KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY (KNUST) – KUMASI, GHANA

COLLEGE OF AGRICULUTRE AND NATURAL RESOURCES
FACULTY OF AGRICULTURE
DEPARTMENT OF HORTICULTURE

DEVELOPMENT OF A VEGETABLE ROTATION TECHNOLOGY AS A SUSTAINABLE FARMING SYSTEM IN SELECTED GROWING LOCATIONS IN THE FOREST ZONES OF THE ASHANTI AND BRONG-AHAFO REGIONS

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

BY

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DECLARATION

I do hereby declare that this work is my own original work and the results of my own investigations and that no such work has been presented in this University or elsewhere, in a previous application for MSc degree.

References made to the works of other authors which served as sources of information are duly acknowledged.

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DEDICATION

I dedicate this work to my dear wife Priscilla Boatemaa, my children, Bismark Frimpong Adamu, Sandra Nafisa Adamu, Martin Hamidu Adamu and a family friend Dr. Moses Zinnah.

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ABSTRACT

An experiment was conducted on-station at the Department of Horticulture,Faculty of Agriculture,Kwame Nkrumah University of Science and Technology (KNUST),Kumasi to study the development of a vegetable rotation technology as a sustainable farming practice in selected vegetable growing locations in the forest zones of Ashanti and Brong Ahafo Regions. The objective of the study was aimed at designing an effective rotation system for vegetable crop producers in the selected locations using the advantages of crop rotation as sustainable farming system for maintenance of soil fertility, weed control and reduction in diseases and pests. Four crop combinations were set up in a Randomised Complete Block Design (RCBD) replicated four times with controlled fields using the same crops without rotating them till the end of the study. Cropping system influenced soil nutrients as rotation of crops within each crop combination improved soil nutrient contents. Nematode population was significantly lower in the rotated plots than the non-rotated plots. The total yields in all the four plantings were significantly higher for rotated plots than the non-rotated. The rotational cropping system reduced the incidence of insect pest damage in all crop combinations but damage was higher in the non-rotated plots. With regard to weed suppression, the rotation cropping system suppressed broad leaved weeds better than the fields cropped continuously with the same vegetable crop. In terms of economics of production, the rotational cropping system gave the highest income compared with the continuous cropping system. The differences are ascribed to the increased yields obtained from the rotational cropping system. It is concluded from the study that rotational cropping system is better in all the crop combinations studied.

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CHAPTER ONE 1.0

INTRODUCTION

Vegetables constitute an important group of food crops which are cultivated in all parts of the world. Apart from being used as food, many of them possess medicinal properties, vitamins and minerals which are normally not present in starchy foods (Grubben, 1977; Sinnadurai, 1992; Rubaihayo, 1994). Vegetables are consumed extensively in one form or the other by many people and it is estimated that 40 percent of foods consumed in developing countries contain vegetables (Rubaihayo, 1995). Some people either wholly or partially depend on vegetables for their living. Tomato for instance contributes substantially to supplementing the dietary needs of most people. It is rich in vitamins, minerals and plant proteins and therefore essential in enhancing the nutritional status of food (AVRDC, 1990).

Vegetables are living entities and continue to respire after harvest. They have high content of water and abundance of cellulose. The cellulose serves as roughage thus promoting normal elimination of waste products (Rice *et al.*, 1993; Rubaihayo, 1995). Leafy vegetables such as amaranths, lettuce, spinach and vegetable jute are high in water content and fibre and because of their succulence they aid in digestion (Rice *et al.*, 1993). Vegetables also neutralize acid substances produced in the course of digestion of other foods such as meat and cheese (Midmore, 1991; Dupriez and De Leener, 1992). It is evident that many people are engaged in the vegetable industry and have relied on it as their sole means of livelihood. Vegetables are also a source of foreign money for the country. For example, exports of garden eggs contribute tremendously to Ghana's Gross Domestic Product. In 1994, 1995 and 1996 it contributed 0.6, 0.13 and 0.16% respectively to the total exports of non-traditional products (Ghana Export Promotion Council, 1997). Okra, green and red chillies also gained foreign market prices of $5.96,

$4.47 and $3.58/ kg contributing to Ghana's Gross Domestic Product (Daily Graphic, 2003).

The traditional farming system of shifting cultivation and extended long fallow periods which ensured the restoration of soil fertility, and the use of little or no chemical fertilizers (Nye and Stephens, 1962) can no longer be practiced because of the dwindling availability of land for cultivation and increased population pressure (Ahn, 1993; Quansah, 1997 Raussen, 1997). Continuous cropping system on the same piece of land has been a farming system also practiced in Ghana and West Africa which has led to shortening of fallow periods resulting in the lowering of crop yields. It has been established that after thirty years of continuous cropping with multiple resistant crop the field becomes 'lethal' to all tomatoes no matter how resistant the variety (Sumner *et al.*, 1990). Bacterial wilt (*Pseudomonas solanaceurum*) and a resistance breaking strain of root-knot nematodes were included in the disease complex. Farmers have therefore resorted to an intensified land use system for vegetable production where different vegetables are grown in an irregular succession on the same piece of land season after season (Obeng *et al.,* 1990). The occurrence of bush fires, reduction or absence of fallow lands and inappropriate land management practices such as continuous cropping, have caused a decline in soil fertility, accumulation of pests and diseases, soil erosion (Yayock *et al., 1*988; Collinson, 2000) and the lowering of agricultural productivity and increasing food insecurity (Ruthenberg,1980; Raussen, 1997).

Agricultural technologies developed to solve farmers' problems are not in many cases applicable to their particular circumstances and farming systems. Variability in rainfall, inaccessibility to market and low price paid for most agricultural produce do not encourage the use of mineral fertilizers.

With trade liberalization, the Ghanaian farmer has been compelled to compete against cheap imports from Europe and the United States of America, many of which are produced under highly subsidized conditions. For instance cheap rice imports from United States are not only collapsing the local rice industry in Ghana but also beginning to have a substitution effect on locally produced foods like cassava and maize. This is compounded by the increasing cost of inputs at the farm level due to structural adjustment programmes that have removed subsidies and increased supply cost due to the deteriorating conditions of rural infrastructure. For instance, in 2002, whereas a metric tonne of urea cost about U.S. $90 FOB (free on board) in Europe (Sanchez, 2002), the same quantity cost a Ghanaian farmer about U.S. $308 at the farm level (ISSER, 2005). Garner *et al*.(1995) demonstrated that an increase in the price of fertilizer without a corresponding increase in the price of the produce reduces the profitability of using fertilizer and hence the demand for fertilizer.

Most farmers, especially small-scale farmers, do not have access to formal credit and therefore cannot afford to buy mineral fertilizers even where it has been demonstrated beyond doubt that it is profitable to do so (Obeng *et al*., 1990). Most of the credit obtained by farmers for their farming activities is from the informal sector with interest rates ranging from 30 to 100% (MOFA, 1998).

The removal of subsidies on mineral fertilizers in Ghana in 1994 led to the decline in fertilizer use from 65,000 metric tonnes to 11,000 metric tonnes in 1996. The purchase of sufficient mineral fertilizers is therefore beyond the financial reach of many small scale farmers. Apart from the problem of affordability of mineral fertilizers, its application sometimes results in the gradual build-up of soil acidity and other residual effects (Gerner *et al*., 1995). Man depends solely on soil for his basic needs of food, shelter and clothing. It is therefore necessary to find alternative means to protect these natural resources which are vital for agricultural production. The practice of vegetable crop rotation could be an appropriate intervention. Vegetable crop rotation provides so many advantages such as allowing operators of small scale farm an opportunity to produce only a second crop during a growing season. Socio-economic advantages also exist in rotation, including the spread of available labour, the spread of economic risks and the diversification of unavailable raw materials.

In recent times there has been increased interest in green manure and cover crops grown as improved short fallow in agricultural research (Delali, 1999). Leguminous cover crops grown as improved short fallow have shown high agronomic potential (Peoples *et al.*, 1995). Green manure and cover crops used in cropping systems such as in a rotation enhance biological mechanism and serve as potential substitute for chemical inputs.

These can be incorporated into the soil before planting cash crops or killed and left on the soil surface as a mulch

The continuous use of conventional pesticide however, may lead to problems such as pesticide resistance developing in insects making them difficult to control, outbreak of new pests and destruction of beneficial predators, parasites and pollinators and environmental pollution. This may also lead to increased expense of pest control involving recurrent cost for equipment and materials, higher risks of exposure to domestic animal, fish and wildlife (California Agriculture, 1990).

The high cost of inputs such as chemical fertilizers and other agro-chemicals has also created an urgent need for an alternative to the use of agro-chemicals for vegetable production in Ghana (ISSER, 2005). As a result of the high cost of inputs. (i.e. fertilizers, insecticides, fungicides, simple garden tools, etc) farmers in an attempt to breakeven, have resorted to the use of unrecommended and dangerous pesticides.

To encourage farmers to develop vegetable crop rotation as a sustainable farming practice calls for proper succession that can be worked out and practiced to achieve the immense contribution it provides in maintaining soil fertility, weed control or suppression and breakdown of diseases and pests.

The need to find ways of maintaining or sustaining productivity of the remaining crop lands can not therefore be overemphasized. Vegetable crop rotation among many cropping systems would be an appropriate intervention.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 INTRODUCTION

The traditional cropping systems which rely on shifting cultivation and the associated land fallow systems as a means of restoring fertility of depleted soils and diseases and pests breakdown seem less practicable nowadays because of land pressure due to ever increasing population and urbanization (Adjei-Nsiah, 2002).

It is even becoming impossible in the rural areas to allow farm lands to fallow. Farmers have therefore resorted to the use of agro-chemicals (fertilizers, insecticides, fungicides, etc) for the control of pests and diseases and the restoration of soil fertility.

The short term benefits from the use of insecticides are immense, with reduction in disease transmission by insect vectors and in losses from field crops, stored products, orchard crops, etc. As a result of these benefits, insecticides have proved popular as a means of pest control, but there are indirect costs associated with their use and also a prime cause of serious problems. Some of the causes include:

2.1.1. Development of Pest Resistance

This has been a serious problem for vegetable growers worldwide as evidenced in Indonesia that *Plutella operculella* has developed resistance to acephate 75 fold, trizophores-62 fold, delfamethrin- 323 fold (Sastrosiswojo, 1988). Youdeowei *et al*.

(1995) indicated that continuous use of insecticides may produce resistant strains of pest. Three species of the beetle, *Stethorus spp.* were found to be important predators of *Tetrancychus urticae* in orchards in Australia by the use of an insecticide to which the mite was known to be resistant (Taksdal, 1978). Due to the excessive use of insecticides (spraying 2-3 times a week) diamondback moth *Plutella xylostella* is now resistant to most categories of insecticides including the bacterial biotoxin *Bacillus thuringiensis* (Primentel and Edwards, 1982).

In the 1950's, it was also known that *Plutella xylostella* was resistant to Dichlorotrichloroethane (DDT) and other organochlorine insecticides (Ankersmith, 1953; Tijen Mo, 1959).

2.1.2 Resurgence of Vegetable Pests

The indiscriminate use of insecticides has eliminated some predators and some minor pests such as *Spodoptera exigua* which have become major ones in Thailand (Talekar *et al*., 1985). Primental (1985) stated that the damage to beneficial insects by insecticides adversely affected plant pollinators, mainly bees, necessitating additional use of chemicals. The frequent application of primethrin, acephate or quinolphos on cabbage increased the fecundity and longevity of *Plutella xylostella* (Sastrosiswojo, 1988).

2.1.3 Environmental Pollution

Primentel (1980) stated that damage to natural balance due to pesticide hazard is estimated at over five hundred million dollars yearly in the USA. According to Ramade (1986) more than half of the amount of pesticide application may go directly into the atmosphere during spraying.

2.1.4 Harmfulness to Consumers

Newson *et al*. (1976) stated that pesticides should be judiciously used not to kill beneficial insects but to lessen the chances of resistance developing and to minimize other drawbacks.

2.1.5 Residue Problems to Consumers/ Farmers

Studies in Togo and Sri Lanka showed that more than fifty percent of vegetables tested, exceeded the German tolerance level for chemical residue (Schweb *et al*., 1986). In Ghana, at Akomadan the effect of chemicals on farmers is evident in the community Owusu Ansah *et al*., 1998). Ntow (1999) reported that research encountered by the Water Research Institute of the CSIR revealed that intensive sampling programme to determine quantitatively pesticide concentrations at various levels of the food chain as well as the environment proved positive the presence of high dose of chemical residue.

2.2 DEFINITION OF CROP ROTATION

Many authors have defined the term 'crop rotation' as follows:

Thompson and Kelly (1959) indicated that rotation as applied in crop production may be defined as a systematic arrangement for the growing of different crops in a more or less regular sequence on the same land. It is also the succession of different crops on the same field in a fixed sequence as contrasted to monoculture or the random growing of crops (Raemaekers, 2001). Berold and Caine (1987) defined vegetable rotation as the growing of different crops one after the other on the same piece of land and indicated that if the rotation is well planned the best yield is obtained while the fertility of the soil is maintained. Youdeowei *et al*. (1995) reported that it is a method of growing selected sequence of crops with or without a fallow period on one area of land over several years which maintains yields.

Amankwatia (2000) also asserted that vegetable crop rotation is a system in which different vegetables are grown in recurrent succession and in definite sequence on the same land. Kirschenmann (1988) described rotation as the primary means of maintaining soil fertility and achieving weed, pest and disease control in organic farming system if farmers conform to include a leguminous crop and crops with different pests and diseases susceptibility.

2.3 ADVANTAGES OF VEGETABLE CROP ROTATION

2.3.1 Efficient Use of Resources

With systematic crop rotation, soil fertility is improved as well as soil pH for proper growth of vegetables especially if the order of rotation is followed as indicated bellow .

i. Shallow –rooted plants to be followed by deep-rooted ones as Raemakers (2001) showed that if shallow rooted crops are followed by deep-rooted perennials, the sub-soil is opened for the subsequent crop.

ii. Crops with high organic matter should be followed by crops with poor ground cover. In the issue, Feeding the Future (2001), it was reported that mucuna could achieve 100% ground cover in two months which primarily improves the soil fertility.

iii. Leguminous vegetables should be followed by non leguminous-ones example cereal. Deomampo (1971) showed that growing cereal in upland farm is not very promising. The crops should be combined with other crops, possibly leguminous vegetables. Francis and Clegg (1990) emphasized that crop rotation influences plant production by affecting soil fertility and survival of plant pathogen, physical properties of soil, soil erosion, soil microbiology and prevalence of nematodes. Webster and Wilson (1980) and Dent (1991) also asserted that rotation of vegetable crops as means of maintaining soil fertility using an appropriate sequence of crops used in rotation and produced better average yield than continuous cultivation of the same crop without the need for additional fertilizers.

Tei-Muno (1991) and Sinnadurai (1992) reported that crop rotation provides efficient use of land and soil resources, a high and stable productivity and reduced labour requirement. Dent (1991) asserted that rotation would often be very important for maximizing yield in using crops that have different rooting habits and hence demand different soil layers. Although cultivated plants absorb the same nutrients from the soil, there is considerable variation in the quantities they use of any given kind. Undue depletion of any one nutrient is checked by practicing rotation (Mulongoy *et al.*, 1993). Addo Quaye *et al*. (1993) indicated that rotation allows for diversification of cropping and thereby reduces the risk of failure. They indicated that by alternating deep and shallow rooted crops, crop rotation would allow for more utilization of nutrients at all horizons. Rice *et al.* (1993) also asserted that vegetable rotation increases the efficient use of soil nutrients. They added the shallow rooted vegetables like cabbage and lettuce should be followed by deep-rooted crops like tomato, sweet pepper, and okro in order to improve the utilization of nutrients at different soil levels. In addition, vegetables from the same plant family should not be grown in the same location during the same year.

2.3.2 Profit Maximization

Addo-Quaye *et al*. (1993) reported that crop rotation gave higher gross returns per unit labour employed during labour searching period. They showed that rotation allows for efficient use of labour and resources on the farm and reduces periods of idleness. Another benefit from crop rotation as indicated by Ware and McCollani (1959) is a high gross margin which is realized because under a well-planned rotation there is no need to use inorganic fertilizers which are very costly.

Rausen (1997) reported that if a farmer disobeys rotational requirements and controls the consequences like pests, diseases, weeds and declining soil fertility to some extent with pesticides and organic fertilizers, it will often not be economic since most small scale farmers do not have access to these inputs. Webster and Wilson (1980) working in Bida and Samara in Nigeria on rice, mucuna, okro rotation found that the appropriate sequence of crops used in a rotation can produce better average yields than continuous cultivation of the same crop without the need for additional fertilizers.

2.3.3 Insurance against uncertainties and vagaries of the weather

Stability of production is another advantage of rotation, which is inline with Singh and Emdem (1979) who stated that an epidemic attack of insect pest or disease kills only one crop and the farmer is always compensated. Fisher (1977), Jodha (1979) and Norman (1992) reported that rotation offers insurance against uncertainties and vagaries of the weather on crop yield as all crops do not fail under adverse climatic conditions, and farmers get some crop instead of losing the entire crop.

Kwarteng and Towler (1994) showed that there is less variability of production over seasons under different conditions, for when one crop fails, grows poorly or is damaged by pests or diseases, there is compensation by the unaffected crops. Onwueme (1982) in a 3-year okro rotation experiment practiced in Egypt reported that, the growing of one crop means the demand of labour occurs during peaks of production resulting in competition. Labour demand is more evenly spread if many crops are grown simultaneously. They further reiterated that crop rotation where the field is divided into several plots offers the farmer some insurance against crop failure and enables him to spread out labour needs. Yayock *et al.* (1988) reiterated that several socio-economic advantages also exist in rotation, including the spread of available labour and the spread of economic risk on the diversification of unavailable raw materials.

2.3.4 Increased production on a given land

One of the first principles of rotation is that, one crop will not be allowed to follow another of the same kind on the same soil. The basis of this principle is that although all cultivated plants absorb the same nutrient from the soil, there is considerable variation in the quantities they use from any given land. Undue depletion of any one nutrient is checked by practicing rotation. They further reiterated that peas and beans incorporation in rotation add nitrogen to the soil.

Youdeowei *et al*. (1995) working on vegetable rotation system reported that the single cropping rotation practiced allow operators of small scale farm an opportunity to produce a second crop during a single season. They indicated that although the rotational cropping system offered more efficient use of land, higher yields and profits were more than some instances of mono cropping, the system demand timely and careful management.

Deomanopo (1971) showed that the returns per unit area of vegetables grown seem attractive to augment farmers' income if it is combined with other crops such as rice. Growing of rice alone in upland farms is not promising. Thompson and Kelly (1959) reported that cropped plants have effects on those that follow. In the experiment at Rhode Island experimental station, it was shown that, mangles, rutabagas, cabbage and buckwheat had a marked depression on the yield of onions that followed. On the other hand, the yield of buckwheat was highest following rutabagas.

2.3.5 Weed Suppression

Rotation suppresses weeds and consequently reduces the number of weeding times considerably (Kasasian, 1971; Carson, 1975). The spreading canopy of beans sown under cereal smothers weeds and makes further weeding unnecessary (Summerfield *et al.*, 1974; Raemaekers, 2001). A report from IITA (1977) showed that uncontrolled weeds reduced the yield of cowpea by 68 percent.

Fordham *et al*. (1985) reported that soil which are not covered by crops are more likely to develop weeds canopies, to loose water by evaporation and to suffer damage during heavy rainfall or irrigation. Ogden (1999) showed that alternating shallow rooted plant like cabbage or lettuce with deep-rooted crop like tomato or squash in a rotation reduced by the root of the plant thus loosening the soil that would otherwise have been done with the hand.

Carsky *et al.* (1998) noted that mucuna suppressed weeds through its physical presence on the soil surface since weeds require light to germinate and carry out photosynthesis.

Temu and Aune (1989) indicated that, the presence of dense cover reduces light availability and thus prevents weed seeds from germination and growth. Carsky *et al.* (1999) and Boa-Amponsem *et al.* (1998) showed the suppressive effects of mucuna being able to control both nut grass (*Cyperus rotundus*) and spear grass (*Imperata cylindrica*) in the tropics. Boa- Amponsem *et al.* (1998) reported that mucuna as green manure plant may also release toxins which have allelopathic effects on growth of the neighbouring plant thus suppressing weeds. It was also reiterated by Feeding the Future (2001) that after one cycle of growing mucuna as sole crop in many instances, abandoned weeds infested fields, *Impereta* infestation was reduced by 90%. After two or three cycles it was eliminated.

