GROWTH, YIELD AND QUALITY FACTORS OF SWEETPOTATO (*Ipomoea batatas* (L) Lam) AS AFFECTED BY SEEDBED TYPE AND FERTILIZER APPLICATION

BY

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JUNE, 2015

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND

TECHNOLOGY, KUMASI

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF CROP AND SOIL SCIENCES

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THESIS SUBMITTED TO THE DEPARTMENT OF CROP AND SOIL SCIENCES, FACULTY OF AGRICULTURE, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE, MASTER OF PHILOSOPHY IN AGRONOMY (CROP PHYSIOLOGY)

JUNE, 2015

DECLARATION

This is to declare that the research work presented in this thesis was carried out by Alex Brobbey, Department of Crop and Soil Sciences, Faculty of Agriculture, College of Agriculture and Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi and has not been submitted to any other University for a degree.

It is entirely his account of the research.

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(Supervisor) Signature Date

Dr. Charles Kwoseh ……. …….

(Head of Department) Signature Date

ABSTRACT

A Field experiment was conducted at CSIR-Crops Research Institute, Fumesua in 2013 to determine the effect of seedbed type (ridge and mound) and fertilizer application (chicken manure, NPK 15-15-15 and combination of the two) on growth, yield and quality factors of sweetpotato (*Ipomoea batatas* (L) Lam). The experimental design used was a 2x4 factorial with treatments arranged in RCBD design. The fertilizers applied were: (i) recommended chicken manure (6 t/ha); (ii) recommended NPK, 15-15-15 (200kg/ha); (iii) ½ chicken manure + ½ NPK (3 t/ha + 100 kg/ha); and no chicken manure and NPK fertilizer (control). The seedbed types used were (i) ridges and (ii) mounds. Each treatment was replicated thrice. 'Sauti', an improved sweetpotato variety released by CSIR-CRI was used.

The results showed significant higher effects of amended treatments on growth, yield and quality factors of sweetpotato than the control. The combined fertilizer treatment effect enhanced growth and yield which resulted in high storage root yield (number of roots and roots weight) on ridges. Chicken manure only treatment effect was high on leaf size and vine length, therefore promoting high vegetative part. The results of the study showed that, the effect of fertilizer application enhanced some quality factors of sweetpotato specifically on mounds.

The results indicated that combining inorganic and organic fertilizers resulted in better root yield than separate application. Also ridge seedbed appeared better than mound seedbed.

DEDICATION

I dedicate this work to the International Food Policy Research Institute (IFPRI) and my family especially Mr Isaac Amoapong, Mrs Comfort Konadu, my parents and siblings for their prayers, encouragement and financial support during my study in the University.

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God richly bless you all. Amen

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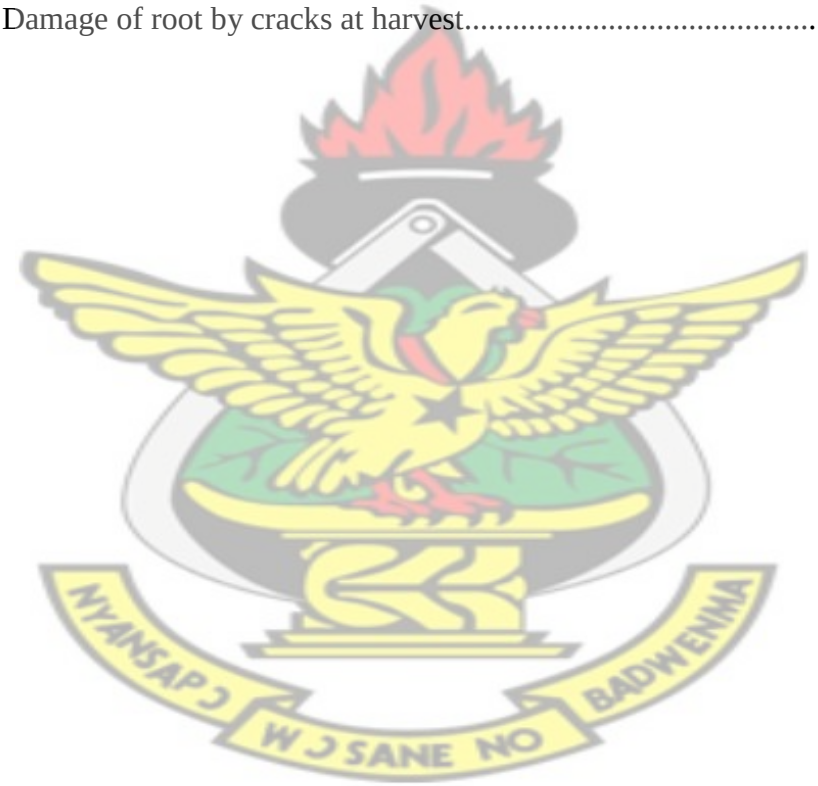

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CHAPTER ONE

INTRODUCTION

Sweetpotato (*Ipomoea batatas* L.) is a tropical root crop believed to have originated from Central America and was introduced to Africa probably at the end of 19th Century (Purseglove, 1972).

It is the only economically important plant of the family *Convolvulaceae* of about 50 genera and 1000 species (Scott and Ewell, 1992). Sweetpotato seems to be the most widely dispersed root crop as it is adaptable and can grow under many different ecological conditions (Purseglove, 1972). The world production is 124 million tonnes and the majority comes from China, with a production of 105 million tonnes from 49,000km^2 (FAO, 2004). China produces 85% of the world's total production, while Africa accounts for just 5% (Awojobi, 2004).

In Africa, sweetpotato is increasingly becoming an important economic crop due to its potential of alleviating poverty, reducing night blindness (using orange flesh varieties), and improving the nutritional status of the rural poor in an inexpensive and sustainable way. Sweetpotato is one of the most important root and tuber crops in Sub-Saharan Africa with both domestic and industrial uses, and its nutritional value far exceeds yam, cassava and cocoyam (Onwueme, 1978). In terms of area under cultivation, Nigeria is the leading producer in Africa followed by Uganda (FAO, 2004).

The crop is now widely grown as an important staple food in a number of African countries including Ghana. In Ghana, sweetpotato is grown by peasant and small-

holder farmers scattered in Upper East and Central Regions. These two regions in Ghana produce about 93603 metric tonnes (SRID, 2007). Yields of sweetpotato recorded in Ghana at the subsistence level are quite low compared with the IITA (1985) varietal studies. Studies conducted to evaluate 19 sweetpotato varieties for yield at Ohawu revealed that an average yield between 6-16 t/ha was recorded for improved varieties and 3.2-10.8 t/ha for unimproved or local varieties (Missah *et al.*, 1991). However, recent improved varieties released by CSIR-CRI Sweetpotato Improvement Programme have yields ranging from 18 – 22 t/ha.

Several tillage practices including mounding, ridging, furrowing, bed and flat methods are practiced in sweetpotato cultivation in different localities. It is preferable to plant sweetpotato on mounds in areas experiencing problems of drainage. In sloppy lands, ridge and furrow system is recommended for the control of soil erosion.

Among the different land preparation methods, the highest root yield of sweetpotato was realized when planted on mounds under Indian conditions and this may probably due to better soil aeration permitted by mounds and less tendency for soil compaction (Ravindran and Mohankumar, 1985). In Bangladesh, high yields of sweetpotato were reported in trench planting followed by ridge and flat method of planting in alluvial soils under irrigated condition (Bhuiyan *et al*., 2006). It is therefore necessary to ascertain the land preparation method that offers the best yield when fertilization is done in the cultivation of sweetpotato under the Ghanaian conditions.

