KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
KUMASI, GHANA

SCHOOL OF GRADUATE STUDIES
DEPARTMENT OF CROP AND SOIL SCIENCES

SOIL APPLICATION OF POULTRY MANURE AND SOME NEMATICIDES FOR THE CONTROL OF ROOT KNOT NEMATODES (*MELOIDOGYNE* SPP.) OF CABBAGE (*BRASSICA OLERACEA VAR. CAPITATA*)

BY

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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY (KNUST), KUMASI, GHANA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE, MASTER OF SCIENCE IN PLANT PROTECTION (NEMATOLOGY)

BY

FREDERICK KANKAM

SEPTEMBER, 2009

DECLARATION

I declare that, except for references to other people's work which have been duly cited, this work is the result of my own original research and that this work has neither in whole nor in any part been presented for a degree elsewhere.

MRS. B.M.S. HEMENG

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DATE 30/09/09

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DATE

DEDICATION

This thesis is dedicated to my wife, Mrs Lucy Kankam for her patience and support during the study period.

Special dedication also goes to my brother, Dr. Kwabena Kankam-Yeboah whose tireless effort has brought me this far.

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ABSTRACT

Two experiments (pot and field) were conducted to investigate the effect of soil application of poultry manure and some nematicides for the control of root knot nematodes of cabbage at the Department of Soil and Crop Sciences, KNUST, Kumasi. There were five treatments with four replications. The treatments were 1.5t/ha of poultry manure, 3.0t/ha of poultry manure, two nematicides (Neemazal 0.3 EC and Marshal 5G) and the control (no nematicide or soil amendment). Completely randomized design was used for the pot experiment. All pots were inoculated with 2000 root knot nematode eggs a week before the application of the different treatments. The parameters studied included; plant height, plant girth, number of leaves, root galling, egg mass indices, population density of *Meloidogyne* juveniles, shoot and root weight of cabbage. Poultry manure application was found reduce *Meloidogyne* infestation and application of 3.0t/ha recorded the largest shoot and root weights. For the field study, a naturally infested root knot nematode field was used. The treatments were as above. Randomized complete block design was used with four replications. The eggs used as inoculums were extracted from the roots with sodium hypochlorite (NaOCl) solution. Data were collected on the following parameters: distribution of nematodes in the experimental site, root galls, egg mass index, density of *Meloidogyne* spp. juveniles per 100 ml of soil, root weight, head diameter and head weight of cabbage. The least number of *Meloidogyne* juveniles and lowest infection indeces (root gall and egg mass indeces) were recorded for 3.0t/ha poultry manure treatments while the highest values were recorded from the control. Similarly the largest head diameter and head weight of cabbage were obtained from poultry manure treated plots when compared with other treatments. There was significant difference among the treatment means for root galls,

egg mass index and density of *Meloidogyne* spp. juveniles per 100 ml of soil. The superiority of poutry manure over Neemazal 0.3 EC and Marshal 5G nematicide for cabbage production was observed.

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CHAPTER ONE

1.0 INTRODUCTION

Cabbage (*Brassica oleracea* var. *capitata* L.) originated in South Europe and is the most popular and important leafy vegetable crop in the family Cruciferae. Although it is a biennial, it is cultivated as an annual (Tindall, 1992). Cabbage is an important crop in the West, Central, Eastern, Northern, and the Southern parts of Africa (Romain, 2001). He further observed that the crop grows well in temperatures between 16 °C and 24 °C and in regions above the altitude of 800m.

The crop grows well in all soil types but they do best on rich sandy loam, or silt loam (Yamaguchi, 1983). It prefers soils that are rich in organic matter, neutral (pH 6.5-7.0) and with a good water-retaining capacity. To obtain satisfactory yields, it is recommended to incorporate manure at a rate of 20-30 t/ha during soil preparation (Romain, 2001). Depending on the growing season and cultivar, yields vary between 10 and 40 t/ha (Grubben and Denton, 2004).

Cervenski and Bugaski (1997) reported that cabbage rates among the most important vegetable crops in human diet. In 2003, Africa produced 17,000 metric tonnes of cabbage on 86,000 hectares of land (Anon., 2003). Cabbage is tasty, nutritious, high quality foodstuff containing an average of 8–10% dry matter, 4-6% carbohydrates, 1-2% proteins, 40-50% vitamins as well as other useful nutrients (Lopandic and Zaric, 1997). Purseglove (1991) also reported that cabbage is used in raw salad and shredded, chopped or dehydrated in soup. It could be steamed or boiled alone and in a mixture of vegetables, as main dish with meat.

Most vegetable crops have been recorded as host for at least one of the three most frequently occurring species of root knot nematodes namely; *Meloidogyne incognita*

M. arenaria and *M. javanica* (Sasser, 1987). Vegetable crop losses in the Tropics due to root knot nematodes are estimated to range between 17 – 20% in egg plant, 18 – 33% in melon and 24 – 38% in tomato (Sasser, 1987). William *et al.* (1991) reported that root knot nematodes are among the major pests in cabbage cultivation in the Tropics. According to Agrios (1997), nematodes also provide courts for entry by other pathogens that are primarily responsible for plant injury and disease complexes.

A number of control measures employed against nematodes have their weakness. For instance, biological control is environmentally friendly yet biological species effective in controlling nematodes in a particular ecology might not survive in other ecology. Crop rotation has also been used with a measure of success but the extensive host range of *Melodogyne* species makes selection of rotation crops very difficult.

Recent concerns expressed about environmental hazards and consumer's health, as a result of the abuse of the use of pesticides by farmers, albeit the high cost, demands that alternative methods of control measures have to be developed (Ofosu-Budu *et al.*, 2005). Duniway (2002) reported that Marshal 5G (carbosulphan) is a possible alternative nematicide to methyl bromide for soil disinfestations. Export markets are much particularly concerned about chemical residues in products by African farmers (Mabbett, 2007). However, poultry manure has been reported to have nematicidal effect on root knot nematode infection in lettuce (Hemeng, 1995). Soil amendments help reduce nematode pest damage through increase in activities in soil microbes antagonistic to nematodes, chemical compounds formed in decomposition processes (propionic, acetic and butyric acids) that can have nematicidal effect to enhance plant

growth and also improved water holding capacity and nutrient levels within the soil (Sitaramaiah, 1990).

It is against this background that the research was initiated to find out the effect of poultry manure application and its effect on nematode control and yield of cabbage.

The goal of the research was to control root knot nematodes on cabbage to increase yield.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Botany of Cabbage

Cabbage belongs to the Cruciferae or mustard family (Bassett, 1986). During the early growth and development of the cabbage plant, the first leaves expand and unfold, forming what is commonly referred to as the frame (Bassett, 1986). Its most highly valued part is its head, the weight of which ranges from one to 10kg (Cervenski and Bugaski, 1997). What is of considerable significance to producers and consumers alike is that the heads are uniform in size and as tightly packed as possible (Cervenski and Bugaski ., 1997).

Messiaen (1994) reported that depending on the earliness of the variety being grown and the conditions, harvesting can take place 60-75 days after transplanting. Grubben and Denton (2004) reported that cabbage is an erect, glabrous, biennial herb up to 60cm tall at the mature vegetative stage, with unbranched stem up to 30cm long, gradually thickening upwards; root system strongly branched. Romain (2001) reported that cabbage leaves are undulating, broad, thick, smooth or crinkled and covered with a waxy substance.

Cabbage responds well to applications of poultry manure particularly when 5.0t/ha is applied. (Messiaen,1994). Compost at 2.0t/ha can promote good growth of cabbage (Williams *et al.*, 1991).

2.2 Cabbage Production in Ghana.

Cabbage was introduced into Ghana by the British although there is no record of the time of its introduction. The crop was grown on a small scale around 1940 and the area under cultivation increased during the second World War (Sinnadurai, 1992).

Cabbage is cultivated almost throughout the world under various varietal names (Tindall, 1992). According to Norman (1973) and Town (1964), after a number of trials in Kumasi, various varieties of cabbage were recommended as suitable for the Ghanaian climatic conditions. These include Copenhagen Market, Steins, Early Flat Dutch, Jersey Wakefield and Glovy of Eukhuizen. Norman also reported that five Japanese hybrids namely 'KK Cross', 'Ky Cross', 'Hayadon', 'Nutsu Wase' and 'Express 60' were suitable for cultivation in Ghana.

Recommended varieties include King Cole, YR, Marion Market, Gloria Fi, Futura Constanta and Oxylus (Norman, 1973). However, KK Cross and Oxylus are the most popular due to their excellent yield.

Cabbage is currently grown in most urban centres by small- holder farmers either as full time job or on part time basis. Cabbage is also popular because it easy to cultivate, have long shelf life and have high nutritive value (Dickson and Wallace, 1986; Norman, 1992). Cabbage yields average 20-30 t/ha with early varieties, 35 to 40 t/ha with intermediate ones and 40 to 50t/ha with the late ones (Cervenski and Bugaski, 1997). However, in the tropics, yields of 20 t/ha are reasonable (Messiaen, 1994).

2.3 Constraints to Cabbage Production.

In many developing countries where cabbage is grown, production has been affected by certain constraints, leading to decreased yields. The causes include environmental factors, seed importation, diseases and insect pests. High temperatures and high relative humidity seriously affected quality of produce by predisposing it to deterioration (Williams *et al.*, 1991). The authors stressed that at high temperatures, plant respiration was very high and harvested vegetables may have reduced nutrient composition.

Seeds of different varieties of cabbage grown in Ghana are imported, however, local production of the seed could be possible (Nyarko *et al.*, 2006). The country spends substantial amount of the scarce foreign exchange on importation of seeds of exotic vegetables. For example US$ 588,000 was spent on importation of seed in 2002 compared with US$ 118,000 in 1999 (Eurotrace, 2004). The seeds are imported because of the phenomenon of vernalization or low temperature requirement for flowering (Yamaguchi, 1983).

The major problems to cabbage production in Ghana are diseases and pests. If vegetables are infested with pests and diseases during production, the quality of the produce will be reduced and may deteriorate more quickly (Williams *et al.*, 1991). Post-harvest and disease problems originate from pre-harvest infection. When conditions are conducive for cabbage development, certain fungal diseases such as leaf spot caused by *Alternaria brassicola* may also cause considerable damage to cabbage (Romain, 2001).

Cabbage is a good host of grey aphids including mealy cabbage aphid (*Brevicoryne brassica*), *Aphis* spp. and whiteflies (*Bemisia tabaci*) (Messiaen, 1994). The waxy

nature of the cabbage leaf causes the insecticidal sprays to run off if no sticker is added to the spray.

The production and consumption of cabbage is on the increase in the country, however, production cost is becoming very high and farmers have resorted to indiscriminate use of agro-chemicals and growth promoters that have made consumers worry about their health (Ofosu-Budu *et al.*, 2005).

