IMPACT OF DIFFERENT LEVELS OF NITROGEN FERTILIZER ON THE POPULATION DYNAMICS AND WITHIN PLANT DISTRIBUTION OF *Podagrica* species AND YIELD OF OKRA

BY

SIMON OSEI–ASSIBEY

NOVEMBER, 2013

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF CROP AND SOIL SCIENCES

IMPACT OF DIFFERENT LEVELS OF NITROGEN FERTILIZER ON THE POPULATION DYNAMICS AND WITHIN PLANT DISTRIBUTION OF *Podagrica* species AND YIELD OF OKRA

BY

SIMON OSEI–ASSIBEY

(B.Sc. (HONS) AGRICULTURE)

NOVEMBER, 2013

IMPACT OF DIFFERENT LEVELS OF NITROGEN FERTILIZER ON THE POPULATION DYNAMICS AND WITHIN PLANT DISTRIBUTION OF *Podagrica* species AND YIELD OF OKRA

BY

SIMON OSEI–ASSIBEY

(B.Sc. (HONS) AGRICULTURE)

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

NOVEMBER, 2013

DECLARATION

I, Osei-Assibey Simon, 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.

Simon Osei-Assibey …… ……

PG4239510 Signature Date

Student

Dr. E. A. Osekre …… ……

Supervisor Signature Date

Certified by:

Dr. Charles Kwoseh …… ……

Head of Department Signature Date

DEDICATION

This dissertation is dedicated to the El Shaddai God for His blessings and assistance in all my educational endeavours and the Presiding Bishop, Dr. Evangelist Dag Heward-Mills of the Lighthouse Chapel International for his immense contribution that has made me what I am today (1 Cor. 15: 10a). Lord God, I am really grateful for how far you have brought me. Thank you

ACKNOWLEDGEMENT

My heartfelt gratitude goes to my supervisor Dr. E.A. Osekre, Dr. Nana Ewusi-Mensah and Dr. V. Logah for creating an enabling environment for the research work to be carried out, and the constructive criticisms they gave me to realize this thesis. I also owe a great deal of appreciation to Mr. A. Abetifia of the Soil Research Institute of the Council for Scientific and Industrial Research, who helped me in a number of ways in the soil and leaf protein analysis. It will be ingratitude on my part not to mention the assistance Mr. K. Brako, a worker at the Plantation Section, Department of Crop and Soil Sciences, Faculty of Agriculture, gave me. Special thanks to Mrs. J. Asante of the Entomology Laboratory, Department of Crop and Soil Sciences, Faculty of Agriculture for assisting me in the Laboratory.

I would not have gotten to this academic height if my wife, Mrs. Grace Osei-Assibey had not supported me emotionally, psychologically, prayerfully and financially. I therefore, seize this opportune time to say a big thank you to you, my love and may the Almighty richly bless you with what money cannot buy, Amen.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

In West Africa, okra cultivation is bedeviled with insect pests' infestation, especially flea beetles, *Podagrica* spp. Several studies on population of these pests have been reported but very little literature is available on their seasonal variation and distribution within the okra plant. This research was undertaken with the objective to investigate the population dynamics and within plant distribution of *Podagrica* spp. on okra as influenced by different levels of N-fertilizer. This research was conducted in the major (April-June) and the minor seasons (July-October) in 2011 at the Plantation Section of the Department of Crop and Soil Sciences of the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. Okra (Asontem variety) was used; three levels of NPK fertilizer (40-30-30, 50-30-30, 60-30-30) $kgha^{-1}$ and a control (no fertilizer) were imposed as soil amendment in Randomised Complete Block Design with four replications. Plots with the highest dose of N recorded significantly ($P< 0.05$) higher number of *Podagrica* spp. and higher yield in both seasons despite the increased *Podagrica* spp. numbers. Plots that received highest dose of N also recorded significantly ($P< 0.05$) number of fruits. Again, significantly ($P< 0.05$) more *Podagrica* spp. aggregated in the upper canopy than the lower canopy in both seasons. Significantly higher number of *Podagrica* spp. was collected in the major season than in the minor season. The per cent number of holes in the leaves was significantly ($P< 0.05$) higher in plots that received higher N doses where significantly more *Podagrica* spp. aggregated. The findings of this study could serve as a guide to design sampling protocol for *Podagrica* spp. on okra.

CHAPTER ONE

1.0 INTRODUCTION

Okra, *Abelmoschus esculentus* (L.) Moench is an important vegetable crop consumed worldwide. It is a member of the malvaeceae family. It is widely cultivated in the tropics and subtropics for its immature edible green fruits and consumed as a vegetable, raw, cooked or fried (George, 1999). It is a common ingredient of soups and sauces. The fruits can be conserved by drying or pickling. The leaves are sometimes used as a substitute for spinach. The tender fruits, leaves and succulent shoots are consumed, either in fresh or dried form (Arapitsas, 2008).

The fruit is a greenish capsule, slightly curved, six-chambered pods of fibrous texture, containing numerous seeds (Lengsfeld *et al*., 2004). The thick slimy juice of the fruit makes it a relish and a thickener of stews and contains vitamin C and some minerals such as phosphorus, calcium and potassium and has larger concentration of thiamine, riboflavin and niacin than many vegetables (Ranganna, 1979). It is a source of carbohydrate, dietary fibre, fat and protein (Asawalam *et al.,* 2007). Okra seeds serve as a good substitute for coffee and contain a considerable amount of good quality oil. Its consumption among other fruit vegetables was found beneficial in moderating blood pressure, fibrinogen concentration and plasma viscosity in Nigerian hypertensives' (Adebawoo *et al.,* 2007).

Problems of okra production in general are insect pests' infestations, disease incidence and poor soil fertility. It has become a common sight to find numerous perforations on the leaves of okra usually by herbivorous insects, which is almost being accepted as a common feature of the crop (Egwuatu, 1982). One of the limiting factors to profitable production of okra is damage by insect pests (Praveen and Dhandapan, 2002). Youdeowi (2002) has documented insects of primary importance in okra cultivation.

In West Africa, the plant is attacked by two flea beetle species (which are also the most important insect pests), *Podagrica uniformis* (Jac) and *Podagrica sjostedti*(Jac) (Odebiyi, 1980) which are responsible for heavy defoliation. These insects also transmit the okra mosaic virus which causes significant yield losses (Vanlommel *et al*., 1996). Important yield losses are reported in Nigeria and Ghana (Obeng-Ofori and Sackey, 2003; Ahmed *et al*., 2007).

Okra grows best on loams and sandy loams, but will produce good yields on heavier soils. One of the effects of applying soil amendments, especially nitrates to the soil is to increase leaf area. This is agronomically the most important result of fertilizer application because an increase in leaf area results in improved radiation intercepted by the crop and therefore higher rate of photosynthesis (Varela and Seif, 2004). Besides its effect on growth, development and yield of crops, application of nitrogen has also been reported to influence the susceptibility of plants to pests and diseases (Youdeowei, 2002).

Several researchers have worked on the population of flea beetles on okra, but not much has been reported on the seasonal variations and their distribution within the okra plant. Echezona *et al.* (2010) researched on flea beetles' population and economic yield of okra. Effective pest management strategy in yet reduced pesticide use would depend on good insect sampling protocol as a way to target insect pests within plants. Quantifying the within- plant distribution of *Thrips* species on cotton is important for the development of reliable and cost-effective sampling protocols (Atakan *et al*., 1996)

Baidoo and Mochiah (2011) researched into the influence of nutrient application on the pests and the natural enemies of the pests of okra. It is also important to note that the distribution of these pests within the plant and seasonal fluctuation of their numbers remain an area with relatively low research. It is against this background that this research was undertaken with

the objective to investigate the population dynamics and within plant distribution of flea beetles (*Podagrica* spp.) on okra as influenced by different levels of N-fertilizer. The hypothesis was that high N-fertilizer levels will increase the protein content of the okra plant whichthis would make the plant more susceptible to *Podagrica* spp. and hence attract higher numbers of the pest. The specific objectives of this research were to determine the:

- effect of different N levels on within plant aggregation of *Podagrica* spp. on okra
- population dynamics of *Podagrica* spp. on okra.
- Effect of the population of *Podagrica* spp. on yield of okra.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Background

Pests have been a major setback for the success or growth of many crops all over the world. It has been shown that pests cause major damage to the foliage and fruits of plants as well as bore into their stems. These forms of damage had caused poor yield of various crop plants including okra. Okra insect pests have been categorized into two; those that attack at early stage, for example, aphids; and those that appear later at the stage of pods production, such as green stink bugs, cabbage loppers, corn earworm, European corn borers and the leaf-footed plant bug.

2.2 History and origin of okra

The geographical origin of okra is disputed, with supporters of South Asian, Ethiopian and West African origin. Supporters of a South Asian origin point to the presence of its proposed parents in that region. Opposed to this is the lack of a word for okra in the ancient languages of India, suggesting that it arrived there in the Christian era. Supporters of West African origin point to the greater diversity of okra in that region; however confusion between Okra and *Abelmoschus caillei* (L.) Moench (West African okra) casts doubt on those analyses. The Egyptians and Moors of the 12th and 13th centuries used the Arabic word for the plant 'bamay', suggesting that it had come from the east (Chauhan, 1972). The plant may have entered south west Asia across the Red Sea or strait to the Arabian Peninsula rather than north across the Sahara, or from India. One of the earliest accounts is by Spanish Moor who visited Egypt in 1216, who described the plant under cultivation by the locals who ate the tender, young pods with meal (NRC, 2006). From Arabia, the plant spread around the shores

of the Mediterranean Sea and eastward. The plant was introduced to the America by ships plying the Atlantic slave trade by 1658, when its presence was recorded in Brazil (Chauhan, 1972).

The Portuguese are believed to have corrupted "Gumbo" to mean, quin-gombo, of the word quillobo, native name for the plant in the Congo and Angola area of Africa. Okra apparently originated in what the geobotanists called the Abyssinian center of origin of cultivated plants, an area that includes present-day Ethiopia, the mountainous or plateau portion of Eritrea, and the eastern, higher part of the Anglo-Egyptian Sudan. The route, by which okra was taken from Ethiopia to North Africa, the eastern Mediterranean, Arabia, and India, are by no means certain. Although it has been commonly cultivated in Egypt for many hundreds of years, no sign of it has ever been found in any of the ancient monuments or relics of old Egypt. Since the Spanish Moors, the absence of any ancient Indian names for it suggests that it reached India after the beginning of the Christian era (Chauhan, 1972).

This crop is suitable for cultivation as a garden crop as well as on large commercial farms. It is grown commercially in India, Turkey, Iran, Western Africa, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Burma, Japan, Malaysia, Brazil, Ghana, Ethiopia, Cyprus and the Southern United States. India ranks first in the world with 3.5 million tonnes (70 % of the total world production) of okra produced from over 0.35 million hectare land (FAOSTAT, 2008). It is quite popular in India because of easy cultivation, dependable yield and adaptability to varying moisture conditions (Chauhan, 1972).

