KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF CROP AND SOIL SCIENCES

GROWTH, YIELD AND ROOT QUALITIES OF TWO SWEET POTATO (*IPOMOEA BATATAS L.*) VARIETIES AS INFLUENCED BY ORGANIC AND INORGANIC FERTILIZER APPLICATION

BY

ALBERT NYARKO

SEPTEMBER, 2015.

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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES,

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI,

IN PATIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE AWARD OF MASTER OF PHILOSOPHY IN AGRONOMY

(CROP PHYSIOLOGY) DEGREE

BY

ALBERT NYARKO

(B.ED AGRICULTURE EDUCATION)

(UEW)

SEPTEMBER, 2015.

DECLARATION

This is to certify that the research work presented in this thesis was carried out by Albert Nyarko, Department of Crop and Soil Sciences, Faculty of Agriculture, College Of Agriculture And Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana and has not been submitted to any other University for a degree. Works of other workers have been duly acknowledged.

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ABSTRACT

A field experiment was conducted at the Crops Research Institute (CRI) at Fumesua – Kumasi from August to December, 2014. The research aimed at determining the growth, yield and root quality responses of sweet potato (*Ipomoea batatas L*) to organic manures (poultry manure and cow dung) and inorganic fertilizers (NPK, 15-15-15) and their combinations. The experimental design used for the project was a 2×3 factorial with treatments arranged in randomized complete block design (RCBD) with three replicates. The treatments were: Sole poultry manure (6t/ha); Sole cow dung (8t/ha); Sole NPK, 3030-30; NPK, 15-15-15 + PM (3t/ha); NPK, 15-15-15 + CD (4t/ha); NPK, 22.5-22.522.5 + PM (1.5t/ha); NPK, 22.5-22.5-22.5 + CD (2t/ha); NPK, 7.5-7.5-7.5 + PM (4.5t/ha); NPK, 7.5-7.5-7.5 + CD (6t/ha); and No fertilizer amendment (control). Two sweet potato varieties were used for the experiment. These were "Apomuden" and Santom Pona". The result indicated that on the average, the organic manure and inorganic fertilizer combinations promoted more growth (215.2cm) than the sole applications and the control (186.7), with the greatest marketable root yield (14.8 t/ha) obtained from 7.5-7.5-7.5 NPK + 4.5 t/ha PM. On root dry matter, NPK 15-15-15 + CD (4t/ha); NPK 15-15-15 + PM (3t/ha); and NPK 7.7-7.5-7.5 + CD (6t/ha) produced the highest responses (32.6%, 31.1%, 30.9%) respectively. NPK 22.5-22.5-22.5 + CD (2t/ha); sole poultry manure (6t/ha); and NPK 15-15-15 + CD (4t/ha) recorded the highest protein content (6.1% each). Integrated application of organic manure and inorganic fertilizers (NPK, 15-15-15) are recommended for improved sweet potato production.

ACKNOWLEDGEMENT

I am grateful to the Almighty God for His protection and strength throughout this study. My profound gratitude and appreciation go to my supervisor, Dr. Joseph Sarkodie –Addo of the Department of Crops and Soil Sciences, KNUST, for his supervision, advice, directions and assistance that have brought this work to a successful end.

My sincere and heartfelt gratitude goes to Mr. Kwadwo Adofo of the CSIR-Crops Research Institute, Fumesua-Kumasi for his immeasurable contribution from the start to the end of this work. In fact, this work could not have been successful without his assistance.

I very much appreciate the contribution of the International Potato Centre at the Crops Research Institute, in sample analysis for the root qualities.

DEDICATION

I dedicate this work to my dearest wife, Debora Nyarko and our beloved son Reginald Nyarko.

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CHARTER ONE

1.1 INTRODUCTION

Root and tuber crops provide a substantial part of the world"s food supply and are an important source of animal feed and industrial products. Globally, approximately 45% of root and tuber crops produced are consumed as food, with the rest used as animal feed or for industrial processing for products such as starch, distilled spirit and a range of minor products.

Sweet potato, *Ipomoea batatas (L)* is a vegetatively propagated vegetable. The exact origin of sweet potato is not known, but it is believed to have originated from Central America or North Western South America (Onweme, 1978). It is a perennial crop but is handled as an annual. The storage root is capable of continued enlargement and does not mature in the sense of reaching some final size of development (Edmond and Ammerman, 1970). It is however normally grown as an annual crop from vine cuttings. The roots of sweet potato do not ripen but continue to enlarge and eventually mature as long as conditions favourable for growth exist (Akorado, 1992).

Today, sweet potato is grown in almost all parts of the tropics, sub-tropics and in the warmer areas of the temperate regions. Major part of the global sweet potato production takes place in China. In the USA, the crop is grown in commercial quantities along the East Coast, in New Jersey, Maryland, Virginia, North Carolina, South Carolina and Florida, in the Gulf State of Alabama, Mississippi, Louisiana, and Texas, in other Southern and Western States (Walsh and Johnson, 1980).

Sweet potato, once mostly a directly consumed food crop, has now a diversified market. It serves as an important staple food for small-holder farmers. The vines, leaves and roots serve as feed for livestock (Yen, 1974). In other countries such as Japan and China, the crop has been put into multiple uses such as animal feed as well as industrial processing of the roots into starch and alcohol. In the savannah regions of Ghana, sweet potato is eaten in different forms such as ampesi, fried chips or can be boiled and mashed (Doku and Banful, 1993).

Inorganic fertilizer has been the conventional method of soil mineral input. But these fertilizers are becoming increasingly expensive. Sole application of organic manure is often non-feasible due to limited availability and bulkiness where available. The use of chemical fertilizer, as a sole application method, is the option for most farmers. Unfortunately, the use of chemical fertilizers comes with problems such as high cost of the fertilizers and the negative effects on the environment. As a result of the high cost of chemical fertilizers, most farmers resort to non-application of soil mineral amendments leading to low yield in sweet potato. It is generally accepted that applying both organic and inorganic inputs are crucial in increasing crop production in West Africa (Palm *et al.*, 1997). A number of studies carried out on organic and inorganic fertilizer combinations in sweet potato production have attested to a positive interaction between the two when applied at the same time (Palm *et a*l., 1997).

It has been reported that sweet potato gives a positive response to varying regimes of nitrogen, phosphorus and potassium fertilizers (Dapaah, 2004). According to Cheng-Wei *et al*. (2014), the nutrient use efficiency of a crop increases through a combined application of organic manure and inorganic fertilizers. Poultry manure in combination with inorganic fertilizer is reported to give significant marketable root yield in sweet potato (Hartemink, 2003).

Yeng *et al*. (2012) observed that organic and inorganic inputs combination for soil mineral supplementation in sweet potato production is a better option than either of organic or inorganic inputs applied solely. The application of organic manure to supplement inorganic fertilizers as an integration management system is of great importance as this will help in reducing the cost of soil mineral inputs, increase yields and sustain sweet potato production in Ghana.

In Ghana, there is very little information on the appropriate combination rates of organic and inorganic fertilizer for sweet potato production (Dapaah, 2004). In most parts of Ghana, especially the Southern sector, there is low patronage of sweet potato by consumers. This is probably as a result of little knowledge about the nutritional values of the crop.

There is the need to assess the response of sweet potato to both organic and inorganic fertilizers, as well as in an integrated management system and how these affect quality factors of the roots. This will provide farmers with alternative ways of fertilization and also provide consumers with the nutritional values of sweet potato.

Making the nutritional values of sweet potato known to consumers will ensure high patronage of the crop and this will provide market for sweet potato farmers. Also, considering the ever-increasing cost of the chemical fertilizers and its potential attendant environmental effects, a research to find alternative ways of providing nutrients for the growth and yield of sweet potato is worth undertaking.

The main objective of the research was to determine the impact of fertilizer application on sweet potato production.

The specific objectives were to:

i. Determine the effects of organic fertilizers (cow dung and poultry manure) and inorganic fertilizer (NPK) on the vegetative growth of two (2) sweet potato varieties

ii. Assess the influence of organic and inorganic fertilizers on the root yield of two varieties of sweet potato iii. Investigate the effects of organic and inorganic fertilizer amendments on the root quality of two sweet potato varieties.

iv. Determine the interaction, if any, between organic and inorganic fertilizers on the root yield and quality of sweet potato.

v. Recommend the appropriate organic and inorganic fertilizer rates for sweet potato production.

vi. Determine the profitability of fertilizer application to sweet potato production.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin and Distribution of sweet potato

The exact origin of sweet potato, (*Ipomoea batatas L*) is not known, but it is believed to have originated from Central America or North Western South America (Onwueme, 1978). According to Beukema and Van Der Zaag (1990), sweet potato originated from the Mountains of South America.

In the 16th century, sweet potato was introduced to Europe, where it gradually became food crop. It became an important food crop in the 18th and 19th centuries, especially for the poor in various countries in Europe. Immigrants from Europe took tubers of sweet potato along with them to North America. The crop was introduced to many tropical and sub-tropical countries, mainly by colonists from Europe during the 19th century (Beukema and Van Der Zaa, 1990).

Sweet potato is now grown in almost all parts of the tropics, sub-tropics and in the warmer areas of the temperate regions (Walsh and Johnson, 1980). Regions where the crop is grown in commercial quantities include North Africa, the plains of India, Bangladesh, Pakistan, Central America, Chile, Argentina and Uruguay.

Sweet potato is the second most widely distributed crop in the world, after maize. It is grown in about 140 countries, more than 100 of which are located in the tropical and sub-tropical zones, with most production still concentrated in the temperate regions in the industrialized countries. About a third of the crop is produced mainly in developing countries in Asia (Beukema and Van Der Zaag, 1990). In Ghana, sweet potato is widely cultivated in the Savannah zones, especially in the Coastal Savannah (Central and Volta regions) and the Guinea Savannah (Northern region).

2.2 Botany of sweet potato

Sweet potato is a dicotyledonous plant that belongs to the family Convolvulaceae. It is a perennial crop and the storage root is capable of continued enlargement and does not mature in the sense of reaching some final size or stage of development (Edmond and Ammerman, 1971). Sweet potato roots do not ‚ripen‟ but would continue to enlarge and eventually mature as long as conditions favourable for growth exist. (P‟obwoya and Mwanga, 1994). It is an asexually propagated vegetable.

