UNIVERSITY OF EDUCATION, WINNEBA

ORGANIC MANURE AND INORGANIC FERTILIZER EFFECT ON THE GROWTH AND YIELD OF CABBAGE (*Brassica oleracea var capitata*) AND INCIDENCE OF INSECT PEST IN THE FOREST TRANSITION ZONE OF GHANA

BY

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DECLARATION

I, hereby declare that except for references to the works of other researchers which have been duly cited, this work is the result of my own original research and that this dissertation has neither in whole nor in part been presented for another degree elsewhere.

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SUPERVISORS' DECLARATION

We hereby declare that the preparation and presentation of this was supervised in accordance with the guidelines for supervision of thesis as laid down by the University of Education, Winneba.

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DEDICATION

This research work is dedicated to Almighty Allah, my late father Sumaila Adama, my mother Abiba Adama and my lovely wife Adisa Mumuni and children Mohammed Ali Iddrisu, Ummul – Khair Iddrisu and Tasleem Lompeh Iddrisu.

ABSTRACT

Two field experiments were conducted at the Multipurpose Crop Nursery of the University of Education, Winneba, Mampong – Ashanti during the 2015 and 2016 cropping seasons from August to November, 2015 and June to September, 2016 respectively. The objective of the study was to determine the organic and inorganic fertilizer effects on the growth and yield of cabbage (*Brassica oleraceae var capitata),* and incidence of pest in the forest transition agro – ecological zone of Ghana. The experimental design used for the field experiment was a randomized complete block design (RCBD) with three replications. The treatments were: poultry manure (20 t/ha) + Cypermetrine (30 l/ha), cow dung (20 t/ha) + Cypermetrine (30 l/ha), N.P.K (300 kg) + Cypermetrine (30 l/ha), foliar + Cypermetrine (30 l/ha), poultry manure (20 t/ha) + neem leaf extract, cow dung (20 t/ha) + neem leaf extract, N.P.K (300 kg) + neem leaf extract, foliar + neem leaf extract and the control (no fertilizer and no insecticide). The results obtained revealed that the application of organic manure (poultry manure and cow dung) and inorganic fertilization is a better option for soil fertility enhancement in cabbage production. Application of poultry manure and N.P.K combined with Cypermetrine and neem leaf extract remarkably improved the growth and yield of cabbage. Cabbage yield in tons per hectare was significantly influenced by the application of poultry manure and N.P.K combined with Cypermetrine and neem leaf extract treatment. In addition, the application of Cypermetrine and neem leaf extract effectively reduced the severity of insect pest infestation. The application of Cypermetrine with poultry manure significantly reduced the percentage incidence of damage by insects on cabbage. The conclusions drawn from the research were, soil amendments with organic fertilizers remarkably improved the soil physical and chemical properties, the application of poultry manure and N.P.K fertilizers combined with Cypermetrine and neem leaf extract effectively improved the growth and yield of cabbage.

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LIST OF ABBREVIATIONS

MoFA	Ministry of Food and Agriculture
FAO	Food and Agriculture Organisation
ml	millilitre
g	gram
mg	milligram
FAOSTAT	Food and Agriculture Organization Statistics
IPM	Integrated Pest Management
PAMS	Prevention, Avoidance, Monitoring and Suppression
LAI	Leaf Area Index
USDA	United States Department of Agriculture
Cyper	Cypermetrine
N	Nitrogen
P	Phosphorus
K	Potassium
Ca	Calcium
Mg	Magnesium
As	Arsenic
Cu	Copper
Zn	Zinc
BARC	Bangladesh Agricultural Research Council
PTTH	Prothoracicotropic hormone
UNESCO	United Nation Education Scientific and Cultural Organisation
N	North
W	West

m	meter
mm	millimetre
t	tons
ha	hectare
$K_2Cr_2O_7$	Potassium dichromate
l	litre
DAT	Days after transplanting
ANOVA	Analysis of variance
LSD	Least Significant Difference
TEB	Total exchangeable bases
CSIR	Council for Scientific and Industrial Research
SRI	Soil Research Institute
Ppm	part per million
CEC	Cation exchange capacity

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Cabbage (*Brassica oleracea var capitata*) is a temperate vegetable crop which has become very popular in tropical Africa. Its origin is thought to be in the west of the Mediterranean basin or in the Asia Minor (Mithen, 2001). Cabbages are distributed mainly in temperate regions of the Northern Hemisphere; in areas of Southwest and Central Asia, China and Japan, Europe, the Mediterranean region and North America (FAOSTAT, 2000). In Africa, major production areas are South Africa which is concentrated more in Mpumalanga, Camperdown and Greytown districts of Kwazulu-Natal, Namibia, Ethiopia, Uganda, Burkina Faso, and Ghana (Bosch et *al.*, 1987). In Ghana it is commonly grown in Berekrum, Dormaa Ahenkro, Sunyani, Accra, Tepa (Amoah *et al.*, 2007). Most of the times the youth tend to grow it because it serves as a source of employment and income to them. It is mostly sold by market women when you go into the production chain.

Cabbage has traditionally been used for medicinal purposes as well as for cooking. It has anti-inflammatory property and contains chemicals which can prevent cancer. Cabbage contains the sulphur-containing compound sinigrin which reacts with the enzyme myrocinase to release the highly reactive compound, isothiocynates, glucose and other products. Isothiocynates consist of sulforaphane and indole-3-carbinol which are potent inducers of the liver's phase II enzymes and thus detoxify carcinogens (Ashworth and Suzanne, 2002). The ancient Greeks used fresh white cabbage juice to treat sores and infected eyes. The juice from the cabbage stem is reported to be a good remedy for ulcers (Silva, 1986) while the seeds are said to prevent hangovers (Norman and Shealy, 2007).

Nutritionally it is an excellent source of essential vitamins particularly Vitamins C and B and minerals such as potassium and calcium. It also adds a good caloric value and some amount of protein into our diet. About 250 ml of raw cabbage contains 21 kilocalories and when cooked contains 58 kilocalories (Haque, 2006).

Cabbage is now grown as an annual crop, although it is a biennial crop which is not sensitive to photoperiod. Flowering is enhanced mainly by temperature below 10 ºC (Agblor *et al*., 2001) which makes seed production difficult under tropical conditions. The plant has a rooting system that grows between 45 and 60cm below the soil surface and depending on the growing season and the cultivar grown; yields vary between 10 and 40 tonnes per hectare (Romain, 2001). Romain (2001) reports that the best yields are obtained in cool, dry season with heads weighing between 2 and 2.5 kg during the rainy season yields of an average weight of head are between 1 and 1.5 kg. In Ghana the average fruit yield of cabbage is 40 tonnes per hectare (MoFA, 2005).

In recent years, vegetable consumption has increased; however, the productivity of cabbage per unit area is low in the developing countries as compared to the developed countries of the world. Among other factors, adequate nutrient supply is an important input for increased yield as well as nutrient content (quality and quantity). It is reported that the response of cabbage is high to nitrogen application and moderate to phosphorus application (Altieri and Nicholls, 2003).

The growth and yield of cabbage is remarkably influenced by organic manure and inorganic fertilizer application (Dauda *et al*., 2005). Generally, nutrient requirement is determined by the variety of crops and the location. Though, the uses of inorganic fertilizers and pesticides have greatly contributed to the growth and yield of cabbage, some school of thought suggests that the misuse of these agrochemicals may actually increase pest problems in the long run (Altieri and Nicholls, 2003). It is also believed by others to impact negatively on human health

because of the residual effect (Hsieh *et al*., 1996). However, with organic fertilizers which may be poultry manure, animal waste or the use of organic compost, it is perceived that such problems may be minimized; hence the global trend for organic farming. Organic manure has been reported by many researchers to give significant improvements in crop growth and yield (Aliyu, 2000; Tindall, 2000; Dauda *et al*., 2008; Chiezy and Odunze, 2009) though its application is constraint by the high quantities required especially in Ghana.

John *et al.* (2004) reported that poultry manure had positive effects on the growth and yield of cabbage due to the fact that manure contained essential nutrient elements associated with high photosynthetic activities which promote root and vegetative growth. Application of poultry manure at high rates improved cabbage yield which translated into an increase in the standard of living of farmers who engaged in cabbage production (John *et al.,* 2004).

Manure by-products have the potential for being recycled on agriculture land. Their beneficial use through land preparation is based on their ability to favourably alter soil properties, such as plant nutrients availability, soil reaction (pH), organic matter content, cation exchange capacity, water holding capacity and soil tilth.

1.2 Problem Statement

Cabbage demand is high on the Ghanaian domestic market, serving as a source of vitamin and mineral requirements as well as a major source of income to the youth and women in urban and peri-urban areas (Timbilla and Nyarko, 2004). The rise in the consumption of cabbage has necessitated the increase in the production of the crop in Ghana. An increase in the production will lead to an improvement in the livelihood of the farmers and also increase in their income earnings. It will create employment opportunities for a lot of people and reduce its importation from neighbouring countries. However, the production of cabbage in Ghana is faced with numerous challenges. These include the high cost of inputs (such as pesticides and fertilizers), insect pest infestation and disease infection.

Notable among the insect pests are the Caterpillars of the Diamondback moth (*Plutella xylostella*), the cabbage Webworm (*Hellula undalis*) and cabbage aphid (*Brevicoryne brassicae*) which cause leaf damage between 18 and 31% (Mochiah *et al*., 2002). To reduce damages caused by insect pests, different synthetic insecticides are applied at different stages of the plant growth. These insecticides cause some toxicological and environmental problems in food, soil, water and adversely affect non target insects and other beneficial organisms as well as the development of resistant strains of insects (Ninsin, 1997).

The potential alternative for sustainable management of these insect pests may be the use of natural plant products. Extract from the neem tree (*Azadirachta indica*) has shown to contain a plethora of chemical compounds. Extracts from the seeds and kernels have been reported to adversely affect the biology of many insect pests (Das *et al*., 2010). The most active compound in neem is azadirachtin (AZA) which has an insecticidal activity as oviposition deterrant, antifeedant, growth retardant, moulting inhibitor and sterilant. (Prakash and Rao, 1997). Research has shown the efficacy of neem extracts against most pests of Cabbage, particularly, Diamondback moth (Liang *et al*., 2003; Cornell University, 2007). Neem leaves extracts are fairly safe to beneficial species (Sontakke and Dash, 1999; Mansour *et al*., 1987, 1993, 1997). Synthetic insecticides on the other hand have proved to be toxic to non-target species (Tetteh and Glover, 2004). Neem generally has limited toxicity to humans (Hydra, 1998; Schmutterer and Archer, 1987).

Cabbage has high requirements for all nutrients, especially nitrogen and it demands for achieving high yields range from 130-310 kg/ha (Lesic *et al*., 2004). Nitrogen over-use in modern agriculture is of importance with respect to both environmental concerns and the quality of plant products.

The plant has good responsiveness on animal manure application in quantity of 40 t/ha. Organic manuring enhances soil biological activity, improves nutrient mobilization, soil

structure and increases soil water retention (Chand *et al*., 2006). Crop production with integrated use of mineral and organic manure has proved to be highly beneficial.

In the past, agricultural production was focused on maximizing the quantity of vegetables produced for commercial markets (Pavla and Pokluda, 2008); while in the last few decades the organic management of crops has gained popularity because of increased consumer's awareness of the health problems that come from food grown under conventional farming. Differences between organic manure and inorganic fertilizers, especially in soil fertility management may affect the nutritive composition of plants (Hassan and Solaiman, 2002).

Ikpe and Powel (2002) reported that manure applied in correct proportion, does not just improve soil porosity but it also contributes to good plant growth, development and yield.

In view of the benefits to the diet and the livelihood of the Ghanaian populace, it is of much importance to find out the influence of organic and inorganic fertilizers on the growth, yield and incidence of insect pest of cabbage.

1.3 Objectives of the Study

The main objective of the study was to determine the organic and inorganic fertilizer effects on the growth and yield of cabbage (*Brassica oleraceae var capitata*) and incidence of pest in the forest transition zone of Ghana.

1.3.1 Specific Objectives

The specific objectives are to:

i. Compare the effectiveness of different organic and inorganic fertilizers namely; poultry manure, cow dung and N.P.K for improvement and or maintenance of soil fertility.

ii. Assess the effect of organic manure and inorganic fertilizer and insecticide combinations on growth and yield of cabbage.

iii. Ascertain the incidence and severity of insect pest damage on cabbage as influenced by fertilizer and insecticide combinations.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and Distribution

Cabbage is believed to have originated from a wild form native to Europe, growing along the coast of the North Sea, the English Channel and the northern Mediterranean (Decateau, 2000). Cabbages spread from Europe into Mesopotamia and Egypt as a winter vegetable, and later followed trade routes throughout Asia and the Americas (Gibson, 2001). In India, cabbage was one of several vegetable crops introduced by colonizing traders from Portugal, who established trade routes from the 14th to 17th century (Small, 2009).

Many cabbage varieties including some commonly grown ones were introduced in Germany, France, and the Asian Countries. By the 17th and 18th centuries, cabbage had become a staple food in Germany, England, Ireland and Russia, and more by Dutch, Scandinavian and German sailors to prevent scurvy during long ship voyages (Dixon, 2007).

Jacques Cartier first brought cabbage to the Americas in 1541– 1542, and by the mid-17th century adopted and planted by both colonists and Native American Indians (Preston *et al*. 2002). Cabbage seeds found its way to Australia in 1788 with the First Fleet, and were planted the same year on Norfolk Island; and by 1830s was a favourite vegetable of the Australians frequently seen at the Sydney Markets (Green, 2006).

The plant scientifically known as *Brassica oleracea var capitata* translate to cabbage of vegetable garden with a head (Morrison and Napier, 2006).

2.2 Botany

Cabbage is a herbaceous flowering plant with leaves forming a compact head. It belongs to the family Cruciferae (Shika and Doug Waterer, 2001). Approximately 400 species of cabbage have been documented into five groups: The first includes the familiar round, smooth-leafed

cabbages with the colours of white, green or red, and wrinkled-leafed varieties, such as Savoy. The second group comprises the pointed cabbages such as European spring and Chinese cabbages. The third group contains the cabbages with abnormally large budding stems like the Brussels sprouts. The fourth group comprises the cabbages with green curly types, such as the kale and collard greens. Cabbage species in this group are often used as animal food or decoration of dishes for presentation. Finally, the last group includes flowering cabbages, like cauliflower and broccoli (Kriple and Ormelas, 2000).

In addition, cabbages are out breeding plants. Therefore, cabbages only produce viable seeds through insect and hand pollination. Most cabbages are self-incompatible, meaning that the pollen is viable, but is unable to grow in a flower on the same plant. This is because the insects must carry pollen from one plant to another instead of just carrying from one flower to another on the same plant, the more insects in a group of plants the better the pollination and seed production (Ashworth and Suzanne, 2002).

Cabbage seedlings have a thin taproot and chordate (heart-shaped) cotyledon. The first leaves produced are ovate (egg-shaped) with a lobed petiole. The plants are 40–60 cm tall in their first year at the mature vegetative stage, and 1.5–2.0 m tall when flowering in the second year (Winer, 2009). The heads average between 0.5 and 4 kg, with fast-growing plants whereas earlier-maturing varieties producing smaller heads. Most cabbages have thick, alternating leaves, with margins that range from wavy or lobed to highly dissected; some varieties have a waxy bloom on the leaves. Plants have root systems that are fibrous and shallow. About 90 percent of the root mass is in the upper 20–30 cm of soil; some lateral roots can penetrate up to 2 m deep (Dixon, 2007).

2.3 Nutritional Value and Uses

Cabbage has been ranked by the Food and Agriculture Organization (FAO) among the top twenty vegetable crops grown, as an important food source globally (FAO, 2002). It is high in

water content, fibre, protein, calcium, iron, and vitamins A and C (Adeniji *et al*., 2010; Meena *et al*., 2010).

According to Norman (1992), cabbage has a high nutritive value, supplying essential vitamins, proteins, carbohydrates and vital minerals. Tindall (2000) listed the nutritive components of Cabbage leaves per 100g edible portion as shown in Table 2.1 below.

Table 2.1: Nutritive components of cabbage leaves

Nutrient	Component per 100g of leaves
Water	93 ml
Calories	23 ml
Proteins	1.5 g
Fat	0.2 g
Carbohydrate	4.0 g
Fibre	0.8 g
Calcium	40 mg
Iron	0.5 g
Vitamin potency	30 iu
Thiamine	0.5 mg
Riboflavin	0.05 mg
Niacin	0.3mg
Ascorbic acid	40mg

Source: (Tindall, 2000).

A study conducted on six hundred (600) men at the University of Utah School of Medicine in 2005 revealed that those who ate the most cruciferous vegetables had a much lower risk of colon cancer; however, consuming excessive amounts of Cabbage may contribute to thyroid

problems, possibly goitre. A well-known remedy for healing peptic ulcers is drinking Cabbage juice (Allen and Allen, 2009).

There is evidence to show that phytonutrients in cruciferous plants work at much deeper levels to reduce cholesterol levels. These compounds actually signal our genes to increase production of enzymes involved in detoxification. Recent studies have shown that those eating the most cruciferous vegetables have shown a lower risk of prostrate, colorectal and lung cancer-even when compared to those who regularly eat other vegetables (Lin, 2008).

Cabbage is used mainly in salads, as a fresh food item, but it is also cooked with other foods, and is suitable for processing into products such as kraut and egg rolls etc.