Akobundu and Poku (1984) reported that mucuna in rotation was the effective control method for *Imperata cylindrica* in a company with herbicides 19 weeks after treatment. Boa-Amponsem and Osei-Bonsu (2001) also asserted that prolonged soil coverage is also required for effective control of noxious weeds such as spear grass.

2.3.6 Reduction of pest incidence

Insect pests attack all stages of development and parts of vegetables in the field. In certain cases they cause substantial yield reduction in the form of reduced stand, reduced leaf and fruit set and quality, reduced market value and even reduced shelf life or stability (Braimah, 1998). Dupriez and De Leener (1992) reported that crop rotation practice in Sahel region with eggplant, cowpea, groundnut and okra grown in that order disinfected the soil and the nematodes died in large numbers. They further indicated that plants from different families grown in succession eradicated the spores and cyst of pests which live in the soil and those that are not very mobile.

Wright (1984) and Raemaekers (2001) showed that rotation with crops other than vegetables reduced the level of infestation of root-knot nematodes to carrot which is more susceptible to it. Rotation has been shown to be effective against Colorado potato beetle (*Leptinotarsa decemlineata*) by Lashomb and Ng (1984) and Wright (1984). They observed 2 different sites on Long Island that with the rotation of potato and wheat the oviposition and first appearance after the beetle were delayed when compared with unrotated potato field. This delay was attributed to physical and environmental barriers that showed emigration from the wheat by the over wintering adults (Lashomb and Ng, 1984).

In a similar study by Wright (1984) early season adult densities were reduced by 95.8% in three out of four comparisons in 1982 and 69.5% in two out of three comparisons in 1983. This effect was not however detectable after the first larval generation but meant that on the average farmers used one less than the early season spray on the rotation fields. Crookston *et al*. (1991) indicated that in Europe, typical rotation involving grasses, legumes and root crops have been used to control wine worms (*Agrots spp*). Owusu-Ansah *et al.* (1998) reported that rotation prevented build up of pests. They indicted that when roots and tubers with cereals, pulses or vegetables were rotated, the transfer of pest was avoided. Dzietror (1984) reported lower incidence of pest attack on crop compensating for less of the other crop thus leading to stability of yield. He further reiterated that rotation reduces the incidence of toxics and efforts that one required in controlling pests which are a major constraint in crop production. Dupriez and De Leener (1992) indicated that rotation is used to eliminate *Pseudomonas*, the bacterium causing late potato blight. They reported that when species resistant to *Pseudomonas* for example, maize, beans and peas are planted; the bacterium has no food and dies out after sometime.

2.3.7 Reduction of disease incidence

Boa-Amponsem and Osei-Bonsu (2001) reported that it is very important to embark on a crop rotation programme in no-till farming. This will make it possible to break disease cycles and therefore eliminate or reduce their adverse effects on crop performance. Keswani and Ndunru (1980) comparing monoculture beans with beans grown in rotation with cabbage found a lower incidence of diseases in the rotation. Messian (1992) noted that the growth of *mycelium* of *Sclerotium* species at soil levels was inhibited when nitrogen was made available by the cowpea in the rotation. Yayock *et al*. (1988) reported that crop rotation reduced the incidence of diseases. They reiterated that soil borne fungi, bacteria and viral diseases are often plant species specific so by rotating crops there is a tendency to prevent the pathogens from completing their life cycle. Dupriez and De Leener (1992) indicated that rotation was used to eliminate *Pseudomonas* causing late potato blight disease. They also added that when species resistant to *Pseudomonas* for example okra, beans and peas are planted; the bacterium has no food and dies out after some time.

2.3.8 Erosion Control

A further advantage associated with crop rotation relates to improvements in soil structure with a consequent reduction in erosion (Yayock *et al*., 1988). Youdeowei *et al*. (1995) noted that differences in cultivation methods due to rotation controls soil erosion. They indicated that crops which cover the soil slowly (e.g. pepper) encourage erosion and should not be grown continuously in the same field.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 LOCATION

The experiment was conducted at the Department of Horticulture, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi (06^0 43` N,O1$^0$36`W) from February, 2003 to February, 2005.

3.2 EXPERIMENTAL SITE

The experimental area was in the past cultivated to other vegetables like tomato, cabbage, vegetable jute, okra and garden eggs and was left fallow for 6 months before being used for the experiment. The site falls within the rainfall pattern of the semideciduous forest zone with a bimodal rainfall regime of about seven (7) months and 4-5 months dry period.

Before the start of the experiment and at the end of each cropping period, soil samples were taken at a depth of 0-20 cm from all the experimental plots. These were bulked and composite sample taken to analyse for pH, organic matter content, total nitrogen, available P_2O_5 and water soluble K_2O. Similarly soil samples were taken to assess nematode incidence at the beginning and the end of each experiment.

The soil of the experimental area was of Akroso series (Ablor,1972) in the classification of forest ochrosols which was predominantly deep, well-drained and moderately well drained soil with good water holding capacity.

3.3 THE ROTATION

The field was divided into four blocks representing the four locations where the initial survey was carried out and the crop combinations were determined. The locations were Kutre/ Mpatapo and Derma in the Brong Ahafo Region and Kofiase and Offinso in the Ashanti Region. The blocks were further divided into plots measuring 3 m x 2.5 m where each plot contained a specific crop. After harvesting the first crop, the plots were planted with different crops according to the planned succession until the 4th cropping within the year after which the project ended.

3.4 PLANTING MATERIALS

Seeds of okro (*Abelmoschus esculentus*), tomato(*Lycopersicon esculentum*), carrot(*Daucus carota*), sweet pepper(*Capsicum annum*), hot pepper(*Capsicum frutescens*) and cabbage(*Brassica oleracea var capitata*) to be used for the experiment were obtained from AGLOW Agricultural Products Ltd. in Kumasi in the Ashanti Region. Mucuna (*Mucuna pruriens)* seeds were also obtained from Ghanaian-German Agricultural Development Project (GTZ/SFSP), Sunyani in the Brong Ahafo Region.

3.5 EXPERIMENTAL DESIGN AND TREATMENTS

A randomized complete block design (RCBD) experiment replicated four times was used.

The treatments were the order of succession of vegetable crops for the four locations:

O - Okra

G – Garden eggs
CA – cabbage

S – Sweet pepper

H – Hot pepper

M – Mucuna

C – Carrot

T – Tomato

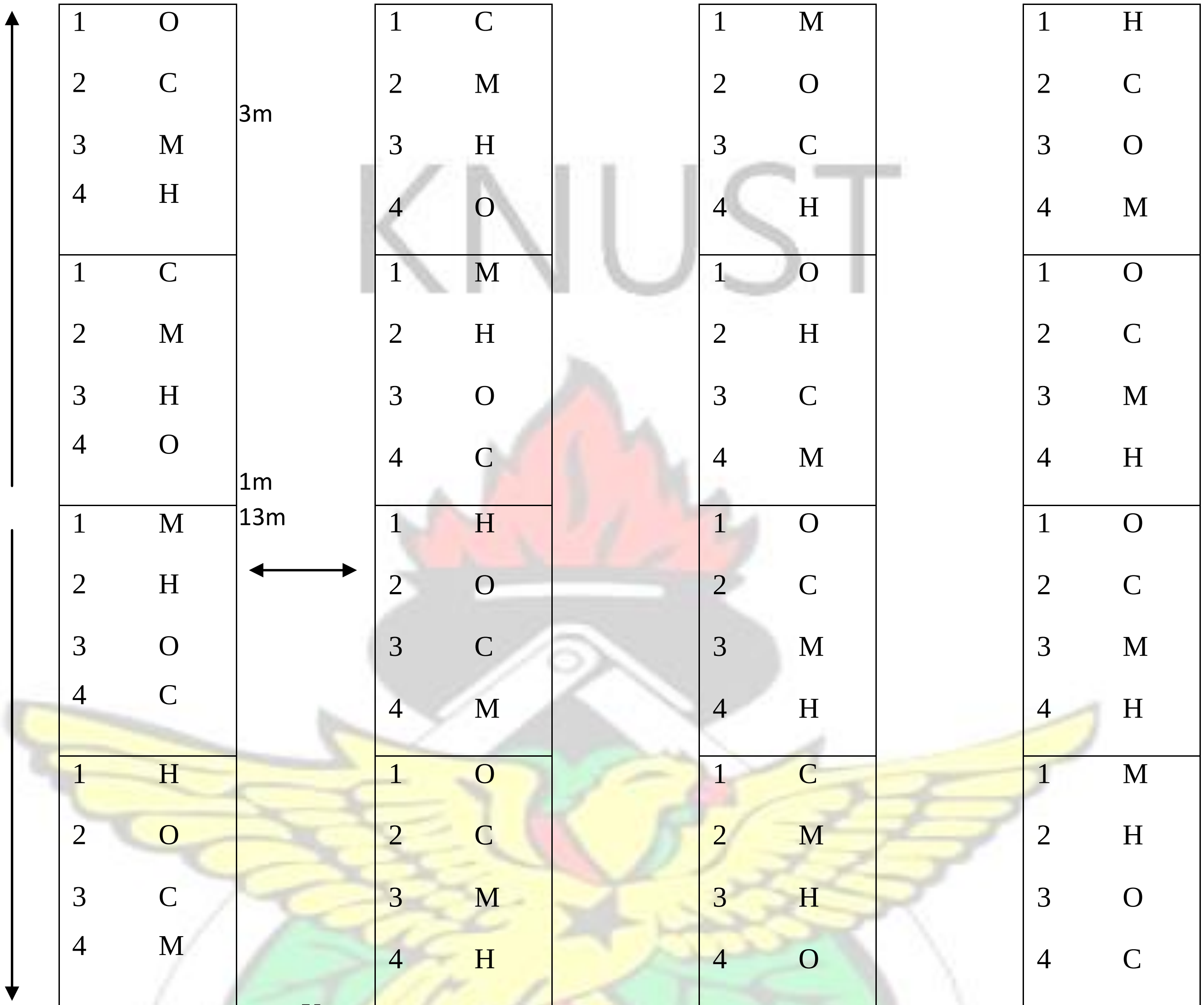
A control field using the same crops without rotating them till the end of the project was used.

3.6 LAND PREPARATION AND EXPERIMENTAL LAYOUT

The field was slashed in January, 2003 and ploughed in February, 2003. Lining and pegging were done. The entire experimental area measuring 70 m X 36 m was divided into four blocks each replicated four times in the main rotation and control experiments giving a total of 128 plots. Each block represented the locality at the on-station with the same size for the control experiment which was not rotated. There was 1m alleyway between plots and blocks. The treatments were allocated to plots based on the succession of crops, as indicated in Figures 1a to 1d.

70m

2.5m



Key:

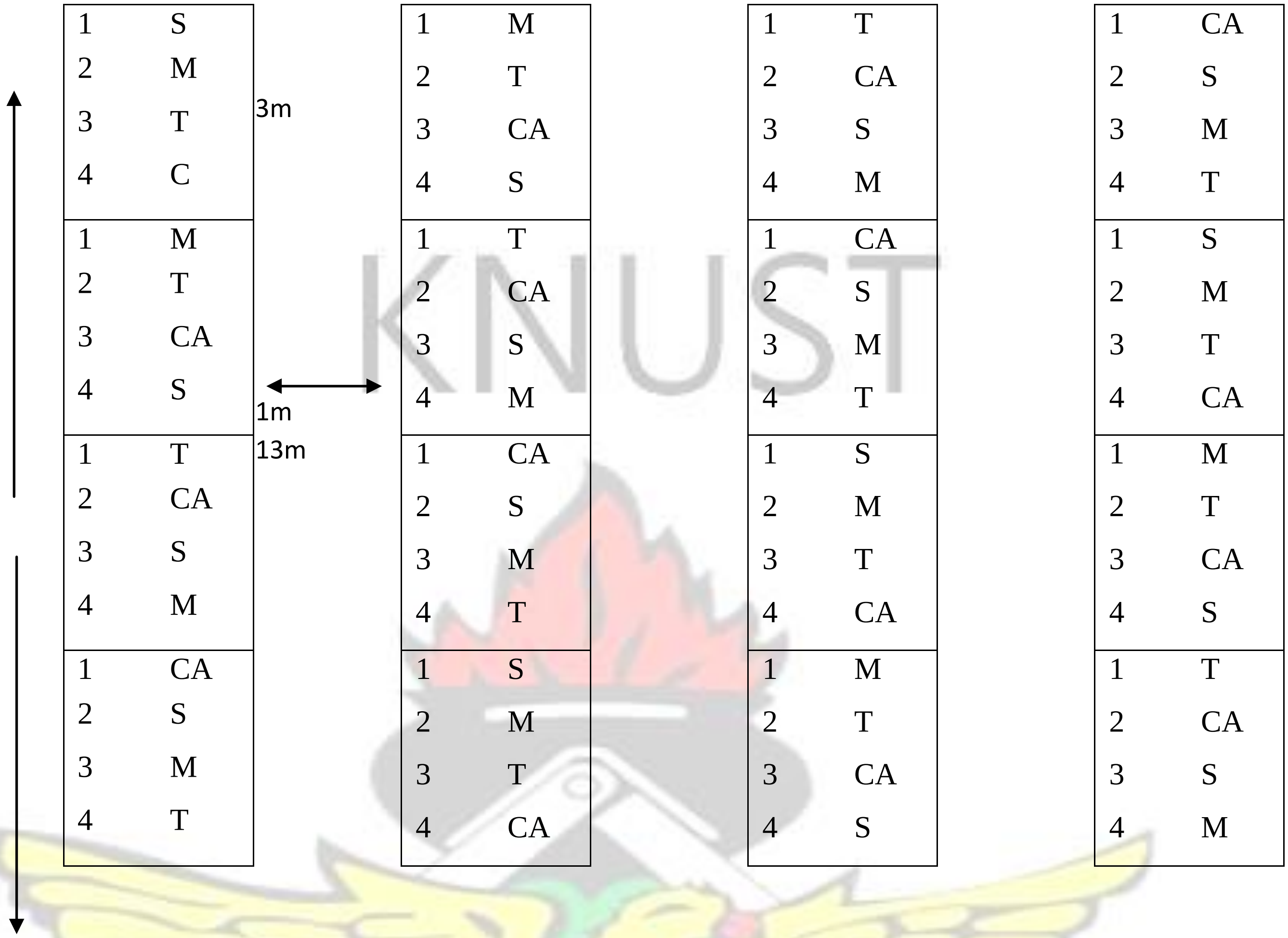
C = Carrot   O = Okra

M = Mucuna   H = Hot pepper

Figure 1a: Experimental Layout of the Succession For Kutre/Mpatapo

70m

2.5m



Key: T = Tomato

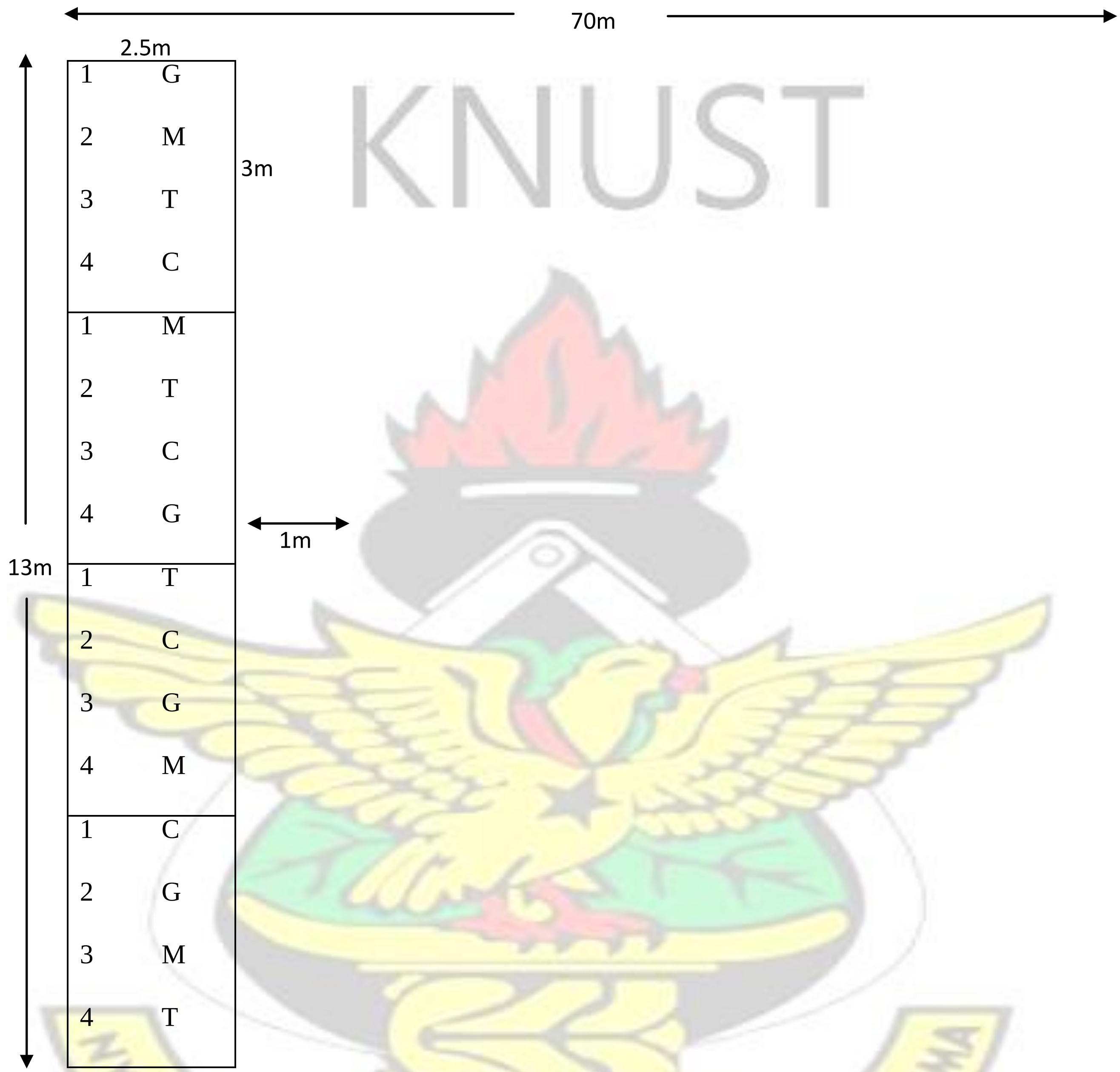
CA = Cabbage

S = Sweet pepper

M = Mucuna

Figure 1b: Experimental Layout of the Succession for Derma

1	M	1	T	1	C
2	T	2	C	2	M
3	C	3	G	3	T
4	G	4	M	4	G
1	T	1	C	1	G
2	C	2	G	2	M
3	G	3	M	3	T
4	M	4	T	4	C
1	C	1	G	1	M
2	G	2	M	2	T
3	M	3	T	3	C
4	T	4	C	4	G
1	G	1	M	1	T
2	M	2	T	2	C
3	T	3	C	3	G
4	C	4	G	4	M



Key: G = Garden egg

T = Tomato

C = Carrot

M = Mucuna

Figure 1c: Experimental Layout of the Succession for Kofiase

1	C	1	M	1	T
2	M	2	T	2	CA
3	T	3	CA	3	C
4	CA	4	C	4	M
1	M	1	T	1	CA
2	T	2	CA	2	C
3	CA	3	C	3	M
4	C	4	M	4	T
1	T	1	CA	1	C
2	CA	2	C	2	M
3	C	3	M	3	T
4	M	4	T	4	CA
1	CA	1	M	1	M
2	C	2	T	2	T
3	M	3	C	3	CA
4	T	4	CA	4	C

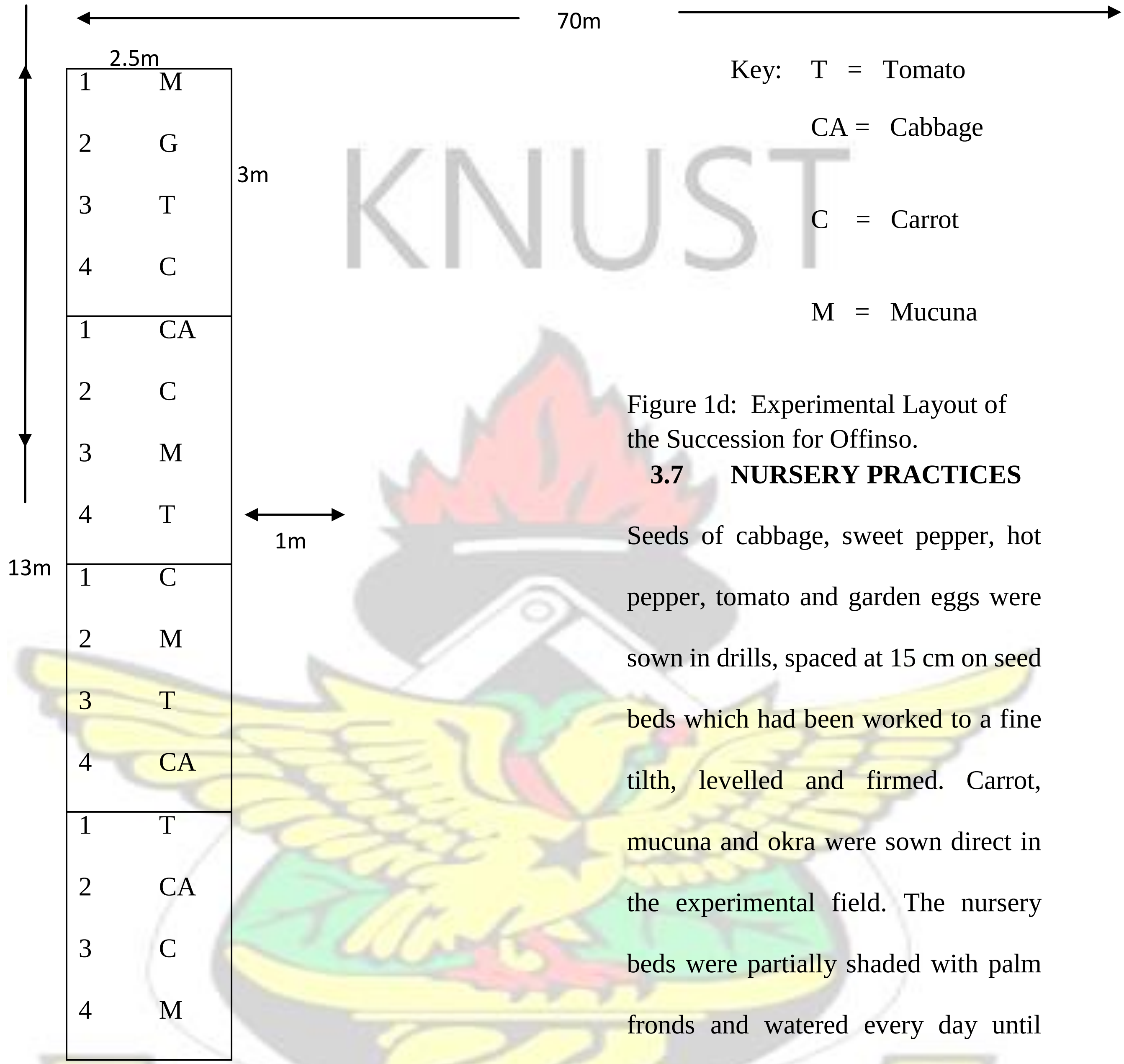


Figure 1d: Experimental Layout of the Succession for Offinso.