The aerial stems, which may be branched, are generally hollow and triangular in cross section. The lower part of the stem is round and solid. The mature leaves are compound consisting of a petiole with terminal leaflet, lateral leaflets, secondary leaflets and sometimes tertiary leaflets. A stem is considered to be a main stem, if it grows directly from the seed tuber. The lower lateral branches from the stem are, called secondary stems. Apart from lateral branching, a potato stem may develop apical branches several times during its growth. The plant generally has shallow roots. The tuber is part of the root adapted to food storage and reproduction (Beukema and Van Der Zaag, 1990).

2.3 Planting Materials

In Africa, sweet potato is mainly planted using stem cuttings from an existing crop, or nursery. Planting materials are selected from healthy and vigorously growing, two to three months old plants. Cuttings are usually 25 – 30cm long, obtained from the vine tip, but the middle part can also be used when planting material is scarce. Planting material from the base of vines should be avoided as this can be weevil infested (CIP, 2012).

2.4 Conditions for growth

Sweet potato does best in well-drained sandy loam soils with a pH range of 5.5 – 7.0. Most farmers plant on mounds or ridges to ensure adequate aeration and space for the growth of storage roots. Good stand establishment at recommended spacing (25 – 30 cm by 75 – 100 cm) helps ensure high root yields. Sweet potato responds well to fertile soils, but can tolerate lower fertility better than many other crops. The crop requires adequate moisture during the critical stages of establishment and storage roots formation during the first two to three months after planting. But then the crop is generally drought tolerant. Weeding during the early stages of growth, and "hilling-up" the soil around the base of the plant ensure no roots are exposed as they develop (CIP, 2012).

2.5 Economic Importance of sweet potato

Sweet potato *[Ipomoea batatas (L*)] is the only specie of economic importance as food in the plant family Convolvulaceae of about 50 genera and 100 species. It plays an important role as a co-staple and secondary staple in the food system in Africa particularly where diet is based on starchy staples like cassava and maize (Scott and Ewell, 1992).

Sweet potato, once a direct food crop now has a diversified market. The vines, leaves and the roots serve as feed for livestock (Yen, 1974). Sweet potato roots can be included in pullet chick diet up to 25 kg per 100 kg of diets, while sweet potato tops can replace wheat offal to a level of 50% or 9.20 kg per 100 kg of diet (Akoroda, 2003). In other countries such as Japan and China, the crop has been put into multiple uses such as animal feed as well as industrial processing of the roots into starch and alcohol. In the savanna regions of Ghana, sweet potato is eaten in different forms such as "ampesi", fried chips or can be boiled and mashed (Doku and Banful, 1993).

Farmers grow sweet potatoes and sell the harvested roots for money to support themselves and their families. The tender tips and young leaves of sweet potato vines are commonly eaten as a vegetable in Asia, West Africa and in parts of southern Africa.

2.6 Nutritional Values of sweet potato

All sweet potatoes contain important vitamins and minerals, especially vitamins C, B6, folic acid, potassium and manganese. The orange-fleshed sweet potato in particular is an important source of beta carotene, a precursor to vitamin A (Stather *et al*., 2013). It is the only starchy staple, which contains appreciable amounts of b-carotene, ascorbic acid and amino acid lysine which is deficient in cereal-based diets (Bradbury and Singh, 1986). Jaarsveld *et al.* (2005) observed that the incorporation of beta-carotene sources, mainly orange-fleshed sweet potato, into the meal significantly increased serum retinol concentration. Sweet potato has energy value comparable to other root and tuber crops, beans, and rice when cooked [sweet potato = 144 kcal, cassava = 124 kcal, yam = 101 kcal, rice (white) = 109 kcal, beans = 118 kcal per 100g of boiled edible portion] (Woolfe, 1992).

Sweet potato also contain appreciable amount of soluble fibre which helps in reducing cholesterol level, and anti-oxidant nutrients which can inhibit the development of coronary heart disease and cancer (WHO, 1990; Woolfe, 1992).

The vines are high in protein, containing 2.7 – 3.4g/100g of raw fresh leaves. Sweet potato are a valuable source of vitamin A and other nutrients (Villareal , 1985).

2.7 Effects of Organic fertilizers on plants growth and yield

Yield of plants has been significantly affected by adding organic manure. Plants grow better in soils amended with organic fertilizer (Ouda and Mahadeen, 2008). According to their research, organic manure seemed to be less effective in increasing the yield of crops than inorganic fertilizers. However, organic manure need more time for nutrients to be available for plant absorption. Eghball and Power (1999), found that about 40% cattle manure become plant available in the first year after application. But according to Ramamurthy and Shivashankar (1996), nutrients present in organic matter are not fully available to the crops in the season of its application.

Organic fertilizers could be used to produce crops with similar or better growth or yields than crops grown from the use of inorganic fertilizers (Russo, 2005; Treadwell *et al*., 2007; Zhao *et al*., 2009). It has also been observed that the effect of organic fertilizers on plant growth seem varied and some studies showed decreased plant growth or yields when using organic fertilizers compared with conventional fertilizers (Ali,1997; Peet *et al*., 2004). This variation could be the result of the differences in organic fertilizer source being used and application rates and timing (Rosen and Allan, 2007). Excessive organic fertilizer depresses plant growth compared with lower fertility levels (Carpio *et al.*, 2005, Kelley and Biernbaum, 2000).

According to Suge *et al*. (2011), organic manure significantly enhance growth and yield of crops. The use of organic manure enhances fertilizer use efficiency of crops (Muneshwar *et al.*, 2001; Nevens and Reheul, 2003). In an experiment, Parraga *et al*. (1995) reported that poultry droppings produced the maximum root diameter of plants. In a research conducted by Granstedt and Kjellenberg (1997), it was observed that yield increase is higher in organic treatments than conventional mineral fertilizer treatments. Also, the average tuber yield of cassava was nearly the same in the organic and inorganic fertilizer treatments, whereas the yield was significantly lower in the unfertilized treatment.

Growth promoting substances like enzymes and hormones present in organic manures make them useful for improvement of soil fertility and productivity (Singh *et al.*, 2008).

Sanwal *et al*. (2007) observed that the application of organic manure produces high and sustainable crop yield. Attarade *et al*. (2012) also asserted that organic manures increase can enhance the nutrient status of fruits.

According to Patel *et al*. (2009), unless it is integrated with inorganic fertilizers, the use of farmyard manure alone may not fully satisfy crop nutrient demand, especially in the first year of application. However, it was revealed that animal manure are useful in improving the efficiency of fertilizer recovery thereby resulting in higher crop yield (Gedam *et al*., 2008). Bayu *et al.* (2006) also reported the possibility of saving up to 50% of the recommended NP fertilizers due to amendment with 5-15t/ ha of farmyard manure to sorghum crop without significantly affecting the optimum possible yield that can be obtained with the application of full dose of inorganic NP fertilizers alone.

The results of an experiment conducted by Ambecha (2001), showed that sweet potato fresh weight is highly responsive to increase levels of farmyard manure. According to his results, as the rate of farmyard manure increased, the development of green top at the expense of production of tuberous root yields was promoted. Also Tesfaye *et al*. (2008) observed that if sweet potato is produced for livestock feed, application of the maximum farmyard manure helps for better fresh foliage production since increasing farmyard manure application and foliage development are positively correlated. The effect of farmyard manure on average vine length is statistically significantly (Teshome *et al.*, 2012). However, Parwada *et al*. (2011) in an experiment found insignificant root counts per plant of sweet potato in response to chicken manure applied at planting. The analysis of various for tuberous root diameter showed that the main effects due to farmyard manure were non-significant on tuberous root diameter.

Najm *et al.* (2010) found a highly significant vine development of potato in response to application of cattle manure. According to Halvin *et al.* (2003), the increase in vine length in response to increase rate of farmyard manure may be ascribed to increase availability of nutrients in the soil for uptake by plant roots that may have enhanced vegetative growth through increasing cell division and elongation. It has also been noticed that plants grown in soils amended with organic fertilizer show vigorous vegetative growth and high yield comparing with application of chemical fertilizer alone.

2.8 Effects of Chemical fertilizers on plant growth and yield.

Inorganic fertilizer is considered a major source of plant nutrients. Yield of crops are significantly affected by adding inorganic fertilizers (Adediran *et al*., 2004). According to Sanwal *et al*. (2007), nitrogen, phosphorus and potassium influence vegetative and reproductive phase of plant growth.

In a research conducted by Parwada *et al*. (2011), the analysis of variance for tuberous root diameter of potato showed that the main effects due to phosphorus were nonsignificant on tuberous root diameter. Also, the main effect of phosphorus was not significant on vine length.

2.9 Effect of fertilization on the yield quality factors of plants

Granstedt and Kjellenberg (1997), made the following observations; the crude protein content of potatoes and wheat was lower in organic treatments, but protein quality was higher (that is relatively pure protein and essential amino acids, lower amount of free amino acids). Resistance to decomposition and store quality for potato were higher in organic treatments and in wheat, starch quality seemed to be higher. The organic treatment resulted in a higher soil fertilizer utilization in crops with higher quality protein, a higher starch content than the inorganic treatments. Crude protein was also significantly higher in the inorganic treatments but the content of relatively pure protein was significantly higher in the organic treatments than the inorganic ones. By organic fertilization, the quality of yield is improved, which is indicated by high concentrations of sugars and vitamin C.

Organic products are expected to be healthier for human consumption than inorganic products (Ouda and Mahadeen, 2008). According to Suge *et al.* (2011), organic manure significantly enhance fruit quality of plants.

2.10 Interactive Effects of Organic and Inorganic Fertilizer Application on the Growth, Yield and Quality Factors of Crops

In an experiment, Parraga *et al*. (1995) found out that application of organic matter with NPK fertilizers increased the root diameters of root per plant. Iqbal (2008) also observed the combined application of organic manure and chemical fertilizers significantly increased the stems of plants. Asghar *et al.* (2009) reported that integrated use of organic waste and N fertilizers significantly increase the uptake of the N. Organic fertilizer applied in combination with inorganic fertilizer could be used as nutrient sources and can meet nutrient requirement for plants. The combination of organic fertilizer and inorganic fertilizers promote plant growth the most (Cheng-Wei *et al*., 2014)

The application of appropriate ratio of organic and inorganic fertilizers in the field act as growth promoter for crops (Deshmiskh *et al*., 2010). According to them the appropriate combination of organic fertilizer with inorganic fertilizer helps to increase plant growth. Also, the application of organic manure in combination with chemical fertilizer has been reported to increase absorption of N, P and K in sugar cane leaf tissue in the plant and ratoon crop, compared to chemical fertilizer alone (Bokhtiar and Sakurai, 2005). Ouda and Mahadeen (2008) indicated that plants grown in soil amended with organic fertilizer show vigorous vegetative growth and high yield compared with application of chemical fertilizer alone.