2.4 Varieties of Cabbage

Cabbages are sold by type, shape and colour rather than by individual variety. Green-coloured Cabbages are the most common, with red Cabbages also in existence. There is a wide range of varieties available and their suitability for a particular area can only be judged by growing them (Murison and Napier, 2006). Some of the varieties are as follows:

i. Corinth: This is a suitable variety for processing and has good disease tolerance. It is similar to green coronet but with a larger frame. It has an average weight of 4 kg.
ii. Green Coronet: It is a good-sized variety with an average weight of 3 kg. It is partially tolerant to black rot. It has a cream-green colour and a good flavour. It takes about 12 weeks to harvest.
iii. Greengold: This is an early maturing variety weighing about 3-4 kg. This variety is a uniformly attractive, light green Cabbage.
iv. Beauty: It is a hybrid with a large cabbage size and matures in about 13 weeks after planting and weighs about 3.5-4.5 kg. It has some resistance to black rot and its colour is grey-green and the leaves are heavily veined.

v. Kameron: This is a uniform Cabbage with large size for cool-season production. It produces large, flattened, globe-shaped heads and has an excellent head- holding ability of the head (Murison and Napier, 2006).

Improved varieties of Cabbage grown in Ghana are Oxylus, Super cross, Santa, and Tropical cross (MoFA, 2005).

2.5 Climatic and Soil Requirements

The optimum temperature for growth and development are from 18 ^{0}C-20 ^{0}C (Thompson, 2002). It is fairly resistant to frost and can survive temperatures as low as -3^{0}C without damage. Cabbage is also adapted to a wide variety of weather conditions and as such can be grown throughout the year in most regions (Thompson, 2002).

In Ghana, Cabbage can be grown anywhere, however, commercial production is done in Southern Ghana particularly Akwapim areas in the Eastern region and in the moist high elevations around Tarkwa in the Western region (MoFA, 2005).

Rainfall is one of the most important factors, especially when vegetables are grown under dry land conditions. Adequate soil moisture is necessary for good crop establishment, good yields and good quality products. This moisture may be obtained from rainfall or irrigation. High rainfall episodes may cause flood damage, partial drowning on certain soil types, and will often favour disease development (William, 2003).

Cabbage thrives in well-drained, moisture-retentive loamy soils well-supplied with organic matter. The ideal soil pH ranges from 5.5 to 6.5 (MoFA, 2008).

2.6 Production Estimates

According to FAO statistics, there are more than two million hectares of cabbage and other brassicas in production globally, with an average yield of 29 tonnes per hectare (FAOSTAT, 2000). Production in the Caribbean region is estimated by FAO to be around 250 thousand

tonnes per annum. The Bahamas produces about 900 tonnes per annum on about 75 hectares of farmland (FAOSTAT, 2000).

In Africa, major production areas are South Africa which is concentrated more in Mpumalanga, Camperdown and Greytown districts of Kwazulu-Natal, Namibia, Ethiopia, Uganda, Burkina Faso, and Ghana (Bosch *et al.*, 1987).

2.7 Crop Propagation

Cabbage is propagated from seeds. Depending on the variety and the ecological zone, cabbages can be grown throughout the whole year.

Land preparation to achieve a fine tilth is carried out through ploughing and harrowing. Ploughing and harrowing interval should not be less than two weeks to allow decomposition of organic matter. In most areas cabbages are nursed and transplanted into raised beds to reduce the effect of heavy rain which would waterlog the soil. Beds should be formed as early as possible to allow them to stabilize before transplanting (Murison and Napier, 2006).

Transplanting is carried out either manually or by using machines. About five to six weeks are required to produce transplants when seedlings have five to six leaves or when they are 3-5 cm tall (Kochler, 1986). Watering cans can be used to apply water to the seedlings when transplanting manually. A good watering immediately after transplanting is important to ensure that the young seedlings become well-established. Recommended plant spacing is given as, 40cm-60cm and 50cm x30cm (CABI, 2004).

2.8 Agronomic Practices

2.8.1 Weed Management

Weeds are controlled mechanically, manually or chemically through the application of registered herbicides. Mechanical weed control should be done during land preparation until

the plants are about half grown. The first weeding should be done two to three weeks after transplanting (Hartmann *et al*., 1988).

Hand-weeding between rows is often necessary to remove weeds two weeks after transplanting and repeated as and when the weeds appear. Nutsedge (*Cyperus rotundus*), a common perennial weed is particularly difficult to manage since there is currently no known selective herbicide for the control of nutsedge (California Agricultural Research Directory, 2007). A 41 % Glyphosate at the rate of 2.0 l t/ha was used to control the nutsedge.

2.8.2 Water management

Cabbage needs regular irrigation to ensure rapid growth and evenness of maturity. The crop can be irrigated by moveable spray lines, travelling irrigators, the use of watering cans, and if the soil is suitable and there is available water, flood irrigation is allowed. Cabbages grown in beds will require more irrigation than those grown on the flat. Soil type and weather will influence the frequency of irrigation (Morrison and Napier, 2006).

2.8.3 Insect Pest Management

A number of caterpillar pests feed on members of the cabbage family that is broccoli, cauliflower, kale, brussel sprouts, collards etc. Whereas a dozen or more caterpillar pests attack this plant group, a few major ones inflict the most damage. Those that cause damage include imported cabbage worm, diamondback moth, loopers and a number of cutworms and armyworms. All these insects go through several stages of their life cycle thus egg, larva, pupa, adult. The larval stage of these insect pests does the damage. Several of these pests normally attack and damage a plant simultaneously (Youdeowei, 2002).

2.8.4 Imported Cabbage Worm (*Artogeia rapae*)

The imported cabbage worm, *Artogeia rapae*, is better known to the farmer or gardener as the cabbage butterfly. This butterfly was imported from Europe to eastern Canada in the mid-

1800s, and has since spread to all parts of the world. The adult is a white butterfly (one and half inches) that has black-tipped forewings. The females have two black spots on top of each of their forewings whereas the males have only one black spot. The hind wings are all white on the surface except for a black spot on the outer front margin. A slightly yellowish hue shows on the undersides of the wings.

Adults appear in the spring, mate and the females begin to lay eggs singly on the leaves of host plant. The eggs are yellow, oblong and deeply ridged length-wise. The eggs are hatched in 3 to 7 days, depending on temperature. The larval stage takes about two weeks to attain full growth, about one inch in length. The larva is soft and velvety green with faint stripes running longitudinally on its back and sides. If it develops completely, the larvae pupate in a pale green chrysalis, which it attaches to any handy objects in the garden. The pupal stage takes 1 to 2 weeks to complete. Three to five generations overlap throughout the season. The larvae feed on the first formed outer leaves of their host plants, which often appear riddled with irregularly shaped holes. As the caterpillars mature, they feed in the centre of the head. Faecal pellets can be seen between the leaves. This pest damages turnip, raddish, mustard in addition to the cabbage group (Youdeowei, 2002).

2.8.5 Diamondback Moth (*Plutella xyllostella)*

Diamondback moth, *Plutella xyllostella* is the second major caterpillar pest of cabbage and other related plants. The pest was introduced from Europe in the nineteenth century, and now has a wide distribution worldwide. The small brown or greyish moths have a wingspan of about three quarter inch or less. When the moth is at rest, the folded wings present an image of light-coloured diamond shapes along the wingbacks where they meet. The adults appear in early spring. After mating, the females deposit small, almost round, yellowish-white eggs singly or in small groups on both sides of leaves of the host plant. Hatching of the eggs take a few days, and the young larvae begin working as miners between the outer leaf tissues. The

moth also feeds on some ornamentals. Larvae become external feeders within a few days of hatching. As they mature and grow larger they remove leaf tissues, creating holes or sunken areas in the leaves. Mature larvae are approximately one third inch long and pale green in appearance. Pupation takes place in a delicate cocoon on leaves or in garden debris. Total life cycle of the moth may take 2 to 7 weeks. About four to six generations occur annually (Youdeowei, 2002).

2.8.6 Cabbage Looper (*Trichoplusia ni)*

The Looper adult, *Trichoplusia ni,* has a wingspan of up to one and half inches. The moth has mottled grey forewings, a distinctive silver comma-like mark occurs in the centre each. It appears in the spring, adults mate and the females lay pale yellow hemispherical eggs singly and in clusters on leaves of host plants. The pale green mature larvae are about one one-third inches long, and have a dark top stripe edged with white lines, and two somewhat obscure white lateral lines. These larvae have three pair of true legs attached to the thoracic segments behind the head, and possess prolegs (false legs) attached further down on the abdomen. While the imported cabbage worm and diamondback moth have five pair of prolegs, loopers possess only three pairs. Because the looper prolegs are attached near the end of the abdomen, it appears to move in a “looping “fashion. Loopers overwinter in the pupal or adult stages. Three to five generations occur annually. Even though they are general feeders, loopers can at times cause significant damage to cabbage and related plants.

The cabbage looper, *Trichoplusia*, is another looper that sometimes attacks these plants. These loopers are extremely similar in appearance and therefore difficult to differentiate between them (Youdeowei, 2002).

2.8.7 Cutworms and Armyworms

A number of cutworms and armyworms can cause considerable damage to cabbage family plants. The adults are mostly drab moths, the same size as the alfalfa looper. They are in the same family of moths which, as adults, are collectively known as "Millers".

Among the many species of armyworms and cutworms that occasionally feed on cabbage, the most commonly encountered are the Bertha armyworms, variegated cutworms, spotted cutworms, western yellow stripped armyworm, zebra caterpillars and the black cutworms. Many of these caterpillars have strong preferences for certain species of weeds. Gardens surrounded by, or overgrown with weeds tend to have more serious cutworms and armyworm problems (Youdeowei, 2002)

2.9 Insect Pest Management Methods in Cabbage Production

Insect pests have existed with man as a component of the agro-system since the start of civilization; however, some activities of man have increased the intensity of pest problems. The aim of crop protection and control is to reduce the damaged effects of pests economically, safely and without causing harm to the environment. The objective of pest control is to minimize the pest population below the economic threshold. There are six methods of controlling pests basically. These are legislative, physical, cultural, biological, chemical, IPM (Integrated Pest Management) and natural pesticides (Botanicals).

2.9.1 Legislative Method

This involves the use of laws and regulations to prevent the importation of pest organisms into a country and also restrict the spread of pest in areas where pests have already gained grounds. The principle is based on exclusion and eradication. The step involves issuing of phytosanitary certificate by an appropriate authority. In Ghana, the certificate is issued by Plant Protection and Regulatory Service Division of the Ministry of Food and Agriculture (MoFA, 2001).

2.9.2 Physical Method

It embodies special operations against insects that kill them by their mechanical or physical action and may be carried out as follows: Fencing, sticky bands, traps, attractants, antecedents, hand picking of pests, flooding, lethal temperatures, chemical barriers, refrigeration, radiation and heronetic changes. These control measures provide immediate and tangible results and as such they are generally popular, but at times costly (Schwab, 1990). However, a lot of the methods have not been adopted by Ghanaian farmers.

2.9.3 Cultural Control

These are operations that can be carried out by the farmer using ordinary farm practices. These agronomic practices employed in crop production have great influence on the incidence and the population of pests. Examples of the cultural control methods are tillage operations, variation in the planting and harvesting dates, use of trap crop, use of resistance varieties, crop rotation, improving the growing conditions of the crops and good sanitation. The method poses minimum threat to the environment and it often enhances biological control of pests. Cooker (1987) stated that cultural methods use a wide range of techniques including the destruction of parasite on host plant, water management and other managerial practices. In all the growing regions of the world, the crop is attacked by many insect pests with the incidence and status varying from one region to another and with season, time of planting and cropping systems (Singh,1984).

2.9.4 Biological Control

The method involves the introduction, encouragement or artificial increase of natural enemies of insect pests. The natural enemies include both insect parasites and insect predators. According to Strong *et al.* (2000) biological control is the deliberate use of parasites, predators and pathogens to maintain the population of another organism at a lower density than they would have occurred in their absence. Such enemies are arthropods, fungi, virus, protozoa,

nematodes or vertebrates. The method is said to be safe and cost effective because it is effective from year to year and devoid of environmental pollution problems.

2.9.5 Chemical Control

Chemical control embodies all substances used for controlling, preventing, destroying, repelling or mitigating pests (Ekpe, 2003) while Ware (1978) and Don-Pedro (1990) defined it as "economic poisons" used for controlling, repelling, preventing, or mitigating any pests. These substances used to control pest are known as pesticides.

2.9.5.1 Insecticides

These include all substances employed for killing insects by means of some form of poisoning. Among the various protection measures, insecticides are the only single method capable of increasing yield in cabbage five or more folds (Trapp *et al*., 2001).

2.10 Integrated Pest Management (IPM)

Integrated Pest Management (IPM) is a systemic plan which brings together different pest control tactics into one programme. It reduces the emphasis on pesticides by including cultural, biological, genetic, physical, regulatory and mechanical controls. To carry out an IPM programme, you need to scout and monitor your field, recognize abnormal conditions and identify their causes, understand the different control methods available and determine the economic costs and benefits. A good IPM programme requires planning, monitoring and evaluation (Private Pesticide Applicator Training Manual, 19th Edition).

The objective of IPM is to eliminate or reduce potentially harmful pesticide use by using a combination of control methods that will reduce the pest to an acceptable level. The control methods should be socially acceptable, environmentally safe and economically practical (Ebesu, 2003).

According to Harold (2003), the adoption of integrated pest management (IPM) systems normally occurs along a continuous series from largely reliant on prophylactic control measures and pesticides to multiple-strategy biologically intensive approaches, and is not usually an "either/or" situation. It is important to note that the practice of IPM is site-specific in nature, with individual tactics determined by the particular crop/pest/environment scenario. Where appropriate, each site should have in place a management strategy for Prevention, Avoidance, Monitoring, and Suppression of pest populations (the PAMS approach).

In order to qualify as IPM practitioners, growers should be utilizing tactics in at least three of the four PAMS components. The rationale for requiring only three of the four strategies is that success in prevention strategies will often make either avoidance or suppression strategies unnecessary.

Prevention is the practice of keeping a pest population from infesting a field or site, and should be the first line of defence. It includes such tactics as using pest-free seeds and transplants, preventing weeds from reproducing, irrigation scheduling to avoid situations conducive to disease development, cleaning tillage and harvesting equipment between fields or operations, using field sanitation procedures, and eliminating alternate hosts or sites for insect pests and disease organisms.

Avoidance may be practised when pest populations exist in a field or site but the impact of the pest on the crop can be avoided through some cultural practice. Examples of avoidance tactics include crop rotation such that the crop of choice is not a host for the pest, choosing cultivars with genetic resistance to pests, using trap crops or pheromone traps, choosing cultivars with maturity dates that may allow harvest before pest populations develop, fertilization programs to promote rapid crop development, and simply not planting certain areas of fields where pest populations are likely to cause crop failure. Some tactics for prevention and avoidance strategies may overlap in most systems.

Monitoring and proper identification of pests through surveys or scouting programs, including trapping, weather monitoring and soil testing where appropriate, should be performed as the basis for suppression activities. Records should be kept of pest incidence and distribution for each field or site. Such records form the basis for crop rotation selection, economic thresholds, and suppressive actions.

Suppression of pest populations may become necessary to avoid economic loss if prevention and avoidance tactics are not successful. Suppressive tactics may include cultural practices such as narrow row spacing or optimized in-row plant populations, alternative tillage approaches such as no-till or strip-till systems, cover crops or mulches, or using crops with allelopathic potential in the rotation. Physical suppression tactics may include cultivation or mowing for weed control, baited or pheromone traps for certain insects, and temperature management or exclusion devices for insect and disease management. Biological controls, including mating disruption for insects should be considered as alternatives to conventional pesticides, especially where long-term control of an especially troublesome pest species can be obtained. Where naturally occurring biological controls exist, effort should be made to conserve these valuable tools. Chemical pesticides are important in IPM programs, and some use will remain necessary.

However, pesticides should be applied as a last resort in suppression systems using the following sound management approach:

(1) The cost: benefit should be confirmed prior to use (using economic thresholds where available).

(2) Pesticides should be selected based on least negative effects on environment and human health in addition to efficacy and economics;

(3) Where economically and technically feasible, precision agriculture or other appropriate new technology should be utilized to limit pesticide use to areas where pests actually exist or are reasonably expected;

(4) Sprayers or other application devices should be calibrated prior to use and occasionally during the use season;

(5) Chemicals with the same mode of action should not be used continuously on the same field in order to avoid resistance development; and

(6) Vegetative buffers should be used to minimize chemical movement to surface water (Harold, 2003).

2.11 Effect of Cypermetrine

Cypermetrine is a synthetic, pyrethriods insecticide that has high insecticidal activity, low avian and mammalian toxicity and adequate stability in air and light (USDA, 2008).It is used to control lepidopterous pests of cotton, fruits and vegetable crops and is available as an emulsifiable concentrate or wettable powder. According to the label Ammo (R) 2.5 EC insecticide, which contains 2.5 kg of Cypermetrine per gallon, the product should not be applied directly to water or to areas where surface water is present. Also, Cypermetrine should not be applied when wind may cause drift beyond intended treatment area. Due to its extreme toxicity to fish and aquatic organisms, Ammo (R) 2.5 EC is registered as a "restricted use pesticide" and is for sale to, and to be used only by certified applicators.

In vertebrates and invertebrates, Cypermetrine acts mainly on the nervous system. It is both a stomach poison and a contact insecticide (Jin and Webster, 1998).