2.3 Structure and botany of okra

Okra is a stout, erect annual herb that grows to 4 m tall with spirally-arranged leaves with leaf blades up to 50 cm diameter and more or less deeply 3-5- and 7-lobed. Leaves are alternate and usually palmately five lobed, whereas the flower is axillary and solitary. Okra plants are characterized by indeterminate growth. Okra pods produce numerous, gray to black seeds. Generally, okra seeds germinate about 5-7 days after sowing and seedlings may have 3-4 leaves per plant with height of approximately 12-18 cm for one to two weeks. The vegetative stage of okra is between three to four weeks from seed germination after which bud and flowering initiation begins. Leaves are bigger and a plant has more than eight leaves. Length of stem between leaves is longer. Yellow solitary flowers are in the leaf axils. Okra usually flowers within 40-90 days after sowing. Flowering is continuous but highly dependent upon biotic and abiotic stress. Flower initiation and flowering are delayed at higher temperatures. There is positive correlation between temperatures and the number of vegetative internodes (Chadha, 2002).

The plant usually bears its first flowers one to two months after sowing. The fruit is a capsule and grows quickly after flowering. Flower opens in the morning. Fruits or pods are green, cylindrical to pyramidal capsule 5-35 cm long and 1-5 cm in diameter. On the seed crop, vegetative growth stops soon after anthesis, all assimilates being partitioned to the reproductive plants parts. Okra is mainly propagated by seeds and has duration of 90-100 days (Chadha, 2002).

2 .4 Climate, soil and growth requirement

Okra is a tropical crop. The plant needs warm weather and plenty of sunshine. It thrives well in different soil conditions, but it is best grown in well- drained sandy and clay loam soil, especially with rich organic matter. The plant is best adapted to a climate with a long, warm

growing season throughout the year producing good yields provided the soil is fertile and there is sufficient moisture. It grows well on a maximum average temperature of 35 ºC with a minimum average above 18 ºC. Seeds will only germinate in relatively warmly soils. Its optimal temperature for germination, growth and fruit setting is between 25 ^{o}C and 30 ^{o}C. No germination occurs below 16 ^{o}C and monthly average temperature range of 20 ^{o}C to 30 ^{o}C is considered favourable for growth, flowering and pod development. Okra is tolerant to a wide range of rainfall; but supplementary irrigation may be required up to the fruiting period if the rainfall is marginal to adequately maintain vigorous growth. Most selections are well adapted to cultivate in up to 500 m and above (Chadha, 2002).

The crop can be grown in soils with pH range from 4.5 to 7. It may be grown at elevations from sea level up to 30 m (Gopalan *et al*., 2007). Okra is planted twice a year, from April to June and October to January. Okra requires a long, warm and humid growing period. It can be successfully grown in hot humid areas. It is sensitive to extremely low temperatures. For normal growth and development a temperature between 24 °C and 28 °C is preferred. At 24 °C the first flower bud may appear in the third leaf axil while at 28 °C it may appear in sixth leaf axil (Chadha, 2002).

The appearance of the flower buds in the sixth leaf axil is not necessarily accompanied with a delay in time but because at higher temperatures the plants grow faster and the higher position is reached earlier. For faster plant growth higher temperature still helps though it delays fruiting. At higher temperatures beyond 40 °C–42 °C, flowers may desiccate and drop, causing yield losses. Beyond this range the germination will be delayed and weak seeds may not even germinate (FAOSTAT, 2008).

2.5 Uses of okra

Okra is mainly grown for its young immature fruits and consumed as a vegetable, raw, cooked or fried. It is common ingredient in soups and sauces. The fruits can be conserved by drying or pickling. The leaves are sometimes used as a substitute for spinach or cattle feed, the fibers from the stem for cord, the mucilages for medical and industrial purposes, and the seeds as a substitute for coffee. Okra seeds contain a considerable amount of good quality oil and protein (Franklin, 1982). Okra is a good source of vitamins and minerals. It is very rich in calcium (70-90 mg/100 g) and other nutrients (USDA, 2000).

2.6 Pests of okra

2.6.1 Insects Pests

Okra is attacked by several species of insect pests and infested by a few diseases from seed germination, seedling emergence, flowering through to fruit setting stage to senescence. Okra is attacked by a number of insect pests at various stages of the plant's development. Okra has a few noticeable pests. Among these insects are whiteflies (*Bemisia tabaci* (Genn)), cotton thrips (*Thrips palmi* (Karny)), okra stem and fruit borer (*Earias vittela* (Fab)), stink bugs, corn ear-worms (*Spodoptera litura* (Fab)), melon aphids (*Aphis gossypii* (Glover)) and flea beetles (*Podagrica* spp. (Jac)). Pods curled or with wart-like protrusions commonly indicate earlier feeding damage by stink bugs and/or leaf footed bugs. Corn earworms also infest pods occasionally (FAO, 2006).

Leafhoppers, aphids and whiteflies attack at seedling to early vegetative stage. These insects transmit yellow vein mosaic virus (YVMV) in okra (Youdeowei, 2002). The stem borers at early vegetative stage damage the shoots. The plants then develop branches to compensate for the damage by stem borers. Fruit worm, stem and pod borer feed on flowers and bore inside

the pods. Cutworm usually feeds on the leaves and this injury does not greatly affect the photosynthetic ability of the whole plant.

Damage to the foliage is normally unimportant, unless Japanese beetle populations are unusually high. Corn earworm and Japanese beetles feed externally on buds, foliage or pods and their chewing habit leaves holes in plants, foliage and the buds while aphids, leaf footed bugs and Stink bugs cause discoloration or distortion of plant.

2.6.2 Flea Beetles (*Podagrica* spp.)

Podagrica flea beetles are reported in most of West Africa countries as the major insect pests of okra with huge numbers of insects per plant (Ogbalu and Ekweozor, 2002; Obeng-Ofori and Sackey, 2003; Ukoima and Okah, 2006). Two species of *Podagrica* have been observed to infest okra plants from the stage of germination to all stages of its growth. They are mainly leaf eaters, and have biting and chewing mouthparts. The Flea beetle species common in West Africa are *Podagrica uniformis* (Jac) and *Podagrica sjostedti* (Jac) (Ogbalu and Ekweozor, 2002) .The same insects have also been recorded on okra in Ghana (Obeng-Ofori and Sackey, 2003). Flea beetles bore holes into the leaves and as a result, reduce the photosynthetic ability of the leaves (Baidoo and Mochiah, 2011). *Podagrica* spp. infest the seedlings and can cause damage of economic importance by feeding on the leaves. According to Obeng – Ofori and Sackey (2003) *Podagrica* spp. cause severe yield losses in okra production in Ghana. It was also reported by Ahmed *et al.* (2007) to cause yield losses in Nigeria. Odebiyi (1980) documented heavy defoliation of okra by *Podagrica* spp. resulting in heavy losses in West Africa.

2.6.3 Biology of Flea Beetle (*Podagrica* spp.)

Flea beetles are tiny pests that take tiny bites, but collectively they can cause severe damage to garden plants. With the exception of the larger spinach flea beetles, these pests, measure

just a few mm long. Most species have darkish or bluish elytra and a typical example is *Podagrica sjostedti* (Jac); the others have a metallic shine or shiny brown elytra and typical example is *Podagrica uniformis* (Jac). Flea beetles are so named for their ability to jump when disturbed; they have large hind legs that give them a surprising vertical leap. Adult flea beetles overwinter in leaf litter, garden debris, or other sheltered places (Adenuga, 1970; Grubinger, 2011).

Their feeding on the leaves of solanaceous crops like eggplant, pepper and tomato can delay establishment of seedlings or even kill them. The flea beetle though are leaf miners, do not get attracted to old or waxier leaves. The waxier leaves are difficult for beetles to grasp and feed on. So, once seedlings have grown beyond the two- or three-leaf stage, flea beetles tend to be less of a threat. The first leaves to emerge on vegetable crops like cabbage, okra, etc are very attractive to them (Grubinger, 2011). The flea beetles do not just attack leaves; in their larval stage they also feed on roots.

As temperatures begin to rise in the cold, the adults emerge and locate suitable host plants on which they feed. Some flea beetles will feed on weeds until garden crops are available. Flea beetles lay eggs in the soil around the base of host plants. The eggs hatch in a week or two and the larvae feed on plants until fully grown. The larvae feed on root hairs of the plant and develop into adults within about 13 days. The adults aestivate in the soil during the dry season and come to the surface of the soil at beginning of another growing season (Adenuga, 1970).

Since, flea beetles prefer fleshy and succulently emerged leaves to old or waxier ones, earlier scouting and identification is crucial. The choice of flower buds, flowers, succulent fruits as well as matured fruits for food by the flea beetles has also been documented by Lingren *et al*.(1993) Newly planted fields should be scouted for flea beetles and their damage every day

or two while plant are small and unable to tolerate much damage (Grubinger, 2011). It is easier to count the beetles if the leaves not disturbed, when scouting. If there is an average of two to five beetles per plant, some control is probably needed to prevent crop loss. Larger plants withstand more feeding injury than the young and tender ones (Grubinger, 2011).

2.7 Effect of fertilization on plant growth

Fertilizers are major input for increased agricultural productivity. Nitrogen is important for plant growth partly due to its influence on leaf area index and consequently light interception (Jones, 1992; Grindlay, 1997).Varela and Seif (2004), 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. It has severally been reported that the main effect of N fertilization is an increased 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), increasing the N supply has been shown to increase the leaf area index, light interception and dry matter production. Lawlor (2002) and Ulukan (2008) have underscored the importance of N for vegetative growth in plants. Leaf growth is greatly affected by N and the response is more pronounced under increasing N supply when N is limiting (Lawlor, 2002).

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. Phosphorus fertilization can influence fruiting and fruit development of okra. Phosphorus is directly involved in most living processes. It is a key constituent of ATP and thus plays a significant role in energy transformation in plants and also in various physiological processes (Shivasankeb *et al*., 1982). Phosphorus helps in nutrients uptake by promoting root growth and thereby ensuring a good pod yield through the increase in total dry matter (Sharma and Yadev, 1976).

Many researchers reported the effect of phosphorus application on green pod yield of okra (Gupta *et al.,* 1981; Mohanta, 1998; Sadat, 2000). 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).

Fertilization as an input influences 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).

The application of nitrate as soil amendment offers crop plant the leverage to produce foliage with large surface area. Nitrogen 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 *etal*., 2004). There is some evidence that application of synthetic fertilizers reduce the resistance of crop plant to insect pests (Yardim and Edwards, 2003). Hence, the application of N fertilizer significantly increases the incidence of pests and diseases (Youdeowei, 2002).