2.4 Nematode as Pests

2.4.1 Biology and Spread of Nematodes

All plant parasitic nematodes belong to the phylum Nematoda. Most of the economically important parasitic genera belong to the order Dorylaimida (Agrios, 1997). Root Knot nematodes (*Meloidogyne* spp.) are major pests in tropical, subtropical and Mediterranean regions, infecting a wide range of varieties of crops, and causing more economic damage than any single group of plant parasitic nematodes (Mai, 1985). They attack more than 2000 species of plants, including almost all cultivated plants, and reduce crop production by about 5% worldwide (Agrios, 1997).

Although over 90 species of *Meloidogyne* have been described to date, four species are of particular economic importance to vegetable production namely *M. incognita, M. javanica, M. arenaria* and *M. hapla* (Sikora and Fernandez, 2005). *M. hapla* is common in colder climates whereas *M. incognita* is predominant in warm humid tropical and subtropical areas (Luc *et al.*, 2005). *M. javanica* prevails in extreme moisture condition (Whitehead, 1969) and the population is slightly higher than *M.*

incognita in that condition.

Mahmood (1988) reported that root knot nematodes infected hundreds of weedy plants in addition to crops of economic importance. Some cultivated vegetables such as cabbage, tomatoes, okra, melon and cucumber develop extreme root manifestation characteristics by heavy infestation of root knot nematodes. Root knot nematodes were more virulent on cabbage (Messiaen, 1994). In Ghana, Addoh (1970) reported that *Meloidogyne* species caused about 33% loss in vegetable crops such as cabbage, okra, Irish potatoes and cucurbits in a single season.

It is difficult to quantify the exact economic losses caused by root knot nematodes, especially in the developing countries. This is due to the fact that plant parasitic nematodes in the soil exist as mixed populations together with other pathogens such as bacteria, fungi and viruses on the same host plants in which the nematodes are feeding (Adesiyan *et al.*, 1987).

2.4.2 Symptoms and Damage Caused by *Meloidogyne* species

Both horticultural and arable crops as well as plantation and root crops are susceptible to attack by *Meloidogyne* (Adesiyan *et al.*, 1990). There are some nematodes which live in association with other disease causing organisms which leads to disease complexes. Losses from disease complexes are between 20-100% (Mai, 1985).

Sasser (1987) reported that endoparasites in root feeders include economically important nematode pest such as the root knot nematodes (*Meloidogyne* spp.), the cyst nematodes (*Heterodera* spp.) and root lesion nematodes (*Pratylenchus* spp.).

Again a single endoparasitic nematode can kill its host or reduce its productivity (Ingham, 1996). Direct feeding by nematodes can decrease a plant's nutrients uptake which can significantly reduce crop productivity when infection occurred immediately after seed germination (Ploeg, 2001)

The presence of root galls is a primary symptom of *Meloidogyne* infection. The size and form of the gall depend on the species involved, the number of nematodes in the tissue, host and plant age (Sikora and Fernandez, 2005).

In addition to the presence of galls, other effects on the host crop may include

(i) patchiness in the field caused by uneven growth of susceptible crops

(ii) chlorosis

(iii) dwarfed host plant

(iv) a tendency to wilt especially in hot weather

(v) death of plant in severe infections

In Benin, curved or hooked taproot on a cabbage seedling due to *Meloidogyne incognita* infection was reported (Sikora, 2002). When vegetables are severely damaged by *Meloidogyne*, the normal root system is reduced to a limited number of severely galled roots with completely disorganized vascular system (Luc *et al.*, 2005). Addoh (1971) reported that in Ghana, nematodes caused as much as 25% crop loss in vegetables.

Heavy root knot nematode infestation of papaya, by *Meloidogyne incognita* and *Meloidogyne javanica*, has been reported from many countries of all continents (Mcsorley, 1981). Root knot nematodes cause severe damage by producing root rot,

reducing the life expectancy of the plant and drastically reducing yield levels (Wolfe and Lynch, 1950). In addition, nematodes bore into the root, usually causing knots or galls to appear on the attacked root (Reiley and Carroll, 1991).

According to Agrios (1997), root knot nematodes often decrease the ability of plants to take up water and nutrients from soil and thus, cause symptoms of water and nutrient deficiencies in the aboveground parts of plants. In some cases, however, it is the plant-nematode biochemical interactions that impair the overall physiology of plants. Nematodes also create infection courts for entry of other pathogens, that are responsible for plant injury. *Meloidogyne* species survive and reproduce at pH levels ranging from four to eight but outside this range, the pH is inimical and may result in the death of some species (Ferris and Van Gundy, 1979).

2.4.3 Control Measures

2.4.3.1 Chemical Control

Chemical control comprises of the application of botanical or organic synthetic compounds that have a killing, inhibiting or repulsive effect on injurious organisms threatening mankind and animals (Oudejans, 1991).

Reiley and Carroll (1991) reported that two chemicals meant specifically for controlling nematodes are Dasanit and Nemagon. Johnson (1970) stated that population of *M. incognita* in soil was reduced with the application of Furadan at the rate of 2.4 per hectare. However, due to toxicity of Nemagon to humans, its production and distribution has been banned. Mulder (1979) also reported that if the seedbed was in good condition, free of large clods, and undecomposed plant

material, the nematode control may be achieved by the use of chemicals. According to Schmidt (1986), the use of fumigants kills 50-90% of nematodes.

In Ghana, Hemeng (1980) reported that phenamiphos ,1,3- and carbofuran each at 5kg a.i./ha were recommended for control of root knot nematodes in Northern Savanah Zone while the rate of application changed to 47 l/ha and 10kg a.i./ha rest in that order for remarkable results in the transitional zone.

Nematicides pose problems in areas of low rainfall. For instance, in regions where planting dates must coincide with rainfall, fields are often too dry to be treated effectively before the rains come. However, when most chemicals are applied after the rains, a delay in planting is necessary to avoid plant toxicity (Sasser, 1987).

Root knot nematodes can be effectively controlled in the greenhouse with soil fumigation with nematicides (Agrios, 1997). Certain plants are able to kill or repel pests, disrupt their lifecycle or discourage them from feeding. Anon. (1992) reported that neem cake, made from crushed neem seeds, provided nitrogen in a slow-release form in addition to protecting plants against parasitic nematodes (Riga and Lazarovits, 2001).

Neemazal 0.3 EC is a proprietary extract of the neem seed kernels, containing Azadirachtin and over 100 limnoids. Neemazal 0.3 EC formulations are powerful insect antifeedants which disrupt insect feeding. It is also a powerful insect growth regulator and interferes with growth of insects (www.indiamart.com/parrysaza/neemazal.html).

Potting soil amended with plant parts from neem tree and chinaberry tree (*Melina azadirach*) inhibited root knot nematode development on tomatoes (Siddiqui, 2001). However, effectiveness of these chemicals depends on time of application, climate

and knowledge of nematode population dynamics.

Neem extracts also exhibit nematicidal properties. Gill and Jain (1995) observed that the application of neem cake at the rate of 15g per spot or 100g per furrow per m^2 enhanced tomatoes yield by 36-50% with corresponding reduction in gall index. Kleeberg *et al.* (1977) found that the mode of action of neem include feeding inhibition, inactivity and moulting inhibition and fertility reduction. Neem products have broad spectrum activity and are known to affect over two hundred species of insects as well as nematodes, fungi, bacteria and even a few viruses (Schmutterer, 1990). Plant leaf extracts as root dip treatment on *Meloidogyne javanica* infecting eggplant *(Solanum melongena* L.) indicated that the neem leaf extract was most effective in controlling root knot nematodes (Aziz and Ahmed, 1995).

Over-reliance on the use of nematicides to control nematodes increases production costs, exposes farmers to toxic chemicals and reduces the chemicals efficiency (Pattison, 1994). Moreover, a certain micro-organisms in the soil may develop resistance to the chemical and break it down to harmless products (Stirling *et al.*, 1992). Considering the numerous disadvantages of chemical control, and the limited possibility of its applications by small-scale farmers, the need for an alternative control is necessary.

2.4.4 Cultural and Physical Control of Nematodes

2.4.4.1 Crop Rotation

Crop rotation is one of the most effective and less expensive control methods for farmers in developing countries (Bridge, 1996). In crop rotation, susceptible crops are rotated with resistant or completely immune crops (Adesiyan *et al.*, 1990).

Crop rotation has been successfully used to control *M. arenaria* race, on tomato when rotated with groundnut (Taylor and Sasser, 1978). Rotation of cabbage, sesame, maize, groundnut, sorghum and resistant sweet potato was effective in controlling *M. incognita* in Cuba (Fernández *et al.*, 1998).

The systems of crop rotation that have been developed to make full use of crops, maintenance of soil fertility in different ecosystems, and rotation for nematode management are to reduce initial populations of damaging nematode species such as *Meloidogyne* species to levels that allow the following crop to become established and complete early growth before being heavily attacked (Nusbaum and Ferris, 1973).

Conversely, in commercial production, where fumigation is the practice of the cropping system for growing susceptible vegetable crops, rotation may not be necessary.

In the tropics and subtropics, vegetable production systems are extremely diverse, with production over a 12 month growing season varying from:

1. sequential cropping of two to five susceptible vegetable crops in one field without a break crop;

ii. rotation of one or more vegetable crops with a non-host;

iii. production of one vegetable crop and one cover crop or a weed fallow and

iv. multiple cropping with vegetables intercropped with non-host crops (Sikora and Fernández, 2005)

2.4.4.2 Flooding

Flooding for longer periods kills plant parasitic nematodes such as *Meloidogyne* species by suffocation. Flooding the soil for seven to nine months killed nematodes by reducing the amount of oxygen available for respiration and increasing concentrations of naturally occurring substances such as methane and hydrogen sulphide which are toxic to the nematodes (MacGuidwin, 1993).

Sasser (1987) reported that plant parasitic nematodes which normally live in fields where the soil is seldom saturated do not infect plants when flooding occurs. Flooding although effective, can be applied only when the soil surface is level and abundant water supply is available.

Taylor and Sasser (1978) stated that flooding has been used to control *Meloidogyne* species by keeping the flood to a depth of about 10 cm for several months. However, besides keeping the land flooded for several months, it creates a suitable breeding ground for mosquitoes which aid in the spread of the deadly malaria disease (Adesiyan *et al.*, 1990).

In Florida, flooding alternated with drying during the summer has been recommended for vegetables grown on mulch soils to reduce root knot nematode

densities, with crops grown in unflooded fields more frequently damaged (Overmann, 1964). Noling (2003) observed that alternating two to three- week cycles of flooding with drying seems to be more effective than long, continuous flooding cycles. Again, root knot juveniles are killed after exposure to anaerobic conditions that begin in the soil a few days after flooding (Padgham *et al.*, 2003).

However, concerns about water conservation would limit the use of flooding in some countries (Noling and Becker, 1994). In addition, availability of water and the ability to control water levels are also a limiting factor in many areas where vegetables are grown (Sikora and Fernàndez, 2005).