3.7 NURSERY PRACTICES

Seeds of cabbage, sweet pepper, hot pepper, tomato and garden eggs were sown in drills, spaced at 15 cm on seed beds which had been worked to a fine tilth, levelled and firmed. Carrot, mucuna and okra were sown direct in the experimental field. The nursery beds were partially shaded with palm fronds and watered every day until seedlings emerged. The seedlings were pricked out 8 days after sowing. Hand picking of weeds, occasional stirring of the soil, diseases and pests control and watering were some of the cultural practices carried out.

3.8 TRANSPLANTING

Healthy and uniform four-week old seedlings were transplanted onto the plots at the following recommended spacing: Tomato – 90 cm x 60 cm

Garden eggs – 90 cm x 60 cm

Hot pepper – 90 cm x 60 cm

Sweet pepper – 60 cm x 60 cm

Cabbage – 60 cm x 60 cm

3.9 SOWING OF CARROT, OKRA AND MUCUNA

Direct sowing of carrot, okra and mucuna seeds was done two weeks before planting the seedlings that needed transplanting. The carrot was drilled at 30 cm between rows and later thinned to 5 cm between plants.

The mucuna was spaced 60 cm x 60 cm at the rate of 3 seeds per stand and thinned to one seedling after germination. It was incorporated into the soil at the visible flower bud stage. Okra was also spaced at 60 cm x 60 cm with 3 seeds per hill and thinned to one seedling after germination.

3.10 CULTURAL PRACTICES

3.10.1 Weed identification and weed control

Weeds were identified on each plot two weeks after transplanting. A metre square (m^2) quadrant was used for each treatment and the dry matter of the weeds within the quadrant was determined after which the plots were hoed to get rid of the weeds.

3.10.2 Irrigation

The sprinkler irrigation was the main source of moisture as the project started during the dry season. Supplementary irrigation was applied using a rubber hose connected to a tap. Rainfall was also a source of moisture.

3.10.3 Pests and diseases control

Insecticides such as Karate 25EC (Lambda cyholathrin) was used to spray from two weeks after transplanting at the rate of 2 ml/litre of water. A fungicide, Dithane M-45 (Mancozeb) was used at the rate of 0.15 gm/litre of water at separate intervals. Major insect pests were observed, identified and the extent of damage scored. Samples of infected plants were taken to the Plant Pathology laboratory at the Faculty of Agriculture, KNUST for examination and identification. The infected plants were rogued, replaced and counts were made on the plant survival after the attack.

3.10.4 Fertilizer application

Recommended rates of fertilizer were given to all the plants as basal application two weeks after transplanting for faster establishment since the field had been intensively cropped.

3.11 PARAMETERS STUDIED

3.11.1 Reproductive Growth Parameters

These included days from transplanting to 50% flower bud appearance, flower opening and fruit set.

3.11.2 Harvesting and yield 3.11.3 Fruit weight

All fruits were weighed immediately after harvesting with a weighing scale. The weight obtained from each plot was divided by the number of surviving plants per plot to obtain average fruit weight per plant. Yield per plot was projected to per hectare basis.

3.11.4 Number of fruits/roots

Harvesting was done at three days intervals. Fruits/roots were counted and recorded for each plot. The total numbers of fruits/roots were divided by the number of surviving plants per plot to obtain the fruit/root number per plant. The unmarketable fruits/roots included those that were rotten, insect damaged, diseased, malformed, too small and wrinkled while the marketable fruits/roots were wholesome and disease-free.

Yield data included:

1. total number of fruits/ha
2. total weight of fruits(t/ha)
3. number of marketable fruits/ha
4. weight of marketable fruits (t/ha)
5. number of unmarketable fruits/ha
6. weight of unmarketable fruits (t/ha)

3.12 NEMATODE EXTRACTION AND IDENTIFICATION

Soil samples were taken from the experimental plots and their periphery for nematode extraction and identification at the termination of each harvest. The extraction and identification procedures are outlined in Appendix 11.

Total number of nematodes before planting and after harvest was determined.

3.13 SOIL NUTRIENT ANALYSES BEFORE AND AFTER EACH EXPERIMENT

Soil samples were taken from the experimental plots at 0-20 cm depth from two locations to determine nitrogen, available water soluble potassium, phosphorus, pH of the soil and exchangeable cations (Ca, Mg K and Na).

3.14 VALUATION OF MARKETABLE FRUITS/ROOTS

During the harvesting period, the main unit prices of one kilogram of the fruits /roots at farm gate level were obtained from the Policy, Planning, Monitory and Evaluation Department (PPMED) in the Ministry of Food and Agriculture (MOFA), Kumasi. Based on this the marketable fruits were priced per kilogram of the fresh fruit/roots till termination of harvest. The production cost, income and profit based on the farm gate price is outlined in Appendix 9.

3.15 ANALYSIS OF DATA

Analysis of variance was performed on all data collected. The LSD Test was used to assess significant differences between treatment means.

3.16 ECONOMIC ANALYSIS

Economic analysis was affected by the method of partial budgeting (identifying variable inputs and quantifying and placing monetary values on them).

CHAPTER FOUR

4.0 RESULTS

Effects of cropping patterns or systems on soil fertility, weed population, nematode infestation and yield were studied for four planting periods. The results of the study are presented in Tables 4.1 to 4.24.

4.1 EFFECT OF CROPPING SYSTEM ON SOIL FERTILITY

Table 4.1 shows the soil organic carbon contents under the eggplant, tomato, mucuna and carrot succession at the initial stages of the experiment, under continuous cropping as well as in rotation. At the initial stage of the rotation soil organic carbon content was low and ranged from 0.91% under tomato to 1.17% under carrot. These levels are not significantly different. Continuous cropping of these vegetables and mucuna generally improved soil organic carbon content above 1.0% except under carrot (less than 1.0%)

Table 4.1 Soil organic carbon contents under egg plant, tomato, mucuna and carrot grown in rotation

	Soil organic carbon (%)		
Treatments	Initial	Continuous cropping	Rotation
Eggplant	0.95	1.17	1.73
Tomato	0.91	1.16	1.59
Mucuna	0.98	1.11	1.54

Carrot	1.17	0.99	1.62
LSD		0.22	0.19

The crop combinations used are as follows:

- Carrot/eggplant/ mucuna/tomato
- Cabbage/sweet pepper/mucuna/tomato
- Mucuna/hot pepper/okra/carrot
- Tomato/cabbage/carrot/mucuna

The initial soil organic carbon level in the various crop combinations had an average value of 0.9%. Soil organic carbon levels improved in all crop combinations when they were put under continuous cropping. Organic carbon level ranged from 0.81 to 1.57% in the first crop combination, 0.91 to 1.44% in the second, 1.27 to 1.29% in the third and 0.99 to 1.17% in the fourth crop combination. Rotation of crops within each crop combination further improved soil organic carbon contents in the first (0.46%) and fourth (0.51%) crop combination. The second and third crop combination had slight increment in soil organic carbon content i.e. 0.19 and 0.23%. From the results obtained, the crop rotation system showed the highest soil organic carbon improvement in the carrot/eggplant/ mucuna/tomato combination. This was followed by the mucuna/hot pepper/okro/carrot combination, which had an average soil organic carbon increment of 0.46% in all the treatment combinations. Mucuna which was believed to improved soil organic carbon content did not show any significant improvement over the other crops. In two of the crop combinations soil organic carbon under mucuna was the least (i.e. 0.8% and 0.95% for the first and second crop combinations respectively)(Table 4.1 and Fig. 1)

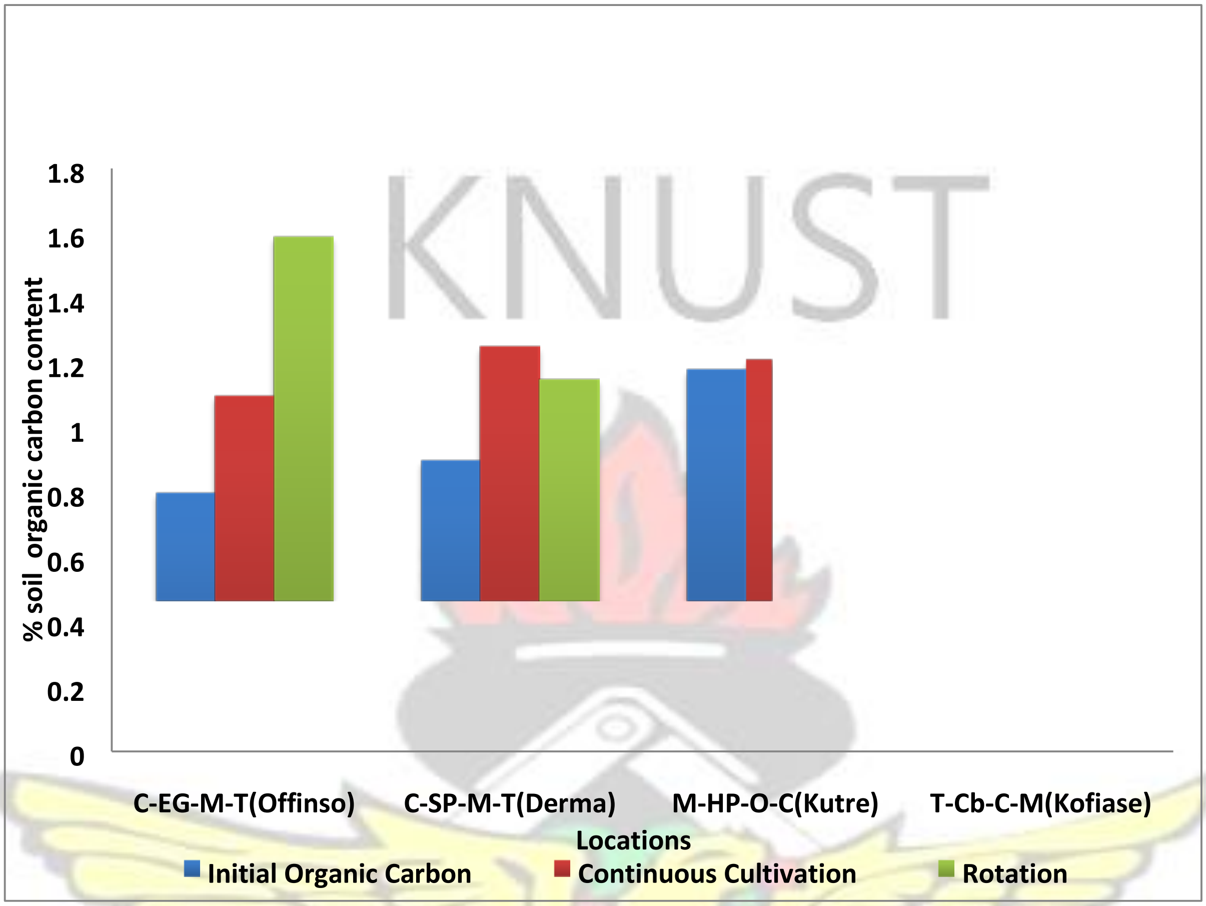


Fig. 1: Soil organic carbon dynamics under rotation and continuous cultivation of four vegetable combinations

4.2 EFFECT OF CROPPING SYSTEM ON SOIL pH

Table 4.2 Soil pH values under sweet pepper, mucuna, tomato and cabbage.

	Soil pH		
Treatment	Initial	Continuous cropping	rotation
Sweet pepper	4.96	5.91	5.91
Mucuna	4.91	6.31	6.32
Tomato	4.87	5.10	5.95
Cabbage	4.83	5.40	6.01

LSD	-	5.40	0.58

The initial pH levels of the soils in the rotations were compared with the last rotation. The result indicated that the pH level before application of the treatments ranged from 4.83 under cabbage to 4.96 under sweet pepper. These values are not significantly different.

Under the sweet pepper/ mucuna/tomato/cabbage crop combinations continuous cropping improved soil pH level as compared to the initial soil pH values. However, general rotation improves soil pH values especially under tomato (i.e. from 5.1 to 5.59) and cabbage (5.4 to 6.01) (Table 4.2).

Table 4.3 Soil pH values under mucuna, okra, carrot and hot pepper

	Soil pH		
Treatment	Initial	continuous cropping	rotation
Mucuna	5.34	5.57	6.26
Okra	5.17	6.04	6.49
Carrot	4.82	5.85	6.38
Hot pepper	5.30	5.66	5.79
LSD		0.54	0.55

As shown in Table 4.3 above, the hot pepper/mucuna/okra/carrot crop combination also followed a similar trend as in Table 4.2.Cropping of the vegetables and mucuna generally improved soil pH. This was most prominent under okra and carrot. Rotations improved soil pH under all crops. In all the vegetable and legume combinations, soil pH improved most under rotation as compared to continuous cultivation.

4.3 EFFECT OF CROPPING SYSTEM ON AVAILABLE PHOSPHORUS

Table 4.4 Soil available Phosphorus under mucuna, carrot, okra and hot pepper.

	Available phosphorus mgkg^{-1}		
Treatment	Initial	Continuous cropping	Rotation
Mucuna	16.68	13.55	16.63
Carrot	15.00	14.83	17.66
Okra	13.58	12.35	15.10
Hot pepper	14.90	13.90	18.44
LSD		0.54	1.59

Table 4.5 Soil available phosphorus under egg plant, tomato, carrot and mucuna

	Available phosphorus mgkg^{-1}		
Treatment	Initial	continuous cropping	rotation
Eggplant	15.00	13.55	16.63
Tomato	14.83	13.50	18.93
Carrot	12.35	17.60	19.63
Mucuna	13.01	16.95	17.63
LSD		2.70	2.59

Table 4.6 Soil available phosphorus under sweet pepper, mucuna, tomato and cabbage.

Available phosphorus mgkg^{-1}

Treatment	Initial	continuous cropping	rotation
Sweet pepper	12.25	12.00	14.73
Mucuna	15.40	12.20	16.40
Tomato	12.60	10.28	12.65
Cabbage	11.95	16.93	12.90
LSD		0.65	1.20

Table 4.7 Soil available phosphorus under cabbage, tomato, carrot and mucuna

	Available phosphorus mgkg^{-1}		
Treatment	Initial	continuous cropping	rotation
Carrot	13.27	12.00	14.73
Mucuna	15.40	16.20	16.40
Tomato	12.20	10.28	12.65
Cabbage	12.00	11.93	12.90
LSD		6.70	5.21

Table 4.8 Mean soil phosphorus levels under the initial soil level, continuous cultivation and rotation.

	Available phosphorus (mg/kg/ soil)		
Crop combination	initial P	continuous cropping	rotation
Egg plant/tomato/carrot/mucuna	13.8	15.4	18.0
Sweet pepper/mucuna/tomato/cabbage	13.1	12.0	14.0

Carrot/mucuna/tomato/cabbage	13.2	12.6	14.2
Hot pepper/carrot/okra/mucuna	15.3	13.7	16.6

Tables 4.4, 4.5, 4.6 and 4.7 show the effects of continuous cropping and rotation of vegetables and legumes (mucuna) on soil available phosphorus levels. The initial available soil phosphorus content was an average value of 13 mg/kg for all crop combinations.

Continuous cultivation resulted in slight decline in soil available phosphorus content in most cases as shown in Tables 4.4, 4.5, 4.6 and 4.7. It was more evident under egg plant and tomatoes where a lot of fruits were harvested from the farm. However, rotation of crops improved available phosphorus level in the soil under most crops. Mean soil available phosphorus levels under the various crop combinations are shown in Table 4.8. In crop rotation, the highest value for available phosphorus was 18 mg/kg under eggplant/tomato/carrot/mucuna crops combination. The lowest available phosphorus levels were observed in the sweet pepper/tomato/cabbage/mucuna and carrot/mucuna/cabbage/tomato rotations.

4.4 EFFECTS OF CROPPING SYSTEM ON SOIL AVAILABLE POTASSIUM

Table 4. 9 Soil available potassium under okra, hot pepper, carrot, and mucuna

	Available potassium $mgkg^{-1}$	
Treatment	Continuous cropping	Rotation
Okra	129.3	148.0
Mucuna	139.3	129.9
Hot pepper	117.6	124.0

Carrot	127.6	127.9
LSD	27.1	48.2

Table 4.10 Soil available potassium under tomato, sweet pepper, cabbage and mucuna

	Available potassium $mgkg^{-1}$	
Treatment	Continuous cropping	rotation
Tomato	137.9	162.2
Mucuna	159.4	132.7
Sweet pepper	128.0	123.2
Cabbage	100.3	102.4
LSD	45.6	33.4

Table 4.11. Soil available potassium under tomato, egg plant, carrot and mucuna

	Available potassium $mgkg^{-1}$	
Treatment	Continuous cropping	rotation
Tomato	129.3	131.4
Mucuna	139.3	99.9
Egg plant	117.6	151.8
Carrot	127.6	135.8

LSD	51.2

Table 4.12. Soil available potassium under tomato, cabbage, carrot and mucuna

	Available potassium mgkg^{-1}	
Treatment	Continuous cropping	rotation
Tomato	129.3	151.1
Mucuna	139.3	115.9
Cabbage	117.6	113.4
Carrot	127.6	156.4
LSD		40.0

Table 4.13. Average soil available potassium levels under continuous cultivation and rotation

	Available potassium (mg/kg soil)	
Crops combination	continuous cultivation	rotation
Egg plant/tomato/carrot/mucuna	128.5	129.7
Sweet pepper/mucuna/tomato/cabbage	131.0	130.1
Carrot/mucuna/tomato/cabbage	128.4	134.2
Hot pepper/carrot/okra/mucuna	128.0	132.4

Soil available potassium levels in all the treatment combinations could be described as adequate. In continuous cultivation, available potassium levels were lowest under cabbage (Tables 4.9, 4.10, 4.11 and 4.12) and egg plant in all crop combinations. Available potassium levels were highest when mucuna was continuously cultivated (Table 4.9, 4.10, 4.11, and 4.12).

The mean soil available potassium levels in the crop combinations were higher under rotation than continuous cultivation especially under carrot/ mucuna/tomato/cabbage and hot pepper/carrot/okra/mucuna combinations (Table 4.13).