Cypermetrine has been shown to inhibit ATPase enzymes involved in movement of ions against a concentration gradient which are regulated by active transport. This action is especially critical to fish and aquatic insects where ATPase enzymes provide the energy necessary to active transport, and are important at sites of oxygen exchange. ATPase inhibition and disruption of active transport, possibly affect ion movement and the ability to maintain ion balance, and disrupt respiratory surface, indicating that Cypermetrine is inherently more toxic to aquatic organisms (Siegfried, 1993).

2.12 Effect of Organic Manure

Organic manure has been reported by many researchers to give significant improvement in crop growth and yield. Parameters such as Leaf Area Index (LAI), plant height, nodule dry weight, total dry matter per hectare, and number of pods per plant in soya bean increased with the application of poultry manure (John *et al*., 2004). Organic manure is a reservoir of nutrients and these nutrients are released during humification, thus supplying the necessary elements for plant growth (Chiezy and Odunze, 2009). The application of organic manure has been observed to consistently increase the yields of horticultural crops such as eggplant (*Solanum melongena*), pepper (*Capsicum annum* L) and tomatoes (*Lycopersicon esculentus*). Aliyu (2000) obtained highest yields of pepper with 5 tonnes farmyard manure (FYM) +5 tonnes of poultry manure +50 kg of nitrogen (N) per hectare.

According to Agbede *et al*. (2008), leaf analysis showed that poultry manure increased plant nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) status of sorghum. Poultry manure had positive effects on growth and yield of vegetables. This could be due to the fact that poultry manure contained essential nutrient elements associated with high photosynthetic activities and thus promotes roots and vegetative growth (John *et al*., 2004). Wanas (2006) reported that there was a significant increase in yield of corn grains under the treatment of ploughing with compost as compared to the treatment of ploughing only, regardless of the level of ploughing (*i.e*. shallow or deep). Incorporation of individual vegetable residues combined or along with manures had resulted in significantly higher dry matter weight of fodder sorghum compared to the control treatment (Mubarak *et al*. 2009).

In order to obtain high yields, there is the need to augment the nutrient status of the soil to meet the crops need and thereby maintaining the fertility of the soil. One of the ways of increasing the nutrient status is either by the use of organic materials such as poultry manure, animal waste, plant residue and the use of compost or with the use of inorganic fertilizers

(Dauda *et al*., 2005). Application of poultry manure, however, at 40 tonnes per hectare improved cabbage yield (Chand *et al*.2006). Increasing yield of cabbage can thus translate in an increase in the standard of living of farmers who engaged in cabbage production. Also, there is global trend towards organic farming, the use of poultry manure as a substitution for inorganic fertilizer will help achieve this aim (Dauda *et al*., 2008).

According to Aliyu (2000), the increase in N as found in poultry manure has its profound effect on the vegetative development of plants and ensures healthy and vigorous growth. Barreto and Dynia (1988) reported that 42 tonnes per hectare of cattle manure was economically beneficial to cowpea. The constraints of these high rates of organic manure recommendations are the unavailability of such enormous amounts. Peasant farmers operating a subsistence level slightly above subsistence cannot generate these quantities of organic manure even for their small plots of less than one hectare. Moreover, apart from unavailability of these high amounts of recommended organic manure, the quality is also very low due to improper storage and handling (Chiezy and Odunze, 2009). The use of compost simultaneously with ploughing will have maximum advantage for improving the physical properties of clayey soil for increasing crop production (Wanas, 2006).

A study conducted at Wye College, University of London, has established the positive influence of garden waste compost on the yield of maize. This was attributed to nutrient released from compost applied as mulch or incorporated into the top soil (Lee, 1997). Adediran *et al*. (2003) compared poultry manure, household, market and farm waste and found that poultry manure at 20 tonnes per hectare had highest nutrient contents and mostly increased yield of tomatoes and soil macro and micronutrients contents. Akande and Adediran (2004) reported that poultry manure at 5 tonnes per hectare significantly increased tomato and dry matter yield, soil pH, N.P.K, Mg and nutrient uptake. Dauda *et al*. (2005) reported an increase in growth of vegetable crops with an increased poultry manure rates. The yield increase of

vegetables with an increase in poultry manure rates suggests that poultry manure supplies nutrients that enhance vigorous growth that culminates in increase in yield (Dauda *et al*., 2008).

Confined animal production (*i.e*. beef and dairy cattle, poultry and swine) is the major source of manure by-products in many countries. Manure by-products have the potential for being recycled on agriculture land. Their beneficial use through land preparation is based on their ability to favourably alter soil properties, such as plant nutrients availability, soil reaction (pH), organic matter content, cation exchange capacity, water holding capacity and soil tilth (Toor and Hunger, 2009).

2.12.1 Effect of Poultry Manure

Poultry manure contains all the essential nutrients including micronutrients and has been well documented that it provides a valuable source of plant nutrients (Harmel *et al*., 2009), especially for organic growers (Preusch *et al*., 2002). According to McGrath *et al*. (2009), addition of poultry manure to soils enhances the physical, chemical and biological properties of soils through increasing the organic matter content, water holding capacity, oxygen diffusion rate and the aggregate stability of the soils (Adeli *et al*., 2009).

Environmental concerns associated with the application of poultry manure include leaching losses of N in sub-surface drainage and to groundwater contamination of surface water with soluble and particulate P, reduced air quality by emission of greenhouse gases and volatile organic compounds and increased metal inputs (Harmel *et al*. 2004).

According to Moore Jr. *et al.* (2006) maintaining the quality of the environment is a major consideration when developing management practices to effectively use poultry manure as a nutrient resource and soil conditioner in agricultural and horticultural systems. Sims *et al*. (2005) reported that most of the environmental problems associated with improper practices of land application of poultry manure have centred on the contamination of ground and surface

water with two major nutrients, N and P. Poultry manure may contain other potentially toxic trace elements such as arsenic (As), copper (Cu) and zinc (Zn), which have received less attention (Jackson *et al*. 2003; Toor and Hunger, 2009).

2.12.2 Effect of Cow Dung

Cow dung is a potential source of nutrients and also a potential benefit to soil amelioration especially for communal farmers who cannot afford fertilizers. However, getting maximum value out of the manure requires applying it at proper rates and frequency in conjunction to a particular soil (Pahlar *et al*., 2013)

Cow dung has beneficial impacts on soil properties and produce safe plants with good source of nutrients (Epstein and Moos,2006).The suitability and usefulness of cow dung has been attributed to high availability of N.P.K content (Kilande *et al*., 2011). Sharafzadeh and Ordookhani (2011) reported that the manure improves the physical properties of the soil.

According to Ayoola and Makinde (2008), application of cow dung resulted in significant increase in soil carbon, nitrogen, pH, cation exchange capacity and exchangeable Ca, Mg and K which invariably enhance crop yield and productivity. Bhardwaj *et al*. (2000) reported higher yield and nutritional quality in cabbage, okra and tomato at the rate of 60 kg N/ha from organic fertilizer source.

Maintenance and improvement of soil quality is vital if agricultural productivity and environmental quality are to be sustained for future generations (Reeves, 1997). Soil aggregation and soil organic matter are important indicators of soil quality. Soil aggregation is important in maintaining soil structural stability. Soil water movement and retention, crusting, and aeration are all influenced by aggregation. Soil organic matter is the primary source of energy and nutrients for many soil organisms and influences soil structure, water holding capacity, cation exchange capacity and the formation of stable aggregates (Craswel and Lefroy, 2001).

2.13 Effects of Inorganic Fertilizer on Growth and Yield of Cabbage

Fertilizers are indispensable for the production system of modern agriculture and play an important role to increase crop yield, provided other factors are not limiting.

Chemical fertilizers today hold the key to the success of crop production system of Ghana's agriculture, contributing 50 % of the total production (BARC, 1997). Among the major nutrients, inorganic fertilizers are used largely by the plants. Physicomorphological and biological development of plants depends on the judicious application and supply of inorganic fertilizer. An excess or deficiency of inorganic fertilizers causes remarkable effect on growth and development of plants.

The type of fertilizer and the quantity to apply depends on soil type, initial nutrient reserves in the soil and yield level. A headed cabbage with a yield of 25 t/ha approximately absorbs 100 kg N, 12 kg P and 75 kg K (Grubben and Denton, 2004). Optimally, cabbage requires 60 – 85 kg N/ha, 60 – 80 kg P_2O_5/ha and 30 – 90 kg K_2O/ha (Agblor *et al*., 2001).

Haque (2006) conducted an experiment in field conditions to study the effect of nitrogen-phosphorous fertilizers on growth, yield and nutrient content of cabbage. The yield and yield components were maximized by N_3P_2 fertilizer treatment. Nutrient content of cabbage varied with fertilizer treatment. The maximum amounts of reducing sugar, ascorbic acid, phosphorous were at the highest rate of N-P fertilization whereas accumulation of acidity, iron, and calcium were at the rate of N_2P_2 treatment. However, pH and ash content were more or less the same throughout the experiment.

Burghardt (2000) observed that under sub-optimal total nutrients supply, a foliar fertilizer (12N: 4P: 6K) at concentrations of up to 15 % was tolerated, without leaf damage by dwarf beans, carrots, beet roots, broccoli, leeks and white cabbages. These concentrations were equivalent to more than 100 kg N/ha. Plant development and leaf colour improved and yields increased by 12 to 74 %. Ribaudo *et al*. (2003) reported that yield of cabbage increased with

increasing levels of nitrogen up to 390 kg/ha. Casely *et al*. (2006) observed that increasing rate of nitrogen (150-250 kg/ha) with basal P and K application increased yield of cabbage, but marketable yield was influenced to a lesser extent.

2.13.1 Effect of D. I. Grow

The complete composition of D.I GROW in the form of ionic elements, plant growth hormones and humic acid has the following benefits: It stimulates root formation and increase the efficiency of basic fertilizer. The continuing process of D.I GROW application to the crop improves the growth of roots. As the process increases Gibberellins and Cytokinins forming in the roots increase. As the concentration of Gibberellins and Cytokinins in the roots increase, some are taken up from the root surface along with root exudates. The hormones added together with photosynthetic materials which gather in the root as root maker materials are also exploited by existing land or ground microbes around the young roots. The metabolism that is brought about by land or ground microbes increase availability of ionic element absorbed by the root, especially for N and P ions. The combination of the mechanism of root development and the metabolism of land or ground microbes increase the amount of ionic element absorbed by the crop during association. Thus, the efficiency of basic fertilizer usage can be improved (Dynapharm Health Wealth Freedom, 2003).

Foliar feeding is a term that refers to the application of essential plant nutrients to above-ground plants. Foliar feeding has been widely used and accepted as an essential part of crop production, especially on horticultural crops. The purpose of foliar feeding is not to replace soil fertilization. Supplying a plants major nutrient needs (nitrogen, phosphorous, potassium) is most effective and economical through soil application. However, foliar application has proven to be an excellent method of supplying plant requirements for secondary nutrients (calcium, magnesium, sulphur) and micro nutrients (zinc, manganese, molybdenum, iron,

copper and boron), while supplying N.P.K needs of the crop during short and critical growth periods (Stewart *et al*. 2005).

Primarily, foliar feeding is intended to delay natural senescence processes shortly after the end of reproductive growth stage. Foliar feeding targets the growth stage where declining rates of photosynthesis and levelling off of root growth and nutrient absorption occur, it attempts to aid translocation of nutrients into seed, fruit, tuber or vegetative development (Bokhtier *et al*. 2008).

Secondly, foliar feeding can be an effective management tool to favourably influence pre-reproductive growth stages by compensating for environmentally induced stresses of adverse growing conditions and or stimulating more vigorous growth or maximizing the yield potential growth stage (William, 2000).

2.13.2 Effects of Nitrogen on Soil Properties and Growth of Cabbage

Nitrogen is an essential plant nutrient, the supply of which can be controlled by man (Shanti *et al*.1997). In maize production it is a major determining factor and its availability in sufficient quantity throughout the growing season is essential for optimum growth (Kogbe and Adediran, 2003). In plant nutrition, nitrogen is involved in the composition of amino acids, proteins and many enzymes. Nitrogen is also a part of the purine and pyrimidic bases, and therefore a constituent of nucleic acids (Mills and Jones, 1996).

Bhardwaj *et al*. (2000) reported higher yields and nutritional quality in cabbage, okra and tomato at the rate of 60kg N/ha from organic fertilizer source. Cabbage has high requirement for all nutrients, especially nitrogen, and cabbage needs 130 – 310kg N/ha to achieve high yields (Lesic *et al*. 2004).

Nitrogen content in plants ranges between 1 and 6 % of the dry matter in leaf tissue. It is absorbed by plants in the form of nitrates and ammonium ions. In moist, warm, well-aerated

soils, the nitrate form is dominant. Once inside the plant, nitrate is reduced to NH_4-N using energy provided by photosynthesis. Glucose composition for protein production is about 50 % higher when N is provided as NO_3^- rather than its NH_4^+. In addition to its role in the formation of proteins, nitrogen is an integral part of chlorophyll, which is the primary absorber of light energy for photosynthesis. An adequate supply of N is associated with vigorous vegetative growth and dark green leaves colour. An imbalance of N or an excess of this nutrient in relation to other nutrients such as P, K and S can prolong growing period and delay crop maturity (Bhardwaj *et al*. 2000). The supply of N is related to carbohydrate utilization. When N supply is limited, carbohydrates will be deposited in vegetative cells, which will cause them to thicken (Mills and Jones, 1996) but adequate supply will lead to more succulent plants.

2.13.3 Effects of Phosphorus on Soil Properties and Growth of Cabbage

Phosphorus (P) is the most important nutrient element (after nitrogen) limiting agricultural production in most regions of the world (Kogbe and Adediran, 2003). Plants absorb P exclusively from the soil in either $H_2PO_4^{2-}$form. There is, however, a strong competition between plants and soils for P in the soil, especially in highly weathered soils of the tropics which contain large amounts of iron and aluminium oxides or amorphous alumino silicate clay which tie up P firmly, making it unavailable for plant uptake. It is estimated that as much as 90 % of added fertilizer phosphorous is fixed in these soils (Potash and Phosphate Institute, 2003). Generally, phosphorus in all its natural forms, including organic forms is very stable or insoluble and only a small proportion exists in the soil at any time (Mahajan *et al*. 2008).

Amounts of P required varies depending on how much the soil has to begin with. Addition of P to the soil year after year, builds up soil P to a point that it becomes detrimental to crops because of excess (Potash and Phosphate Institute, 2003). However, once P is built to a good level, that level would remain for many years without any additional P input. The reason is that unlike nitrogen, it is less soluble in water and leaching is minimal.

Phosphorus-deficient plants are therefore stunted, with a limited root system and thin stems. Internally; most plants require 0.2 to 0.5 % P in the dry matter for normal growth

2.13.4 Effects of Potassium on Soil Properties and Growth of Cabbage

In soils, potassium is quite mobile as compared to phosphate. It exists as K in soil solution and is absorbed by roots in that form. Although K can be retained to some extent by negative charges on clay surfaces, Ca^2 or Mg^2 can displace it into the soil solution, when gypsum or dolomite is added. Thus if K is not taken up by plants, it might be lost by leaching (Lesic *et al*. 2012). One way to reduce K leaching is to add organic matter such as compost to the soil. Organic matter usually has large cation exchange capacity which retains K effectively.

Potassium is needed in large quantities by many crops as indicated by Hue and Silva (2000). It is required for maintaining the osmotic potential of cells and turgidity of plants. Since K regulates the osmotic potential of cells, and the closure or opening conditions of stomata, it plays an important role in water relations in the plant.

Fruits and vegetables grown with an adequate K seem to have a longer shelf life. Consequently, K-deficient plants show low resistance to diseases and their seeds and fruits are small and shrivelled (Haque, 2000). However; potassium is not fully effective without its co – efficient such as N and P (Haque, 2000).

2.14 Use of Botanicals

Botanical insecticides are naturally occurring chemicals extracted from plants which breakdown readily in the soil and are not stored in plant or animal tissue. Often their effects are not long lasting as those of synthetic pesticides (Arong *et al.* 2011). Botanical insecticides are generally pest-specific and are relatively harmless to non-target organisms. These natural insecticides especially that of plant origin have proved to be effective, biodegradable, low cost, low technological base, selective and environmentally friendly (Shazia *et al.* 2000).Also, the possibility of insects developing resistance to botanical insecticides is less (Scot *et al.* 2003).

Furthermore, plant extracts act as mortality agents, repellents, anti-feedant, attractants, oviposition deterrant and sterility agents (Lale, 2002). A research conducted on the use of natural pesticides as an alternate to synthetic insecticides for both field and storage crop protections are increasing because of their low toxicity to human beings (Raja *et al.* 2000). Stoll (1988) and Panhwar (2002) independently reported that the effect of plant extracts on crop yield and yield component is dependent on the effectiveness of the individual plant extract. However, many require other plant species with different mode of action, depending on the ratio and rate of application to increase their potency (Oparaeke, 2004). Over 2000 species of plants are known to possess insecticidal activities (Sariah, 2010; Arong *et al,*2011). Some of these plant materials include powders, water extracts, oil and wood ash from plants like neem tree (*Azadirachta indica*), groundnut (*Arachis hypogeae*), nutmeg (*Myristica fragrans*) and coconut (*Cocos nucifera*). Others are leaf extracts of ginger (*Zingiba officinale*), garlic (*Allium sativum*) (Oparaeke *et al*, 2003).