The cost and difficulties of flooding land specifically to control nematodes is generally unacceptable to most farmers in the tropics (Bridge, 1996). However, it may take two years to kill all nematodes egg masses (Yepsen, 1984). Hemeng (1998) reported that natural seasonal flooding in third world countries is not effective against root knot nematodes. Also, in the Philippines, populations of root knot were reduced on susceptible dry season crops following flooded lowland rice than in upland areas (Castillo *et al.*, 1976).

2.4.4.3 Fallows

Fallow, strictly a land left uncropped after harvesting and therefore a bare fallow, can also refer to a land deliberately left with no vegetation cover and to land which is allowed to revert to a natural state Bare fallow is an effective means of managing root knot nematode population especially, when it was used in the hot dry season between crops where alternative weed hosts were seldom a problem (Brown and Kerry, 1987; Netscher and Sikora, 1990).

Duc (1980) reported that fallow during the dry season, with soil tillage to dry the soil, followed by non-hosts during the wet season resulted in significant reductions in *Meloidogyne* populations. Dropkin (1980) also reported that bacteria growth as result of the flooded field under aerobic conditions reduced nematode population due to emanating of hydrogen sulphide which killed the nematodes. There are many cases of successful reductions in nematode damage by the use of planted fallows, mainly with non-host pasture grasses, such as its use in nematode root knot management on tobacco (Shepherd and Barker, 1990), which provided some immediate returns to the farmer.

In Ghana, populations of root knot nematode were reduced by leaving the land fallow for more than two years (Peacock, 1957). For effective control, the fallow should be complete or 'bare' where no host plants including weeds are allowed to grow. Bare fallow is not the most acceptable method of reducing nematode population because of soil degradation by erosion and the cost with no immediate returns from the land (Bridge, 1996).

2.4.4.4 Crops with Antagonistic Effect

Antagonistic crops produce antihelminthic compounds (Grainge and Almed, 1988) which contain toxic substances with different modes of action (Pandey *et al.*, 2003). Certain plants produce toxic exudates which directly kill nematodes, whilst in other plants, nematodes fail to complete their life cycle after invasion of the plant tissue. Plants which exhibit this type of antagonism are often known as trap crops.

Adeniji and Chheda (1971) reported that antagonistic plants such as African marigold (*Tagetes* spp.), *Crotalaria* spp. and *Cynodon* spp. have been used to control

root knot nematodes. It has been postulated that these crops produce root exudates that contain nematicidal substances (Mai *et al.*, 1968).

Sesame and Castor have been tested in the Southern USA. for nematode control with some success (Mcsorley *et al.*, 1994). *Crotalaria longirostata*, when grown as a cover crop and then incorporated in to the soil, reduces *M. incognita* and *M. arenaria* galling of tomato (Sikora and Fernàndez, 2005). Netscher (1983) found that population levels of *M. incognita* on highly infected land dropped to zero after 18 months of continuous culture of *Panicum maximum*. The *Tagetes* spp. tested for control of nematodes are the African marigold (*T. erecta*), and the French marigold (*T. minuta)* were effective in reducing root knot nematodes (Bridge, 1996).

2.4.5 Poultry manure

2.4.5.1 Poultry manure Applications and their Effect on Growth and Yield of Crops

The benefits of using manures and compost as soil additives is a well established and ancient agricultural practice used by small and large scale farmers alike.

Since poultry manure is organic, it is able to have good effect on the physical and chemical properties of the soil. Hileman (1971) reported that poultry manure enhances rapid release of ammonia. Poultry manure also increases water infiltration rate, water holding capacity, cation exchange capacity and structural stability of the soil (Moore *et al.*, 1995). Compost or rotted organic manure is also good for cabbages at a rate of 20t/ha in addition to mineral fertiliser (Williams *et al.*, 1991).

Miller and Turk (1991) observed that poultry manure promoted the growth of plants as a result of the presence of micronutrients, organic matter, microorganisms and the presence of growth regulating substance(s). Application of poultry manure results in higher yields of crops. 22.25 ton/hectare of poultry manure increased tomato yield in the first and the subsequent year (Wear and John, 1968).

Liebhardt (1976) reported that addition of 5t/ha of poultry manure doubled yield as compared with the control. When the rate was further increased to 20t/ha, there was no further increase of yield.

Ofosu-Budu and Adamptey (2002) demonstrated that poultry manure application promoted early flowering, increased yield and significantly reduced incidence of diseases in tomato, compared to chemical fertilizer. According to Bandel *et al.*, (1972), poultry manure contains appreciable amount of N.P.K. based on the following percentages: Nitrogen 45%, Phosphorous 2.5% and Potassium 2%. Poultry manure is the richest and most concentrated farm yard manure (Ahn, 1993).

Kallah and Adamu (1998) also showed that the relative efficiency of organic matter in improving soil fertility followed the order: poultry manure, pig manure and then farm yard manure. Rydin (1985) reported that seedlings of sweet orange, *citrus sinensis* and grape fruit, *citrus paradise* grown in pots containing poultry manure increased in height, girth and root growth. Grubben and Denton (2004) found that application of compost or stable manure at the rate of 2.0-5.0 t/ha increased yield and growth of cabbage.

2.4.5.2 Poultry Manure Applications and their Effect on Root Knot Nematode

The use of organic amendments has been suggested by many nematologists. Organic amendments in all cases, the material is added to the soil and in some cases, the material in a dried state is applied (Sikora and Fernàndez, 2005).

Hemeng (1995) reported that increasing the rate of poultry manure decreased plant parasitic nematodes considerably with a corresponding increase in yield of rice.

Zuckerman (1971) observed that a significant reduction in root knot nematode population occurred during the decomposition of organic matter. The basis of sustainability of nematode control is the maintenance of a healthy soil food web. This begins with routine application of organic matter (Kiss, 1990).

In India, Alam (1991) reported that oil seed cakes of castor,, mustard, neem and groundnut significantly reduced nematodes on vegetables, mainly *M. incognita* and *Tylenchorhynchus brassicae* and improved plant growth. Neem cake significantly decreased the number of infected tubers while sawdust reduced the nematode population by 56% over the control (Sharma and Raj, 1987).

Furthermore, significant reductions in nematode populations and yield increases have been achieved experimentally. For example, cocoa pod husks incorporated at 6000 kg/ha resulted in 28% reduction in galling and 6.7% increase in yield of cowpea (Egunjobi and Olaitan, 1986).

Animal manure and cotton seed cakes have been used with success to control the reniform nematode (Badra *et al.*, 1979). The use of water extract of neem leaves as a systemic nematicide and cassava peeling as a soil amendment respectively against *Pratylenchus brachyurus* has been documented by Adesiyan *et al.* (1990). Dropkin

(1980) observed that the application of organic matter to soil improved the soil condition for good crop and controlled phytonematodes.

However, the problem with organic amendments for effective nematode control is often limited by availability and in some cases by the large quantities needed, and they will reduce nematode population densities by different degrees (Sikora and Fernàndez, 2005).

CHAPTER THREE

3.0 MATERIALS AND METHODS

Two experiments were conducted namely pot experiment (inoculated with a mixture of M. incognita and M. javanica in plant house) and field experiment (in naturally infested root knot nematode field).

3.1 Pot experiment with a Mixture of *Meloidogyne incognita and M. javanica* in Plant House

The experiment was conducted at the Nematology plant house, Department of Crop and Soil Sciences, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi. The plant house constructed with the following materials, wood, chicken wire net, mosquito net and roofed with aluminium and transparent roofing sheets operates under natural conditions of 12 hours of daylight. No artificial light was used. The experiment was conducted during the major season.

3.1.1 Soil for Pot Experiment

A steam sterilized mixture of top black soil and river sand was used for the pot experiment. The black soil was collected from an old refuse damp. Three parts of the soil were mixed with one part of the river sand

3.1.2 Sterilization of Soil

The 1:3 top soil-river sand mixture was sterilized by steam using a steel barrel sterilizer at KNUST (B.M.S. Hemeng pers. Comm.). The steam sterilizer was filled with soil and covered with a wet jute sack to prevent steam from escaping. The steam sterilizer has two chambers, the lower chamber containing water and the upper

chamber filled with soil spread on jute sack on a bench. Heat energy was supplied from pieces of firewood set under the steam sterilizer supported by three metal stands. When temperature of 103°C was obtained at the top layer of the soil and maintained for two hours the soil was considered well sterilized and allowed to remain on the fire for 24 hours. Four steam-sterilizers were used and each had a capacity of 150 litres that was filled with soil.

3.1.3 Confirmation of Soil Sterilization

Modified Baermann tray (Whitehead and Hemmings, 1965) method was used to verify the effectiveness of the sterilization of the soil. The procedure involved spreading thinly 100ml of the sterilized soil on a two-ply tissue paper nested in a plastic basket. Each basket with its content was placed in a shallow tray and the set-up was placed on a laboratory bench. Tap water was added gently in each tray until the soil in the basket was moist. Each set up was left undisturbed for a period of 48 hours. After this period, the baskets were lifted and tilted to allow the film of water at the bottom of the basket to drain into the tray. The water in each tray was shaken to make any nematode extracted to be in the water suspension before pouring into a beaker and each suspension was concentrated for 24 hours. The supernatant of each suspension was poured off leaving the concentrated suspensions. The concentrated suspension was examined for the presence of nematode using dissecting microscope and Doncaster (1962) counting tray.

3.1.4 Source of Seed and nematicides

Seeds of the cabbage variety 'Oxylus' was purchased from Obek Agro Services, Kumasi (Certified Seed Company). Marshal 5G (Carbosulphan) and Neemazal 0.3

EC were also purchased from the same source. Poultry manure (layer droppings) was purchased from Yamoah Farms, Kumasi.

3.1.5 Source and Preparation of Poultry Manure

Decomposition of the poultry (chicken droppings) manure was done at a site behind the Nematology Plant house, Faculty of Agriculture, KNUST. Water was sprinkled on it and covered with black polythene sheet for rapid decomposition of the poultry manure as a result of heat generated. The poultry manure was monitored for 30 days until decomposition was completed.

3.1.6 Source and Preparation of *Meloidogyne* Inoculum

Naturally *Meloidogyne* infected cabbage plants with gall symptoms were collected from freshly harvested beds around Hall Six Residential area at KNUST, Kumasi. The samples were sealed in polythene bags and transported to the Nematology/Pathology Laboratory.