4.5 SURVIVAL OF GARDEN EGG AND TOMATO PLANTS DURING *SCLEROTIUM* WILT INFECTION

The number of garden egg and tomato plants that survived during *Sclerotium* wilt infection was higher in the continuous cropping fields than in the rotated fields. The other crops were not affected by the disease.

4.6 FFECT OF CROPPING SYSTEM ON NEMATODE POPULATION IN VEGETABLES

Four village cropping systems were simulated in an on-station trial. This was to examine the effect of rotation on vegetable crops with mucuna cropped as soil improver to study several aspect of vegetable production. Nematode population changes in the soil during the rotation were assessed.

Table 4.14 shows the results of the three seasons and the details of Tables 4.14 to 4.16.

At the beginning of the three seasons, that is, the first season under Kutre/Mpatapo, Derma, Kofiase and Offinso, there were no significant differences in the nematode population in all simulated villages. There were also no significant differences between the plots within the rotated plots and those of continuous cropping plots. This was expected since the rotation period was not long enough for the treatments to show their effects. Kutre had 2080 and 2640 nematodes per litre of soil for rotation and non- rotation crops respectively. Even though there were over 500 nematodes more than the rotation plots the difference could not be attributed to the rotation treatments. The rest of the treatments in the other simulated villages showed no significant difference between the rotated and non rotated plots.

Presented in table 4.6.2 are also the second season results from soils of the four simulated villages. There is a rise in all the population of the nematodes recorded for the four villages, with no significant difference in the nematode numbers between the villages and within the soil samples of each simulated village. The only significant changes observed were within the simulated Offinso samples where the number of nematodes recorded for the non-rotation plot is double that of the rotation plots. Since the samples were taken after the second season the higher numbers of the nematodes may be due to rise in the free-living nematodes resulting from rotten mucuna mulch.

Table 4.14 Nematode population changes in vegetable rotation trials in each simulated villages having rotated (R) and no rotation (NR) systems (First/ planting season).

	Kutre/Mpatapo	Derma	Kofiase	Offinso

Treatments	Rotation	No Rotation	Rotation	No Rotation	Rotation	No Rotation	Rotation	No Rotation
Mucuna	470	440	920	620	570	683	680	810
Hot Pepper	590	660						
Carrot	420	550			580	830	680	250
Okra	600	890						
Tomato			630	620	490	650	530	620
Cabbage			580	700			940	840
Sweet Pepper			780	600				
Garden Egg					680	670		

Simulated villages

Table 4.15 Nematode population changes in vegetable rotation trials with each simulated village having rotated (R) and no rotation (NR) systems (second season/planting)

Simulated villages

Treatments	Kutre/Mpatapo		Derma		Kofiase		Offinso	
	Rot.	NR	Rot.	NR	Rot.	NR	Rot.	NR
Mucuna	1060	1330	1300	1280	260	1200	810	1400
Hot Pepper	1040	1000			1010	250	1290	1370
Carrot	960	1040						
Okra	1360	1240						
Tomato		830	1080	910	980	620	1100	1250
Cabbage			700	1040			840	1120
Sweet Pepper			700	1040				
Garden Egg					670	1080		

Table 4.16 Nematode population changes in vegetable rotation trials with each simulated villages having rotated (R) and no rotation (NR) system (Third season/planting)

	Simulated villages							
	Kutre/Mpatapo		Derma		Kofiase		Offinso	
Treatments	Rot.	NR	Rot.	NR	Rot.	NR	Rot.	NR
Mucuna	620	840	330	590	250	300	670	910
Hot Pepper	400	580						
Carrot	620	830		410	730	460	540	840
Okra	320	750						
Tomato			530	510	470	910	490	740
Cabbage			380	650			470	720
Sweet Pepper			330	590				
Garden Egg					460	610		

The summarized results from the end of the third season are presented in Table 4.17. These results show that the rotation had positive effects on the number of nematodes. The number of these pests appeared to be significantly lower in the rotated plots than the non rotated plots in all the villages. Locations such as Kutre and Kofiase had as much as double the nematode numbers in non-rotated plots as that recorded for rotated plots.

Table 4.17 NEMATODE POPULATION CHANGES IN VEGETABLE ROTATION TRIALS IN EACH SIMULATED VILLAGE (R) HAVING MAIN PLOTS AND NO ROTATION PLOTS (NR) SUMMARY OF TREATMENTS

TREATMENT	VILLAGES

	Kutre/Mpatapo		Derma		Kofiase		Offinso	
	R	NR	R	NR	R	NR	R	NR
1ST SEASON	2080	2640	2910	2540	2570	2910	2890	2520
2ND SEASON	4420	4610	3760	4510	3600	4180	2520	4910
3RD SEASON	1640	3000	1740	2330	1540	3360	1860	2420

4.7 EFFECT OF CROPPING SYSTEM ON YIELD PARAMETERS OF VEGETABLES

Table 4.18 shows the marketable, unmarketable and total yield of okra in rotation and non-rotation for four plantings. There was no significant difference between rotation one and two but marked significant difference between rotation one and four for the marketable yields. However, rotation four recorded the highest marketable yield of 5810.56kg/ha. The total marketable yield was significantly higher than the marketable yield of the continuous cropping fields. The marketable yield for the continuous cropping field was significantly different from other plantings with a value of 1251.13kg/ha.

Rotation Plantings	No Rotation Marketable yield (kg/ha)	No Rotation unmarketable yield. (kg/ha)	Total	Rotation marketable yield (kg/ha)	Rotation unmarketable yield (kg/ha)	Total
1st Planting	2034.72±371A	347.90±66B	2382.62	3019.24±286B	131.90±59A	3151.14
2nd Planting	2134.12±378A	41.21±132B	2175.33	3101.05±624B	139.37±48A	3240.42
3rd Planting	2128.15±373A	554.65±98A	2684.59	5128.54±124A	142.69±36A	5271.23
4th Planting	1251.13±665B	159.00±12B	1410.13	5810.56±154A	174.03±64A	6184.59
F	20.43	18.21		2.24	0.21	
Df	3	3		3	3	

P 0.0005 0.0006 0.0002 0.23

Table 4.18. Effect of cropping systems on the yield of okra

***Means in each column followed by the same letter do not differ significantly at the 5% level.**

The highest significant marketable yields were recorded in rotation and the lowest in no rotation plots. The total yield was high in rotation one and very low in rotation four. In the continuous cropping system marketable yields were very low compared to that of the rotational systems of cropping. However, the rotation four showed significant difference between the other three plantings recording a lower value of 1699.95 kg/ha. The marketable and unmarketable yields of continuous cropping in rotation four also showed significant difference between the other three plantings.

Table 4.19 Effect of cropping systems on the yield of carrot

Rotation Plantings	Rotation marketable yield (kg/ha)	Rotation unmarketable yield (kg/ha)	Total	No Rotation Marketable yield (kg/ha)	No Rotation unmarketable yield. (kg/ha)	Total
1st Planting	3024.92±507B	1626.62±110A	4651.55	666.65±82B	132.19±10B	798.84
2nd Planting	3193.92±497A	1300.63±132A	4494.55	670.98±75B	114.77±11B	785.75
3rd Planting	3248.54±428A	1432.45±126A	3780.99	668.31±79B	125.36±56B	793.87
4th Planting	1699.95±253C	999.97±65B	2699.93	963.31±264A	174.11±19A	1837.42
F	1.25	0.48		0.57	5.31	
df	3	3		3	3	
P	0.0002	0.0006		0.001	0.002	

*Means in each column followed by the same letter do not differ significantly at the 5% level.**

Table 4.20 shows the marketable, unmarketable and total yield in both rotation and continuous cropping system. Although rotation showed higher marketable yield than the no rotation plantings there were no significant differences between them. Similarly, rotation recorded a higher unmarketable yield than the other three plantings there was no significant difference. They rather showed marked significant difference between the total yield in first planting and the other plantings in the rotational cropping system. The third planting in the rotation cropping system showed reduced unmarketable yield than in the continuous cropping system.

Table 4.20. Effects of cropping systems on the yield of hot pepper

Rotation Plantings	No Rotation Marketable yield (kg/ha)	No Rotation unmarketable yield. (kg/ha)	Total	Rotation marketable yield (kg/ha)	Rotation unmarketable yield (kg/ha)	Total
1st Planting	3557.88±113A	74.83±28B	3632.72	4260.9±737A	17.77±2A	4278.70
2nd Planting	3746.08±111A	125.84±34A	3871.91	4134.6±275A	19.93±2A	4154.56
3rd Planting	3648.47±112A	84.56±31B	3733.03	4172.3±384A	18.26±2A	4190.56
4th Planting	3083.11±288B	96.77±13B	3179.88	4113.33±32A	25.73±2A	4139.06
f	9.46	7.32		0.57	0.95	
df	3	3		3	3	
p	0.002	0.0006		0.54	0.031	

***Means in each column followed by the same letter do not differ significantly at the 5% level.**

The marketable and total yields of Table 4.21 showed higher yields in the rotation than the continuous cropping system. There were significant differences between the yields in the third planting that recorded the highest yield of 635.2 kg/ha and the other plantings. There was no significant difference between marketable yields in continuous cropping system. There was no significant difference in all the unmarketable yields of the continuous cropping system. The unmarketable yield in the rotational plantings showed significant differences in the second planting compared to the other plantings.

Table 4.21. Effect of copping systems on the yield of sweet pepper

Rotation Plantings	No Rotation Marketable yield (kg/ha)	No Rotation unmarketable yield. (kg/ha)	Total	Rotation marketable yield (kg/ha)	Rotation unmarketable yield (kg/ha)	Total
1st Planting	363.48±119A	68.33±13A	631.81	534.19±13.1B	130.84±8B	565.02
2nd Planting	316.27±94.3A	57.99±11A	374.26	594.49±14.6B	159.2±6.77A	6531.94
3rd Planting	362.57±24.A	62.98±12A	425.55	635.25±25.9A	134.28±29B	669.53
4th Planting	305.15±2A	54.24±7A	359.39	589.36±21.1B	56.69±17B	639.00
F	0.56	3.56		8.65	10.52	
Df	3	3		3	3	
P	0.28	0.13		0.0006	0.001	

***Means in each column followed by the same letter do not differ significantly at the 5% level.**

Table 4.22 shows the marketable, unmarketable and total yields of both rotation and continuous cropping systems. Significant differences were observed in the rotational plantings for marketable and unmarketable yields. Rotations three and one had the highest yield values of 1756.38 and 1203.64 kg/ha respectively. Similarly, Significant differences were shown in the continuous cropping system where the fourth planting had the highest value of 846.05 kg/ha for marketable yield and the second planting had a lower for unmarketable yield (30.51 kg/ha).

Table 4.22. Effect of copping systems on the yield of tomato

Rotation Plantings	Rotation marketable yield (kg/ha)	Rotation unmarketable yield (kg/ha)	TOTAL	No Rotation Marketable yield (kg/ha)	No Rotation unmarketable yield. (kg/ha)	Total
1st Planting	1363.30±453C	1203.64±480A	2566.93	485.65±118B	308.99±82A	
2nd Planting	1387.17±142C	871.98±169B	2259.14	425.66±119B	30.51±82B	456.16
3rd Planting	1756.38±237A	894.14±187B	2740.52	468.95±118B	346.25±82A	815.20
4th Planting	1433.80±255B	224.33±26C	1658.13	846.05±172A	371.66±212A	1217.70
F	11.36	21.65		15.26	9.25	
Df	3	3		3	3	
P	0.0014	0.0008		0.003	0.002	

***Means in each column followed by the same letter do not differ significantly at the 5% level.**

Apart from unmarketable yield in the rotational cropping system, significant differences were observed in the marketable, unmarketable and total yields of both the rotation and continuous croppings. Rotation one had a lower value of 8449.79 kg/ha compared to the others recording over 1000 kg/ha. In the continuous cropping however, the fourth plantings had 5743.1 kg/ha and 1391.0 kg/ha for marketable and unmarketable yields respectively.

Table 4.23. Effect of copping systems on the yield of cabbage

Rotation Plantings	Rotation marketable yield (kg/ha)	Rotation unmarketable yield (kg/ha)	TOTAL	No Rotation Marketable yield (kg/ha)	No Rotation unmarketable yield. (kg/ha)	Total
1 Planting	8449.79±114B	4916.54±153A	13366.3	6766.5±389A	3566±407A	10333.07
2nd Planting	10196.4±394A	4546.8±157A	14743.2	7404.8±657A	3622±322A	11027.39
3rd Planting	12450.4±342A	4752.3±154A	17202.7	6954.2±354A	3486±354A	10440.20
4th Planting	14132.9±328A	598.99±263A	14731.9	5743.1±270B	1391±501B	7134.82
F	5.26	3.76		6.32	12.45	
df	3	3		3	3	
P	0.002	0.06		0.0008	0.001	
st						

***Means in each column followed by the same letter do not differ significantly at the 5% level.**

In Table 4.24 significant differences are shown in marketable and unmarketable yields for both rotational and continuous cropping systems. No significant difference was however recorded in the marketable yield for continuous cropping system. Rotation four showed significantly lower yields of 4673.15 kg/ha than the other plantings. For unmarketable yield, rotation four had the highest value of 6867.82 kg/ha. Similarly, a higher value of 1188.9 kg/ha was obtained for the continuous cropping system.

Table 4.24. Effect of cropping systems on the yield of garden egg

Rotation Plantings	Rotation marketable yield (kg/ha)	Rotation unmarketable yield (kg/ha)	TOTAL	No Rotation Marketable yield (kg/ha)	No Rotation unmarketable yield. (kg/ha)	Total
1st Planting	9676.86±184A	270.62±76B	9947.48464	7235.9±214A	238.23±31B	7474.15
2nd Planting	9137.74±152A	163.99±34B	9301.74078	3827.5±919A	152.57±31B	3980.14
3rd Planting	9457.62±165A	192.35±52B	9649.97	3954.1±754A	192.36±31B	3146.46
4th Planting	4673.15±520B	6867.82±180A	11540.97	1080.60±147A	1188.9±232A	2269.56
F	13.54	0.54		0.3	6.35	
Df	3	3		3	3	
P	0.001	0.004		0.04	0.0008	

***Means in each column followed by the same letter do not differ significantly at the 5% level.**

4.7.1 Effect of cropping systems on pest damage in okra

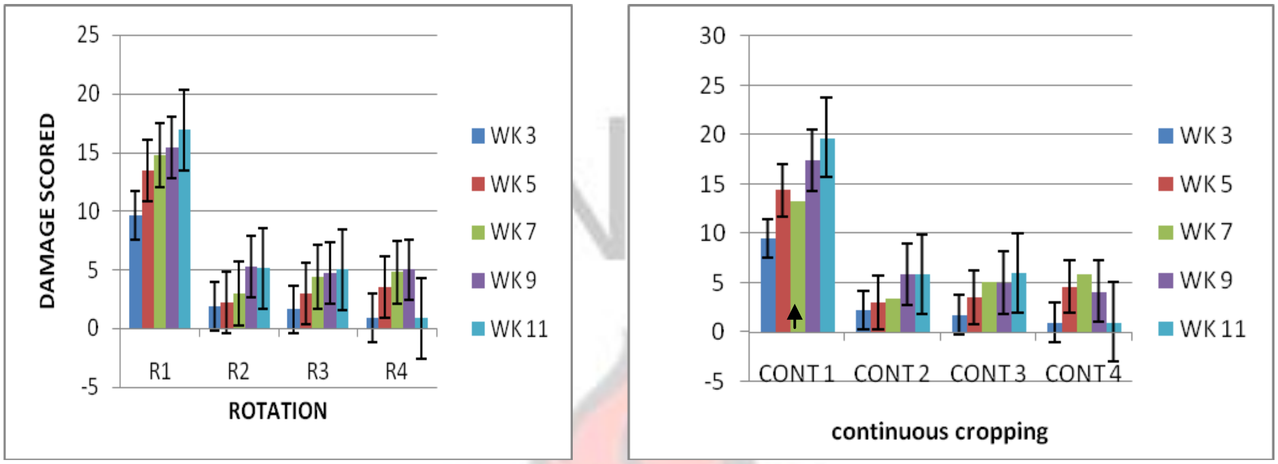


Fig. 2. The level of pest infestation on okra in both rotation and continuous cropping.

The incidence of insect pest damage was significantly high in the first planting in both rotated and continuous cropping systems. The rotational cropping system reduced the incidence of pest damage in second, third and fourth plantings. This was similar in the continuous cropping system but the incidence of damage was higher as compared to rotation.

In all the cropping systems, the rotational system minimized the incidence of pest damage due to the successional cropping in the rotation. A low incidence level of 0.88 was observed in the eleventh week after planting. This was also similar in the continuous cropping but the level of damage observed was high level of 1.0.

4.7.2 Effect of rotation and continuous cropping on pest damage in cabbage

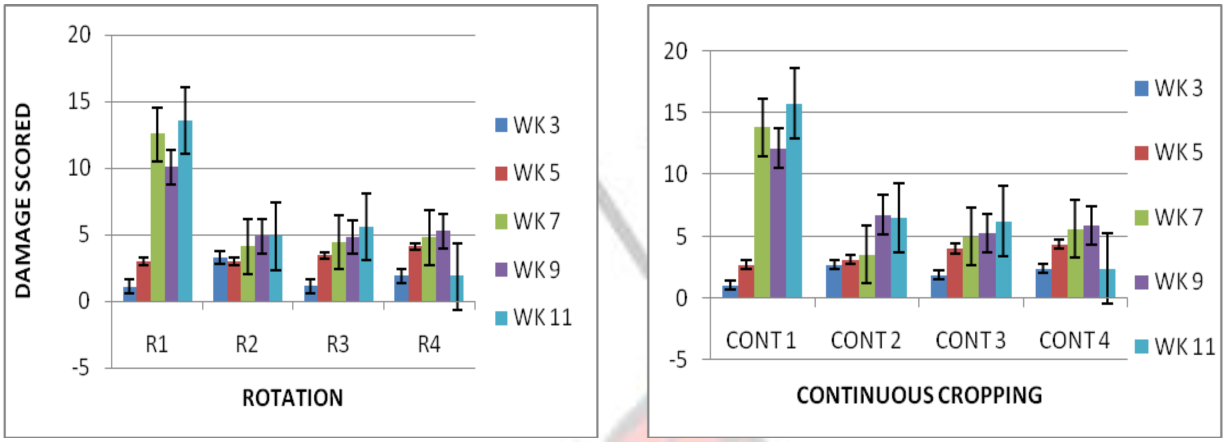


Figure 3. The effects of rotation and continuous cropping on insect pest damage on cabbage

The incidence of insect pest damage was low from the beginning of planting but increased as the crop matured. This was similar in the continuous cropping system. The cropping system showed significant (P<0.01) differences in the insect pest damage. The damage reduced drastically in the next two, three and four rotations. The rotational cropping significantly (P<0.01) affected the insect pest level of damage. The insect damage reduced to 1.88 in rotation system compared to 2.38 in the continuous cropping system.

4.7.3 Effect of cropping systems on pest damage in garden eggs

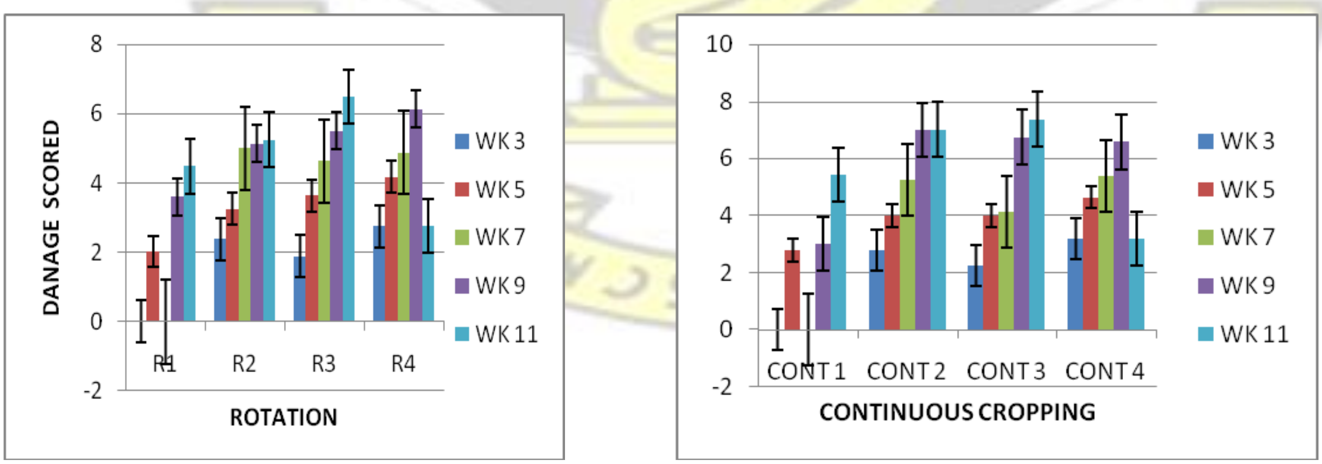


Figure 4. The effect of cropping systems of rotation and continuous cropping on pest damage in garden eggs.