Bhuiya and Akanda (1982) reported that organic manure in combination with chemical fertilizer showed excellent response to rice production. Combined application of organic and inorganic fertilizer results in higher yields than sole application of each nutrient source.

Tolessa and Friesen (2001) reported that the application of 25% recommended inorganic N P fertilizers with enriched farmyard manure resulted in the higher marginal rate of returns in maize, indicating that the integrated approach can enable farmers to save up to 75% of commercial fertilizers. According to Deshmiskh *et al*. (2010), a combination of organic and inorganic sources of nutrients might be helpful to obtain a good economic return with good soil health for subsequent crop yield. Also, it was reported in an experiment that the integrated use of farmyard manure and commercial N P fertilizers significantly enhanced potato tuber yield as compared to the use of each fertilizer source separately, thus potentially reducing the cost of production (Balemi, 2012). Negassa *et al*. (2001) have shown improved grain yield of maize due to integrated use of farmyard manure and inorganic N P fertilizers.

Somanath and Syeenivasmuthy (2005) reported improved dry matter yield in *Coleus forskohlii* due to integrated use of farmyard manure with NPK than using NPK alone. In an experiment, Parwada *et al*. (2011) found that interactive effect of P and FYM was statistically non-significant on average tuber number of sweet potato per plant.

However, the tuber root diameter was significantly affected by the interactive effects of FYM and P.

Teshome *et al.* (2012) conducted an experiment and reported that vine length was highly influence by the interactive effect of FYM with P. It was also reported that organic manure and inorganic fertilizer supplied all the essential nutrients at seedling stage resulting in increased plant height.

Bwembya and Yerokun (2001) also reported that plants treated with both inorganic fertilizer and manure were significantly taller than that received either of the treatments, indicating positive interaction effect of the two fertilizers on this trait. Sustaining soil and soil fertility in intensive cropping systems for higher crop yields and better quality can be achieved through integrated organic and inorganic nutrient management (Teshome *et al.*, 2012).

2.11 Factors Underlying Low Sweet Potato Yields

There are many factors underlying the low yields of sweet potato. Among these factors are the use of varieties with low yield potentials; failure to plant on time under rain-fed conditions; poor quality planting materials; poor cultural practices including weeding, fertility and water management, and pests (particularly weevils) infestation and rodents (CIP, 2012).

2.12 Diseases of Sweet Potato

2.12.1 Black Rot Disease

This disease is caused by fungus called *Ceratocystis fimbriata*. The disease can cause significant losses in storage, in the transplant bed and in the field. The pathogen not only reduces yield and yield quality but also gives sweet potato a bitter taste.

The initial symptoms black rot are small, circular, slightly sunken, dark brown spots on the roots. Spots enlarge and appear greenish black to black when wet and greyish black when dry. Within the spots are small, black fungal structures with long necks which appear to the naked eye as dark bristles. The rot usually remains firm and shallow. However, if secondary fungi or bacteria invade the tissue, the flesh beneath the spot turns black, and this blackened area may extend to the centre of the root. Tissue near the discoloured area may have a bitter taste. Eventually, the entire root may rot (Sikora and Dangler, 1995).

Control measures include the following:

- It can be controlled with crop rotation, since most crops are not affected by the disease.
- Disinfect seedbeds if a clean site is unavailable.
- Propagate plants from healthy vine cuttings.
- Apply a postharvest fungicide.
- Do not wash and package roots showing symptoms of black spot.
- Decontaminate equipment that come in contact with an infected crop.
- Spray empty washing machines and crates with fungicides.
- Fumigate storage structures (Sikora and Dangler, 1995).

2.12.2 Fusarium Surface Rot and Fusarium Root Rot

These are caused by species of the fungal Fusarium. Fusarium surface rot is common on roots stored for any length of time after harvest.

Surface rot occasionally occurs prior to harvest on roots that have been mechanically injured, split by growth cracks, or damaged by nematodes, insects or other soil pests. Lesions on fleshy roots are circular, light to dark brown, firm and dry.
Decay remains shallow, usually not extending beyond the roots vascular ring. Externally, lesions appear solid brown and are often centred on a broken rootlet. When infected roots are stored for an extended period, the tissue around lesions dries and becomes shrunken and the root eventually becomes hard and mummified.

Root rot lesions are circular and commonly exhibit light and dark brown concentric rings. Internal rotting extends beyond the vascular area into the centre of the root and may eventually affect the entire root. Older lesion is dark brown, dry, spongy and ovalshaped cavities occur near the root surface. These cavities often have white fungal growth on their inner surfaces. As the lesions grow the infected tissue shrinks, dries up, and eventually mummifies.

Surface rot is prevalent when sweet potatoes are mechanically harvested, when soil is wet and cold at harvest or excessively dry prior to harvest (causing increased skinning of sweet potato), when sweet potato are exposed to high or low temperatures for extended periods after harvesting and prior to harvesting and curing, or when conditions are favourable for desiccation of wounded tissues.

Control

The following measures are useful in controlling Fusarium surface rot and Fusarium root rot:

- To reduce root rot, control surface rot.
- Use sanitary practices and properly handle harvested roots.
- Minimize injury during harvesting and handling.
- Cure roots immediately after harvest.
- Reduce surface rot in the field by controlling root-knot nematodes and insects that can rupture the skin of sweet potato.
- Reduce the spread of Fusarium root rot to sprout on the transplant beds by planting disease-free roots treated with fungicides.

2.12.3 Rhizopus Soft Rot

This is caused by the fungus *Rhizopus stolonifer.* It is often referred to as the bread mould fungus. The disease mostly occurs after sweet potato have been harvested.

Infection and decay commonly occur at one or both ends of the root, although infection occasionally begins elsewhere. Rotting may be inhibited under dry conditions, but under humid conditions the affected sweet potatoes become soft and watery and the entire root rots within a few days. If the humidity is high, the sweet potato becomes heavily "whiskered" with a grayish black fungal growth. This feature distinguishes Rhizopus soft rot from other storage rots. The colour of the root is not significantly altered, but an odour is produced that attracts fruit flies to the area.

Spores of Rhizopus are common in the soil and in the atmosphere. The fungus can also survive in crop debris and to some extent, on contaminated equipment. The fungus usually infects through wounds made during harvesting. Once established, the fungus is capable of attacking healthy, uninjured tissues. Chilling and heating damage also predisposes sweet potato to infection.

Control

The following control measures will help to control rhizopus soft rot:

- Carefully handle sweet potato harvest to prevent unnecessary wounding.
- Properly cure roots immediately after harvesting.
- Apply recommended fungicide after harvest.
- Do not allow sweet potato to be exposed to sunlight for extended periods (to prevent heat damage) or to be chilled on the field.

2.12.4 Charcoal Rot

This disease is caused by the fungus *Macrophomina phaseoli.* It can cause losses to sweet potatoes in storage, but serious losses seldom occur.

Symptoms in storage begin as a reddish brown, firm, moist rot, initially restricted to the area just beneath the sweet potato skin. As the decay progresses, the pathogen moves towards the centre of the sweet potato, causing further rot. Although the lesions are sometimes restricted, charcoal rot usually consumes the entire root, which eventually dries, becoming hard and mummified. The fungus is soil borne and survives in plant debris or in the soil.

Control of Charcoal Rot

Properly cure sweet potato immediately after harvest to reduce the incidence of charcoal rot.

2.13 Pests of Sweet Potato

2.13.1 Sweet Potato weevil

This is the most serious pest of sweet potato. It causes damage in the field and in storage. Sweet potato weevil was first identified in Louisiana in 1875. It is now found throughout the coastal plain from North Carolina to Texas. It is also found in Hawaii and Puerto Rico and widely around the world in the tropical regions. A complete life cycle one to two months, with 35 to 40 days being common during the summer months (Capinera, 2014).

This weevil feeds on plants in the family Convolvulaceae. Although it has been found associated with several genera, its primary hosts are in the genus *Ipomea.* Sweet potato weevil is considered the most serious pests of sweet potato, with reports of losses ranging from 5% to 95% in areas where the weevil occurs. A symptom of infestation by sweet potato weevil is yellowing of the vines, but a heavy infestation is necessary before this is apparent. Thus, incipient problems are easily overlooked and damage not apparent until tubers are harvested. The principal damage to sweet potato is mining of the tuber by larvae. The infested tuber is often riddled with cavities, spongy in appearance and dark in colour. In addition to damage caused directly by tunnelling, larvae cause damage indirectly by facilitating entry of soil-borne pathogens. Even low levels of feeding induce a chemical reaction that imparts a bitter taste and terpene odour to the tubers. Larvae also mine the vine of the plant, causing it to darken, crack or collapse. The adult may feed on the tubers, creating numerous small holes that measure about the length of its head (Capinera, 2014).

Planting time applications of insecticides are commonly made to the soil to prevent injury to the slips or cuttings. Either granule or liquid formulations are used or systemic insecticides are preferred. Post plant applications are sometimes made to the foliage for adult control, especially if fields are likely to be invaded by adjacent areas, but if systemic insecticide is applied, some suppression of larvae development in the vine may also occur. Insecticides are also applied to tubers being placed into storage to prevent reinfestation and inoculation of nearby fields (Capinera, 2014).

2.13.2 Whitefringed Beetles

The whitefringed beetle was first observed in North America near Svea, Florida in 1936 (Wayne, 2014). Whitefringed beetles are considered serious pests of many agricultural crops (Young *et al*., 1950). The most common hosts are cotton, peanuts, okra, soybean, cowpea, sweet potato among others (Johnson and Tappan, 1987). Though difficult control, planting in rotation with leguminous crops is of great help (Wayne, 2014).

CHAPTER THREE

MATERIALS AND METHOD

3.1 Experimental Side

The research was carried out at the Crops Research Institute (CRI) at Fumesua-Kumasi from August to December, 2014. Fumesua is located within latitude 6°, 41 North and 1°, 28 west. The area has a bimodal rainfall pattern with the major season rains around April to June and minor season rains from August to November. The average annual rainfall for the area is 1,345mm per annum. The area usually have a temperature between 22°C to 31°C. The vegetation is that of humid forest type. The soil is that of Ferric Acrisol Asuansi Series type (Adu and Asiamah, 1992).

3.2 Land Preparation

The land was manually cleared of all vegetation. The debris were collected from the field. A tractor was used to plough and later harrowed. A tractor was used to construct ridges measuring 1m in width. Pegging was later done to demarcate the ridges into 1×3m.

3.3 Experimental Design and Field Layout

The experiment design used for the project was 2×3 factorial with treatments arranged in Randomized Complete Block Design (RCBD). Two improved sweet potato varieties – Santom Pona and Apomuden were used.