According to Buresh *et al*. (1997) and Palm *et al*. (1997), it has generally been accepted that both inorganic and organic fertilizers are needed to increase crop production in West Africa. The use of organic manure to supplement inorganic

fertilizer use, as an integrated nutrient management strategy to reduce the high cost of soil mineral input which is one of the constraints in sweetpotato production.

A number of studies carried out on organic and inorganic fertilizers combination in sweetpotato production, have attested to a positive interaction between them when simultaneously applied. In addition, the use of poultry manures as a supplement improves the physical properties of the soil (Palm *et al*., 1997). Several hypotheses have been formulated concerning possible positive interaction between inorganic and organic inputs when applied simultaneously (Giller *et al.*, 1998) resulting in added benefits in terms of improved crop yields, soil fertility or both and lower cost of production (Palm *et al.*, 1997).

Despite the several hypotheses that have been formulated, very little information is reported on the optimum combination level of organic and inorganic fertilizers application on a particular land preparation in sweetpotato especially in Ghana. Therefore, there is the need to investigate and recommend the best combination of organic and inorganic fertilizers application to farmers engaged in the production of sweetpotato.

The objectives of this study were;

- To determine the effect of the organic and mineral fertilizer on the growth and yield of sweetpotato
- To evaluate the optimum planting bed method for high yield in sweetpotato
- To assess the effect of fertilizer application on quality factors of sweetpotato
- To determine the effect of interaction between planting bed and fertilization on growth and yield of sweetpotato

CHAPTER TWO

LITERATURE REVIEW

2.1 WHAT IS *IPOMOEA BATATAS* (L) LAM?

Ipomoea batatas is a member of the *Convolvulaceae* family (Purseglove, 1972). According to Yen (1974) and Austin (1978, 1988), eleven (11) species in the section *batatas* have been recognized which includes sweetpotato. Sweetpotato is a perennial crop but is cultivated as an annual and the closest relatives appear to be *Ipomoea trifida* that is found wild in Mexico and *Ipomoea tabascana*. Sweetpotato has a chromosome number of 2n = 90. Since the basic chromosome number for the genus *Ipomoea* is 15, sweetpotato is said to be a hexaploid. Most sweetpotato cultivars are self-incompatible. It is accepted that cultivated sweetpotato originated in Central America or South America. Nishiyama (1971) and Martin and Jones (1972) suggested Mexico as a centre of diversity of the *batatas* section of *Ipomoea*.

When sweetpotato is planted from stem cuttings, adventitious roots arise from the cutting in a day or two. These roots grow rapidly and form the root system of the plant. Research has shown that the roots of sweetpotato can penetrate the soil to a depth of over 2m, the exact depth attained being dependent on the soil condition (Onwueme, 1978; Kays, 1985). During the early ontogeny of young adventitious roots emerging from the stem, they are often separated into two groups, namely thin and thick roots (Togari, 1950). According to Wilson (1982) and Kays (1985) thin roots are typically tetrarch in the arrangement of their primary vascular tissue, i.e., four xylem and phloem poles found within the vascular cylinder. The thick roots are pentarch or hexarch in structure. Under adverse conditions thick roots are reported to give rise to string roots (primary fibrous roots) and pencil roots depending on the primary cambial

activity and the amount of lignifications of cells of the stele (Hahn and Hozyo, 1984; Du Plooy, 1989). The most important functional differences between these root types are their capacity for storage root initiation in a specific region of the thick roots. Storage roots arise from pentarch or hexarch thick young roots if the cells between the protoxylem points and the central metaxylem cell do not become lignified (Wilson and Lowe, 1973). The increase in storage root size is attributed to the activity of the vascular cambium as well as the activivty of the anomalous cambia (Wilson, 1982). Chua and Kays (1982) reported that, the initial sign of storage root formation is the accumulation of photosynthates consisting predominantly of starch. According to Agata and Takeda (1982), storage root formation starts about 30 to 35 days after planting and root dry weight increases linearly until harvest.

The stem of sweetpotato is called vine. The vine is a long thin stem that trail on the surface of the soil which can produce roots at the nodes. The length of the vine varies and ranges from 1 to 6m. Internodes lengths also rise to 10cm. The stem is circular or slightly angular and it is predominantly green in colour.

2.2 USES OF SWEETPOTATO

Sweetpotato serves as important crop for both domestic and industrial purposes. According to Collins (1984), the crop is used as raw material for industrial purposes as a starch source and for alcohol production. It is also used in the baking industries and the preparation of adhesives, textile and paper sizing. The storage roots are used as staple food and also to feed animals. In some part of the world, the crop is made into flour, which is cooked for human consumption. Sweetpotato preparation varies with respect to location and the purpose for which it is been used.

2.3 ECOLOGY

Sweetpotato is widely grown between latitudes 40°N to 40°S, and at altitudes as high as 2500m at the equator (Haln and Hozyo, 1984). They grow best where the average temperature is 24°C, the thermal optimum is reported to be about 24°C (Kay, 1973). At temperatures below 10°C, growth is severely retarded. The crop is damaged by frost and this restricts the cultivation of sweetpotato in the temperate regions to areas with a minimum frost-free period of 4 to 6 months. Even where the frost-free period is sufficiently long, it is still essential that temperatures should be relatively high during much of the growing period. In the tropics, yield declines with increasing altitude as do the number of roots and the proportion of roots that are marketable. Increasing altitude also delays maturity (Negeve *et al*., 1992). Sekioka (1964) reported yields to be 5 to 6 times higher at 25/20°C (day/night), and higher at a soil temperature of 30°C than 15°C. On the other hand, Young (1961) found that high night temperatures, by increasing carbon loss through respiration, are deleterious with yield substantially lower at 29/29°C than at 29/20°C. Seasonal plantings in north-western Argentina suggest that flower and seed production are with daily maximum temperatures between 23°C to 24°C and minimum temperatures between 13°C to 19°C (Folquer, 1974).

Sweetpotato performs best in regions with 750-1000mm of rainfall per annum, with about 500mm falling during the growing season. The timing and distribution of moisture supply as well as the amount affect yields. The crop is intolerant of water deficit during tuber initiation. Hahn and Hozyo (1984) suggest that at other times it may have tolerance to drought. The crop is intolerant of water logging, particularly during tuber initiation (Wilson, 1982; Hahn and Hozyo, 1984). The crop grows best on sandy-loam soils and does poorly on clay soils. Good drainage is essential since

the crop cannot withstand water logging. Where the water table is high, the crop is planted on mounds or ridges. Soil with high bulk density or poor aeration tends to retard tuber formation and result in reduced yields (Watanabe *et al*., 1968). Wet soil conditions at harvest lead to an increase in root rot and adversely affect yields, storage life, nutritional and baking quality (Ton and Hernandez, 1978).

2.4 TILLAGE AND SEEDBED PREPARATION

The purpose of primary cultivation is to improve the infiltration of water, the penetration of roots and to incorporate plant residues into the soil.

Root and tuber crops in general require a loose soil in which the tubers can grow with little hindrance. The reasons for this seem to lie in the manner in which the roots form and penetrate the soil. Many root and tuber crops such as cassava, sweetpotato and Irish potato initially form relatively thin roots or stolons, which first penetrate the soil and later enlarge to form the tuber. On the basis of the type of land tillage, three general methods are used for sweetpotato production.