2.14.1 Neem Tree (*Azadirachta indica* Adr.Juss) as a Pesticide

Neem tree, (*Azadirachta indica*) belongs to the family Meliaceae. It is a native of Southeast Asia and grows in many countries throughout the world (Naveena *et al.,* 2010). It is an aboriginal tree found in the tropical and semi-tropical countries such as Burma, India and Ghana. According to Rappaport (1992), the tree originated from India sub-continent. Arnold (1995) indicated that, the tree is common in Southeast Asia, Sub-Saharan Africa and part of Central America. Neem tree can be easily propagated by cuttings, stumps, tissue culture or seed. Seed propagation followed by direct planting into the field is the accepted method to produce plantation stands quickly and efficiently (Jacobson, 1989).

It is widely used as a shade tree in many areas because it tolerates a wide range of field conditions (Wondafrash *et al*., 2012). Fruit bearing takes three years and reaches a maximum fruiting yield of 50kg seed/year, ten years after planting (Wondafresh *et al*. 2012). Even though

the neem has been used in households for years, it was only during the 1920's, that it was given attention, with a number of research being conducted on the international level to understand the benefits and potentials of neem. After initial controversies, it is now used in commercial quantities ranging from cosmetics to agriculture and from pharmaceuticals to other products.

All biologically active Neem compounds are suspected to be derived from one parent compound, the tetracyclic triterpenoid titrucallol. All other products formed are considered successive rearrangement and oxidation products of titrucallol (Ahmed *et al,* 20012). It is generally accepted that the tetranotritterpenoid (also called Limonoid) compound Azadirachtin is responsible for the majority of biological effects seen in organisms exposed to the neem compound (Shukla and Toke, 2013). About twenty five (25) different biologically active compounds have been isolated from neem seeds (Naveena *et al.,* 2010). Other compounds present in neem oil for example are responsible for some of the biological activity observed. Blaney *et al.* (2000) realized that salanin and nimbin, and two other compounds present in neem seed extract, exhibit an entirely different mode of action than azadirachtin including oviposition repellency, sterility, longevity, growth disruption, interference with reproduction, fitness and inhibition of chitin biosynthesis (Ahmed *et al*. 2012; Adjei-Boateng *et al.* 2003).

Pest control using extracts from neem tree occurs in more than fifty-five countries worldwide and neem products have been used in parts of Asia, such as Burma and India for more than two thousand five hundred years (Koul *et al*, 2004). Substances that have been found promising or used as insect control on food crops and vegetables include extracts from the neem tree (Das *et al*., 2010).

Neem extracts may not kill insects instantly but incapacitate them in several ways. The precise effect of various neem extracts on insect species is often difficult to tell. A research conducted

at the Cornell University (2007) revealed that neem has a fairly broad spectrum of activity against insects and some insects are more susceptible than others while results usually vary from pest to pest. According to Das *et al.* (2010) neem can be used as an insecticidal repellent, antifeedant, growth regulation, fungicide, anti- oviposition, egg sterilization and nematicide.

It is known that many leaf-feeding larvae are susceptible to azadirachtin-based products especially lepidopterous larvae (caterpillars), leaf-feeding beetle larvae and sawflies. Sap-feeding insects such as aphids, leafhoppers and plant bugs are also fairly well controlled by products based on azadirachtin. Adults of many insect groups are also responsive to azadirachtin. Japanese beetles and grasshoppers are said to avoid neem-treated foliage. Neem oil products are said to be effective against aphids, whiteflies, scale crawlers and spider mites. Neem products are generally not effective against mealy bugs, weevils, thripes or adult scales.

Fertilizers mixed with neem cake that has been applied to the soil before planting of rice in India and other Asian countries have been effective against nematode. According to researchers like Deepanjan *et al*., (2000) and Shah and Faheem (2000), neem products such as the seed powder and the seed cake have been reported to be nitrification inhibitors because of azadirachtin, the active ingredient of the neem plant.

Agyarko *et al*. (2000) indicated that higher levels of neem leaf with corresponding high amounts of azadirachtin might have played a similar nitrification inhibitory role in their study. The problem of neem extract, however, is with the degradation of the azadirachtin by ultraviolet light and daylight. Some producers according to Friends (1990) bypass this problem by mixing neem extract with pyrethrum derivatives. The active constituents in the mixture is said to synergize and are long lasting.

2.14.2 Biological Effect of Neem on Insects

2.14.2.1 Insect Growth Regulation

Shakla and Toke (2013) stated that insect growth regulatory effects of azadirachtin are remarkably similar among species. Wondafrash *et al*. (2012) indicated that various developmental, post-embryonic, reproductive and growth inhibitory effects have been seen, causing malformation and mortality in a dose-dependent manner. Das *et al*. (2010) indicated that azadirachtin modifies the programmes of insects by influencing hormonal systems, especially that of ecdysone. The effects of azadirachtin are both dose and time dependent, prevent both ecdysis and apolysis, and can cause death before or during moulting, possibly inducing "permanent "larvae (Shakla and Toke, 2013). Exogenous application of growth hormones did not deter the effects of azadirachtin, leading researchers to suggest that the most probable site of action of azadirachtin is at the site of synthesis and release of Prothoracicotropic hormone (PTTH) (Naveena *et al.,* 2010). The main action of azadirachtin appears to be at the release sites of PTTH from the corpora cardiac. Azadirachtin appears to block the release of neurosecretory material from the corpora cardiac resulting in a reduced turnover rate.

According to Das *et al*. (2010), all insect growth regulatory effects of azadirachtin are indirectly influenced by temperature, with greater activity seen at higher temperature.

Neem extracts contain compounds with growth inhibition and chemosterilant action making it biologically active against insects (Javaid *et al*., 2000) particularly on juvenile hormones. The enzyme, ecdysome, responsible for moulting is said to be actively suppressed when azadirachtin is used. Thus, a larva fails to moult, and remains in larvae stage and finally die. If the concentration of azadirachtin is not sufficient enough, the larvae manage to enter the pupa stage but dies at this stage. If the concentration is still less, then the adult emerges from pupa 100% malformed, absolutely sterile without any capacity for reproduction (Shukla and

Toke, 2013). Naveena *et al.* (2010) also stated that neem, when applied, affects insect pest by sterilizing the adult and disrupting sexual communication and mating. The structure of azadirachtin is such that the azadirachtin molecule, the decalin fragment, is responsible for the insect growth regulation and development (Wondafrash *et al*., 2012).

2.14.2.2 Feeding Deterrent

Primary and secondary antifeedant effects have been seen in the case of azadirachtin (Wondafrash *et al*. 2012). Primary effects include the process of chemoreception by the organism (for example, sensory organs on the mouthparts which stimulate the organism to begin feeding) whereas secondary processes are effects such as gut mortality disorders due to topical application only (Das *et al.* 2010). Inhibition of feeding behaviour by azadirachtin results from blockage of input receptors for Phagostimulants or by the stimulation of deterrent receptor cells or both (Shukla and Toke, 2013). The crude extract from neem could act as antifeedant causing death to insects through starvation (Adjei-Boateng *et al*., 2003).When neem extract is applied, the presence of azadirachtin, salamin and melandriol cause anti-peristaltic wave in the alimentary canal (vomiting action) in the insect. Thus the ability of insect to feed is blocked (Shukla and Toke, 2013).

Warthan (1999) listed twenty species of Coleoptera, three species of Diptera, fourteen species of Hemiptera, two species of Lepidoptera and five species of Othoptera that respond to neem as a feed deterrent. The hydroxyl furan fragment of the azadirachtin molecule is said to cause the antifeedant effects more widely noticed among target species (Aldhous, 1992). Studies by Yoshida and Toscana (1994) showed the relative consumption rate of *Heliothis virescens* larvae treated with azadirachtin to be 25% of the control, attributing to the lowest assimilation efficiency of all natural insecticides tested. In other research, the larvae consumed less food, gained less weight and were less efficient at converting ingested and digested food into biomass (Barnby and Klocke, 1987). The order Lepidoptera appears most sensitive to

azadirachtin's antifeedant effects, with Coleoptera, Hemiptera and Homoptera being less sensitive (Shukla and Toke, 2013).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site and Climatic Conditions

3.1.1 Experimental Site

Two field experiments were conducted at the Multipurpose Crop Nursery at the University of Education Winneba, Mampong campus from August to November, 2015 and June to September, 2016. In both seasons, cabbage seeds were nursed, transplanted and taken care of with the appropriate agronomic practices until they were harvested.

Mampong Ashanti is located within the transitional agro ecological zone, lying between the semi deciduous forest to the south and the Guinea savannah region to the north. It is located at Latitude $07^0$047'N and longitude $010^0$224'W. It is 457.5 m above sea level.

Mampong - Ashanti has a bimodal rainfall pattern. The major rainy season starts from March/April and ends in July with a short dry spell in August. The minor rainy season starts from September and ends in November. The annual rainfall ranges between 1270 mm and 1534 mm with the monthly being 91 .2 mm. The mean monthly temperature is between 25 ºC and 32 ºC (Ghana Meteorological Agency – Mampong Ashanti, 2002)

The soils at the site belong to the Savannah Ochrosols derived from the Voltain sandstone of the Afram plains. The soil has been classified by FAO/UNESCO (1988) legend as Chromic Luvisol as the Bediesi series with a pH range of 4. 0 – 6. 5 and it is good for tuber, cereal vegetable and legume crop production (Asiamah, 1988). It occurs on the upper and middle slopes of the catena. The soil is well drained, and has satisfactory moisture holding capacity.

3.1.2 Climatic Conditions at the Experimental Site

Differences in climatic factors (temperature, rainfall and relative humidity) were observed between both cropping seasons (Tables 3.1 and 3.2). The total monthly rainfall for 2015

cropping season was 287.5 mm and it occurred from August, 2015 to November 2015 with the peak in September and October. The mean monthly temperature for the area for the 2015 cropping season ranged between 22.8 ºC to 30.8 ºC with the highest daily temperature of 32.6ºC occurring in November, 2015. The mean monthly relative humidity ranged from 60.3 to 92.2 % with the peak occurring between September and November.

In the 2016 cropping season, during experiment two (2), the total monthly rainfall was 647.8 mm and it occurred from June to September, with the peak in June, July and September. The mean monthly temperature of the area for the 2016 cropping season ranged between 22.4 ºC to 29.4 ºC with the highest daily of 30.1 ºC occurring in June. The mean monthly relative humidity ranged from 71 to 96 % with the peak occurring between June and September.

Table 3.1: Climatic Data for 2015 Cropping Season (Experiment One)

Month	Total Rainfall (mm)	Mean Relative Humidity (%)		Mean Temperature (ºC)	
		06.00hrs	15.00hrs	Min.	Max.
August	2.9	92	66	22.0	28.6
September	101.7	92	61	22.5	30.3
October	142.2	93	60	23.1	31.8
November	40.7	92	54	23.4	32.6

Source: Ghana Meteorological Agency- Mampong Ashanti, 2015

Table 3.2: Climatic Data for 2016 Cropping Season (Experiment Two)

Month	Total Rainfall (mm)	Mean Relative Humidity (%)		Mean Temperature (°C)	
		06.00hrs		Min.	Max.
		15.00hrs			
June	155.5	96	68	22.8	30.1
July	108.1	96	71	22.3	29.0
August	55.1	96	72	22.0	28.4
September	329.1	97	71	22.4	30.0

Source: Ghana Meteorological Agency- Mampong Ashanti, 2016

3.2 Experimental Design and Treatment Combinations

3.2.1 Experimental Design

The field was laid in a randomized complete block design (RCBD). There were nine (9) treatments with three replications. The nine treatments were made up of eight organic manure and fertilizer rates and the control (without amendment) and chemical insecticides (Cypermetrine and neem leaf extract) which were assigned to each block.

3.2.2 Treatments for the Experiment

There were eight treatment combinations and a control (Table 3.3).

Table 3.3: Treatment Combinations

Treatment	Fertilizer Rates	Insecticide Rates
T_1	Poultry Manure (20t/ha)	Cypermetrine (30l/ha)
T_2	Cow Dung (20t/ha)	Cypermetrine (30l/ha)
T_3	N.P.K (300 kg)	Cypermetrine (30l/ha)
T_4	Foliar	Cypermetrine (30l/ha)
T_5	Poultry Manure (20t/ha)	Neem leaf extract
T_6	Cow Dung (20t/ha)	Neem leaf extract
T_7	N.P.K (300kg)	Neem leaf extract
T_8	Foliar	Neem leaf extract
T_9	No fertilizer (Control)	No insecticide (Control)

3.3 Organic Manure Preparation

Poultry manure and cow dung used for the research work were collected from the animal farm of the College of Agriculture Education of the University of Education, Winneba – Mampong Campus poultry farm and kraal respectively and heaped under shade to dry before use. Sub - samples of the dried manure were taken for nutrient analysis. The dried poultry manure and cow dung were applied and worked into the soil two weeks before transplanting of cabbage seedlings.

3.4 Soil and Manure Sampling

After lining and pegging, the experimental area was demarcated into plots and before transplanting, soil, poultry manure and cow dung were mixed thoroughly. Samples of the mixture of soil and manure and no – manure (control) were randomly taken at a uniform depth of 0 – 20 cm for chemical and physical analysis.

3.5. Soil Physical and Chemical Analyses

Samples of soil and a mixture of soil and manure from the various replicates and treatments with the exception of DI'GROW (Foliar) plot were taken for analysis at the Soil Research Institute, Kwadaso in Kumasi. The characteristics analysed for included, Bulk density, soil texture, soil pH, organic matter, organic carbon, total nitrogen, exchangeable calcium, magnesium, potassium and sodium, effective cation exchange capacity, total exchangeable bases and available phosphorus and potassium.

3 .5.1 Determination of Soil Organic Carbon

Organic carbon was determined by the wet combustion method of Wakley and Black (1934). A half gram (0.5 g) of air-dried and sieved soil (0.5 mm sieve) sample was weighed into a conical flask. Ten (10) ml of 0.167 M potassium dichromate ($K_2Cr_2O_7$) and 20 ml of concentrated sulphuric acid (H_2SO_4) were added. The flask was swirled to ensure that all the soil particles were in contact with the solution and digested. The content of the flask was allowed to settle for 30 minutes. The unreduced potassium dichromate ($K_2Cr_2O_7$) remaining in solution after the oxidation of the oxidizable organic material in the soil sample was titrated with 0.2 M ferrous ammonium sulphate after adding 10 ml orthophosphoric acid and 2 ml of barium diphenylalanine sulphate (an indicator) until colour change from a dirty brown colour to a bright green end point. Standardization of the potassium dichromate ($K_2Cr_2O_7$) with the ferrous ammonium sulphate was done. The titre value was used to calculate the percent carbon (%C) as:

%C = [0.3x (10− XN)] W×1.33

Where X = Titre value of the ferrous ammonium sulphate

N = Molarity of the ferrous ammonium sulphate (0.2M)

W = Weight of the soil sample

3.5.2 Determination of Total Nitrogen

The Kjedahl (1883) method was used in the determination of total nitrogen. Two (2) grams of soil was weighed into 300 ml Kjedahl flask and a tablet of a digestion accelerator (selenium catalyst) was added. This was followed by addition of 5 ml of concentrated H_2SO_4. The mixture was digested until the digest became clear. The flask was then cooled and its content transferred into a 100 ml volumetric flask. The content was made to the 100 ml mark with distilled water. An aliquot of 5 ml of the digest was taken into a Markham distillation apparatus and 10 ml of 40% NaOH was added and the mixture distilled. The distillate (liberated ammonia) was collected in 5 ml of 2% boric acid (H_3BO_3). Three drops of a mixed indicator containing methylene blue and methyl red were added to the solution and then back titrated with 0.01M HCl from green to reddish end point.

The percentage N was calculated as follows:

%N = 0.01 × titre volume× 0.014 × volume of extract ×100 $\frac{Soil\ Sample\ weight\ (g)}{volume\ of\ aliquot\ (mL)}$

Where

0.01 = Molarity of HCl and 0.014 = Milliequivalent of Nitrogen

3.5.3 Available Phosphorus Determination

Available P of the soils was determined using Bray 1 method. Five grams (5g) of soil was weighed into a centrifuge tube in duplicates. Fifty (50) milliliters of Bray solution (0.03 N NH4F +0.025 N HCl) was added.

3.5.4 Exchangeable Cations (Na, K, Ca and Mg)

Ten grammes (10 g) of soil were weighed into an extraction bottle and 100 ml of 1 M ammonium acetate (NH4OAc) was added and shaken for 30 minutes. The suspension was allowed to settle, after which it was decanted and filtered. The filtered solutions (aliquots)

were used for the determination of Ca, Mg, K and Na. The concentrations of potassium (K) and sodium (Na) were determined using the flame photometer (Chapman, 1965).

The tubes were shaken end-over-end on a mechanical shaker for 5 min and were then centrifuged at 2500 rpm for 5 min. The suspensions were each filtered through a No. 42 Whatman filter paper into a 50 ml Erlenmeyer flask. Phosphorus in the filtrate was determined using the molybdate-ascorbic acid method as follows:

An aliquot of 1 ml was transferred into a 50 ml Erlenmeyer flask and about 30 ml of distilled water was added in duplicate. The pH was adjusted using P-nitrophenol indicator and neutralized with a few drops of 4 M NH_4OH until the solution turned yellow. Five (5) milliliters of a mixture of ascorbic acid, ammonium molybdate, antimony potassium tartarate and concentrated HSO_4 (reagent A) were added to the volume (50 ml) with distilled water. The solution was mixed thoroughly by shaking and allowed to stand for about 50 min for the colour to stabilize. A blank was prepared with distilled water and 5 ml of reagent B (1.056 g of ascorbic acid in 200 ml of reagent A).

