KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI GHANA

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DEPARTMENT OF HORTICULTURE

EFFECT OF SOIL AMENDMENTS AND BOTANICALS ON THE PERFORMANCE OF SPRING ONIONS (*Allium Fistulosum* L.) AND CONTROL OF ONION THRIPS (*Thrips Tabaci*)

A thesis submitted to the School of Research and Graduate Studies, Kwame Nkrumah University of Science and Technology, Kumasi Ghana in partial fulfillment of the requirements for the award of Master of Science (Olericulture) degree

By

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DECLARATION

I hereby declare that this work submitted as a dissertation for the MSc Olericulture degree is the results of my own investigation. Works in this dissertation previously published by other persons that served as sources of information have been duly acknowledged.

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ABSTRACT

Two field experiments were conducted during the 2009 minor rainy season and 2010 major rainy season at the experimental field of the Department of Horticulture, Kwame Nkrumah University of Science and Technology, Kumasi to study the effect of soil amendments and botanicals on the growth, yield and quality (crude protein, crude fibre, fat and ash) of spring onions (*Allium fistulosum* L) and the efficacy of the botanicals in controlling onion thrips (*Thrips tabaci*). The experiment was a 3 x 3 factorial laid out in a Randomized Complete Block Design (RCBD) with three replications. The treatments consisted of three types of soil amendments (Poultry manure, Green manure and No manure) and three types of botanicals (Moringa leaf extract, Neemazal and No botanical). The number of leaves, number of daughter shoots, plant height and yield were the parameters studied in both experiments. In the minor season, no significant differences were observed in the parameters studied as affected by soil amendments, except plant height at harvest, where poultry manure and green manure treated plots produced taller plants (40.81cm) and (39.88cm) respectively than the control (no manure) (34.85cm). Botanicals did not significantly influence growth and yield of spring onion in the first experiment, however, the number of leaves damaged by thrips was significantly reduced by the botanicals, where neemazal was the most effective in the control of onion thrips against leaf damage. The highest net benefit of GH¢ 6600 was obtained by poultry manure plots sprayed with neemazal while the lowest net benefit of GH¢ 2430 was obtained by green manure plots sprayed with moringa leaf extract. In the major season experiment, soil amendment significantly increased the number of leaves, number of daughter shoots, height and yield of spring onion where poultry manure treated plots produced the highest number of leaves (17.23), number of daughter shoots (4.25), the tallest plants (41.16cm) and highest yield (2.68t/ha). Plots which were not treated with any manure produced the lowest yield, number of leaves, number of daughter shoots and plant height.

Botanicals again did not significantly influence growth and yield of spring onion in the second experiment but the number of leaves damaged by thrips was significantly reduced by the botanicals. Neemazal and moringa leaf extract were more effective. The highest net benefit (GH¢ 714) was recorded by poultry manure treatments which were not sprayed with any botanical. Poultry manure appears to be the most important and cost effective organic manure in this study, the use of which should be encouraged in both the minor and major rainy seasons. Neemazal and moringa leaf extracts were found to be effective in reducing the

number of leaves damaged by onion thrips in the minor and major rainy seasons by preventing them from feeding and causing damage to the leaves of spring onion.

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CHAPTER ONE

1.0 INTRODUCTION

Vegetable crops, especially the leafy ones are important sources of vitamins and minerals (Coombs, 1995). They are excellent sources of important nutrients like protein, carbohydrates, fats and oils. They form an essential part of a balanced diet. Vegetables are also excellent sources of fibre or roughage which plays an important role in digestion by helping to move food through the digestive system (Foster *et al.*, 1985). They may be eaten as side dishes in the raw form or in the cooked form, alone, with meat or fish, in stew, soup and various preparations (Okigbo, 1983).

Spring onion belongs to the family *Alliaceae*. It has elongated food storage leaves which are hollow and rounded. It also has a short bulb stem and a fibrous root system which exists at the base of the bulb stem (Tindall, 1986). It originated in Siberia, and is very popular in the East where it is known as Japanese leek. It has slightly enlarged bulbs, which are very long and are covered with dry membranous, onion-like scales for some distance above ground (Stephens, 2009). The plant requires a well-drained and moist soil. It cannot grow in the shade and it prefers a pH range of 6.5 to 7.5. But lower pH of about 4 is satisfactory in organic soils (Brewster, 1994).

The bulb of spring onion contains an essential oil that is rich in sulphur compounds (Nguyen and Thi Nhu, 1989). It is antibacterial and antiseptic (Duke and Ayensu, 1985). It is used in the treatment of colds and abdominal coldness and fullness (Yeung, 1985). The use of the bulb in the diet impedes internal parasites (Duke and Ayensu, 1985). Externally, the bulb can be made into a poultice to drain pus from sores, boils and abscesses (Chevallier, 1996). The juice of the plant is used as a moth repellent. The whole plant is said to repel insects and moles (Riotte, 1978).

There are a number of ways to use spring onions in cooking. They can be chopped and added to sauces, stir fries, and other dishes. They can also be grilled and eaten plain, or roasted and served as a garnish or side vegetable. Some people enjoy eating spring onions raw with a little bit of salt. They can also be used raw in salads (Christman, 2009).

The entire plant may be pulled and eaten like a green onion or leaf portions may be snipped off and used for flavoring (Stephens, 2009). A nutritional analysis of the leaves showed that they contain 1.4% protein, 0.3% fat, 4.6% carbohydrates, 0.8% ash, some vitamin B1 and moderate levels of vitamin C (Reid, 1977).

One major cause of poor crop growth in the tropics is the very low inherent fertility of the soils. The use of chemical fertilizers to sustain crop productivity on a long-term basis has not been effective, because they often lead to a decline in soil organic matter content, soil acidification and soil physical degradation, which may in turn lead to increased soil erosion, reduced crop yield and nutrient imbalance (Kang and Juo, 1980; Agboola *et al.*, 1982; Obi and Ebo, 1995; Ojeniyi, 2000).

Environmental pollution has become a serious threat for human health as a result of the use of synthetic chemicals. In vegetable production, the aim of growing crops organically is to market safe food and not threaten human health without polluting the environment (Korkmaz, 2009).

There was a time when our food came from our own gardens or from local farms. Farmers planted diverse crops that fed their local communities. Synthetic chemicals for agricultural use did not exist. Organic agriculture was the way. The use of synthetic chemicals to combat the explosion of pests and diseases has led to over one third of the marketed food having pesticide residue (Brain, 2006). Many crop species respond well to the application of organic manure which can sustain yield under continuous cropping on most soils unlike the use of NPK chemical fertilizer. The potentials of organic matter and nutrient supply of the soil are particularly important in today's agriculture in the tropics where chemical fertilizers are no longer as readily available and economically feasible (Ibeawuchi *et al.*, 2006).

Poultry manure is an efficient organic fertilizer and is also an important source of plant nutrients. It releases nutrients to the soil and also improves the physical properties of the soil. The average nutrient content is 3.03 % N, 2.63 % P_2O_5 and 1.4 % K_2O (Reddy and Reddi, 1995). Poultry manure is essential for establishing and maintaining optimum soil physical condition and also for improving plant growth. It is also cheap and effective as a good source of N for sustainable crop production (Rahman, 2004; Dauda *et al.*, 2008).

The main contribution of green manure to soil fertility restoration is the supply of nutrients and the protection of the soil from both physical and chemical degradation (Leijder, 1995). The decomposing green plant materials stimulate microbial activities. The concept of green manuring has a worldwide acceptance and has proven to be a good source of soil fertility (Onwu *et al*., 2008). In the tropics, spring onion growers maintain a high level of soil fertility using organic manure and well controlled irrigation (Brewster, 1994).

Thrips (*Thrips tabaci*) are a major pest of spring onions and are the most damaging pests of *Alliums* worldwide. They are most severe in warmer production regions (Brewster, 1994). They are small sucking insects that prefer to hide in the lower neck of the onion plant and feed and cause small, white to silvery patches and streaks on leaves (Diane and Drost, 2008).

Insecticides cause a lot of pesticide related diseases. This is as a result of people inhaling insecticide fumes and eating food covered with pesticide residues (Tukur *et al.,* 2009). Neemazal is the purified active ingredient of the seed kernels of the tropical Neem tree (*Azadirachta indica* A.Juss.). The active substance permeates into the leaves and is distributed partially systemic in the plant; the pest insects take it up orally upon feeding. It has a special mode of action by stopping the insect´s feeding and damaging activity. It is active for the control of thrips, white fly, aphids, caterpillars, scale insects, and mealy bugs. It therefore helps to reduce the damage of leaves and increase the yield of crops. Neemazal does not harm beneficial insects and predators. There was no evidence of acute toxicity and reproductive effects obtained in valid studies. There were no residues of azadirachtin detected in Neemazal trials three days after application. It is of low toxicity and it is permissible for use in certified organic production (Sonata *et al.,* 2005). Neem extracts are available to poor farmers at minimum cost (Tukur *et al.*, 2009).

Moringa leaf spray applied on crops produced plants that were firmer and more resistant to pests and diseases (Foidl *et al*., 2001). Moringa leaves buried into soil before planting prevented damping off disease (*Pythium debaryanum*) among seedlings (HDRA, 2002).

The main objective of this study was therefore to determine the effect of two organic soil amendments (poultry manure and moringa as green manure) and two botanicals (moringa leaf extract and neemazal) on the growth and yield of spring onion (*Allium fistulosum* L.) and the effectiveness of moringa leaf extract and neemazal in controlling onion thrips (*Thrips tabaci*).

The specific objectives were:

- To determine how *Moringa oleifera* as green manure affects the yield and yield components of spring onion.
- To determine how poultry manure affects the yield and yield components of spring onion.
- To determine how neemazal and moringa leaf extract as pesticides affect the yield and yield components of spring onion.
- To assess the efficacy of neemazal and moringa leaf extract as pesticides in the control of onion thrips in spring onion.
- To determine how the interactions of the soil amendments and botanicals affect the yield and yield components of spring onion

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin, distribution and production of spring onion

Spring onion (*Allium fistulosum*) is widely cultivated in Siberia and Tropical Asia and shows the largest morphological variability in China, Korea, and Japan (Friesen *et al.*, 1999). It is grown throughout the world, but the main area of cultivation remains Eastern Asia; from Siberia to Indonesia. In Africa, it is only locally important and its cultivation is reported from Sierra Leone, Ghana, Cameroon, Congo, Democratic Republic of Congo, Sudan, Kenya, Zambia and Zimbabwe. No worldwide statistics for *Allium fistulosum* is available, as information on its production is often combined with that of other *Allium* spp. China, Japan, Korea, Taiwan and Indonesia are the main producers. In 1984, production in Japan reached 563,000 t from 24,000 ha of land area and in Korea 432,000 t from 19,000 ha (www.prota.org).

2.2 Botanical description of spring onion

Spring onion belongs to the family *Alliaceae* (Tindall, 1986). Two types can be distinguished on the basis of their use as vegetables and are sometimes taxonomically treated as two subspecies: *fistulosum* with four varieties and subsp. *caespitosum* with three varieties (Kasakova, 1978).

2.3 Uses and nutritional components of leafy vegetables

Vegetables are those herbaceous plants whose part or parts are eaten as supporting food or as main dishes and they may be aromatic, bitter or tasteless (Edema, 1987). The utilization of leafy vegetables is part of Africa's cultural heritage and they play important roles in the customs, traditions and food culture of the African household. They are included in meals mainly for their nutritional value; however, some are reserved for the sick and convalescence because of their medicinal properties. Green leafy vegetables are used for preparing soups (Mensah *et al*., 2008).

Leafy vegetables are nutritious with more protein, minerals, carbohydrate and vitamins than some exotic vegetables (Schipper, 2004). Leafy vegetables are said to be substitute for meat and therefore form important part of daily diets. They are useful in addressing some of the problems of nutritional deficiencies (Mensah *et al*., 2008). Food Value of onion is as follows: Moisture - 86.6%, Calcium - 47 mg, Protein - 1.2%, Phosphorus - 50 mg, Fat - 0.1%, Iron - 0.7 mg, Carbohydrates - 11.1%, Vitamin C - 11 mg, Fibre - 0.6% (www.best-home-remedies.com).

2.4 Quality components of leafy vegetables

Producers aim at producing leafy vegetables that have good appearance and with few visual defects. Market distributors prefer green, well developed leaves with long shelf-life. Consumers prefer leaves that look good and green with good flavor and nutritive value (Bailey, 1989).

2.4.1 Flavour

The overall flavour intensity of leafy vegetables is influenced by sugars, acids and their interactions. High acids and high sugars give the best flavour (Bailey, 1989).

2.4.2 Colour

Leaves are green because they contain a green pigment called chlorophyll. Other colours that are hidden by the chlorophyll appear when chlorophylls breakdown. When this happens, the yellow colour of the pigment called xanthophylls or orange-red tones of the carotene pigment may show. In addition, a group of red and purple pigments called anthocyanins are formed in dying leaves. When chlorophyll breaks down, the leaf can no longer be used for food (Bailey, 1989).

2.4.3 Acceptance

There are variations in size and shape among cultivars of leafy vegetables. A consumer's acceptance for a particular size and shape depends on the intended use. The presence and magnitude of defects greatly influence the acceptance of vegetable leaves. Minor defects may not affect eating quality and therefore, be accepted but more serious defects may lead to rejection (Bailey, 1989).

2.5 Effect of organic manure on growth, yield and quality of crops

Premsekhar and Rajashree (2009) performed an experiment to determine the influence of different organic manures on growth, yield and quality of okra. The organic manures they used were farm yard manure, poultry manure, vermicompost and neemcake. Results revealed that all the organic manure treatments showed positive effect on growth and yield characters. They attributed this to the fact that the chlorophyll content in the leaves was significantly improved with the application of organic source of nutrients. But the application of farm yard manure at 20 t/ha performed better than the other treatments in plant height, number of fruits per plant and yield. They said that application of farm yard manure, which contained appreciable quantities of magnesium, might have helped in chlorophyll synthesis which in turn increased the rate of photosynthesis. Higher yield response was observed. This was due to organic manures being able to improve the physical and biological properties of the soil which resulted in better supply of nutrients leading to good crop growth and yield. The reason for increased yield was attributed to solubilisation effect of plant nutrients by the addition of farm yard manure, leading to increased uptake of NPK. They also said that farm yard manure helped the soil to improve the nutrients status and water holding capacity. For the quality characteristics, organic manures gave better quality fruits with less fibre content. Application of farm yard manure at 20 t ha^{-1} recorded fruits with less crude fibre content and less moisture content. They said that application of farm yard manure might have caused accumulation of nutrients and dry matter in fruits than synthetic fertilization which resulted in better quality fruits in crops treated with farm yard manure.

Kipkosgei *et al.* (2003) researched on the effect of farmyard manure and nitrogen fertilizer on vegetative growth, leaf yield and quality attributes of black nightshade (*Solanum villosum*). The study was with an objective of determining the effects of various levels of farmyard manure and Calcium Ammonium nitrate on vegetative growth, yield and quality of *Solanum villosum.* Incorporation of various concentrations of farm yard manure significantly improved the vegetative attributes of plant height, plant width (girth), number of branches and number of leaves per plant. The above attributes improved with increasing levels of farm yard manure incorporated into the soils. The significant improvement of farm yard manure beyond the inorganic N was attributed to observed significant improvement of the rooting system, girth and height of plants, number of bearing branches of the plants and the higher levels of N P K in farm yard manure compared to Calcium Ammonium nitrate. They also said that it is possible that there was lower leaching of N due to possible improved soil texture, structure, water holding capacity and CEC of soils amended with farm yard manure. The content of ß-carotene in edible portions increased with increasing levels of fertilizers. This was attributed to Nitrogen facilitating the formation of chloroplasts, which are rich in ß-carotene. Results also showed that farm yard manure increased the vitamin C content of edible leafy portions of *Solanum villosum* while inorganic nitrogen decreased vitamin C content. They reported that application of N decreases vitamin C content in crops.

In an experiment to determine the growth and yield of roselle as affected by farmyard manure and intra-row spacing, plant height was significantly influenced by manure application. Plants that received higher dose of manure produced taller plants. It was found that manure application significantly increased the seed yield of roselle. This was due to the role of manure in increasing plant vigour (Tukur *et al.,* 2009).

Akparobi (2009) studied the effect of different level of farmyard manures on the growth and yield of *Amaranthus cruentus.* The amaranthus treated with the highest level of manure attained the highest plant height than those that received no manure. This was attributed to the adequacy of manure which decreased the number of days from planting to first harvesting, and increased the plant height of amaranthus. Farm yard manure provided adequate mineral nutrients and increased the soil organic matter content. The result also showed that the higher the quantity of manure applied, the higher the number of leaves produced per plant. The least average number of leaves per plant was produced by amaranthus that received no manure during the period under study. He reported that this was due to low organic matter content of the soil because amaranthus require soils with high organic matter content to enable it produce high leaf number and leaf area. He stated that low rates of fertilizer gave the least leaf number and leaf area per plant when compared to other higher level of fertilizer application in amaranthus. The result also showed that fresh weight and dry weight per plant increased with increase in quantity of manure applied. Plants treated with 35 t/ha manure had higher fresh weight and dry weight than those treated with 25 t/ha, 15 t/ha, and 0 t/ha manure respectively. This was attributed to the fact that manure decreased the number of days from planting to first harvesting, increased the number of harvests before senescence because manure increased the organic matter content of the soil and improved the rate of growth and production of fresh weight of amaranthus.

A research was conducted by Gambo *et al*. (2008) to determine the effects of farmyard manure, nitrogen and weed interference on the growth and yield of onion. Two field trials were conducted during dry seasons under irrigation. The results showed that increasing rates of farmyard manure increased bulb yield of onion with the highest values at 30 tons/ha although this was not significantly different. The results showed that there is the tendency for higher onion bulb yield with higher application of farmyard manure. They reported that organic manure is a supplier of N, P and K in the soil, which also increases the phosphate solubulising bacteria in the rhizosphere, increases the nutrient status of a soil, which leads to increase in yield. Akoun (2004) also confirmed that manure increases the nutrient status of a soil, which leads to increase in yield.