2.4.1 Mounding

Mounding is a common practice in traditional agriculture. Essentially, the topsoil is gathered into more or less conical heaps at various points in the field. Hoes with wide blades are used for the mounds making. The size of each mound, the mean distance between mounds and the number of sweetpotato cuttings planted on each mound vary from place to place. In general, big mounds have greater distances between them and greater number of cuttings may be planted.

According to Onwueme (1978), in some parts of south-eastern Nigeria, mounds may attain heights of up to 1m. The distances between the mounds can be as much as 3m.

On mounds of this size, 6 to 10 cuttings can be planted at various points on the sloping side of the mound.

In most sweetpotato growing areas of Africa smaller mounds of 50cm in height are more common and only 5 or 6 cuttings are planted on each mound. There are several advantages of high mounds; they provide a favourable seedbed for tuber development, large yields of tubers per plant and the most uniformly shaped roots are often obtained from mound plantings.

A second factor that may contribute to the high yield of mound grown plants is that the process of mound making collects the rich topsoil and the entire depth of the mound consists of the more fertile topsoil. A third advantage of mounding is that, it facilitates harvesting. In soils where the water table is high, mounds also serve to keep most of the roots above the water table. Besides all its advantages, mounding has the major disadvantage of not being mechanized. Mound making is an extremely tedious and labour consuming operation, which is very difficult to mechanize (Onwueme, 1978).

2.4.2 Ridging

Planting on ridges is the most universally recommended method of growing sweetpotato. It has been shown that the higher the ridge, the greater the yield. According to Edmond and Ammerman (1950), ridge height of 36cm gives greater yield. The optimum height of the ridge will depend on the soil type and the cultivar being grown. A high ridge provides ample depth of loose, fertile soil for root and tuber development. Also high, broad ridge is less readily washed away by rain during the cropping season. Planting on ridges has several advantages as that of mounds. In addition, planting on ridges makes mechanization easy and ridging along the contour

and slopes helps in the control of erosion. The major disadvantage of ridge planting is that during the course of the season rains tend to wash soil away from the ridge-top, thereby decreasing the height of the ridges. The washing may progress to an extent where tubers and roots growing within the soil become exposed. Such exposed roots are generally unpalatable and are easily attacked by rodents and insects. Sometimes roots of sweetpotato growing on a ridge will penetrate downward through the loose soil until it encounters the harder soil at the base of the ridge. Further growth of the root will cause it not so much to penetrate the hard soil below, but to exert upward pressure (heaving). In such a situation, the top portion of the tuber or root may become exposed even if no appreciable soil wash has occurred. The consequences of such exposure are similar to those caused by soil wash (Onwueme, 1978).

2.4.3 Flat planting

Ploughing and harrowing are typically done on the flat before planting of sweetpotato. After that, the vines are planted in rows on the flat land. Planting of sweetpotato on flat has several advantages as planting on ridges. Compared to the mound and ridge methods the top soil may be shallow and this may affect yield.

2.5 PLANTING MATERIAL

Vine cuttings are commonly used to propagate sweetpotato. Vine cuttings for sweetpotato propagation have numerous reasons including, free from soil-borne diseases plants, better yield, more uniform size and shape. Apical cuttings are considered and appropriated than cutting of vines from the middle and basal portion of the stem (Shanmugavelu *et al.*, 1972). In cutting of the vines, a length of 30cm is recommended since length of the vine cuttings affect root yield. Increase length of

vines tends to increase yield of sweetpotato (Onwueme, 1978). Sprouts from roots are also used as means of propagation but they are not recommended because, poor yields are produced as compared to vine cuttings (Ikemoto, 1971).

2.6 CROPPING SYSTEMS

The system that is normally practiced is sole cropping. However, sweetpotato can be grown in intercropping and rotation systems with crops such as bean, soybean, sorghum, maize and cassava (Davis *et al.*, 1986). It is alternated with swamp rice or hungry rice in Sierra Leone (Onwueme, 1978). The tillage operation necessary before planting and at harvesting sweetpotato provide aeration beneficial to the root system of tree when is in a mixture with tree crops. Rotation system in sweetpotato helps in the control of weed. The ability of sweetpotato to control weeds is because of the vigorous vines growth. Sweetpotato is used as the lead crop in rotation system except in soils of high fertility which may promote vegetative growth and slow tuberization process (Janssens, 2001). It is possible to grow two crops of sweetpotato a year especially in areas with adequate and evenly distributed rainfall (750-1250mm) but only one crop in areas with unimodal rainfall.

2.7 CULTURAL PRACTICES

2.7.1 Planting

The vine is planted into the soil such that one-half to two-third of its length is beneath the soil surface. The cuttings are generally planted vertically, at an angle or horizontally to the surface with at least one-third of the cutting above the soil and this

portion should have at least one node. Mechanical planters plant vine cuttings horizontally and this has resulted greater yield (Chen *et al*., 1982). In most parts of the tropics, planting of vines and sprouts is done by hand. Onwueme (1978) reported that, the vines are normally planted 25cm to 30cm apart on ridges that are 60cm to 75cm apart which require 44,000 to 67,000 cuttings per hectare. The number of roots per plant decreases, the mean weight per root decreases, and the yield per plant decreases as the plant population per hectare increases beyond 70,000 cuttings per hectare. Planting early in the season is the best so that the rainy season can be utilized since water critical in the early stage of growth of the crop.

2.7.2 Weeding

Canopy of leaves of sweetpotato may reach its fullness in six weeks after planting (Onwueme, 1978). Weed growth is intensive in the first two months of sweetpotato growth since the canopy has not reached fullness. Degras (2003) reported that, 57 percent of crop plants are lost in some part of Africa due to weeds. Vigorous growth of the vines causes fast and total ground cover which hinders the growth of weeds. Weed control is usually done mechanically using hand tools like hoes, cutlass or hand pulling. Most traditional farmers do single hoe weeding normally about four weeks after planting. However, in various parts of the world, the use of herbicides to control weeds is common. Several herbicides are commonly used in the U.S.A. Diphenamide (2.7- 4.4 kg/ha) or Chloramben (3.3 kg/ha) is applied on newly planted plots, or Vernolate (3.3 $kg.ha^{-1}$ is incorporated into the soil just before planting (Talbert, 1967). In southern Ethiopia, weeds are typically controlled by hand weeding. Hernandez *et al.* (1969) reported that herbicide use has been found not to affect the storage root or processing quality.

2.7.3 Fertilization

Sweetpotato has a high requirement for potassium relative to nitrogen. A crop yielding 30 t/ha of top growth and 22 t/ha of storage roots takes up 80 kg/ha N, 29 kg/ha P and 185 kg/ha K (AVRDC, 1975). According to Tewe *et al.* (2001), the optimum NPK requirement is 45-N, 15-P and 70-K. Poultry manure is one of the important organic fertilizers that is effectively used to replace inorganic fertilizer especially when it is having 9% N content (Tewe *et al*., 2001). A six (6) t/ha chicken manure and 200kg/ha 15-15-15 NPK are recommended on poor soils (Yeng *et al*., 2012).

