significant ($P < 0.05$) differences between the control and the N treatment plots in the fruit yield. There were significant ($P < 0.05$) differences in the fruit yield between all the N treatment plots (Table 4.7).

Table 4.7: The growth and yield parameters of eggplant treated with different levels of N in liquid fertilizer (minor season), 2011

Treatment	Plant height (cm)	Leaf area (cm^2)	Mean no. of fruits /plot	Yield (kg/ha)	% Increase in yield
SLF + 1 % S A	71.8	243.5	204.0	370.0	46.5
SLF + 0.5 % S A	58.0	288.0	172.0	311.8	36.6
SLF	57.7	280.0	130.0	197.8	27.5
Control	40.	161.0	98.0	273.0	–
Lsd (5%)	16.7	41.4	13.1	25.1	
CV (%)	7.7	3.1	4.1	4.2	

4.9.1 Percentage N analysis (major season)

Analysis of the percentage N partitioned into leaves revealed significant ($P < 0.05$) differences between the control and the N treatment plots for this parameter. Also, there were significant ($P < 0.05$) differences between all the percentage N treatment plots analyzed (Table 4.8).

Table 4.8: Percentage N in the leaves of eggplant treated with different levels of N in liquid fertilizer (major season), 2011

Treatment	% N in Leaves	% Increase in N
SLF + 1 % S A	3.80	68.68
SLF + 0.5 % S A	2.85	58.25
SLF	2.30	48.26
Control	1.19	–
Lsd (5%)	0.24	
CV (%)	2.80	

4.9.2 Percentage N analysis (minor season)

Similar results were also recorded in this season. Significant (P < 0.05) differences in the percentage N in leaves were recorded between the control and the N treatment plots. The difference between all the N treatment plots were also significant. (Table 4.9).

Table 4.9: Percentage N in the leaves of eggplant treated with different levels of N in liquid fertilizer (minor season), 2011

Treatment	% N in Leaves	% Increase in N
SLF + 1 % S A	3.56	68.82
SLF + 0.5 % S A	2.69	58.74
SLF	2.16	48.61
Control	1.11	–
Lsd (5%)	0.30	
CV (%)	4.10	

CHAPTER FIVE

5.0 DISCUSSION

5.1 Population fluctuations of *Aphis gossypii* and *Thrips palmi* with the application of N fertilizer

The presence of *Aphis gossypii* on plants is due to the availability of food in the phloem sap (Gomez *et al*., 2006). The increase in the population was due to the use of fertilization (Erdal *et al*., 2003), and excessive nutrient application which contributed to increased reproduction, longevity and overall fitness of the pests (Jahn, 2004). The population increase was also due to the adequate supply of N which is associated with high photosynthetic activity, vigorous vegetative growth and a dark green colour of the leaves (John *et al*., 2004).

The increase in aphid infestation began two weeks after transplanting of the seedling. Increase in numbers recorded was in response to high N fertilization which supported the finding that N may influence semio-chemicals and nutritional values of plants and also behavioural characteristics of herbivores (Hunt *et al*., 1992; Herms, 2002). N content in host plants is generally considered an indicator of food quality that affects host selection by aphids and thrips (Jansson and Smilowitz, 1986). The high rate of N fertilizer which may have significantly increased the number of eggs laid by the aphids and thrips, resulted in population increase (Kalule and Wright, 2002). N was found to modify the plant nutrition and reduce the resistance against aphids (Kasyab and Batra, 1987; Eigenbrode and Pimentel, 1988; Bentz *et al*., 1995; Phelan *et al*., 1995).

N application was partitioned in the crop in the form of phenols and amino acids (protein), making the foliage extremely succulent and therefore susceptible to both diseases and pest incidence (Jansson and Smilowitz, 1986; Marschner, 1995; Youdeowei, 2002).

5.2 Seasonal fluctuations of *Aphis gossypii* and *Thrips palmi* on eggplant

The population of aphids recorded in the major season was slightly higher than that recorded in the minor season but Hosoda *et al*. (1993) reported that aphids population could become very important in the cool dry season which is associated with the minor season in Ghana.

However, thrips population in the minor season was slightly higher than that recorded in the major season and this is in agreement with the report by Gallo *et al*. (2002) that thrips mostly attack eggplants during the cool dry season.

5.3 Natural enemies of *Aphis gossypii* and *Thrips palmi* on eggplant

Ladybird beetles were observed to be the major natural enemies of *A. gossypii* and *T. palmi* in the field. Their population was found to increase with increase in the number of aphids and thrips. Capinera (2007) indicated that if these natural enemies are present in sufficient numbers, before aphid populations expand, they can keep aphids under control this was in agreement with this current study as the aphid numbers was checked by the natural enemy population. Ramachandran *et al*. (2001) and Northfield *et al*. (2008) also reported that the population of thrips reduces greatly in summer as natural enemies become important factors affecting their abundance. This was also in agreement with this study as thrips population was checked by the natural enemy and summer is associated with the major season in Ghana.

Funderburk *et al*. (2002) documented the ability of *O. insidiosus* to effectively suppress *Frankliniella* thrips on crops in greenhouse studies. Most successes were reported with *F. occidentalis* rather than *F. tritici* and *F. bispinosa*. Biological control of thrips is achievable but it varies from crop to crop as noted by Hulshof *et al*. (2003).