The concentration of phosphorus was then determined on a Philips' UV spectrophotometer at a wavelength of 712 nm. Available phosphorus content of the soil was calculated with equation (7).

3.5.5 Potassium (K) Determination

The flame photometer was standardized such that 10 mg/kg of K gave 100 full scale deflections. The flame photometer after standardization was used to determine the concentration of potassium in 10 ml aliquot. The result was used in the calculation of the amount of potassium present in the soil as shown in the formula below.

Exchangeable K (cmolkg⁄soil) = R × V ×100 weight of soil ×39.1

Where

R= Flame Photometer reading for K (ppm)

39.1=Molecular weight of Potassium

V= Volume of extract (100 ml)

3.5.6 Sodium (Na) Determination

The flame photometer was standardized in a way that 10 mg/kg of Na gave 100 full scale deflections. After the standardization of the photometer, the concentration of sodium in 10mL aliquot was determined. The result was then used in the calculation of the amount of sodium (Na) present in the soil as shown by the formula below.

Exchangeable Na (cmolkg⁄soil) = R ×V×100 weight of soil × 23

Where

R= Flame photometer reading for Sodium (ppm)

V= Volume of extract (100 ml)

23=Molecular weight of Sodium

3.5.7 Calcium (Ca) Determination

To a 10 ml aliquot of the sample solution, 10 ml of 10% KOH and 1ml triethanolamine (TEA) were added. Three drops of 1M KCN solution and a few crystals of Cal-red indicator were then added after which the mixture was titrated with 0.02M EDTA solution from red to blue end point. The titre value was used in the calculation of calcium as shown below.

Ca (*cmolkg⁄*) = Titre value × N × Vol.of extract × 100 (meq/100 g) Vol. of aliquot × Weight of soil

Where N = Molarity of EDTA

3.5.8 Magnesium (Mg) Determination

A 10 ml aliquot of the sample solution, 5 ml of ammonium chloride – ammonium hydroxide buffer solution was added followed by 1ml of triethanolamine. Three drops of 1M KCN solution and a few drops of Eriochrome black T solutions were added after which the mixture was titrated with 0.02M EDTA solution from red to blue end point. The end point titre value

determines the amount of calcium and magnesium in the solution. The titre value of magnesium was then determined by subtracting the value obtained for calcium above from the new titre value obtained. The titre value of magnesium was then used for the calculation of the concentration of magnesium (Mg) as shown below.

Mg (*cmolkg*/) =Titre value × N × Vol.of extract × 100 (meq/100 g) Vol. of aliquot × Weight of soil

Where N = Molarity of EDTA

3.6 Land Preparation, fertilization and Planting

The land was cleared, ploughed and harrowed and then pegged for planting. Cow dung and the poultry manure were applied depending upon the treatment at the rate of 20t/ha and worked into the soil two weeks before transplanting of cabbage seedlings. The inorganic fertilizer (15 -15 -15 N.P.K) at the rate of 300 kg/ha was applied to the respective plots on the various replicates two weeks after transplanting.

Cabbage seeds used for the experiment were obtained from Kaakyire Agrochemical Mampong – Ashanti. The variety that was used was Oxylus. The seedlings were transplanted four weeks after nursing at a spacing of 50 cm x 30 cm and at a depth of 1.0 cm. Transplanting of seedlings for each season was carried out early in the morning to prevent the seedlings from the shock of the sun. Each experimental plot contained four (4) rows and ten (10) plants within each row. There were sixteen (16) plants within the harvest area (two central rows per plot). Each experimental plot measured 2.0 m x 3.0 m with 1.0 m between plots and 2.0 m between blocks. The total field size for each season was 27.0 m x13.0 m (358.8m^2).

3.7 Agronomic practices

Supplementary watering by the use of watering cans was done due to the irregular rainfall pattern. Weeds were controlled manually and chemically. The first weeding was done two to

three weeks after transplanting. Hand-weeding between rows was often done to remove weeds two weeks after transplanting and was repeated as and when the weeds appeared. Nutsedge (*Cyperus rotundus*), a common perennial weed was particularly difficult to manage since there is currently no known selective herbicide for the control of nutsedge (California Agricultural Research Directory, 2007). A 41 % Glyphosate at the rate of 2.01 t/ha was used to control the nutsedge.

3.8 Pest Control

3.8.1 Preparation of Neem Leaf Extract

A mixture of 100 g of fresh neem leaves were air-dried at a temperature of 25 ^{o}C for 24 hours. The dried leaves were ground with a blender and added to one litre of water and left to stand overnight. This was filtered to obtain the neem extract and 10 g of alata soap was added to the neem extract. This serves as an adhesive (Facnath, 2000). The neem leaf extracts was evenly applied a week after transplanting and repeated every two weeks using CP 15 Knapsack sprayer on the cabbage plant except the control treated plants until head formation to control insect pests.

The insecticide (Cypermetrine) was also evenly applied on the cabbage plant except the control treated plants every two weeks. This was stopped two weeks before harvesting.

3.9 Data Collection

3.9.1 Vegetative Data

The percentage plant establishment was measured at 21 days after planting (DAT). This was achieved by counting the number of plants in the two middle rows and the percentage crop establishment estimated. The vegetative data that were taken were leaf number, diameter of open leaves, canopy width, stem diameter, leaf fresh weight, root fresh weight, leaf dry weight and root dry weight. Three plants were randomly sampled and tagged from the two middle rows from each treatment plot for leaf number, canopy width, diameter of open leaves and

stem diameter. These parameters were measured at two weeks interval from 21 DAT to 63 DAT. The stem diameter was measured using a vernier calliper while the canopy width and diameter of open leaves were measured using the meter rule.

Three plants were also destructively sampled and weighed for leaf fresh weight and root fresh weight at two weeks interval from 21 DAT to 63 DAT using an electronic weighing scale. Mean values for treatment were estimated. After the destructive sampling for leaf fresh weight and root fresh weight, the samples were oven – dried at 75 ^{o}C for 72 hours to remove the moisture. The dried samples were then weighed using an electronic weighing scale and the mean estimated.

3.9.2 Yield and Yield Components

The number of heads per plant harvested, total head weight, weight of shoot harvested, weight of root harvested, head weight per plot, head weight per plant and head diameter were estimated from the two central rows. Head diameter was measured from the middle portion of the head using the vernier calliper.

3.9.3 Pest Assessment

The heads harvested from the two central rows of each plot were sorted based on visual estimation of number of holes per head due to pest infestation and the number of multiple heads per plant. The percentage pest infestation was estimated from the heads harvested from the two central rows.

3.9.4 Damage incidence and severity

Leaf or head damage severity assessment was done visually with a slight modification of Olorunju *et al*. (2001) to suit the measured condition of a scale of 1 – 5, where 1 indicates a healthy plant, 2 indicates a minimal damage (1-20% of crop infested or with holes), 3 indicates moderate damage (21-50%), 4 indicates highly damaged (51-70%) and 5 indicates severely

damaged (above 70% crop infested or with holes or total damage). Damage incidence was scored as percentage of cabbage infested.

3.10 Data Analysis

The data collected were analysed using Analysis of Variance (ANOVA). The data obtained were analysed using Genstat Release II statistical package and the Least Significant Difference (LSD) was used to separate the means at 5 % level of probability.

CHAPTER FOUR

4.0 RESULTS

4.1 Nutrient Levels of Organic Amendments

Generally, the nutrient levels of the poultry manure applied in the 2015 cropping season was comparatively higher than the cow dung (Table 4.1). In 2016, both organic amendments had lower nutrient level relative to that of 2015. The level of potassium was 0.1 and 0.3 % for poultry manure and cow dung respectively in 2016. The pH for 2015 for both amendments was almost neutral and that of the 2016 was moderately acidic.

Table 4.1 Nutrient Levels of Organic Amendments, 2015 &2016 Cropping Seasons

Treatment	pH	Ca %	Mg %	P %	K %	N %
2015						
Poultry Manure	6.18	3.40	1.92	0.63	0.86	3.54
Cow Dung	6.87	1.00	1.05	0.23	0.84	2.01
2016						
Poultry Manure	5.97	2.11	0.48	0.70	0.10	0.86
Cow Dung	4.89	0.14	1.10	0.25	0.34	0.76

4.1.1 Soil Chemical Properties before treatment application

In 2015, soil analysis before application of treatments indicated that the soil was slightly acidic with a pH of 6.13, whereas that of 2016 was moderately acidic with a pH of 5.70. The Nitrogen, Potassium and Organic matter contents for both seasons were$\leq 0.06\%, 0.27\%$ and $\leq 1.16\%$ respectively (Table 4.2) (Soil analytical data guide of CSIR – SRI, 2007). Cations levels were low in the range of 0.1 – 4.8 meq/100g; calcium had an average of 4.5 meq/100g and the total exchangeable bases (TEB) were 6.13 and 5.45 for both cropping seasons.

Effective cation exchange capacity for both cropping seasons was low, ranging between 6.00 meq/100g and 6.23 meq/100g respectively (Table 4.2).

Table 4.2: Soil Chemical Properties before treatment application for both Cropping Seasons

				Exchangeable Cations (meq/100g)							Available Nutrients (ppm)	
pH (1:1H_2O)	Org C (%)	Total N (%)	Org Matter (%)	Ca^{2+}	Mg^{2+}	K^+	Na^+	TEB*	ECEC* (meq/100g)	Base Sat (%)	P	K
2015												
6.13	0.64	0.05	1.10	4.81	1.07	0.25	0.10	6.13	6.23	98.39	24.32	47.99
2016												
5.70	0.67	0.06	1.16	4.27	0.80	0.27	0.11	5.45	6.00	90.83	7.64	11.00

4.1.3 Changes in Soil Characteristics after Cropping

The pH of the fertilized soils remained slightly acidic or neutral (6.18 – 6.87) compared to the untreated soil which remained slightly acidic (6.13) after the 2015 season (Tables 4.3a, Appendix A). After the 2016 cropping season, soils of the untreated, poultry manure or N.P.K remained moderately acidic (5.70 -5.97) while that treated with cow dung became very acidic (Tables 4.3b & Appendix A). The cow dung treated plots recorded higher levels of organic carbon than poultry manure, N.P.K, or the untreated (control) for both cropping seasons. After the 2015 cropping season, soil amendments slightly improved percentage total nitrogen; however, they still remained within the low range (Tables 4.3a & Appendix A). Soil amendments improved percentage total N from the initial low levels to moderately high levels after the 2016 cropping season. While cow dung or poultry manure slightly improved organic matter, though still in the low category after the 2015 season, they significantly improved organic matter to the moderate or high levels after the 2016 cropping season. The application of cow dung left more organic matter in the soil in both years than the other amendments. Low levels of exchangeable cations, total exchangeable bases and effective cation exchange capacity were recorded for all treatments after both seasons, though slightly higher than the untreated (control). All the fertilized plots recorded moderate to high levels of available P or available K after both cropping seasons.

Table 4.3a: Chemical Properties of Soil after amendments for 2015 cropping season

TREATMENTS	pH 1:1	Org C (%)	Total N (%)	Org Matter (%)	Exchangeable Cations				TEB	ECEC	Base Sat (%)	Avail P (ppm)	Avail K(ppm)
					Ca^{2+} (meq/100g)	Mg^{2+}	K^{+}	Na^{+}		(meq/100g)			
Cow dung	6.87	0.67	0.07	1.16	5.87	0.53	0.69	0.24	7.09	7.19	98.61	27.11	168.51
Poultry manure	6.18	0.33	0.08	1.15	5.34	0.53	0.38	0.16	0.25	6.35	98.43	49.43	79.39
N.P.K	6.29	0.30	0.06	1.02	5.34	0.27	0.27	0.13	5.88	5.98	98.33	33.56	51.96
Untreated soil (Control)	6.13	0.64s	0.05	1.10	4.81	0.25	0.25	0.10	6.13	6.23	98.39	24.32	47.99

Table 4.3b: Chemical Properties of Soil after amendment for 2016 Cropping Season

TREATMENTS	pH 1:1	Org C (%)	Total N (%)	Org Matter (%)	Exchangeable Cations				TEB	ECEC*	Base Sat (%)	Avail P (ppm)	Avail K (ppm)
					Ca^{2+} (meq/100g)	Mg^{2+}	K^{+}	Na^{+}		(meq/100g)			
Cow dung	4.89	1.99	0.18	3.44	2.94	0.52	0.72	0.25	4.43	5.63	78.69	10.84	168.51
Poultry manure	5.97	0.86	0.17	2.78	5.07	0.93	0.24	0.16	6.56	6.86	95.63	19.21	79.39
N.P.K	5.87	1.61	0.14	1.48	3.34	0.67	0.28	0.15	4.44	4.84	91..74	10.34	51.96
Untreated Soil (Control)	5.70	0.67	0.06	1.16	4.27	0.80	0.27	0.11	5.45	6.00	90.83	7.64	11.00

4.2 Crop Growth and Yield

4.2.1 Crop Establishment

In 2015, percentage crop establishment was not significantly affected by any of the fertilizers combined with insecticides and were similar to the control (Table 4.4a and b). Generally, higher percentage crop establishment (>95%) was achieved across treatments with NPK + Cypermetrine, Poultry manure + neem, N.P.K + Neem or Foliar fertilizer + neem achieving 100% crop establishment.

Similarly, in 2016, fertilizer application combined with insect control did not negatively affect crop establishment. The percentage established crop population ranged between 96 and 100 (Table 4.5c and d).

4.2.2 Number of open leaves and open leaf diameter

Generally, number of open leaves was not significantly affected by fertilizer and insecticide combinations from 21 DAT to 63 DAT in 2015 (Table 4.5a and b). All the treatment effect increased between 21 and 35 DAT, after which some begun declining.

At 21 and 49 DAT, fertilizer and insecticide combinations did not significantly influence cabbage open leaf diameter in 2015 (Table 4.5a and b). However, significant differences occurred at 35 DAT with poultry manure + Cypermetrine producing larger open leaves compared with the control treatment only.

In 2016, the number of open leaves increased from 21 DAT to 35 DAT, peaked at 49 DAT and then declined (Table 4.5c and d). At 21 DAT, there were no significant differences between the numbers of open leaves for the various treatments. However, at 35 and 45 DAT, cabbage treated with cow dung combined with Cypermetrine or neem produced significantly more open leaves than the control or foliar fertilizer combined with Cypermetrine.

The diameter of open cabbage leaves generally increased from 21 DAT and peaked between 35 and 49 DAT then declined by 63 DAT (Table 4.5c and d). At 21, 35 and 49 DAT, leaves of cabbage treated to foliar fertilizer combined with neem or the control treatment were significantly lower than the leaves of cabbage treated to the other fertilizers combined with neem or synthetic insecticide. Poultry manure combined with Cypermetrine produced broader leaves than all the other treatments.

4.2.3 Canopy width and Stem Diameter

In 2015, there were no significant differences between the canopy width of cabbage treated with fertilizer and insecticide combinations at 21, 35, 49, and 63 DAT (Table 4.5a and b). Canopy width mostly increased at 21 DAT to 49 DAT except for foliar fertilizer combined with insecticide (Cypermetrine or neem) or N.P.K combined with neem where canopy width increased through to 63 DAT.

Stem diameter increased across the sampling period (21 DAT – 63 DAT). At 21DAT, there were no significant differences between the stem diameters of cabbage for all the treatments except for poultry manure which had thicker stems than the control (Figure 1.0a). At 35 and 63 DAT, plots treated with poultry manure combined with Cypermetrine, poultry manure combined with neem, cow dung combined with Cypermetrine, cow dung combined with neem or N.P.K combined with Cypermetrine had crops with thicker stem than the control. Also, all the treatments produced crops with thicker stem than the control at 49 DAT.

In 2016, the application of fertilizer combined with neem produced cabbage with wider canopies than fertilizers combined with Cypermetrine or the control. Canopy width also increased from 21 DAT up to 49 DAT and then declined by 63 DAT (Table 4.5c and d). N.P.K combined with neem or cow dung combined with neem significantly produced cabbage with wider canopy compared

with the other fertilizers combined with insecticide or the control by 49 DAT. The foliar fertilizer combined with Cypermetrine produced plants with the least canopy width, though, similar to the control.

Also, Poultry manure combined with Cypermetrine, cow dung combined with neem, or N.P.K combined with neem significantly produced bigger stems than the foliar fertilizer combined with Cypermetrine or neem, or the control at 35 and 49 DAT (Figure 1.0b). At 63 DAT, Foliar fertilizer combined with Cypermetrine or the control treatment produced slender stems (1.5cm), whereas Poultry Manure combined with Cypermetrine consistently produced thicker stemmed plants throughout the crop's growing phase.

4.2.4 Crop Dry Matter Production

In 2015, dry matter production was not significantly influenced by fertilizer and insecticide application in the early stages (21 – 35 DAT) of crop growth (Figure 2.0). However, at 49 DAT, the application of fertilizer and insecticides significantly affected crop dry matter production with poultry manure combined with neem, N.P.K combined with neem, Cow dung combined with Cypermetrine or poultry manure combined with Cypermetrine producing 116, 76, 70 or 56% more dry matter respectively than the control.

Similarly, in 2016, there were no significant differences in dry matter production among fertilizer and insecticide treatments (Figure 2.0b). However, production without any form of fertilizer and insect pests control reduced dry matter production by 10 – 40 % compared to when production is done with some form of nutrient supply and insect pest control.