The eggs used as inoculum were extracted from the roots with sodium hypochlorite (NaOCl) using Hussey and Baker (1973) method. The roots were gently washed with slow running tap water to remove all soil particles but not the eggs. The clean infested roots were then cut into small pieces of about 3cm long using a pair of scissors on a clean board. 100g of chopped roots were placed in a jar and enough 0.5% sodium hypochlorite solution added to just cover the pieces. The jar with its content was covered tightly with a lid and vigorously shaken for 4 minutes to break up the gelatinous matrix surrounding the egg masses, and to release the eggs from the roots. The NaOCl solution containing the nematode eggs and the root debris was quickly poured through a 200µm mesh sieve nested over a 500µm mesh sieve. The

200µm sieve was gently tapped at the side so that eggs were washed into the 500 mm sieve. The residual Sodium Hypochlorite in the two sieves was rinsed several times by placing them under slowly running tap water. The eggs were collected from the 500µm sieve into a clean beaker and covered.

The process was repeated several times till the rest of the chopped roots were processed to obtain enough inoculum. The suspensions were left to stand undisturbed for 24 hours to allowed the eggs to settle at the bottom of the beaker by gravitational force. The supernatant was slowly and carefully decanted leaving only the concentrated suspension at the bottom of the beaker. The concentrated suspension, was then poured into a 200ml beaker which was topped with distilled water to the 200ml mark for easy counting of the number of eggs in the suspension using Doncaster counting tray.

3.1.7 Experimental Design of the Pot Experiment

Completely Randomised Design (CRD) with five treatments including control and four replications were used for the pot experiment.

T_1 = Neemazal 0.3 EC

T_2 = Marshal 5G

T_3 = 1.5t/ha of Poultry manure

T_4 = 3.0t/ha of Poultry manure

T_5 = Control – no nematicide or soil amendment

* Ps: Inoculum of 2000 eggs of *Meloidogyne* spp. was inoculated to each cabbage seedling in a pot.

3.1.8 Parameters Measured

1) Root gall and egg mass indices
2) Population density of *Meloidogyne* juveniles per 100ml of soil.
3) Plant parameters
   a) Plant height
   b) Plant girth
   c) Number of leaves
   d) Fresh and dry shoot weight
   e) Fresh and dry root weight

3.1.9 Counting of *Meloidogyne* eggs in Water

The suspension was stirred continually whilst a pipette was carefully used to draw 1ml aliquot of the egg- suspension to determine the number of eggs per unit volume of the suspension. The 1ml aliquot pipetted was poured into a Doncaster (1962) counting tray and stirred slightly to ensure the eggs spread evenly in the tray dish. This was also to ensure the uniform distribution of the eggs in the dish. Nematode eggs in the channels were counted under a dissecting microscope of magnification x100 using a tally counter to ensure accuracy. The counting was done in only channel three of the counting tray. After counting, the egg suspension in the counting tray was poured back into the beaker and stirred to ensure uniform distribution of the eggs. The counting process was repeated three times. The egg density of the 200ml suspension was as follows:

Count (1ml)	1	=	1920
Count (1ml)	2	=	2010
Count (1ml)	3	=	2070

Total count = 6000

Average density = 2000 eggs/1ml

3.1.10 Nursing of Cabbage Seedlings

Cabbage seeds (Oxylus) were sown in a seed box measuring 60cm x 30cm containing the sterilized soil. Ten days after sowing, the seedlings were pricked out into nursery boxes, filled with 200g of sterilized soil and arranged at 15cm x 15cm apart. The plants were maintained in the plant house for three weeks prior to transplanting. At two leaf stage, the seedlings were sprayed with Karate 25 EC (Lambda cyhalomethrin) at a rate of 2ml/L of water against insect pests attack. The temperature of the plant house ranged from 26 to 30°C.

3.1.11 Transplanting of Cabbage Seedlings

Eighty plastic pots each measuring (27cm x 21cm x 15cm) were filled with 7kg steam sterilized soil and placed on raised platforms in the planthouse. Four-week-old, healthy cabbage seedlings were transplanted into the plastic pot with sterilized soil. Each pot was planted to one plant.

Daily watering was done up to harvesting.

3.1.12 Inoculation of Cabbage Seedlings with *Meloidogyne* eggs and Harvesting

The plants to be inoculated were watered the day before inoculation. A hole of about 3cm deep was made near the base of seedling in a pot and inoculated with 1ml of egg suspension containing approximately 2000 eggs of *Meloidogyne incognita.* The hole was covered with soil and lightly watered.

After 16 weeks of inoculation, the plants were harvested and their roots washed

under tap water to rid them of soil and other debris. The roots were then scored for galling after which they were stained in Phloxine 'B' (0.15g per litre tap water) and rated for the presence of egg masses. The root knot rating chart by Bridge and Page (1980) was used to score galling and egg masses.

3.1.13 Statistical Analysis

All data collected were subjected to analysis of variance (ANOVA), which are shown in Appendices 1 - 15. Genstat (2002) Statistical Package was used. Means were compared using Least Significant Differences (LSD) at 5%.

3.2 Field Experiment in Naturally Infested Root Knot Nematode Field

3.2.1 Experimental Site

The site had bimodal rainfall pattern, and the location was near Hall Six adjacent to Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi. It lies betweeen latitude 06°, 43° North and longitude 01°, 36° West. The experiment was carried out between September and December, 2007 during the minor season.

3.2.2 Soil Type

The soil type is forest ochrosols described as the Nta soil series. This is sandy loam with a dark- greyish-brown colour. The top soil is about 5.0cm deep (Ablorh, 1972). The soil pH was slightly acidic nearer to the surface; decreasing gradually to strong acid in lower layers. The area had been under cultivation of varieties of vegetables including lettuce, carrots, onion and cabbage over the years by hand and mechanization.

3.2.3 Planting Material

Cabbage variety and source of supply was as already described in Section 3.1.4. (Pages 22 and 23).

3.2.4 Experimental Design

The design for field experiment was randomized complete block design (RCBD) with five treatments. Each treatment was replicated four times.

The treatments have been already described in section 3.1.7 (page 24).

3.2.5 Parameters Studied

The parameters were as follows:

(i) distribution of nematodes in the experimental site

(ii) root knot nematode bioassay

(iii) root gall and egg mass indices of cabbage

(iv) plant height

(v) plant girth

(vi) head weight of cabbage

(vi) head diameter of cabbage, at harvest

(viii) fresh root weight and

(ix) nematode population in soil at harvest.

3.2.6 Land Preparation, Field Layout and Transplanting

The field, measuring 20m x 16.5m (330m^2) was ploughed and harrowed to a fine tilt. A total of 20 plots, each measuring 3m x 3m was laid out. The field was divided into four blocks each being 20m x 3.0m. Each block was further divided into five plots of

3.0m x 3.0m ($9m^2$). The blocks were also separated by 1.5m apart and 1.0m furrowed between plots in a block. Twelve (12) seedlings were transplanted per plot at a spacing of 50cm x 60cm, giving plant population of 240 plants.

3.2.7 Methodology of Experiment

To determine the distribution of nematodes on the experimental site per plot, three random samples were taken with 5cm diameter auger to the depth of 0 – 15cm. In every plot, three sub samples were taken which were mixed thoroughly and a representative sample of 100ml taken for extraction of migratory nematodes using modified Baermann tray (Whitehead and Hemming, 1965) method.

The different genera of nematodes recovered were counted as described earlier in the text. Holes were made in the soil with hand trowel. Thirty days old cabbage seedlings were transplanted into the field at a spacing of 50cm x 60cm. Marshal 5G (Carbosulphan) and Neemazal 0.3 EC were applied at the rate of 5kg ai/ha and 15ml per 15L capacity sprayer a week before transplanting. Application of poultry manure was also done one week before transplanting at a rate of 1.5t/ha and 3.0t/ha.

3.2.8 Data Collection

Two weeks after transplanting, plant height and girth were recorded and continued at two weeks intervals till harvesting. Records were taken on six plants of the middle row of each plot. A 30cm rule was used to measure the height of the plant from soil level surface to the apical meristem. For plant girth, 5cm above the ground was measured by means of a thread. Exact measure was determined by stretching the thread along a 30 cm rule. At harvest, weight per head was obtained by an electronic scale. Six heads of the central row from each plot were cut vertically into two halves

and the diameter of the head measured horizontally using a 30cm rule.

Twelve (12) weeks after transplanting, the plants were uprooted for root knot nematode galling assessment, as already described in Section 3.1.13 (Page 27). *Meloidogyne* juveniles were extracted from the root rhizosphere of cabbage plants to determine the final nematode population build-up at the end of the experiment. Monthly rainfall distribution and monthly mean temperature were also obtained from the nearby Meteorological station at Crop and Soil Sciences Department, KNUST, Kumasi.

3.2.9 Root Knot Nematode Bioassay on Tomatoes

Hundred 100ml of soil were used for root knot nematode (juveniles) extraction. Three week old susceptible local tomato cultivar seedlings grown in steam sterilized soil were transplanted into 500ml plastic pots containing the soil for the bioassay. The indicator crop/test crop (tomato) was rated for galling eight weeks after transplanting using the Bridge and Page (1980) rating chart.

3.2.10 Staining of Nematodes in Plant Tissues

The lacto–phenol (Bridge *et al.*, 1982) was used to stain female *Meloidogyne* in the roots. The roots of cabbage were chopped, wrapped in calico bags and placed in boiling solution of equal volumes of glycerol lactic acid and distilled water plus 0.05% acid fuschin in a deep beaker (500cm^3). The samples were boiled for five minutes and allowed to cool overnight. The wrapped samples were then removed from the stain solution and were rinsed under tap water. The roots were then cleared in equal volume of glycerol and distilled water for at least 72 hours.

3.2.11 Preparation of Perineal Patterns

Perineal patterns of mature stained females from the galls were prepared for each root knot nematode isolates following the method reported by Taylor and Netscher (1974). Twenty (20) matured pear-shaped females were teased out of each root system with forceps. The posterior sections with vulva and anus were cut off with sharp blade. The inside tissues were cleaned with camel hair brush. The sections were then placed in a drop of 45% lactic acid in a plastic Petri dish for four days. The lactic acid facilitates the removal of inside tissues that adhere to the cuticle.

The perineal pattern was trimmed. Final cleansing was done using a pulp canal file. The sections were then transferred into a drop of glycerine on a clean glass microscope slide. The inside of each section faced the slide. A cover slip was then gently placed on the glycerine drop. The cover slip was sealed with candle wax and the slide was labelled for microscope identification.

3.2.12 Identification of *Meloidogyne* spp.

Root knot nematodes were identified to species level based on perineal pattern characteristics for identification. The patterns were compared with micrographs of perineal patterns of *Meloidogyne incognita, M. arenaria* and *M. javanica* provided by the International *Meloidogyne* Project (Sasser and Carter, 1982)

3.2.13 Data Analysis

Nematode population per 100 ml of soil was log (x+1) transformed. Data collected were analysed as before and least significant differences (LSD) at 5% were used for comparing mean differences.

CHAPTER FOUR

4.0 RESULTS

4.1 Soil Chemical Properties

Table 4.1 Soil nutrient levels before treatments application

Horizon (cm)	pH	Organic Carbon (%)	Total N (%)	P (ppm)	K (ppm)	Exchangeable Ca (me/100g)	Exchangeable Mg (me/100g)
0 - 15	5.78	0.05	0.05	48.95	0.31	7.20	4.80

Table 4.1 shows the initial soil nutrients before the application of the treatments. The results showed that, the soil contained low levels of Nitrogen, Phosphorus and Potassium.