3.4 Treatments and treatment application The fertilizer treatments studied were:

1. Poultry Manure (6t/ha)
2. Cow dung (8t/ha)
3. NPK, 30-30-30
4. NPK 15-15-15 + Poultry Manure (3t/ha)

5. NPK 15-15-15 + Cow dung (4t/ha)
6. NPK 22.5-22.5-22.5 + Poultry Cow dung (1.5t/ha)
7. NPK 22.5-22.5-22.5 + Cow dung (2t/ha)
8. NPK 7.5-7.5-7.5 + Poultry Manure (4.5t/ha)
9. NPK 7.5-7.5-7.5 + Cow dung (6t/ha)
10. No fertilizer amendment

The organic fertilizers and inorganic fertilizer were applied in the second week before planting and fourth week after planting respectively. The organic fertilizers were incorporated into the soil while the inorganic fertilizer was applied by top-dressing.

3.5 Planting Material

Two varieties of sweet potato, „Apomuden‟ and „Santom Pona‟ were used for the experiment. The planting materials (vines) were obtained from the Crops Research Institute, Fumesua-Kumasi.

„Apomuden‟ is a sweet potato variety released by the Crops Research Institute in the year 2005. It has an orange root skin colour and reddish (deep) orange root flesh colour. It has a maturity period of between 3 – 3.5 months, root yield of 30 t/ha and a dry matter content of 21.9%. It has high beta carotene levels, excellent industrial products such as beverages, baby foods; local dishes (very good for „mpotompoto‟ and „Tuozaafe‟).

„Santom Pona‟ on the other hand was released in the year 1998 by the Crops Research Institute. The root skin colour is dark cream with light yellow root flesh colour. Its maturity period is 4 months, total root yield of 17t/ha and dry matter content of 34.4%. It is very good for ampesi (tastes like yam variety, Pona), and has high foliage production.

3.6 Sampling and analysis of soil, poultry manure and cow dung.

Samples of the soil at the experimental field were randomly taken at a depth of 0 – 15 cm at three different spots within each of the replications. The samples were bulked together and sent to the laboratory for analysis. The soil samples were air-dried and sieved through a mesh of 2mm. The analysis carried out included soil P^H, organic carbon, total nitrogen, exchangeable potassium and available phosphorus. Samples of the poultry manure and cow dung were also taken to the laboratory for similar analysis.

3.7 Planting

Vines with at least four (4) nodes were planted with at least two nodes buried in the soil. The vines were planted at 30 cm spacing on the ridges. Planting was done on 8th August, 2014.

3.8 Cultural Practices

The following cultural practices which undertaken:

3.8.1 Weed Control

Weed control was manually done by hoeing and handpicking. The debris were left on the field to serve as mulch. Weeding was done two times before harvesting.

The first weeding was done in the 4th week after planting while the second weeding was done in the 10th week after planting.

3.8.2 Irrigation

Irrigation water was supplied to the crops to supplement the natural rain, whenever necessary. Irrigation was usually done in the mornings for about two hours. The type of irrigation used was the sprinkler.

3.8.3 Earthening-up

Earthening-up was done after each weeding. This was to prevent the exposure of the roots after weeding.

3.8.4 Pests and Disease Control

There was no incidence of disease and therefore no control measures were taken. There were some grasshopper infestations. There were no control measures since the infestation did not reach economic threshold.

3.9 Data collection

Parameters were measured based on the International Board for Plant Genetic Resources (IBPGR) Descriptor for sweet potato published in 1991.

3.9.1 Growth Data

Data taken at the vegetative stage included the following:

3.9.1.1 Plant Establishment

This parameter was taken by taking a physical count of the number of vines that sprouted from the two central rows of each plot. The count was done three weeks after planting (WAP).

3.9.1.2 Vine Length

The vine length was taken by measuring the main vine of the selected plants from the base to the tip of the vine. This was done with the use of a tape measure. Three plants were selected from each plot, measured and their means were computed and recorded.

This parameter was taken three months after planting.

3.9.2 Yield Data

Yield data were measured at harvest (4 months after planting). These parameters included the following:

3.9.2.1 Number of Plants Harvested

This parameter was taken by physical count of number of plants which were harvested from the two central rows of each plot. Harvesting was done manually with the use of hoes.

3.9.2.2 Number of Plants with Roots

This parameter was taken by checking the roots after harvesting. Any plant which had a root with food reserve was counted as having roots. Such plants from the two central rows were counted per plot and recorded.

3.9.2.3 Number and Weight of Marketable Roots

The marketable roots were determined by measuring the root diameter from the middle portion of the root using the Vernier calipers. Roots with diameter of 5cm and above were considered as marketable roots. All roots considered marketable per plot were bulked together and weighed, using a digital scale.

3.9.2.4 Non-Marketable Roots

Roots of the harvested plants within the two central rows were measured from the middle portion of the roots using Vernier callipers. Roots with diameter of less than 5cm were considered non-marketable. Roots which were badly damaged by weevils were also considered non-marketable. These roots were bulked together and weighed with a digital scale.

3.9.2.5 Fresh Vine Yield

This parameter was taken by bulking all the vegetative parts above the ground of all the plants harvested per plot and measuring their weight on a scale. Their readings were recorded per plot.

3.9.2.6 Roots Cracks

Root cracks were measured by visual examination of the roots and severity was scored on against a scale of 1 – 5.

3.9.2.7 Weevil Attack

Weevil infestation of the roots was measured by visual examination and severity was scored against a scale of 1 – 5.

3.9.2.8 Millipede Attack

Millipede attacks were measured by visual examination of holes created on the roots by millipedes. Severity was measured on a scale of 1 – 5.

3.9.3 Root Quality Assessment

Samples of the roots from each plot were taken to the laboratory for analysis. Yield quality factors such as beta carotene, dry matter content, zinc, iron, crude protein, sugar content and starch contents of the roots were analysed using the Near-Infrared Reflectance Spectrophotometer (NIRS) computer. The steps involved at the laboratory were washing, pealing, cleaning, freeze drying, milling and scanning by the NIRS scanner. The analysis were done at the International Potato Centre (CIP-Ghana) SASHA

Near-Infrared spectroscopy Laboratory, located at CSIR-Crops Research Institute, Fumesua-Kumasi.

CHAPTER FOUR

RESULTS

4.1 Physical and chemical properties of soil, poultry manure and cow dung. Table 1 indicates the physical and chemical properties of the soil, poultry manure and cow dung samples. The total organic carbon, total nitrogen and the exchangeable potassium of the soil samples were 2.26%, 0.13%, and 0.38 cmol/kg respectively while available phosphorus was 4.96mg/kg. The soil had a P^H of 6.8, with the texture being sandy loam.

The properties of the poultry manure were found as follows: organic carbon was 25.24%, calcium of 3.22%, total nitrogen was 2.38%, potassium as 3.11cmol/kg, available phosphorus was 1.08mg/kg and a P^H of 7.61. It also had sodium and magnesium contents of 0.22% and 4.60 respectively.

With regards to the cow dung, the total organic carbon was found to be 11.27%, the total nitrogen was 1.26%, the exchangeable potassium as 0.23 cmol/kg, that of available phosphorus to be 0.17 and a P^H

Table 1. Physical and chemical properties of soil, poultry manure and cow dung

Physical properties	**Soil (0-15 cm)**	**Poultry Manure**	**Cow Dung**
Organic carbon (%)	2.26	25.24	11.27
Calcium (%)	**-**	3.22	0.45
Total nitrogen (%)	0.13	2.38	1.26
Potassium (k) (Cmol/kg)	0.38	3.11	0.23
Available Phosphorus (P) (mg/kg)	4.96	1.08	0.17
P^H	6.9	7.61	7.2
Soil Texture	Sandy loam	_	_
Magnesium (%)	-	4.70	0.18

4.2 PLANT ESTABLISHMENT AND VINE LENGTH

There was no significant difference in the two varieties in respect of plant establishment. In the same way, there was no significant difference among any of the fertilizer types. There was no significant difference between „Apomuden‟ and „Santom Pona‟ in vine length. For fertilizer type, the effects of Poultry manure only, NPK 15-15-15 + Pm (3t/ha), NPK 15-15-15 + CD (4t/ha), NPK 7.5-7.5-7.5 + Pm (4.5t/ha) treatments were all significantly higher than that of the 22.5-22.5-22.5 NPK plus 2 tons cow dung treatment only. All other treatment differences were not significant (P > 0.05).

Table 2: effects of variety and fertilizer type on plant establishment and vine length.

Treatment	Plant Establishment (Number)	Vine Length (cm)
Variety		
Apomuden	18.0	202.0
Santom Pona	18.3	186.1
LSD (5%)	NS	NS
Fertilizer Type		
Poultry manure only	18.3 18.5	204.7
Cow dung only	17.8 18.8	182.5
200 NPK	18.7 17.8	186.7
100 NPK + 3t PM	17.8 18.0	213.2
100 NPK + 4t CD	18.5	215.2
150 NPK + 1.5t PM	17.8	196.2
150 NPK + 2t CD		160.2
50 NPK + 4.5t PM		208.3
50 NPK + 6t CD		186.0
Control		186.7
LSD (5%) CV	NS	40.7
(%)	4.9	18.0

All NPK fertilizers are in kg/ha

PM = Poultry manure, CD = Cow dung

4.3 Number of plants harvested and plants with roots

The results of the number of plants harvested are presented in Table 3. There was a significant difference between the varieties as „Santom Pona‟ recorded greater number than „Apomuden‟ variety. Fertilizer treatments did not significantly affect number of plants harvested.

The number of plants with roots was greater ($P < 0.05$) in the „Santom Pona‟ variety than in „Apomuden‟. Fertilizer treatments did not significantly affect ($P > 0.05$) number of plants with roots.

Table 3: Effect of variety and fertilizer type on the number of plants harvested and number of plants with roots.