4.2.5 Head formation and yield

In the 2015 experiment, days to head initiation was significantly influenced by fertilizer and insecticide treatments (Table 4.5a). Head initiation for all treatments started 2 – 3 weeks earlier

than the control with poultry manure combined with neem or Cypermetrine requiring the least days to head initiation.

Head diameter was also significantly influenced by the fertilizer and insecticide treatments (Table 4.5a). Poultry manure or cow dung regardless of the insecticide applied produced bigger cabbage heads which were 7 – 7.4 cm bigger than the control.

Weight of heads produced was significantly affected by fertilizer and insecticide application with poultry manure combined with Cypermetrine significantly producing heavier heads than the control, or foliar combined with neem or Cypermetrine. The heads produced from the poultry manure combined with Cypermetrine were 0.80kg heavier than the control, foliar combined with Cypermetrine or neem.

Cabbage yield per hectare in 2015 was significantly influenced by fertilizer and insecticide treatment (Table 4.5a). The application of poultry manure and Cypermetrine or neem significantly produced 32.50 – 37.23 tonnes (468 – 537%) more cabbage than the control. Foliar fertilizer regardless of the insecticide combined produced yields similar to the control. Harvest index was however not influenced by the treatments.

In 2016, days to cabbage head initiation ranged between 78 -97 days (Table 4.5b). However, the production of cabbage without any form of fertilizer and insecticide application increased the number of days to head initiation by 10 to 19 days. The use of Poultry manure combined with neem or Cypermetrine required significantly less days (6-8days) to head initiation compared with NPK combined with Neem or Cypermetrine, cow dung combined with neem or foliar fertilizer combined with neem (Table 4.5b).

The control, foliar fertilizer combined with neem or Cypermetrine, N.P.K combined with Cypermetrine, or cow dung combined with neem produced significantly lighter cabbage heads

compared with poultry manure combined with neem or Cypermetrine, cow dung combined with Cypermetrine, or N.P.K combined with neem (Table 4.6b). The use of Poultry manure combined with neem or Cypermetrine produced cabbage heads that were 350 – 450% heavier than the cabbage heads of the control (0.20kg). N.P.K combined with neem or Cypermetrine also produced heads that were 150 – 315% heavier than the control.

Again in 2016, significantly higher yields of 278, 266, 289 and 131% percent over the control (9 tonnes/ha) were recorded for poultry manure combined with neem, N.P.K combined with neem, poultry manure combined with Cypermetrine, or cow dung combined with neem respectively over the control (Table 4.5b). The control or foliar combined with Cypermetrine recorded least yields of 10 and 9 tonnes/ha respectively.

Table 4.4a: Effect of Treatments on Percentage Crop Establishment (%), number of leaves, open leaf diameter and canopy width (2015)

TREATMENT	PERCENTAGE (%) ESTABLISHMENT	NUMBER OF OPEN LEAVES (DAYS AFTER TRANSPLANTING)			
		21	**35**	**49**	**63**
PoultryMan+Cyper	95.83	12	19	16	11
Cow dung+ Cyper	95.83	12	19	17	14
N.P.K+ Cyper	100.0	12	18	18	13
Foliar + Cyper	95.83	10	17	18	16
PoultryMan+NLE	100.0	12	19	17	14
Cow dung+ NLE	95.83	12	19	22	20
N.P.K+ NLE	100.0	11	18	21	20
Foliar + NLE	100.0	10	14	14	15
Control	95.83	10	15	16	19
SED(0.05)	**2.06**	**1.28**	**2.1**	**2.2**	**4.15**

cyper = cypermetrine, man = manure

Table 4.4b: Effect of Treatments on Percentage Crop Establishment (%), number of leaves, open leaf diameter and canopy width (2015)

TREATMENT	PERCENTAGE (%) ESTABLISHMENT	OPEN LEAF DIAMETER (cm) (DAYS AFTER PLANTING)			CANOPY WIDTH (cm) (DAYS AFTER TRANSPLANTING)			
		21	35	49	21	35	49	63
PoultryMan+Cyper	95.83	14.33	19.00	18.33	38.67	49.33	50	44.67
Cow dung+ Cyper	95.83	13.33	16.00	16.67	35.67	47.67	45.67	46.67
N.P.K+ Cyper	100.00	10.33	11.67	10.33	28.67	37.67	40.00	38.33
Foliar + Cyper	95.83	10.00	10.33	7.33	25.33	31.33	33.33	34.67
PoultryMan+NLE	100.00	14.33	15.67	12.00	38.00	43.33	51.66	51.33
Cow dung+ NLE	95.83	11.33	13.33	17.00	33.67	37.33	43.67	43.00
N.P.K+ NLE	100.00	10.33	12.00	12.33	27.67	41.00	42.00	44.00
Foliar + NLE	100.00	9.00	10.00	12.00	26.67	32.33	32.67	35.00
Control	95.83	8.00	9.33	8.33	24.67	27.00	31.00	31.33
SED(0.05)	2.06	2.26	2.61	3.14	6.09	8.87	7.84	9.34

cyper = cypermetrine, man = manure

Table 4.4c: Effect of Treatments on Crop Establishment (%) and number of open leaves (2016)

TREATMENT	PERCENTAGE (%) ESTABLISHMENT	NUMBER OF OPEN LEAVES (DAYS AFTER TRANSPLANTING)			
		21	35	49	63
Poultry Man+Cyper	100.00	13	19	23	19
Cow dung+ Cyper	100.00	13	21	27	19
N.P.K+ Cyper	97.92	11	18	23	17
Foliar + Cyper	97.92	11	19	22	18
Poultry Man+NLE	95.83	12	20	23	17
Cow dung+ NLE	100.00	13	20	28	18
N.P.K+ NLE	100.00	13	22	27	21
Foliar + NLE	100.00	12	20	26	23
Control	100.00	11	17	24	23
SED (0.05)	1.78	2.55	2.05	3.12	2.55

cyper = cypermetrine, man = manure

Table 4.4d: Effect of Treatments on open leaf diameter and canopy width (2016)

TREATMENT	OPEN LEAF DIAMETER(cm) (DAYS AFTER PLANTING)				CANOPY WIDTH (cm) (DAYS AFTER TRANSPLANTING)			
	21	35	49	63	21	35	49	63
PoultryMan+Cyper	16.00	19.67	18.00	11.67	27.33	47.67	49.33	43.33
Cow dung+ Cyper	12.67	13.67	14.33	12.33	31.33	49.00	53.00	36.67
N.P.K+ Cyper	12.00	14.33	12.67	7.67	25.30	48.00	50.67	41.33
Foliar + Cyper	12.67	14.00	12.00	7.00	24.67	39.00	45.00	33.00
PoultryMan+NLE	13.33	15.33	11.67	8.67	31.67	50.33	50.00	47.67
Cowdung+NLE	12.00	13.33	12.00	9.67	30.67	52.33	56.67	51.67
N.P.K+ NLE	12.33	13.33	13.33	13.33	33.00	58.67	63.37	50.33
Foliar + NLE	9.00	9.67	8.33	7.33	31.00	46.33	52.00	44.00
Control	9.33	10.00	7.33	9.33	24.67	41.67	50.67	42.00
SED (0.05)	1.83	2.87	3.82	2.04	3.72	5.53	4.97	6.34

cyper = cypermetrine, man = manure

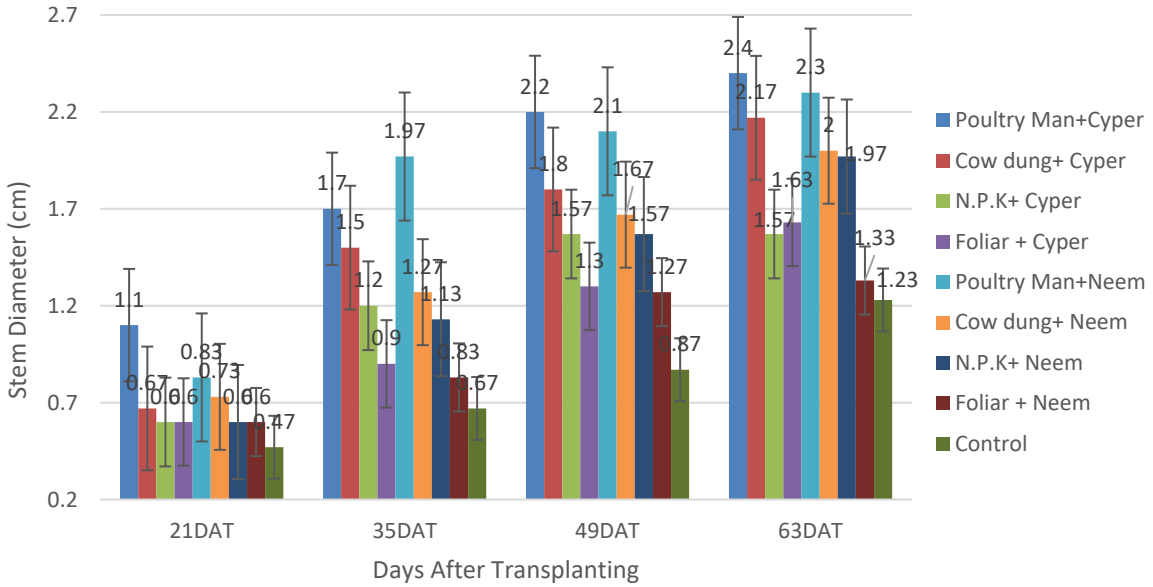

Figure 1.0a effect of treatments on stem diameter - 2015

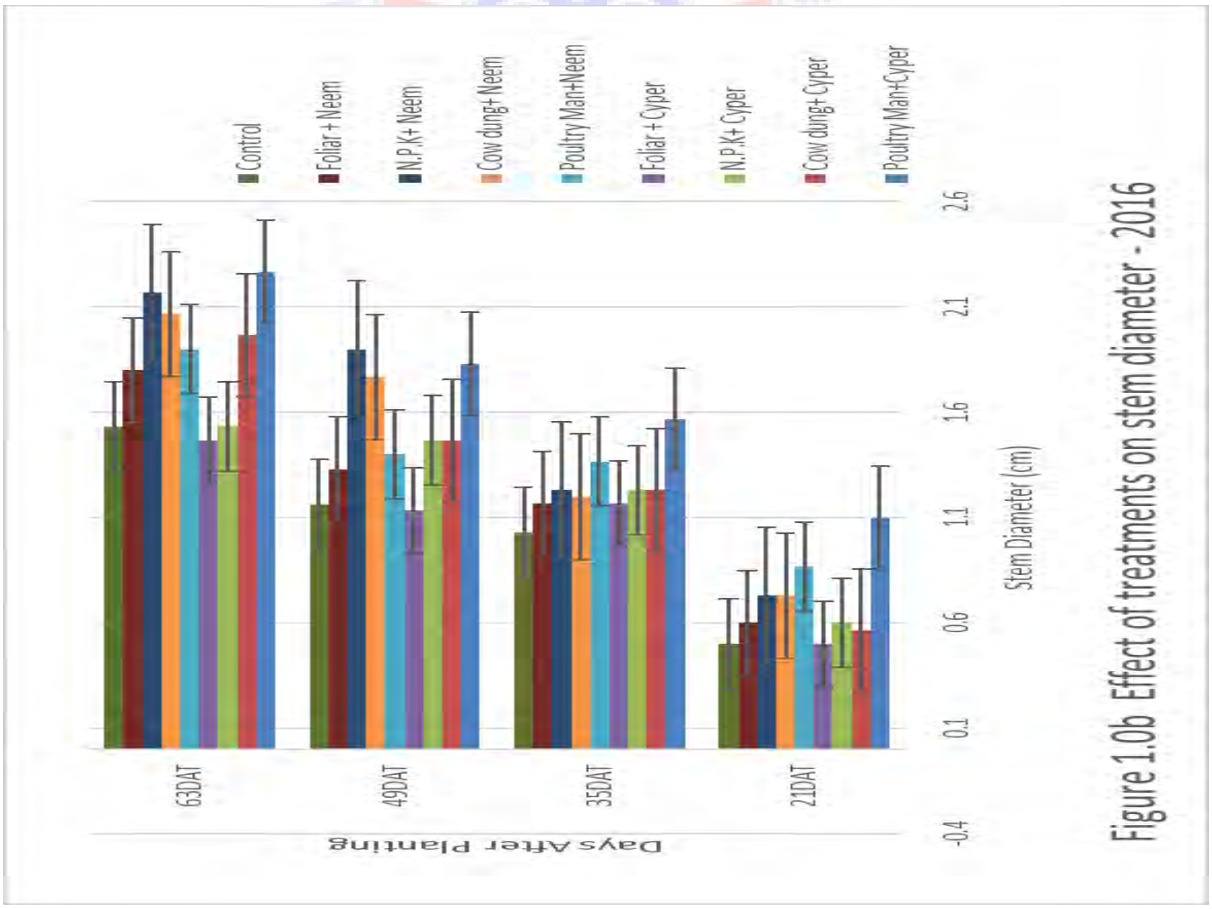

Figure 1.0b Effect of treatments on stem diameter - 2016

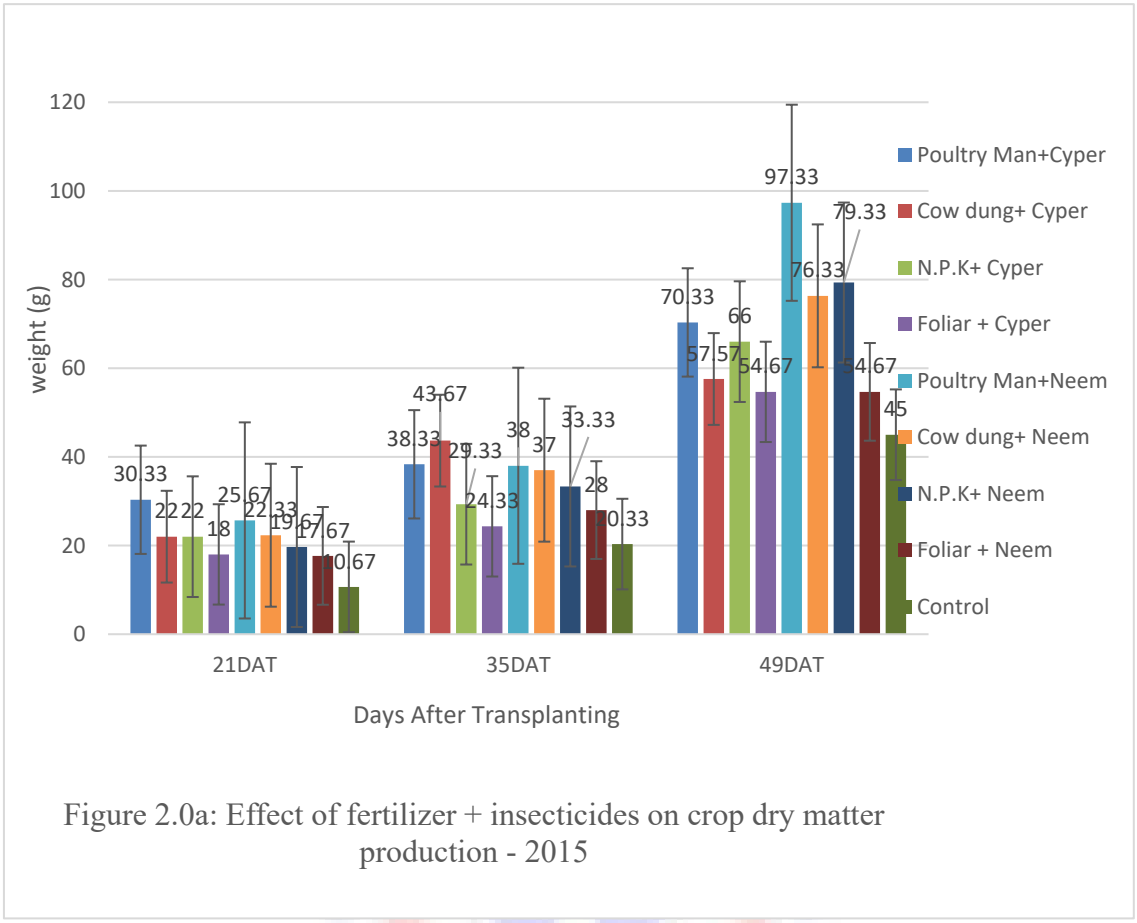

Figure 2.0a: Effect of fertilizer + insecticides on crop dry matter production - 2015