4.2 Poultry manure Analysis

Table 4.2 Nutrient content of poultry manure

pH	Organic Carbon (%)	Total N (%)	Available P (ppm)	Available K (ppm)	Ca (%)	Mg (%)
7.68	31.29	1.56	1.50	2.4	9.20	1.34

The poultry manure analysed showed higher amounts of Nitrogen, Phosphorus and Potassium. (Table 4.2)

4.3 Pot Experiment Results

4.3.1 Plant Height

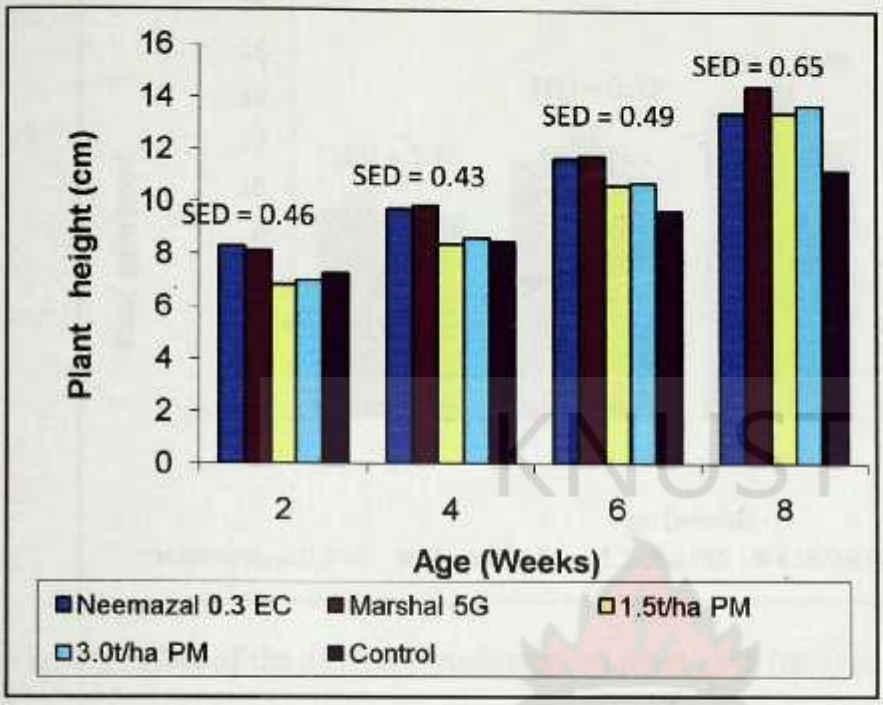

Fig. 4.1 Effect of the different treatments on plant height of cabbage at different weeks after transplanting in pots

Figure 4.1 shows growth pattern as measured by mean plant height (cm). The highest plant height occurred on Marshal 5G treated plants and this was followed by Neemazal treated plants.

4.3.2 Plant Girth

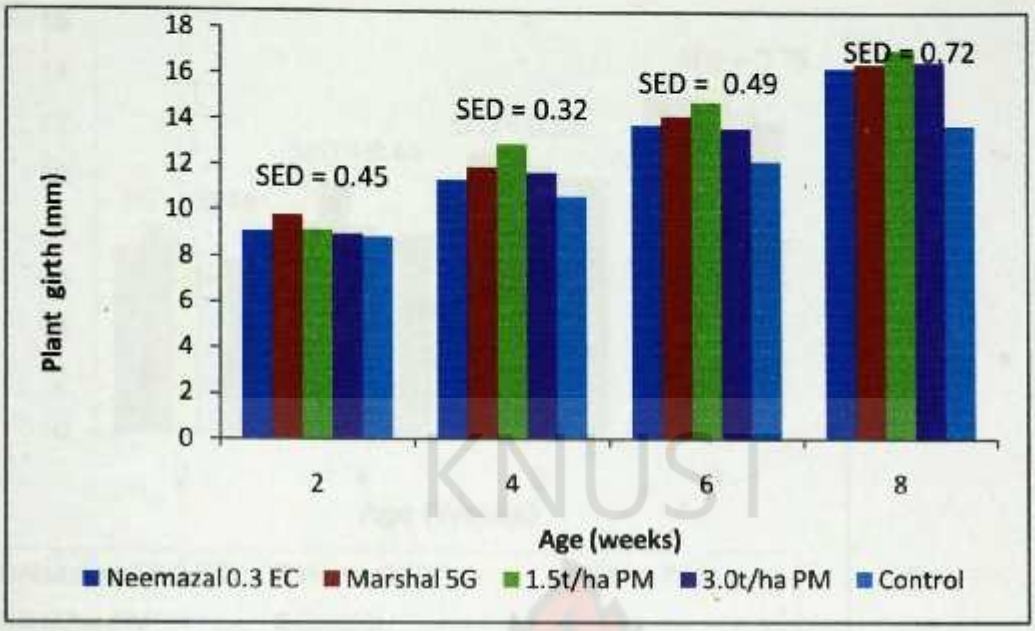

Fig. 4.2 Effect of the different treatments on plant girth (mm) in pots

Figure 4.2 shows consistent increase in plant girth from the fourth to eighth week after transplanting. Bigger stem girth was produced when 1.5t/ha of poultry manure was applied as compared to the other treatments. The mean values for 1.5 and 3.0t/ha of poultry manure treated plants were significantly higher than that of the control treated plants.

4.3.3 Number of Leaves

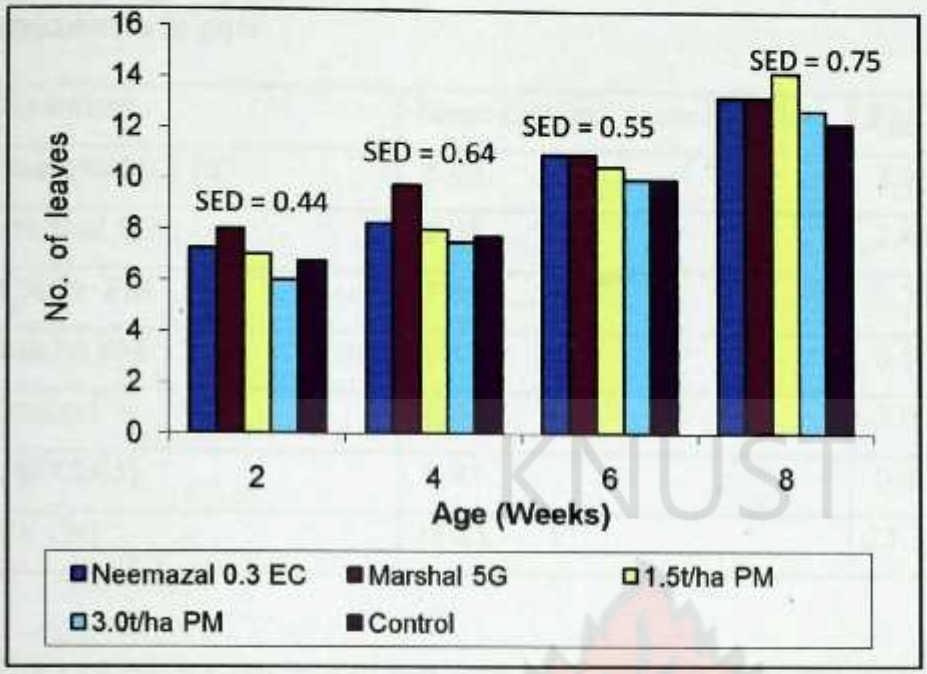

Fig. 4.3 Effect of the different treatments on number of leaves of cabbage at different weeks after transplanting

Figure 4.3 shows that plants treated with 1.5t/ha of poultry manure produced more number of leaves at eight week after transplanting. However, small number of leaves was recorded by the control.

4.3.4 Root Galling and Egg Mass Indices in Pots

Table 4.3.1 Root galling and egg mass indices of cabbage with the different treatments in pots

Treatment	Mean root gall score (0-10)	Egg mass
Neemazal 0.3 EC	5.40	3.00
Marshal 5G	5.95	3.43
1.5t/ha PM	1.60	0.75
3.0t/ha PM	0.13	0.10
Control	6.00	3.00
LSD(0.05)	0.93	0.80
CV (%)	15.85	25.39

The root galling scores and egg masses of cabbage indicated that 3.0t/ha of poultry manure produced plants with the lowest infection index. This was followed by plants treated with Marshal 5G, Neemazal, and 1.5t/ha of poultry manure respectively. There were significant difference between 1.5t/ha poultry manure, 3.0t/ha poultry manure and the control (p=0.05).

4.3.5 Population of *Meloidogyne* spp. in Pots

Table 4.3.2 Population density of second stage Juveniles of *Meloidogyne* spp. in soil of inoculated potted cabbage.

Treatment	Untransformed mean	Transformed mean
Neemazal 0.3 EC	1133.26	3.02
Marshal 5G	1330.42	3.11
1.5t/ha PM	255.53	2.35
3.0t/ha PM	47.00	1.68
Control	1477.63	3.15
LSD(0.05)	604.50	0.29
CV (%)	47.00	7.10

The population density of *Meloidogyne* juveniles recovered from soil in pots indicated that 3.0t/ha of poultry manure had the lowest density of *Meloidogyne* juveniles followed by 1.5t/ha of poultry manure. The mean values for 3.0t/ha PM and 1.5t/ha PM were significantly different from Neemazal, Marshal 5G and the control plants (P=0.05). (Table 4.3.2).

4.3.6 Fresh and Dry Shoot Weight

Table 4.3.3 Effect of the different treatments on mean fresh and dry shoot weights of cabbage in pots

Treatments	Fresh shoot weight (g)	Dry shoot weight (g)
Neemazal 0.3 EC	105.80	15.68
Marshal 5G	109.28	20.48
1.5t/ha PM	346.43	64.10
3.0t/ha PM	350.93	53.02
Control	133.09	22.73
LSD(0.05)	51.78	10.29
CV (%)	61.40	18.00

The results show that the mean values for plants treated with 1.5t/ha and 3.0t/ha of poultry manure of fresh and dry shoot weight were significantly higher than plants treated with Neemazal, Marshal 5G and control (P = 0.05).

4.3.7 Fresh and Dry Root Weight

Table 4.3.4 Effect of the different treatments on mean fresh and dry root weight of cabbage in pots

Treatments	Fresh root weight (g)	Dry root weight (g)
Neemazal 0.3 EC	24.16	7.50
Marshal 5G	27.01	8.40
1.5t/ha PM	28.54	7.40
3.0t/ha PM	30.76	9.28
Control	20.59	6.19
LSD (0.05)	5.20	2.15
CV (%)	12.87	18.00

Table 4.3.4 shows that there were significant differences (p = 0.05) on mean fresh and dry root weight of cabbage in pots, due to the effect of poultry manure. Application of 3.0t/ha of poultry manure recorded heavier roots with the control recording the least.