2.8 Response of Okra crop to Nitrogen Fertilizer

One of the factors limiting okra production is soil nutrient content especially N. The N-fertilizer makes up to 50 % of all the nutrients inputs, and its availability play an important role in determining farmers' crop yield. This has been attributed to the fact that its role in the plant cannot be easily subsidized (Kaarstad, 1997). Application of N has been reported to significantly improve okra growth (Sharma *et al*., 1976; Katung *et al*., 1996), dry matter partitioning (Akanbi *et al*., 2002) and fruit yield (Fatokun and Cheda, 1981). Nitrogen is an essential element and important determinant in growth and development of crop plants. It plays an important role in chlorophyll, protein, nucleic acid, hormone, vitamin synthesis and also helps in cell division and cell elongation.

Several workers have reported linear increase in green pod yield of okra with the application of N from 56 to150 $kgha^{-1}$(Hooda *et al.*, 1980; Mani and Ramanathan, 1980; Majanbu *et al.*, 1985; Singh, 1995). It was reported by Sultana (2002) that N fertilizer level at 100 $kgha^{-1}$enhances growth, development and yield of okra. The finding of Firoz (2009), upon assessing the impact of N and P on growth and development of okra was not different. It is the nutrient that is most commonly deficient in soils, contributing to reduce crop yields throughout the world (Van and Hartley, 2000). Nitrogen may influence semiochemicals and nutritional values of plants and also behavioural characteristics of 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* (Hubner) in maize leaves (Kalule and Wright, 2002).

Nitrogen 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). Bentz *et al*. (1995) found that the (protein) N 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* (Genn) (Phelan *et al*., 1995)on Poinsethia which also increases linearly with the increase of plant N content.

Herbivorous flies 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). Nitrogen is 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 pest incidence (Anon, 1994; Youdeowei, 2002). It is hypothesized that increases in N levels in plants can enhance populations of invertebrate herbivores living on them (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* (Genn) (Bentz *et al*., 1995) and attracted more individuals to oviposit on them. 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. The 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). 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). High levels of N reduced glycoalkaloid synthesis, which has inhibitory effect on insect pests of potatoes (Fragoyiannis *et al*., 2001).

Barbour *et al*. (1991), investigating interactions between fertilizer regimes and host-plants resistance in tomatoes, showed that the survival of Colorado potato beetles and 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 tomato receiving large amounts of N, N could also cause significantly faster insect development and increased pupal biomas (Hunt *et al*., 1992).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study site and location

The research was carried out at the experimental site (Plantation) of the Department of Crop and Soil Sciences of the Kwame Nkrumah University of Science and Technology Kumasi, Ghana. The area lies at altitude 261.4 MSL, Latitude 06^0 41'N and Longitude 01^0 33' W, (Ghana Meteorological Service, 2011).

3.2 Climatic conditions of the study site

The area is within semi-deciduous forest zone with bimodal rainfall. The major season starts from March to June and the minor season starts July through to December. The mean monthly rainfall, temperature and relative humidity for the period are 139.9 mm, 26.95 ^oC and 72.5 % respectively. Generally, the area records the highest sunshine duration between October and May, (within the range of 5.1-7.5 h) with the peak falling on November, and the lowest range of sunshine duration recorded between June and September (within the range of 2.0-4.2 h) with minimum duration occurring in August, 2011(Ghana Meteorological Service, 2011).

3.3 Routine Soil 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:

3.3.1 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.

3.3.2 Soil Organic Carbon

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

3.3.3 Total nitrogen

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

3.3.4 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). Phosphorus in the sample was determined on a spectrophotometer by the blue ammonium molybdate with ascorbic acid as a reducing agent.

3.3.5 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.

3.4 Preparation of the experimental field

The experimental plot was slashed, ploughed and harrowed to a fine tilt and divided into four blocks, each measuring 10.0 m × 24.0 m. Each block is made up of four treatment plots with each measuring 6.0 m x 10.0 m, with alleys of 1.0 m between them. Between each of the four blocks was an alley of 2.0 m.

3.5 Experimental design and treatment allocation

The experiment was arranged in a randomized complete block design. These were three treatments and a control. Each treatment was allocated to each of the plots within a block. The treatments were randomly assigned to the plots. No insecticides were applied throughout the experiment. The treatment allocations to the various plots were as follows:

T1 = control (no NPK fertilizer application)

T2 = 40-30-30 NPK kg ha^{-1}

T3 = 50-30-30 NPK kg ha^{-1}

T4 = 60-30-30 NPK kg ha^{-1}

3.6 Source Seed and Variety

Okra seeds (Asontem var) were obtained from the Horticulture Department of the Crops Research Institute of the Council for Scientific and Industrial Research (CSIR-CRI), Kwadaso, Kumasi. This variety is early maturing, relatively high yielding and thrives well in West Africa, especially Ghana where it is commonly grown. It has a long shell life. It is also susceptible to *Podagrica* spp.

3.7 Sowing of seeds

The okra seeds were soaked overnight to hasten germination, and viable seeds (seeds that sunk) were selected and those that floated (non-viable seeds) discarded. To facilitate seedling emergence, sowing was done after a good rain, having prepared the land adequately to a fine tilt. The land was lined and pegged and sowing was then done with use of a dibber at three seeds per hill at the depth of 3.0 cm and at spacing of 80.0 cm between rows and 60.0 cm within rows. Filling in of seeds was done seven days after emergence.There were seven rows

of seedlings and the seedlings were later thinned to one plant per stand at the two seed-leaf stage.

3.8 Cultural practices

All cultural practices were employed as and when needed. No herbicides were applied. Weeds were controlled manually three days after seedlings emerged from the soil and at 14, 28, 42 and 56 days after emergence (DAE). During the second season it became necessary to water the plots using watering can. To ensure that the soil nutrients became available to the crops, watering was carried out for four weeks at three days interval in order to get the seedlings well established after emergence.

3.9 Application of treatments

The sources of the N-fertilizers were NPK and sulphate of ammonia. The treatment application was split into two; first application was done two weeks after seedling emergence and the second, two weeks after the first application.

Application of NPK at 30-30-30 for the three treatments (40-30-30; 50-30-30 and 60-30-30 kg NPK ha^{-1}) was done at the rate of 18 g/ per okra plant. To make up for the remaining levels of N (10, 20 and 30) in the respective treatments, sulphate of ammonia was used where 15 % of N was calculated for each of the remaining N-levels and applied as 4 g, 8 g and 12 g per plant, respectively. The NPK fertilizer was applied using ring application and top-dressed with the sulphate of ammonia.

After the NPK application, the sulphate of ammonia as a top dressing was applied two days after the ring application to avoid the tender seedlings from scorching. The application of treatments was repeated four weeks after seedling emergence when the plant really needed nutrient for fruit setting. A control plot had no fertilizer application.

3.10 Data collection

3.10.1 Sampling for *Podagrica* spp.

Sampling for the insects began at the three-leaf stage. Samples were taken between 0700 and 0900 h. For the first four weeks after seedling emergence, the above- ground parts of five plants were randomly cut weekly into separate 0.5 l plastic containers containing 70 % ethanol and transported to the Entomology laboratory for processing. The sampled plants were taken from the two middle rows of each treatment plot. From the fifth week onwards, a leaf from the lower and upper canopies each of five randomly selected plants from the middle rows in each plot were sampled and separately subjected to the same laboratory procedure stated previously.

Approximately sixth weeks after seedlings emergence, random sampling for flower buds and flowers began. At the field, flower buds and flowers were sampled at random from five plants from each plot. The sampled flower buds and flower were put into separate plastic containers containing 70 % ethanol and transported to the laboratory for processing. The numbers of adult *Podagrica* spp. were determined per plant part for each sample after the samples had been examined under stereomicroscope.

3.10.2 Leaf Damage and Percentage Defoliation

Percent leaf defoliation and number of holes made on the leaves of the sampled plants were recorded as damage done to the crops by the flea beetles. For the estimation of percentage defoliation, critical observation of leaves was made and sections of the leaves that have lost virtually all the photosynthetic sites (scarified leaves or holes) through the feeding habits of the flea beetles were considered as defoliated. Percentage defoliation was calculated as follows:

$$\% \text{ Defoliation } = \frac{\text{Total number of leaves defoliated}}{\text{Total number of leaves in a sample}} \text{ x } 100$$

3.11 Yield and Growth Components

3.11.1 Plant Height

Plant height of 16 treated plots was considered. The plants from which measurement were taken were randomly selected from the other rows apart from the ones used for sampling for insects and the border plants. Five plants of each treated plot were measured 2 cm from the base of the plants to the crown or the terminal point of the plant with a tape measure and values recorded. Weekly measurement of plant height started two weeks after seedling emergence and continued consecutively for eight weeks.

3.11.2 Number of leaves

The number of leaves of the plants, whose plant heights were taken, was also recorded on weekly basis for a period of eight weeks and the means determined.

3.11.3 Leaf area determination

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.

3.11.4 Yield analysis

Harvesting of fresh fruits started seven weeks after seedling emergence and it was done three days interval for four consecutive weeks. Fruits that broke easily when pressed at the tip of

the fingers were selected and harvested. Harvested fruits of each treatment were counted. The weight and the length of fruits harvested were taken using weighing scale and metre rule.

3.11.5 Total Nitrogen of the Okra leaves

The macro Kjeldahl method involving digestion and distillation as described in Soil Laboratory Staff (1984) was used in determining the N content of the leaves.

3.12 Data Analysis

Data for each season were subjected to analysis of variance [ANOVA] using SAS (8.2) GLM procedure (SAS institute, 2010). For the insects, data collected over the period were 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 levels (upper and lower) and other plant parts (flower buds and flowers) were run separately. The other data (plant height, pods length, leaf area &pods weight) were also 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 other data at 5 % probability level.

The plant data (height, pods length, pods weight, etc) and soil data recorded throughout the experiment were subjected to ANOVA using Genstat Windows Software Pack (version 9).

CHAPTER FOUR

4.0 RESULTS

4.1 Background of Selected physico-chemical properties of soil of the experimental field

The initial physico-chemical properties of the field (soil)are presented in Appendix 1.The results indicated that the soil was moderate in available P, total N and effective cations exchange capacity. Exchangeable K, Ca and Mg of the soil were moderately adequate for okra production. The soil was moderately and predominantly sandy loam. The pH of the soil was within the range of 6.07-7.04.

4.1.1 Selected Chemical Properties of soil after application of treatment

The Appendices 2 and 3 indicate some selected physico-chemical properties of the soil after application of treatments during the experiment.