2.7.3.1 Nitrogen

Nitrogen contributes to storage root and biomass yield of sweetpotato. High nitrogen rates may result in low yield. Nandpuri *et al*. (1971) reported that in India, beyond 56 kg/ha N may result in yield decline and beyond 94 kg/ha N in Puerto Rico (Landrau and Samuels, 1951). Hill *et al.* (1990) reported that some sweetpotato cultivars are able to produce high root yields in low nitrogen soils because of the presence of organisms like *Azospirillum* which is capable of fixing nitrogen in the root environment which may increase storage root yield by 22%.

2.7.3.2 Phosphorus

Nishimoto *et al.* (1977) reported that, the response of sweetpotato to phosphorus is low as compare to nitrogen and potassium and it is responsible for 70% of the crop's maximum yield at a soil solution concentration as low as 0.003 ppm P_2O_5.

2.7.3.3 Potassium

Potassium is needed as important nutrient component for the development of storage root. Gollifer (1972) reported that storage root yield increases up to 86% with

112kg/ha potassium in the Solomon Islands. This confirms that, high concentrations of potassium in leaves promote translocation of photosynthates from leaves to storage roots. AVRDC (1975) reported that storage root enlargement occurs when the nitrogen to potassium ratio is low and they recommended a ratio of 1:3, because high nitrogen concentration promotes vine growth but reduces potassium concentration and this affects storage roots.

2.7.4 Diseases and Pests

Diseases and pests can cause losses both in the field prior to harvest or on roots in storage. Numerous virus, fungal and nematode diseases and insects, attack sweetpotato crops especially in the field.

According to Geddes (1990), sweetpotato virus disease (SPVD) is the most important disease affecting sweetpotato. The mosaic is another serious virus disease of sweetpotato in the USA, and it is becoming serious in Africa as well (Onwueme, 1978). Plants infected with the mosaic virus have malformed, small and mottled leaves and this leads to little roots or rootless. Infected plants should be removed and burnt to prevent spreading. Feathery mottle complex is also a virus disease that infects sweetpotato. It is identified in almost all places where sweetpotato is grown. Feathery mottle complex comprises viruses such as the leaf spot virus, the white fly transmitted yellow dwarf virus and internal cork virus. Feathering mottle complex causes yellowish spotting in older leaves, yellowing of the veins in the younger leaves and stunting of the plants. Campbell *et al*. (1974) reported that strains of this virus have been shown to be the causal agents to several of the virus diseases of sweetpotato. The internal cork virus, which is one of the viruses in the feathery mottle complex, is

characterized by the development of corky areas within the flesh of the root. The affected areas of the root taste bitter when cooked. The internal cork virus is transmitted by aphids. The symptoms are not shown on the roots externally but can be seen when cut.

Fungal diseases that infect the crop include black rot, scurf, fusarium wilt and soft rot. Black rot is the most important fungal disease of sweetpotato. It causes young plants to turn yellow and the underground stem portion to black. On the storage roots, dark circular depressions develop and the rot may spread through the entire root. Wilson *et al.* (1970) reported that infected storage roots produce toxins that cannot be removed by boiling or baking of the storage roots. Scurf is another fungal disease known to infect sweetpotato. It has been reported by Onwueme (1978) that the growth of the scurf disease is very slow in some parts of the world. It causes brownish blotches on the roots and it does not directly affect the cortex or under lying tissues of the storage root. Fusarium wilt is also a fungal disease also known as stem rot caused by *Fusarium oxysporum f. batatis*. It destroys the vascular tissues especially the xylem when it enters the plant through an open. This makes the plant leaves grow wrinkled and yellowish in colour and in all growth becomes stunted. Soft rot which is commonly called *Rhizopus* soft rot is a serious post-harvest fungal disease of sweetpotato. Control of fungal infected plants are mainly by the use of resistant varieties, treating planting material in fungicides before planting, planting only disease-free planting materials and burning of all infected crop residues.

Nematode attack causes poor growth, low yield and cracked roots (Giamalva *et al*., 1963). Sweetpotato crops are attacked by three major types namely the root knot nematode (*Meloidogyne*) which is the widest spread of the three, sting nematode

(*Belonolaimus gracilis*) and the lesion nematode (*Pratylenchrus*). Nematode can be controlled by the use of resistant varieties and crop rotation.

The crop suffers serious damage from insect pests both in field and in storage. The most widespread and serious pest is generally considered to be the sweetpotato weevil of the genus *Cylas* of which about six species have been reported feeding on the crop (Lema, 1992). Three species have been identified in Africa which includes *C. formicarius*, *C. puncticollis* and *C. brunneus*. The adult weevils feed on the leaves and vines as well as on storage roots but the most severe damage are caused by the larvae which create tunnels during feeding and deposit frass to render the roots unfit for human consumption and livestock (Horton, 1989). Infestation by the weevil varies with season and infestation is serious during the dry season. Onwueme (1978) reported that temperatures at or below freezing can kill the adult in 7 days, the larvae in 15 days and the pupae in 21 days. The weevil is less likely to attack roots found deep in the soil and according to IITA (1975), earthing-up around the roots reduces the degree of infestation.

Taleker (1982) reported that, defoliators particularly sweetpotato butterfly *Acraea acerata* (Hew), stem borers, namely the clear wing moth (*Synanthon spp*) and stripped sweetpotato weevil (*Alcidodes spp*) have been reported to cause damage to the crowns thus minimizing food translocation to the root. Sweetpotato butterfly is reported to cause extensive damage in Africa. The larvae feed on the leaves of sweetpotato and heavy attacks can result in complete defoliation of the vines. Hill *et al*. (1988) reported that, the insect is distributed over the whole of Eastern Africa and the Congo.

Addo (1971) also reported that, other root pests which include millipedes. Millipedes are mostly common in soils which are moist and high in organic matter. There is no

appropriate control of millipedes. Millipedes injure plants by eating the roots of various plants, tunnel into root and stem tubers.

In general, control of diseases and pests in sweetpotato production has been mainly the use of chemical and cultural methods or both.

2.8 Harvesting

Harvesting in sweetpotato production is done between 12 and 35 weeks after planting but according to Chen and Xu (1982), growth period and harvesting depend on the cultivar and environmental conditions under which the crop is grown. Readiness of the crop for harvesting is characterized by yellowing of the leaves. Early harvest may results in low root yields and late harvest may results in fibrous and unpalatable roots as well as exposure to sweetpotato weevils and other rots attack. The two main components of root yields are root weight and root number. Storage roots of a given crop mature at different periods, for this reason, harvesting is done at a time majority of the roots have matured. According to Wilson *et al.* (1989), the average weight of a mature root is between 0.2 and 0.5kg. Crop yields of up to 40 ton/ha after 4 months of planting are obtained without fertilizer in a well managed soil (IITA, 1976).

2.9 Quality factors

Quality factors like percentage dry matter content, protein, iron, zinc, fructose, glucose, sucrose, maltose, total sugars of roots of sweetpotato variety trial (SPVT) for 13 sweetpotato genotypes in Ghana including Sauti are presented in the CSIR-CRI sweetpotato varietal release brochure, 2012 as shown in Appendix 1 and 2.

CHAPTER THREE

MATERIALS AND METHODS

3.1 EXPERIMENTAL SITE

The study was conducted at the CSIR-Crops Research Institute, research fields at Fumesua- Kumasi. Fumesua is located on longitude 06^{o} 34' E and 10^{o} 36 ' W. The soil is generally sandy loam and the soil type is of Kumasi-Asuansi/Nta-Offin association which is medium to coarse textured, good structured with fairly high moisture holding capacity (Adu, 1992). Fumesua is located in the forest agro-ecological zone of Ghana.