2.6 Effect of poultry manure on soil fertility

Poultry manure is a potential source of plant nutrients and chemical conditioner. The exchangeable bases increased with application rate in all soil types, thus indicating positive effects on soils. Similarly, significant increases of N and P were observed following addition of poultry manure (Dikinya and Mufwanzala, 2010). Adeleye and Ayeni (2010) reported that increase in soil and plant nutrients content was due to the application of cocoa pod ash and poultry manure because they contained macro and micronutrients. According to Adekiya and Agbede (2009) poultry manure improved soil nutrient status by increasing soil organic carbon, total N, available P and exchangeable K, Ca and Mg. Ewulo *et al.* (2008) reported an increase in soil nutrient contents due to the application of poultry manure. They said that improved soil nutrient contents caused by the addition of poultry manure led to increased uptake of N, P, K, Ca and Mg by tomato plant. Adesodun *et al.* (2005) also found that the application of poultry manure to soil increased soil organic matter, N and P and aggregate stability. The improvement in soil physical properties was attributed to improvement in soil organic matter content. Aluko and Oyedele (2005) reported that poultry manure improved soil moisture and was attributed to the mulching effect of organic matter and improved moisture retention as a result of improved soil structure and macro porosity.

2.7 Effect of poultry manure on growth and yield of crops

In an experiment conducted to evaluate the effect of plant nutrient source and weeding regime on the growth and yield of onion, poultry manure significantly produced the highest number of leaves per plant among the different sources of plant nutrients. It was also observed that poultry manure produced larger bulb size and the highest bulb yield than other fertilizer sources (Tukur *et al.,* 2009). The superiority of poultry manure over the other plant nutrient sources with respect to number of leaves per plant, bulb size and bulb yield was attributed to the high nutrient content and its ability to release adequate nutrients to the plants, leading to the development of adequate leaf area index, which is necessary for assimilate production and translocation to sinks.

Dauda *et al.* (2008) studied the efficacy of different levels of poultry manure on the growth and yield of watermelon (*Citrullus lanatus*). The results showed that application of poultry manure significantly enhanced growth and yield. They attributed the significant performance of watermelon over the control in growth parameters and yield to the fact that poultry manure contained essential nutrient elements associated with high photosynthetic activities and thus promotes vegetative growth. Increased number of fruits and average weight was attributed to the ability of poultry manure to promote vigorous growth, increase meristematic and physiological activities in the plants due to supply of plant nutrient and improvement in the soil properties, thereby, resulting in the synthesis of more photo-assimilates, which is used in producing fruits. Hence, an increase in fruit number and size. Aliyu (2003) reported that poultry manure supplies nutrients, which enhance vigorous growth and increase yield.

Awodun (2007) carried out a study to find out the effect of poultry manure and NPK fertilizer on the growth, leaf nutrient content and yield components of Telfaria (*Telfaria occidentalis* Hook F) at two sites in Akure, Nigeria. The treatments applied were 0, 2, 4, 6 t ha^{-1} poultry manure and 250 kg ha^{-1} NPK 15-15-15 fertilizer. Application of 250 kg ha^{-1} of NPK fertilizer gave the highest number of leaves and stem girth at the two sites. He attributed this to high and fast release of nutrients in the NPK as against the use of the poultry manure.

In an experiment involving the use of poultry litter for vegetable production, the level of poultry litter application affected carrot yield significantly. Application of poultry litter gave better yields of carrot than application of cattle manure and the control. Poultry litter is better than cattle manure for cabbage. Lack of positive response to increasing levels of poultry litter was attributed to the low C/N ratio which might have resulted in the loss of nitrogen through volatilization and leaching (AMAS, 2001).

Adekiya and Agbede (2009) found that application of poultry manure resulted in better growth and yield of tomato than NPK fertilizer alone. It improved the performance of tomato and its nutrient status. The finding that all levels of poultry manure performed better than the NPK fertilizer alone was attributed to the fact that poultry manure supplied more nutrients than NPK fertilizer. The poultry manure could have supplied micronutrients which are essential for tomato growth and yield. Stephenson *et al.* (1990) and Oladotun (2002) reported that poultry manure contains macro and micro nutrients such as N, P, K, S, Ca, Mg, Cu, Mn, Zn, Bo and Fe.

An experiment was conducted on single application of cocoa pod ash, poultry manure and their residual effects on soil chemical properties, nutrient content and yield components of maize. It was reported that the poultry manure increased grain yield than cocoa pod ash due to the lower C/N ratio of the poultry manure which ensured quicker release of N and P (Adeleye and Ayeni, 2010).

2.8 Green manure

Green manuring involves the soil incorporation of any field or forage crop while green or soon after flowering, for the purpose of soil improvement. A major benefit obtained from green manures is the addition of organic matter to the soil. During the breakdown of organic matter by microorganisms, compounds are formed that are resistant to decomposition such as gums, waxes, and resins. These and the mycelia, mucus, and slime produced by the microorganisms help bind together soil particles as granules, or aggregates. A well-aggregated soil tills easily, is well aerated, and has a high water infiltration rate. Increased levels of organic matter also influence soil humus. Humus is the substance that results as the end product of the decay of plant and animal materials in the soil. It provides a wide range of benefits to crop production. Nitrogen production from legumes is a key benefit of growing green manures. The amount of nitrogen available from legumes depends on the species of legume grown, the total biomass produced, and the percentage of nitrogen in the plant tissue. Cultural and environmental conditions that limit legume growth such as a delayed planting date, poor stand establishment, and drought will reduce the amount of nitrogen produced. Conditions that encourage good nitrogen production include getting a good stand, optimum soil nutrient levels and soil pH, good nodulation, and adequate soil moisture. The portion of green-manure nitrogen available to a following crop is usually about 40% to 60% of the total amount contained in the legume. A rapid increase in soil microorganisms occurs after a young, relatively lush green manure crop is incorporated into the soil. The soil microbes multiply to attack the freshly incorporated plant material. During microbial breakdown, nutrients held within the plant tissues are released and made available to the following crop.

Factors that influence the ability of microorganisms to break down organic matter include soil temperature, soil moisture, and carbon to nitrogen ratio of the plant material. The C:N ratio of plant tissue reflects the kind and age of the plants from which it was derived. As plants mature, fibrous (carbon) plant material increases and nitrogen content decreases. In addition to nitrogen from legumes, green manure helps recycle other nutrients on the farm. Nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), and other nutrients are accumulated during a growing season. When the green manure is incorporated, these plant-essential nutrients become slowly available during decomposition (Sullivan, 2003).

2.9 Synthetic pesticide: history and usage in Ghana

Pesticide is any substance or mixture of substances intended for preventing, destroying, repelling or mitigating pest. By their very nature, most pesticides create some risk of harm to humans, animals or the environment as they are designed to kill or otherwise adversely affect living organisms. At the same time, they are useful because of their ability to kill potential disease causing organisms and pests. Ideally, pesticides should reduce pest population, target specific organisms, breakdown quickly and have low toxicity to humans and other animals. Although synthetic insecticides have been an important part of pest management for many years, the disadvantages and risk of using them have become apparent. Some leave unwanted residues in food, water and the environment. Synthetic pesticides present users with threat to human and environmental safety, pests developing resistance and high cost. Thus, the need for alternatives is very important. Biologically based pesticides may constitute new avenues of pest control materials. They are usually less toxic than conventional pesticides, they affect only the target pest and closely related organisms as well, they are effective in very small quantities resulting in lower exposures and largely avoiding pollution problems caused by conventional pesticides (Tukur *et al.,* 2009).

Before 1942 many chemicals like arsenic, fluorine, sulphur and copper were used. The discovery of DDT as insecticide by Paul Muller of Switzerland and subsequent development by the allies of World War II led to a new concept in insect control. Almost immediately DDT was hailed as a means of stamping out insect borne diseases and winning the farmers war against crop destroyers over night (Hassan *et al.,* 2007).

Pesticides are not new. Ancient Romans killed insect pests by burning sulphur. In the 1600s, ants were controlled with mixtures of honey and arsenic. By the late nineteenth century, farmers were using copper acetoarsenite, calcium arsenate, nicotine sulfate and sulphur to control insect pests in field crops, but results were often unsatisfactory because of the primitive chemistry and application methods. An emergence in pesticide use began after the second world war with the introduction of DDT, BHC, aldrin, dieldrin, endrin and 2,4-D. These new chemicals were inexpensive, effective and enormously popular. DDT was especially favoured for its broad-spectrum activity against insect pests of agriculture and human health. 2, 4-D was an inexpensive and effective way to control weeds in grass crops such as corn. Under constant chemical pressure, some pests became genetically resistant to pesticides, non-target plants and animals were harmed, and pesticide residues appeared in unexpected places. With the publication of Rachel Carson's book *Silent Spring6* in 1962, public confidence in pesticide use was shaken. Carson painted a grim picture of environmental consequences of careless use of pesticide. The result has been a redirection of research toward more pest-specific pesticides and cropping methods that reduce reliance on pesticides. Many of today's pesticides are designed after "natural" pesticides. For example, "pyrethroid" insectides are modeled after "pyrethrins," which are natural, plant-derived poisons that have been used as insecticides for hundreds of years (Delaplane, 2000).

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Insect growth regulators affect insect growth, but they have little effect on non target animals. These products and similar ones using bacteria, viruses or other natural pest control agents are called "bio-rational" pesticides. In the 1960s, researchers began developing a different approach to pest control called "integrated pest management (IPM)." IPM aims to keep pests at economically insignificant levels by using crop production methods that discourage pests, encouraging beneficial predators or parasites that attack pests, and timing pesticide applications to coincide with the most susceptible period of the pest's life cycle. IPM assumes that certain low levels of pests are tolerable. Eradication is not necessarily a goal or even desirable in some cases, because the elimination of a pest may also cause the loss of the beneficial predators or parasites that need the pest in order to survive. IPM rarely is a substitute for using pesticides; rather, it is more often used to improve the effectiveness or reduce the overall use of pesticides. Even with IPM, however, pesticides frequently are the only way to deal with emergency pest outbreaks. Most shoppers do not buy fruits or vegetables with blemishes from plant disease or insects. Because of this consumer bias, farmers cannot afford to produce foods with even minor signs of pest damage, so they are forced to use pesticides (Delaplane, 2000).

According to Gerkenl *et al*. (2001) the extent of pesticide use can only be estimated. The official import figures for pesticides do not cover all pesticides found on the market. Insecticides including restricted cocoa pesticides rank highest in terms of imported quantities. There is a high proportion of extremely and highly hazardous pesticides used mainly in the cocoa sector. Farmers have limited information on pesticides and rely to a large extent on recommendations from pesticide dealers. Labels of pesticides are often not specific enough for farmers to apply the product properly and effectively. It is common practice among pesticide dealers that they repack a large proportion of pesticides for sale without proper labeling. This is in response to farmers demand for small quantities of pesticides due to cash problems and small areas to be treated. The average rate of application of pesticides per hectare cultivated land is low. There are large differences though between cocoa and vegetables on one side and roots and tubers on the other side concerning actual pesticide use per unit area. There is lack of adequate information on the extent to which external effects of pesticides affect human health and the environment. The extent may be considerable, even though the qualitative information is very general. Many farmers have experienced side effects in the application of pesticides concerning health and phytotoxicity. Despite the awareness of possible dangers from pesticide application, farmers do not use appropriate protective gear. Education and training are inadequate to prevent side-effects. Pesticide information and poison centers as well as trained medical personal are not in place. The lack of adequate management practices, first aid, diagnosis and treatment can worsen the effects of pesticide poisoning.

2.10 Problems associated with the use of pesticides

To deal with pesticides responsibly, their benefits and their risks must be balanced. Benefits are usually measured in economic terms, whereas risks are measured in terms of human and environmental health. People differ in the priorities they give these two factors. In the worst case, this means opposing groups compare money and human lives. In the best case, groups are forced to seek solutions that are both environmentally wise and economically realistic. The risk of a substance is a function of the substance’s toxicity and the amount of exposure to that substance. In other words the dose makes the poison. Toxic substances can enter the body through the skin, mouth, eyes or lungs. The two types of toxicity are acute toxicity and chronic toxicity. In acute toxicity, toxic effects result after a short exposure to the pesticide. In chronic toxicity, toxic effects result after a long exposure (up to several years). To bring out the understanding of acute toxicity of a substance, scientists use a measure termed the LD50, which is the Lethal Dose needed to kill 50 percent of laboratory test animals (usually measured as milligrams of poison per kilogram body weight). The poison is more dangerous when the LD50 is smaller (Delaplane, 2000).

The use of pesticides has become an integral part of modern agriculture, allowing great strides forward in meeting global food demands. Without pesticide alone, world food production would be reduced by an estimated 30%. Therefore pesticides have played a major role in crop protection and control of vector-borne diseases. Today their use is recognized throughout the world as an effective, relatively simple and quick method of pest control. Without chemical control crops would be destroyed by diseases, insect pests, weeds and severe loss of food production would occur. Despite all these benefits some serious health hazards 'potential to cause harm' are associated with chemical pesticide use (Hassan *et al.,* 2007).

Humans may be poisoned by exposure to large amount of pesticide, whereas lower levels of many pesticides pose a long-term threat to cancer. Since some pesticides persist environmentally and are accumulated in our tissues with multiple, unpleasant and even lethal consequences, the long-term effect of using pesticides cause pollution which also poses a problem to human health (Kumar, 1986).

2.10.1 Health problems

Farmers, farm workers and their families, bystanders and consumers are exposed to dangerous synthetic pesticides. Handling, storage and disposal of these chemical agricultural inputs can cause acute and chronic negative health effects; cancer, malfunctioning of reproductive and endocrine systems. Pesticide residues in food and drinking water can cause similar problems affecting an even greater number of people (PAN, 2007).

2.10.2 Social and economic problems

The use of synthetic pesticides very often is connected to a vicious cycle of financial dependency and dependency on credits for these inputs. This agrochemical treadmill is leading to increasing indebtedness of farmers with immense negative effects for the economy of farm families and rural communities. Suicides committed because of debts are common. Other consequences of indebtedness are migration, loss of land and culture. External costs due to pesticides impact on health and environment are not reflected in the costs of pesticides (costs for health treatment, costs arising from illness related lack of work, loss in biodiversity and costs for water treatment). The high input of synthetic pesticides in conventional agriculture creates a spiral of dependency as they destroy beneficial organisms and induce resistance, creating the need for new and more expensive pesticides. The total dependency on chemical pesticides and the pesticides industry results in a lack of choice for farmers and their families in terms of choice of crops, choice of seeds, choice of production system, and it contradicts the right to food sovereignty. Pesticide-based agriculture deprives women of access to land, to seed and to credit (PAN, 2007).

2.10.3 Environmental problems

Pesticides are nowadays found in virtually all natural habitats, including those where pesticides have never been applied. They have severe negative effects on natural flora and fauna, biodiversity, water resources and ecosystem functioning and the equilibrium of agricultural systems (PAN, 2007).

2.10.4 Insect resistance to insecticides

Pesticide resistance is a genetically based phenomenon. Resistance occurs when a pest population-insects, for instance-is exposed to a pesticide. When this happens, not all insects are killed. Those individuals that survive frequently have done so because they are genetically predisposed to be resistant to the pesticide. Repeated applications and higher rates of the insecticide will kill increasing numbers of individuals, but some resistant insects will survive. The offspring of these survivors will carry the genetic makeup of their parents. These offspring, many of which will inherit the ability to survive the exposure to the insecticide, will become a greater proportion with each succeeding generation of the population. Because of the rapid reproductive rate of many pests, a generation of many insects can take place in a few weeks, thus many generations can be produced in a single season or year. It’s easy to see that repeated applications of an insecticide will quickly eliminate all susceptible insects in the population, essentially selecting out those individuals that are resistant. In a short period the entire population of insects will be resistant. The more times a population is exposed to a pesticide, especially a broad-spectrum pesticide, the more quickly resistance will develop (Bellinger, 1996).

After a pest species develops resistance to a particular pesticide, one can control by using a different pesticide, especially one in a different chemical class or family of pesticides that has a different mode of action against the pest. It allows a pest to be controlled until other management strategies can be developed and brought to bear against the pest. These strategies often include the use of pesticides, but used less often and sometimes at reduced application rates (Bellinger, 1996).

2.11 Biopesticides and their use in pest control

Biopesticides are pest management tools that are based on beneficial micro organisms or other safe, biologically-based active ingredients. Benefits of biopesticide are control of insects, plant diseases and weed, as well as posing no threat to human and environment. The increasing use of a wide range of toxic chemicals which are deliberately released into the environment is causing widespread concern about their impact on human health and the damage caused to the environment, particularly in developing countries that usually lack appropriate resources to minimize these risks and rectify associate problems. Biopesticides control pests effectively, are environmentally friendly and good for humans (Tukur *et al.,* 2009).

2.11.1 Categories of biopesticides

i) Those that contain microorganisms as the active ingredients known as microbial pesticides. The most widely known are varieties of the bacterium, *Bacillus thuringiensis* (Bt) which controls certain insects in cabbage, potatoes and other crops.

ii) The plant pesticides. They are pesticidal substances that plants produce from genetic materials that have been added to the plant. Scientist can take the gene and introduce into the plant's own genetic material. For example, the gene for the Bt pesticidal protein can be taken and introduced into a plant's genetic material. The plant then manufactures the substance to destroy the pest.

iii) The biochemical pesticides. They are naturally occurring substances that control pests by non-toxic mechanisms. They contain substances that interfere with the growth or mating of the pest (Tukur *et al.,* 2009).

2.12 Botanicals as pesticides

The extensive use of chemicals to protect plants has led to serious social and environmental repercussions (IPM of Alaska, 2003) hence; plant products have recently attracted the attention of agricultural scientists because of the products' usefulness as pesticides in providing effective crop protection in a pollution-free environment (Rajappan *et al.*, 2000). The efficacy of neem oils in controlling okra flea beetle was reported by Tuker *et al.* (2009) and the population of flea beetles was reduced. This was due to the efficacy of the active ingredients azadirachtin, melean triols and salannin contained in neem plant. The efficacy may have to do with repelling activities of the active ingredients when sprayed on the crops. The lower leaf damage and higher yield of okra green pods may be due to the inhibitory activities of the active ingredient azadirachtin which deter flea beetles from causing damage to the okra leaves and flowers. According to Drew (1992) the active ingredient does not kill the flea beetle immediately, but it inhibits their growth and reproduction.