5.4 Distribution of *Aphis gossypii* and *Thrips palmi* within eggplant

The lower canopy recorded higher population of aphids than the upper canopy which was not in agreement with the report of Freeman and Smith, 1999 that cotton aphids prefer to feed on younger leaves in the upper canopy. The situation was different in the case of thrips where the upper canopy recorded higher numbers than the lower canopy. This confirmed reports of Reitz (2008) and Tsai *et al*. (1996) that thrips occur on flowers and feed on pollen. Also, Toapanta *et al*. (1996) documented that thrips aggregated and fed on leaves on the initial stages of plant growth but shifted to aggregate in flowers when blooming begins but all thrips were recorded on leave. Ananthakrishnan (1993) also reported that fresh young leaves are preferred by thrips and this is in agreement with this study because, thrips were found on new succulent leaves in the upper canopy than older ones in the lower canopy. Funderburk *et al*. (2002) indicated that the leaves are a more stable food source than flowers. This could also be attributed to the increase in N making leaves to be more succulent.

5.5 Growth components and yield

5.5.1 Plant Height

Taller plants were recorded in the treatment plots with the highest N fertilizer.

This was expected because usually plants with high N dosages undergo vigorous vegetative growth (Aliju *et al*., 1992; John *et al*., 2004) and also reported by Lawlor (2002) and Ulukan (2008) who underscored the importance of N for vegetative growth in plants.

5.5.2 Leaf Area

The application of NPK resulted in an increase in leaf area. The plots that received highest amount of N recorded the largest leaf area whilst plants on the control plots had the least leaf area.

Increase in leaf area may be due to adequate supply of N which is associated with high photosynthetic activity. John *et al*. (2004) argued that plants that receive more N undergo increased photosynthetic and vigorous vegetative growth and produce dark green leaves. Nitrogen is important for plant growth, increase in leaf area and consequently light interception (Jones 1992; Grindlay 1997). It was also reported that main effect of N fertilization is an increase in leaf area index leading to increased light interception in crops such as eggplant (*Solanum melongena* L.) (Rosati *et al*., 2001), lettuce (*Lactuca sativa* L. 'Vegas') and lucerne (*Medicago sativa* L.) (Lemaire *et al*., 2005).

5.5.3 Yield

The number and weight of eggplant fruits do not depend only on environmental factors but also on combined effects of pests and diseases and good nutrition of the crop on the field. Higher number of fruits was recorded on the treatment with the highest N fertilizer. The control plots recorded the lowest yield.

The mean weight of fruits was significantly higher in the highest N treatment plots than the lower N treatment plots, with the control recording the least. This result was expected because the N applied was expected to improve plant performance and increase leaf area and sunlight interception to enhance the rate of photosynthesis as reported by Varela and Seif (2004) and John *et al*. (2004). Plots with high doses of N also recoded a higher yield; it has been reported that the main effect of N fertilization increases the dry matter production in crops such as eggplant (*Solanum melongena* L.) (Rosati *et al*., 2001), lettuce (*Lactuca sativa* L. 'Vegas') and lucerne (*Medicago sativa* L.) (Lemaire *et al*., 2005).

Zhang *et al*. (2007) found that applying the equivalent of 5 g N/plant to maize in soil with about 0.096% total N increased mature dry matter weight by 9-26% compared to plants that received no N depending on variety and soil moisture. This was also in agreement with the results of this study because increase in N recorded increases in fruit yield.

Despite the fact that aphids and thrips pest population increased with increasing N treatment, their numbers did not affect yield. This could be due to the fact that the populations were not high enough to adversely affect yield.

5.6 Determination of % N of the eggplant leaves

The various N treatment plots recorded appreciable amounts of N in the leaves. The eggplant leaves quickly absorbed and partitioned the N component of the liquid fertilizer to use in the synthesis of amino acid (proteins) to make them rich and succulent. The control treatment recorded the least because of the use of N already present in the soil. This is in agreement with Jansson *et al*. (1986) and Marschner (1995) that increase in N fertilization results in the accumulations of amino acid in the plant thus attracting sucking insects. Adequate supply of N is associated with high photosynthetic activity, vigorous vegetative growth and a dark green colour of the leaves (John *et al*., 2004).

Also, N partitioned in the crop in the form of phenols and amino acids (protein), making the foliage extremely succulent, therefore, becoming susceptible to both diseases and pests incidence (Youdeowei, 2002).

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The population dynamics of *Aphis gossypii* and *Thrips palmi* and their within-plant patterns of aggregation needs to be known before implementing integrated pest management programmes. *A. gossypii* population was higher in the major season than the minor season which also corresponded with the population of the natural enemy, *Epilachna chrysonilia*. The highest *A. gossypii* population was recorded on the treatment plots with the highest N fertilizer and the lowest recorded on the control plot. Also, more *A. gossypii* were sampled in the lower canopy in both seasons than in the upper canopy. However, the *Thrips palmi* population was higher in the minor season than the major season and also corresponded with their natural enemy population (ladybird beetles). More *T. palmi* were sampled in the upper canopy than the lower canopy in both the major and the minor seasons. The highest *T. palmi* population was recorded on the highest N treatment plots and the lowest on the control plots. The major season recorded higher yield than the minor season despite increased insect (*A. gossypii* and *T. palmi*) population and the high yield was recorded in the highest N treatment plots.

6.2 Recommendation

It is recommended that the research be extended beyond two seasons to better understand the dynamics of the insects over a long period probably in a different agro-ecological zone.

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