4.4 Field Experiment Results

4.4.1 Root Galling and Egg Mass Indices in the field

Table 4.4.1 Effect of the different treatments on root galling and egg mass of cabbage in the field

Treatments	Mean root gall score (0-10)	Mean egg mass
Neemazal 0.3 EC (T_1)	3.00	2.25
Marshal 5G (T_2)	2.00	1.75
1.5t/ha PM (T_3)	2.00	1.25
3.0t/ha PM (T_4)	1.00	0.75
Control (T_5)	6.00	6.00
LSD (0.05)	1.32	0.99
CV (%)	4.00	0.00

Table 4.4.1 shows that 3t/ha poultry manure treated plant produced plants with fewer galls and egg masses followed by 1.5t/ha poultry manure. The mean values of 3t/ha poultry manure were significantly higher than the other treatments (P = 0.05).

4.4.2 Root Knot Nematode Bioassay on tomatoes

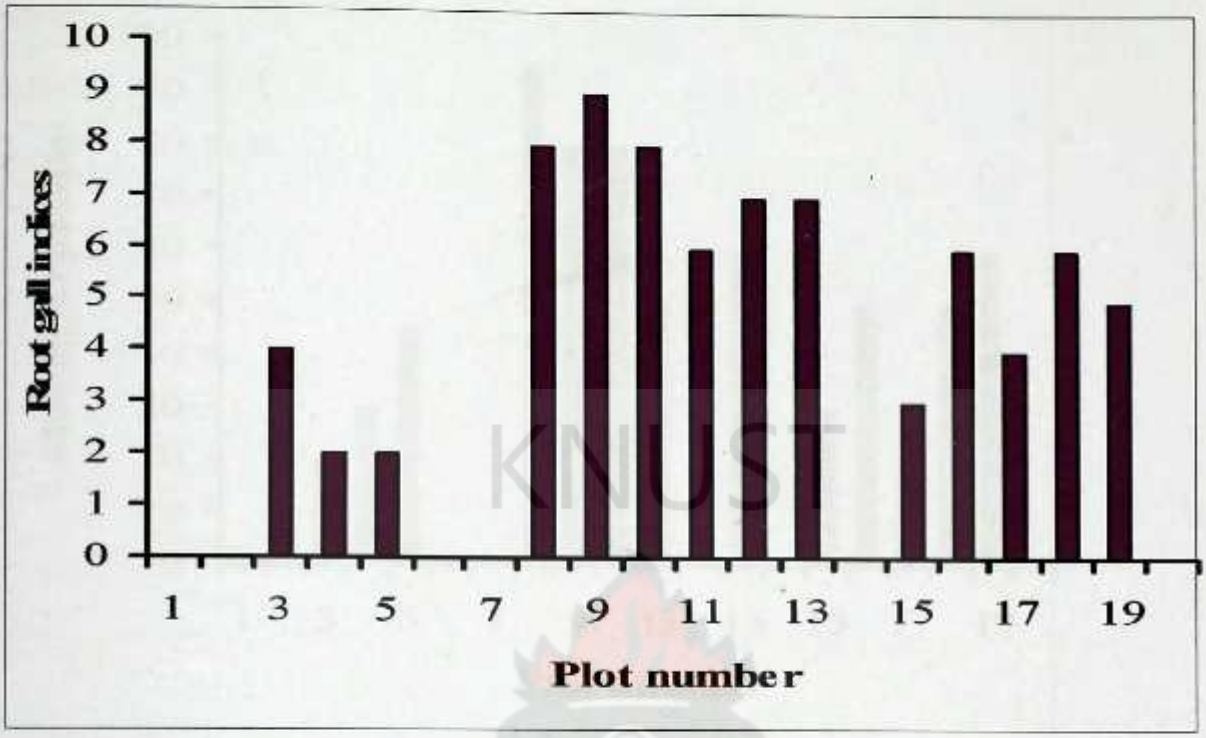

Fig. 4.4 Root knot nematode bioassay on tomatoes before field experiment

The bioassay results show that root knot nematodes were fairly distributed in most of the experimental plots though the galling indices were variable.

4.4.3 Distribution of Nematodes in the Field

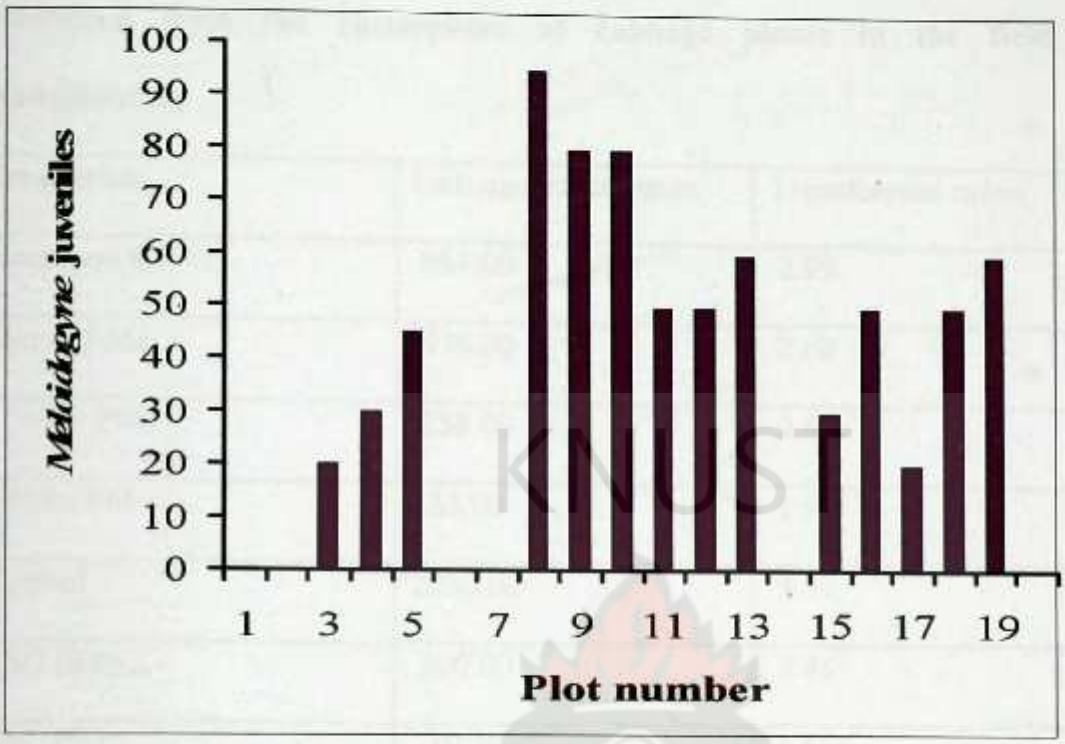

Fig. 4.5 Distribution of *Meloidogyne* juveniles on the experimental site

The population density of the *Meloidogyne* juveniles followed similar trend as the indices on the tomato indicator crop.

4.4.4 Population of *Meloidogyne* spp. Recovered from Rhizosphere of Cabbage

Table 4.4.2 Population density of second stage juveniles of *Meloidogyne* recovered from the rhizosphere of cabbage plants in the field after transplanting

Treatments	Untransformed mean	Transformed mean
Neemazal 0.3 EC	984.00	2.99
Marshal 5G	476.00	2.68
1.5t/ha PM	258.00	2.42
3.0t/ha PM	83.00	1.92
Control	2050.00	3.31
LSD (0.05)	300.00	2.48
CV (%)	10.30	1.05

***Log (x+1) transformed, where x = mean count**

Table 4.4.2 shows that plants treated with 3t/ha poultry manure had the lowest density of *Meloidogyne* juveniles, followed by 1.5t/ha poultry manure. 3t/ha poultry manure and 1.5t/ha poultry manure were significantly higher than the Control (P = 0.05).

4.4.5 Cabbage Head Weight

Table 4.4.3 Effect of the different treatments on head weight of cabbage at harvest in the field

Treatments	Mean cabbage head fresh weight (g))
Neemazal 0.3 EC	305.00
Marshal 5G	327.00
1.5t/ha PM	745.00
3.0t/ha PM	826.00
Control	241.00
LSD (0.05)	173.10
CV (%)	15.60

The largest fresh head weights were recorded on 3t/ha poultry manure and 1.5t/ha poultry manure. There were significant differences between 1.5t/ha poultry manure, 3t/ha poultry manure and the Control (P=0.05). However, there was no difference between 3t/ha and 1.5t/ha poultry manure treated plants.

4.4.6 Cabbage Head Diameter

Table 4.4.4 Effect of the different treatments on cabbage head diameter at harvest in the field

Treatments	Mean head diameter (cm)
Neemazal 0.3 EC	10.30
Marshal 5G	10.50
1.5t/ha PM	12.10
3.0t/ha PM	14.00
Control	8.70
LSD (0.05)	0.87
CV (%)	1.70

The result indicates that 1.5t/ha and 3t/ha poultry manure produced plants with the highest diameters. There were significant differences (P=0.05) between plants treated with 3t/ha poultry manure and the other treatments (Table 4.4.4). However, the control plants produced the least diameter.

4.4.7 Fresh Root Weight

Table 4.4.5 Effect of the different treatments on fresh root weight of cabbage at harvest in the field

Treatments	Mean cabbage fresh root weight (g)
Neemazal 0.3 EC	13.41
Marshal 5G	14.04
1.5t/ha PM	23.73
3.0t/ha PM	28.00
Control	10.00
LSD (0.05)	5.41
CV (%)	15.30

The results indicate that 1.5t/ha and 3t/ha poultry manure produced plants with bigger fresh roots than the other treatments (Table 4.4.5). The mean values of 1.5t/ha poultry manure and 3t/ha poultry manure were significantly larger than the other treatments ($P = 0.05$).

CHAPTER FIVE

5.0 DISCUSSION

The results showed consistent increase in plant height from the 2nd to the 8th week in the pot experiments (Fig. 4.1) and this is the expected pattern of normal plant growth. Highest plant height (14.47cm) occurred in Marshal 5G treated plants followed by poultry manure at 3.0t/ha with a height of 13.43cm. The heights produced by Neemazal 0.3 EC and poultry manure at 1.5t/ha were 13.75 cm and 13.43cm, respectively. The least plant height of 11.22cm was recorded for the control. This demonstrated that when poultry manure was applied at the rate of 1.5 and 3.0t/ha at the early life of the crop, good plant height was enhanced.

The positive height responds by cabbage to poultry manure application (Fig. 4.1) agrees with Rydin (1985) who found that seedlings of *Citrus sinensis* and *Citrus paradise* grown in pots containing poultry manure increased in height, girth and root growth. The lowest height in the control crop suggests least plant nutrients availability in the soil.