2.12.1 Neemazal as insecticide and its effect on the environment and human health

Marcic *et al.* (2009) in an experiment to determine the effectiveness of azadirachtin (NeemAzal-T/S) in controlling pear psylla (*Cacopsylla pyri*) and European red mite *(Panonychus ulmi*) reported that azadirachtin and abamectin achieved 100% efficacy, while the effectiveness of mineral oil was 97.4% and that of diflubenzuron a mere 59%. All four insecticides significantly reduced the number of older yellow eggs and larvae, the efficacy being 80.5-92.6% (yellow eggs), 69.8-79.3% (larvae I-III instar) and 94.3-100% (larvae IV-V instar). Azadirachtin, abamectin and mineral oil achieved 100% efficacy against white and yellow eggs in evaluation while diflubenzuron achieved 93% and 86.9% efficacy. All four insecticides were found to demonstrate high efficacy against I-III instar larvae (99.2-100%), but mineral oil treatment alone achieved high efficacy against IV-V instar larvae (92.4%) as well. They reported that neem-based products have considerable oviposition deterrence against winterform pear psylla females.

Azadirachtin reportedly breaks down within 100 hours in water or light. It is relatively immobile in soil (Martineau, 1994). Azadirachtin is not likely to accumulate or cause long-term effects (Miller and Uetz 1998). Fish toxicity is moderate and azadirachtin is not expected to kill fish under normal use. Azadirachtin has little or no negative effect on adult beneficials. It is reported to be relatively harmless to bees, spiders, ladybeetles, parasitoid wasps, and adult butterflies. The product labels advise not to apply it when honeybees are actively foraging. In a few trials, negative effects have been noted on immature stages of beneficial species exposed to neem (Banken and Stark 1997). However, neem products are generally thought to be suitable for inclusion into integrated pest management programs (Lowery and Isman 1994; Ruckin, 1992). The effects of neem on many non-target organisms have not been studied, and it seems likely that some may be affected. Studies of azadirachtin mutagenicity and acute toxicity have shown that it likely does not pose a significant risk to human health. However, some people have exhibited skin and mucous membrane irritation from neem seed dust (Weinzierl and Henn 1991).

2.12.2 Efficacy of neem extracts and mode of action

Neem extracts have been shown to affect over 200 insect species including some species of whiteflies, thrips, leaf miners, caterpillars, aphids, scales, beetles, true bugs and mealy bugs (Thacker 2002; Copping 2001). Although neem products are labeled for many species, efficacy against them varies greatly. Besides insects, other pests including mites (Miller and Uetz.1998) and snails (Mostafa and Abdel-Megeed, 1996) have been reported susceptible to neem.

Tukur *et al*. (2009) determined the efficacy of neem oils in the control of okra leaf beetle and reported that ripe neem seed oil extract controlled the pest from damaging the okra leaves. The population of flea beetle in plots treated with ripe neem seed oil extract was drastically reduced. This was due to the efficacy of the active ingredients azadirachtin, melean triols and salannin contained in the neem plant. They said that the efficacy may have to do with the repelling activities of the active ingredients when sprayed on crops. Spraying neem seed oil on okra recorded lower leaf damage and higher yield of okra green pods. They attributed this to the inhibitory activities of the ingredients azadirachtin which deter flea beetles from causing damage to okra leaves and flowers.

In a research to assess the efficacy of azadirachtin on larval growth (determined by measuring head dimensions) and feeding activity (determined by food consumption and faecal output) of the pine processionary moth (*Thaumetopoea pityocampa* (Schiff.)), the results show that azadirachtin inhibits larval growth and reduces the feeding activity of *T. pityocampa*. In conclusion, this study has revealed that azadirachtin has antifeedant and growth inhibition properties against *T. pityocampa* (Unal and Akkuzu, 2009).

Azadirachtin, one of the more than 70 compounds produced by the neem tree, acts mainly as an insect growth regulator, but also has anti-feedant and oviposition (egg-laying) deterrent properties. First isolated in 1968, azadirachtin is thought to be the most bioactive ingredient found in the neem tree; however, such speculation may be due to it having been investigated more thoroughly than the other compounds (Thacker 2002; Quarles 1994). Most commercially available neem products have azadirachtin as the primary active ingredient. Such products are broad-spectrum insecticides, which work by contact or ingestion. As an insect growth regulator, azadirachtin prevents insects from molting by inhibiting production of ecdysone, an insect hormone. Azadirachtin is chemically similar to ecdysonlids, the hormones responsible for triggering molts (Weinzierl and Henn 1991). As an anti-feedant it may cause an insect to stop feeding after ingestion due to secondary physiological effects. As an egg-laying deterrent, volatile compounds from neem may repel some insects from depositing eggs on a plant surface.

There is evidence that other compounds found in neem have insecticidal attributes that contribute to a given product's efficacy. A study conducted at Washington State University in conjunction with the W.R. Grace and Company (manufacturers of the neem product Margosan-O) found that products containing both azadirachtin and neem oil have greater efficacy in controlling aphids than either ingredient alone (Stark and Walter 1995). They hypothesize that neem oil may help spread the chemicals on both plant and insect surfaces and allow them to penetrate into the insect more effectively. Neem seed oil is formulated and used somewhat like other horticultural oils and controls some foliar diseases as well as certain insects and mites. The oil is also made into an insecticidal soap, which probably acts similarly to other insecticidal soaps by disrupting insect membranes.

Active neem constituents can be absorbed through plant roots and systemically move upward through the plant through xylem tissues (Nisbet, *et al.*, 1993; Osman and Port 1990). This works best when sufficient quantities are applied to the root zone. Systemic effects are much less apparent from foliar sprays. Different plant species also differ widely in their ability to have systemic effects from neem. Neem constituents last much longer within the plant than when sprayed on the leaves. However, over time they will be diluted by growth.

Spraying of vegetables with neemazal can avoid the damage of most harmful pests. The main effects are due to the repellent and/or deterrent properties of neemazal. Lepidoptera are among the organisms most sensitive to neem extracts (Martinez and van Emden, 1999).

2.12.3 *Moringa oleifera* as a biopesticide

Moringa oleifera belongs to the family *Moringaceae*, a native to the sub-Himalayan tracts of India, Pakistan, Bangladesh and Afghanistan. It is a perennial softwood tree with timber of low quality, but which for centuries has been advocated for traditional medicinal and industrial uses. All parts of the Moringa tree are edible and have long been consumed by humans (Fahey, 2005). HDRA (2002) reported that moringa can be used as a natural pesticide by digging Moringa leaves into the soil before planting, damping off disease (Pythium debaryanum) can be prevented among seedlings. According to Fuglie (1999) moringa is used as biopesticide. The active ingredient in moringa oleifera extracts is saponins. The saponins are naturally occurring surface-active glycosides. They are mainly produced by plants, but also by lower marine animals and some bacteria (Riguera, 1997; Yoshiki *et al.*, 1998). Saponins occur constitutively in many plant species (Fenwick *et al.* 1991). Triterpenoid saponins have been detected in many legumes. Many saponins are known to be antimicrobial, to inhibit mould, and to protect plants from insect attack. Saponins are considered a part of plants' defense systems, and as such have been included in a large group of protective molecules found in plants named phytoanticipins or phytoprotectants (Morrissey and Osbourn, 1999). The family *Moringaceae* is rich in compounds containing the simple sugar, rhamnose, and it is rich in a fairly unique group of compounds called glucosinolates and isothiocyanates. Specific components of Moringa preparations that have been reported to have hypotensive, anticancer, and antibacterial activity include benzyl isothiocyanate, benzyl isothiocyanate, niazimicin, pterygospermin, benzyl isothiocyanate and benzyl glucosinolate (Fahey, 2005).

2.13 Moringa leaf extract as plant growth promoter

According to Rehman and Basra (2008), the leaves of moringa are rich in zeatin, a natural source of cytokinin. In addition, they are also rich in ascorbates, carotenoids, phenols, potassium and calcium which are capable of promoting growth. Antioxidants such as ascorbic acid and glutathione are also found at high concentrations in moringa chloroplasts and other cellular compartments. They are crucial for plant defense against oxidative stress. A plant growth spray made from moringa leaves increased crop production 20-35%. Moringa Leaf Spray affects crops in the following ways:

- It increases the life-span of crops

- It produces heavier roots, stems and leaves
- It produces more fruit and larger fruit
- It increases yield by 20-35%.

All these highlight the opportunities of using moringa leaf extract as a foliar spray to accelerate growth of young plants. Moringa leaves are a source of plant growth factors, antioxidants, β-carotene, vitamin C, and various glucosinolates and their degraded products which are used as antibacterial, antioxidant, and carcinogenic and anti-pest agents. The extract being rich in zeatin, a cytokinin enhance plant growth and yield by delaying the senescence. Exogenous application of moringa leaf extract as seed treatment or root application improves the seed germination and produce vigorous seedlings. The vigorous seedlings have also resistance against many biotic stresses such as chilling, drought and salinity as well abiotic stresses such as pest and diseases. And plants sprayed with this plant growth promoter also produce more and larger harvest produce and yield. For example, foliar application of the extract in wheat at tillering, jointing, booting and anthesis has been reported to increase wheat yield. For most of the horticultural and some field crops like onions, bell pepper, soya, maize, sorghum, coffee, tea, chili and melon, 25-30 percent increased yield are reported. Foliar application of leaf extract should be used in addition to other fertilizers, watering and sound agricultural practices.

2.14 Plant pests

Every plant species on earth serves as food for at least one species of insect. No parts of a plant are immune from attack by insects. Even plants that manufacture potent insecticides have insect pests that are especially adapted to feed on their tissues and detoxify their chemical defenses (Tukur *et al.*, 2009).

2.14.1 Onion thrips (*Thrips tabaci*): classification and life cycle

Thrips are the most damaging pests of onions worldwide (Brewster, 1994). Thrips can severely damage alliums through their feeding activities by piercing the leaf cell and feeding on the sap (Chaput and Schooley, 1998).

The classification of onion thrip is shown below:

Kingdom: Animalia

Phylum: Arthropoda

Class: Hexapoda

Order: Thysanoptera

Family: Thripidae

Genus: Thrips (Poole and Gentili, 1996).

They are parthenogenetic which means that the females can reproduce without mating, inserting eggs completely into leaf tissue. Nymphs, hatch from eggs 5 to 10 days later and develop through four stages including two larval instars, a prepupal and a pupal stage, over a period of 15 to 30 days. The first two instars are spent on the host plant and the later non-feeding stages are spent in the soil. Up to eight generations can occur annually (Drees and Jackman, 1999).

2.14.1.1 Feeding injury

Thrips use their rasping and sucking mouthparts to scrape the leaf surface and suck up the exuding plant juices. This feeding produces silvery-white, mottled lesions on the leaf surface. The lesions may become so numerous that the entire plant takes on a white or straw-coloured appearance. Continuous feeding results in leaf distortion, followed by wilting, browning and premature lodging. During hot, dry seasons, damage from thrips becomes most serious and may result in reduced onion yields. Feeding also puts added stress on the plant, making the onion more susceptible to bacterial rot and fungal attack (Chaput and Schooley, 1998).

Thrips prefer to feed on the newly emerged leaves in the center of onion necks. Under crowded conditions, they will move toward leaf tips to feed. Both adult and larval thrips feed within the mesophyll layer of the leaf. The mouthparts are beak-shaped with one enlarged mandible. The beak and mandible is used to puncture the leaf epidermis and sap released from injured plant cells is sucked up (Alston and Drost, 2008).

The Onion Thrips (*Thrips tabaci*) attacks all edible allium according to Soni and Ellis (1990). Probably, the most damaging pests worldwide are the insignificant looking thrips or thunderflies. These are slender insects only about 2 mm long as adults. They are found wherever alliums are grown, but are most severe in the warmer production regions (Brewster, 1994). The temporal and spatial arrival of onion thrips population into onion fields is variable and relatively unpredictable (Gangaloff, 1999). According to Kranz *et al*. (1977), the number of thrips on a crop can increase rapidly in dry weather and decrease rapidly after rain. They found that large number of thrips attacking a crop at the seedling stage could cause severe or even total losses. However, once established and growing vigorously, most plants could tolerate feeding damage. They also reported that control of alternative host plants is unlikely to be a useful method except under exceptional circumstances, because of wide host range. The crop may be protected by bringing forward planting date so that the maximum population of thrips does not coincide with the seedling stage. Raheja (1973) reported that population of thrips gradually built up and reached a peak 50 days after transplanting.

Insecticides have been the primary tactic for their management; however, repeated applications often lead to resistance in the thrips population, suppression of natural enemies, and unsustainable management. Life history characteristics of onion thrips that enhance their pest status include a short generation time, high reproductive potential, asexual reproduction by females and non-feeding life stages. Recent research has shown that the majority of onion thrips on a plant is in the non-feeding egg stage and thus, not exposed to insecticides and other suppressive tactics. Multi-pronged pest management strategies that boost onion plant health and tolerance to thrips, in addition to suppressing thrips densities, have proven the most sustainable and economically viable (Alston and Drost, 2008).

Onion thrips have a broad host range that includes grasses and broadleaves. They are pests of agricultural crops, home gardens, landscapes, and greenhouses. Primary vegetable hosts include onion, garlic, leek, cabbage, cauliflower, bean, tomato, cucumber, and asparagus. Common field crop hosts include alfalfa, small grains, and cotton. They may cause damage to bedding plants and some flowers. Onion thrips are the most injurious insect pest to onions. Immature and adult thrips prefer to feed on young leaves in the inner neck of plants. Moderate to severe thrips feeding causes reduced bulb size (Alston and Drost, 2008).

2.14.1.2 Management of thrips

Insecticides are a major tool for the control of thrips, but they are prone to develop resistance. Long-term, sustainable management of thrips includes crop cultural practices, onion varietal resistance, biological control, and insecticide resistance management. Key thrips population management strategies include

- Cultural practices to increase onion plant tolerance and reduce attractiveness to thrips
- Begin thrips suppression in the early summer before a reservoir of eggs builds up in plants
- Use of long-term suppressive strategies that target all life stages of onion thrips.

Onion transplants should be inspected for thrips infestation, and discarded. Onions should be fertilized with adequate nitrogen, but not excessive amounts. Moderate, consistent availability of nitrogen has been associated with a healthy onion crop and reduced onion thrips densities.

Straw or other mulch placed on the plant bed has been shown to reduce thrips populations and improve onion growth by suppressing weeds, reducing soil moisture loss, reducing soil erosion, and enhancing soil organic matter. This helps to increased biological control of thrips through enhancement of predator populations, creation of a barrier for pre-pupae and pupae to access soil, and reduced temperatures, which slow thrips development and population increase.

Overhead sprinkler irrigation has been shown to reduce thrips populations on onion plants. The physical action of water washing thrips from plants and water droplets standing on leaf surfaces are inhibitory to thrips because thrips prefer warm and dry conditions. In addition, water applied through sprinklers may cause a crust to form on the soil surface and reduce the ability of pre-pupae and pupae to seek shelter in the soil. Onion plant matter left on the soil surface can harbor thrips to survive and spread the next season. Insecticides are the most common tactic for onion thrips management. Despite their ease of use and availability of numerous classes or modes of action, rapid development of resistance to insecticides is a key problem. To prolong the effectiveness of insecticides, it is important to limit the number and frequency of insecticide applications, rotate insecticide classes or modes of action between applications, and apply insecticides with thorough coverage. Sprays applied with high pressure and high water volume penetrate better into the inner neck. Insecticides vary in their toxicity to thrips life stages. Most insecticides are effective in killing the early larval stages because the young stages are small and actively feeding. Some insecticides are active against adults and only a few have ovicidal activity. Adults have a thicker cuticle than larvae and fly quickly when disturbed, so they are more difficult to kill than larvae. Eggs are laid within the leaf so are not accessible except to systemic insecticides that are absorbed through the leaf. Older larvae are non-feeding and they hide in the soil or at the base of onion plants, and escape contact by most insecticides. Insecticides grouped by their mode of action that are effective in reducing thrips on onions have been reported as follows: Botanical, Insect Growth Regulator (azadirachtin, pyriproxyfen), Microbial (spinosad, spinetoram), Organophosphate (diazinon, malathion, methyl parathion), Particle Barrier or Repellent, Suffocant or Disruptant (insecticidal soap, stylet oil), Synthetic Pyrethroid (cypermethrin, lambda-cyhalothrin, permethrin, zeta-cypermethrin) (Alston and Drost, 2008).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location and history of site

The experiment was conducted in the research field of the Department of Horticulture, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi from 17th August to 12th November, 2009 (minor rainy season) and repeated from 22nd March to 17th June, 2010 (major rainy season). The experimental area had been under cultivation to various vegetables for a considerable number of years.

3.2 Experimental materials and sources

3.2.1 Source of spring onion planting materials

Spring onion transplants were purchased from an identified spring onion farmer in Kumasi.

3.2.2 Source and analysis of poultry manure

Poultry manure was obtained from a commercial poultry farm in Kumasi. Manure was analyzed for available nitrogen, phosphorus, potassium, organic carbon, organic matter, exchangeable cations and pH. Poultry manure was applied at 5.98 t/ha.

3.2.3 Source, planting and incorporation of moringa green manure

Seeds of *Moringa oleifera* obtained from a farmer in Kumasi were planted at a spacing of 10cm x 10cm between rows and within rows and dug into the soil after 25 days. On the day of ploughing in the green manure, the biomass of moringa was taken. The time gap between digging in of green manure and transplanting of spring onion was two weeks. This was to prevent nutrient losses from the decomposing green manure (IFOAM, 2002). At two weeks after digging in the green manure, soil samples were taken at depth of 0 – 15cm on the green manure treated plots and analyzed to determine the amount of nutrients added to the soil by the green manure.

3.2.4 Source and preparation of botanicals

3.2.4.1 Moringa leaf extract

The moringa leaf extract was made by pounding young moringa shoots. A litre of water was added to 10kg freshly pounded material. The fibrous material was filtered out of the solution by placing the solution in a muslin cloth and wringing out the liquid.

3.2.4.2 Neemazal

The neemazal was obtained from a commercial producer in Kumasi.

3.3 Soil analysis

For each of the two experiments, two soil analyses were carried out. The first soil samples were taken at different locations on the experimental site at a depth of 0 – 15cm before application of treatments. The samples were bulked and analyzed for available nitrogen, phosphorus, potassium, organic carbon, organic matter, exchangeable cations and pH of the soil. The final soil samples were taken from the differently treated plots after harvest at (0 – 15cm) and analyzed for available nitrogen, phosphorus, potassium, organic carbon, organic matter, exchangeable cations and pH of the soil.