Treatment	No of Plants Harvested/4.2m^2	No of Plants with Roots/4.2m^2
Variety		
Apomuden	9.1	8.3
Santom Pona	11.2	10.3
LSD (5%)	1.4	1.4
Fertilizer Type		
Poultry manure only	10.5	8.7 9.0
Cow dung only	9.8	8.7
200 NPK	9.3	10.3 9.2
100 NPK + 3t PM	10.8 9.8	10.0
100 NPK + 4t CD	10.3 9.8	8.8
150 NPK + 1.5t PM	10.8	9.8
150 NPK + 2t CD	10.7	10.0
50 NPK + 4.5t PM	9.3	8.7
50 NPK + 6t CD		
Control		
LSD (5%) CV (%)	NS 26.9	NS 29.4

All NPK fertilizers are in kg/ha

PM = Poultry manure, CD = Cow dung

4.4 Number of marketable and non-marketable roots

There was no significant difference (P > 0.05) between the varieties in the number of marketable roots. However, there were significant difference in responses to fertilizer application (Table 4). The treatment effect of 22.5-22.5-22.5 NPK plus 2 tons cow dung was the least, and this was significantly lower than treatment effects of poultry manure only, 15-15-15 NPK plus 3 tons poultry manure, and 7.5-7.5-7.5 NPK plus 4.5 tons poultry manure treatments only. All other treatment differences were not significant.

The number of non-marketable roots was not significantly (P > 0.05) affected by both sweet potato variety and fertilizer treatments (Table 4).

Table 4: Effects of variety and fertilizer type on the number of marketable and non-marketable roots of sweet potato

Treatment	**Number of Marketable Roots /4.2m^2**	**Number of Non Marketable Roots /4.2m^2**
Variety		
Apomuden	15.8	18.6
Santom Pona	13.3	17.6
LSD (5%)	NS	NS
Fertilizer Type		
Poultry manure 6t/ha	18.7	18.6
Cow dung 8t/ha	12.2	17.6
NPK (15:15:15) 200kg/ha	12.8	16.7
NPK 100kg/ha + Pm 3t/ha	16.7	23.8
NPK 100kg/ha + CD4t/ha	15.7	15.7
NPK 150kg/ha + Pm1.5t/ha	15.3 9.3	19.8
NPK 150kg/ha + CD2t/ha	18.3 15.0	14.7
NPK 50kg/ha + Pm 4.5t/ha	11.7	20.2
NPK 50/ha + CD6t/ha		19.5
No fertilizer amendment		17.7
LSD (5%) CV (%)	6.5 38.3	NS 43.1

4.5 Weight of marketable and non-marketable roots

The results of weight of marketable and non-marketable roots are presented in Table 5. There was a significant difference between the varieties with regards to weight of marketable roots. The treatment effect of „Apomuden‟ was greater than that of „Santom Pona‟ variety. The 7.5-7.5-7.5 NPK plus 4.5 tons poultry manure treatment effect was the greatest, but this was significantly (P < 0.05) higher than the effect of cow dung only, NPK only, 22.5-22.5-22.5 NPK plus 2 tons cow dung, and the control treatments only. The treatment effect of 22.5-22.5-22.5 NPK plus 2 tons cow dung was the least, but it was similar to that of cow dung only, NPK only and control treatments.

For weight of non-marketable roots, the treatment effect of the „Apomuden‟ variety was significantly higher (P < 0.05) than that of „Santom Pona‟ variety. Among the fertilizer treatments, the greatest effect was measured in the 15-15-15 NPK plus 3 tons poultry manure, but this was significantly higher than that of the NPK only treatment. All other treatment effects were similar.

Table 5: Effects of variety and fertilizer type on weight of marketable roots and weight of non-marketable roots of sweet potato

Treatment	**Weight of Marketable Roots (t/ha)**	**Weight of Non-Marketable Roots (t/ha)**
Variety		
Apomuden	12.2	4.2
Santom Pona	9.2	2.6
LSD (5%)	2.2	1.1

Fertilizer Type		
Poultry manure only	11.8	3.8
Cow dung only	8.5	3.7
200 NPK	8.3	2.2
100 NPK + 3t PM	13.3 10.4	4.8
100 NPK + 4t CD	12.0 7.5	2.7
150 NPK + 1.5t PM	14.8	3.6
150 NPK + 2t CD	11.2	3.0
50 NPK + 4.5t PM	7.9	3.5
NPK 50/ha + 6t CD		3.8
Control		2.7
LSD (5%) CV (%)	5.0 19.9	2.4 31.9

4.6 Vine yield and root cracks

From Table 6, fresh vine yield of „Santom Pona" was significantly (P < 0.05) higher than that of „Apomuden". Fresh vine yield was greatest in the 7.5-7.5-7.5 NPK plus 4.5 tons poultry manure and this was significantly higher than all treatment effects, except that of 22.5-22.5-22.5 NPK plus 1.5 tons poultry manure treatment and 15-15-15 NPK + 3 tons poultry manure. The least effect was measured in the control treatment but this was similar to those of cow dung only, NPK only, 15-15-15 NPK plus 4 tons cow dung, and 22.5-22.5-22.5 NPK plus 2 tons cow dung treatments.

All treatment differences for cracks development were not significant at 5% level of probability (Table 6).

Table 6: Effects of Variety and Fertilizer Type on Fresh Vine Yield and Root Cracks.

Treatment	Fresh Vine Yield (t/ha)	Roots Cracks
Variety		
Apomuden	7.3	1.1
Santom Pona	11.7	0.9
LSD (5%)	1.8	NS

Fertilizer Type		
Poultry manure only	9.4	1.5
Cow dung only	8.7	0.5
200 NPK	7.4	1.5
100 NPK + 3t PM	10.3	1.0
100 NPK + 4t CD	8.5	1.0
150 NPK + 1.5t PM	12.6	1.3
150 NPK + 2t CD	8.3	0.1
50 NPK + 4.5t PM	13.7	1.0
50 NPK + 6t CD	9.1	1.5
Control	7.3	
LSD (5%)	4.0	NS
CV (%)	21.8	147.0

4.7 Weevil and millipede damage

Table 7 shows a significant greater weevil damage in „Apomuden‟ than „Santom Pona‟. However, there were no significant differences between the fertilizer types.

With regards to millipede damage, there was no significant difference between the varieties (Table 7). Millipede damage was greatest in the 22.5-22.5-22.5 NPK plus 2 tons cow dung treatment, and this was significantly higher than that of 7.5-7.5-7.5 NPK plus 4.5 tons poultry manure treatment only. All other treatment differences were not significant.

Table 7: Effects of variety and fertilizer type on Weevil and Millipede damage on sweet potato roots.

Treatment	Weevil damage	Millipede damage
Variety		
Apomuden	3.1	1.4
Santom Pona	1.3	1.2
LSD (5%)	0.5	NS

Fertilizer Type		
Poultry manure 6t/ha	2.3 2.3	1.3 1.5
Cow dung 8t/ha	2.5 2.2	1.2 1.2
NPK (15:15:15) 200kg/ha	2.3 2.2	1.3 1.2
NPK 100kg/ha + Pm 3t/ha	2.5 1.7	1.7 1.0
NPK 100kg/ha + CD4t/ha	2.2	1.3
NPK 150kg/ha + Pm1.5t/ha	2.0	1.7
NPK 150kg/ha + CD2t/ha		
NPK 50kg/ha + Pm 4.5t/ha		
NPK 50/ha + CD6t/ha		
No fertilizer amendment		
LSD (5%) CV	NS	0.6
(%)	41.4	36.9

4.8 Root dry matter and starch content

Table 8 shows that starch and dry matter contents were greater in „Santom Pona" than in „Apomuden" variety. Fertilizer treatments had significant effects on both starch and dry matter contents. Dry matter content was greatest in the 15-15-15 NPK plus 4 tonnes cow dung treatment, which was significantly higher than those of cow dung only, NPK only, 22.5-22.5-22.5 NPK plus 1.5 tons poultry manure, and 7.5-7.5-7.5 NPK plus 4.5 tons poultry manure treatments only.

The greatest starch content was measured in the 15-15-15 NPK plus 4 tons cow dung treatment, and this was significantly higher than those of cow dung only, NPK only, 22.2-22.5-22.5 NPK plus 1.5 tons poultry manure, and 7.5-7.5-7.5 NPK plus 4.5 tons poultry manure treatments. All other treatment effects were similar.

Table 8: Effect of variety and fertilizer type on dry matter content and starch content of roots.

Treatment	Dry matter (%)	Starch Content(%) of dry matter
Variety		
Apomuden	24.9	46.8
Santom Pona	36.7	66.6

LSD (5%)	1.2	1.4
<u>Fertilizer Type</u>		
Poultry manure only	30.1 29.9	56.5 55.8
Cow dung only	29.8 31.1	55.6 57.9
200NPK	32.6 29.7	59.2 55.7
100 NPK + 3t PM	30.7 29.8	57.5 54.9
100 NPK + 4t CD	30.9	56.7
150 NPK + 1.5t PM	30.6	57.6
150 NPK + 2t CD		
50 NPK + 4.5t PM		
50 NPK + 6t CD		
Control		
LSD (5%) CV	2.6	3.2
(%)	7.4	4.8

4.9 Protein and Fructose Contents

Varietal differences in protein content was not significant (Table 9). The least fertilizer treatment effect was recorded in the cow dung only treatment, but this was significantly lower than those of poultry manure only, 15-15-15 NPK plus 4 tons cow dung, and 22.5-22.5-22.5 NPK plus 2 tons cow dung only.

Fructose content in „Apomuden" variety was significantly higher than in the „Santom Pona" variety (Table 9). The cow dung only treatment recorded the greatest effect, but this was lower than that of the 15-15-15 NPK plus 3 tons poultry manure treatment only.

Table 9: Effects of Variety and fertilizer type on Protein Content and Fructose Content of roots of sweet potatoes.

Treatment	**Protein content (%) of dry matter**	**Fructose Content (%) of dry matter**
<u>Variety</u>		
Apomuden	5.5	3.3
Santom Pona	5.9	1.7
LSD (5%)	NS	0.3

<u>Fertilizer Type</u>		
Poultry manure only	6.1	2.3 2.9
Cow dung only	4.8	2.4 2.1
200NPK	5.3	2.3 2.5
100 NPK + 3t PM	5.8	2.5 2.7
100 NPK + 4t CD	6.1	2.6
150 NPK + 1.5t PM	5.8	2.8
150 NPK + 2t CD	6.1	
50 NPK + 4.5t PM	5.9	
50 NPK + 6t CD	5.8	
Control	5.2	
LSD (5%) CV (%)	1.0 15.7	0.7 24.5

4.10 Glucose and Sucrose Contents

Sweet potato varietal difference for glucose content was significant, with „Apomuden‟ effect (4.58%) being greater than that of „Santom Pona‟ (2.34%) as shown in Table 10. Also the cow dung only treatment effect was the greatest, but statistically, it was greater than the 15-15-15 NPK plus 3 tons poultry manure effect only.