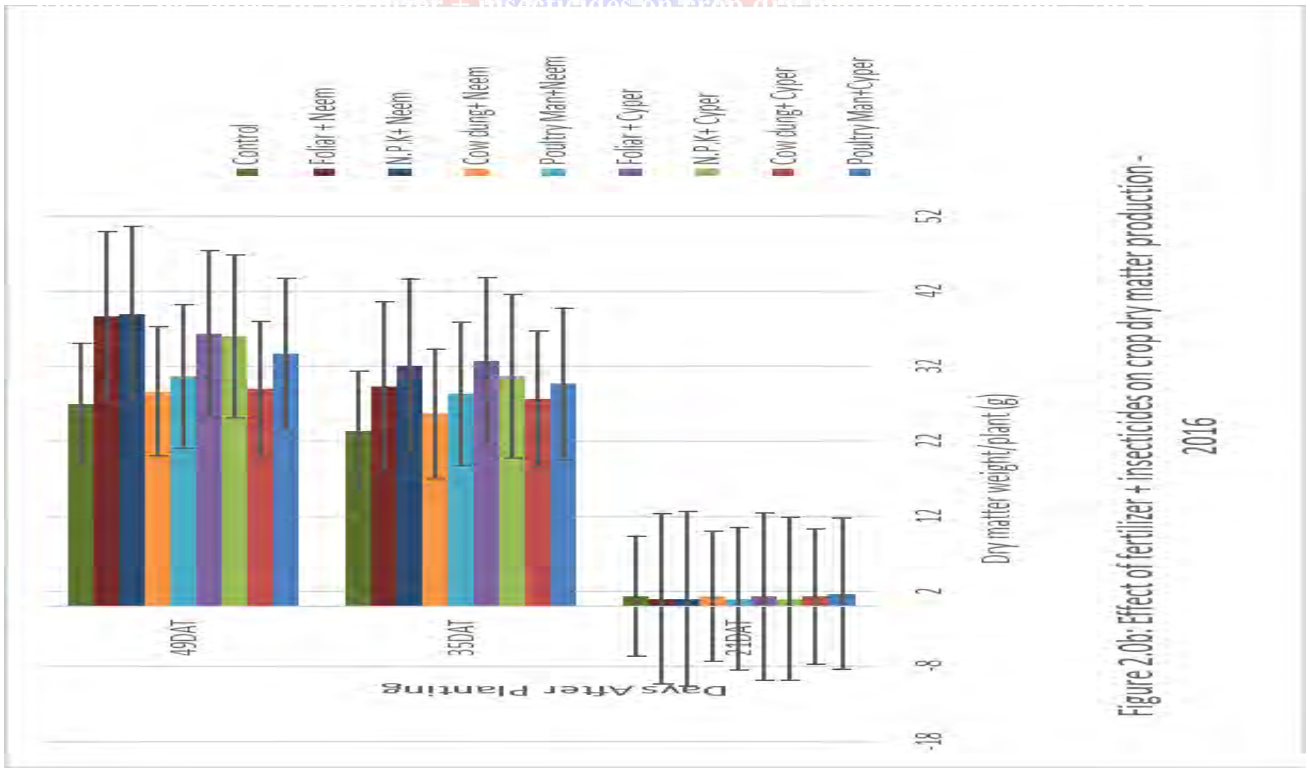

Figure 2.0b: Effect of fertilizer + insecticides on crop dry matter production - 2016

Table 4.5a: The effect of fertilizer + insecticides on cabbage yield and yield parameters-2015

Treatment	Days to Head Initiation	Head Diameter(cm)	Head Weight/Plant (kg)	Yield (ton/ha)	Harvest Index
Poultry Man+Cyper	80	10.03	1.03	39.44	0.83
Cow dung+ Cyper	82	10	0.80	24.58	0.85
N.P.K+ Cyper	86	8.67	0.53	22.78	0.79
Foliar + Cyper	82	5.07	0.17	9.86	0.67
Poultry Man+NLE	78	9.67	0.73	44.17	0.86
Cow dung+ NLE	85	9.67	0.73	23.33	0.75
N.P.K+ NLE	87	8.33	0.53	26.81	0.89
Foliar + NLE	87	5.33	0.20	18.47	0.54
Control	101	2.67	0.20	6.94	0.50
SED (0.05)	4.04	2.96	0.24	10.83	0.18

cyper = Cypermetrine, man = manure

Table 4.5b: The effect of fertilizer + insecticides on cabbage yield and yield parameters 2016

Treatment	Days to Head Initiation	Head Diameter (cm)	Head Weight/Plant (kg)	Yield (ton/ha)	Harvest Index
Poultry Man+Cyper	79	10.03	1.10	32.56	0.79
Cow dung+ Cyper	82	10	0.73	19.11	0.82
N.P.K+ Cyper	85	8.67	0.50	18.11	0.75
Foliar + Cyper	82	5.072	0.17	10.00	0.77
Poultry Man+NLE	78	9.65	0.90	33.56	0.86
Cow dung+ NLE	85	9.67	0.50	20.56	0.79
N.P.K+ NLE	85	8.33	0.83	34.56	0.86
Foliar + NLE	87	5.34	0.40	17.10	0.83
Control	97	2.66	0.20	8.89	0.81
SED (0.05)	4.17	2.94	0.28	6.81	0.16

cyper = cypermetrine, man = manure

4.3 Incidence and severity of cabbage leaves or head damage

In 2015, the application of Cypermetrine or neem with any of the fertilizers significantly reduced the percentage of cabbage damaged by insects by 57 -74%, 62 – 75% and 79 – 88 % at 28, 35 and 49 DAT respectively, and cabbage head by 84 – 89% at harvest relative to the control (Table 4.7a). Generally, damage incidence of less than 15% was recorded with the application of Cypermetrine or neem whereas damage incidence of the control increased from 27% at 28 DAT to 86% at harvest (Table 4.7a).

Severity of damage was very mild in the initial stages of growth (up to 28 DAT) for cabbage treated with the insecticides combined with fertilizers or the control (Table 4.7a). However, while the application of Cypermetrine or neem extracts kept damages at minimal levels from 35 DAT till harvesting, the untreated had moderate to high gravity of damage.

In 2016, very low insect damage incidence (less than 4%) was recorded with the application of insecticides at 28 or 35 DAT relative to the untreated (Table 4.7b). At 49 DAT or harvest, percentage of damaged crops on insecticide treated plots were not more than 10%. The application of Cypermetrine or neem regardless of the fertilizer combined, reduced damage incidence by 86 – 91, 86 – 89, 84 – 94 or 88 – 94% relative to the control at 28, 35, 49 or at harvest respectively. While very mild magnitude of insect damages was recorded with the application of any of the insecticides throughout the growing season regardless of the fertilizer combined, the control recorded mild damage degrees at the initial stages. Damages, however, became moderate or highly severe at the later stages of crop growth till harvest for the control.

Table 6a: Effect of insecticides application on cabbage damage incidence and severity - 2015

Treatment	Percentage(%) Incidence (Days after transplanting)				Severity (Days after transplanting)			
	28	35	49	Harvest	28	35	49	Harvest
PoultryMan+Cyper	7.67	7.67	8.33	9.67	1.67	1.67	2.00	2.00
Codung+Cyper	7.67	9.00	9.33	10.67	2.00	2.00	2.00	2.00
N.P.K+ Cyper	11.67	7.67	8.00	11.67	1.67	1.67	1.67	2.00
Foliar + Cyper	9.00	10.67	13.67	14.33	2.00	2.00	1.67	2.00
Poultry Man+NLE	7.67	9.67	10.67	13.67	2.00	2.00	2.00	2.00
Cowdung+NLE	7.00	9.33	10.00	13.00	2.00	2.00	2.00	2.00
N.P.K+ NLE	11.67	11.67	13.00	13.67	1.67	1.67	1.67	2.00
Foliar + NLE	11.00	11.00	11.33	13.67	1.67	1.67	1.67	2.00
Control	27.00	30.67	64.67	85.67	2.30	3.30	4.00	4.30
SED (5%)	4.83	5.36	4.95	4.89	0.40	0.42	0.37	0.21

cyper = cypermetrine, man = manure

Table 6b: Effect of insecticides application on cabbage damage incidence and severity– 2016

Treatment	Percentage(%) Incidence (Days after transplanting)				Percentage(%) damage Severity (Days after transplanting)			
	28	35	49	Harvest	28	35	49	Harvest
PoultryMan+Cyper	2.67	3.67	4.00	5.00	1.30	1.30	1.30	1.30
Cowdung+ Cyper	2.33	3.33	6.67	7.67	1.30	1.70	1.70	1.70
N.P.K+ Cyper	2.00	3.00	9.00	10.00	1.30	1.30	1.70	1.70
Foliar + Cyper	2.33	3.00	6.67	8.00	1.30	1.30	1.70	1.70
Poultry Man+NLE	2.67	3.00	4.67	8.67	1.30	1.30	1.70	1.70
Cow dung+ NLE	2.67	3.33	6.67	8.67	1.30	1.30	1.70	1.70
N.P.K+ NLE	2.67	3.33	4.67	5.67	1.30	1.30	1.30	1.70
Foliar + NLE	3.00	3.33	7.00	7.33	1.30	1.30	1.30	1.70
SED (5%)	2.01	2.26	5.42	3.58	0.27	0.22	0.24	0.22
Control	21.33	27.00	57.00	86.00	2.30	3.00	3.67	4.00

cyper = cypermetrine, man = manure

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effectiveness of fertilizers for soil improvement and maintenance

The differences in pH and nutrient levels of the organic manure in 2015 and 2016 are substantiated by the fact that no two different remains from different sources could be the same in nutrient levels (Sutton and Lander, 2003). In an experiment conducted in South Africa using poultry manure collected from different parts of the country, it was realized that the pH, percentage P, total N, Ca and Mg differed significantly (Ravindran *et al.* 2017). It has been suggested that the growth of plants is optimal when soil pH is between 5.8 and 6.5 and sometimes to a maximum of 7.5 depending on the plant species (Ontario Ministry of Agriculture, 2009). The application of the organic manure left the soil pH within a range needed for optimum plant growth except for cow dung in 2016. It will not be wrong to deduce that the pH of the soil became acidic after the season because pH of the cow dung was acidic. This is partly because the parent material for soil formation has a role to play in the overall pH of the soil formed. It has been established that soils respond differently to changes in pH depending on the soil's buffering ability (CEC) (Page-Dumroese *et al.* 1995). The initial CEC of the soil in 2016 before the application of the cow dung was low and this does not allow the holding of cations to the soil surfaces to aid in neutralization. Such soils are unable to control nutrient losses through leaching too.

The application of organic manure provides benefits of improved fertility, water holding capacity, structure, increased organic matter and organic carbon (Adebayo *et al.* 2011). Much organic matter and carbon was left on the cow dung treated plots principally because cow dung needs much time to decompose than poultry manure and therefore has a longer residual effect than poultry manure. Decomposition of organic matter is dependent on the C/N ratio of the organic

material, with materials of lower C/N ratio decomposing faster. C/N ratio documented for cow dung include 24:1 (Orhorhoro *et al.,* 2016); 16:1 (Dhroso *et al*., 2014); 32:1 (Adebayo *et al*., 2011) and 17:1 (Tewelde *et al.,* 2012) among others. Reported C/N ratio for poultry manure include Ravindran *et al*. (2017) who recorded a range of 9.5:1 – 25:1 with an average 16:1 from poultry manure materials from 10 different locations in South Africa, 25:1 (Adebayo *et al.,* 2011) and others. Cow dung may have a longer stay to decomposition than poultry, hence the result. According to Zaman (2017), cow dung has been documented long as perhaps the best desired animal manures due to its high nutrient and organic matter content. The application of cow dung raises the organic carbon of degraded soils which may result in improving activity of beneficial soil microorganisms and the fertility of the soil by increasing availability of nutrients for plants from soil. Huge improvements were however not seen because the period of one or two years of application was not enough.

5.2 Effect of fertilizers on cabbage growth and yield

The high percentage crop stand establishment achieved with the application of the treatments is very important to cabbage production since crop stand at harvest is a very important determinant of yield at the end of the cropping season. A critical look at the number of open leaves and open leaves diameter dynamics gives an indication that head initiation started from the point when the number of open leaves decline. Number of open leaves started declining at 49 DAT for the control which was 2 weeks later than for Poultry manure, cow dung or NPK combined with any of the insecticides and was confirmed by data on days to head initiation. It is clear that plant nutrients play a major role in whether head initiation would happen at the right time or it would be delayed. According to Hara and Sonoda (1981), cabbage head development is quick and efficient when adequate nutrients are supplied to the plants and there are enough functional outer leaves for photosynthesis with N being the most needed nutrient. According to John *et al*., (2004), poultry

manure contained essential nutrient elements associated with photosynthetic activities and thus promote roots and vegetative growth. Ayoola and Makinde (2008) also reported that cow dung resulted in significant increase in soil nitrogen and other soil properties necessary for crop yield and productivity. According to Bhardwaj *et al*., (2000), adequate amounts of nitrogen may be obtained from reasonable amounts of organic matter applied to the soil and is directly responsible for vegetative growth of plants. Nitrogen functions in plants by being part of chlorophyll which is important in photosynthesis, and improves the quality of leaf (Bhardwaj *et al*., 2000). The growth and yield response of cabbage to manure as observed in the study has also been shown for studies in other crops such as tomato and cucumber (Chiezy and Odunze, 2009). According to Ribaudo *et al.* (2003), yield of cabbage increased with increasing levels of nitrogen up to 390 kg/ha. Casely *et al.* (2006) observed that increasing rate of nitrogen (150-250 kg/ha) with basal P and K application increased yield of cabbage. The increase in water holding capacity in poultry manure and cow dung treatments also provided additional advantage for growth and yield to cabbage grown on such plots (Frempong *et al.* 2006; Agyarko *et al.* 2006; Emulo *et al.* 2008).

The application of foliar fertilizer might have not been effective principally because nutrients are absorbed and transported to other parts of the plant, however, because the diameter of open leaves were smaller, they had smaller leaf surface area to take enough nutrients. According to Fageria *et al.,* (2009), a larger leaf area is required for absorbing foliar fertilizers and nutrients solutions may have to be applied in sufficient amounts. More than one application may also be necessary depending on severity of nutrient deficiency. The wider canopies, thicker stems, head weight and yield of cabbage treated to poultry manure, cow dung or NPK combined with Cypermetrine or neem are indicative of the fact that nutrient supply was better on with those treatments than the foliar application. It also raises the question whether nutrient absorption for plant use may be effectively done by the roots than the leaves. Fageria *et al*., (2009) confirmed that while soil

uptake is more common and most effective especially when nutrients are required in higher amounts and that in such situations foliar supply alone may not be enough to supply the needed amount.

5.3 Effect of treatments on cabbage insect damage

The results achieved with the application of neem extract indicates that it is able to reduce the incidence and severity of insects' damage to cabbage leaf and head; and that neem extract is as effective as the synthetic insecticide used. Similar results were obtained by Schmutterer (1992) who reported a percentage cabbage head damage of 4 – 27 with the application of neem extract depending on the concentration and percentage damage of 77 for the untreated. Also, Goudegnon *et al*., (2000) observed that neem extract was effective at controlling diamondback moth (DBM) and resulted in the production of more undamaged and marketable cabbage heads than the synthetic insecticide used or the control. Reed and Reed (1984) also reported that the application of neem extract resulted in an extremely low cabbage insect damage incidence and severity than the untreated. The efficacy of neem extract is due to the fact that it contains azadirachtin, azadiradione and salanin which enable it to function as an antifeedant, insecticide or a growth modifier (Das *et al*., 2010; Reed and Reed, 1984; Goudegnon *et al*., 2000; Schmutterer, 1992; Michereff-Filho *et al*., 2008). The result obtained is very important because the application of insecticides play a major role in the prevention of insect damage in order to supply the demand of the local and international market not only for the quantity but the quality of the produce too. Osei *et al*. (2004) indicated that pests can markedly reduce the amount of harvestable produce and that considerable economic losses are mostly suffered without pesticide use. Pesticide use has increased over time in Ghana and is particularly elevated in the production of high-value cash crops and vegetables (Gerken *et al.,* 2001). The use of synthetic insecticides, however, apart from the risk on applicators (farmers) may also leave residues of their active ingredients on the produce

in case of pesticide abuse and this may be harmful to consumers. Synthetic insecticides also have the potential of killing both target and beneficial insects. According to Das *et al*. (2010), Goudegnon *et al.,* (2000) and Schmutterer (1992), neem extract has components that are selective and do not negatively affect parasitoids and predators. The results also show that peasants can prepare their own effective insecticides if the materials are available and neem extract could also be used to solve the insect damage problems faced by organic farmers.

The application of the fertilizers, especially the manure might have also contributed to the success of reducing the damage by insects. Apart from increasing plant vigour through the addition of nutrients, poultry manure and cow dung have nematicidal and pesticides properties (Agyarko *et al.,* 2007). Again the suppression of pests by organic amendments may be attributed to the chemical by-products from decomposing materials in the soil which are injurious to the development of most pests.

According to Webster *et al.,* (2000), pesticides have been an integral part of plant processes by reducing losses from weeds, diseases and insect margin that result from pesticide use.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

On the basis of the results obtained from both seasons, the following conclusions were drawn;

- Soil amendments both organic and inorganic fertilizers remarkably improved the soil physical and chemical properties.
- Application of poultry manure and cow dung combined with neem leaf extract effectively improved canopy width and number of open leaves respectively.
- Application of poultry manure and N.P.K combined with Cypermetrine significantly improved head weight and cabbage yield.
- Insecticide application, both neem leaves extracts and Cypermetrine significantly reduced the severity of insect pest infestation on cabbage.

6.2 Recommendations

On the basis of the experimental results, it is recommended that:

- Cabbage growers can combine organic and inorganic fertilizers to reduce the cost of production due to the high cost of inorganic fertilizers in the market.
- Since organic manure releases both major and minor nutrients, cabbage and vegetable farmers in general should go into the use of available manure which includes poultry manure and cow dung for effective growth and yield as they are readily available in their communities.

- To control the incidence of pests on cabbage farms, cabbage farmers should embark on the use of neem leaf extract and Cypermetrine for effective growth and yield as the neem leaf extract are cheap to come by in their localities.
- Cabbage growers are encouraged to use poultry manure and cow dung when cultivating cabbage as their application improve the soil physical and chemical properties.
- For wider head diameter and heavy head weight, cabbage growers are encouraged to use poultry manure at 20 t/ha combined with Cypermetrine.
- Cabbage growers should use poultry manure combined with neem leaf extract (NLE) for earliest head initiation.