3.4 Cultural practices

3.4.1 Land preparation

The experimental area measuring 4.5m x 10.5m was ploughed and harrowed. Beds were then raised and weeds and stones removed. Soil clods were broken down thoroughly and raked to good tilth. Beds were leveled with rake. The area was divided into three blocks, each measuring 1.2m x 10.5m with 0.45m between blocks. Each block was divided into nine plots, each measuring 1.2m x 0.9m

3.4.2 Transplanting

Planting materials were separated into uniform daughter shoots and transplanted at a spacing of 30cm between rows and 15cm within rows. Transplanting was done using one transplant per hole after lining and pegging. Thirty five plants were obtained per plot.

3.4.3 Watering

Watering was done soon after transplanting and subsequently as and when necessary to ensure good establishment of plants. Afterwards, watering was done once a day.

3.4.4 Weeding and stirring of soil

Weeding of the plots was done manually at fortnightly intervals after transplanting.

3.4.5 Pest control

Onion thrips (*Thrips tabaci*) were controlled with two botanicals (moringa leaf extract and neemazal). The moringa extract was diluted at a ratio of 1ml of extract to 32ml of water and sprayed directly onto the plants at 25ml per plant according to Lowell (2003). Neemazal was applied at 3litres per hectare. It was diluted at 10ml to 1 litre of water. Spraying of each pesticide was carried out on weekly basis for 3 consecutive weeks.

3.5 Experimental design

The experiment was a 3 x 3 factorial laid out in a randomized complete block design (RCBD) with three replications for both experiments. The first factor was type of soil amendment and the second factor was botanicals. There were three types of soil amendments [No manure (A_0), Green manure (A_1) and Poultry manure (A_2)] and three types of botanicals [No Botanical (B_0), Moringa leaf extract (B_1) and Neemazal (B_2)]. There were nine treatment combinations as follows:

Treatment (1) - no manure + no botanical

Treatment (2) - no manure + moringa leaf extract

Treatment (3) - no manure + neemazal

Treatment (4) - green manure + no botanical

Treatment (5) - green manure + moringa leaf extract

Treatment (6) - green manure + neemazal

Treatment (7) - poultry manure + no botanical

Treatment (8) - poultry manure + moringa leaf extract

Treatment (9) - poultry manure + neemazal

3.6 Parameters assessed

The following parameters were assessed:

- **Number of leaves per plant**

Number of leaves per plot was counted and divided by the number of data plants to get the number of leaves per plant. This was done from two weeks after transplanting and continued weekly until harvesting.

- **Number of daughter shoots per plant**

Number of daughter shoots per plot was counted and divided by the number of data plants to get the number of daughter shoots per plant. This was done from two weeks after transplanting and continued weekly until harvesting.

- **Plant height (cm)**

Plant height was taken from the base of the plant to the tip of the longest leaf. This was done from two weeks after transplanting and continued weekly until harvesting.

- **Yield (t/ha)**

The data plants harvested (pulled) from a plot as green onion was weighed and the result was divided by the number of plants harvested. Values were converted to per hectare value.

- **Non marketable yield (t/ha)**

All diseased, pest infested and discoloured leaves were removed from harvested plants and weighed. This was used to determine non marketable yield per hectare.

- **Marketable yield (t/ha)**

The entire plant harvested (pulled) as a green onion with uniform green leaves, free from insect pests and diseases after all diseased, pest infested and discoloured leaves have been removed. This was used to determine the marketable yield per hectare.

- **Number of damaged leaves per plant**

Nine plants, three from each of the three middle rows of the plot were used for the data on this parameter. Leaves with silvery spots on them as a result of feeding activities of thrips were counted on these plants before spraying and weekly after spraying.

3.7 Cost benefit analysis

Total cost values were determined by dividing man-days by man- hours and multiplying them by the amount of money charged per day. The total sales figures were obtained after selling a unit weight of the marketable produce. The amount paid for the unit weight was used to determine the total sales by simple proportion. The net benefit figures were determined by subtracting the total variable cost from the total benefit.

3.8 Nutritional analysis

The proximate analyses (crude proteins, crude fibre, fat and ash) of all the treatments were determined at the nutrition laboratory of KNUST, Kumasi.

3.9 Statistical analysis

Results were statistically analysed using the Statistical Analysis System (SAS) Package. The Analysis of Variance (ANOVA) was used to establish the statistical significance or otherwise of the treatments and the Least Significant Difference (LSD) Test was used to determine the differences between treatment means.

CHAPTER FOUR

4.0 RESULTS

4.1 Experiment one (Minor rainy season)

4.1.1 Chemical properties of soil amendments and soil in experiment one (minor season)

4.1.1.1 Chemical properties of poultry manure and soil (minor season)

Table 4.1 shows the chemical properties of poultry manure and the soil used in the minor season experiment. The poultry manures used had pH of 6.77. The value of organic matter was 8.67%. The values of N, P and K in the poultry manure were 3.00%, 0.67 mg kg^{-1} and 3.43 cmol kg^{-1} (Table 4.1). The values of the other exchangeable cations were 4.00 cmol kg^{-1} for Ca, 3.47 cmol kg^{-1} for Na and 8.00 cmol kg^{-1} for Mg. The pH of the soil was 5.17. The values of percent organic matter, N, P and K in the soil were 1.27%, 0.15%, 155.56 mg kg^{-1}, and 0.33 cmol kg^{-1} respectively (Table 4.1). The other exchangeable bases (Na, Ca and Mg) were 1.21 cmol kg^{-1}, 4.00 cmol kg^{-1} and 4.00 cmol kg^{-1} respectively.

Table 4.1: Chemical properties of poultry manure and soil for minor season experiment

Property	Poultry Manure	Soil
pH	6.77	5.17
Organic matter (%)	8.67	1.27
Total-N (%)	3.00	0.15
Available P (mg kg^{-1})	0.67	155.56
Exchangeable K (cmol kg^{-1})	3.43	0.33
Exchangeable Ca (cmol kg^{-1})	4.00	4.00
Exchangeable Na (cmol kg^{-1})	3.47	1.21
Exchangeable Mg (cmol kg^{-1})	8.00	4.00

4.1.1.2 Chemical properties of green manure plots before planting, 25 days after planting and 2 weeks after incorporation in the minor season

The chemical properties of the soil before planting green manure, 25 days after planting green manure and 2 weeks after incorporation of green manure in the minor season experiment is shown in Table 4.2. The initial soil pH increased from 5.17 to 6.52 after planting green manure for 25 days, but it decreased to 6.42 after incorporating green manure for 2 weeks. Organic matter, nitrogen, phosphorus and calcium also increased after planting green manure for 25 days, but they decreased after incorporating green manure for 2 weeks. The other exchangeable cations (potassium, sodium and magnesium) decreased after planting green manure for 25 days. But they increased after incorporating green manure for 2 weeks (Table 4.2).

Table 4.2: Chemical properties of green manure plots before planting, 25 days after planting and 2 weeks after incorporation of green manure in the minor season

Property	Before planting	25 days after planting	2 weeks after incorporation
pH	5.17	6.52	6.42
Org. matter (%)	1.27	2.14	1.55
Total-N (%)	0.15	0.21	0.14
Avail. P (mg/kg)	155.56	214.12	187.49
Exch. K (cmol/kg)	0.33	0.21	0.25
Exch. Ca (cmol/kg)	4.00	7.20	2.80
Exch. Na (cmol/kg)	1.21	0.24	0.26
Exch. Mg (cmol/kg)	4.00	1.20	2.20

Org. =organic, Avail. =available, Exch. =exchangeable

4.1.1.3 Chemical properties of green manure, poultry manure and no manure plots before treatment and at the end of the minor season experiment

Data on the chemical properties of green manure, poultry manure and no manure plots before treatment and at the end of the minor season experiment is presented in Table 4.3. Soil pH increased from 5.17 to 7.00 in green manure plots, from 5.17 to 6.98 in poultry manure plots and from 5.17 to 7.13 in plots where no manure was applied (No manure). Organic matter contents and all the exchangeable cations also increased in green manure, poultry manure and no manure plots. Total nitrogen and available phosphorus on the other hand decreased in green manure, poultry manure and no manure plots (Table 4.3).

Table 4.3: Chemical properties of green manure, poultry manure and no manure plots before treatment and at the end of the minor season experiment

Parameter	Before treatment	At the end of experiment		
		Green manure	Poultry manure	No manure
pH	5.17	7.00	6.98	7.13
Org. matter (%)	1.27	1.52	1.79	1.55
Total-N (%)	0.15	0.13	0.13	0.11
Avail. P (mg kg^{-1})	155.56	52.20	49.07	50.61
Exch. K (cmol kg^{-1})	0.33	0.89	0.92	0.69
Exch. Ca (cmol kg^{-1})	4.00	7.60	7.60	6.80
Exch. Na (cmol kg^{-1})	1.21	1.56	1.69	1.35
Exch. Mg (cmol kg^{-1})	4.00	5.80	5.40	5.80

Org. =organic, Avail. =available, Exch. =exchangeable

4.1.2 Number of spring onion leaves as influenced by soil amendments and botanicals (minor season)

Soil amendments showed no significant effect on number of leaves from 2 weeks after transplanting to 7 weeks after transplanting in the minor season. Number of leaves at 7 weeks after transplanting ranged from 19.04 to 21.91 (Table 4.4).

Number of leaves was also not significantly influenced by the application of botanicals. Number of leaves at 7 weeks after transplanting ranged from 19.53 to 21.11 (Table 4.5).

Table 4.4: Number of leaves of spring onion as influenced by soil amendments in the minor season

	Weeks after transplanting (WAT)					
Soil Amendments	2weeks	3weeks	4weeks	5weeks	6weeks	7weeks
Green manure	9.22	12.56	14.53	16.81	18.21	20.48
Poultry manure	9.53	12.75	14.60	16.68	18.76	21.91
No manure	9.42	12.20	13.67	15.85	17.27	19.04
Mean	9.39	12.50	14.27	16.45	18.08	20.48
C.V (%)	11.55	9.15	11.82	14.54	15.88	13.72
LSD (5%)	NS	NS	NS	NS	NS	NS

CV= Coefficient of variation, NS=Not Significant, LSD=Least Significant Difference

Table 4.5: Number of leaves of spring onion as influenced by botanicals in the minor season

	Weeks After Transplanting			
Botanicals	4 weeks	5weeks	6weeks	7weeks
Moring Extract	14.01	15.96	18.31	20.79
Neemazal	14.57	17.35	18.75	21.11
No Botanical	14.22	16.04	17.19	19.53
Mean	14.27	16.45	18.08	20.48
C.V (%)	11.82	14.54	5.88	13.72
LSD (5%)	NS	NS	NS	NS

CV= Coefficient of variation, NS=Not Significant, LSD=Least Significant Difference

4.1.3 Number of daughter shoots of spring onion as affected by soil amendments and botanicals in the minor season

Soil amendments did not significantly influence number of daughter shoots from 2 weeks after transplanting to 7 weeks after transplanting in the minor season. The number daughter shoots at 7 weeks after transplanting ranged from 5.26 to 5.94 (Table 4.6).

Botanicals application also had no significant effect on the number of daughter shoots. Daughter shoot number ranged from 5.49 to 5.90 at 7 weeks after transplanting (Table 4.7).

Table 4.6: Number of daughter shoots of spring onion as affected by soil amendments in the minor season

	Weeks after transplanting (WAT)					
Soil Amendments	2weeks	3weeks	4weeks	5weeks	6weeks	7weeks
Green manure	2.12	2.73	3.02	3.74	4.20	5.94
Poultry manure	2.15	2.94	3.21	3.95	4.47	5.75
No manure	2.12	2.73	3.02	3.64	4.07	5.26
Mean	2.13	2.80	3.09	3.78	4.25	5.65
C.V (%)	11.68	12.05	13.89	10.56	14.37	14.15
LSD (5%)	NS	NS	NS	NS	NS	NS

CV= Coefficient of variation, NS=Not Significant, LSD=Least Significant Difference

Table 4.7: Number of daughter shoots of spring onion as affected by botanicals (minor season)

	Weeks after transplanting (WAT)			
Botanicals	4weeks	5weeks	6weeks	7weeks
Moringa Extract	3.06	3.74	4.16	5.49
Neemazal	3.18	3.84	4.30	5.90
No Botanical	3.01	3.75	4.28	5.56
Mean	3.09	3.78	4.25	5.65
C.V (%)	13.89	10.56	14.37	14.15
LSD (5%)	NS	NS	NS	NS

CV= Coefficient of variation, NS=Not Significant, LSD=Least Significant Difference

4.1.4 Effect of soil amendments and botanicals on plant height (cm)

There were no significant differences in height of spring onion as influenced by soil amendments from 2 weeks after transplanting to 6 weeks after transplanting in the minor season (Table 4.8). However, plant height was significantly ($P<0.05$) influenced by soil amendment at 7 weeks after transplanting. Poultry manure and green manure treated plots produced spring onion plants that were significantly ($P<0.05$) taller than plants produced by plots that were not treated with any manure (34.85cm). The difference between plant heights produced by poultry manure plots (40.81cm) and green manure plots (39.88cm) was not significant (Table 4.8).

Plant height was not significantly influenced by botanicals. Height of spring onion plants ranged from 36.76cm to 39.44cm at 7 weeks after transplanting (Table 4.9).

Table 4.8: Effect of soil amendments on plant height (cm) in the minor season

	Weeks after transplanting (WAT)					
Soil Amendments	2weeks	3weeks	4weeks	5weeks	6weeks	7weeks
Green manure	24.99	28.30	32.53	35.98	37.32	39.88
Poultry manure	23.43	26.50	29.99	34.07	37.22	40.81
No manure	24.03	27.61	30.65	33.68	33.90	34.85
Mean	24.15	27.47	31.06	34.58	36.15	38.51
C.V (%)	12.80	12.58	12.48	11.89	12.69	12.38
LSD (5%)	NS	NS	NS	NS	NS	4.76

CV= Coefficient of variation, NS=Not Significant, LSD=Least Significant Difference

Table 4.9: Effect of botanicals on plant height (cm) in the minor season

	Weeks after transplanting (WAT)			
Botanicals	4weeks	5weeks	6weeks	7weeks
Moringa Extract	30.46	33.87	34.72	36.76
Neemazal	30.79	34.55	36.69	39.44
No Botanical	31.93	35.31	37.02	39.34
Mean	31.06	34.58	36.15	38.51
C.V (%)	12.48	11.89	12.69	12.38
LSD (5%)	NS	NS	NS	NS

CV= Coefficient of variation, NS=Not Significant, LSD=Least Significant Difference

4.1.5 Interactive effects of soil amendments and botanicals on number of leaves, number of daughter shoots and plant height (cm) at harvest

Interaction between soil amendments and botanicals had no significant effect on number of leaves, number of daughter shoots and plant height (cm) in the minor season. Number of leaves ranged from 17.22 to 23.22, number of daughter shoots ranged from 4.78 to 6.33 and plant height ranged from 34.19cm to 44.65cm at 7 weeks after transplanting.

4.1.6 Effect of soil amendments and botanicals on yield of spring onion (t/ha)

Yield of spring onion was not significantly influenced by soil amendments in the minor season. For total yield, values ranged from 6.41t/ha to 7.23t/ha. For marketable yield, values ranged from 5.76t/ha to 6.58t/ha. Nonmarketable yield ranged from 0.59t/ha to 0.79t/ha (Table 4.10).

Botanicals also had no significant effect on the yield of spring onion. Total yield ranged from 6.27t/ha to 7.06t/ha. Marketable yield ranged from 5.65t/ha to 6.40t/ha. Nonmarketable yield ranged from 0.62t/ha to 0.75t/ha (Table 4.11).

Table 4.10: Yield of spring onion as influenced by soil amendments in the minor season

Soil Amendment	Total yield (t/ha)	Marketable yield (t/ha)	Nonmarketable yield (t/ha)
Green manure	6.41	5.82	0.59
Poultry manure	7.23	6.58	0.65
No manure	6.54	5.76	0.79
Mean	6.73	6.05	0.68
C.V (%)	24.89	25.33	33.47
LSD (5%)	NS	NS	NS

CV= Coefficient of variation, NS=Not Significant, LSD=Least Significant Difference

Table 4.11: Yield of spring onion as influenced by botanicals in the minor season

Botanicals	Total yield (t/ha)	Marketable yield (t/ha)	Nonmarketable yield (t/ha)
Moringa Extract	6.27	5.65	0.62
Neemazal	7.06	6.40	0.66
No Botanical	6.86	6.12	0.75
Mean	6.73	6.05	0.68
C.V (%)	24.89	25.33	33.47
LSD (5%)	NS	NS	NS

CV= Coefficient of variation, NS=Not Significant, LSD=Least Significant Difference

4.1.7 Interactive effect of soil amendments and botanicals on yield of spring onion (minor season)

Interaction between soil amendments and botanicals had no significant effect on the yield of spring onion in the minor. Total yield ranged from 4.57 t/ha to 8.52 t/ha. Marketable yield ranged from 4.14 t/ha to 7.73 t/ha and nonmarketable yield ranged from 0.43 t/ha to 0.94 t/ha.

4.1.8 Effect of botanicals on the number of leaves damaged by thrips (minor season)

The number of leaves damaged by onion thrips recorded significant differences ($p<0.05$) before botanicals were applied in the minor season (Table 4.12). The difference between number of leaves damaged in neemazal treated plots (6.72) and no botanical plots (6.39) was insignificant. However, they were significantly higher than the number of damaged leaves (4.17) recorded in moringa extract plots. At one week and two weeks after spraying, the differences in the number of damaged leaves were not significant. However, at three weeks after spraying, difference in the number of leaves damaged by thrips was significant ($p\leq0.05$). Number of damaged leaves was significantly ($p\leq0.05$) reduced by neemazal and moringa leaf extract plots than plots that were not sprayed with any botanical (4.83). But the difference between neemazal treated plots (1.72) and moringa leaf extract plots (2.94) was insignificant (Table 4.12).