Sucrose content in the „Apomuden‟ variety was significantly higher than that of „Santom Pona‟ variety (Table 10). Among the fertilizer treatments, the greatest effect was measured in the 7.5-7.5-7.5 NPK plus 4.5 tons poultry manure, but this was significantly higher than that of the control treatment only. All other treatment effects were similar.

Table 10: Effect of Variety and fertilizer types on glucose and sucrose contents

Treatment	**Glucose Content (%) of dry matter**	**Sucrose Content (%) of dry matter**
<u>Variety</u>		
Apomuden	4.6	20.9
Santom Pona	2.3	6.1
LSD (5%)	0.5	1.1

Fertilizer Type Poultry manure only Cow dung only 200 NPK 100 NPK + 3t PM 100 NPK + 4t CD 150 NPK + 1.5t PM 150 NPK + 2t CD 50 NPK + 4.5t PM 50 NPK + 6t CD Control	 3.1 4.1 3.4 2.8 3.1 3.5 3.5 3.8 3.5 3.8	 14.0 14.1 14.2 12.7 11.8 14.4 13.0 14.9 13.0 12.6
LSD (5%) CV (%)	1.0 25.0	2.4 15.1

4.11 Iron and Zinc Contents

„Apomuden" variety had significantly greater Iron and Zinc contents than „Santom Pona" variety (Table 11). Among the fertilizer treatments, the 7.5-7.5-7.5 NPK plus 4.5 poultry manure recorded the greatest iron content in the roots, but this was significantly higher than in the cow dung only treatment. All other treatment effects were similar.

The greatest zinc content was found in the 22.5-22.5-22.5 NPK plus 1.5 tons poultry manure treatment, but this was significantly higher than that of the cow dung only treatment. Other treatment differences were not significant.

Table 11: Effects of Variety and fertilizer type on Iron and Zinc Content of sweet potato

Treatment	Iron Content (%) of dry matter	Zinc Content (%) of dry matter
Variety Apomuden Santom Pona	 2.6 2.1	 1.4 1.2
LSD (5%)	0.1	0.1

Fertilizer Type		
Poultry manure only	2.4 2.2	1.4 1.2
Cow dung only	2.3 2.4	1.3 1.3
200 NPK	2.4 2.4	1.3 1.4
100 NPK + 3t PM	2.4 2.5	1.4 1.4
100 NPK + 4t CD	2.4	1.3
150 NPK + 1.5t PM	2.2	1.3
150 NPK + 2t CD		
50 NPK + 4.5t PM		
50 NPK + 6t CD		
Control		
LSD (5%) CV	0.2	0.1
(%)	7.7	8.5

4.12 B-carotene content of Apomuden variety

Table 12 shows the B-carotene content of the various treatments. The NPK only treatment effect was the greatest, but it was significantly higher than that of the 7.5-7.5-7.5 NPK plus 6t cow dung treatment only. All other treatment effects were similar.

Table 12: Effect of fertilizer type on B-Carotene content of Apomuden.

Treatment (Fertilizer Type)	**B-Carotene content (%)**
Fertilizer Type	
Poultry manure only	29.5 31.3
Cow dung only	32.9 29.1
200 NPK	27.2 30.0
100 NPK + 3t PM	29.5 30.8
100 NPK + 4t CD	28.4
150 NPK + 1.5t PM	30.7
150 NPK + 2t CD	
50 NPK + 4.5t PM	
50 NPK + 6t CD	
Control	
LSD (5%) CV	3.9
(%)	7.8

4.13 Economic analysis

The results of the economic analysis of the various treatments indicates that 50 kg/ha

(7.5-7.5-7.5) NPK +4.5 t/ha poultry manure treatment gave the greatest net benefit of GH¢ 13927.50 in the „Santom Pona" variety while 100 kg (15-15-15) NPK + 3 t/ha poultry manure recorded the greatest net benefit of GH¢ 9072.50 in the „Apomuden" variety. The least net benefit of GH¢ 4147.50 was given by 8 t/ha cow dung in „Santom Pona" while 150 kg (22.5-22.5-22.5) NPK + 2 t/ha cow dung gave the least net benefit of GH¢ 2757.50 in „Apomuden".

50 kg (7.5-7.5-7.5) NPK + 4.5 t/ha poultry manure treatment gave the highest extra benefit of GH¢ 5207.00 in the „Santom Pona" variety while 100 kg/ha (15-15-15) NPK + 3 t/ha poultry manure treatment gave the highest extra benefit in the „Apomuden" variety. The 8 t/ha cow dung, 200 kg/ha (30-30-30) NPK, 150 kg/ha (22.5-22.5-22.5) NPK and 50 kg/ha (7.5-7.5-7.5) NPK + 6 t/ha cow dung gave negative extra benefits of GH¢3990.00, -GH¢3880.00, -GH¢1380.00 and -GH¢1110.00 respectively in the „Santom Pona" variety whilst 150 kg/ha (22.5-22.5-22.5) + 2 t/ha cow dung gave a negative extra benefit of -GH¢280.00.

Table 13: Economic Analysis

Variety	APOMODEN										SANTOM PONA									
Fert. Type	PM 6t/ha	CD 8t/ha	NPK 200 kg/ha	NPK 100kg/ha + PM 3t/ha	NPK 100kg/ha + CD 4t/ha	NPK 150kg/ha + PM 1.5t/ha	NPK 150kg/ha + CD 2t/ha	NPK 50kg/ha + PM 4.5t/ha	NPK 50kg/ha + CD 6t/ha	Control	PM 6t/ha	CD 8t/ha	NPK 200 kg/ha	NPK 100kg/ha + PM 3t/ha	NPK 100kg/ha + CD 4t/ha	NPK 150kg/ha + PM 1.5t/ha	NPK 150kg/ha + CD 2t/ha	NPK 50kg/ha + PM 4.5t/ha	NPK 50kg/ha + CD 6t/ha	Control
A.Y	15.1	7.6	7.3	13.8	13.5	15.1	10.2	18.2	10.7	10.1	8.5	9.4	9.4	12.4	7.4	8.9	5.8	11.4	11.6	5.3
AD. Y	13.6	6.8	6.6	12.4	12.2	13.6	9.2	16.4	9.6	9.9	7.7	8.5	8.5	11.5	6.7	8.0	5.2	10.3	10.4	4.8
G. B	13600.00	6800.00	6600.00	12400.00	12200.00	13600.00	9200.00	16380.00	9600.00	9900.00	7700.00	8500.00	8500.00	11500.00	6700.00	8000.00	5200.00	10300.00	10400.00	4800.00
T. V. C	2492.50	2652.50	2342.50	2427.50	2507.50	2402.50	2442.50	2452.50	2572.50	1762.50	2492.50	2652.50	2342.50	2427.50	2507.50	2402.50	2442.50	2452.50	2572.50	1762.50
N. B	11107.50	4147.50	4257.50	9972.50	9692.50	11197.50	6757.50	13927.50	7027.50	8137.50	5207.50	5847.50	6157.50	9072.50	4192.50	5597.50	2757.50	7847.50	7827.50	3037.50
E. B	2970.00	-3990.00	-3880.00	1835.00	1555.00	3060.00	-1380.00	5790.00	-1110.00	-	2170.00	2810.00	3120.00	6035.00	1155.00	2560.00	-280.00	4810.00	4790.00	-
M. A	4.07	-4.48	-6.70	2.76	2.09	4.78	-2.03	8.39	-1.37	-	2.97	3.16	5.38	9.08	1.55	4.00	-0.41	6.97	5.91	-
%	407	-448	-670	276	209	478	-203	839	-137	-	297	316	538	908	155	400	-41	697	591	-

A.Y = Average Yield, AD. Y= Adjustable Yield, G. B = Gross Benefit, T. V. C. = Total Variable Cost, N. B. = Net Benefit, E. B = Extra Benefit, M. A. = Marginal Analysis,

CHAPTER FIVE

DISCUSSION

5.1 Plant establishment

Though there were no significant differences among the various treatments, plant establishment was very high. There was optimum sprouting of the vines. This might be attributed to the fact that the planting materials were taken from fresh and actively dividing portions of the vines. Dapaah (2004), Yeng *et al*. (2012) and CIP (2012), have observed that planting materials from healthy and vigorously growing vines as well as optimum planting depth, spacing and good land preparation ensure good sprouting of vines.

5.2 Effects of variety and fertilizer type on vine length of sweet potatoes

Although the difference was not significant, „Apomuden‟ recorded greater value for vine length than „Santom Pona‟. On responses to fertilizer types, NPK (15-15-15) + cow dung (4t/ha) gave the highest response in terms of vine length, followed by NPK (15-15-15) + poultry manure (3t/ha), and NPK (7.5-7.5-7.5) + poultry manure (4.5t/ha). Cheng-Wei *et al*. (2014), Ouda and Mahadeen (2008) stated that combined application of organic and inorganic fertilizers results in the vigorous vegetative growth of plants. Teshome *et al*. (2012) also reported that interactive effect of organic manure and inorganic fertilizers highly influence vine length and plant height. Again, Bwembya and Yerokum (2001) reported that plants treated with both inorganic fertilizers and manure were significantly taller than those that received either of the treatments. Deshmiskh *et al*. (2010) indicated that the appropriate ratio of organic and inorganic fertilizers in the field act as growth promoters for crops; as organic fertilizers increase absorption of N and K (Bokhtiar and Sakurai, 2005). The release of nutrients from chemical fertilizers is very fast, after which there is a slow release of nutrients from the organic fertilizers. This ensures continuous supply of nutrients to the plants. This might account for the organic and inorganic fertilizer combinations performing better than the sole applications.

5.3 Effects of variety and fertilizer type on the number and weight of marketable roots

The results of the research indicated that „Apomuden‟ produced greater number of marketable roots as compared with „Santom Pona‟. This result depends on the characteristics of the two varieties of sweet potatoes, which resulted in „Apomuden‟ producing greater yield (about 30t/ha) than „Santom Pona‟ (about 17t/ha).

Poultry manure only treatment produced the greatest value for the number of marketable roots. This supports a report by Parraga *et al.* (1995) that poultry droppings produced the maximum root diameter. Ouda and Mahadeen (2008) and Suge *et al*. (2011) observed that organic manure significantly enhanced the yield of plants. The highest responses to marketable root weight was produced by NPK (7.5-7.5-7.5) + poultry manure (4.5t/ha). Parraga *et al*. (1995) also found out that application of organic matter with NPK fertilizers increased the root diameter. Tolessa and Friesien (2001) also reported that the application of 25% recommended inorganic N and P fertilizers with enriched farmyard manure resulted in higher marginal rates of returns in maize.