3.2 EXPERIMENTAL DESIGN

The experimental design used was 2x4 factorial with treatments arranged in RCBD design. The factors were seedbed types (mound and ridge) and types of fertilizer use were:

- recommended chicken manure (CM) (6t CM/ha)
- recommended NPK (15- 15-15) fertilizer (RIF) (200 kg NPK/ha)
- 100 kg NPK/ha + 3 t CM/ha (that is, ½ RIF + ½ CM)
- no chicken manure and inorganic fertilizers (control)

Each treatment was replicated thrice.

3.3 LAND PREPARATION

The land was ploughed and harrowed with a tractor. Lining and pegging were done to establish the plots for the treatments. Ridges and mounds were made with hoes to

heights of 30-40cm and 40-50cm respectively. Ridges were separated at 1m spacing and 0.3m within rows, whilst mounds were separated at 1m spacing and 1m within rows. The chicken manure was applied and worked into the plots of Treatments 2 and 4 of both ridges and mounds for one week to allow further decomposition before planting of vines.

Fig. 1: Prepared ridges

Fig. 2: Prepared mounds

3.4 PLANTING

Sauti, an improved sweetpotato variety released by CSIR-CRI was used. Planting was done manually by hand using cutlass at a spacing of 1 x 0.3m on the ridges and 1 x 1m on the mounds.

3.5 CULTURAL PRACTICES

Weeding was done three times especially on plots with the chicken manure at 3rd, 8th and 12th weeks after planting. Irrigation was done in the morning almost throughout

the field experiment from the time of planting to a week to harvesting. Remounding and heaping of soil around ridges were done after every weeding.

3.6 GROWTH AND YIELD PARAMETERS

The International Board for Plant Genetic Resources (IBPGR) Descriptor for sweetpotato published in 1991 was used in measuring the targeted study variables.

Foliage characters measured at 3 months after planting (MAP) were mature leaf size, petiole length, vine length and percentage ground cover. Other parameters taken at harvest (5MAP) included number of plants harvested, number of plants with roots, fresh vine weight, number of marketable and number of non-marketable roots according to sizes, marketable root weight, non-marketable root weight, total root yield, weight per root, root crack, harvest index and commercial harvest index. The marketable and non-marketable roots were determined by measuring root diameter from the middle portion of the root using vernier callipers. Roots with root diameter less than 4 cm were considered non-marketable, while those with root diameter of 4 cm or more were considered as marketable roots. Root crack was evaluated by visual examination and severity was scored against the scale of 1-5 using the sweetpotato descriptor. Harvest index was estimated as the ratio of the total storage root yield to total storage root yield and fresh vine weight at harvest. Commercial harvest index was also estimated as the ratio of marketable root weight to total root yield at harvest.

Leaf size was determined by measuring the length from the basal lobes to the tips of the leaves of three plants of each plot and the mean was calculated. Petiole length was measured from the base to the insertion of the leaf to the point of attachment to the vine. Data was taken on three leaves from each plot and the mean was calculated.

Vine length was determined by measuring from the base to the tip of the vine in each plot. Estimated percentage ground cover was determined by visual examination on each plot.

3.7 DISEASES AND PESTS

Incidences of diseases and pests were recorded by visual examination on the plant and root and severity was determined by scoring using the sweetpotato descriptor (CIP/AVRDC/IBPGR, 1991). *Cylas spp* and millipede infestations and sweetpotato virus disease (SPVD) were determined visually by examining the harvested roots from each plot for *Cylas* and millipede feeding damage. The extent of the damage was scored on the scale of 1-5, where 1 = no damage, 2 = very little damage, 3 = moderate damage, 4 = considerable damage and 5 = severe damage (CIP/AVRDC/IBPGR, 1991).

3.8 QUALITY FACTORS

Quality factors of percentage dry matter, zinc, iron, protein, sugars, starch and betacarotene of the roots were analysed using the Near-Infrared Reflectance Spectrophotometer (NIRS) computer which were measured in mg/100g. The steps involved at the laboratory were processing, freeze drying, milling and scanning by the NIRS computer.

3.8.1 Processing

Sweetpotato samples brought from the field were washed with water and fresh weight of 50g was taken for each treatment. The samples are the frozen in deep freezer at about -28^{o}C for a day. The samples are the sent to the vacuum freeze dryer to dry.

3.8.2 Freeze drying

In the vacuum freeze dryer, the frozen samples were placed on the shelves and sealed where they were preserved and moisture was removed through sublimation.

3.8.3 Milling

Milling of samples was done using the Wiley Mini Mill after recording the dry weight of samples from the freeze dryer.

3.8.4 Scanning

Scanning of the samples was done with the Near Infrared Reflectance Spectrophotometer (NIRS) after filling the corvette in the NIRS machine with approximately 2g of the milled samples of each treatment and placed in the Iris Adaptor. The Infrared light went through the samples to give the nutrient levels in the sweetpotato.

3.9 SOIL CHEMICAL AND PHYSICAL PROPERTIES

The results of the chemical and physical properties of the top 30 cm soil at the experimental site are shown in Table 2 and Table 3 respectively. The soil pH value indicated that the soil was slightly acidic whereas soil nitrogen value as indicated in Table 1 was low.

3.9.1 Soil pH

Soil pH was measured in a 1:1 soil-water ratio using a glass electrode (H19017 Microprocessor) pH meter. Approximately 25 g of soil were weighed into a 50 ml polythene beaker and 25 ml of distilled water was added to the soil. The soil-water solution was stirred thoroughly and allowed to stand for 30 minutes. After calibrating the pH meter with buffers of pH 4.01 and 7.00, the pH was read by immersing the electrode into the upper part of the soil solution and the pH value recorded.

3.9.2 Soil organic carbon

Soil organic carbon was determined by the modified Walkley-Black method as described by Nelson and Sommers (1982). The procedure involves a wet combustion of the organic matter with a mixture of potassium dichromate and sulphuric acid. After the reaction, the excess dichromate is titrated against ferrous sulphate. Approximately 1.0 g of air-dried soil was weighed into a clean and dry 250 ml Erlenmeyer flask. A reference sample and a blank were included. Ten ml 0.1667*M* potassium dichromate ($K_2Cr_2O_7$) solution was accurately dispensed into the flask using the custom laboratory dispenser. The flask was swirled gently so that the sample was made wet. Then using an automatic pipette, 20 ml of concentrated sulphuric acid (H_2SO_4) was dispensed rapidly into the soil suspension and swirled vigorously for 1 minute and allowed to stand on a porcelain sheet for about 30 minutes, after which 100 ml of distilled water was added and mixed well. Ten (10) ml of ortho-phosphoric

acid and 1 ml of diphenylamine indicator was added and titrated by adding 1.0*M* ferrous sulphate from a burette until the solution turned dark green at end-point from an initial purple colour. About 0.5 ml 0.1667*M* $K_2Cr_2O_7$ was added to restore excess $K_2Cr_2O_7$ and the titration completed by adding $FeSO_4$ drop-wise to attain a stable end-point. The volume of $FeSO_4$ solution used was recorded and % C calculated.