The incidence of pest damage observed was similar in trend in both the rotated and continuous cultivation plots. However, the damage was higher in the continuous cropping plots. The incidence was low from the first three weeks and showed significant (P<0.01) increment as the crop matured until at the eleventh week after planting when the incidence also started reducing.

4.7.4 Effect of cropping systems of insect pest damage on mucuna

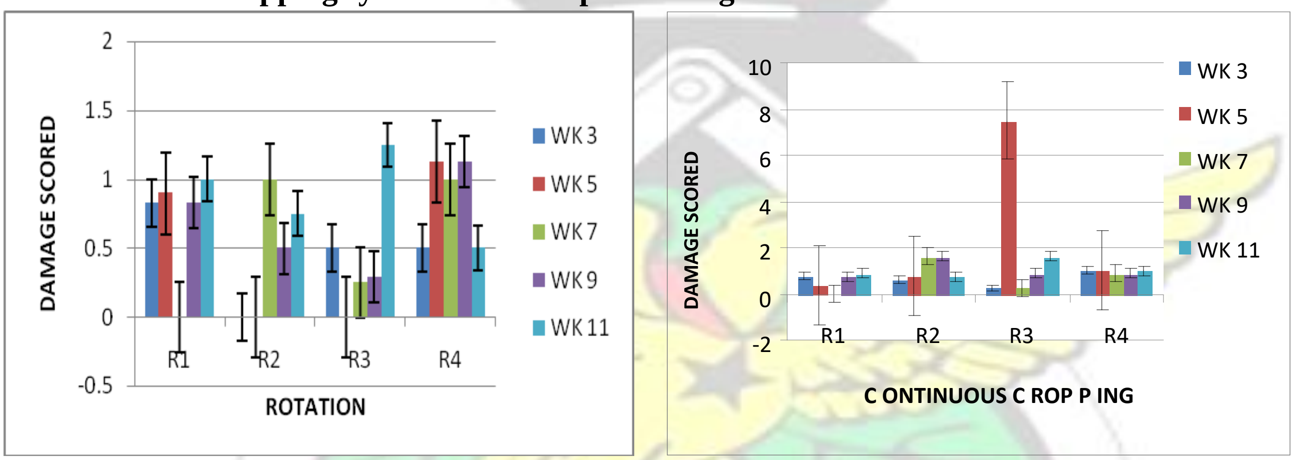


Figure 5. The effect of cropping systems of rotation and continuous cropping on pest damage in mucuna.

The extent of insect damage between the rotational fields and the continuous cropping fields was significant (P<0.05) in all the planting periods. There was higher incidence of damage in the fifth week planting in the continuous cropping fields with lower incidence in the other plantings. The abnormally high incidence of pests in rotation three of continuous cropping of mucuna occurred due to the population of pests in the weeds bordering the field since mucuna plot moved to the edges of the field..

4.7.5 Effect of cropping systems on pest damage in hot pepper

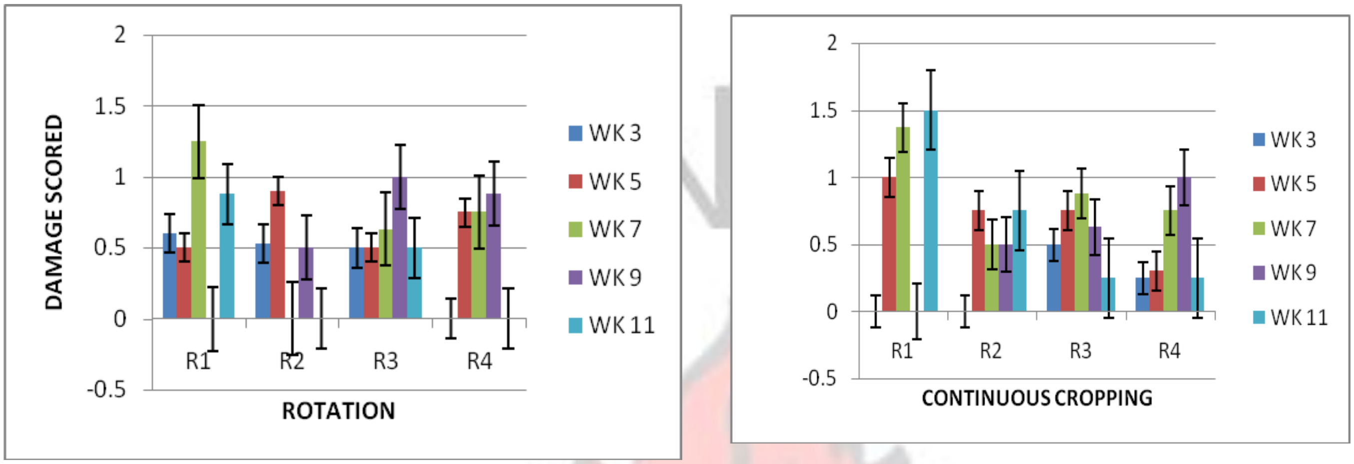


Figure 6. The effect of cropping systems of rotation and continuous cropping on pest damage in hot pepper

The cropping systems had influence on insect pest damage on pepper. The rotational cropping system showed significantly *(P<0.01)* lower damage by insect pest than continuous cropping. However the incidence of pest damage was significantly *(P<0.01)* high in the first planting in both cropping systems.

4.7.6 Effect of cropping systems on pest damage in tomato

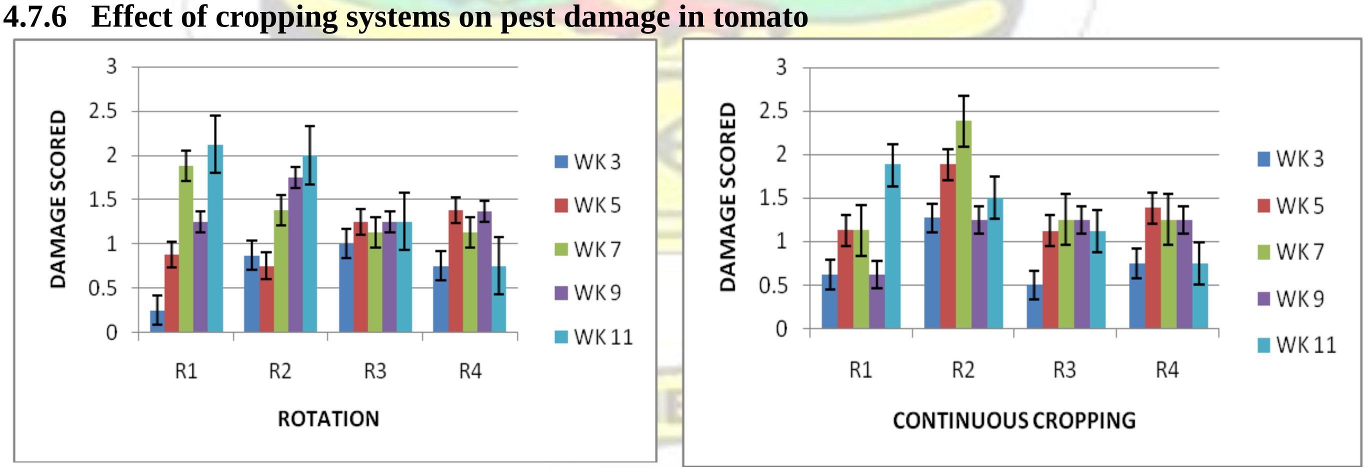


Figure 7. The effect of cropping systems of rotation and continuous cropping on pest damage in tomato

The incidence of pest damage was significantly (P<0.001) higher in the first planting/rotation than in the continuous cultivation. This was similar in the second planting in the rotational cropping system. However, in both cropping systems the damage reduced during maturity period of the crops.

4.7.7 Effects of cropping systems on pest damage in sweet pepper

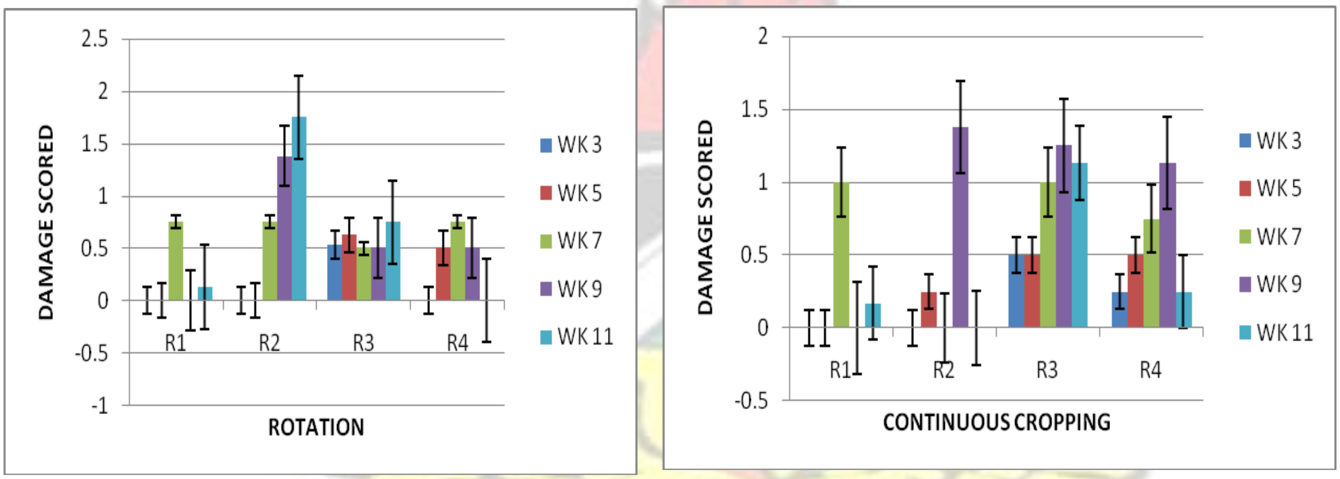
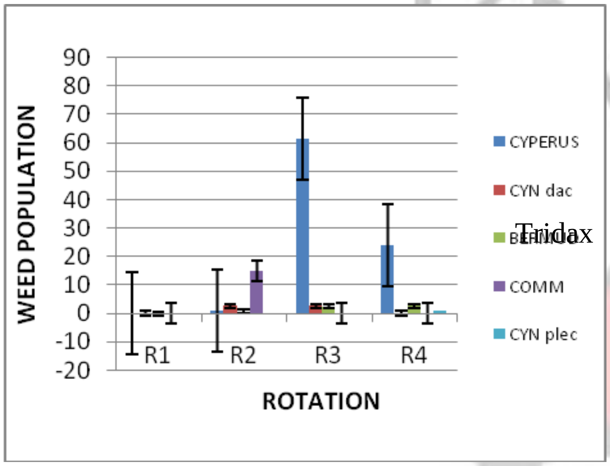


Figure 8. The effect of cropping systems of rotation and continuous cropping on insect damage in sweet pepper

The incidence of insect pest damage was low in the rotational system compared to continuous cropping system. Though damage showed high pest damage in the continuous cropping at the third and fourth planting. The initial stages of planting showed less incidence in both rotated and continuous cultivated fields.

4.8 WEED POPULATION

4.8.1 Effect of cropping system of weed population in okra



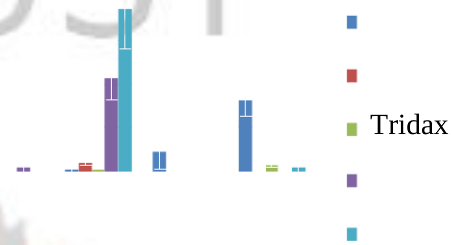


Figure 9. The effect of cropping systems of rotation and continuous cropping on weed population in okra

Figure 9 shows results of weed population in cropping system on the yield of okra. There was significant difference (P<0.001) between weed population in rotations one and two. However, there were significant differences between the weed species in the rotational cropping system since *Cyperus spp.* dominated in the third planting. With regard to continuous cropping system, the foliage of okra suppressed the weeds *(Cyperus spp.)* but in the second planting *Cynodon plectostychus* dominated. In both cropping systems the foliage of okra suppressed the broad leaves better than the grasses.

4.8.2 Effect of cropping system of weed population in mucuna

The results of cropping system on weed population are shown in Fig. 10. There were significant differences between the weed species in the rotational cropping system. *Cyperus rotundus* and *Cynodon dactylon* were observed to be higher incidence of weed population in second planting of the rotational cropping system than the broad leafed weeds. In the case of continuous cropping system the *Cynodon dactylon* dominated indicating that mucuna could not suppress it better than the other weed species. There was also a significant difference between *Cynodon plectostychus* and *Cynodon dactylon* in second and third plantings with the other weed species.

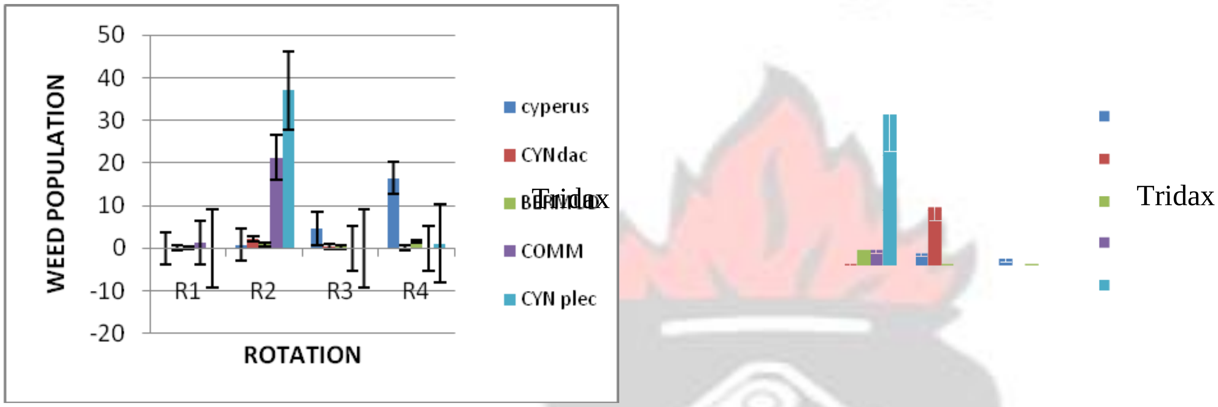


Figure 10. The effect of cropping systems of rotation and continuous cropping on weed population in mucuna

4.8.3 Effect of cropping system on weed population in hot pepper

Figure 11 shows the effect of cropping system on weed population in hot pepper stands, whereas the first and second plantings recorded the lowest weed population per plot the population was higher in the third and fourth plantings per plot with regards to *Cyperus rotundus* dominating the weed species. This is similar to the continuous cropping system with the exception of *Commelina spp*. showing highly significant differences between the weed species in the second planting.

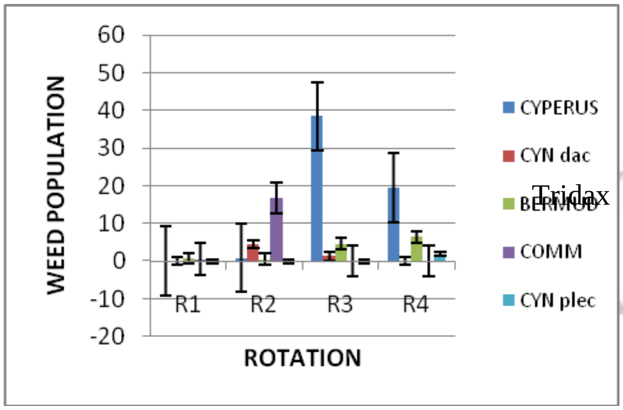


Figure 11. The effect of cropping systems of rotation and continuous cropping on weed population in hot pepper

4.8.4 Effect of cropping system of weed population in carrot

Figure 12 shows significant differences in the weed population in carrot. In the rotational cropping system *Cyperus rotundus* were observed to be highest in weed population in the third and fourth plantings. Continuous cropping system also recorded highest population in *Commelina spp.* and *Cyperus rotundus.* in second and third plantings respectively.

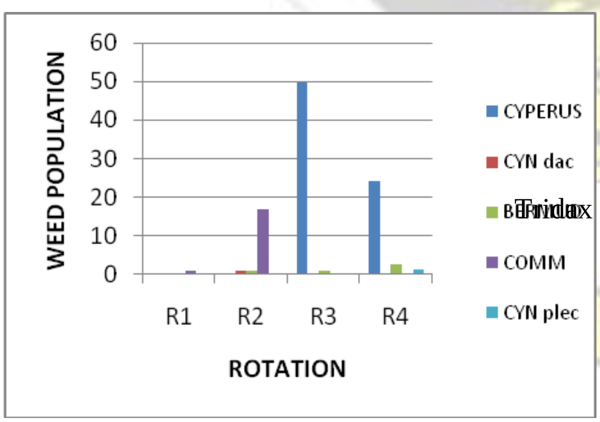


Figure 12. The effect of cropping systems of rotation and continuous cropping on weed population in carrot

4.8.5 Effect of cropping system on weed population in sweet pepper

Cropping systems affected weed population in sweet pepper production (Fig. 13). The weed population was higher in the first and second plantings, the incidence of weed population reduced in the third and fourth plantings in the rotational cropping system. The continuous cropping system showed similar trend of higher weed population for *Cyperus rotundus.*

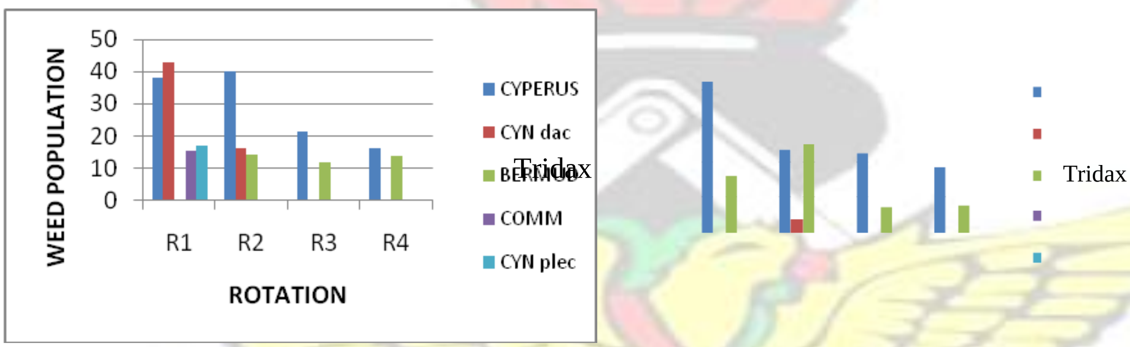


Figure 13. The effect of cropping systems of rotation and continuous cropping on weed population in sweet pepper

4.8.6 Effect of cropping system of weed population in tomato

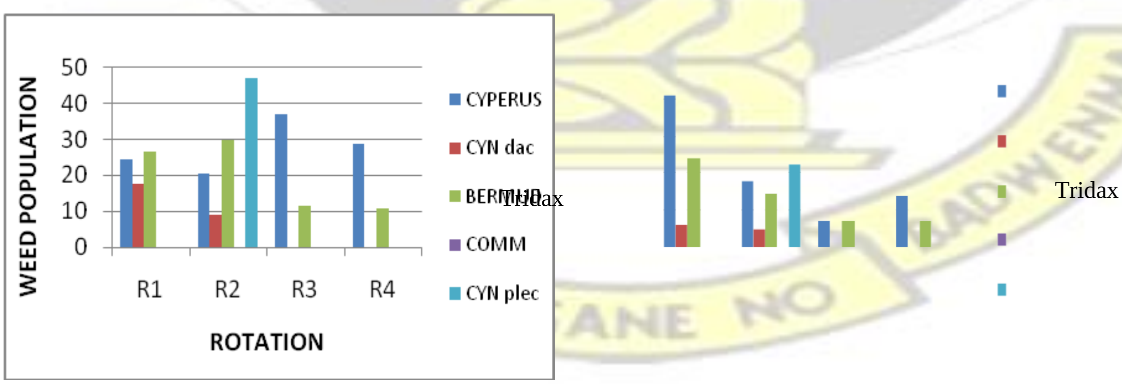


Figure 14: The effect of cropping systems of rotation and continuous cropping on weed population in tomato

Figure 14 shows the effect of cropping system on weed population in tomato stand. The tomato foliage suppressed the broad leaves better than the grasses. The *Cynodon plectoge* and *Cyperus rotundus* were highest in population, showing marked significant differences between the weed species in the rotational cropping system at the second and third plantings. The *Cyperus rotundus* and *Bermuda spp*. were also higher in population than in the other crop species, with traces of *Cynodon dactylon*.