5.4 Effects of variety and fertilizer types on the fresh vine yield of sweet potatoes

From the results, the fresh vine yield of „Santom Pona‟ was significantly higher than „Apomuden‟. This is a characteristic of „Santom Pona‟ as it produces large amount of foliage. The effect of the various fertilizers on fresh vine yield indicated that NPK (7.57.5-7.5) + poultry manure (4.5t/ha) and NPK (22.5-22.5-22.5) + poultry manure (1.5t/ha) were significantly higher than the other treatments. Many researchers have indicated that organic and inorganic amendments significantly increase the vegetative growth of plants

(Parraga *et al*., 1995; Cheng-Wei *et al*., 2014; Ouda and Mahadeen, 2008). All the amended treatments, but cow dung only produced higher responses than the control. This might probably be due to augmentation of the nutrients in the soil by the fertilizers.

5.5 Effects of variety and fertilizer type on weevil attack on sweet potatoes

The result indicated that the weevil attack on „Apomuden‟ was significantly higher than „Santom Pona‟. This might be due to the higher contents of sucrose, beta-carotene and other minerals in „Apomuden‟, coupled with its higher moisture content. These make „Apomuden‟ sweeter and preferred by the weevils.

There were no significant differences among the fertilizer treatments with respect to the levels of attack by weevils. This might be due to the fact that various fertilizer amendments did not significantly alter the taste and texture of storage roots of sweet potatoes. Although the differences were not significant, NPK (7.5-7.5-7.5) + poultry manure (4.5t/ha) and the control produced the least effects.

5.6 Effects of variety and fertilizer type on root dry matter and weight of sweet potatoes

From the result, it was evident that „Santom Pona‟ showed significant difference as compared with „Apomuden‟ In terms of dry matter content of the roots. A release from the Crops Research Institute of Ghana indicates „Santom Pona‟ has a dry matter content of 34.4% while „Apomuden‟ has a dry matter content of 21.9%.

On response to fertilizer type, NPK (15-15-15) + cow dung (4t/ha), NPK (15-15-15) + poultry manure (3t/ha) and NPK (7.5-7.5-7.5) + cow dung (6t/ha) produced the highest responses. The least response to dry matter production was given by NPK (22.5-22.522.5) + poultry manure (1.5t/ha), NPK (7.5-7.5-7.5) + poultry manure (4.5t/ha) and poultry manure only. This is in line with the results obtained by Yeng *et al.* (2012), which stated that cow dung amended treatments produced higher dry matter contents. Somanath and Syeenivasmuthy (2005) also reported improved dry matter yield in *Coleus forskohlii* due to integrated use of farmyard manure with NPK. The dry weight followed the pattern of responses by the dry matter.

5.7 Effects of variety and fertilizer type on quality factors of sweet potatoes

The two varieties showed no significant differences for protein content, though „Santom Pona‟ gave relatively higher value for protein content then „Apomuden‟. On fertilizer responses, NPK (22.5-22.5-22.5) + cow dung (2t/ha), poultry manure only, and NPK (15-15-15) + cow dung (4t/ha) produced the highest responses for protein content. Cow dung only and the control produced the least values for protein content. Granstedt and Kjellenberg (1997) observed higher quality protein in organic treatments. The relatively lower protein content in the sole cow dung amended soil might be as a result of the slow release of nutrients. Eghball and Power (1999), found that about 40% cattle manure become plant available in the first year after application.

„Santom Pona‟ recorded significantly higher value for starch content than „Apomuden‟. With regards to response to fertilizer type, cow dung applied in combination with NPK (15-15-15) produced the highest responses. These higher responses might have been induced by the organic manure added. The least starch content was recorded by NPK (22.5-22.5-22.5) + poultry manure (1.5t/ha). Grandstedt and Kjellenberg (1997) reported that organic treatments produced higher starch content than inorganic fertilizers.

„Apomuden‟ contained greater fructose and glucose contents than „Santom Pona‟. On responses to fertilizer types, cow dung only produced the greatest response for both glucose content and fructose content. Granstedt and Kjellenberg (1997) observed that by organic fertilization, the quality of fruit is improved, which is indicated by high concentrations of sugars and vitamins. Suge *et al*. (2011) reported that organic manure significantly enhanced fruit quality of plants. The control produced better response than all the other amended treatments. This indicates that poultry manure and NPK (15-15-15) led to reduction of glucose and fructose contents of sweet potatoes.

The results indicated that „Apomuden" produced response which was significantly higher than „Santom Pona" in terms of Iron content. With regards to fertilizer types, all the soils amended with fertilizer produced better responses than the soil without amendment (the control).

CHAPTER SIX

6.1 CONCLUSION

The results of the research indicate that sweet potato growth responds better to an integrated application of organic manure and inorganic fertilizers than sole application of either of the two.

Application of poultry manure (6t/ha) as sole application produced the greatest marketable roots, while NPK, 15-15-15(7.5-7.5-7.5) + poultry manure (4.5t/ha) produced the greatest marketable root weight and fresh vine yield in sweet potatoes. Generally, the combination of organic and inorganic fertilizers enhance the root qualities of sweet potatoes. The most profitable fertilizer treatment for „Santom Pona" production is 50 kg/ha (7.5-7.5-7.5) NPK + 4.5 t/ha poultry manure but in „Apomuden", the application of 100 kg/ha (15-15-15) NPK + 3 t/ha poultry manure is more profitable.

6.2 RECOMMENDATIONS

The following recommendations are made in respect of the results

- Sweet potato farmers should adopt integrated nutrient management for better yield instead of single organic or inorganic fertilizer.
- Further research to monitor rate of release of nutrients from the organic fertilizers.
- Similar work should be done using additional improved sweet potato varieties to verify if the result is applicable to them.

REFERENCES

Adediran, A.J., Taiwo, L.B., Akande, M.O., Sobulo, R.A. and Idowu, O.J. (2004): Application of organic and inorganic fertilizers for sustainable maize and cowpea yields in Nigeria. J.plant Nutr., 27: 1163-1181.

Adu, S.V and Asiamah, R.D (1992): Soils for the Ayensu-Densu Basin Central, Eastern and Greater Accra Regions of Ghana. Council for Scientific and Industrial Research (CSIR). Research Institute memoir NO. 9. Pp. 117.

Akorada, M.O (1992): Root crops for food in Africa; proceedings of the fifth triennial symposium of the international society for tropical root crops – Africa research held in Kampala – Uganda.

Akorada, M.O (2003): Root crops; the small processor and development of local food industries for market economy. Proceedings of 8th ISTRC – AB Symp. Ibadan, Nigeria 2001.

Ali, Y.S.S. (1997): Influence of organic and inorganic fertilization on the growth of some annual flowers. Res.Bull. Center. King Saud Univ. 70: 5 – 20.

Ambecha, O. (2001): Influence of Nitrogen and Phosphorus on the yield and yield components and some quality traits of two sweet potatoes [*Ipomoea batatas (L)]* cultivars. An MSc thesis presented to the school of graduate studies, Alemaya University 94p.

Asghar, H.N., Ishaq M., Zahir, Z.A., Khalid, M. and Arshad, M. (2009): Response of raddish to integrated use of Nitrogen fertilizer and recycled organic waste. Available at http//www.pakbs.org.

Attarade, S.B., Narkhede, S.D., Patil, R.P. and Ingle, S.T. (2012): Effect of organic and inorganic fertilizers on the growth and nutrient content of okra crop. Internal journal of current research vol. 4, issue 10, pp 137 – 140.

Balemi, T. (2012): Effect of integrated use of cattle manure and inorganic fertilizers on tuber yield of potato in Ethiopia; Journal of soil Science and Plant Nutrition, 2012, 12(2), 253 – 261.

Bayu, W., Rethman N.F.G., Hammes, P.S. and Alemu, G. (2006): Effect of farmyard manure and inorganic fertilizers on sorgum growth, yield and nitrogen use in semi-arid areas of Ethiopia. Journal of plant nutrition 29, 391 – 407.

Beukema, H.P. and Van Der Zaag, D.E. (1990): Introduction to potato production;

Centre for Agriculture Publishing and Documentation for root and tuber crops. Vol. III.

Bhuiya, M.R. and Akanda, M.S. (1982) Effect of different sources of organic materials alone and combination with two fertilizer levels on growth parameters and comparison of rice. Bangladesh J. Agril. 7(3 – 14): 32 – 39.

Bokhtiar, S.M. and Sakurai, K. (2005): Effects of organic manure and chemical fertilizer on soil fertility and productivity of plants and ratoon crops of sugarcane. Archives of Agronomy and Soil Science, 51: 325 – 334.

Bradbury, J.H. and Singh, U. (1986): Thiamin, riboflavin and nicotin acid contents of tropical root crops from the South Pacific. Journal of Food Science 51(6): 1563 – 64.

Bwembya, S. and Yerokun, O.A. (2001): Effect of cassia spectabillis, cowdung and their combination on growth and grain yield of maize. Seventh Eastern and Southern Africa Regional Maize Conference, 11th – 15th February, 2001. Pp. 361 – 366.

Capinera, J.L. (2014): Sweet potato pest insects, EENY – 027; US Department of Agriculture, UF/IFAS Extension Services, University of Florida.

Carpio, L.A., Davies F.T. and Arnold M.A. (2005): Arbuscus mycorrhizal fungi, organic and inorganic controlled-release fertilizers; Effect on growth and leachate of container-grown bush morning glory under high production temperatures. J. Amer. Soc. Hort. Sci. 130: 131 – 139.

Cheng-Wei, L.A., Sung, Y., Bo-Ching C. and Hung-Yu, L. (2014): Effects of nitrogen fertilizers on the growth and nitrate content of lettuce (*Lactuca sativa L.)*; Int. J. Environ Res Public Health. April 2014; 11(4): 4427 – 4440.

CIP (2012): What you should know about growing orange-fleshed sweet potato

Dapaah, H.K. (2004): Sweet potato production guide: a resource and reference manual. IFAD/MOFA Root and Tuber Improvement Programme (RTIP) Publication. RTIP, MOFA, Kumasi – Ghana.

Deshmukh, S.S., Chaudhari V.S., Narkhede, S.D., Jadhav, R.N. and Attarde, S.B. (2010): Effects of three different composts on the growth rate of wheat. International Journal of Plant Sciences, 6(1): 22 – 26.

Doku, E.V. and Banful, B. (1993): Proceedings of the second national workshop on root and tuber crops and plantains; DOA printing press, Kumasi – Ghana.

Edmond, J.B. and Amerman, G.R. (1971): Sweet potatoes: production, processing, marketing. AVI publishing co., Westport, CT.