Poultry manure at the rate of 3.0t/ha did not produce better performance than the 1.5 t/ha suggesting that 1.5 t/ha is probably the optimum rate above which cabbage does not respond. This conforms with observation made by Bandel *et al.* (1972) that poultry manure contained appreciable amount of NPK on the following percentages: N=45%, P=2.5% and K=2%, respectively.

However, 3.0t/ha poultry manure was not better than that of 1.5t/ha poultry manure, which may be due to the fact that 3.0t/ha poultry manure applied was more than what

the plant could utilize. This confirms the findings of Hileman (1971) that excessive application of plant nutrients resulted in inefficient use by plants as high total dissolved salt levels accumulate in the soil making nutrients unavailable. Similarly, Musa (1975) reported that yield increase was better in sorghum with application of 4t/ha of manure rather than applying higher rate of 15 t/ha.

Figure 4.2 demonstrates growth pattern as measured by mean plant girth (mm) for cabbage with application of poultry manure. Marshal 5G produced the highest mean plant stem girth for week two followed by 3.0t/ha poultry manure, Neemazal 0.3 EC, 1.5t/ha poultry manure and the control (Fig. 4.2). On the contrary, in week four, 1.5t/ha poultry manure produced the highest mean plant stem girth followed closely by Marshal 5G and 3.0t/ha poultry manure (Fig. 4.2). This supports Kallah and Adamu (1998) findings that organic amendment promoted vigorous growth and development, strong root system as well as strong stem development.

Similarly, at week six and eight, application of 1.5t/ha poultry manure produced bigger stems than the other treatments. The mean values for 1.5 and 3.0t/ha poultry manure were significantly higher than that of the control (P= 0.05). This supports the recommendation by Williams *et al.* (1991) that poultry manure is good for cabbage at a rate of 2.0t/ha.

Figure 4.3 shows growth pattern as measured by mean number of leaves of cabbage plants with poultry manure applications. The rate of 1.5t/ha of poultry manure produced plants with more leaves than the other treatments (Fig. 4.3). This might be the reason for highest yield whenever poultry manure was applied.

Hemeng (1995) observed that organic soil amendment and their multiple benefits to crop production decreased soil nematodes in addition to increase in crop yield.

Similarly, Miller and Turk (1991) reported that the rate of application of poultry manure enhanced the growth and yield of crops by providing adequate amount of micronutrients and source of nutrients for micro-organisms. The control plots produced the least number of leaves due to lack of soil nutrients (Table 4.1).

The application of 3.0t/ha poultry manure produced plants with the heaviest root weight of 30.76g, followed by 1.5t/ha (28.54g), Marshal 5G (27.01g) and Neemazal 0.3 EC (24.16g) (Table 4.4.7). Mean values for Neemazal 0.3 EC, 1.5t/ha poultry manure and 3.0t/ha poultry manure were significantly higher than that of the control. However, there were no significant differences between mean values of 1.5t/ha poultry manure and 3.0t/ha poultry manure (P=0.05). The smaller roots sized recorded in the control, where no manure was applied could be attributed to the large number of root knot nematode population (Table 4.3.2). Ploeg (2001) reported that feeding by nematodes drastically decreased plants uptake of nutrients and water, and they had severe adverse effect on crop productivity.

In the field experiment, 3.0t/ha and 1.5t/ha of poultry manure treatments produced plants with bigger fresh roots than the other treatments (Table 4.4.5). The control recorded the lowest. The mean values for 1.5 and 3.0t/ha poultry manure were significantly different from the control and other treatments (P=0.05). This might be attributed to nitrogen being soluble and mobile and therefore readily available for plant uptake during the vegetative growth phase of the plant life. This assertion agrees with Smith (1995) that application of organic manure was essential for intense biological activity in the root zone. The organic matter helps in soil aggregation and thereby improves the physical structure of the soil. Moore *et al.* (1995) also observed that poultry manure increased water infiltration rate, water holding

capacity, cation exchange capacity and structural stability of soil (Table 4.2). Similar trend was also observed on both experiments as plants with poultry manure had thicker roots than other treatments (Tables 4.4.5 and 4.3.4).

The bioassay results (Fig. 4.4) show the initial distribution of *Meloidogyne* juveniles in the field before planting of cabbage. Of the 20 plots used, *Meloidogyne* juveniles were found in the fourteen of the plots representing 70% of the experimental area. Root gall indices observed on the roots of the indicator tomato plants ranged from two to nine giving a mean of 5.5 (Fig. 4.4).

The presence of *Meloidogyne* in the field confirms Mahmood's (1988) assertion that several weeds are among the hosts of *Meloidogyne* spp. The concentration of nematodes from the 8th to13th plot (Fig 4.5) agrees with earlier report by Sikora and Fernandez (2005) that the nematode distribution has been assumed to have a random distribution, but plant parasitic nematodes have an aggregated distribution

Table 4.3.1 shows the mean root galling and egg mass indices on a scale of 0-10 (Bridge and Page, 1980) on cabbage plants grown in plastic pots. The lowest index of 0.13 was recorded on 3.0t/ha poultry manure treated cabbage roots whilst the highest index of six was recorded on the roots of the control plants. This was followed by Marshal 5G, Neemazal 0.3.EC and 1.5t/ha poultry manure. The mean values for 1.5t/ha and 3.0t/ha were significantly different from the Neemazal 0.3 EC, Marshal 5G treatments and the control (P=0.05). The results suggested that 3.0t/ha of poultry manure suppressed root knot nematodes reproduction hence, very low root gall index. This is in agreement with report by Anon. (1992) that poultry manure reduced root knot nematode index to zero. However, there were no differences

between 1.5t/ha and 3.0t/ha poultry manure. The low galling index of 3.0t/ha poultry manure could be attributed to it releasing some toxic substances into the soil which inhibited the nematodes from entering the roots (Adesiyan *et al.*, 1990). This is confirmed by Table 4.3.2 where population of *Meloidogyne* juveniles/100ml of soil obtained for 1.5t/ha poultry manure was very low compared to that of the control with the highest galling index.

Similarly, the results in Table 4.3.1 for egg mass showed that poultry manure rates 1.5 and 3.0t/ha markedly controlled the nematodes. However, the control produced the highest egg mass index of 3.43. There were no differences between 1.5t/ha and 3.0t/ha PM and between Neemazal 0.3 EC, Marshal 5G and the control.

The results in Table 4.4.1 showed that 3.0t/ha poultry manure produced roots with fewer galls and egg masses resulting in a rating of 1.00 and 0.75 respectively. This was followed closely by 1.5t/ha poultry manure. The gall and egg masses from 3.0t/ha poultry manure treatment was significantly higher than that of the control (P=0.05) but were not different from means of Neemazal 0.3 EC and Marshal 5G. However, there was no significant difference between the means of Neemazal 0.3 EC and Marshal 5G with respect to root galling and egg mass indices. This implies that poultry manure had decreasing effect on root galling and egg mass with increasing poultry manure (Table 4.4.1)..

The trend was similar to the observation by Egunjobi and Olaitan (1986) that cocoa pod husks as organic material incorporated at 6000kg/ha led to 28% reduction in galling and 6.7% increase in yield of cowpea. Hemeng (1995) also reported that organic matter resulted in 40% reduction of root galling of lettuce root. Sikora and

Fernandez (2005) reported that the presence of galls on the root system is the primary symptom associated with *Meloidogyne* infection and that the size and the form of gall depended on the number of nematodes in the tissue.

The results of both pot and field experiments showed positive correlation with poultry manure with respect to galling and egg mass indices.

The population of second stage juveniles of *Meloidogyne* recovered from the pot experiment at harvest (Table 4.4.2) indicated that cabbage treated with poultry manure at 3.0t/ha had the lowest population density of 47 juveniles/100ml of soil. This was followed by 1.5t/ha poultry manure with 256 juveniles/ 100ml of soil, Neemazal 0.3 EC with 1133 juveniles /100ml of soil and the control with 1477.

The mean values for 1.5t/ha and 3.0t/ha poultry manure were significantly higher than that of Neemazal, Marshal and control treatments (P=0.05). However, there were no significant differences between Neemazal and Marshal and between 1.5t/ha and 3.0t/ha poultry manure (P=0.05). The result indicates that poultry manure had effect on the population density of *Meloidogyne* Juveniles in the soil planted to cabbage. This supports the findings by Sikora and Fernandez (2005) that organic amendments increased the number and density of antagonistic organisms and organic compounds formed during degradation processes of the soil amendments thereby decreasing the nematode numbers. Zuckerman (1971) also observed a significant reduction in root knot nematode population during the decomposition of organic matter.

Kiss (1990) reported that the basis of sustainability of nematode control was the maintenance of healthy soil food web with a routine application of poultry manure. According to Taylor (1967), organic matter promoted growth of saprophytic

nematodes, bacteria and nematode trapping fungi which attack larvae of plant parasitic nematodes.

Population of second stage juveniles of *Meloidogyne* spp. recovered from the field experiment at harvest presented in Table 4.4.2 shows that 3.0t/ha poultry manure had the lowest density of 83 juveniles /100ml of soil, while the highest density of 2050 juveniles /100 ml of soil was recorded on the control. There were significant differences (P=0.05) between 1.5 and 3.0t/ha of poultry manure and that of the control. However, there were no differences (p=0.05) between 1.5t/ha poultry manure and between Neemazal 0.3 EC and Marshal 5G. The trend was similar as observed from the pot experiment.

Sikora and Fernandez (2005) reported that adequate moisture favoured the reproduction and development of nematodes. Adesiyan *et al.* (1990) also observed that higher temperature affects nematode mobility, egg hatch, penetration, growth, reproduction and survival. The fair rainfall distribution with higher temperature levels in 2007 (Appendix 16) might have contributed to increased root knot nematode population but the nematicidal effect of poultry manure at the rate of 1.5 and 3.0t/ha was responsible for the reduction of *Meloidogyne* juvenile population (Table 4.4.2).

Poultry manure applied at 3.0t/ha produced plants with highest fresh shoot weight of 350.93g followed by 1.5t/ha . Neemazal 0.3 EC recorded the lowest fresh shoot weight of 105.8g while a mean of 133.09g was obtained from the control, resulting in a decrease of 13.38% from the control plots. Dixit (1997) reported that nitrogen in poultry manure increased plants growth and yield characters including the number of shoots produced.

It was found that the heaviest mean cabbage dry shoot weight of 64.10g was recorded for 1.5t/ha poultry manure and the lowest mean dry shoot weight of 15.68g was obtained from the Neemazal 0.3 EC. Mean dry weights of cabbage ranged from 15.68g – 64.10g. The results indicated that mean values for 1.5t/ha and 3.0t/ha poultry manure for fresh and dry shoot weight were significantly higher than that of Neemazal 0.3 EC, Marshal 5G, and Control (p=0.05).