Calculation:

The organic carbon content of soil was calculated as:

$$\%\ \mathrm{O.C} = \frac{\mathrm{M} \times 0.39 \times \mathrm{mcf} \times (\mathrm{V}_1 - \mathrm{V}_2)}{s}$$

where;

M = molarity of ferrous sulphate solution.

V_1 = ml of ferrous sulphate solution required for blank.

V_2 = ml of ferrous sulphate solution required for sample.

s = weight of air − dry sample in grams.

mcf = moisture correcting factor $\frac{(100 + \%\ \text{moisture})}{100}$.

$0.39 = 3 \times 0.001 \times 100\ \% \times 1.3$ (3 = equivalent weight of carbon).

1.3 = a compensation factor for the incomplete combustion of the organic carbon.

3.9.3 Total nitrogen

Total nitrogen was determined by the Kjeldahl digestion and distillation procedure as described in Soil Laboratory Staff (1984). Approximately 0.2 g of soil was weighed into a Kjeldahl digestion flask and 5 ml distilled water added. After 30 minutes a tablet of selenium and 5 ml of concentrated H_2SO_4 were added to the soil and the

flask placed on a Kjeldahl digestion apparatus and heated initially gently and later vigorously for at least 3 hours. The flask was removed after a clear mixture was obtained and then allowed to cool. About 40 ml of distilled water was added to the digested material and transferred into 100ml distillation tube. 20 ml of 40 % NaOH was also added to the solution and then distilled using the Tecator Kjeltec distiller. The digested material was distilled for 4 minutes and the distillate received into a flask containing 20 ml of 4 % boric acid (H_3BO_3) prepared with PT5 (bromocresol green) indicator producing approximately 75 ml of the distillate. The colour change was from pink to green after distillation, after which the content of the flask was titrated with 0.02*M* HCl from a burette. At the end-point when the solution changed from weak green to pink the volume of 0.02*M* HCl used was recorded and % N calculated. A blank distillation and titration was also carried out to take care of traces of nitrogen in the reagents as well as the water used.

Calculation:

The percentage nitrogen in the sample was expressed as:

$$\% \text{ N} = \frac{(\text{M} \times (\text{a} - \text{b}) \times 1.4 \times \text{mcf})}{\text{s}}$$

Where

M = concentration of hydrochloric acid used in titration.

a = volume of hydrochloric acid used in sample titration.

b = volume of hydrochloric acid used in the blank titration.

s = weight of air − dry sample in grams.

$$\text{mcf} = \text{moisture correcting factor } \frac{(100 + \% \text{ moisture})}{100}$$

3.9.4 Bray's No. 1 Phosphorus (available phosphorus)

The readily acid-soluble forms of phosphorus were extracted with a HCl:NH_4F mixture called the Bray's no.1 extract as described by Bray and Kurtz (1945) and Nelson and Sommers (1982). Phosphorus in the extract was determined on a spectrophotometer by the blue ammonium molybdate method with ascorbic acid as reducing agent. Approximately 5 g of soil was weighed into 100 ml extraction bottle and 35 ml of extracting solution of Bray's no. 1 (0.03*M* NH_4F in 0.025*M* HCl) was added. The bottle was placed in a reciprocal shaker and shaken for 10 minutes after which the content was filtered through Whatman no.42 filter paper. The resulting clear solution was collected into a 100 ml volumetric flask.

An aliquot of about 5 ml of the clear supernatant solution was pipetted into 25 ml test tube and 10ml colouring reagent (ammonium paramolybdate) was added as well as a pinch of ascorbic acid and then mixed very well. The mixture was allowed to stand for 15 minutes to develop a blue colour to its maximum. The colour was measured photometrically using a spectronic 21D spectrophotometer at 660 nm wavelength. Available phosphorus was extrapolated from the absorbance read.

A standard series of 0, 1.2, 2.4, 3.6, 4.8 and 6 mg P/l was prepared from a 12 mg/l stock solution by diluting 0, 10, 20, 30, 40 and 50 ml of 12 mg P/l in 100 ml volumetric flask and made to volume with distilled water. Aliquots of 0, 1, 2, 4, 5 and 6 ml of the 100 mg P/l of the standard solution were put in 100 ml volumetric flasks and made to the 100 ml mark with distilled water.

Calculation:

$$\mathrm{P\ (mgkg^{-1})} = \frac{(a - b) \times 35 \times 15 \times mcf}{s}$$

where

$a =$ mg/l P in sample extract.

$b =$ mg/l P in blank.

$s =$ weight of air $-$ dry sample in gram.

$$\text{mcf} = \text{moisture correcting factor } \frac{(100 + \%\ \text{moisture})}{100}$$

$35 =$ volume of extracting solution.

$15 =$ final volume of sample solution.

3.9.5 Determination of available Potassium

Available potassium extracted using the Bray's no. 1 solution was determined directly using the Gallenkamp flame analyzer. Available potassium concentration was determined from the standard curve. Potassium standard solutions were prepared with the following concentrations: 0, 10, 20, 30, and 50 µg K / ml of solution. The emission values were read on the flame analyser. A standard curve was obtained by plotting emission values against their respective concentrations.

Calculation:

$$\text{K}\ (\text{mg kg}^{-1}) = \frac{(a - b) \times 35 \times \text{mcf}}{s}$$

where

$a =$ µgK/ml in sample.

$b =$ µgK/ml in blank.

$s =$ weight of air $-$ dry sample in gram.

$35 =$ volume of extracting solution.

$$\text{mcf} = \text{moisture correcting factor } \frac{(100 + \%\ \text{moisture})}{100}$$

3.9.6 Extraction of the exchangeable bases

A 5 g soil sample was transferred into a leaching tube and leached with 100 ml of buffered 1.0*N* ammonium acetate (NH_4OAc) solution at pH 7.

3.9.7 Determination of Calcium

A 25 ml portion of the extract was transferred to an Erlenmeyer flask. Hydroxylamine hydrochloride (1.0 ml), potassium cyanide (1.0 ml of 2 % solution) and potassium ferrocyanide (1.0 ml of 2 %) were added. After a few minutes, 4 ml of 8*M* potassium hydroxide and a spatula of murexide indicator were added. The solution obtained was titrated with 0.01*N* EDTA solution to a pure blue colour. The titre value was again recorded.

3.9.8 Determination of calcium and magnesium

For the determination of the calcium plus magnesium, a 25 ml of the extract was transferred into an Erlenmeyer flask. A 1.0 ml portion of hydroxylamine hydrochloride, 1.0 ml of 2.0 per cent potassium cyanide buffer (from a burette), 1.0 ml of 2.0 per cent potassium ferrocyanide, 10.0 ml ethanolamine buffer and 0.2 ml Eriochrome Black T solution were added. The solution was titrated with 0.01*N* EDTA (ethylene diamine tetraacetic acid) to a pure turquoise blue colour. The titre value was recorded.

The titre value for calcium was subtracted from this value to get the titre value for magnesium.