4.8.7 Effect of cropping system of weed population in cabbage

In both cropping systems the Fig.15 shows that *Bermuda spp.* was the only weed with high population. The *cyperus rotundus* weed continued to dominate for the third and fourth plantings in continuous cropping system. Cropping system affected the incidence of weed population in both farming practices.

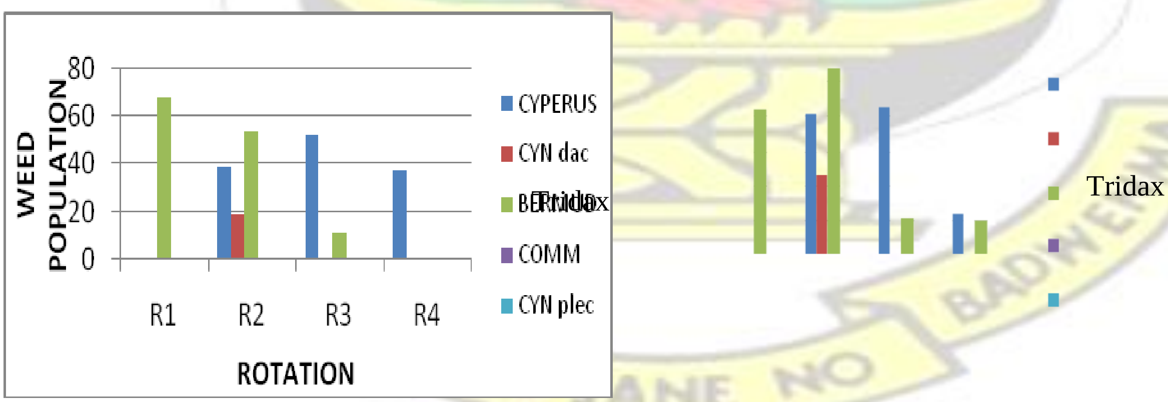


Figure 15: The effect of cropping systems of rotation and continuous cropping on weed population in cabbage

4.8.8 Effect of cropping system of weed population in garden eggs

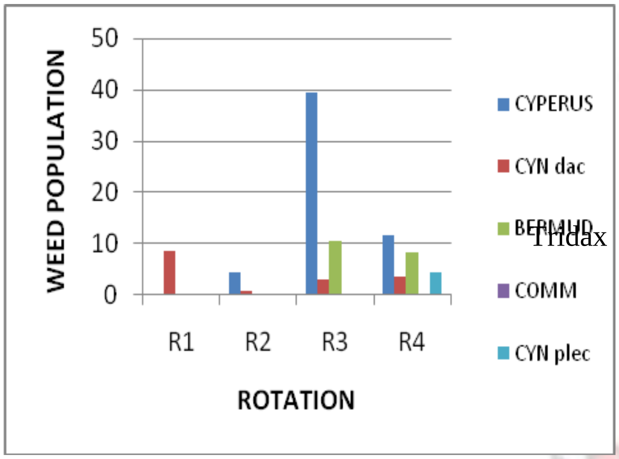


Fig 16: The effect of cropping systems on rotation and continuous cropping on weed population in garden eggs

The cropping system significantly affected the incidence of weed population as indicated in Fig. 16. The incidence of *Cyperus rotundus* was recorded higher than the other weed species recorded lower. In both cropping systems the incidence of damage in the first and second cropping was recorded low. The garden eggs suppressed most of the weed species with some traces of other weeds observed in the rotational cropping system at the third and fourth plantings respectively. Some of the common weeds identified in the fields that were very smaller in population included *Borhenia diffuses, Agyeratum Conyzoides, Eleusine indica, Corchorus spp., Aspillia africana and Lantana camara.*

4.9 ECONOMIC ANALYSIS

Table 4.25 shows the income, Profit and Benefit Cost analysis as affected by cropping system.

With regard to income from cabbage, the two systems only obtained from the rotational cropping system was higher than the continuous cropping system, followed by garden eggs following the same pattern. The profit and benefit cost also showed similar pattern with the maximum in rotation than the continuous cropping for both crops with the least showing in tomato.

Although cost of production was higher ($P < 0.05$) for hot pepper, total income, profit and benefit cost ratio were high. This treatment was followed by carrot and tomato which did not differ much from each other. The lowest production cost was from sweet pepper. Profit was very high in the rotational cropping system compared with the continuous cropping system

Marginal income was lower in all the crops for continuous cropping than the rotational cropping since the yield was lower in all the crops for the continuous cropping than the rotation.

Crop	Cost of Production ¢	Income		Profit		Benefit Cost Ratio	
		Rotation ¢	Continuous Cropping	Rotation	Continuous Cropping	Rotation	Continuous Cropping
Tomato	6,940,000	8,910,960	3,339,480	1,970,960	–3,600,530	1.28	– 0.48
Garden Eggs	5,580,000	20,426,123	9,980,822	14,846,123	4,400,822	3.66	1.79

Cabbage	5,070,000	33,922,110	20,151,360	28,852,110	15,081,360	6.69	3.97
Carrot	7,090,000	13,959,150	3,711,550	6,869,100	–3,378,450	1.97	–0.52
Hot Pepper	8,745,000	26,377,021	221,193,729	17,632,021	13,448,729	3.02	2.54
Sweet Pepper	4,970,000	8,959,350	5,053,050	3,989,350	83,050	1.80	1.02
Okra	6,365,000	10,662,125	4,717,575	4,297,125	–1,647,425	1.68	–0.74

Table 4.25 Economic Analysis

CHAPTER FIVE

5.0 DISCUSSION

5.1 EFFECT OF CROPPING SYSTEMS ON SOIL FERTILITY

Soil organic carbon management is viewed as central to the sustainability of soil systems. In most tropical environments the conversion of forested vegetation to agricultural land results in a decline of the soil organic matter content to a new lower equilibrium (Woomer and Ingram, 1990). This may result from changes in the physical and biological factors determining the equilibrium level. Changing any of these factors concerned could reverse this decline so that soil organic matter content will increase to a new equilibrium (Mulongoy and Merckx, 1991). Levels of organic matter in soils depended largely on the quality and quantity of plant materials returned to the soil.

The result of the analysis indicated that soil organic carbon levels improved in all crop combinations when they were put under continuous cropping and crop rotation systems. However, the highest soil organic carbon content were recorded in the carrot/egg plant/mucuna/tomato combination. Delali (1999) reported that soil organic carbon increased the feeding habit of the various crops, feeding zone, capability of nutrient fixation and amount of biomass produced.

The mucuna might have fixed nitrogen in the continuous cropping plots resulting in the relatively higher levels of organic carbon. Singh (1993) also asserted that cowpea contributed 46-50kg/ha of nitrogen to the following seasons sweet corn crop.

Agyei-Nsiah (2006) also asserted that decomposition of garden egg foliage incorporated into the soil ensured faster growth and increase of yields. He further indicated that the roots of garden eggs are able to penetrate deep into the soil and bring nutrients from deep in the soil to the soil surface. Litter falls from garden eggs and sweet potato to provide the canopy that protect the soil from direct action of the sun, increase water infiltration and enhance the earthworm population in the soil. Saidou *et al.* (2004) reported of the extensive use of sweet potato as cover crop for soil fertility regiment in some parts of Benin.

The rotation of vegetables and mucuna (legumes) generally improved soil pH and this was most prominent under okra and carrot (Table 4.3). However, in all the vegetable and legume combinations, soil pH improved best under rotation as compared to continuous cropping system. This probably enhanced microbial activities in the soil as Youdeowei *et al.* (1995) reported that bacteria are more active in moderately to slightly acid soils. They further indicated that nitrification and nitrogen fixation take place most vigorously only at pH above 5.5.

With regard to available phosphorus, high levels were recorded in the rotation cropping system for all crop combinations. Continuous cultivation resulted in slight decline in soil available phosphorus content in most cases (Tables 4.4, 4.5, 4.6, and 4.7). This was particularly observed in the case of egg plant, tomatoes, sweet pepper, hot pepper and okra where a lot of fruits were harvested out of the farm.

The highest average soil available phosphorus was recorded in eggplant/tomato/mucuna crops combination while the lowest available phosphorus was recorded in sweet pepper/tomato/cabbage/mucuna and carrot/mucuna/cabbage/tomato combinations in continuous cropping system.

The amounts of potassium taken up by crops vary. Some crops such as the leafy vegetables take up a lot more potassium than carrots, peppers, etc (Dupriez and Leener, 1992). This results in decline in soil available potassium. Rotation of crops enables crops with different root morphology to feed from different soil depths. Deep rooted plants (e.g. Mucuna) can search for potassium in deep soil layers and bring them to the soil surface. These nutrients are deposited on the soil surface especially when the leaves are not harvested out of the farm, but incorporated into the soil. Mucuna was not harvested out of the farm. This could explain why potassium level under mucuna was higher in rotational cultivation whereas it was lower under cabbage in continuous cultivation.Mucuna could be playing a role of raising soil potassium level whereas crops which are harvested out of the farm (tomato, eggplant, cabbage) deplete the soil of potassium.In the Village Oriented Development Programme (V.O.D.P.,1995) a rotational model field at Chapatera in Zambia indicated that deep rooting crops, e.g. sunflower, helps to create ploughing layers and to use and recycle nutrients from deeper layers for the use by shallow rooted crops e.g. cabbage.

5.2 EFFECT OF CROPPING SYSTEMS ON NEMATODE POPULATION

The incidence of nematodes prior to planting was high but a lower incidence of nematodes was obtained after crop harvest. This phenomenon could be attributable to the cropping system imposed since the number of nematodes, after harvest was significantly reduced by the cropping system.

The nematode counts indicated that there were over 500 nematodes more in the continuous cropping system than that of the rotational system. The results further showed that changes were observed also within eggplant/tomato/carrot/mucuna crop combination in the continuous cultivation cropping system when the incidence of nematode population increased. Tahvanainen and Root (1972) and Root (1973) who studied on *Brassica spp* indicated that with an increase in vegetational diversity in an ecosystem, there is a corresponding decrease in pest species density. Netscher and Sikora (1990) also showed that damage intensity of plant parasitic nematodes usually increases slowly with time in rotational cropping system as compared to the rapid increase in damage encountered in large scale vegetable production where near monoculture (continuous cultivation) is practiced.

The higher number of nematodes may be due to a rise in the free-living nematode population resulting from rotten mucuna mulch.

5.3 EFFECT OF CROPPING SYSTEMS ON YIELD

Since marketable fruits/roots are a component of total yield, the rotational cropping system which produced higher total yield per hectare was more likely to produce higher marketable yields than the continuous cultivation plots which produced less total yields per hectare. The rotational plots gave higher yields than the continuous cultivation plots because there was a well planned succession. Raussen (1997) reported that the total yield of okra grown in a well planned rotation (succession) was significantly greater than okra grown on monocropping system. Another advantage of the rotation plots recording highest marketable yield of okra (5810.56 kg ha^{-1}) may be attributed to the different plant species extracting nutrients at different depths. Yayock *et al.* (1988) reported that it is more advantageous to rotate deep rooted crops with shallow rooted crops. The results in Table 4.5 indicated that as carrots followed okra, mucuna and hot pepper in the rotational fields that increased yield.

The cropping system continued to have influence on the yield of carrot since the rotational plots showed significant difference in the marketable and total yields of the crop.

Even though there was no significant difference between the first three plantings for the marketable yields (Table 4.6), the first planting in the rotational cropping system gave the highest number of roots. This could be due to the availability of water to the plants during the dry period where temperatures were high and plants demand more water for their living. This is similar to the findings of Yayock *et al.* (1988) on the influence of water content of various plant tissues expressed as percentage of fresh weight of produce. They reported that water is involved in energy balance and also acts as a medium for the moderation of temperature in crop canopies. Water content of 88.2% increased the yield of carrot when temperatures were high. Fisher (1977), Jodha (1979) and Norman (1992) also reiterated that rotation offers insurance against uncertainties and vagaries of the weather on crop yield as all crops may not grow under adverse climatic conditions, and farmers get some crops instead of losing the entire crop in monocropping.

The result of the hot pepper trial did not show any significant differences between the plantings. However, the highest yield obtained was when hot pepper followed mucuna in the succession Boa-Amponsem and Osei-Bonsu (2001) also reported that mucuna incorporation in the rotation added nitrogen to the soil to increase yield.

The yield of sweet pepper responded positively to the cropping system. The marketable yields were significantly higher in the rotation than in the continuous cultivation plots. Webster and Wilson (1980) working on soya bean, groundnut and cotton rotation, found that an appropriate sequence of crops used in rotation can produce better average yields than continuous cultivation of the same crop without the need for additional fertilizers.

The present study indicated that as sweet pepper followed cabbage in tomato, cabbage, sweet pepper combination improved soil nutrients and yield. Scholes and Salazar (1986) asserted that vegetable rotation increases efficient use of soil nutrients and yields. They also reported that shallow rooted vegetables like cabbage and lettuce, should be followed by deep rooted crops like tomato, sweet pepper, okra in order to improve nutrients and yields of crops. With regard to tomato yields, the rotational cropping system out yielded the continuous cultivation plots. The highest yield was obtained in the third planting in the rotation cropping system and this might have been due to tomato following cabbage in succession (Table 4.9). The mucuna tended to increase the nutrients by adding nitrogen into the soil. Yayock *et al.* (1988), indicated in his finding that, the practice of rotation allows for balanced nutrient removal from the soil from a group of vegetables put in succession such as tomato, pumpkin and groundnut, rotation cropping system.

Even though the yield in the first planting was high, the unmarketable yield recorded was also high (Table 4.18) . This might be due to some tomato plants infected with the disease pathogen *Fusarium* which Agrios (1988) cited as one of the prevalent and damaging diseases of tomato that gives small, misshapened, rotten fruits etc. This highlights one of the advantages of rotation over sole cropping where rotation offers insurance against uncertainties and vagaries of the weather on crop yield as all crops do not fail under adverse climatic conditions or disease incidence and farmers get some crop instead of loosing the entire crop (Jodha, 1979; Norman, 1982).

The significant differences in yield recorded among the rotational planting (Table 4.10), could be attributed to the arrangement of the crop combinations. For example, sweet pepper, mucuna and tomato are deep rooted crops and were followed by cabbage that is a shallow rooted crop. This enabled the cabbage plants to extract nutrients at the shallow depths as indicated by Yayock *et al*. (1988). Raussen (1997) also reported that rotation with deep rooted crops, example sunflower, helps to break ploughing layers and to use and recycle nutrient from deeper layers.

With respect to garden eggs yield, the marketable yield of the first three plantings was significantly different from the fourth plantings. The rotational cropping system showed markedly higher yield than the continuous cropping field as this might be due to different plants taking different nutrients out of the soil and adding other trace elements and this prevents gardens from becoming exhausted from season to season. The crop sequencing of which garden eggs followed carrot in the garden eggs, mucuna, tomato, and carrot succession increased the total yield of the crops. The low yield could be attributed to the depletion of soil nutrients (Tables 4.1 to 4.13), where the soil fertility trend declined in all aspects of production. Ogden (2001) who studied vegetable crop rotation of beans, broccoli, beets and green manure crop combination reported that crop rotation controlled build up of organic matter and soil nutrients that certain plants use during their life cycle.

5.4 EFFECT OF CROPPING SYSTEMS ON PEST INCIDENCE

The results showed that pest incidence and their damage on the various vegetables varied considerably with planting season and cropping system. This is indicative of the role factors such as climate change, crop type and agriculture patterns play in determining the distribution of insect pests, their activity and magnitude of damage on host plants. The high insect pest problems recorded especially aphids on tomatoes in the first plantings of both the rotation and continuous cropping patterns rather than in the consequent plantings, could be due to different rainfall intensities during the planting periods.

The observation by Schmatterer (1990) indicated that the intensity and impact of rainfall have more influence on aphid number rather than the average amounts. His results also indicated that the practice of rotation reduced pest infestation particularly of sweet potato. It is thought that the high concentration of host plants in the continuous cultivation stands of sweet pepper provided more resources for exploitation by the pests thereby boosting their population densities. Crop rotation however, did not increase pest population due to the sequence of cropping patterns (succession). This is indicated by Braimah (1998) who in his work on IPM on eggplant, okra, pepper and tomato reported that lepidopterous pests (cotton leaf roller, cotton stainer etc.) can be controlled best by the use of crop rotation and cultivation of resistant varieties. The number of garden eggs and tomato plants that survived after exposure to Sclerotium wilt (*Sclerotium rolfsii*) after transplanting could be attributed to the cropping system used.Fewer garden egg and tomato plants survived in continuous cropping system compared to the rotational cultivated plots. Messiaen(1992)reported that mycelium of *Sclerotium rolfsii* at soil level are inhibited in the presence of soluble nitrogenous compounds. Thus nitrogen made available by mucuna could have inhibited disease development in the rotation plots. .

Messiaen's (1992) report indicated that rotations raise resistance of crops since the crop sequences disrupt the survival of the pathogens hence the high survival rate of the crop in the rotational cropping system.

Raussen (1997) in his work on integrated soil fertility management on small scale farms also asserted that pest and/or disease pressure increase if a crop is grown continuously on the same piece of land. This is because many pests and diseases survive in the soil or on the crop residues would still be in the field when the same crop is planted again. A typical example is the increase in leaf spots of groundnuts if the crop is not rotated because the disease survives on the crop residue. Owen (2003) also reported that growing the same vegetables in the same spot each year can help pests and diseases which thrive on that particular crop, build up in the soil to epidemic levels as evidenced in Table 4.17 where nematode population increased in the continuous cropping plots than in the rotation plots.

5.5 EFFECT OF CROPPING SYSTEMS ON WEED INFESTATION

With regard to weed population the rotational cropping system of the various vegetables gave fewer stands of the broad leaved weeds than in the continuous cropping plots. This issimilar to work done by Midmore *et al,* (1991) on sustainable agriculture who reported that if properly managed, diversity can buffer a farm in a biological sense since annual cropping systems and crop rotation can be used to suppress weeds, pathogens and insect pests. In all the crop combinations, rotational cropping system suppressed weeds especially the broad leaved weeds better than the grassy weeds. The continuous cropping systems encouraged profuse growth of broad-leafed weeds with grassy weeds such as the *Cynodon spp* dominating. The rotation system reduced the number of weeding times considerably. The spreading canopy of the mucuna in the well arranged sequence of planting did not encourage further weeding. Mulongoy and Mercks (1991) noted that mucuna suppresses weeds through its physical presence on the soil surface that deprives weed seeds of light to germinate and carry out photosynthesis. The garden egg plant stayed in the soil for a longer period of time (perennial) and developed a lot of canopies which led to the suppression of weeds as according to the finding of Fordham and Biggs (1985) who reported that soil surfaces which are not covered by crops are more likely to develop weed canopies, loose water by evaporation and suffer damages during heavy rainfall or irrigation. The mucuna further suppressed *Cyprus rotundus* weeds in the rotational cropping system. According to Mulongoy *et al.* (1993) the presence of dense cover reduced light availability and thus prevented weed seeds from germination and growth. Reports from Feeding in the Future (2001 as well as Boa-Amponsem and OseiBonsu (2001) showed that mucuna as green manure plant may also release toxins which have allelopathic effect on the growth of the neighbouring plants thus suppressing weeds. Weed population was influenced by the green manure in both the rotational and continuous cropping systems. Seed bearing weeds might have sprouted but might have been suppressed by the dense, tall stands. From Benin it was reported that intensive fallow with *Cajanus cajan* helped control *Imperata cylindrica* (Floquet, 1990). Akobundu and Poku (1984) observed that within 19 weeks, *Mucuna utilis* could completely cover plots infested with *Imperata cylindrica*. A vegetable rotation experiment conducted with squash, tomato, beans and onion succession foiled insects and diseases attack, deterred weeds and balanced nutrient demands each crop made in the soil (Ogden, 2001).

ECONOMICS OF PRODUCTION

Income from all the crops was significantly affected by the cropping systems.

The yields for all the crops were lower in continuous cropping system than in the rotation system leading to lower marginal profits for the continuous cropping.

The rotational cropping system gave the highest income compared with the continuous cropping system (Table 4.25). The differences in income are ascribed to the increased yields and hence higher profit obtained from the rotational cropping systems. A similar finding by Youdeowei *et al.* (1995) indicated that the rotational cropping system offered more efficient use of land, higher yields and profits than of continuous / mono cropping system.