4.2 INSECT PEST POPULATION

4.2.1. Aggregation of *Podagrica* spp. on okra in response to N during the major season

Generally, NPK application resulted in higher *Podagrica* spp. numbers than the control. The aggregation of *Podagrica* spp. per leaf recorded on the control plots in almost all the sample dates were in the range of 0.5 and 1.5.

Within the N-applications, *Podagrica* spp. numbers per leaf increased as the N levels in the treatments were raised (Fig. 4.1). NPK 40-30-30 plots recorded increases in the number of *Podagrica* spp. per leaf from 19th May to 23rd June but dropped by 30th June. It recorded a density peak of 1.5 per leaf on 2nd June and 23rd June.

The trend was not different from what was recorded on the NPK 50-30-30 and 60-30-30 plots. Similarly, a peak density of 1.8 per leaf of *Podagrica* spp. collected on NPK 50-30-30

occurred on 2nd June and 23rd June. The NPK 60-30-30 plots, on the other hand, recorded a single peak of 2.0 per leaf on 23rd June.

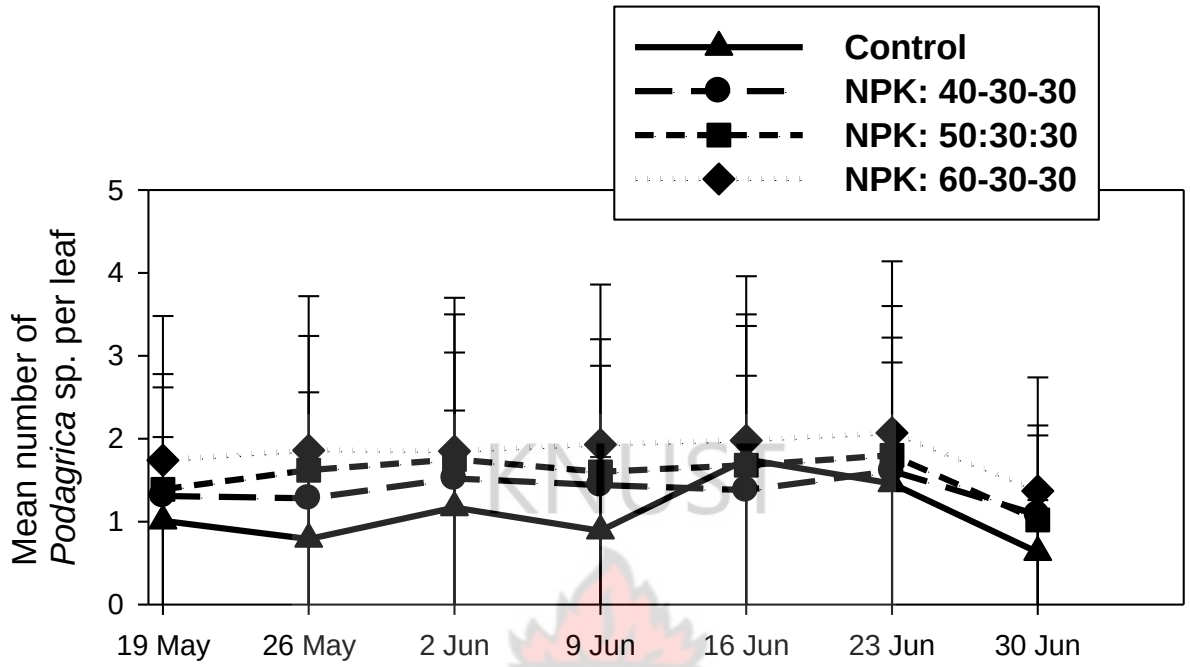

Fig 4.1: Mean (±SEM) **number of *Podagrica* spp. per leaf recorded during the major Season on okra**

4.2.2 Aggregation of *Podagrica* spp. on okra in response to N during the minor season

The minor season's results were similar to that of the major season. The control treated plots recorded least numbers of *Podagrica* spp. on all sample dates. Within the N-applications, *Podagrica* spp. number per leaf increased, similar to what was recorded during the major season with their densities increasing as the N levels in the treatments were raised (Fig. 4.2). In the NPK 40-30-30 fertilizer treated plots the densities increased steadily and peaked at 1.4 per leaf on 29th September. It dropped on 6th October but rebound and peaked on 13th October. The NPK 50-30-30 and 60-30-30 also recorded increases in numbers over the period but dropped on 6th October and peaked again on 13th October (Fig.4.2).

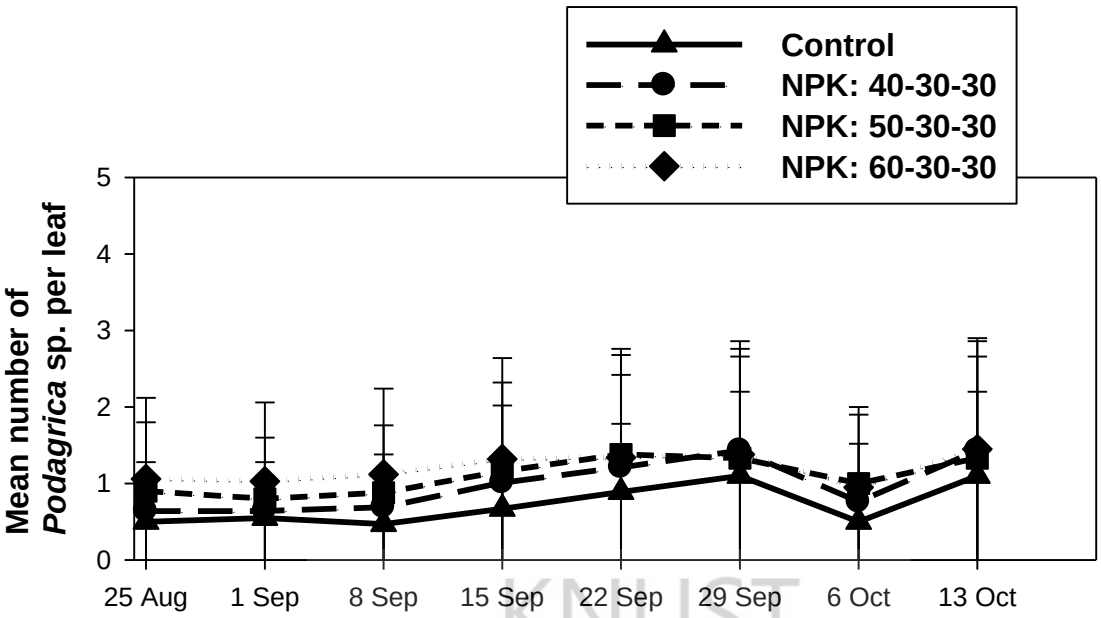

Fig. 4.2: Mean (±SEM) **number of *Podagrica* spp. per leaf recorded during the minor Season on okra**

4.2.3 Aggregation of *Podagrica* spp. on okra flower and flower buds in response to N

The densities of *Podagrica* spp. per flower and flower buds were greater than onein all N treated plots inboth the major and minor seasons (Table4.1).

In the major season, no significant differences were recorded among the treatments with respect to the densities of *Podagrica* spp. collected in the flower buds and flowers (Table 4.1). However, significant ($P < 0.05$) differences were recorded among the treatments in the minor season. More of the insects aggregated in the flowers of the 60-30-30 and 50-30-30 treated plots than that of the 40-30-30 and the untreated control. More *Podagrica* spp. were collected in the flowers of the 40-30-30 treated plots than the control plots. The number of the insects that aggregated in the flowers of the 60-30-30 plots was not significantly different from that collected in the 50-30-30 plots.

Table 4.1: Mean (±SEM) **numbers of *Podagrica* spp. per okra (*Abelmoschus esculentus*) flower and flower bud grown in different N treatments during both seasons, (April-June and July-Oct.) in 2011.**

	Mean number of *Podagrica* spp.	
Treatment	Major season	Minor season
40-30-30 (NPK) kgha^{-1}	$1.03 \pm 0.09\ a$	$1.00 \pm 0.05\ b$
50-30-30 (NKK) kgha^{-1}	$1.00 \pm 0.09\ a$	$1.26 \pm 0.05\ a$
60-30-30 (NPK) kgha^{-1}	$1.00 \pm 0.09\ a$	$1.30 \pm 0.05\ a$
Control	$0.71 \pm 0.09\ a$	$0.59 \pm 0.06\ c$

Means with the same letters within columns are not significantly different at 5% level of probability using Tukey´s test.

4.2.4 Aggregation of *Podarica* spp. within okra plant canopy in response to N

The mean numbers recorded were significantly ($P < 0.05$) higher in N treated plots than the control. In both seasons, untreated plots (control) recorded significantly ($P < 0.05$) higher densities of *Podagrica* spp. in the upper than the lower canopies (Tables 4.2 and 4.3).Tables 4.2 and 4.3 show similar trend for the NPK treated plots. The aggregation was significantly more in the upper than the lower canopy (Plates 1 and 2).

Table 4.2: Mean (±SEM) **numbersof *Podagrica* spp. per okra (*Abelmoschus esculentus*) collected on canopies during the major season (April-June) in 2011.**

	Mean number of *Podagrica* spp. per NPK treatments			
Canopy	Control	40-30-30	50-30-30	60-30-30
Upper canopy	$0.65 \pm 0.05\ a$	$0.82 \pm 0.06\ a$	$0.88 \pm 0.06\ a$	$1.55 \pm 0.05\ a$
Lower canopy	$0.15 \pm 0.03\ b$	$0.53 \pm 0.05\ b$	$0.51 \pm 0.05\ b$	$0.65 \pm 0.05\ b$

Means with the same letter within columns are not significantly different at 5% level of probability using Tukey´s test.

Table 4.3: Mean (±SEM) **numbersof *Podagrica* spp. per okra (*Abelmoschus esculentus*) collected on canopies during the minor season (July-October) in 2011.**

	Mean number of *Podagrica* spp. per NPK treatments			
Canopy	Control	40-30-30	50-30-30	60-30-30
Upper canopy	$0.55 \pm 0.05\ a$	$0.81 \pm 0.06\ a$	$0.84 \pm 0.06\ a$	$1.10 \pm 0.05\ a$
Lower canopy	$0.14 \pm 0.03\ b$	$0.48 \pm 0.05\ b$	$0.51 \pm 0.05\ b$	$0.62 \pm 0.05\ b$

Means with the same letter within columns are not significantly different at 5 % level of probability using Tukey´s test.

Plate1. Shows *Podagrica* spp. sampled on the upper canopy.


Plate 2. Shows *Podagrica* spp. sampled on the lower canopy.