Calculation:

$$\text{Exchangeable Calcium (cmol of Ca (+) kg}^{-1}\text{soil)} =$$

$$\left[\frac{V_1 - V_2}{V_3} \times V_4 \times N \times \frac{100}{w}\right] \times mfc$$

where

V_1 = volume of EDTA required for sample aliquot titration, ml

V_2 = volume of EDTA required for blank titration,

V_3 = volume of aliquot taken, ml

V_4 = total volume of original NH_4OAc extracts, ml

N = normality of EDTA

w = weight of sample taken in g

$$\text{mcf} = \text{moisture correcting factor } \frac{(100 + \%\ \text{moisture})}{100}$$

$$\text{Exchangeable Calcium plus Magnesium (cmol of Ca + Mg kg}^{-1}\text{ soil)} = \left[\frac{V_5 - V_6}{V_7} \times V_4 \times N \times \frac{100}{w}\right] \times \text{mfc}$$

where

V_5 = volume of EDTA required for sample aliquot titration, ml V_6 = volume of EDTA required for blank aliquot titration, ml

V_7 = volume of aliquot taken, ml

V_4 = total volume of original NH_4OAc extracts, ml

N = normality of EDTA

w = weight of sample taken in g

$$\text{mcf} = \text{moisture correcting factor } \frac{(100 + \%\ \text{moisture})}{100}$$

1ml 0.01 N EDTA = 0.2004 mg Ca^{2+} = 0.1216 Mg^{2+}

3.9.9. Exchangeable potassium and sodium determination

Potassium and sodium in the percolate were determined by flame photometry. A standard series of potassium and sodium were prepared by diluting both 1000 mg/l potassium and sodium solutions to 100 mg/l. This was done by taking a 25 ml portion of each into one 250 ml volumetric flask and made to volume with water. Portions of 0, 5, 10, 15 and 20 ml of the 100 mg/l standard solution were put into 200 ml volumetric flasks respectively. One hundred milliliters of 1.0*N* NH_4OAc solution was added to each flask and made to volume with distilled water. The standard series obtained was 0, 2.5, 5.0, 7.5, 10.0 mg/l for potassium and sodium. Potassium and sodium were measured directly in the percolate by flame photometry at wavelengths of 766.5 and 589.0 nm respectively.

Calculations:

$$\text{Exchangeable K } (\text{cmolkg}^{-1}\text{soil}) = \frac{(a-b) \times 250 \times \text{mcf}}{10 \times 39.1 \times s}$$

$$\text{Exchangeable Na } (\text{cmolkg}^{-1}\text{soil}) = \frac{(a-b) \times 250 \times \text{mcf}}{10 \times 23 \times s}$$

where

a = mg/l K or Na in the diluted sample percolate.

b = mg/l K or Na in the diluted blank percolate.

s = weight of air − dry sample in gram.

$$\text{mcf} = \text{moisture correcting factor } \frac{(100 + \%\ \text{moisture})}{100}$$

3.9.10 Exchangeable acidity

Exchangeable acidity is defined as the sum of Al + H and this was determined in 1.0*M* KCl extract as described by Page *et al.* (1982). The soil sample was extracted with unbuffered 1.0*M* KCl, and the sum of Al + H was determined by titration. Ten grams of soil sample was put in a 100 ml bottle and 50 ml of 1.0*M* KCl solution added. The bottle was capped and shaken for 1.0 hour and the filtered. Twenty five milliliters portion of the filtrate was taken with a pipette into a 250 ml Erlenmeyer flask and 2 – 3 drops of phenolphthalein indicator solution added. The solution was titrated with 0.1*M* NaOH until the colour just turned permanently pink. A blank was included in the titration.

Calculation:

$$\text{Exchangeable acidity (cmolkg}^{-1}\text{soil)} = \frac{(a - b) \times M \times 2 \times 100 \times mcf}{s}$$

where

a = ml NaOH used to titrate sample.

b = ml NaOH used to titrate blank.

M = molarity of NaOH solution.

s = weight of air − dry sample in gram.

2 = 50/25 (filtrate/pipetted volume)

$$mcf = \text{moisture correcting factor } \frac{(100 \times \%\ \text{moisture})}{100}$$

3.9.11 Effective cation exchange capacity (ECEC)

Effective cation exchange capacity was determined by the sum of exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) and exchangeable acidity (Al^{3+} + H^{+}).

3.9.12 Soil Physical Analysis (Soil texture)

The soil texture was determined by the Hydrometer method. Approximately 40 g of soil was weighed into 250 ml beaker and oven dried at 105 ^{0}C over night. The sample was removed from the oven and then placed in a desiccator to cool, after, which it was weighed and the oven dry weight taken. A 100 ml of dispersing agent commonly known as Calgon (Sodium Bicarbonate and Sodium Hexa-metaphosphate) was measured and added to the soil. It was then placed on a hot plate and heated until the first sign of boiling was observed. The content in the beaker was washed completely into a shaking cup and then fitted to a shaking machine and shaken for 5 minutes. The sample was sieved through a 50 microns sieve mesh into a 1.0 L cylinder. The sand portion was separated by this method while the silt and clay went through the sieve into the cylinder. The sand portion was dried and further separated using graded sieves of varying sizes into coarse, medium and fine sand. These were weighed and their weights taken.

The 1.0 L cylinder containing the dispersed sample was placed on a vibrationless bench and then filled to the mark. It was covered with a watch glass and allowed to stand overnight. The Hydrometer method was used to determine the silt and the clay contents. The cylinder with its content was agitated to allow the particles to be in suspension, it was then placed on the bench and hydrometer readings taken at 30 seconds, 4 minutes, 1 hour, 4 hours and 24 hours intervals. At each hydrometer

reading the temperature was also taken. Coarse silt, medium silt, fine silt and clay portions were then calculated graphically. The various portions were expressed in percentage and using the textural triangle the texture was determined.

Table 1. Initial, chemical and physical properties of soil at the experimental site

Parameter	Value
pH (1:1 H_2O)	5.93
O.C (%)	1.25
O.M (%)	2.16
Total N (%)	0.10
Available P (mg/kg)	7.26
Available K (mg/kg)	74.40
Exchangeable Cations :	
Ca (Cmolc/kg)	4.80
Mg (Cmolc/kg)	1.60
Na (Cmolc/kg)	0.14
K (Cmolc/kg)	0.23
T.E.B (Cmolc/kg)	6.77
Ex. A. (Cmolc/kg)	0.25
ECEC (Cmolc/kg)	7.02
% BS	96.44
Sand (%)	75.16
Silt (%)	16.84
Clay (%)	4.00

Source: Soil Analytical Services Division at CSIR-Soil Research Institute, Kwadaso Kumasi.

3.10 CHEMICAL PROPERTIES OF CHICKEN MANURE

Chemical properties of chicken manure are shown in Table 2. Nitrogen content of the chicken manure was higher than that of the soil. The nutrient contents of the manure were moderate to high, especially the nitrogen, phosphorus and potassium.

3.10.1 Nitrogen

Total nitrogen was determined by the Kjeldahl method in which plant material was digested with concentrated sulphuric acid and hydrogen per-oxide with selenium as catalyst. The organic N present was converted into NH_4^+. The ammonium ion, which reacted with the excess of sulphuric acid to form ammonium sulphate, was distilled off in an alkaline medium into boric acid.

$$NH_3 + H_3BO_3 \rightarrow NH_4^+ + H_2BO_3^-$$

The $H_2BO_3^-$ that was formed was titrated with standard hydrochloric acid back to H_3BO_3. About 20.0 g oven-dried plant materials was ground in a stainless steel hammer mill with a sieve mesh of 1 mm, and mixed well to ensure homogeneity. Approximately 0.2 g of the plant material was weighed into a Kjeldahl flask, a tablet of selenium catalyst was added and 5 ml of concentrated H_2SO_4 was also added to the mixture. This was digested on the Electrothermal Kjeldahl apparatus for three hours. After the clear digest has cooled, about 20 ml of distilled water was poured into the Kjeldahl flask containing the digested material before it was transferred into a 100 ml distillation tube. In the distillation tube another 20 ml distilled water was added plus 20 ml 40 % NaOH then distilled for 4 minutes. The distillate was received in a conical flask containing 20 ml of 4 % boric acid with PT5 indicator (methyl red and bromocresol green indicators). The received greenish solution was titrated against 0.1

M HCl dispensed from a burette. % N was calculated from the volume of HCl used to attain end-point (Soil Laboratory Staff, 1984).