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APPENDICES

APPENDIX A

Table 4.4 Guide to Interpretation of Soil Analytical Data

Nutrient	Rank/Grade
Phosphorous, P(ppm), (Bray 1)	
< 10	Low
10 – 20	Moderate
>20	High
Potassium, K(ppm)	
<50	Low
50 – 100	Moderate
>100	High
Calcium, Ca(ppm)/Meg=0.25Ca	
<5.0	Low
5.0 – 10.0	Moderate
>10.0	High
ECEC cmol (+)/kg	
<10	Low
10 – 20	Moderate
>20	High
Soil pH (Distilled Water Method)	
<5.0	Very Acidic
5.1 – 5.5	Acidic
5.6 – 6.0	Moderately Acidic
6.0 – 6.5	Slightly Acidic
6.5 – 7.0	Neutral
7.0 – 7.5	Slightly Alkaline
7.6 – 8.5	Alkaline
>8.5	Very Alkaline
Organic Matter (%)	
<1.5	Low
1.6 – 3.0	Moderate
>3.0	High
Nitrogen (%)	
<0.1	Low
0.1 – 0.2	Moderate
>0.2	High
Exchangeable Potassium (cmol)	
<0.2	Low
0.2 – 0.4	Moderate
>0.4	High

(SRI, 2007)

APPENDIX B

Analysis of variance on growth parameters

Tukey HSD All-Pairwise Comparisons Test of LDM21F for TREAT

TREAT	Mean	Homogeneous Groups
PMCYP	73.667	A
CDNEE	68.000	A
PMNEE	66.000	A
NPKCYP	52.000	A
CDCYP	50.333	A
FOLIARCYP	41.333	A
FOLIARNEE	40.667	A
NPKNEE	38.333	A
CONTROL	15.667	A

Alpha 0.05 Standard Error for Comparison 17.325
Critical Q Value 5.035 Critical Value for Comparison 61.677
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of LDM35F for TREAT

TREAT	Mean	Homogeneous Groups
CDCYP	157.67	A
PMCYP	150.00	A
PMNEE	142.00	A
NPKCYP	127.33	A
CDNEE	117.67	A
NPKNEE	83.67	A
FOLIARNEE	82.00	A
FOLIARCYP	68.33	A
CONTROL	44.33	A

Alpha 0.05 Standard Error for Comparison 35.297
Critical Q Value 5.035 Critical Value for Comparison 125.66
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of LDM49F for TREAT

TREAT	Mean	Homogeneous Groups
PMNEE	266.67	A
NPKNEE	218.33	A
PMCYP	214.67	A
NPKCYP	187.00	A
CDNEE	169.00	A
FOLIARNEE	153.33	A
CDCYP	147.33	A
FOLIARCYP	89.00	A
CONTROL	73.00	A

Alpha 0.05 Standard Error for Comparison 64.549
Critical Q Value 5.035 Critical Value for Comparison 229.80
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of LDM63F for TREAT

TREAT	Mean	Homogeneous Groups
CDCYP	152.00	A
PMCYP	148.33	A
NPKNEE	143.33	A
NPKCYP	133.67	A
CDNEE	125.67	A
PMNEE	122.67	A
FOLIARNEE	113.67	A
CONTROL	82.67	A
FOLIARCYP	71.33	A

Alpha 0.05 Standard Error for Comparison 40.858
Critical Q Value 5.035 Critical Value for Comparison 145.46
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of RDM21F for TREAT

TREAT	Mean	Homogeneous Groups
CDNEE	6.0000	A
NPKCYP	5.6667	A
PMCYP	5.6667	A
FOLIARNEE	4.6667	A
PMNEE	4.6667	A
CDCYP	4.3333	A
FOLIARCYP	4.3333	A
NPKNEE	4.0000	A
CONTROL	2.0000	A

Alpha 0.05 Standard Error for Comparison 1.6685
Critical Q Value 5.035 Critical Value for Comparison 5.9401
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of RDM35F for TREAT

TREAT	Mean	Homogeneous Groups
PMNEE	23.333	A
PMCYP	22.000	A
CDCYP	20.667	A
NPKCYP	16.333	A
NPKNEE	15.333	A
FOLIARNEE	13.000	A
FOLIARCYP	12.667	A
CDNEE	11.667	A
CONTROL	8.333	A

Alpha 0.05 Standard Error for Comparison 6.0520
Critical Q Value 5.035 Critical Value for Comparison 21.546
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of RDM49F for TREAT

TREAT	Mean	Homogeneous Groups
NPKNEE	29.333	A
FOLIARNEE	23.000	A
PMCYP	22.333	A
PMNEE	20.333	A
NPKCYP	19.000	A
CDNEE	18.333	A
CDCYP	16.667	A
CONTROL	13.333	A
FOLIARCYP	13.000	A

Alpha 0.05 Standard Error for Comparison 7.0341
Critical Q Value 5.035 Critical Value for Comparison 25.042
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of RDM63F for TREAT

TREAT	Mean	Homogeneous Groups
NPKCYP	18.667	A
PMCYP	15.667	A
PMNEE	14.667	A
CDNEE	14.333	A
NPKNEE	14.000	A
CDCYP	12.667	A
FOLIARNEE	12.000	A
CONTROL	11.333	A
FOLIARCYP	10.667	A

Alpha 0.05 Standard Error for Comparison 3.6540
Critical Q Value 5.035 Critical Value for Comparison 13.009
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of OpLEV21 for TREAT

TREAT	Mean	Homogeneous Groups
CDNEE	12.000	A
PMNEE	12.000	A
CDCYP	11.667	A
NPKCYP	11.667	A
PMCYP	11.667	A
NPKNEE	11.333	A
CONTROL	10.333	A
FOLIARCYP	10.333	A
FOLIARNEE	10.000	A

Alpha 0.05 Standard Error for Comparison 1.2802
Critical Q Value 5.035 Critical Value for Comparison 4.5576
Error term used: REP*TREAT, 16 DF

There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of OpLEV35 for TREAT

TREAT	Mean	Homogeneous Groups
CDNEE	19.333	A
PMNEE	19.333	A
PMCYP	19.000	A
CDCYP	18.667	A
NPKCYP	18.000	A
NPKNEE	17.667	A
FOLIARCYP	16.667	A
CONTROL	15.000	A
FOLIARNEE	14.000	A

Alpha 0.05 Standard Error for Comparison 2.0964
Critical Q Value 5.035 Critical Value for Comparison 7.4636
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of OpLEV49 for TREAT

TREAT	Mean	Homogeneous Groups
CDNEE	21.667	A
NPKNEE	21.000	A
FOLIARCYP	18.000	A
NPKCYP	17.667	A
CDCYP	17.333	A
PMNEE	17.000	A
PMCYP	16.333	A
CONTROL	16.000	A
FOLIARNEE	14.333	A

Alpha 0.05 Standard Error for Comparison 2.1999
Critical Q Value 5.035 Critical Value for Comparison 7.8318
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of OpLEV63 for TREAT

TREAT	Mean	Homogeneous Groups
CDNEE	20.000	A
NPKNEE	19.667	A
CONTROL	19.333	A
FOLIARCYP	15.667	A
FOLIARNEE	14.667	A
PMNEE	14.333	A
CDCYP	14.000	A
NPKCYP	13.333	A
PMCYP	11.000	A

Alpha 0.05 Standard Error for Comparison 4.1500
Critical Q Value 5.035 Critical Value for Comparison 14.774
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of StemD21 for TREAT

TREAT	Mean	Homogeneous Groups
PMCYP	1.1000	A
PMNEE	0.8333	A
CDNEE	0.7333	A
CDCYP	0.6667	A
FOLIARCYP	0.6000	A
FOLIARNEE	0.6000	A
NPKCYP	0.6000	A
NPKNEE	0.6000	A
CONTROL	0.4667	A

Alpha 0.05 Standard Error for Comparison 0.2126
Critical Q Value 5.035 Critical Value for Comparison 0.7568
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of StemD35 for TREAT

TREAT	Mean	Homogeneous Groups
PMNEE	1.9667	A
PMCYP	1.7000	A
CDCYP	1.5000	A
CDNEE	1.2667	A
NPKCYP	1.2000	A
NPKNEE	1.1333	A
FOLIARCYP	0.9000	A
FOLIARNEE	0.8333	A
CONTROL	0.6667	A

Alpha 0.05 Standard Error for Comparison 0.4036
Critical Q Value 5.035 Critical Value for Comparison 1.4370
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of StemD49 for TREAT

TREAT	Mean	Homogeneous Groups
PMCYP	2.2000	A
PMNEE	2.1000	A
CDCYP	1.8000	AB
CDNEE	1.6667	AB
NPKCYP	1.5667	AB
NPKNEE	1.5667	AB
FOLIARCYP	1.3000	AB
FOLIARNEE	1.2667	AB
CONTROL	0.8667	B

Alpha 0.05 Standard Error for Comparison 0.3159
Critical Q Value 5.035 Critical Value for Comparison 1.1246
Error term used: REP*TREAT, 16 DF
There are 2 groups (A and B) in which the means
are not significantly different from one another.

Tukey HSD All-Pairwise Comparisons Test of StemD63 for TREAT

TREAT	Mean	Homogeneous Groups
PMCYP	2.4000	A
PMNEE	2.3000	A
CDCYP	2.1667	A
CDNEE	2.0000	A
NPKNEE	1.9667	A
FOLIARCYP	1.6333	A
NPKCYP	1.5667	A
FOLIARNEE	1.3333	A
CONTROL	1.2333	A

Alpha 0.05 Standard Error for Comparison 0.3382
Critical Q Value 5.035 Critical Value for Comparison 1.2039
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of rootDM21F for TREAT

TREAT	Mean	Homogeneous Groups
CDNEE	2.6667	A
PMNEE	2.6667	A
NPKCYP	2.3333	A
CDCYP	1.6667	A
PMCYP	1.6667	A
FOLIARCYP	1.3333	A
NPKNEE	0.6667	A
CONTROL	0.0000	A
FOLIARNEE	0.0000	A

Alpha 0.05 Standard Error for Comparison 1.1863
Critical Q Value 5.035 Critical Value for Comparison 4.2235
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of rootDM35F for TREAT

TREAT	Mean	Homogeneous Groups
NPKCYP	6.6667	A
PMCYP	6.6667	A
FOLIARNEE	6.3333	A
NPKNEE	6.3333	A
CDCYP	5.3333	A
CONTROL	5.3333	A
FOLIARCYP	5.3333	A
PMNEE	5.3333	A
CDNEE	5.0000	A

Alpha 0.05 Standard Error for Comparison 1.8274
Critical Q Value 5.035 Critical Value for Comparison 6.5059
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of rootDM49F for TREAT

TREAT	Mean	Homogeneous Groups
FOLIARNEE	10.000	A
NPKNEE	9.333	A
CDCYP	7.333	A
CONTROL	6.333	A
PMNEE	6.333	A
FOLIARCYP	6.000	A
NPKCYP	5.667	A
PMCYP	5.667	A
CDNEE	4.333	A

Alpha 0.05 Standard Error for Comparison 3.4467
Critical Q Value 5.035 Critical Value for Comparison 12.271
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

APPENDIX C
Analysis of variance on Yield and Yield components

Tukey HSD All-Pairwise Comparisons Test of DaystoHea for TREAT

TREAT	Mean	Homogeneous Groups
CONTROL	97.333	A
FOLIARNEE	87.000	AB
CDNEE	85.333	AB
NPKNEE	85.000	AB
NPKCYP	84.667	AB
CDCYP	82.333	B
FOLIARCYP	81.667	B
PMCYP	79.333	B
PMNEE	78.000	B

Alpha 0.05 Standard Error for Comparison 4.1707
Critical Q Value 5.035 Critical Value for Comparison 14.848
Error term used: REP*TREAT, 16 DF
There are 2 groups (A and B) in which the means
are not significantly different from one another.

Tukey HSD All-Pairwise Comparisons Test of HeaWTplot for TREAT

TREAT	Mean	Homogeneous Groups
NPKNEE	3.3333	A
PMCYP	2.8667	A
CDNEE	2.6000	A
PMNEE	2.6000	A
FOLIARNEE	2.2333	A
CDCYP	1.6333	A
CONTROL	1.4667	A
NPKCYP	1.3667	A
FOLIARCYP	0.8667	A

Alpha 0.05 Standard Error for Comparison 1.0186
Critical Q Value 5.035 Critical Value for Comparison 3.6264
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of Nmulthead for TREAT

TREAT	Mean	Homogeneous Groups
FOLIARNEE	3.0000	A
CONTROL	1.6667	A
CDCYP	1.3333	A
NPKNEE	1.3333	A
CDNEE	1.0000	A
NPKCYP	1.0000	A
PMCYP	0.6667	A
PMNEE	0.3333	A
FOLIARCYP	0.0000	A

Alpha 0.05 Standard Error for Comparison 1.3426
Critical Q Value 5.035 Critical Value for Comparison 4.7797
Error term used: REP*TREAT, 16 DF

There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of Npest for TREAT

TREAT	Mean	Homogeneous Groups
FOLIARCYP	4.3333	A
NPKCYP	3.0000	A
NPKNEE	2.0000	A
CDCYP	1.6667	A
CONTROL	1.6667	A
PMNEE	1.6667	A
CDNEE	1.3333	A
FOLIARNEE	1.3333	A
PMCYP	1.3333	A

Alpha 0.05 Standard Error for Comparison 2.1053
Critical Q Value 5.035 Critical Value for Comparison 7.4949
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of RootWTptk for TREAT

TREAT	Mean	Homogeneous Groups
PMCYP	0.3333	A
CDCYP	0.2000	A
CDNEE	0.2000	A
NPKCYP	0.2000	A
PMNEE	0.1667	A
FOLIARCYP	0.1333	A
NPKNEE	0.1333	A
CONTROL	0.1000	A
FOLIARNEE	0.1000	A

Alpha 0.05 Standard Error for Comparison 0.0768
Critical Q Value 5.035 Critical Value for Comparison 0.2733
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of ShtWTpltk for TREAT

TREAT	Mean	Homogeneous Groups
PMCYP	1.2667	A
PMNEE	1.0333	A
CDCYP	0.9000	A
NPKNEE	0.8000	A
CDNEE	0.7333	A
NPKCYP	0.6000	A
FOLIARNEE	0.5000	A
CONTROL	0.4333	A
FOLIARCYP	0.4333	A

Alpha 0.05 Standard Error for Comparison 0.2963
Critical Q Value 5.035 Critical Value for Comparison 1.0548
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of headWTPla for TREAT

TREAT	Mean	Homogeneous Groups
PMCYP	1.1000	A
PMNEE	0.9000	A
NPKNEE	0.8333	A
CDCYP	0.7333	A
CDNEE	0.5000	A
NPKCYP	0.5000	A
FOLIARNEE	0.4000	A
CONTROL	0.2000	A
FOLIARCYP	0.1667	A

Alpha 0.05 Standard Error for Comparison 0.2811
Critical Q Value 5.035 Critical Value for Comparison 1.0009
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of headWTplo for TREAT

TREAT	Mean	Homogeneous Groups
NPKNEE	10.367	A
PMNEE	10.067	AB
PMCYP	9.667	ABC
CDNEE	6.167	ABC
CDCYP	5.733	ABC
NPKCYP	5.433	ABC
FOLIARNEE	5.133	ABC
FOLIARCYP	3.000	BC
CONTROL	2.667	C

Alpha 0.05 Standard Error for Comparison 2.0445
Critical Q Value 5.035 Critical Value for Comparison 7.2787
Error term used: REP*TREAT, 16 DF
There are 3 groups (A, B, etc.) in which the means
are not significantly different from one another.

Tukey HSD All-Pairwise Comparisons Test of yieldlg for TREAT

TREAT	Mean	Homogeneous Groups
NPKNEE	34.556	A
PMNEE	33.556	AB
PMCYP	32.222	ABC
CDNEE	20.556	ABC
CDCYP	19.111	ABC
NPKCYP	18.111	ABC
FOLIARNEE	17.111	ABC
FOLIARCYP	10.000	BC
CONTROL	8.889	C

Alpha 0.05 Standard Error for Comparison 6.8151
Critical Q Value 5.035 Critical Value for Comparison 24.262
Error term used: REP*TREAT, 16 DF
There are 3 groups (A, B, etc.) in which the means
are not significantly different from one another.

Tukey HSD All-Pairwise Comparisons Test of pltheadHa for TREAT

TREAT	Mean	Homogeneous Groups
PMCYP	16.000	A
CDNEE	15.000	A
FOLIARCYP	14.667	A
NPKCYP	14.667	A
NPKNEE	14.333	A
PMNEE	14.000	A
CDCYP	13.667	A
FOLIARNEE	13.667	A
CONTROL	12.333	A

Alpha 0.05 Standard Error for Comparison 1.2717
Critical Q Value 5.035 Critical Value for Comparison 4.5275
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.

Tukey HSD All-Pairwise Comparisons Test of HeadDia for TREAT

TREAT	Mean	Homogeneous Groups
CDNEE	11.667	A
PMNEE	10.667	A
PMCYP	10.500	A
CDCYP	10.333	A
NPKCYP	8.667	A
FOLIARNEE	8.333	A
NPKNEE	7.833	A
CONTROL	5.333	A
FOLIARCYP	4.967	A

Alpha 0.05 Standard Error for Comparison 2.4641
Critical Q Value 5.035 Critical Value for Comparison 8.7725
Error term used: REP*TREAT, 16 DF
There are no significant pairwise differences among the means.