4.3 Relationship between numbers of *Podagrica* spp. and % N in leaves

Figures 4.3 and 4.4 show the association between *Podagrica* spp. numbers and % N in okra leaves in the two seasons. Significant positive associations were observed between N content of the leaves and *Podagrica* spp. with R^2 values of 0.86 and 0.87 for the major and minor

seasons respectively. The R values on the other hand for the two seasons were 0.93 and 0.92 showing significant correlation ($P< 0.05$). Thus, N levels in plants imparted greatly on aggregation of the insects. As the N fertilization increased, there was steady rise of % N in the leaves. Hence, the abundance of *Podagrica* spp. are directly linked to the crude protein content of the leaves.

.

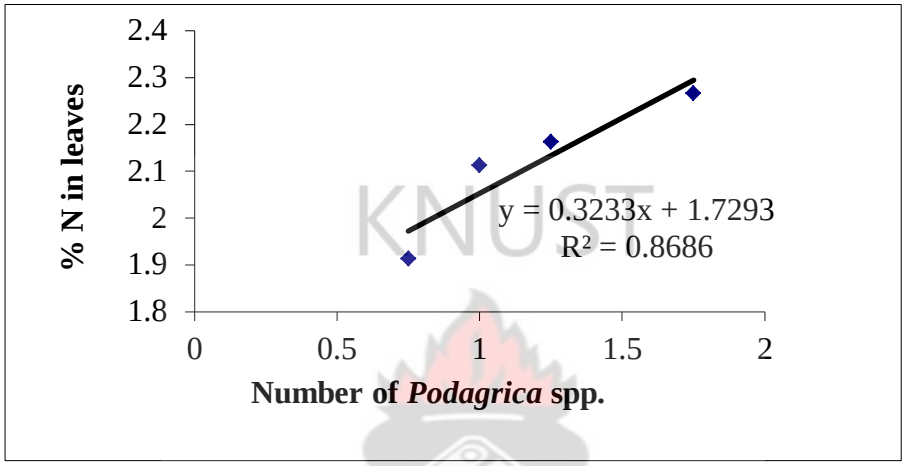

Fig. 4.3: Relationship between numbers of *Podagrica* spp. and % N in leaves during the major season.

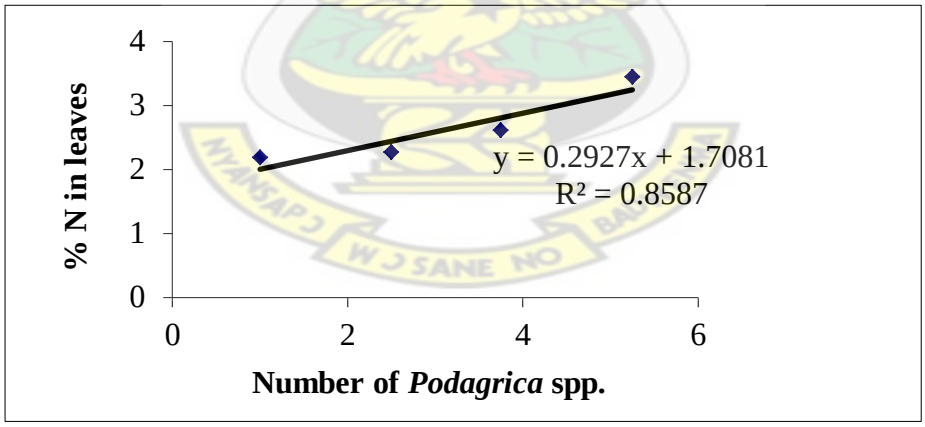

Fig.4.4: Relationship between numbers of *Podagrica* spp. and % N in leaves during the minor season.

4.4 Evaluating the relationship between numbers of *Podagrica* spp. and leaf damage

Figures 4.5 and 4.6 show the relationship between numbers of *Podagrica* and okra leaves damage. There was positive correlation between *Podagrica* numbers and number of holes in the leaves and the R^2 values for both seasons were 0.97 and 0.96. The R values for the two seasons was approximately 0.98. Thus okra leaves damage was pronounced with increased numbers of *Podagrica* spp. and vice versa. The positive correlation was significant ($P<0.05$).

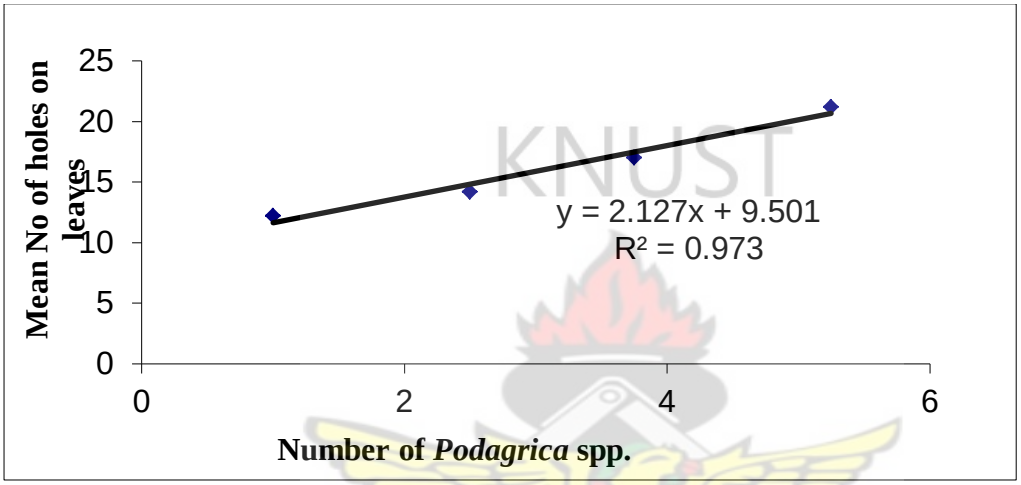

Fig 4.5: Relationship between *Podagrica* spp. and number of holes on leaves during major season, 2011.

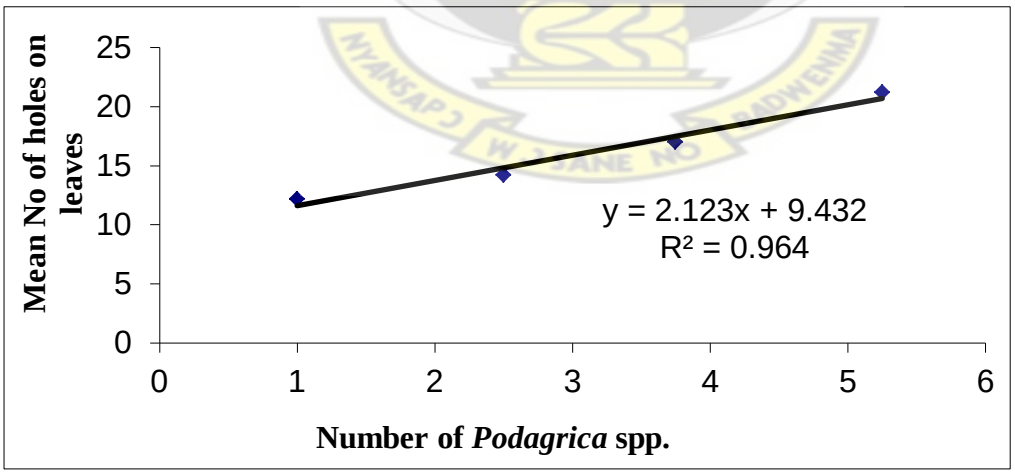

Fig 4.6: Relationship between *Podagrica* spp. and number of holes on leaves during minor season, 2011.

4.5 Damage of leaves by *Podagrica* spp.

Table 4.4shows the damage of okra leaves by *Podagrica* spp. for the two growing seasons. It can be observed that the percentage defoliation increased across N-fertilization levels. The per cent defoliation recorded in the control plots for the major season was 6.0 % as against 2.0 % in the minor. The 60-30-30 NPK treated plots, on the other hand, recorded 14.5 % and 10.5 %, respectively, in the major and minor seasons.

There were significant ($P<0.05$) differences between the control plots and the NPK fertilization levels. There were also significant ($P<0.05$) differences among NPK treatments in both the seasons, except between the 50-30-30 and 60-30-30 during the major season and between the 40-30-30 and 50-30-30 treated plots in the minor season.

Table 4.4: Percentage defoliation of okra leaves by *Podagrica* spp. in both seasons, 2011.

Treatment	Major	Minor
40-30-30 (NPK) $kgha^{-1}$	8.8	5.6
50-30-30 (NPK) $kgha^{-1}$	12.5	7.4
60-30-30 (NPK) $kgha^{-1}$	14.5	10.5
Control	6.0	2.0
Lsd (5 %)	2.3	2.4
CV %	21	11

4.6 Growth and Yield Data

4.6.1 Leaf Area

The mean leaf areas recorded on N-treated plots in both seasons were significantly bigger than that recorded for the control plots. The values for the control were 120.04 cm^2 and 155.0 cm^2 whilst 230.0 cm^2 and 313.1 cm^2 were recorded for the NPK 60-30-30 treated plots for the minor and major seasons, respectively. There were also significant ($P<0.05$) differences in the leaf area among the N-treated plots for both seasons (Tables 4.5 and 4.6). The 60-30-30 treated plots recorded significantly bigger ($P<0.05$) leaf area than the 50-30-30 plots which also had significantly bigger ($P<0.05$) leaf area than the 40-30-30 plots (Tables 4.5 and 4.6).

4.6.2 Plant Height

The mean plant heights recorded for all the N-treated plots during the two seasons were significantly ($P<0.05$) more than the control. The least plant height was recorded from plants of the NPK 40-30-30 treated plots. The 60-30-30 recorded plant heights of 18.01 cm and 27.30 cm respectively in the minor and major seasons. There was significant ($P<0.05$) difference between the plant heights of the 50-30-30 and 60-30-30 treated plots and each of these plots recorded taller plants than the 40-30-30 treated plots for both seasons (Tables 4.5 and 4.6).

4.6.3 Mean number of okra fruits

There were generally significant ($P<0.05$) difference between the control and all the NPK treated plots with respect to the number of fruits harvested for both seasons. Within the NPK treated plots, there was a significant ($P<0.05$) difference between the 40-30-30 and 50-30-30. There was also a significant $P<0.05$) differences between the 50-30-30 and 60-30-30 but that of the 40-30-30 and 60-30-30 was highly significant ($P<0.05$). However, there were no

significant differences between 50-30-30 and 60-30-30 treated plots during the minor season (Table 4.5 and 4.6).

4.6.4 Yield

There were significant ($P<0.05$) differences between the control and the all the NPK treated plots for both seasons. Within the NPK treated plots, there was a significant ($P<0.05$) difference between the 40-30-30 and the 50-30-30 plots in the minor season, but there were no significant ($P<0.05$) differences in the major season. Again, there was a significant ($P<0.05$) difference between the 40-30-30 and the 60-30-30 NPK treated plots for both seasons (Tables 4.5 and 4.6).

Table 4.5: The effect of NPK fertilizer on growth and yield parameters of okra during the major season 2011.