Table 4.12: Number of leaves damaged by onion thrips from before spraying to three weeks after spraying in the minor season

Botanicals	Before Spraying	One Week After Spraying	Two Weeks After Spraying	Three Weeks After Spraying
Moringa Leaf Extract	4.17	6.28	5.17	2.94
Neemazal	6.72	6.39	3.61	1.72
No Botanical	6.39	7.72	6.50	4.83
Mean	5.76	6.80	5.09	3.16
C.V (%)	34.28	47.57	46.84	54.19
LSD (5%)	1.97	NS	NS	1.72

CV= Coefficient of variation, NS=Not Significant, LSD=Least Significant Difference

4.1.9 Correlation and regression analyses for growth and yield parameters

4.1.9.1 Correlation analysis for minor season experiment

The results for the correlation analysis for the minor season experiment are shown in Table 4.13. There was a significant positive correlation between plant height and the number of leaves of spring onion (r=0.73; p<.0001; n=27). There was a significant positive correlation between plant height and the number of daughter shoots of spring onion (r=0.66; p=0.0002; n=27). There was a significant positive correlation between number of leaves and number of daughter shoots of spring onion (r=0.66; p=0.0002; n=27).

Table 4.13: Correlation analysis for minor season experiment

	Number of Leaves	Number of Daughter shoots	Plant height
Number of leaves	——	0.66 (p=0.0002)	0.73 (p<.0001)
Number of daughter shoots		——	0.66 (p=0.0002)
Plant height			——

4.1.9.2 Relationship between total yield and number of leaves, number of daughter shoots and plant height at harvest (minor season)

There was a positive and significant relationship between total yield and number of leaves of spring onion in the minor season such that 32% of the variation in total yield was explained by number of leaves of spring onion (Y = -2.74 + 0.46X; R^2=0.32). There was a positive and significant relationship between total yield and plant height such that 63% of the variation in total yield was explained by the height of spring onion (Y = -2.90 + 0.25X; R^2=0.63). There was a positive and significant relationship between total yield and number of daughter shoots of spring onion such that 30% of the variation in total yield was explained by the number of daughter shoots (Y = -1.94 + 1.54X; R^2=0.30).

4.1.10 Proximate analysis (minor season)

The proximate analysis of the nutrients in the spring onion for the minor season experiment is shown in Table 4.14. No manure + Moringa Leaf Extract plots had the highest fat content (2.00%) compared to the other treatments. The highest ash content (16.50%) was recorded in Poultry manure + No botanical plots. All poultry manure plots and green manure treated ones recorded high ash contents except Poultry manure + Moringa Leaf Extract plots which recorded the least (10.50%). Fibre content was low in poultry manure and green manure treated plots except Green manure + No botanical plots which recorded the highest fibre content (14.18%). The highest crude protein content (18.30%) was recorded by Green manure + Moringa leaf extract plots, followed by Poultry manure + No botanical (14.00%). The lowest (9.49%) was recorded by green manure plots that were not sprayed with any botanical (Table 4.14).

Table 4.14: Proximate analysis for minor season experiment

Treatments	Crude Protein (%)	Crude Fibre (%)	Fat (%)	Ash (%)
No manure + No Botanical	11.60	14.06	0.50	13.00
No manure + Moringa Leaf Extract	10.50	13.59	2.00	11.00
No manure + Neemazal	12.10	12.87	1.00	12.50
Poultry manure + No Botanical	14.00	12.16	1.00	16.50
Poultry manure + Moringa Leaf Extract	12.30	12.67	0.50	10.50
Poultry manure + Neemazal	12.10	12.62	0.50	14.00
Green manure + No Botanical	9.49	14.18	0.50	14.50
Green manure + Moringa Leaf Extract	18.30	10.11	1.00	15.50
Green manure + Neemazal	13.00	11.98	1.00	14.50

4.1.11 Cost-benefit analysis (minor season)

The cost/benefit analysis for the various treatments in the minor season experiment is shown in Tables 4.15 and 4.16. Table 4.15 shows the components involved in total variable cost and Table 4.16 shows the total benefit, total variable cost and net benefit for each treatment. Every amount is quoted in Ghana cedis (GH¢). The highest cost of GH¢ 2140 was incurred for green manure plots sprayed with moringa leaf extract while the lowest cost (GH¢ 1225) was incurred for no manure plots sprayed with no botanical. The highest net benefit of GH¢ 6600 was obtained by poultry manure plots sprayed with neemazal while the lowest net benefit of GH¢ 2430 was obtained by green manure plots sprayed with moringa leaf extract treatments (Table 4.16).

Table 4.15: Cost-benefit analysis of minor season experiment

Treatment	Total Benefit (GH¢/ha)	Total Variable Cost (GH¢/ha)	Net Benefit (GH¢/ha)
A_0B_0	6420	1225	5195
A_0B_1	6980	1400	5580
A_0B_2	6240	1330	4910
A_1B_0	8240	1965	6275
A_1B_1	4570	2140	2430
A_1B_2	6420	2070	4350
A_2B_0	5930	1815	4115
A_2B_1	7250	1990	5260
A_2B_2	8520	1920	6600

A_0=No manure, A_1= Green manure, A_2= Poultry manure, B_0=No Botanical, B_1=Moringa Leaf Extract, B_2=Neemazal

Table 4.16: Components involved in total variable cost in the minor season experiment

Component	Cost (GH¢)
Planting materials	635
Poultry manure	540
Green manure (moringa seeds)	700
Neemazal	30
Moringa Leaf Extract	100
Application of botanicals	75
Ploughing	40
Poultry manure application	50
Incorporation of green manure	40
Slashing	50
Weeding	50
Bed preparation	100
Planting	100
Irrigation	250
Harvesting	100

GH¢=Ghana cedis

4.2 Experiment two (Major rainy season)

4.2.1 Chemical properties of soil amendments and soil in the major rainy season experiment

4.2.1.1 Chemical properties of poultry manure and soil (major season)

Table 4.17 shows the chemical properties of poultry manure and the soil used for the spring onion experiment in the major rainy season. The poultry manures used had pH of 6.74. The value of organic matter was 11.90%. The values of N, P and K in the poultry manure were 3.64%, 0.13 mg kg^{-1} and 2.39 cmol kg^{-1}. The values of the other exchangeable cations were 3.52 cmol kg^{-1} for Ca, 3.64 cmol kg^{-1} for Na and 3.65 cmol kg^{-1} for Mg.

The pH of the soil was 7.08. The values of percent organic matter, N, P and K in the soil were 1.59%, 0.13%, 58.83 mg kg^{-1}, and 0.92 cmol kg^{-1} respectively. The other exchangeable cations (Na, Ca and Mg) were 1.00 cmol kg^{-1}, 7.40 cmol kg^{-1} and 6.00 cmol kg^{-1} respectively (Table 4.17).

Table 4.17: Chemical properties of poultry manure and soil for the major season

Property	Poultry Manure	Soil
pH	6.74	7.08
Organic matter (%)	11.90	1.59
Total-N (%)	3.64	0.13
Available P (mg kg^{-1})	0.13	58.83
Exchangeable K (cmol kg^{-1})	2.39	0.92
Exchangeable Ca (cmol kg^{-1})	3.52	7.40
Exchangeable Na (cmol kg^{-1})	3.64	1.00
Exchangeable Mg (cmol kg^{-1})	3.65	6.00

4.2.1.2 Chemical properties of green manure plots before planting, 25 days after planting and 2 weeks after incorporation in the major season

The chemical properties of the soil before planting green manure, 25 days after planting green manure and 2 weeks after incorporation of green manure in the major season experiment is shown in Table 4.18. The initial soil pH decreased from 7.08 to 5.35 after planting green manure for 25 days. But it increased to 5.59 after incorporating green manure for 2 weeks. The exchangeable cations (potassium, calcium, sodium and magnesium) decreased after planting green manure for 25 days. But they increased 2 weeks after incorporation. Total nitrogen in the soil after planting green manure for 25 days was the same as before planting green manure (0.13%). But it increased to 0.15% after incorporating green manure for 2 weeks. Organic matter in the soil increased from 1.59% to 1.79% after planting green manure for 25 days. It increased again from 1.79% to 2.31% after incorporating green manure for 2 weeks. Phosphorus also increased from 58.83 mg/kg to 87.45 mg/kg after planting green manure for 25 days. It increased again from 87.45 mg/kg to 100.69 mg/kg after incorporating green manure for 2 weeks (Table 4.18).

Table 4.18: Chemical properties of green manure plots before planting, 25 days after planting and 2 weeks after incorporation of green manure in the major season

Property	Before planting	25 days after planting	2 weeks after incorporation
pH	7.08	5.35	5.59
Org. matter (%)	1.59	1.79	2.31
Total-N (%)	0.13	0.13	0.15
Avail. P (mg/kg)	58.83	87.45	100.69
Exch. K (cmol/kg)	0.92	0.19	0.21
Exch. Ca (cmol/kg)	7.40	6.40	6.60
Exch. Na (cmol/kg)	1.00	0.14	0.16
Exch. Mg (cmol/kg)	4.00	0.60	1.20

Org. =organic, Avail. =available, Exch. =exchangeable

4.2.1.3 Chemical properties of green manure, poultry manure and no manure plots before treatment and at the end of major season experiment

Data on the chemical properties of green manure, poultry manure and no manure plots before treatment and at the end of the major season experiment is presented in Table 4.19. Soil pH decreased from 7.08 to 5.47 in green manure plots, from 7.08 to 5.38 in poultry manure plots and from 7.08 to 5.48 in plots where no manure was applied. Organic matter increased in all the treatments.

Total nitrogen increased from 0.13% to 0.14% in green manure and poultry manure plots. But it remained the same (0.13%) in no manure plots. Available phosphorus increased in all the treatments. All the exchangeable cations (Ca, K, Na and Mg) decreased in all the treatments (Table 4.19).

Table 4.19: Chemical properties of green manure, poultry manure and no manure plots before treatment and at the end of the major season

Parameter	Before treatment	At the end of experiment		
		Green manure	Poultry manure	No manure
pH	7.08	5.47	5.38	5.48
Org. matter (%)	1.59	2.14	2.24	2.00
Total-N (%)	0.13	0.14	0.14	0.13
Avail. P (mg kg^{-1})	58.83	79.43	90.44	77.02
Exch. K (cmol kg^{-1})	0.92	0.16	0.21	0.14
Exch. Ca (cmol kg^{-1})	7.40	6.00	6.40	5.40
Exch. Na (cmol kg^{-1})	1.21	0.11	0.14	0.13
Exch. Mg (cmol kg^{-1})	4.00	1.20	0.80	2.00

Org. =organic, Avail. =available, Exch. =exchangeable

4.2.2 Number of spring onion leaves as influenced by soil amendments and botanicals (major season)

Table 4.20 shows the effect of soil amendments on number of leaves per plant from 2 weeks after transplanting to 7 weeks after transplanting (harvest) in the major season. Differences in number of leaves at 2 weeks after transplanting were not significant. They ranged from 3.86 to 4.02. However, there were significant ($P<0.05$) differences at 3, 4, 5, 6 and 7 weeks after transplanting. At 3 weeks after transplanting, green manure and poultry manure effect on number of leaves was not significant, but difference between poultry manure treated plots and plots that were not treated with any manure was significant ($P<0.05$) where poultry manure plots produced the higher number of leaves (5.88). The number of leaves produced by green manure plot (5.84) was also significantly ($P<0.05$) higher than the number of leaves produced by plots that were not treated with any manure (4.70). Similar trends were observed at 4, 5 and 6 weeks after transplanting. Poultry manure treated plots produced the highest number of leaves (17.32) at 7 weeks after transplanting. This was significantly ($P<0.05$) higher than the number of leaves produced by green manure treated plots (15.11) and plots that were not treated with any manure (11.48). The number of leaves produced by plots that were treated with green manure was significantly higher than number of leaves produced by plots that were not treated with any manure (Table 4.20).

There were no significant differences in number of leaves as influenced by botanicals. Number of leaves at 7 weeks after transplanting ranged from 14.21 to 15.17 (Table 4.21).

Table 4.20: Number of leaves of spring onion as influenced by soil amendments (major season)

	Weeks after transplanting (WAT)					
Soil Amendments	2weeks	3weeks	4weeks	5weeks	6weeks	7weeks
Green manure	3.91	5.84	9.41	11.72	12.96	15.11
Poultry manure	3.86	5.88	9.39	12.37	14.51	17.32
No manure	4.02	4.70	7.22	8.88	10.12	11.48
Mean	3.93	5.47	8.76	10.99	12.53	14.64
C.V (%)	14.99	8.28	10.43	9.26	12.34	14.26
LSD (5%)	NS	1.00	0.90	1.02	1.55	2.09

CV= Coefficient of variation, LSD=Least Significant Difference

Table 4.21: Number of leaves of spring onion as influenced by botanicals (major season)

	Weeks after transplanting (WAT)			
Botanicals	4weeks	5weeks	6weeks	7weeks
Moringa Extract	8.52	10.91	12.19	14.21
Neemazal	8.91	11.30	12.42	14.53
No Botanical	8.59	10.75	12.99	15.17
Mean	8.67	10.99	12.53	14.64
C.V (%)	10.43	9.26	12.34	14.26
LSD (5%)	NS	NS	NS	NS

CV= Coefficient of variation, NS=Not Significant, LSD=Least Significant Difference

4.2.3 Number of daughter shoots of spring onion as affected by soil amendments and botanicals in the major season

Soil amendments had significant ($P<0.05$) effect on the number of daughter shoots from 3 weeks after transplanting to 7 weeks after transplanting in the major season (Table 4.22). No significant differences were observed at 2 weeks after transplanting. Number of daughter shoots ranged from 1.24 to 1.27. The difference in number of daughter shoots between green manure (1.57) and poultry manure (1.66) was not significant at 3 weeks after transplanting. However, they were significantly ($P<0.05$) higher than the number of daughter shoots produced by plots that were not treated with any manure (1.36). Similar trend was observed at 4 weeks after transplanting. At 5 weeks after transplanting, poultry manure plots produced the highest number of daughter shoots (3.02). This was significantly higher than daughter shoots produced in green manure treated plots (2.78) and plots that were not treated with any manure (2.17). The number of daughter shoots produced by green manure plots was significantly higher than plots that were not treated with any manure. At 6 weeks after transplanting, the difference between number of daughter shoots produced by green manure (3.62) and poultry manure (3.86) was not significant. But they were significantly ($P<0.05$) higher than the number of daughter shoots produced by plots that were not treated with any manure (2.53). Similar trend was observed at 7 weeks after transplanting where poultry manure plots produced 4.25 daughter shoots and green manure plots produced 3.97 daughter shoots. These were significantly ($P<0.05$) higher than daughter shoots produced by no manure plots (2.80).

Number of daughter shoots was not significantly affected by botanicals. Number of daughter shoots ranged from 3.60 to 3.78 at 7 weeks after transplanting (Table 4.23).

Table 4.22: Number of daughter shoots of spring onion as affected by soil amendments (major season)

	Weeks after transplanting (WAT)					
Soil Amendments	2weeks	3weeks	4weeks	5weeks	6weeks	7week
Green manure	1.27	1.57	2.37	2.78	3.62	3.97
Poultry manure	1.32	1.66	2.46	3.02	3.86	4.25
No manure	1.24	1.36	1.80	2.17	2.53	2.80
Mean	1.28	1.53	2.21	2.66	3.34	3.67
C.V (%)	14.43	12.51	11.98	8.86	12.71	11.68
LSD (5%)	NS	0.19	0.07	0.24	0.42	0.43

CV= Coefficient of variation, NS=Not Significant, LSD=Least Significant Difference

Table 4.23: Number of daughter shoots of spring onion as affected by botanicals (major season

	Weeks after transplanting (WAT)			
Botanicals	4weeks	5weeks	6weeks	7weeks
Moringa Extract	2.19	2.64	3.38	3.78
Neemazal	2.31	2.80	3.36	3.64
No Botanical	2.13	2.53	3.27	3.60
Mean	2.21	2.66	3.34	3.67
C.V (%)	11.98	8.86	12.71	11.68
LSD (5%)	NS	NS	NS	NS

CV= Coefficient of variation, NS=Not Significant, LSD=Least Significant Difference

4.2.4 Effect of soil amendments and botanicals on plant height (cm)

Soil amendments had no significant effect on plant height at 2 weeks after transplanting and 3 weeks after transplanting in the major season. Plant height ranged from 22.15cm to 22.39cm at 2 weeks after transplanting and 23.05cm to 23.61cm at 3 weeks after transplanting (Table 4.24). However, there were significant ($P<0.05$) differences in plant height at 4 weeks after transplanting to 7 weeks after transplanting. At 4 weeks after transplanting, poultry manure plots produced the tallest plants (28.06cm), followed by green manure treated plots (25.89cm) and no manure treated plots (23.89cm). At 5 weeks after transplanting, the difference between the heights recorded by poultry manure plots (32.33cm) and green manure plots (30.27cm) were not significant, but they were significantly ($P<0.05$) higher than the height recorded by plots that were not treated with any manure (26.20cm). At 6 weeks after transplanting, the difference in plant height was significant at ($P<0.05$) where poultry manure plots produced the tallest plants (38.30cm), followed by plots treated with green manure (34.37cm) and plots that were not treated with any manure (28.14cm). The result was similar at 7 weeks after transplanting with poultry manure treated plots producing the tallest plants (41.16cm), followed by green manure treated plots (35.94cm) and plots that were not treated with any manure (29.99cm) (Table 4.24).

Plant height was not significantly affected by botanicals. Height of spring onion plants ranged from 35.14cm to 36.31cm at 7 weeks after transplanting (Table 4.25).

Table 4.24: Effect of soil amendments on plant height (cm) in the major season

	Weeks after transplanting (WAT)					
Soil Amendments	2weeks	3weeks	4weeks	5weeks	6weeks	7weeks
Green manure	22.39	23.46	25.89	30.27	34.37	35.94
Poultry manure	22.15	23.61	28.06	32.33	38.30	41.16
No manure	22.25	23.05	23.89	26.20	28.14	29.99
Mean	22.26	23.37	25.95	29.60	33.60	35.70
C.V (%)	12.11	10.93	6.56	8.47	11.68	13.24
LSD (5%)	NS	NS	1.70	2.51	3.92	4.72

CV= Coefficient of variation, NS=Not Significant, LSD=Least Significant Difference

Table 4.25: Effect of botanicals on plant height (cm) in the major season

	Weeks after transplanting (WAT)			
Botanicals	4weeks	5weeks	6weeks	7weeks
Moringa Extract	25.96	29.35	32.98	35.14
Neemazal	25.81	29.98	33.84	36.31
No Botanical	26.06	29.48	33.99	35.64
Mean	25.95	29.60	33.60	35.70
C.V (%)	6.56	8.47	11.68	13.24
LSD (5%)	NS	NS	NS	NS

CV= Coefficient of variation, NS=Not Significant, LSD=Least Significant Difference

4.2.5 Interactive effect of soil amendments and Botanicals on number of leaves, number of daughter shoots and plant height (cm)

Interaction between soil amendments and botanicals had no significant effect on number of leaves in the major season except at four weeks after transplanting. Poultry manure plots that were not sprayed with any botanical recorded the highest number of leaves (10.48), followed by green manure plots that were sprayed with neemazal (10.11). These were not significantly higher than the leaves produced by poultry manure and green manure plots sprayed with neemazal which produced 9.37 and 9.30 leaves respectively. The least number of leaves (6.48) was produced by no manure plots that were not sprayed with any botanical (Fig. 1). At 7 weeks after transplanting, number of leaves produced ranged from 11.04 to 19.30. However, differences were not significant.