However, there was no significant difference between 1.5t/ha and 3.0t/ha. The results agreed with Mathias (1997) who found that the highest poultry manure rate resulted in significantly highest mean stem dry matter and plants without produced the lowest yields due to inadequate soil nutrients. This is in agreement with the findings by Agyenim- Boateng (1999) working on maize also found that the total weight of dry matter was higher in plants with highest rate of poultry manure.

The highest cabbage fresh head weight of 826g was obtained from 3.0t/ha poultry manure, followed by 1.5t/ha poultry manure with 745g. The control recorded the lowest mean head weight of 241g. This is in agreement with Grubben and Denton (2004) that application of poultry manure at the rates of 2.0-5.0t/ha increased yield and growth of cabbage. Hileman (1971) also reported that poultry manure enhances rapid release of ammonia. There were significant differences (P=0.05) between 1.5 and 3.0t/ha of poultry manure and the other treatments. However, there was no significant (p=0.05) difference between 1.5 and 3.0t/ha poultry manure treatments. This is in agreement with the report by Romain (2001) that in order to obtain satisfactory yields, it is recommended to incorporate poultry manure at a rate of about 2.0-3.0t/ha during soil preparation. Messiaen (1994) also recommended that cabbage responded well to applications of poultry manure at the rate of 5.0t/ha.

Marshal 5G and Neemazal 0.3 EC notwithstanding performed poorly because lower yields were obtained from the plots treated with the two treatments (Table 4.4.3).

Table 4.4.4 shows the result of the effect of different treatments on head diameter of cabbage. The highest head diameter of 14cm was obtained when 3.0t/ha of poultry manure was applied. This was followed by 1.5t/ha poultry manure, with 12.10cm, Marshal 5G, with 10.50cm, Neemazal, with 10.30cm and the control, with 8.70cm/plant. There were significant differences between 3.0t/ha poultry manure and the other treatments (P=0.05). However, there was no difference (P=0.05) between Neemazal 0.3 EC and Marshal 5G treatments. The cabbage head diameter recorded from 3.0t/ha of poultry manure was greater because of highest plant growth. Head diameter is an important determinant of yield since the leaves are the sites for photosynthesis. Therefore, all other factors being constant, plants with larger head diameter would be expected to have undergone higher photosynthesis which would be translated to higher head weight and root weight (Tables 4.4.3 and 4.4.5).

Head weight and diameter of cabbage were not recorded in the pot experiment since heads were not properly formed. This may be due to insufficient sunlight in the plant house. However, in the field, heads were properly formed due to optimum exposure to sun during the entire growth cycle. The result confirms the finding that cabbage formation responds positively to photoperiod (Romain, 2001).

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The study was to investigate the effect of soil application studies on poultry manure and some nematicides for nematodes control. Results obtained in the two studies have shown that the poultry manure reduced nematode population more than the nematicide Marshal 5G and Neemazal 0.3 EC, promoted good growth and increased yield of cabbage. Poultry manure applied at 3t/ha significantly reduced *Meloidogyne* spp. population

From the pot experiment, the yield of cabbage (fresh and dry shoot weights) where manure was applied, were larger than the control treatment. Similar results were obtained for head weight and head diameter of cabbage plants in the field experiment. One of the factors responsible for higher plant growth and yield could be due to the reduction in nematode population. Another factor responsible for the increase in yield could be enhanced nutrient availability released by the poultry manure.

6.2 Recommendations

The study recommends the application of poultry manure for nematode control, growth and yield of cabbage as an alternative to chemical control to safeguard pesticide residues in vegetables. However, further studies need to be conducted at different rates of application such as 3.0t/ha to determine optimum level for maximum yield of cabbage. There might be also the need for some studies to be

carried out to determine the socio-economic implications of poultry manure and other treatments in the control of root knot nematode.

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APPENDICES

Appendix 1. Summary ANOVA for the effect of the different treatments on population of *Meloidogyne* juveniles recovered from soil/pot

Source of Variation	Degree of freedom	Sum of squares	Mean sum of square	F – value	Probability values
Replication	3	1208.00	403.00	0.26	
Treatment	4	55181.00	13795.00	9.03	0.001
Error	12	18340.00	1528.00		
Total	19.00	74729.00			

CV (%) = 51.16 LSD (0.05) = 60.23

Appendix 2. Summary ANOVA for the effect of poultry manure and some nematicides on root galling in pots

Source of Variation	Degree of freedom	Sum of squares	Mean sum of square	F – value	Probability values
Replication	3	0.93	0.31	0.85	
Treatment	4	121.03	30.26	82.99	(.00)
Error	12	4.3750	0.36		
Total	19.00	126.34			

CV (%) 15.85 LSD (0.05) 0.93

Appendix 3. Summary ANOVA for the effect of poultry manure and some nematicides on egg mass index in pots

Source of Variation	Degree of freedom	Sum of squares	Mean sum of square	F – value	Probability values
Replication	3	1.93	0.65	2.41	
Treatment	4	37.03	9.26	34.50	<.001
Error	12	3.22	0.27		
Total	19	42.19			

CV (%) = 25.39 LSD (0.05) = 0.80

Appendix 4. Summary ANOVA for the effect of poultry manure and some nematicides on fresh root weight (g) in pots

Source of Variation	Degree of freedom	Sum of squares	Mean sum of square	F – value	Probability values
Replication	3	17.60	5.87	0.52	
Treatment	4	250.35	62.59	5.50	0.009
Error	12	136.52	11.38		
Total	19	404.48			

CV (% = 12.87 LSD (0.05) = 5.20

Appendix 5. Summary ANOVA for the effect of poultry manure and some nematicides on dry root weight (g) in pots

Source of Variation	Degree of freedom	Sum of squares	Mean sum of square	F – value	Probability values
Replication	3	2.42	0.81	0.41	
Treatment	4	21.66	5.42	2.78	0.08
Error	12	23.35	1.95		
Total	19	47.42			

CV (%) = 18.00 LSD (0.05) = 2.15

Appendix 6. Summary ANOVA for the effect of poultry manure and some nematicides on dry shoot weight (g) in pots

Source of Variation	Degree of freedom	Sum of squares	Mean sum of square	F – value	Probability values
Replication	3	50.80	16.93	0.38	
Treatment	4	76.23.50	1905.88	42.73	<.001
Error	12	535.19	44.60		
Total	19	8209.50			

CV (%) = 19.97 LSD (0.05) = 10.29

Appendix 7. Table for mean plant height (cm) at two weeks interval after transplanting in pots

Treatment	Weeks			
	2	4	6	8
Neemazal 0.3 EC	8.31	9.73	11.70	13.43
Marshal 5G	8.13	9.84	11.78	14.47
1.5t/ha PM	6.81	8.41	10.68	13.53
3.0t/ha PM	7.12	8.69	10.75	13.75
Control	7.25	8.50	9.69	11.22

Appendix 8. Table for mean plant girth (mm) at two weeks interval after transplanting in pots

Treatment	Weeks			
	2	4	6	8
Neemazal 0.3 EC	9.06	11.31	13.75	16.25
Marshal 5G	9.98	11.88	14.15	16.45
1.5t/ha PM	9.13	12.88	14.75	17.06
3.0t/ha PM	8.94	11.66	13.56	16.44
Control	8.81	10.60	12.16	17.72

Appendix 9. Table for mean number of leaves of cabbage at two weeks interval after transplanting

Treatment	Weeks			
	2	4	6	8
Neemazal 0.3EC	7.25	8.25	11.00	13.25
Marshal 5G	8.00	9.75	11.00	12.50
1.5t/ha PM	7.00	8.00	10.50	14.25
3.0t/ha PM	6.00	7.50	10.00	12.75
Control	6.75	7.75	10.00	12.25

Appendix 10. Summary ANOVA for the effect of poultry manure and some nematicides on root galling in the field

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F – value	Probability values
Replication	3	0.20	0.07	0.09	
Treatment	4	92.80	23.20	31.64	< .001
Error	12	8.80	0.73		
Total	19	101.80			

CV (%) = 4.00 LSD (0.05) = 1.32

Appendix 11. Summary ANOVA for the effect of poultry manure and some nematicides on egg mass index in the field

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F – value	Probability value
Replication	3	0.00	0.00	0.00	
Treatment	4	69.80	17.45	41.88	<.001
Error	12	5.00	0.416		
Total	19	74.48			

CV (%) = 0.00 LSD (0.05) = 0.99

Appendix 12. Summary ANOVA for the population of *Meloidogyne* spp. juveniles recovered from the field

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F – value	Probability value
Replication	3	936.87	31229	0.82	
Treatment	4	10017759	2504440	65.93	<.001
Error	12	45586			
Total	19	10567307			

CV (%) = 10.30 LSD (0.05) = 300.30

Appendix 13. Summary ANOVA for the effect of poultry manure and some nematicides on head weight (g) in the field

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F – value	Probability value
Replication	3	87486.	29162.	2.31	
Treatment	4	1202903.	300726	23.82	<.001
Error	12	151529.	12627.		
Total	19	1441918.			

CV (%) = 16.60 LSD (0.05) = 173.10

Appendix 14. Summary ANOVA for the effect of poultry manure and some nematicides on head diameter (cm) in the field

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F – value	Probability value
Replication	3	0.53	16.03	0.55	
Treatment	4	64.10	0.32	50.05	<.001
Error	12	3.84			
Total	19	68.47			

CV (%) =1.70 LSD (0.05) = 0.87

Appendix 15. Summary ANOVA for the effect of poultry manure and some nematicides on fresh root weight (g) in the field

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	F – value	Probability value
Replication	3	112.65	37.55		
Treatment	4	934.50	233.63	3.04	<.001
Error	12	148.01	12.33	18.94	
Total	19	1195.17			

CV (%) =15.30 LSD (0.05) = 5.41

Appendix 16. The mean total rainfall (mm) and mean temperature (%) of KNUST in January to December, 2007

Month	Mean total rainfall (mm)	Mean temperature (°C)
January	26.4	28.4
February	50.7	28.5
March	98.0	27.0
April	204.2	28.0
May	180.0	27.8
June	260.1	26.5
July	280.4	26.0
August	140.5	25.5
September	207.4	26.0
October	200.1	27.0
November	50.0	26.4
December	0	26.5

Source: Crop and Soil Sciences Department Weather Station, KNUST, Kumasi.

Appendix 17. Root knot Rating Chart after Bridge and Page (1980).

0. - No knots on roots

1. - few small knots, difficult to find.

2. - small knots why but clearly visible. Main roots clean.

3. - some large knots visible. Main roots clear.

4. - Larger knots predominate, but main roots clear.

5. - 50% of roots infested; Knotting on parts of main roots; Reduced root system.

6. - knotting on main roots

7. - majority of main roots knotted.

8. - All main roots knotted. Few clean roots visible.

9. - All roots severely knotted. Plant usually dying

10 - All roots severely knotted. No root system. Plant usually dead.