Treatment	Plant height (cm)	Leaf area cm^2	Meanno. of fruits/plot	Yield $kgha^{-1}$
40-30-30 (NPK) $kgha^{-1}$	24.3	155.0	185.0	195.2
50-30-30 (NPK) $kgha^{-1}$	25.9	229.1	204.0	192.5
60-30-30 (NPK) $kgha^{-1}$	27.3	313.1	214.2	233.0
Control	20.1	63.1	151.1	179.2
Lsd (5 %)	18	1.6	11.6	9.4
CV %	8.2	24.1	18.5	243

Table 4.6: The effect of NPK fertilizer on growth and yield parameters of okra during the minor season 2011.

Treatment	Plant height (cm)	Leaf area cm^2	Meanno. of fruits/plot	Yield $kgha^{-1}$
40-30-30 (NPK) $kgha^{-1}$	10.8	120.1	94.1	124.2
50-30-30 (NPK) $kgha^{-1}$	11.3	156.2	114.1	130.4
60-30-30 (NPK) $kgha^{-1}$	11.8	230.0	131.7	164.5
Control	8.2	50.3	79.3	106.5
Lsd (5 %)	1.2	1.4	11.2	8.6
CV %	8.6	23.2	23.3	2.3

4.7 Nitrogen content of the okra leaves

Table 4.7 shows N content in the okra leaves during the major and minor seasons. The % N of the leaves increased across the treatments levels. The control treated plots recorded significantly ($P<0.05$) lower values for both seasons. The values were 1.2 % and 2.1 % N for the minor and major seasons. The higher N levels, on the other hand, recorded significantly ($P<0.05$) higher amounts. For example, the 60-30-30 NPK treated plots recorded 2.3 % and 3.4 % in the minor and major seasons, respectively. There was significant ($P<0.05$) difference between the control and 60-30-30 NPK treated plots. There were also significant ($P<0.05$) differences among the NPK treated plots except between the 40-30-30 and 50-30-30 treated plots during the minor season (Table 4.7).

Table 4.7: Percentage N of the okra leaves in the major and minor seasons, 2011.

	% Nitrogen	
Treatment	Major season	Minor season
40-30-30 (NPK) $kgha^{-1}$	2.2	2.1
50-30-30 (NPK) $kgha^{-1}$	2.6	2.1
60-30-30 (NPK) $kgha^{-1}$	3.4	2.3
Control	2.1	1.2
Lsd (5 %)	0.4	0.4
CV %	2.4	2.3

CHAPTER FIVE

5.0 DISCUSSION

5.1 Aggregation of *Podagrica* spp. on okra leaves in response to N

The increased numbers of *Podagrica* spp. from three weeks after planting (3WAP) through to the last week of sampling could be attributed to availability of adequate amounts of N which provided resources for the production of succulent plant parts (food) for the insects, especially during the reproductive phase of the plant growth. Adequate supply of N is associated with high photosynthetic activity, vigorous vegetative growth and dark green colour of the leaves (John *et al*., 2004), resulting from the production of phenols and amino acids making the foliage extremely rich and succulent to make it susceptible to both insects and pests (Jansson and Smilowitz, 1986; Youdeowei, 2002).

Hunt *et al*. (1992) and Herms (2002) also noted that high N may influence semio-chemicals and nutritional values of plants and also behavioural characteristics of herbivores. Jansson and Smilowitz (1986) indicated that N in host plants is generally considered an indicator of food quality that affected host selection by the aphids and thrips. It was no surprising that the NPK fertilizer treated plots recoded significantly more *Podagrica* spp. than the content.

Echezona *et al*. (2010) and Draycott and Christenson (2003) had reported that excessive application of N increases tissue hydration and succulence and could therefore predispose such organs to more pests and diseases attack. Egwuatu and Taylor (1976) noted that greater number of insect aggregation is highly expected when there is abundant source of food supply.

Olaifa and Alimi (1988), in their study in Nigeria, reported that the incidence of insect infestation on okra plant is higher during the dry season (minor season) than the rainy season

(major season), which is contrary to the results obtained in this study; higher densities of *Podagrica* spp. were recorded in the major planting season than the minor planting season. The generally higher numbers of *Podagrica* spp. collected in the major season could also be attributed to the fact that the mean monthly temperature and relative humidity recorded during the period was more favourable for the insect's development. Adequate rainfall during the major season also facilitated proper dissolution, absorption and assimilation of the fertilizer treatment imposed. Youdeowei (2002) documented that, readily absorbed N fertilizer is partitioned in the crop in the form of phenols and amino acids (protein), making the foliage succulent and therefore becoming susceptible to both diseases and pests.

5.1.1 Aggregation of *Podagrica* spp. on okra Flower Buds in response to N

It was no surprise that relatively higher numbers of *Podagrica* spp. were recorded in the flower buds and flowers in both the major and minor seasons because of the presence of higher amount of protein in these parts. Insects generally aggregate at sites and areas of plants such as flower buds and flowers and especially in plant parts that have relatively high amount of protein where there is abundance of food to consume. The choice of flower buds, flowers, succulent fruits as well as matured fruits for food by the flea beetles has also been documented by Lingren *et al*. (1993). Reitz (2008) reported that thrips aggregate in large numbers in the flowers where there is abundance of feed. Pollen grains are known to attract several insects including thrips and flea beetles. Thrips usually aggregate more in flowers to obtain high protein pollen for egg development (Reitz, 2008). Reitz (2008) and Tsai *et al*. (1996) reported that thrips occur on flowers and feed on pollen for the development of various instars (larvae development) to evolve before adulthood. This phase of the insects' development is energy demanding, hence the aggregation.

5.1.2 Distribution of *Podagrica* spp. within okra plant canopy in response to N

Higher numbers of *Podagrica* spp. recorded in the upper canopy of okra than the lower canopy could be attributed to the presence of more reproductive plants parts in that canopy. The N fertilization may have contributed to the richness (protein) and susceptibility of the reproductive plants' parts in the upper canopy. Reports from several workers buttress the fact that the application of N makes the leaves rich; dark green and attractive to insects (Jansson and Smilowitz, 1986 and Youdeowei, 2002).

It is reported that insects migrate to the upper canopy for the pollen grains, to feed and consequently pollinate and feed (Reitz, 2008). Reitz (2008) reported that insects move to the blooming part (upper canopy) to feed on the pollen/ nectar; and flea beetles, being notorious leaf miners, consume the fleshy, succulent and tender parts of the leaves which have less secondary metabolites. Grubinger (2011) reported that insects' larvae get attracted and migrate to newly emerged leaves to feed. Invariably, leaves in the upper canopy are noted to be more nutritious and succulent than that in the lower canopy and would therefore attract more insects (John *et al*., 2004). This supported the report by Grubinger (2011) that insects leave waxier or older leaves and get attracted to more succulent ones to consume. He explained that waxier leaves usually on the lower canopy are difficult for flea beetles to grasp and consume.

5.2 Damage of leaves by *Podagrica* spp. as influenced by N

Higher injury (per cent number of holes) was recorded in NPK fertilizer treated plots in the present study, as expected. Flea beetles in general are known to be notorious leaf miners and consume the fleshy, succulent and tender parts of the leaves which have less secondary metabolites in them. *Podagrica* spp. were attracted and aggregated in higher numbers on the leaves of plants supplied with higher levels of N fertilization and this resulted in the increased

damage in those plots. The higher rate of leaf damage was caused by reduction of glycoalkaloid as result of high levels of N (Fragoyiannis *et al*., 2001).

5.3 Growth and Yield Data

5.3.1 Leaf Area

The application of N resulted in an increase in leaf area. The highest N level-treated plot recorded the largest leaf areas expected. This is because Lemaire *et al*. (2005) underscored a linear relationship between increasing N supply and leaf area index. Lawlor (2002) reported that leaf growth is substantially affected by increasing N levels when is limiting. Increase in leaf area may be due to adequate supply of N which is associated with high photosynthetic activity. John *et al*. (2004) noted that N fertilization vigorously enhances vegetative growth and photosynthetic activity. The soil physico-chemical condition is known to have a bearing on growth performance of a crop. Therefore, the quantity of nutrient applied may have influenced the physico-chemical properties and nutrient content of the soil which also impacted leaf area.

5.3.2 Plant Height

Okra plants grown on N-treated plots were relatively taller than those in the control due to relatively higher nutrient content of the soil. The relatively taller plants recorded on the plots which received the highest N levels were in agreement with the report by Rosati *et al*. (2001) and Lemaire *et al*. (2005), that in solanaceous plants, increasing N levels lead to a corresponding increase inleaf area index, light-interception and dry matter partition. Increased plant height due to application of N was observed by Yadav *et al*. (2004). The higher dose of N might have enhanced cell division and formation of more tissues resulting in luxuriant vegetative growth and thereby increased plant height. Sultana (2002) also reported similar result. Majanbu *et al*. (1985) observed that plant height was enhanced appreciably by

N fertilizer application up to100 kg N/ha. The N must have been used in the dry matter partitioning and growth (Sharma *etal*., 1976; Katung *et al*., 1996; Akanbi *et al*., 2001).

5.3.3 Yield of okra in response of N

N fertilizer application has been reported to improve growth (Sharma *et al*., 1976; Katung *et al*., 1996), dry matter partitioning (Akanbi *et al*., 2002) and fruit yield (Fatokun and Cheda, 1981). It is reported that when nutrients are applied in their required quantity they help in the formation of amino acids, phenols, etc (Palaniapan and Annadurai, 1999) that impart on the yield. Hence, despite the greater numbers of *Podagrica* spp. on the 60-30-30 treatment plots, yield was not significantly affected.It is reported 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 (Zhang *et al*., 2007). Hence, a substantial yield is expected on the highest N level treated plots. The differences of yield among the four treatment levels are attributable to the difference of fruits per plant and weight of fruits per plant. As the number and weight of fruits were higher in the plant from the highest N level (60-30-30), the ultimate fruit yield was higher. This result is similar to the findings of Firoz (2009) and Sultana (2002). Again, it could be explained that *Podagrica* spp. did not severely attack crop beyond the injury level at seedling/tender and the reproductive stages, hence the reasonable yield.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

The primary aim of this study was to determine within plant distribution of *Podagrica* spp. and their seasonal fluctuation or abundance on okra plant as necessitated by different N levels of NPK fertilizer application. The results show that irrespective of the seasons, the okra flea beetles, *Podagrica* spp. numbers were significantly higher on plots treated with higher N fertilizer levels than those with lower amounts of N. The major season had higher *Podagrica* spp. numbers. The aggregation of *Podagrica* spp. was significantly more in the upper canopy than in the lower canopy, where the leaves were succulent, fleshy and nutritious. *Podagrica* spp. are leaf miners and caused significantly more damage at the upper canopy and the magnitude was highest in highest N treatment plots.