Eghball, B. and Power, J.F. (1999): Phosphorus and nitrogen-based manure and soil compost application, corn production and soil phosphorus. Soil Sci. Soc. Amer. J. 63: 895 – 901.

Gedam, V.B., Rametke, J.R. and Power M.S. (2008): Influence of organic manures on yield, nutrient uptake and change in physico-chemical properties of soil after harvest of groundnut. Crop Research, 36: 111 – 114.

Granstedt, A. and Kjellenberg, L. (1997): Long – term field experiment in Sweden; Effects of organic and inorganic fertilizers on soil fertility and crop quality; proceedings of an international conference in Boston, Tufts University, Agricultural production and nutrition, Massachusetts, March 19 – 21, 1997.

Halvin, J.L., James, D.B., Samuel, L.T. and Warner, L.N. (2003): Soil fertility and fertilizers, an introduction to nutrient management (6th ed.). Peasant Education Inc., New Delhi, India.

Hartemink, A.E. (2003): Soil fertility decline in the tropics; with case study in plantations. CABI Publishing, Wallingford, Oxon OX10 8DE, UK.

Iqbal, M.A. (2008): Effects of cow dung and neem leaf on growth and development of stem of amaranth. M.Sc Thesis, Dept of Agroforestry, Bangladesh Agricultural University, Mymensinch.

Jaarsveld, P.J., Faber, M., Tanumihardjo, S.A., Nestel, P., Lombard, C.J. and Benade, A.J. (2005): B-carotene rich orange-fleshed sweet potato vitamin A status of primary school children assessed with the modified-related-dose sesponse test. American Journal of Clinical Nutrition. 81, 1080 – 7.

Johnson, F. and Tappan, W.P. (1988): Field crop and pastures in 1988 Florida Insect Control Guide. Institute of Food and Agricultural Sciences, University of Florida, Gainesille, Florida.

Jones, A., Dukes, P.D. and Cuthbert, F.P. (1986): Mass selection in sweet potato: breeding for resistance to insects and diseased for horticultural characteristics. J. Am Sci. 1976; 103:374 – 376.

Kelly, K.M. and Biernbaum, J.A. (2000): Organic nutrient management of greenhouse production of edible flowers in containers. Hort. Science 35: 452.

Muneshwar, S., Singh, V.P., Reddy, K.S. and Singh, M. (2001): Effect of integrated use of nitrogen fertilizer and farmyard manure or green manure on translocation of N, K and S productivity of rice-wheat system on a vertisol. J. Indian Soc. Soil SCI. 49: 430 – 435.

Najm, A.A., Haj Seyed Hadi, M.R., Fazeli F., Taghi Darzi, F. and Shamorady, R. (2010): Effect of utilization of organic and inorganic nitrogen source on the potato shoots dry matter, leaf area index and plant height, during middle stage of growth. International Journal of Agricultural and Biological Sciences, 1: 26 – 29.

Negassa, W., Negisho, K., Friesen, D.K., Ransom, J., Yadessa, A. (2001): Determination of optimum farmyard manure and N P fertilizers for maize on farmers‟ field. Seventh Eastern and Southern Africa Regional Maize Conference. 11th – 15th February. 387 – 393.

Nevens, F. and Reheul, D. (2003): The application of vegetable, fruit and garden waste compost in addition to cattle slurry in a silage maize monoculture: nitrogen availability and use. Europ. J. Agron., 19: 189 – 203.

Onwueme, I.C. (1978): The Tropical Root Crop; The Pitman Press, Great Britain.

Ouda, B.A. and Mahadeen, A.Y. (2008): Effect of fertilizers on growth, yield, yield components, quality and certain nutrient contents in broccoli (*Brassica oleraceal)*. International Journal of Agriculture and Biology 2008 vol. 10 No. 6 pp. 627 – 632.

P"obwoya, C.O. and Mwanga, R.O.M. (1994): Root crops for food security in Africa; International Society for Tropical Root Crops – Africa Branch, Ibadan, Nigeria.

Palm, C.A., Myers, R.J.K. and Nandwa, S.M. (1997): Combined use of organic and inorganic nutrient sources for fertilizer maintenance and replenishment. Madison, WI.

Parraga, M.S., Pereira, A.L., Medeiros, J.L. and Carvalho, P.F.P. (1995): Effect of organic matter on quantity and quality of roots in carrots harvested at three different dates, Semira (Londrina), 16: 80 – 85.

Parwada, C; Gadzirayi, T. and Sithole, A.B. (2011): Effect of ridge height and planting orientation on *Ipomoea batatas* (sweet potato) production. J. Agric. Biotechnol. Sustainable Dev. 3(4): 74 – 76.

Patel, J.R.,, Patel J.B., Upadhyay, P.N. and Usadadia, V.P. (2009): The effect of various agronomic practices on the yield of chicory (*Cichorium intybus)*. JOURNAL O Agricultural Sciences 135, 271 – 278.

Peet, M.M., Rippy, J.M., Nelson, P.V. and Catignani, G.L. (2004): Organic production of greenhouse tomatoes utilizing the bag system and soluble organic fertilizers. Acta Hort. 659: 707 – 709.

Ramamurthy, V. and Shivashankar, K. (1996): Residual effect of organic matter and phosphorus on growth, yield and quality of maize (*Zea mays)*. Indian Journal of Agronomy 41: 247 – 251.

Rossen, C.J. and Allan, D.L. (2007): Exploring the benefits of organic nutrient sources for crop production and soil quality. Hort. Technology 17: 422 – 430.

Russo, V.M. (2005): Organic vegetable transport production. Hort. Science 40: 623 – 628.

Sanwal, S.K., Lakminarayana, K., Yadav, R.K., Rai, N., Yadav, D.S. and Mousumi, B. (2007): Effect of organic manure on soil fertility, growth, physiology, yield and quality of turmeric. Indian Journal of Hort. 64(4): 444 – 449.

Scott, G.J. and Ewell, P. (1992): Sweet potato in Africa food systems, product development for root and tuber crops. Vol. III.

Sikora, E.J. and Dangler, J.M. (1995): Alabama Cooperative Extension System (Alabama A and M University and Auburn University), an equal opportunity educator and employer.

Singh, R.R.R., Shama, K.S., Gupta, R.K. and Patil, R.T. (2008): Vermicompost substitution, influence on growth, physiological disorders, fruit yield and quality of strawberry. Bioresource Technology, 99: 8507 – 8511.

Somanath, B.S. and Sreenivasmurthy, C.A. (2005): Influence of farmyard manure and inorganic fertilizers (NPK) and sources of potassium on the yield 0f *Coleus foreskohlii.* Journal of medicinal and aromatic plant sciences 27, 16 – 10.

Stather, T., Benjamin, M., Katcher, H., Blakenship, J. and Low, J. (2013): Everything you ever wanted to know about sweet potato: Reaching agents of TOT Manual 2: Orange-fleshed sweet potato and nutrition. International potato centre, Nairobi Kenya Vol. 2.

Suge, J.K., Omunyin, M.E. and Omani, E.N. (2011): Effect of organic and inorganic sources of fertilizer on growth, yield and fruit quality of eggplant; Achives of Applied Science Research, 2011, 3(6): 470 – 479.

Tesfaye, K., Tesfaye, L., Estifanos, T. and Mieso, G. (2008): Effects of levels of substitution of sweet potato (*Ipomoea batatas L)* vines for concentrate on body weight gain and carcass characteristics of browsing Arsi-Bale goats. J. Cell Anim. Biol., 2(2): 036 – 042.

Teshome, A., Nigussie, D. and Yibekal, A. (2012): Sweet potato growth parameters as affected by farmyard manure and phosphorus application at Adami Tulu, Central Rift Valley of Ethiopia. Agricultural science research journal, vol. 2(1), pp. 1 –

12.

Tolessa, D. and Friensen, D.K. (2001): Effects of enriching farmyard manure with mineral fertilizer on grain yield of maize at Bako, Western Ethiopia. Seventh Eastern and Southern Africa Regional Maize Conference. 11th – 15th February; 335 – 337.

Treadwell, D.D., Hochmuth, G.J., Hochmuth, R.C., Simonne, E.H., Davis, L.L., Laughlin, W.L., Li, Y., Olczyk, T., Sprenkel, R.K. and Osborne, L.S. (2007): Nutrient management in organic greenhouse herb production: where are we now? Hort. Technology 17: 461 – 466.

Villareal, V. (1985): Sweet potato vine tips as vegetables, a natural resource for the tropics, CRC Press, Boca Raton, USA.

Walsh, P.A. and Johnson, E. (1980): Agricultural statistics; US Government Printing Office. Washington D.C.

Wayne, N.D. (2014): Sweet potato pest insects, EENY-294; US Department of Agriculture, UF/IFAS, Extension services, University of Florida, Gainesville, Florida.

WHO (1990): Diet, nutrition and the prevention of chronic diseases. Report of a WHO study group, WHO Geneva.

Woolfe, J. (1992): Sweet potato; an untapped food resource, Cambridge University Press. Cambridge U.K.

Yen, D.C. (1974): The sweet potato and Oceania; B.P. Bishop Mus. Bull.

Yeng, S.B., Agyarko, K., Dapaah, H.K., Adomako, W.J. and Asare, E. (2012): Growth and yield of sweet potato (*Ipomoea batatas L.*) as influenced by integrated application of chicken manure and inorganic fertilizer; African Journal of Agricultural Research vol. 7(39), pp. 5387-5395.

Young, H.C., Gill, J.B and Hollingswoth, H.S. (1950): Whitefringed beetles and how to combat them. USDA Circular 850: 1 – 15.

Zhao, X., Nechols, J.R., Williams, K.A., Wang, W. and Carey, E.E. (2009): Comparison of phenolic acids in organically and conventionally grown pac choi (*Brassica rapa L. Chinensis)*. J. Sci. Food Agr. 89: 940 – 946.

APPENDICE

ECONMIC ANALYSIS

Variable cost

- Land Preparation

Slashing = GH¢175.00

Ploughing = GH¢ 125.00

Ridging = GH¢625.00

- Planting Materials = GH¢312.50
- Cost of planting = GH¢125.00
- Weeding = GH¢200.00
- Harvesting = GH¢200.00

Cost of fertilizers

- NPK = GH¢115.00 per 50 kg
- Poultry manure = GH¢2.00 per 25 kg
- Cow dung = GH¢2.00 per 25 kg
- Cost of fertilizer application = GH¢100.00
- Cost of poultry manure transportation = GH¢150.00
- Cost of NPK transportation = GH¢15.00
- Cost of cow dung transportation = GH¢150.00