Effect of interaction between soil amendments and botanicals on number of daughter shoots and plant height (cm) were not statistically significant. Number of daughter shoots ranged from 2.44 to 4.55 and plant height ranged from 28.81cm to 43.93cm at 7 weeks after transplanting.

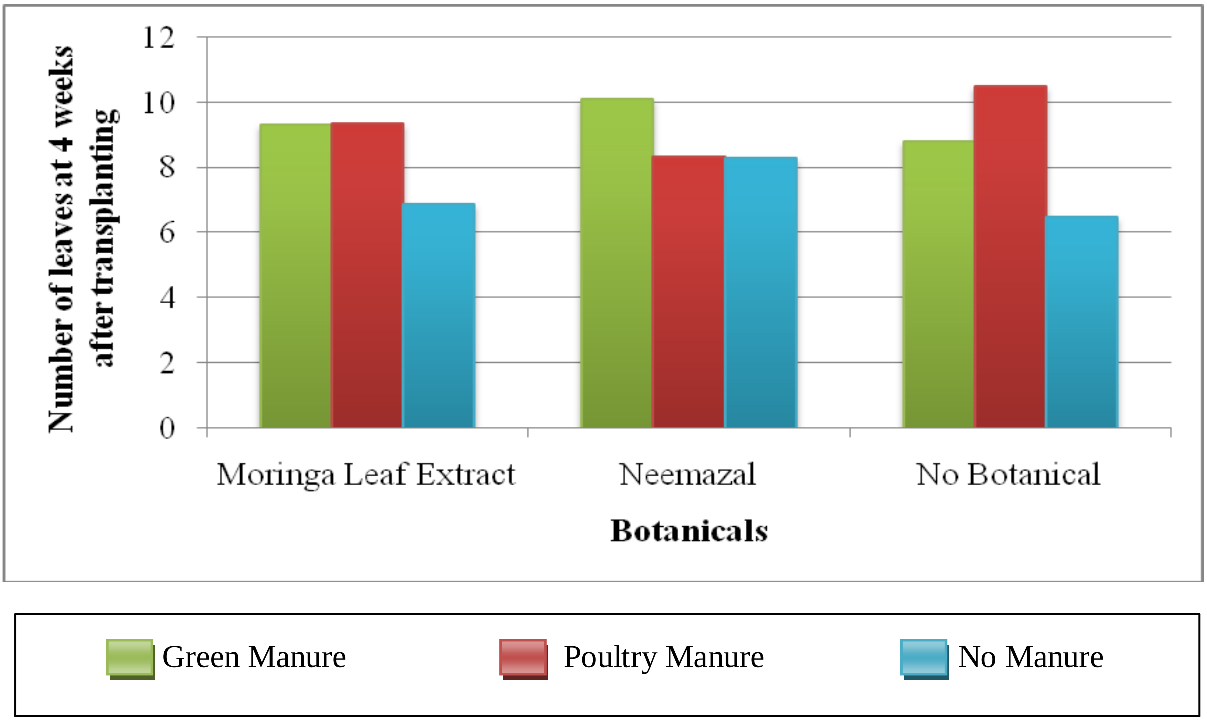

Fig. 1: Interactive effect of soil amendments and botanicals on number of leaves at 4 weeks after transplanting in the major rainy season

4.2.6 Effect of soil amendments and botanicals on yield of spring onion (t/ha)

Soil amendments significantly influenced total and marketable yields of spring onion in the major season (Table 4.26). The total yield produced by poultry manure (2.68 t/ha) was significantly ($P<0.05$) higher than the yield produced by plots that were not treated with any manure (1.16 t/ha). But total yield produced by poultry manure plots was not significantly different from the yield produced by green manure plots (1.92 t/ha). The results was similar for marketable yield. Soil amendments did not significantly influence nonmarketable yield. Nonmarketable yield ranged from 0.28 t/ha to 0.33 t/ha (Table 4.26).

Botanicals had no significant influence on the yield of spring onion. The total yield ranged from 1.79 t/ha to 2.16 t/ha. The marketable yield ranged from 1.51 t/ha to 1.81 t/ha while nonmarketable yield ranged from 0.28 t/ha to 0.33 t/ha (Table 4.27).

Table 4.26: Effect of soil amendments on yield of spring onion (major season)

Soil Amendments	Total yield (t/ha)	Marketable yield (t/ha)	Nonmarketable yield (t/ha)
Green manure	1.92	1.61	0.31
Poultry manure	2.68	2.27	0.39
No manure	1.16	0.95	0.22
Mean	1.92	1.61	0.31
C.V (%)	42.85	44.43	46.91
LSD (5%)	0.82	0.72	NS

CV= Coefficient of variation, LSD=Least Significant Difference

Table 4.27: Effect of botanicals on yield of spring onion (major season)

Botanicals	Total yield (t/ha)	Marketable yield (t/ha)	Nonmarketable yield (t/ha)
Moringa Extract	1.79	1.51	0.28
Neemazal	1.80	1.51	0.30
No Botanical	2.16	1.81	0.33
Mean	1.92	1.61	0.30
C.V (%)	42.85	44.43	46.91
LSD (5%)	NS	NS	NS

CV= Coefficient of variation, NS=Not Significant, LSD=Least Significant Difference

4.2.7 Interactive effect of soil amendments and botanicals on yield of spring onion (major season)

The interactive effect of soil amendments and botanicals on yield of spring onion was not significant in the major season. Total yield ranged from 0.95 t/ha to 3.37 t/ha. Marketable yield ranged from 0.77 t/ha to 2.84 t/ha and nonmarketable yield ranged from 0.17 t/ha to 0.49 t/ha.

4.2.8 Effect of botanicals on number of leaves damaged by thrips (major season)

Number of leaves damaged by onion thrips was not significantly different before spraying and at one week after spraying in the major season. The number of leaves damaged by onion thrips ranged from 2.94 to 4.28 before spraying and from 2.28 to 3.72 at one week after spraying (Table 4.28). However, significant ($p<0.05$) differences were observed at two weeks and three weeks after spraying botanicals. At two weeks after spraying, the number of leaves damaged on plots sprayed with neemazal (1.94) was significantly ($p<0.05$) lower than plots that were not sprayed with any botanical (4.28). The difference between leaf damage on neemazal plots and moringa leaf extract plots (3.39) was not significant. But the number of leaves damaged on moringa leaf extract plots was not significantly lower than plots that were not sprayed with any botanical. At three weeks after spraying, there was no significant difference between plots sprayed with neemazal (1.39) and moringa leaf extract (3.17). However, these were significantly lower than the number of leaves damaged on plots that were not sprayed with any botanical (7.17) (Table 4.28).

Table 4.28: Number of leaves damaged by onion thrips from before spray to three weeks after spraying (major season)

Botanicals	Before Spraying	One Week After Spraying	Two Weeks After Spraying	Three Weeks After Spraying
Moringa Leaf Extract	4.28	3.61	3.39	3.17
Neemazal	2.94	2.28	1.94	1.39
No Botanical	2.94	3.72	4.28	7.17
Mean	3.39	3.20	3.20	3.91
C.V (%)	57.35	43.16	37.45	56.96
LSD (5%)	NS	NS	1.46	2.71

CV= Coefficient of variation, NS=Not Significant, LSD=Least Significant Difference

4.2.9 Correlation and regression analysis for growth and yield parameters

4.2.9.1 Correlation analysis for major season experiment

There was a significant positive correlation between plant height and number of leaves of spring onion (r=0.909; p<.0001; n=27) during the major season. There was a significant positive correlation between plant height and number of daughter shoots of spring onion (r=0.724; p<.0001; n=27). There was a significant positive correlation between number of leaves and number of daughter shoots of spring onion (r=0.831; p<.0001; n=27) (Table 29).

Table 4.29: Correlation analysis for the major season experiment

	Number of Leaves	Number of Daughter shoots	Plant height
Number of leaves	——	0.831 (p<.0001)	0.909 (p<.0001)
Number of daughter shoots		——	0.724 (p<.0001)
Plant height			——

4.2.9.2 Relationship between total yield and number of leaves, number of daughter shoots and plant height at harvest (major season)

There was a positive and significant relationship between total yield and number of leaves of spring onion in the major season such that 85% of the variation in total yield was explained by the number of leaves of spring onion (Y = -2.83 + 0.33X; R^2=0.85). There was a positive and significant relationship between total yield and plant height such that 82% of the variation in total yield was explained by the height of spring onion (Y = -3.49 + 0.15X; R^2=0.82). There was a positive and significant relationship between total yield and number of daughter shoots of spring onion such that 42% of the variation in total yield was explained by number of daughter shoots (Y = -1.95 + 1.05X; R^2=0.42).

4.2.10 Proximate analysis (major season)

The proximate analysis of the nutrients in the spring onion for the major season experiment is shown in Table 4.30. No manure + Moringa Leaf Extract and Poultry manure + Moringa Leaf

Extract plots had the highest fat content (3.50%) compared to the other treatments. The highest ash content (15.50%) was recorded in Poultry manure + No botanical plots. All poultry manure and green manure treated plots recorded high ash contents except Poultry manure + Moringa Leaf Extract plots which recorded the least (9.00%). The fibre content was highest (11.98%) in Green manure + No Botanical plots, while the least (9.94%) was recorded by No manure + No Botanical plots. The highest crude protein content (17.00%) was recorded by Poultry manure + Moringa Leaf Extract plots, followed by poultry manure plots sprayed with no botanical (16.4%). The lowest was recorded by plots that were not treated with any manure but sprayed with moringa leaf extract (10.9%).

Table 4.30: Proximate analysis for the major season experiment

Treatments	Crude Protein (%)	Crude Fibre (%)	Fat (%)	Ash (%)
No manure + No Botanical	13.70	9.94	2.00	11.00
No manure + Moringa Leaf Extract	10.90	10.47	3.50	10.00
No manure + Neemazal	13.20	11.49	2.50	11.00
Poultry manure + No Botanical	16.40	11.56	1.00	15.50
Poultry manure + Moringa Leaf Extract	17.00	10.59	3.50	9.00
Poultry manure + Neemazal	15.60	11.11	3.00	12.00
Green manure + No Botanical	12.60	11.89	1.00	13.50
Green manure + Moringa Leaf Extract	14.40	11.12	1.00	14.50
Green manure + Neemazal	14.60	10.89	2.00	13.00

4.2.11 Cost-benefit analysis (major season)

The cost/benefit analysis for the various treatments in the major season experiment is shown in Tables 4.31 and 4.32. Table 4.32 shows the components involved in total variable cost and Table 4.31 shows the total benefit, total variable cost and net benefit for each treatment. Every amount is quoted in Ghana cedis (GH¢). The highest cost of GH¢ 1630 was incurred for green manure with moringa leaf extract treatments while the lowest cost (GH¢ 760) was incurred for no manure with no botanical treatments. The highest total benefit of GH¢ 2029 was obtained by poultry manure with no botanical treatments while the lowest total benefit of GH¢ 550 was obtained by no manure with no botanical treatments. The highest net benefit (GH¢ 714) was produced by poultry manure plots which were not sprayed with any botanical while the lowest net benefit of GH¢ -573 was obtained by green manure plots sprayed with moringa leaf extract treatments (Table 4.31).

Table 4.31: Cost-benefit analysis of major season experiment

Treatment	Total Benefit (GH¢/ha)	Total Variable Cost (GH¢/ha)	Net Benefit (GH¢/ha)
A_0B_0	550	760	-210
A_0B_1	621	905	-285
A_0B_2	857	835	22
A_1B_0	1300	1485	-185
A_1B_1	1057	1630	-573
A_1B_2	1100	1560	-460
A_2B_0	2029	1315	714
A_2B_1	1564	1460	104
A_2B_2	1279	1390	-111

A_0=No manure, A_1= Green manure, A_2= Poultry manure, B_0=No Botanical, B_1=Moringa Leaf Extract, B_2=Neemazal

Table 4.32: Components involved in total variable cost in the major season experiment

Component	Cost (GH¢)
Planting materials	500
Poultry manure	540
Green manure (moringa seeds)	700
Neemazal	30
Moringa Leaf Extract	100
Application of botanicals	45
Ploughing	25
Poultry manure application	15
Incorporation of green manure	25
Slashing	25
Weeding	25
Bed preparation	50
Planting	50
Irrigation	45
Harvesting	100

GH¢=Ghana cedis

CHAPTER FIVE

5.0 DISCUSSION

5.1 Experiment one (Minor rainy season)

5.1.1 Chemical properties of soil and soil amendments in the minor rainy season

5.1.1.1 Chemical properties of poultry manure and soil at the beginning of the minor season experiment

The analysis of poultry manure used for the minor season experiment appeared to have high amounts of the nutrients essential for crop production. Organic matter was very high compared to the critical level of 3% reported by Agboola and Corey (1973). Application of poultry manure to the soil is expected to increase Nitrogen, Magnesium and organic matter contents of the soil. The soil is acidic according to USDA (1998) and the organic matter content of the soil was very low (Agbede *et al*., 2008; Kartika and Susila, 2007 and Agboola and Corey, 1973). The soil was adequate in available Phosphorus, and exchangeable K, Ca, Na and Mg using the established critical level of 3% for OM, 0.15% for N, 8 – 10 mg kg $^{-1}$ for available P, 0.20c mol kg $^{-1}$ for K, and 0.26 c mol kg $^{-1}$ for Mg and 5, 1, 5, 3 mg kg $^{-1}$ for Fe, Cu, Mn and Zn respectively (Akinrinde and Obigbesan, 2000; Adeleye and Ayeni, 2010).

5.1.1.2 Chemical properties of green manure plots (minor season)

The pH of the soil changed from strongly acidic to slightly acidic after growing the green manure and two weeks after decomposition (USDA, 1998). The high calcium levels were probably responsible for the high pH (Boateng *et al.,* 2006). There was an increase in total Nitrogen and organic matter. The increase in total nitrogen was probably due to nitrogen fixation (Sullivan, 2003). There were decreases in the concentration of exchangeable cations except Calcium. Which were probably due to crop uptake as reported by Boateng *et al.* (2006).

Nitrogen and Organic matter levels in green manure plots decreased 2 weeks after incorporation. This was probably as a result of immobilization by microorganisms during decomposition as suggested by Boateng *et al* (2006). Potassium did not show any appreciable increase at 2 weeks after incorporation of green manure. A slight increase was observed for the exchangeable cations. The increase in exchangeable cations might be due to additions during decomposition of the green manure. According to Sullivan (2003) the organic acids produced during the decomposition of green manure react with insoluble mineral rocks and phosphate precipitates, releasing phosphates and exchangeable nutrients.

5.1.1.3 Chemical properties of soil at the end of the minor season experiment

The chemical properties of the soil at the end of the minor season experiment shows that N and P decreased whilst K increased. The decreased N and P after cultivation were probably due to crop uptake (Boateng *et al.*, 2006). Ca and Mg were increased. The increase in calcium content of the soil was probably responsible for the increase in pH (Boateng *et al*., 2006).

5.1.2 Effect of soil amendments on the growth and yield of spring onion in the minor rainy season experiment

5.1.2.1 Effect of soil amendments on the number of leaves, number of daughter shoots and yield of spring onion in the minor season

In the minor rainy season, soil amendments did not significantly influence the number of leaves per plant, the number of daughter shoots and the yield of spring onion. There might have been adequate levels of phosphorus and exchangeable cations already in existence in the soil at the experimental site to promote photosynthetic activities of plants and thus support these growth parameters. Phosphorus plays a major role in capturing and converting the sun's energy into useful plant compounds making it vital in normal plant development and production and helping in the uptake of some nutrients. It is essential for the general health and vigor of the plant by stimulating root development, increasing stalk and stem strength (Taiz and Zeiger 1991). According to Anburani and Manivannan (2002), Magnesium is involved in chlorophyll synthesis which in turn increases the rate of photosynthesis.

5.1.2.2 Effect of soil amendments on plant height (cm) in the minor season

Poultry manure and green manure significantly ($P<0.05$) increased the height of spring onion plants at harvest in the minor rainy season. This suggests that poultry manure and green manure might have increased the soil organic matter content and supplied nutrients for increased meristematic activities in the spring onion plants over the growth period. Organic manures provide micronutrients such as Zn, Cu, Fe, Mn, and Mg in optimum levels and help in plant metabolic activities through the supply of important nutrients which are involved in chlorophyll synthesis and photosynthesis (Premsekhar and Rajashree, 2009; Oladotun, 2002).

Tindall (1975) reported that soils with high organic matter content, and adequate mineral nutrients favoured the production of tall plants in amaranthus. According to Dauda *et al.* (2008) poultry manure has the ability to promote vigorous growth and increase meristematic and physiological activities in the plants due to the supply of plant nutrients. From the results in the table for manure analysis, it was evident that poultry manure and green manure contained high levels of nutrients to support plant growth.

5.1.2.3 Effect of botanicals on number of damaged leaves in the minor season

Botanicals significantly reduced the number of leaves damaged by thrips in the minor rainy season. There was a decline in the number of damaged leaves for all the botanicals from one week after spraying to three weeks after spraying. This is an indication of a decline in thrips population as spring onion plants aged. Salguero-Navas *et al.* (1991) reported that host plant phenology plays a very important role in pest population dynamics, where younger plants are attacked by greater densities of the pest than older plants. The lower leaf damage of spring onion by thrips in neemazal and moringa leaf extract treated plants than the non treated plots may be due to the fact that they were better able to protect plants from insect attack. This might have been due to the presence of the active ingredients in neemazal and moringa leaf extract which might have prevented thrips from causing damage to the leaves. Tukur *et al.* (2009) reported that the active ingredient in neemazal (azadirachtin) deters thrips from causing damage to spring onion leaves. Azadirachtin inhibits the feeding activities of the pest, repels and disrupts their growth and development and according to Morrissey and Osbourn (1999), saponins which are the active ingredient in moringa leaf extract are known to protect plants from insect attack and are considered a part of plants' defense systems.