The leaves at the upper canopies were significantly attacked during the study irrespective of the seasons. The leaf damage was pronounced with a linear increase in N fertilizer levels. The plant height and leaf area were significantly higher in the plots that received the highest doses of N. The yield components were significantly higher in the plots that received the highest doses of N.

6.2 RECOMMENDATION

1. The study has shown that within the okra plant, *Podagrica* spp. aggregate more in the upper canopies than the lower canopy. Hence, in designing sampling protocol and control measures, the canopies should be of critical consideration.
2. It is suggested that the study be repeated to cover more than one year.

REFERENCES

Adebawoo, O.O., Salau, B.A., Adeyanju, M.M., Famodu, A.A. and Osilesi, O. (2007). Fruits and Vegetables moderates blood pressure, Fibrinogen concentration and plasma viscosity in Nigerian hypertensives. *African Journal of Food, Agriculture, Nutrition and Development* 7 (6): 1-13.

Adenuga, A.O. (1970). Studies on the biology of *Podagrica* sjostedti (Jac.) and *P*. uniformis (Jac.) (Coleoptera:Chrysomelidae). Nigeria Entomologists' Magazine 2: 39-42.

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

Akanbi, W.B., Tongun, O.A., Akinfasoye, J.O. and Baiyewu, R.A. (2002). Nutrient Uptake and Yield of okra (*Abelmoschus esculentus* (L) Moench) as affected by variety and Nitrogen mixed fertilizer. 16th Annual conference of Agriculturists Horston pp: 145-150.

Aliju, L., Karikari, S.K., and Ahmed, M. R. A. K, (1992). Yield and yield components of eggplant (*Solamun gilo* L.) as affected by date of transplanting, intra-row spacing and nitrogen fertilization. *Journal of Science and Technology* 2 (1):7-12.

Anonymous, (1994). Report of the national program on vegetable crops, fruits and tuber plants of INERA. INERA Ouagaduoguo, Burkina Faso.

Arapitsas, P. (2008). Identification and quantification of polyphenolics compounds from okra seeds. *Food Chemistry*110:1041-1045.

Asawalam, E.F., Emeasor, K.C.and Adieze, O. (2007). Influence of some soil amendments on insect pest infestation and damage to okra *Abelmoschus esculentus* (L.) Moench in Umudike, Abia State. *Research Journal of Biological Science 2* (1): 108-111.

Atakan, E., Coll, M. and Rosen, M. D. (1996). Within-plant distribution of thrips and their predators: Effect of cotton variety and developmental stage. *Bulletin of Entomological Research* 86:641-646.

Baidoo, P.K and Mochiah M. B (2011). Influence of nutrients on pests and natural enemies of pests of okra. *Journal of Applied Bioscience* 20: 2771-2784.

Barbour, J.D., Farrar, R. R. and Kennedy, G.G. (1991). Interaction of fertilizer regime with host-plant resistance in tomato. *Entomology of Experimental and Applied Science* 60:289-300.

Bentz, J. A., Reeves, J., Barbosa, P. and Francis, B. (1995). Nitrogen fertilizer effect on selection, acceptance, and suitability of *Euphorbia pulcherrima* (Euphorbiaceae) as a host plant to *Bemisia tabaci* (Genn) (Homoptera: Aleyrodidae). *Environmental Entomology* 24:40-45.

Black, C.A. (1986). Methods of soil analysis, Part 1. Physical and mineralogical properties, including statistics of measurement and sampling, Part11. Chemical and microbiological properties. Agronomy series USA, 343pp.

Bray, R.H., and Kurtz, L.T. (1945). Determination of total organic and available forms of phosphorus in soil. *Soil Science* 599: 39-45.

Chadha, K.L. (2002). Hand book of Horticulture, Indian Council of Agricultural Research on Okra. India: pp.422-427.

Chauhan, D. V.S. (1972). Vegetable Production in India, 3rd edition. Ram Prasad and Sons (Agra) 123pp.

Dauda. S. N., Aliju, L. and Chiezey, U. F. (2005). Effect of variety, seedling, age andpoultry manure on growth and yield of garden egg (*Solamun gilo* L.). *The Nigerian Academic Forum* 9 (1): 88-95.

Demotes-Mainard, S., Boumaza, R., Meyer, S. and Cerovic Z.G. (2008). Indicators of nitrogen status for ornamental woody plants based on optical measurements of leaf epidermal polyphenol and chlorophyll contents. *Scientia Horticulturae*115: 377-385.

Draycott, A. P. and Christenson, D.R. (2003). Nutrients for sugar beet production: Soil plantrelationships. *Technology and Engineering*. 242 pp.

Echozona, B.C., Asigbu J.E. and Izuagba, A.A. (2010). Flea Beetle Populations and Economic yield of okra as influenced by Nitrogen and 2, 3-Dihydro-2, 2-dimethylBenzofuran. *African Crop Science Journal* 18 (3):97-105.

Eigenbrode, S.D. and Pimentel, D. (1988). Effects of manure and chemical fertilizers on insect pest populations on collards. *Agriculture Ecosystem and Environment* 20:109-125.

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

Egwuatu, R.I. and Taylor, T.A. (1976). Aspects of the spatial distribution *of Acanthomiatom entosicollisstal* (Heteroptera, Coreidae) in *Cajanus cajan* (Pigeon pea) *Journal of Economic Entomology* 69 (5):591-594.

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

FAO, (2006). Okra Integrated Pest Management, AN ECOLOGICAL GUIDE. LOA-FNPP/GLO/002/NET with the National Crop Protection Center through the UPLB Foundation, Incorporation in support of Participatory Action Research Program to Develop Okra IPM. Inter-country Programme for Integrated pest Management on Vegetables in Asia, Bangladesh.

Fasunwon, B.T. and Banjo, A.D. (2010). Seasonal population fluctuations of *Podagrica* species on okra. *Journal of Agricultural and Biological sciences* 6(3): 283-288.

Fatokun, C.A. and Cheda, H.R. (1981). The effect of nitrogen and phosphorus on yield and chemical composition of okra (*Abelmoschus esculentus* (L.) Moench) paper presented on the 6th African Horticulture Symposium; Ibadan Nigeria.

Firoz, Z. A. (2009). Impact of Nitrogen and Phosphorus on the growth and yield of okra in hill slope condition. *Bangladesh Journal of Agricultural Research* 34(4): 713-722.

Fragoyiannis, D.A., McKinlay, R.G. and D'Mello, LEE, (2001). Interactions of aphid herbivory and nitrogen availability on the total foliar glyeoalkaloid content of potato plants. *Journal of Chemistry and Ecolology* 27:1749-1762.

Franklin, W. M. (1982). Okra Potential Multi-Purpose Crop for the Temperate Zones and Tropics. *Economic Botany* 36 (3): 340-345.

Ghana Meteorological Service, (2011). The Annual Report of Ghana Meteorological Service, 2011.

George, R.A.T. (1999). Vegetable seed population (2nd edition), CABI Publication, 328 pp.

Gopalan. C., Ramasastri. B.V. and Balasubramanian .S. (2007). Nutritive Value of Indian Foods, published by National Institute of Nutrition (NIN), ICMR.

Grindlay, D. J. C. (1997). Towards an explanation of crop nitrogen demand based on the optimization of leaf nitrogen per unit leaf area. *Journal of Agricultural Science*128: 377-396.

Grubinger, V. (2011). Flea Beetles Management. *Journal University of Vermont Extention*.1:1-5.

Grubinger, V. (2011). Colorado Potato Beetle. *Journal University of Vermont Extention*.4:1-23.

Gupta, A. Srinivas, K and Shukla, V. (1981). Response of okra (*Abelmoschus esculentus* (L). Moench) to plant spacing and nitrogen, phosphorus fertilization. *Indian Journal Horticulture Science* 38(3-4): 218-222.

Herms, D.A. (2002). Effects of fertilization on insect resistance of woody ornamental plants: Reassessing an entrenched paradigm. *Environmental Entomolology* 31:923-933.

Hooda, R. S., Pandita, M. L. and Sidhu, A. S. (1980). Studies on the effect of nitrogen phosphorus on growth and green pod yield of okra *Abelmoschus esculentus (*L.) Moench. *Haryar Journal of Horticulture Science* 9: 180-183.

Hunt, D.W.A., Drndy, C.G. and Maw, H.E.L. (1992). Influence of nitrogen on the performance of Colorado potato beetle (Coleoptera: Chrysomelidae) on tomato. *Environmental Entomolology* 21:817-821.

Jansson, R.K. and Smilowitz, Z. (1986). Influence of nitrogen on population parameters of potato insects: Abundance, population growth and within-plant distribution of the

green peach aphid, *Myzuspersicae* (Homoptera: Aphididae). *Environmental Entomolology* 15:49-55.

Jahn, G.C. (2004). "Effect of soil nutrients on the growth, survival and fecundity of insect pests of rice: an overview and a theory of pest outbreaks with consideration of research approaches.Multi-trophic interactions in Soil and Integrated Control. *International Organization for Biological Control Bulletin* 27 (1): 115-122.

John, L.W., Jamer, D.B., Samuel, L.T. and Warner, L.W. (2004). Soil Fertility and Fertilizers: An Introduction to Nutrient Management. Pearson Education, India 106-153.

Jones, H.G. (1992). Plants and Microclimate: A Quantitative Approach to Environmental Plant Physiology (2nd Edition), Cambridge University Press, Cambridge, 428 pp.

Kaarstad Ola. (1997). Fertilizer's significance for cereal production and cereal yield from 1950.*In:*'Third International Dahlia Greidinger Symposium on Fertilisation and The Environment, April 1997.' J.J. Mortwerdt, and A. Shaviv, Edition, Technion, Haifa.

Kalule, T. and Wright, D.J. (2002). Tritrophic interactions between cabbage cultivars with different resistance and fertilizer levels, cruciferous aphids and parasitoids under field conditions. *Bulletin of Entomology Research* 92:61-69.

Kasyap, R.K. and Batra, B.R. (1987). Influence of some crop management practices on the incidence of *Heliothis armigera* (Hubner) and yield of tomato *(Lycopersicon esculentum* Mill.) in India. *Tropical Pest Management* 33:166-169.

Katung, M.D., Olanrewaju, J.D., Gupta, U. S. and Kureh, .I. (1996). Fruit and seed yields of okra as influenced byfarmyard manure and nitrogen fertilizer. *In:* Procedure 14th HORTSON Center; Ago - Iwoye, 1- 4 April, 1996.

Lawlor, D. W. (2002). Carbon and nitrogen assimilation in relation to yield: Mechanisms are the key to understanding production systems. *Journal of Experimental Botany* 53: 773-787.