Webster and Wilson (1980) also reported that okra grown under rotation produced higher profits, due to increased yield per hectare. They indicated that okra in rotation with the appropriate sequence of crops can produce average yields and higher profit than continuous cultivation of the same crop without additional fertilizer.

Report by Ware and McCollani (1968) showed another benefit of crop rotation as a high gross margin which is realized because under a well-planned rotation there is no need to use inorganic fertilizers which are very costly.

CHAPTER SIX 6.0 SUMMARY AND CONCLUSION

An experiment to study the development of a vegetable rotation technology as a sustainable farming system in selected growing locations in the forest zones of the Ashanti and Brong-Ahafo Regions was carried out at the Department of Horticulture,
Kwame Nkrumah University of Science and Technology, Kumasi from February 2003 to March, 2005.

The experiment was a Randomised Complete Block Design (RCBD) replicated four times for each of the four simulated locations. A controlled field using the same crops without rotating them till the end of the project was also used. Before the experiment started, soil samples were collected, and analysed for pH, organic matter content, available nutrients and water soluble potassium, exchangeable cations at the Soil Fertility Section of the Soil Research Institute, Kwadaso, Kumasi. Nematode extraction, identification and counts were carried out at the Nematology Laboratory, Department of Crop and Soil Sciences, KNUST, Kumasi. Other parameters studied included reproductive growth, marketable and unmarketable yields, survival of garden egg and tomato plants during *Sclerotium* wilt infection, weed assessment, insect pests incidence and economics of production.

Cropping system influenced the nutrition level in all crop combinations. The organic carbon content, available phosphorus, water soluble potassium and the pH were significantly ($P<0.05$) affected by the cropping system in the rotation fields.

Nematode population was influenced by cropping system. The nematode counts indicated that there were over 500 nematodes more in continuous cropping system than that of the rotational system.

The marketable and total yields were significantly ($P<0.05$) higher in the rotational cropping fields than the continuous cropping fields in all the crop combinations.

The cropping system significantly ($P<0.05$) affected the incidence of weed population. Garden eggs suppressed the incidence of weeds in most of the weed species with some traces of other weeds in recording in the rotational cropping system than the continuous cropping.

The rotational cropping system reduced the incidence of insect pest damage than the continuous cropping system. The minimized incidence of pest damage was due to the successional croppings in the rotation system.

The incomes, profit and benefit cost analysis were affected by cropping system. Income from the cabbage was higher in the rotational cropping system than the continuous cropping. The profit and benefit cost also were higher in the rotational cropping than the continuous cropping. The rotation was better in all crop combinations.

CONCLUSION

Rotation is a technology which when encouraged can help farmers save money from the purchase of synthetic pesticides, keep down effect of pest damage to crops, suppressed weeds, save lives of farmers and consumers as well as the environment from misuse of synthetic pesticides which also join the food chain to harm human beings. The experiment should be repeated using the farmer's field to promote the technology.

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APPENDICES

APPENDIX I: PRODUCTION COST FOR CARROT

ACTIVITY / INPUT	QUANTITY	UNIT COST	TOTAL COST
Land preparation			
Seeds	200g	100g/70	140,000
Slashing		280,000	280,000
Bed preparation	10 persons x 5 days	20,000	1,000,000
Planting	10 x 5 days	20,000	1,000,000
Weeding			
1st	10 persons x 5 days	20,000	1,000,000

2nd	10 persons x 3 days	20,000	1,000,000
Fertilizer NPK	250kg	180,000/50kg	900,000
Cost of fertilizer app.	10 persons	20,000	200,000
Harvesting	8 persons x 5 days	20,000	800,000
Total			**7,090,000**

INCOME

ROTATION	-	CONTINUOUS
YIELD INCOME	-	YIELD INCOME
2791.83KG	-	74231KG
13,959,150	-	3,711,550

APPENDIX 2: PRODUCTION COST FOR GARDEN EGG

ACTIVITY / INPUT	QUANTITY	UNIT COST	TOTAL COST
Seeds	250kg	60,000/100kg	150,000
Land preparation			
Slashing			250,000
Nursery cost			200,000
Transplanting	4 persons x 2 days	30,000	240,000
Weeding			
1st	8 persons x 2 days	30,000	480,000
2nd	8 persons x 2 days	30,000	480,000
Pesticides			
Insecticide	2 litres	200,000	400,000
Topspin M	1kg	80,000	80,000
Cost of spraying	4 persons x 5 days	20,000	400,000
Fertilizers			
NPK (15-15-15)	250kg	180/50kg	900,000
Sulphate of ammonia	250kg	120/50kg	600,000
Cost of fertilizer apply	20 persons	20,000	400,000
Harvesting	10 persons x 5 days	20,000	1,000,000
Total			**5,580,000**

INCOME

ROTATION - CONTINUOUS YIELD YIELD

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-

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8236.34KG	4024.53KG
INCOME	INCOME
20,426,123	9980,822,000

APPENDIX 3: PRODUCTION COST FOR GARDEN SWEET PEPPER

ACTIVITY / INPUT	QUANTITY	UNIT COST	TOTAL COST
Land preparation			
Slashing		250,000	250,000
Seeds	250kg		
Nursery cost		200,000	200,000
Transplanting	7 persons x 2 days	30,000	420,000
Weeding			
1st	8 persons x 2 days	30,000	480,000
2nd	8 persons x 2 days	30,000	480,000
Pesticides			
Insecticide (Karate 2.5EC)	1 litre	200,000	200,000
Fungicide (Topsin M)	1kg	80,000	80,000
Cost of spraying	4 persons x 2 days	20,000	160,000
Fertilizers			
NPK	250kg	180/50kg	900,000
Sulphate of ammonia	250kg	120/50kg	600,000
Cost of fertilizer apply	20 persons	2,000	400,000
Harvesting	10 persons x 4 days	20,000	800,000
Total			**4,970,000**

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INCOME

ROTATION - YIELD	CONTINUOUS YIELD
597.29KG	336.87KG
INCOME	INCOME
8,959.350	5,053,950

APPENDIX 4: PRODUCTION COST FOR CABBAGE

ACTIVITY / INPUT	QUANTITY	UNIT COST	TOTAL COST
Seeds	100gs	360,000	360,000
Land preparation			
Slashing		250,000	250,000
Cost of Nursery		200,000	200,000
Transplanting	8 persons x 2 days	30,000	420,000
Weeding			
1st	8 persons x 2 days	30,000	480,000
2nd	8 persons x 2 days	30,000	480,000
Pesticides			
Karate	2 litres	180,000	360,000
Diapel 2x			
Cost of spraying	4 persons x 4 days	20,000	360,000
Fertilizers			
NPK	250kg	180/50kg	900,000
Sulphate of ammonia	250kg	120,000/50kg	600,000
Cost of fertilizer apply	10 persons 2 days	20,000	400,000

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Harvesting	4 persons x 2.5 days	20,000	200,000
Total			**5,070,000**

INCOME

ROTATION	- CONTINUOUS YIELD	YIELD
	11,307,37KG	6,717,12KG
	INCOME	INCOME
	33,922,110	20,151,360

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APPENDIX 5: PRODUCTION COST FOR GARDEN EGG

ACTIVITY / INPUT	QUANTITY	UNIT COST	TOTAL COST
Land preparation			
Slashing			250,000
Seeds	2.5kg	10kg	375,000
Planting	8 persons x 2.5 days	20,000	400,000
Weeding 1st	8 x 2	20,000	320,000
2nd	8 x 2	20,000	320,000
Pesticides			
Karate (2.5EC)	2 litres	200,000	400,000
Cost of spraying	4 x 5	20,000	400,000
Fertilizers			
NPK (15-15-15)	250kg	120/50kg	900,000
Sulphate of ammonia	250kg	120/50kg	600,000
Cost of fertilizer apply	10 persons x 2 days	20,000	400,000
Harvesting	10 x 10	20,000	2,000,000
Total			**6,365,000**

INCOME

ROTATION	-	INCOME
YIELD	-	INCOME
4264.85KG	-	10.662,125
CONTINUOUS	-	1887.03
YIELD	-	4,717,575

APPENDIX 6: PRODUCTION COST FOR TOMATO

ACTIVITY / INPUT	QUANTITY	UNIT COST	TOTAL COST
Seeds			

Land preparation			
Slashing			250,000
Ridging	20 persons	20,000	400,000
Nursery cost			200,000
Transplanting	7 persons x 2 days	30,000	420,000
Weeding (1st)	8 persons x 2 days	30,000	480,000
Earthened up/2nd weeding	8 persons x 2 days	30,000	720,000
Pesticides			
Insecticide (Karate)	1 litre	200,000	200,000
Fungicide (Topsion)	2kg	80,000	160,000
Diathane	2kg	60,000	120,000
Cost of spraying	4 persons x 5 days	20,000	400,000
Fertilizers NPK (15-15-15)	5 bags	180/50kg	900,000
Sulphate of ammonia	5 bags	120,000	600,000
Cost of fertilizer apply	20 persons	20,000	400,000
Harvesting	12 x 4	30,000	144,000
Total			**6,940,000**

INCOME

ROTATION	-	CONTINUOUS
YIELD	-	YIELD
1485.16KG	-	556.58KG
INCOME	-	INCOME
8,910,960	-	3,339,480

APPENDIX 7: PRODUCTION COST FOR HOT PEPPER

ACTIVITY / INPUT	QUANTITY	UNIT COST	TOTAL COST
Land preparation			
Seeds	250kg	11,000/100g	2750,000

Cost of Nursery			200,000
Transplanting	7 persons x 2 days	30,000	420,000
Weeding 1st	7 persons x 2 days	30,000	420,000
2nd	7 persons x 2 days	30,000	420,000
Pesticides			
Insecticide (Karate 2.5EC)	5 litres	200,000	100,000
Fungicide (topsion M)	1kg	80,000	800,000
Cost of spraying	4 persons x 2 days	20,000	160,000
Fertilizers			
NPK (15-15-15)	100kg	180,000	360,000
Sulphate of ammonia	2 bags	120,000	240,000
Cost of fertilizer apply	8 persons	20,000	160,000
Harvesting	23 x 10	20,000	5,000,000
Total			**8,745,000**

INCOME

ROTATION	-	CONTINUOUS
YIELD	-	YIELD
4170.28KG	-	3508.89KG
INCOME	-	INCOME
26,377,021	-	22,193,729

APPENDIX 8: CROP COMBINATION

BLOCK I

Okra	Carrot	mucuna	hot pepper	Rot I
Carrot	mucuna	hot/pepper	okro	Rot II
Mucuna	ho/pepper	okra	carrot	Rot III
Hot/pepper	okra	carrot	mucuna	Rot IV

Control okra	carrot	mucuna	hot/pepper	Rot I II III IV

BLOCK II

Sweet pepper	mucuna	tomato	cabbage	Rot I
Mucuna	tomato	cabbage	sweet pepper	Rot II
Tomato	cabbaaage	sweet pepper	mucuna	Rot III
Cabbage	sweet pepper	mucuna	tomato	Rot IV
Control Sweet pepper	mucuna	tomato	cabbage	Rot I II III IV

BLOCK III

Garden eggs	mucuna	tomato	carrot	Rot I
Mucuna	tomato	carrot	garden eggs	Rot II
Tomato	carrot	garden eggs	mucuna	Rot III
Carrot	garden eggs	mucuna	tomato	Rot IV
Control Garden eggs	mucuna	tomato	carrot	Rot I II III IV

BLOCK IV

Cabbage	carrots	mucuna	tomato	Rot I
Carrots	mucuna	tomato	cabbage	Rot II
Mucuna	tomato	cabbage	carrots	Rot III
Tomato	cabbage	carrots	mucuna	Rot IV
Control Cabbage	carrot	mucuna	tomato	Rot I II III IV

APPENDIX 9: PPMED PRICE LIST 2001 (¢)

Tomato	-	6,000/kg
Okra	-	2,500/kg
Garden eggs	-	2,480/kg
Pepper	-	6,325/kg
Cabbage	-	3,000/kg
Carrot	-	5,000/kg

Sweet pepper	-	15,000/kg

Source: PPMED (2001) Kumasi

MIN. OF FOOD AND AGRICULTURE:

APPENDIX 10: Results of soil nutrient analyses before experiment

pH	5.1
% Organic matter	2.7
% Total nitrogen	0.16
Available P (control/kg)	13.5
Water soluble (control/kg)	11.5
Exchangeable cations (cmol/kg)	
Ca	4.4
Mg	1.6
K	0.54
Na	0.11
Cation Exchange Capacity (cmol/kg)	5.9

APPENDIX 11: PROCEDURE FOR THE EXTRACTION AND EXAMINATION OF NEMATODES

Procedure: Four steps were involved

a) Obtaining the extract

b) Pouring stage

c) Decanting supernatant water

d) Preservation of the nematodes

Two large plastic baskets were picked and the inside of each plastic basket was lined with a double layer of tissue paper. The basket was allowed to stand in a collecting plastic plate.

150ml of finely crumbed soil was evenly spread in a thin layer over the tissue in each basket. Water was carefully added down the inside edge of the collecting plastic plate until the soil layer looked wet. To obtain a clean extract, the plastic plate was not tampered with or moved. The above procedure was carried out for each of the sixty samples. The extract was allowed to stay for forty-eight hours. The basket was then slowly and carefully removed and the nematode suspension from the plastic plate was concentrated by pouring into plastic cups. It was allowed to settle for twenty hours. Afterwards the supernatant water was decanted. Each suspension was concentrated by passing it three or four times through fine sieves. The nematodes were washed off the sieve and collected into a vessel. Each suspension was heated at 60^{o}C and allowed to cool for about 4 hours. They were poured into film containers and "TAF" a preservative was added to equal volume of the extract. The nematodes were identified under microscope and a classified into free-living and parasitic types.

Total number of nematodes before planting and after harvesting was determined.

Appendix 12: Means and standard errors of weed population and insect pests damage in vegetables at rotation 1

Crop	Variables	Means	Standard error

Carrot	Insect pest in wk 3	0	0
	Insect pest in wk 5	0	0
	Insect pest in wk 7	0	0
	Insect pest in wk 9	0	0
	Insect pest in wk 11	0	0
	Cyperus spp	0	0
	C. dactylon	0	0
	Bamuda spp	0	0
	Commelina	1.15 0	1.15 0
	C, plectostychus	1.10	0.31 0.35
	Insect pest in wk 3	2.97	1.40 1.11
	Insect pest in wk 5	12.55 10.10	1.72
Cabbage	Insect pest in wk 7	13.60	0
	Insect pest in wk 9	0	0
	Insect pest in wk 11	0	20.69
	Cyperus spp	27.60	0
	C. dactylon	0	0
	Bamuda spp	0	0
	Commelina	0	0
	C, plectostychus	0	0.25 0.10
	Insect pest in wk 3	0.75 0.12	0.16
	Insect pest in wk 5	0.13	0
	Insect pest in wk 7	24.05 0	0
	Insect pest in wk 9	28.77	6.98 0
Sweet pepper	Insect pest in wk 11	0	0
	Cyperus spp	0	0
	C. dactylon	0	0.29 0.41
	Bamuda spp	0.5	1.25
	Commelina	1.25 1.35	0.19
	C, plectostychus	0.88	0
	Insect pest in wk 3	0	0
	Insect pest in wk 5	0	0.20
	Insect pest in wk 7	0.77	0
	Insect pest in wk 9	0.55 0	0
	Insect pest in wk 11	0.25 0.87	0.25 0.42
Hot pepper	Cyperus spp	1.87 1.25	0.37 0.75
	C. dactylon	2.12	0.12
	Bamuda spp		
	Commelina		
	C, plectostychus		
	Insect pest in wk 3		
	Insect pest in wk 5		
	Insect pest in wk 7		
	Insect pest in wk 9		
	Insect pest in wk 11		
Tomato			

	Cyperus spp	14.42 12.62	3.42 6.92
	C. dactylon	18.89	6.96
	Bamuda spp	0	0
	Commelina	0	0
	C, plectostychus	0	0
	Insect pest in wk 3	2.02 1.94	0.41 0.24
Garden egg	Insect pest in wk 5	3.60	0.75
	Insect pest in wk 7	5.42	0.86 0
	Insect pest in wk 9	0	3.32
	Insect pest in wk 11	8.5	0
	Cyperus spp	2.20	0
	C. dactylon	0	0
	Bamuda spp	0	1.13 1.69
	Commelina	9.62	1.34 1.67
	C, plectostychus	13.42 14.37	1.02
	Insect pest in wk 3	15.37	0
	Insect pest in wk 5	16.65	0
	Insect pest in wk 7		0
Okra	Insect pest in wk 9		1.32 0
	Insect pest in wk 11		1.32 0.38
	Cyperus spp		0.13 0.43
	C. dactylon		0.52
	Bamuda spp		0
	Commelina	1.13 1.25	0
	C, plectostychus	1.60 1.12	0
	Insect pest in wk 3	2.12	1.98
	Insect pest in wk 5	0	0
	Insect pest in wk 7	0	
	Insect pest in wk 9	0	
	Insect pest in wk 11	4.80	
mucuna	Cyperus spp	0	
	C. dactylon		
	Bamuda spp		
	Commelina		
	C, plectostychus		

Appendix 13: Means and standard errors of weed population and insect pests damage in vegetables at rotation 2

Crop	Variables	Means	Standard error

Carrot	Insect pest in wk 3	0	0
	Insect pest in wk 5	0	0
	Insect pest in wk 7	0	0
	Insect pest in wk 9	0	0
	Insect pest in wk 11	0	0
	Cyperus spp	0.25 0.82	0.25 0.28
	C. dactylon	1.08	0.78 4.98
	Bamuda spp	24.05	2.90 0.28
	Commelina	25.52	0.35 0.23
	C, plectostychus	3.30 3.0	0.47
	Insect pest in wk 3	3.50 6.75	0.35
	Insect pest in wk 5	4.87	10.79 3.76
Cabbage	Insect pest in wk 7	16.90 10.76	12.97
	Insect pest in wk 9	23.67	0
	Insect pest in wk 11	0	0
	Cyperus spp	0	0
	C. dactylon	0	0
	Bamuda spp	0.25 0.24	0.25 0.39
	Commelina	1.37	0.25
	C, plectostychus	1.75	10.34 3.47
	Insect pest in wk 3	26.10 16.45	14.38
	Insect pest in wk 5	14.78	0
	Insect pest in wk 7	0	0
	Insect pest in wk 9	0	0.30 0.53
Sweet pepper	Insect pest in wk 11	0.52 0.90	0.29 0.25
	Cyperus spp	0.62 0.50	0.20 0.51
	C. dactylon	0.75 0.85	1.60 0.52
	Bamuda spp	4.55	2.74
	Commelina	0.52	0
	C, plectostychus	16.75	0.41 0.43
	Insect pest in wk 3	0	0.71 2.59
	Insect pest in wk 5	0.87 0.75	0.75
	Insect pest in wk 7	1.37 1.75	0.44
	Insect pest in wk 9	2.00	
	Insect pest in wk 11	20.52	
Hot pepper	Cyperus spp		
	C. dactylon		
	Bamuda spp		
	Commelina		
	C, plectostychus		
	Insect pest in wk 3		
	Insect pest in wk 5		
	Insect pest in wk 7		
	Insect pest in wk 9		
	Insect pest in wk 11		
	Cyperus spp		
Tomato			

Garden egg	C. dactylon Bamuda spp Commelina C, plectostychus Insect pest in wk 3 Insect pest in wk 5 Insect pest in wk 7 Insect pest in wk 9 Insect pest in wk 11 Cyperus spp C. dactylon Bamuda spp Commelina C, plectostychus	9.15 29.93 0 0 2.37 3.25 5.00 5.12 5.25 4.45 0.77 0 0 0 1.87 2.20 3.0 5.25 5.12	0.51 0.51 0 1.30 0.43 0.32 0.35 0.47 0.43 3.00 0.50 0 0 0 0.24 0.14 0.50 0.14 0.12 0.54
Okra	Insect pest in wk 3 Insect pest in wk 5 Insect pest in wk 7 Insect pest in wk 9 Insect pest in wk 11 Cyperus spp C. dactylon Bamuda spp Commelina C, plectostychus	0.82 2.50 0.50 14.92 20.12 0 0 0 0 0 0.25 1.33	1.05 0.50 2.79 0 0 0 0 0 0 0.25 1.32 4.75
mucuna	Insect pest in wk 3 Insect pest in wk 5 Insect pest in wk 7 Insect pest in wk 9 Insect pest in wk 11 Cyperus spp C. dactylon Bamuda spp Commelina C, plectostychus	4.75 14.76 36.97	14.70 16.66

Appendix 14: Means and standard errors of weed population and insect pests damage in vegetables at rotation 3