5.1.2.4 Correlation and regression analysis (minor season)

The correlation analyses showed that plant height increased together with the number of leaves and the number of daughter shoots (Table 4.13). This means that taller plants produce more leaves and daughter shoots. A similar correlation trend was reported by Islam *et al.* (2007) in onion. According to Tahir *et al.* (2002) when plant height is more, the number of leaves will be more providing greater fixation of carbon leading to more accumulation of dry matter and leading to increase in stem size.

The regression analysis revealed that plant height, leaf number and daughter shoot number are very important in causing increase in the yield of spring onion. This shows that agronomic practices such as good weed control, irrigation, fertilizer application and pest control which will increase plant height, leaf number and daughter shoot number should always be done to ensure good yield in spring onion.

5.1.2.5 Proximate analysis (minor season)

The values obtained in the proximate analysis of the minor season experiment for crude protein, crude fibre, crude fat and ash are higher compared to that reported by Odebunmi *et al.* (2010) for *Allium sativum*. The fat contents were very low compared to the value (2.43%) reported by Hussain *et al.* (2010) for *Allium sativum*. Poultry manure and green manure plots produced spring onion with less fibre content. This might be due to the supply of nutrients by poultry manure and green manure. According to Premsekhar and Rajashree (2009) the application of organic manure caused accumulation of nutrients which resulted in better quality fruits with less fibre. The high crude protein and fat contents produced by green manure and moringa leaf extract is an indication that it is good for improving either the protein or fat contents of spring onion. High ash in poultry manure is an indication of high inorganic mineral content (Oloyede, 2005).

5.1.2.6 Cost-benefit analysis (minor season)

The cost-benefit analysis of the minor rainy season revealed that the profit was highest (GH¢ 6600) when neemazal was combined with poultry manure, followed by green manure plots which were not sprayed with any botanical (GH¢ 6275). This indicates that spring onion cultivation could be economically beneficial if it is grown in poultry manure amended soil than moringa green manure amended soil. This could be due to the higher yield produced by poultry manure than green manure coupled with the high cost of moringa seeds and labour for planting and of incorporation of green manure. The least net benefit (GH¢ 2430) was obtained when green manure was combined with moringa leaf extract. This is due to the increase in expenditure when green manure plots were sprayed with moringa leaf extract. The highest cost (GH¢ 2140) was incurred when moringa green manure was combined with moringa leaf extract spray. This means that using moringa as green manure with leaf extract spray increased the cost of production.

5.2 Experiment two (Major rainy season)

5.2.1 Chemical properties of soil and soil amendments in the major rainy season

5.2.1.1 Chemical properties of poultry manure and soil at the beginning of the major season experiment

The poultry manure used in the major rainy season appeared to have high amounts of organic matter and nutrients essential for crop production. The application of poultry manure to the soil is expected to increase Nitrogen, Magnesium and organic matter contents of the soil. The soil was low in organic matter and nitrogen according to Agbede *et al*., (2008). The high calcium content in the soil was probably responsible for the high soil pH (Boateng *et al.*, 2006). The soil was adequate in available Phosphorus, and exchangeable K, exchangeable Ca, exchangeable Na and exchangeable Mg using the established critical level of 3% for OM, 0.15% for N, 8 – 10 mg kg $^{-1}$ for available P, 0.20c mol kg $^{-1}$ for K, and 0.26 c mol kg $^{-1}$ for Mg and 5, 1, 5, 3 mg kg $^{-1}$ for Fe, Cu, Mn and Zn respectively (Akinrinde and Obigbesan, 2000 and Adeleye and Ayeni, 2010).

5.2.1.2 Chemical properties of green manure plots (major season)

The increase in organic matter and nitrogen at 2 weeks after decomposition in the major might probably be due to the release by the decomposition of the green manure (Boateng *et al.* 2006). The decrease in the exchangeable cations after growing the green manure is most probably due to crop uptake as reported by Boateng *et al.* (2006). The rise in pH level after decomposition was probably due to the release of ammonia from the decomposing manure. This has been reported by Boateng *et al*. (2006). Potassium, sodium, magnesium and calcium increased at 2 weeks after incorporation of green manure. This might be as a result of their release through the decomposition of green manure. According to Sullivan (2003) the organic acids produced during decomposition of green manure react with insoluble mineral rocks and phosphate precipitates, releasing phosphates and exchangeable nutrients.

5.2.1.3 Chemical properties of soil at the end of the major season experiment

The increase in nitrogen in the poultry manure and green manure plots observed in the major season probably was because of the release of nitrogen by the manures. The highest organic matter in poultry manure plots was probably because of the high organic carbon content of the poultry manure and the decrease in exchangeable cations at the end of cultivation was probably due to crop uptake. The increase in calcium content of the soil was probably responsible for the increase in pH (Boateng *et al.*, 2006).

5.2.2 Effect of soil amendments on the growth and yield parameters in the major rainy season

Soil amendments had no significant effect on the number of leaves, number of daughter shoots and plant height at the initial stages of growth in the major rainy season. This probably was due to the fact that the transplants had not been fully established coupled with the insufficient release of nutrients from the poultry manure and green manure at this stage. Onwu *et al.* (2008) observed no significant effect of organic manure on the height of castor oil at the first year of cropping and it was suggested that the seedlings had not fully established coupled with the insufficient release of nutrients applied from the incorporated green manure. According to Premsekhar and Rajashree (2009), nutrients from organic manures especially nitrogen are released slowly.

5.2.2.1 Effect of soil amendments on number of leaves of spring onion (major season)

Results on the number of leaves in the major season from 3 weeks after transplanting to 7 weeks after transplanting revealed that soil amendments significantly increased the number of leaves (Table 4.20). The significant increase in the number of leaves by poultry manure and green manure over the control might probably be due to the chlorophyll content in the leaves being significantly improved with the application of organic manures. The application of the organic manures might have supplied appreciable quantities of magnesium which might have helped in chlorophyll synthesis and increased rate of photosynthesis which in turn increased the number of leaves (Premsekhar and Rajashree, 2009). The significant ($P<0.05$) increase in the number of leaves by poultry manure than green manure and the control at 7 weeks after transplanting might be due to appreciable amount of essential nutrients contained in the poultry manure for the promotion of plant growth. Stephenson *et al.* (1990), Oladotun (2002) and Dauda *et al.* (2008) reported that poultry manure contains nutrients such as N, P, K, S, Ca, Mg, Cu, Mn, Zn, Bo and Fe associated with high photosynthetic activities and the promotion of vegetative growth. The poultry manure might have supplied more nutrients and organic matter than the moringa green manure. The analysis of poultry manure showed that it contained adequate amounts of the nutrients and organic matter essential for plant growth.

Tindall (1975) reported that soils with high organic matter content favoured the production of leaf number and leaf area. The better performance of green manure plots than no manure plots indicates that the green manure enhanced vigorous growth of spring onion.

5.2.2.2 Interactive effect of soil amendments and botanicals on the number of leaves at 4 weeks after transplanting (major season)

Soil amendment and botanical interaction influenced the number of leaves at 4 weeks after transplanting in the major season. Poultry manure producing more leaves without any botanical shows that it provided adequate nitrogen which increased plant vigour and produced healthy onion plants which reduced onion thrips. The mulching effect of poultry manure might have also reduced the soil temperature to slow down thrips development and population increase according to Alston and Drost (2008).

5.2.2.3 Effect of soil amendments on number of daughter shoots of spring onion in the major season

The significant ($P<0.05$) increase in number of daughter shoots by poultry manure and green manure plot over the no manure plots from 2 weeks after transplanting to 7 weeks after transplanting in the major season suggests that organic manure increased daughter shoot production in spring onion. This might be due to the supply of nutrients by poultry manure and green manure which could have increased the number of leaves. The supply of nutrients by poultry manure and green manure might have resulted in higher rates of photosynthesis in the leaves, hence increased shoot growth as a result of allocation of resources into the shoots. It is evident from the correlation analysis that increase in the number of leaves resulted in an increase in the number of daughter shoots (Table 4.30). According to Muthaura *et al.* (2010), increase in shoot height and stem diameter probably reflected the allocation of resources into the shoot.

5.2.2.4 Effect of soil amendments on plant height (cm) in the major season

The significantly ($P<0.05$) taller plants produced in the major season by poultry manure over green manure and the control at 4, 6 and 7 weeks after transplanting might be due to the nutrient content of the manure. Poultry manure might have supplied adequate quantities of nutrients which helped in chlorophyll synthesis and meristematic activities and thus increased plant height. This suggests that the poultry manure contained appreciable quantity of magnesium and high organic matter which might have helped in chlorophyll synthesis and increase in plant height respectively. According to Dauda *et al.* (2008), poultry manure promotes vigorous growth and increases meristematic and physiological activities in the plants due to the supply of plant nutrient. Premsekhar and Rajashree (2009) also reported that appreciable quantities of magnesium in the manure helped in chlorophyll synthesis and Tindall (1975) reported that soils with high organic matter content, and adequate mineral nutrients favoured the production of tall plants in amaranthus.

5.2.2.5 Effect of soil amendments on yield of spring onion (major season)

The significant ($P \leq 0.05$) difference in total and marketable yields between poultry manure and no manure in the major season suggests that poultry manure encouraged vigorous growth. The vigorous growth as a result of the application of poultry manure suggests that poultry manure contained adequate quantity of nutrients. Premsekhar and Rajashree, (2009) reported that higher yield response observed in okro was due to organic manures being able to improve the physical and biological properties of the soil which resulted in better supply of nutrients.

5.2.2.6 Effect of botanicals on the number of damaged leaves (major season)

The lower leaf damage of spring onion by thrips in the major season may be due to the fact that the botanicals are able to protect plants from insect attack. This might have been possible because of the presence of the active ingredients in neemazal and moringa leaf extract. The active ingredients might have either repelled or prevented pests from feeding. Tukur *et al.* (2009) reported that the active ingredient in neemazal (azadirachtin) deters thrips from causing damage to spring onion leaves. Azadirachtin inhibits the feeding activities of the pest, repels and disrupts their growth and development. According to Morrissey and Osbourn (1999) saponin which is the active ingredient in moringa leaf extract are known to protect plants from insect attack and are considered a part of plants' defense systems.

5.2.2.7 Correlation and regression analysis (major season)

The correlation analyses in the major season showed that plant height increased together with the number of leaves and number of daughter shoots (Table 4.29). This means that taller plants produce more leaves and daughter shoots. A similar correlation trend was reported by

Islam *et al.* (2007) in onion. According to Tahir *et al.* (2002) when plant height is more, the number of leaves will be more providing greater fixation of carbon leading to more accumulation of dry matter and leading to increase in stem size.

The regression analysis revealed that plant height, leaf number and daughter shoot number are very important in causing increase in yield of spring onion. This shows that agronomic practices such as good weed control, irrigation, fertilizer application and pest control which will increase plant height, leaf number and daughter shoot number should always be done to ensure good yield in spring onion.

5.2.2.8 Proximate analysis (major season)

The highest protein content obtained for spring onion in poultry manure plots sprayed with moringa leaf extract in the major season is only a little higher than the value reported for *Allium sativum* study (15.33%) by Otunola *et al.* (2010). In this study, the values obtained for green manure plots and no manure plots are a little lower than the value reported by Otunola *et al.* (2010). The fibre contents obtained for all the treatments were higher than the values reported for *Allium sativum* study (2.10%) and (0.73%) by Otunola *et al.* (2010) and Odebunmi *et al.* (2010) respectively. The high fibre contents of spring onion serve as a boost to the total dietary fibre of the dishes in which they are used. The fat contents were very similar to that reported by Hussain *et al.* (2010) for *Allium sativum*. The results indicate that poultry manure produced high protein and fat contents. Poultry manure should therefore be used as the manure for spring onion fertilization for high protein and fat contents. The high ash in poultry manure and green manure plots is an indication of high inorganic mineral content.

5.2.2.9 Cost-benefit analysis (major season)

The cost benefit analysis of the major rainy season experiment revealed that the profit was highest (GH¢ 714) when poultry manure plots were not sprayed with any botanical, followed by poultry manure plots which were sprayed with neemazal (GH¢ 104). This indicates that spring onion cultivation could be economically beneficial if it is grown in poultry manure amended soil than moringa green manure amended soil. This could be due to the higher yield produced by poultry manure than green manure coupled with the high cost of moringa seeds and labour for planting and of incorporation of green manure. The least net benefit (GH¢ -573) was obtained when green manure was combined with moringa leaf extract. This is due to the increase in expenditure when green manure plots were sprayed with moringa leaf extract. The highest cost (GH¢ 1630) was incurred when moringa green manure was combined with moringa leaf extract spray. This means that using moringa as green manure with leaf extract spray increased the cost of production.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

The experiment which was carried out in the minor rainy season and repeated in the major rainy season was conducted at the research field of the Department of Horticulture, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi to investigate the effect of soil amendments and botanicals on the performance of spring onion (*Allium fistulosum* L.) and the efficacy of the botanicals in controlling onion thrips (*Thrips tabaci*). The minor rainy season experiment which was 3 x 3 factorial laid out in a randomized complete block design (RCBD) with three replications was conducted from 17th August to 12th November, 2009 and repeated from 22nd March to 17th June, 2010 as the major rainy season experiment. The treatments were the three types of soil amendments (Green manure, Poultry manure and No manure) combined with two botanicals (Moringa leaf extract and Neemazal) and the control (No Botanical). The following parameters were assessed: number of leaves, number of daughter shoots, plant height, total, marketable and nonmarketable yields.
Soil amendments had no significant influence on the growth and yield of spring onion in the minor rainy season. Poultry manure amended plots produced the highest number of leaves, height and yield at harvest and green manure amended plots produced the highest number of daughter shoots though not significantly different. Green manure amended plots produced the least nonmarketable yield. Botanicals had no significant effect on the growth and yield parameters. Soil amendments and botanicals interaction was also not significant at harvest with respect to all the parameters studied, however botanicals significantly influenced the number of leaves damaged by onion thrips. Neemazal significantly reduced the number of damaged leaves. Number of leaves, number of daughter shoots, plant height, marketable and total yields were positively correlated. However, plant height was highly and positively correlated with number of leaves, total and marketable yields. Poultry manure plots sprayed with neemazal recorded the highest profit.

In the major rainy season, soil amendments significantly influenced the growth and yield of spring onion. Poultry manure significantly ($P<0.05$) increased the number of leaves, daughter shoots, plant height, marketable and total yields. Plots that were not treated with any manure produced the least nonmarketable yield. Botanicals had no significant effect on the growth and yield parameters. Soil amendments and botanicals interaction was also not significant at harvest with respect to all the parameters studied. The number of leaves damaged by onion thrips was significantly influenced by botanicals. Neemazal significantly reduced the number of leaves damaged by thrips. Plots which were not sprayed with any botanical recorded the highest number of damaged leaves. The number of leaves, number of daughter shoots, plant height, marketable and total yields were positively correlated. Plant height and number of leaves were highly and positively correlated with number of leaves, total and marketable yields. Poultry manure plots which were not sprayed with any botanical recorded the highest profit.

6.2 Conclusion

The study showed that the growth and yield of spring onion were significantly enhanced by the application of poultry manure in the major rainy season cropping. This indicates that poultry manure contains adequate quantity of essential nutrients which might have increased the growth and yield of spring onion in this season. For both seasons, the interactive effects were not significant and it was found that the cost of producing spring onion with moringa green manure as soil amendment was very high compared to when poultry manure was used. This could be due to the high cost of moringa seeds and labour for planting and for incorporating it as green manure. From this study, it may be concluded that the application of moringa as green manure may not be suitable for spring onion production in both minor and major seasons. It is profitable to grow spring onion in poultry manure amended soil than moringa green manure amended soil. Botanicals were found to be effective in the control of onion thrips against leaf damage. This indicates that neemazal posses stronger anti-feedant properties against thrips to greatly reduce the number of leaves damaged. Hence, it can be concluded that neemazal may be used by farmers to control onion thrips both in the major and minor rainy seasons because of its availability, affordability and safety to humans and environment.

6.3 Recommendations

Poultry manure was found to increase the yield of spring onion than green manure in the major rainy season thus the use of poultry manure needs to be encouraged since increasing yield and production of spring onion can lead to an increase in the standard of living of spring onion farmers. Also, the use of poultry manure as a substitute for inorganic fertilizer will help achieve the global trend towards organic farming. This trend is aimed at using organic manure as a substitute for inorganic fertilizer to reduce environmental pollution and produce foods that pose no serious threat for human health. To obtain maximum yields of spring onion and a higher net profit in the rainy season, farmers could grow the plants with poultry manure. Production of spring onion with poultry manure should be recommended to spring onion and other leafy vegetable growers because it is easily available, economical and improves the nutrient composition of the soil and the yield of the crop. Where it becomes necessary to control onion thrips and other pests, it is recommended that neemazal should be used.

It is suggested that:

a) The experiment should be repeated to determine the use of other green manure crops like mucuna for soil amendment to solve the problem of high cost of transportation of poultry manure in places that are very far from poultry farms.
b) The experiment should be repeated also to find out the effect of length of decomposition period of the green manure on the nutrient composition of the soil.