Lemaire, G., Avice, J. C., Kim, T. H. and Ourry, A. (2005). Developmental changes in shoot N dynamics of lucerne (Medicago sativa L.) in relation to leaf growth dynamics as a function of plant density and hierarchical position within the canopy. *Journal of Experimental Botany* 56: 935-943.

Lengsfeld, C., Titgemeyer, F., Faller, G. and Hensel, A. (2004). Glycosylated compounds from okra inhibit adhesion of *Helicobacter pylori* to human gastric mucosa. *Journal of Agricultural and Food Chemistry* 52 (6):1495-1503.

Lingren, P.D., Bryant, V. M., Raulston, Jr., Pendleton, J. R. M., Westbrook, J. and Jones, G.D. (1993). Adult feeding host range and migratory activities of corn earworm, cabbage looper and celery looper (Lepidoptera: Noctuidae) moths as evidenced by attached pollen. *Journal of Economic Entomology* 86: 1429-1439.

Liptay, A. and Nicholls, S. 1993. Nitrogen supply during greenhouse transplant production affects subsequent tomato root growth in the field. *Journal of American Society of Horticultural Science* 118: 339-342.

Majanbu, I. S., Ogunlela,V. B, Ahmed, M. K. and Olarewaju, J. D. (1985). Response of two okra varieties to fertilizers, yield and yield components as influenced by nitrogen and phosphorus application. *Fertilizer Research* 6(3): 257-267.

Mani, S. and Ramanathan K.M. (1980). Effect of nitrogen and phosphorus on the yield of bhindi fruits. *South Indian Horticulture* 20:136-138.

Mochiah, M.B., Baidoo, P.K. and Owuso-Akyaw, W. (2011). Nutrient application on insect population and damage to cabbage. *Journal of Applied Biosciences* 38: 2564-2572.

Mohanta, H.C. (1998). Effect of phosphorus and genotypes on the yield and contributing characters in okra *(Abelmoschus esculentus* L. Moench). MSc Thesis. Dept.of Horticulture, IPSA, Salna, Gazipur.

Nelson, D.W. and Sommers, L.W. (1982). Total carbon, organic carbon and organic matter. *In*: Page, A.L., R.H. Miller, and D.R. Keeney. (Eds.). Methods of soil analysis. 2. Chemical andmicrobiological Properties. *Journal of Agronomy* 9: 301-312.

National Research Council (2006). Lost Crops of Africa, Volume 2: Vegetables. The National Academies Press, Washington D.C, USA.134.

Obeng-Ofori, D. and Sackey, J. (2003). Field evaluation of non-synthetic insecticides for the management of insect pests of okra, *Abelmoschus esculentus* (L.) Moench in Ghana. *Ethiopian Journal of Science* 26: 145-150.

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

Ogbalu O.K, and Ekweozor IKE (2002). The distribution of okra flea beetles on three varieties of okra in traditional farms of the Niger Delta. *Tropical Science* 42: 52-56.

Olaifa, J. I. and Alimi, J.T. (1988). Economics of spraying times and rate of Application of Carbonyl on the field of Okra (*Abelmoschus esculentus* L. Moench). Ife. *Journal of Agriculture* 10: 1-2

Olsen, S. R. and Sommers, L. E. (1982). Phosphorus. In: Page, AL., and RH. Miller, and D.R Keeney. (Eds.). Methods of soil analysis. 2. Chemical and microbiological Properties. *Agronomy* 9: 403-430.

Palaniapan, S.P. and Annadurai, K. (1999). Organic Farming Theory and Practice, Jodhpur India, Scientific Publishers 53-73.

Patriquin, D.G., Baines, D., Lewis, J. and MacDougall, A. (1995). Aphid infestations of soya beans on an organic farm in relation to weeds inter crops and added nitrogen. *Agricultural Ecosystem and Environment* 20:279-288.

Phelan, P. L., Mason, J. F. and Stinner, B.R. (1995). Soil fertility management and host preference by European corn borer, *Ostrinia nubilalis*, on *Zea mays*: a comparison of organic and conventional chemical farming. *Agricultural Ecosystem and Environment* 56: 1–8.

Praveen, P.M and Dhandapani, N. (2002). Eco-friendly management of major pests of okra (*Abelmoschus esculentus* (L.) Moench). *Journal of Vegetable Crop Production* 7(2): 3-11.

Ranganna, S. (1979). Manual Book for Analysis of Fruit and Vegetable Products. 2nd Edition. Central Food Technological Research Institute, Mysore, India, pp: 5-6, 10-12,317.

Rasband, W.S. (2011). Image J: (US Natural Institute of Health: Bethesda, MD). Available at *http:/image J. nih.gov/il.*

Reitz, S.R. (2008). Comparative bionomic of *Frankliniella* occcidentalis and *Frankliniella tritici. Florida Entomology* 91:474-476.

Rosati, A., Badeck, F. W. and Dejong, T. M. (2001). Estimating canopy light interception and absorption using leaf mass per unit leaf area in (*Solanum melongena* L.). *Annals of Botany* 88: 101-109.

Sadat, M. S. I. (2000). Studies on the effects of different levels of nitrogen, phosphorous and potassium on the growth, yield and seed production of okra *(Abelmoschus esculentus* L.) MSc.Thesis. Department of Horticulture, Bangladesh Agricultural University, Mymensingh, Bangladesh.

SAS Institution, (2010). Statistical Analytical Systems SAS/STAT user's guide version 8.2 (GLM) Cary NC: USA.

Shivasankeb, A., Reddy, P.R. and Singh. G. (1982). Nitrogen nutrition in groundnut. 2. Effect of phosphorus on nitrogen fixation and dry matter partitioning. *Legume Research* 7:105.

Sharma, B. M. and Yadev, J. P. S. (1976). Availability of phosphorus to grain as influenced byphosphatic fertilization and irrigation. *Indian Journal of Agriculture Science*46**:** 205-210.

Singh, I. P. (1995). Effect of various doses of nitrogen on seed yield and quality of okra *(Abelmoschus esculentus* (L) Moench). *Annals of Agricultural Research* 16(2): 227-229.

Soil Laboratory Staff (1984). Analytical methods of the service Laboratory for soil, plant and water analysis. Part I: Methods for soil analysis. Royal Tropical Institute, Amsterdam.

Sultana, S. (2002).Effect of nitrogen, phosphorus, potassium, sulphur and boron on okra. M. S Thesis. Department of Soil Science, Banghabandhu Sheikh Muijibur Rahman Agricultural University, Gazipur.

Tsai, J.H., Yue, B.S., Funderburk, J.E. and Webb, S.E. (1996). Effect of plant pollen on growth and reproduction of *Frankliniella bispinos*. *ActaHorticulturae* 43:535-541.

Ulukan, H. (2008). Agronomic adaptation of some field crops: A general approach. *Journal of Agronomy and Crop Science* 194: 169-179.

Ukoima, H.N. and Okah, A. (2006). Use of some bio pesticides in controlling pests and diseases of okra (*Abelmoschus esculentus* L. Moench) in the field. *Environmental Ecology* 24:773-776.

USDA National Nutrient Database for Standard Reference, (2000). Release 16: Vitamin K Content of Selected Foods per Common Measure, Sorted by Nutrient Content.

Van, K. C. and Hartley, C. G. (2000). Agricultural management of grain legumes: has it led to an increase in fixation? *Field Crop Research* 65:165–181.

Vanlommel, S.,Chateau, L. and Coosemans, J. (1996). The effect of okra mosaic virus and beetle damage on yield of four okra cultivars. *African Crop Science Journal* 4:71-77.

Varela, A.M. and Seif, A. (2004). A Guide to IPM and Hygiene Standards in Okra Production in Kenya. *Insect Management for Okra*.

White, T.C.R. (1984). The abundance of invertebrate herbivores in relation to the availability of nitrogen in stressed food plants. *Oecologia* 63:90-105.

Yadav, P.,Singh, P.,Yadav, R. L. and Lal, R. (2004). Ameliorative organic manures and nitrogen levels on okra.Haryana *Journal of Horticultural Science* 33: 124-126.

Yardim, E.N. and Edwards, C.A. (2003). Effects of organic and synthetic fertilizer sources on pest and predatory insects associated with tomatoes. *Phytoparasitica* 31 (4): 324-329.

Youdeowei, A. (2002). Integrated pest management practices for the production of vegetables.

Zhang, L. X., Zhang, H. and Liang, Z. S. (2007). Nitrogen rates and water stress effects on production, lipid peroxidation. *Journal Agronomy and Crop Science* 193: 387-397.

Zhao, D., Reddy, K. R., Kakani, V. G. and Reddy, V. R. (2005). Nitrogen deficiency effects on plant growth, leaf photosynthesis, and hyper spectral reflectance properties of sorghum. *European Journal of Agronomy* 22: 391-403.

Appendix 1. Table 4.8: Mean values (±SD) of selected physico-chemical characteristics of the soil before experiment (0-15 cm depth)

Soil Parameters	Values
pH(1:2.5)	6.07 ± 0.32
Organic C (%)	1.76 ± 0.30
Total N (%)	5.27 ± 0.02
Bray's P (mg/kg^{-1})	12.30 ± 0.75
Exchangeable bases ($Cmol/kg^{-1}$)	
Ca	4.77 ± 1.40
Mg	2.43 ± 0.71
K	0.11 ± 0.13
Na	0.12 ± 0.03
Textural class	Sandy loam

- **Means represent duplicate samples (±SEM)**

Appendix 2.Table 4.9: The selected chemical properties of soil after application of treatment major season 2011.

Treatment	**C**	**Ca**	**K**	**N**	**Na**	**P**	**Mg**
Control	140.3	3.96	0.177	11.8	0.197	8.9	2.26
40-30-30 (NPK)	159.9	3.99	0.177	14.8	0.200	9.8	2.35
50-30-30 (NPK)	156.2	4.01	0.260	21.7	0.197	10.4	2.35
60-30-30 (NPK)	178.0	4.05	0.207	15.3	0.207	15.3	2.40
Lsd (5%)	17.17	0.086	0.103	12.49	0.020	24.31	0.16
CV (%)	2.0	0.4	16.9	17.8	0.6	16.1	1.6

Appendix 3.Table 4.10: The selected chemical properties of soil after application of treatment, minor season 2011

Treatment	C	Ca	K	N	Na	P	Mg
Control	104.2	1.84	0.09	5.87	0.10	4.1	0.74
40-30-30 (NPK)	113.5	1.60	0.11	8.21	0.12	5.3	0.72
50-30-30 (NPK)	137.5	2.21	0.09	10.18	0.12	7.2	1.29
60-30-30 (NPK)	124.4	2.01	0.12	6.30	0.11	9.0	1.22
Lsd(5%)	19.62	0.60	0.055	4.834	0.035	17.26	0.806
CV (%)	15.5	6.6	9.8	29.7	3.3	11.3	2.1