Crop	Variables	Means	Standard error

Carrot	Insect pest in wk 3	0	0
	Insect pest in wk 5	0	0
	Insect pest in wk 7	0	0
	Insect pest in wk 9	0	0
	Insect pest in wk 11	0	0
	Cyperus spp	49.72	14.68
	C. dactylon	0.25	0.25
	Bamuda spp	0.90	0.53
	Commelina	0	0
	C, plectostychus	0	0
	Insect pest in wk 3	1.12 3.45	0.13 0.16
	Insect pest in wk 5	4.42 4.82	0.32 0.11
Cabbage	Insect pest in wk 7	5.62	0.12
	Insect pest in wk 9	42.27 0	8.57
	Insect pest in wk 11	11.35	0
	Cyperus spp	0	1.18
	C. dactylon	0	0
	Bamuda spp	0.53 0.63	0
	Commelina	0.50 0.50	0.30 0.37
	C, plectostychus	0.75	0.28 0.28
	Insect pest in wk 3	21.50 0	0.25
	Insect pest in wk 5	11.90	2.67
	Insect pest in wk 7	0	0
	Insect pest in wk 9	0	1.85
Sweet pepper	Insect pest in wk 11	0.50 0.50	0
	Cyperus spp	0.62 1.00	0
	C. dactylon	0.50	0.28 0.28
	Bamuda spp	28.65	0.38 0.35
	Commelina	1.28	0.28 6.83
	C, plectostychus	4.60	0.49
	Insect pest in wk 3	0	1.39
	Insect pest in wk 5	0	0
	Insect pest in wk 7	1.00 1.25	0
	Insect pest in wk 9	1.12 1.25	0
	Insect pest in wk 11	1.25	0.29 0.13
Hot pepper	Cyperus spp	27.02	0.14 0.12
	C. dactylon		2.50
	Bamuda spp		
	Commelina		
	C, plectostychus		
	Insect pest in wk 3		
	Insect pest in wk 5		
	Insect pest in wk 7		
	Insect pest in wk 9		
	Insect pest in wk 11		
	Cyperus spp		
Tomato			

	C. dactylon	0	0
	Bamuda spp	11.45	1.07
	Commelina	0	0
	C, plectostychus	0	0
	Insect pest in wk 3	1.87 3.62	0.31 0.32
Garden egg	Insect pest in wk 5	4.63 5.50	0.23 0.20
	Insect pest in wk 7	6.50	0.31 4.31
	Insect pest in wk 9	29.52 3.15	1.53
	Insect pest in wk 11	10.57	2.91
	Cyperus spp	0	0
	C. dactylon	0	0
	Bamuda spp	1.62 3.00	0.23 0.35
	Commelina	4.37 4.70	0.07 0.12
	C, plectostychus	5.00	0.28
	Insect pest in wk 3	31.67	I8.00
	Insect pest in wk 5	2.47	0.71
	Insect pest in wk 7	2.35	0.33
Okra	Insect pest in wk 9	0	0
	Insect pest in wk 11	0	0
	Cyperus spp	0.50 0.50	0
	C. dactylon	1.00 1.25	0.28 0.25
	Bamuda spp	1.25	0.14 0.25
	Commelina	22.45	5.14 0.52
	C, plectostychus	0.52	0.33
	Insect pest in wk 3	7.6	0
	Insect pest in wk 5	0	0
	Insect pest in wk 7	0	
	Insect pest in wk 9		
	Insect pest in wk 11		
mucuna	Cyperus spp		
	C. dactylon		
	Bamuda spp		
	Commelina		
	C, plectostychus		

Appendix 15: Means and standard errors of weed population and insect pests damage in vegetables at rotation 4

Crop	Variables	Means	Standard error

Carrot	Insect pest in wk 3	0	0
	Insect pest in wk 5	0	0
	Insect pest in wk 7	0	0
	Insect pest in wk 9	0	0
	Insect pest in wk 11	0	0
	Cyperus spp	24.17	3.24
	C. dactylon	0	0
	Bamuda spp	2.70	0.17
	Commelina	0	0
	C, plectostychus	1.25 1.87	0.25 0.38
	Insect pest in wk 3	4.12 4.77	0.12 0.36
	Insect pest in wk 5	5.25	0.14 0.37
Cabbage	Insect pest in wk 7	1.87	5.92
	Insect pest in wk 9	27.45 0	0
	Insect pest in wk 11	11.25	1.98
	Cyperus spp	0	0
	C. dactylon	0	0
	Bamuda spp	0	0.25 0.29
	Commelina	0.50 0.75	0.25 0.29
	C, plectostychus	0.50	0.23
	Insect pest in wk 3	0.25	2.38
	Insect pest in wk 5	16.27 0	0
	Insect pest in wk 7	13.85	1.59
	Insect pest in wk 9	0	0
Sweet pepper	Insect pest in wk 11	0	0
	Cyperus spp	0	0.25 0.15
	C. dactylon	0.75 0.75	0.25
	Bamuda spp	0.88	0.31
	Commelina	0.25	0
	C, plectostychus	19.50	0.25
	Insect pest in wk 3	0	0
	Insect pest in wk 5	6.90	1.73
	Insect pest in wk 7	0	0
	Insect pest in wk 9	1.95 0.75	0.42 0.25
	Insect pest in wk 11	1.37 1.12	0.12 0.13
Hot pepper	Cyperus spp	1.37	0.12 0.25
	C. dactylon	0.75	1.22
	Bamuda spp	18.27	
	Commelina		
	C, plectostychus		
	Insect pest in wk 3		
	Insect pest in wk 5		
	Insect pest in wk 7		
	Insect pest in wk 9		
	Insect pest in wk 11		
	Cyperus spp		
Tomato			

Garden egg	C. dactylon	0	0
	Bamuda spp	10.75	2.61
	Commelina	0	0
	C, plectostychus	0	0
	Insect pest in wk 3	2.75 4.17	0.14 0.39
	Insect pest in wk 5	4.88 6.12	0.23 0.13
	Insect pest in wk 7	2.75	0.14
	Insect pest in wk 9	11.75	2.07
	Insect pest in wk 11	0	0
Okra	Cyperus spp	8.12	2.20
	C. dactylon	0	0
	Bamuda spp	4.43 0.87	2.74 0.31
	Commelina	3.50 4.80	0.54 0.10
	C, plectostychus	5.00	0.20 0.31
	Insect pest in wk 3	0	7.01
	Insect pest in wk 5	88.07	0
	Insect pest in wk 7	24.00	0.33 0.89
	Insect pest in wk 9	4.62	0.40
	Insect pest in wk 11	0	0
	Cyperus spp	3.60	0.35 0.39
	C. dactylon	0	0.24
	Bamuda spp	1.00 1.07	0.10
	Commelina	1.62	3.0
	C, plectostychus	0	0
mucuna	Insect pest in wk 3	11.32	0.98
	Insect pest in wk 5	0	0
	Insect pest in wk 7	9.75	0.50
	Insect pest in wk 9	0	
	Insect pest in wk 11	0.77	
	Cyperus spp		
	C. dactylon		
	Bamuda spp		
	Commelina		
	C, plectostychus		

Appendix 16: Means and standard errors of weed population and insect pests damage in vegetables at continuous cropping 1

Crop	Variables	Means	Standard error

Carrot	Insect pest in wk 3	0	0
	Insect pest in wk 5	0	0
	Insect pest in wk 7	0	0
	Insect pest in wk 9	0	0
	Insect pest in wk 11	0	0
	Cyperus spp	0	0
	C. dactylon	0	0
	Bamuda spp	0	0
	Commelina	1.15 0	1.33
	C, plectostychus	1.02	0
	Insect pest in wk 3	2.72	1.02
	Insect pest in wk 5	12.62 12.60	2.75
Cabbage	Insect pest in wk 7	13.67	13.82 12.60
	Insect pest in wk 9	0	15.75
	Insect pest in wk 11	0	0
	Cyperus spp	27.70	0
	C. dactylon	0.	0
	Bamuda spp	0	42.00
	Commelina	0	0
	C, plectostychus	0	0
	Insect pest in wk 3	1.00 0	0
	Insect pest in wk 5	0.16	0
	Insect pest in wk 7	30.05 0	1.00 0.11
	Insect pest in wk 9	32.07	0.12
Sweet pepper	Insect pest in wk 11	0	44.00
	Cyperus spp	0	22.07
	C. dactylon	0	0
	Bamuda spp	1.0	0
	Commelina	1.37 0	0
	C, plectostychus	1.50	1.0
	Insect pest in wk 3	0	1.37 0.13
	Insect pest in wk 5	0	1.50
	Insect pest in wk 7	2.23	0
	Insect pest in wk 9	0.22 0	0
	Insect pest in wk 11	0.62 1.12	2.22
Hot pepper	Cyperus spp	1.12 0.63	0.55
	C. dactylon	1.87	0
	Bamuda spp		0.63 1.12
	Commelina		1.13 0.62
	C, plectostychus		1.87
	Insect pest in wk 3		
	Insect pest in wk 5		
	Insect pest in wk 7		
	Insect pest in wk 9		
	Insect pest in wk 11		
Tomato			

	Cyperus spp	32.33 11.80	42.32 11.80
	C. dactylon	37.95	47.95
	Bamuda spp	0	0
	Commelina	0	0
	C, plectostychus	0	0
	Insect pest in wk 3	2.77 1.76	2.77 3.00
Garden egg	Insect pest in wk 5	3.60	5.42
	Insect pest in wk 7	5.42 0	0
	Insect pest in wk 9	2.35	2.35
	Insect pest in wk 11	0	0
	Cyperus spp	0	0
	C. dactylon	0	0
	Bamuda spp	9.50	0
	Commelina	14.37 13.32	9.50
	C, plectostychus	17.40	14.35 13.32
	Insect pest in wk 3	19.67	17.40
	Insect pest in wk 5	0.80 0.57	19.68
	Insect pest in wk 7	0.34 1.32	0
Okra	Insect pest in wk 9	0.34 0.87	0
	Insect pest in wk 11	1.75 1.60	0
	Cyperus spp	0.87	1.32
	C. dactylon	1.00	0
	Bamuda spp	0	0.13 0.25
	Commelina	0	0.23
	C, plectostychus	0	0.12
	Insect pest in wk 3	5.67	0
	Insect pest in wk 5	0 s	0
	Insect pest in wk 7		0
	Insect pest in wk 9		0
	Insect pest in wk 11		0
	Cyperus spp		0
mucuna	C. dactylon		
	Bamuda spp		
	Commelina		
	C, plectostychus		

Appendix 17: Means and standard errors of weed population and insect pests damage in vegetables at continuous cropping 2

Crop	Variables	Means	Standard error

Carrot	Insect pest in wk 3	0	0
	Insect pest in wk 5	0	0.25
	Insect pest in wk 7	0	0
	Insect pest in wk 9	0	0
	Insect pest in wk 11	0	0
	Cyperus spp	0.25 0.82	0.25 0.77
	C. dactylon	1.07	0.75
	Bamuda spp	24.07	11.03
	Commelina	25.52	2.21 0.12
	C, plectostychus	3.30	0.37 0.35
	Insect pest in wk 3	3.00 4.12.	0.48
	Insect pest in wk 5	4.87	0.35
Cabbage	Insect pest in wk 7	4.87	10.79 3.75
	Insect pest in wk 9	38.60 18.72	16.30
	Insect pest in wk 11	43.87	0
	Cyperus spp	0	0
	C. dactylon	0	0
	Bamuda spp	0	0.25 0.10
	Commelina	0	0.24
	C, plectostychus	0.75 1.37	0
	Insect pest in wk 3	1.75	10.47 1.69
	Insect pest in wk 5	40.10 16.45	14.38
	Insect pest in wk 7	14.10	0
	Insect pest in wk 9	0	0
Sweet pepper	Insect pest in wk 11	0	0
	Cyperus spp	0.52 0.65	0.25 0.28
	C. dactylon	0.50 0.50	0.29 0.25
	Bamuda spp	0.90	0.53 2.02
	Commelina	4.20 4.2	3.10
	C, plectostychus	1.52	3.46
	Insect pest in wk 3	24.00	0
	Insect pest in wk 5	0	0.24
	Insect pest in wk 7	1.27 1.88	0.37
	Insect pest in wk 9	2.37 1.25	0
	Insect pest in wk 11	2.00	0.28
Hot pepper	Cyperus spp		0.25
	C. dactylon		
	Bamuda spp		
	Commelina		
	C, plectostychus		
	Insect pest in wk 3		
	Insect pest in wk 5		
	Insect pest in wk 7		
	Insect pest in wk 9		
	Insect pest in wk 11		
Tomato			

	Cyperus spp	20.52 9.15	0.52 0.39
	C. dactylon	29.92 0	1.76
	Bamuda spp	47.20	0
	Commelina	2.80 4.00	0
	C, plectostychus	5.25 7.00	0.33 0.40
	Insect pest in wk 3	7.00 0.34	0.47 0.64
Garden egg	Insect pest in wk 5	1.20	0.54 0.30
	Insect pest in wk 7	0	0.76
	Insect pest in wk 9	0	0
	Insect pest in wk 11	0	0
	Cyperus spp	2.20 3.00	0
	C. dactylon	3.37 5.87	0.28 0.35
	Bamuda spp	5.87 0.85	0.11 0.12
	Commelina	2.30	0.13 0.54
	C, plectostychus	0.87	1.09 0.52
	Insect pest in wk 3	21.30	1.71
	Insect pest in wk 5	37.00	27.93
	Insect pest in wk 7	0.75 0.25	0.43
Okra	Insect pest in wk 9	0.87 0.37	0
	Insect pest in wk 11	0.57 0.25	0.51
	Cyperus spp	0.85	0.38
	C. dactylon	0.30	0
	Bamuda spp	14.50	0.28 0.52
	Commelina	49.22	0.30
	C, plectostychus		2.61
	Insect pest in wk 3		16.67
	Insect pest in wk 5		
	Insect pest in wk 7		
	Insect pest in wk 9		
	Insect pest in wk 11		
mucuna	Cyperus spp		
	C. dactylon		
	Bamuda spp		
	Commelina		
	C, plectostychus		

Appendix 18: Means and standard errors of weed population and insect pests damage in vegetables at continuous cropping 3

Crop	Variables	Means	Standard error

Carrot	Insect pest in wk 3	0	0
	Insect pest in wk 5	0	0
	Insect pest in wk 7	0	0
	Insect pest in wk 9	0	0
	Insect pest in wk 11	0	0
	Cyperus spp	49.72	11.42
	C. dactylon	0.25	0.39
	Bamuda spp	0.90	0.74
	Commelina	0	0
	C, plectostychus	0	0
	Insect pest in wk 3	1.87	0.24 0.29
	Insect pest in wk 5	4.00 5.0	0.20 0.25
Cabbage	Insect pest in wk 7	5.25	0.27
	Insect pest in wk 9	6.25	10.50
	Insect pest in wk 11	42.85	0
	Cyperus spp	10.45	1.41
	C. dactylon	0	0
	Bamuda spp	0	0
	Commelina	0	0.28 0.28
	C, plectostychus	0.50 0.50	0.32 0.14
	Insect pest in wk 3	1.00 1.25	0.12
	Insect pest in wk 5	1.13	3.08 0
	Insect pest in wk 7	44.95 0	0.77
	Insect pest in wk 9	14.37	0
Sweet pepper	Insect pest in wk 11	0	0
	Cyperus spp	0	0.28 0.15
	C. dactylon	0.28 0.14	0.31 0.38
	Bamuda spp	0.31 0.38	0.27 2.30
	Commelina	0.25 8.43	0.30
	C, plectostychus	0.30	0.30
	Insect pest in wk 3	0.30	0
	Insect pest in wk 5	0	0
	Insect pest in wk 7	0	0.28
	Insect pest in wk 9	0.50 0.12	0.13 0
	Insect pest in wk 11	0.14 1.25	0.14 0.i3
Hot pepper	Cyperus spp	1.30	1.75
	C. dactylon	37.02	0
	Bamuda spp	0	
	Commelina		
	C, plectostychus		
	Insect pest in wk 3		
	Insect pest in wk 5		
	Insect pest in wk 7		
	Insect pest in wk 9		
	Insect pest in wk 11		
	Cyperus spp		
	C. dactylon		
Tomato			

Garden egg	Bamuda spp	14.07	0.74
	Commelina	0	0
	C, plectostychus	0	0
	Insect pest in wk 3	2.25 4.00	0.14 0.28
	Insect pest in wk 5	5.12 6.75	0.39 0.47
	Insect pest in wk 7	7.37	0.31 3.47
	Insect pest in wk 9	38.77 5.25	2.48
	Insect pest in wk 11	10.45	2.54
	Cyperus spp	0.	0
	C. dactylon	0	0
	Bamuda spp	1.75 3.50	0.14 0.75
Okra	Commelina	5.05	0.12 0.20
	C, plectostychus	5.0	0.28 0.42
	Insect pest in wk 3	6.0	0.44
	Insect pest in wk 5	30.05	0.26
	Insect pest in wk 7	0.72	0
	Insect pest in wk 9	0.40	0
	Insect pest in wk 11	0	0
	Cyperus spp	0	0.28 0.38
	C. dactylon	0	0.25 0.37
	Bamuda spp	0.50 0.25	0.25 0.70
	Commelina	0.62	0.52 1.14
	C, plectostychus	0.25	0.63
mucuna	Insect pest in wk 3	11.42	
	Insect pest in wk 5	0.52	
	Insect pest in wk 7	1.20	
	Insect pest in wk 9	0	
	Insect pest in wk 11	0	
	Cyperus spp		
	C. dactylon		
	Bamuda spp		
	Commelina		
	C, plectostychus		

Appendix 19: Means and standard errors of weed population and insect pests damage in vegetables at continuous cropping 4

Crop	Variables	Means	Standard error

Carrot Cabbage Sweet pepper Hot pepper Tomato	Insect pest in wk 3 Insect pest in wk 5 Insect pest in wk 7 Insect pest in wk 9 Insect pest in wk 11 Cyperus spp C. dactylon Bamuda spp Commelina C, plectostychus Insect pest in wk 3 Insect pest in wk 5 Insect pest in wk 7 Insect pest in wk 9 Insect pest in wk 11 Cyperus spp C. dactylon Bamuda spp Commelina C, plectostychus Insect pest in wk 3 Insect pest in wk 5 Insect pest in wk 7 Insect pest in wk 9 Insect pest in wk 11 Cyperus spp C. dactylon Bamuda spp Commelina C, plectostychus Insect pest in wk 3 Insect pest in wk 5 Insect pest in wk 7 Insect pest in wk 9 Insect pest in wk 11 Cyperus spp C. dactylon Bamuda spp Commelina C, plectostychus Insect pest in wk 3 Insect pest in wk 5 Insect pest in wk 7 Insect pest in wk 9	0 0 0 0 0 29.32 0 3.02 0 1.25 2.37 4.37 5.60 5.87 2.37 39.70 0 13.00 0 0 0.25 0.28 0.43 0.13 0.25 6.07 0 15.10 0 0 0.75 3.00 0.75 1.00 0.25 16.25 0 0.75 0 2.0 0.75 1.38 1.25 1.25 0.75 29.90 0 14.17 0 0 3.17 4.62 5.37 6.57	0 0 0 0 0 0.31 0 1.07 0 0.14 0.35 0.12 0.33 0.24 0.39 0.86 0 0.84 0 0 0.26 0.29 0.45 0.13 0.25 6.07 0 1.16 0 0 0.25 1.15 0.25 0 0.27 1.29 0 0.57 0 0.290 0.25 0.12 0.14 0.14 0.25 28.90 0 16.70 0 0 0.19 0.39 0.32 0.12

Garden egg			

	Insect pest in wk 11	3.17	0.14
	Cyperus spp	17.95	2.05
	C. dactylon	0	0
	Bamuda spp	10.92	2.84
	Commelina	0	0
	C, plectostychus	3.52 1.00	1.89 0.20
	Insect pest in wk 3	4.62 5.47	0.12 0.22
	Insect pest in wk 5	4.12	1.39 0.20
Okra	Insect pest in wk 7	1.00	3.26
	Insect pest in wk 9	27.00	0
	Insect pest in wk 11	0	0.33
	Cyperus spp	5.67	0
	C. dactylon	0	0.22
	Bamuda spp	3.76	0
	Commelina	0	0.25 0.28
	C, plectostychus	0.75	0.24
	Insect pest in wk 3	0.50 1.0	0
	Insect pest in wk 5	0	2.05
	Insect pest in wk 7	6.20	0.0.80
	Insect pest in wk 9	0	0
mucuna	Insect pest in wk 11	1.57	0.52
	Cyperus spp	0	0.54
	C. dactylon	1.10	
	Bamuda spp		
	Commelina		
	C, plectostychus		