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8.0 APPENDICES

APPENDIX A:

Anova Tables for the effect of soil amendments and botanicals on growth and yield of spring onion in the minor rainy season

Anova table for number of leaves per plant at two weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	P>F
REP	2	2.019	1.009		
SOIL AMENDMENT	2	0.438	0.219	0.19	0.832
BOTANICALS	2	0.139	0.070	0.06	0.943
INTERACTION	4	8.446	2.111	1.79	0.179
ERROR	16	18.822	1.176		
TOTAL	26	29.864			

Anova table for number of leaves per plant at three weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	P>F
REP	2	8.546	4.273		
SOIL AMENDMENT	2	1.428	0.714	0.55	0.590
BOTANICALS	2	1.595	0.797	0.61	0.556
INTERACTION	4	12.055	3.014	2.30	0.103
ERROR	16	20.943	1.310		
TOTAL	26	44.567			

Anova table for number of leaves per plant at four weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	P>F
REP	2	10.857	5.429		
SOIL AMENDMENT	2	4.902	2.451	0.86	0.441
BOTANICALS	2	1.409	0.704	0.25	0.784
INTERACTION	4	19.305	4.826	1.70	0.200
ERROR	16	45.512	2.845		
TOTAL	26	81.984			

Anova table for number of leaves per plant at five weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	P>F
REP	2	43.462	21.731		
SOIL AMENDMENT	2	4.871	2.436	0.43	0.661
BOTANICALS	2	10.904	5.452	0.95	0.407
INTERACTION	4	13.163	3.291	0.58	0.685
ERROR	16	91.568	5.723		
TOTAL	26	163.967			

Anova table for number of leaves per plant at six weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	55.617	27.808		
SOIL AMENDMENT	2	10.276	5.138	0.62	0.549
BOTANICALS	2	11.734	5.867	0.71	0.506
INTERACTION	4	14.253	3.563	0.43	0.783
ERROR	16	131.919	8.245		
TOTAL	26	223.799			

Anova table for number of leaves per plant at seven weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	37.290	18.645		
SOIL AMENDMENT	2	37.210	18.605	2.36	0.127
BOTANICALS	2	12.553	6.277	0.79	0.469
INTERACTION	4	13.983	3.496	0.44	0.776
ERROR	16	126.354	7.897		
TOTAL	26	227.390			

Anova table for number of daughter shoots per plant at two weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	0.083	0.042		
SOIL AMENDMENT	2	0.004	0.002	0.03	0.969
BOTANICALS	2	0.059	0.029	0.47	0.631
INTERACTION	4	0.111	0.028	0.45	0.772
ERROR	16	0.991	0.062		
TOTAL	26	1.248			

Anova table for number of daughter shoots per plant at three weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	0.369	0.184		
SOIL AMENDMENT	2	0.263	0.132	1.16	0.340
BOTANICALS	2	0.025	0.013	0.11	0.896
INTERACTION	4	0.321	0.080	0.71	0.600
ERROR	16	1.821	0.114		
TOTAL	26	2.800			

Anova table for number of daughter shoots per plant at four weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	0.025	0.013		
SOIL AMENDMENT	2	0.204	0.102	0.56	0.584
BOTANICALS	2	0.139	0.070	0.38	0.690
INTERACTION	4	0.475	0.119	0.65	0.638
ERROR	16	2.939	0.184		
TOTAL	26	3.782			

Anova table for number of daughter shoots per plant at five weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	0.366	0.183		
SOIL AMENDMENT	2	0.443	0.221	1.39	0.278
BOTANICALS	2	0.051	0.026	0.16	0.853
INTERACTION	4	1.477	0.369	2.32	0.102
ERROR	16	2.548	0.159		
TOTAL	26	4.885			

Anova table for number of daughter shoots per plant at six weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	3.175	1.588		
SOIL AMENDMENT	2	0.733	0.367	0.98	0.395
BOTANICALS	2	0.101	0.050	0.13	0.875
INTERACTION	4	2.209	0.552	1.48	0.254
ERROR	16	5.956	0.372		
TOTAL	26	12.174			

Anova table for number of daughter shoots per plant at seven weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	3.598	1.799		
SOIL AMENDMENT	2	2.216	1.108	1.73	0.208
BOTANICALS	2	0.872	0.436	0.68	0.520
INTERACTION	4	2.634	0.659	1.03	0.422
ERROR	16	10.219	0.639		
TOTAL	26	19.539			

Anova table for plant height (cm) at two weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	132.178	66.089		
SOIL AMENDMENT	2	11.259	5.629	0.59	0.566
BOTANICALS	2	1.347	0.673	0.07	0.932
INTERACTION	4	36.024	9.006	0.94	0.4648
ERROR	16	152.878	9.555		
TOTAL	26	333.685			

Anova table for plant height (cm) at three weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	213.386	106.693		
SOIL AMENDMENT	2	14.934	7.467	0.63	0.548
BOTANICALS	2	4.090	2.045	0.17	0.844
INTERACTION	4	63.070	15.768	1.32	0.305
ERROR	16	190.994	11.937		
TOTAL	26	486.473			

Anova table for plant height (cm) at four weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	333.686	166.843		
SOIL AMENDMENT	2	31.299	15.650	1.04	0.376
BOTANICALS	2	10.684	5.342	0.36	0.706
INTERACTION	4	55.522	13.881	0.92	0.475
ERROR	16	240.444	15.028		
TOTAL	26	671.636			

Anova table for plant height (cm) at five weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	542.534	271.267		
SOIL AMENDMENT	2	27.319	13.660	0.81	0.463
BOTANICALS	2	9.440	4.720	0.28	0.760
INTERACTION	4	112.402	28.100	1.66	0.207
ERROR	16	270.132	16.883		
TOTAL	26	961.827			

Anova table for plant height (cm) at six weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	586.705	293.352		
SOIL AMENDMENT	2	68.054	34.027	1.62	0.229
BOTANICALS	2	28.011	14.005	0.67	0.527
INTERACTION	4	76.423	19.106	0.91	0.482
ERROR	16	336.465	21.029		
TOTAL	26	1095.656			

Anova table for plant height (cm) at seven weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	847.020	423.510		
SOIL AMENDMENT	2	185.484	92.742	4.08	0.037
BOTANICALS	2	41.543	20.771	0.91	0.421
INTERACTION	4	96.938	24.235	1.07	0.405
ERROR	16	363.576	22.724		
TOTAL	26	1534.560			

Anova table for total yield (t/ha)

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	73.085	36.542		
SOIL AMENDMENT	2	3.512	1.756	0.63	0.547
BOTANICALS	2	3.059	1.530	0.55	0.590
INTERACTION	4	28.074	7.019	2.50	0.084
ERROR	16	44.892	2.806		
TOTAL	26	152.621			

Anova table for marketable yield (t/ha)

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	63.215	31.608		
SOIL AMENDMENT	2	3.821	1.910	0.81	0.461
BOTANICALS	2	2.553	1.277	0.54	0.591
INTERACTION	4	24.268	6.067	2.58	0.077
ERROR	16	37.611	2.351		
TOTAL	26	131.467			

Anova table for nonmarketable yield (t/ha)

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	0.595	0.297		
SOIL AMENDMENT	2	0.186	0.093	1.82	0.195
BOTANICALS	2	0.080	0.040	0.78	0.475
INTERACTION	4	0.374	0.093	1.83	0.173
ERROR	16	0.818	0.051		
TOTAL	26	2.052			

APPENDIX B:

Anova tables for the effect of soil amendments and botanicals on number of leaves damaged by onion thrips in the minor rainy season

Anova table for number of leaves damaged by thrips before spraying

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	2.30	1.15		
SOIL AMENDMENT	2	16.96	8.48	2.18	0.146
BOTANICALS	2	34.74	17.37	4.46	0.029
INTERACTION	4	12.82	3.20	0.82	0.530
ERROR	16	62.37	3.90		
TOTAL	26	129.19			

Anova table for number of leaves damaged by thrips at one week after spraying

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	2.74	1.37		
SOIL AMENDMENT	2	70.30	35.148	3.36	0.060
BOTANICALS	2	11.63	5.82	0.56	0.584
INTERACTION	4	35.70	8.93	0.85	0.512
ERROR	16	167.26	10.45		
TOTAL	26	287.63			

Anova table for number of leaves damaged by thrips at two weeks after spraying

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	11.63	5.82		
SOIL AMENDMENT	2	8.30	4.15	0.73	0.498
BOTANICALS	2	37.63	18.82	3.31	0.063
INTERACTION	4	39.93	9.98	1.75	0.188
ERROR	16	91.04	5.69		
TOTAL	26	188.52			

Anova table for number of leaves damaged by thrips at three weeks after spraying

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	5.56	2.78		
SOIL AMENDMENT	2	12.67	6.33	2.15	0.149
BOTANICALS	2	44.22	22.11	7.51	0.005
INTERACTION	4	10.44	2.61	0.89	0.494
ERROR	16	47.11	2.94		
TOTAL	26	120.00			

APPENDIX C:

Anova tables for regression analysis of growth and yield parameters in the minor rainy season

Anova table for the relationship between total yield and number of leaves at harvest

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	48.655	48.655	11.70	0.002
Error	25	103.966	4.159		
Total	26	152.621			

Anova table for the relationship between total yield and plant height at harvest

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	95.895	95.895	42.26	<.0001
Error	25	56.726	2.269		
Total	26	152.621			

Anova table for the relationship between total yield and number of daughter shoots at harvest

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	46.012	46.012	10.79	0.003
Error	25	106.609	4.264		
Total	26	152.621			

APPENDIX D:

Anova tables for the effect of soil amendments and botanicals on growth and yield of spring onion in the major rainy season

Anova table for number of leaves per plant at two weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	3.748	1.874		
SOIL AMENDMENT	2	0.121	0.061	0.17	0.841
BOTANICALS	2	0.403	0.201	0.58	0.572
INTERACTION	4	3.761	0.940	2.70	0.068
ERROR	16	5.565	0.348		
TOTAL	26	13.598			

Anova table for number of leaves per plant at three weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	16.898	8.449		
SOIL AMENDMENT	2	8.002	4.001	4.00	0.039
BOTANICALS	2	0.135	0.068	0.07	0.935
INTERACTION	4	8.279	2.070	2.07	0.133
ERROR	16	16.007	1.001		
TOTAL	26	49.321			

Anova table for number of leaves per plant at four weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	46.754	23.377		
SOIL AMENDMENT	2	28.457	14.228	17.38	<.0001
BOTANICALS	2	0.783	0.391	0.48	0.629
INTERACTION	4	14.106	3.526	4.31	0.015
ERROR	16	13.100	0.819		
TOTAL	26	103.199			

Anova table for number of leaves per plant at five weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	51.764	25.882		
SOIL AMENDMENT	2	62.101	31.050	30.02	<.0001
BOTANICALS	2	1.392	0.696	0.67	0.524
INTERACTION	4	11.293	2.823	2.73	0.066
ERROR	16	16.546	0.819		
TOTAL	26	143.096			

Anova table for number of leaves per plant at six weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	94.442	47.221		
SOIL AMENDMENT	2	88.904	44.452	18.60	<.0001
BOTANICALS	2	3.072	1.536	0.64	0.539
INTERACTION	4	11.715	2.929	1.23	0.339
ERROR	16	38.244	2.390		
TOTAL	26	143.096			

Anova table for number of leaves per plant at seven weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	71.824	35.912		
SOIL AMENDMENT	2	156.563	78.282	17.98	<.0001
BOTANICALS	2	4.322	2.161	0.50	0.618
INTERACTION	4	26.089	2.929	1.50	0.250
ERROR	16	69.677	4.355		
TOTAL	26	328.475			

Anova table for number of daughter shoots per plant at two weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	0.103	0.052		
SOIL AMENDMENT	2	0.026	0.013	0.38	0.691
BOTANICALS	2	0.046	0.023	0.68	0.520
INTERACTION	4	0.274	0.068	2.01	0.141
ERROR	16	0.544	0.034		
TOTAL	26	0.993			

Anova table for number of daughter shoots per plant at three weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	1.288	0.644		
SOIL AMENDMENT	2	0.435	0.218	5.93	0.012
BOTANICALS	2	0.053	0.026	0.71	0.505
INTERACTION	4	0.133	0.033	0.91	0.484
ERROR	16	0.587	0.037		
TOTAL	26	2.496			

Anova table for number of daughter shoots per plant at four weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	0.111	0.056		
SOIL AMENDMENT	2	2.316	1.158	16.55	0.0001
BOTANICALS	2	0.150	0.075	1.07	0.366
INTERACTION	4	0.470	0.118	1.68	0.204
ERROR	16	1.119	0.070		
TOTAL	26	4.166			

Anova table for number of daughter shoots per plant at five weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	0.099	0.050		
SOIL AMENDMENT	2	3.471	1.736	31.30	<.0001
BOTANICALS	2	0.334	0.167	3.01	0.078
INTERACTION	4	0.393	0.098	1.77	0.184
ERROR	16	0.887	0.056		
TOTAL	26	5.185			

Anova table for number of daughter shoots per plant at six weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	0.325	0.163		
SOIL AMENDMENT	2	9.042	4.521	25.11	<.0001
BOTANICALS	2	0.063	0.032	0.18	0.841
INTERACTION	4	1.180	0.295	1.64	0.214
ERROR	16	2.881	0.180		
TOTAL	26	13.491			

Anova table for number of daughter shoots per plant at seven weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	0.281	0.141		
SOIL AMENDMENT	2	10.598	5.299	28.76	<.0001
BOTANICALS	2	0.152	0.076	0.41	0.670
INTERACTION	4	1.326	0.332	1.80	0.178
ERROR	16	2.948	0.184		
TOTAL	26	15.305			

Anova table for plant height (cm) at two weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	45.624	22.812		
SOIL AMENDMENT	2	0.275	0.138	0.02	0.981
BOTANICALS	2	5.035	2.517	0.35	0.712
INTERACTION	4	32.475	8.119	1.12	0.383
ERROR	16	116.276	7.267		
TOTAL	26	199.685			

Anova table for plant height (cm) at three weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	44.699	22.349		
SOIL AMENDMENT	2	1.495	0.748	0.11	0.892
BOTANICALS	2	0.506	0.253	0.04	0.962
INTERACTION	4	29.952	7.488	1.15	0.370
ERROR	16	104.358	6.522		
TOTAL	26	181.009			

Anova table for plant height (cm) at four weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	109.900	54.950		
SOIL AMENDMENT	2	78.380	39.190	13.55	0.0004
BOTANICALS	2	0.278	0.139	0.05	0.953
INTERACTION	4	22.914	5.729	1.98	0.146
ERROR	16	46.280	2.893		
TOTAL	26	257.749			

Anova table for plant height (cm) at five weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	94.549	47.275		
SOIL AMENDMENT	2	175.483	87.742	13.96	0.0003
BOTANICALS	2	1.977	0.988	0.16	0.856
INTERACTION	4	37.960	9.490	1.51	0.246
ERROR	16	100.592	6.287		
TOTAL	26	410.561			

Anova table for plant height (cm) at six weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	384.195	192.097		
SOIL AMENDMENT	2	472.418	236.209	15.33	0.0002
BOTANICALS	2	5.401	2.701	0.18	0.841
INTERACTION	4	50.120	12.530	0.81	0.535
ERROR	16	246.465	15.404		
TOTAL	26	1158.598			

Anova table for plant height (cm) at seven weeks after transplanting

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	445.696	222.848		
SOIL AMENDMENT	2	562.488	281.244	12.59	0.0005
BOTANICALS	2	6.209	3.105	0.14	0.871
INTERACTION	4	70.672	17.668	0.79	0.548
ERROR	16	357.307	22.332		
TOTAL	26	1442.372			

Anova table for total yield (t/ha)

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	16.083	8.041		
SOIL AMENDMENT	2	10.427	5.214	7.72	0.005
BOTANICALS	2	0.822	0.411	0.61	0.556
INTERACTION	4	2.424	0.606	0.90	0.488
ERROR	16	10.805	0.675		
TOTAL	26	40.561			

Anova table for marketable yield (t/ha)

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	11.601	5.801		
SOIL AMENDMENT	2	7.934	3.967	7.74	0.005
BOTANICALS	2	0.536	0.268	0.52	0.603
INTERACTION	4	1.660	0.415	0.81	0.537
ERROR	16	8.205	0.513		
TOTAL	26	29.935			

Anova table for nonmarketable yield (t/ha)

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	0.487	0.243		
SOIL AMENDMENT	2	0.141	0.070	3.43	0.058
BOTANICALS	2	0.013	0.007	0.31	0.735
INTERACTION	4	0.099	0.025	1.21	0.346
ERROR	16	0.329	0.021		
TOTAL	26	1.068			

APPENDIX E:

Anova tables for the effect of soil amendments and botanicals on number of leaves damaged by onion thrips in the major rainy season

Anova table for number of leaves damaged by thrips before spraying

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	77.56	38.78		
SOIL AMENDMENT	2	2.67	1.33	0.35	0.708
BOTANICALS	2	10.67	5.33	1.41	0.273
INTERACTION	4	15.33	3.83	1.01	0.429
ERROR	16	60.44	3.78		
TOTAL	26	166.67			

Anova table for number of leaves damaged by thrips one week after spraying

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	41.41	20.70		
SOIL AMENDMENT	2	6.74	3.37	1.76	0.203
BOTANICALS	2	11.63	5.82	3.04	0.076
INTERACTION	4	17.26	4.32	2.26	0.108
ERROR	16	30.59	1.91		
TOTAL	26	107.63			

Anova table for number of leaves damaged by thrips two weeks after spraying

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	22.30	11.15		
SOIL AMENDMENT	2	9.19	4.59	3.19	0.068
BOTANICALS	2	24.96	12.48	8.67	0.003
INTERACTION	4	10.15	2.54	1.76	0.186
ERROR	16	23.04	1.44		
TOTAL	26	89.63			

Anova table for number of leaves damaged by thrips three weeks after spraying

SOURCE	DF	ANOVA SS	MEAN SQUARE	F VALUE	Pr > F
REP	2	24.07	12.04		
SOIL AMENDMENT	2	8.30	4.15	0.84	0.451
BOTANICALS	2	157.63	78.82	15.91	0.0002
INTERACTION	4	1.26	0.315	0.06	0.992
ERROR	16	79.26	4.95		
TOTAL	26	270.52			

APPENDIX F:

Anova tables for regression analysis of growth and yield parameters in the major rainy season

Anova table for the relationship between total yield and number of leaves at harvest

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	34.600	34.600	145.11	<.0001
Error	25	5.961	0.238		
Total	26	40.561			

Anova table for the relationship between total yield and plant height at harvest

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	33.043	33.043	109.88	<.0001
Error	25	7.518	0.301		
Total	26	40.561			

Anova table for the relationship between total yield and number of daughter shoots at harvest

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	16.996	16.996	18.03	0.0003
Error	25	23.565	0.943		
Total	26	40.561			

APPENDIX G:

Average biomass of green manure (from shoots and roots) in the minor and major rainy seasons

Season	Average biomass in t/ha (Shoots+Roots)
Minor rainy season	6.23 t/ha
Major rainy season	5.47 t/ha