Calculation:

$$\%\ \mathrm{N\ DM^{-1}} = \frac{(a - b)\ \times M\ \times 1.4\ \times mcf}{s}$$

where

a = volume of 0.1 M HCl used for sample titration.

b = volume of 0.1 M HCl used for the blank titration.

M = molarity of HCl.

$1.4 = 14\ \times 0.001\ \times 100\%$ (14 = atomic weight of N)

s = weight of sample in gram.

3.10.2 Determination of phosphorus and potassium

Phosphorus and potassium were determined in plant ash using the Vanado-Molybdenum method. Approximately 0.5 g of the plant material was weighed into a porcelain crucible and ashed in a muffle oven at a temperature of 450 – 500 ^{0}C. The ashed sample was removed from the oven after cooling then made wet with 1–2 drops of distilled water and 10 ml of 1:2 dilute HNO_3 added. The crucible was then heated on a water bath until the first sign of boiling was observed. The crucible was removed and allowed to cool. The content was filtered into a 100 ml volumetric flask using a no. 540 filter paper. The crucible was washed two times with about 5 ml distilled water followed by the filter which was also washed two times with about 20 ml distilled water. After 10 ml each of ammonium vanadate and ammonium molybdate solutions were added and shaken thoroughly. The solution was allowed to stand for 10 minutes for full colour development and then filled to the 100 ml mark. A standard

curve was also developed concurrently with P concentrations ranging from 0, 1, 2, 5, 10, and 15 to 20 µg P per millilitre of solution. The absorbance of the sample and standard solutions were read on the spectrophotometer (spectronic 21D) at a wavelength of 470 nm. A standard curve was obtained by plotting the absorbance values of the standard solutions against their concentrations. Phosphorus concentration of the samples was determined from the standard curve. Potassium in the ash solution was determined using a Gallenkamp flame analyser. Potassium standard solutions were prepared with the following concentration: 0, 10, 20, 40, 60 and 100 µg K per millilitre of solution. The emission values were read on the flame analyser. A standard curve was obtained by plotting emission values against their respective concentrations.

3.10.3 Determination of calcium and magnesium

For the determination of calcium plus magnesium a 25ml aliquot of the extract as described in the determination of plant Phosphorus and potassium was taken and transferred into an Erlenmeyer flask. The following reagents were added, potassium ferrocynide (1ml), buffer solution (5ml) and a drop Eriochrome Black T indicator and the solution titrated against Ethylene Diamine Tetra Acetic (EDTA) to a blue end point. The titre value was recorded.

3.10.4 Determination of calcium

Another 25ml aliquot of the extract was transferred to an Erlenmeyer flask. Cabamate (1ml of 2% solution), potassium hydroxide (5ml) and a pinch of murexide indicator were added. The solution was titrated with EDTA to a purple end point.

3.10.5 Carbon analysis

Organic matter will be determined by dry combustion (ignition) method at 550 ^{o}C. Organic matter is estimated by loss on ignition.

% organic carbon = % organic matter X 0.580

Table 2. Chemical properties of chicken manure

Element	Percentage (%)
Total N	1.61
Total P	1.39
Total K	0.52
Total Ca	0.27
Total Mg	0.31

Source: Soil Analytical Services Division at Soil Research Institute, Kwadaso.

3.11 DATA ANALYSES

.The analysis of variance (ANOVA) procedure was used to analyse all data using the GENSTAT analytical tool. The means were separated using the Least Significant Difference (LSD) at 5% probability.

3.12 WEATHER CONDITIONS

The weather conditions at the experimental site from July, 2013 to December, 2013 are shown in the Table 3.

Table 3. Weather conditions at the experimental site, 2013

Month	Rainfall (mm)	Temperature (^{o}C)		Relative humidity (%)
		Max.	Min.	
July	124.2	27.2	24.0	91.1
August	7.4	26.3	23.7	89.1
September	255.4	27.4	24.7	90.1
October	171.4	28.4	25.1	89.1
November	95.0	29.0	25.8	87.5
December	5.8	27.9	25.1	74.7

Source: Meteorological Station at CSIR-Crops Research Institute, Fumesua.

Fig 3: Growth and development of sweetpotato at 4 MAP.

Fig 4: **Harvesting at 5 MAP**

Fig 5: Damage of root by cracks at harvest

CHAPTER FOUR

RESULTS

4.1 GROWTH PARAMETERS

4.1.1 Percentage crop establishment

Table 4 shows percentage crop establishment recorded at 4 weeks after planting. The results indicated no significant differences ($P>0.05$) in crop establishment due to seedbed type. Crop establishment was 100% and 99.17% on ridge and mound respectively. On the other hand, there was no significant difference among the fertilizer types used. All the fertilizer treatments recorded 100% crop establishment except the combined fertilizer treatment which had 98.33%.

4.1.2 Leaf size

The mean leaf sizes recorded at 3 months after planting are shown in Table 4. Leaf size differed significantly between crops on the two seedbed types ($P<0.05$). Leaf size of plants on mounds were bigger than (16.90 cm) those on ridges averaging 15.62 cm. Significant difference in leaf size was observed among fertilizer treatments. All the amended treatments supported greater leaf size than the control treatment. Among the amended treatments, chicken manure and combined fertilizer treatment effects had higher mean leaf size at the same value (17.66 cm) but either effect was significantly greater than those of NPK only and the control treatments. The control and the NPK fertilizer only treatments have similar effect.

4.1.3 Petiole length

The results of mean petiole length recorded at 3 months after planting are shown in Table 4. There were no significant differences ($P>0.05$) between mean petiole length

of plants on the different seedbed type. Among the fertilizer treatments, chicken manure resulted in significant and highest petiole length compared to the control and NPK only treatments. The treatment effect of chicken manure and the NPK fertilizer was also significantly higher than that of the control treatment. However, there were no significant differences between the control and NPK fertilizer only at 5% level of probability.

Table 4. Effect of seedbed type and fertilizer application on crop establishment, leaf size and petiole length of sweetpotato

Treatments	Crop establishment (%)	Leaf size (cm)	Petiole length (cm)
Seedbed			
Ridge	100	15.62	26.69
Mound	99.17	16.90	24.27
Lsd (5%)	1.79	0.88	2.88
Fertilizer			
Control	100	14.54	22.25
Chicken manure	100	17.66	28.42
NPK	100	15.17	24.11
Chicken manure +NPK	98.33	17.66	27.15
Lsd (5%)	2.53	1.24	4.08
CV (%)	2.0	6.2	12.90

4.1.4 Fresh vine length

Fresh vine length measured at 3 months after planting showed no significant differences (P>0.05), among seedbed type although plants on ridges recorded the longer mean vine length of 153.10 cm (Table 5). Among the fertilizer treatments, chicken manure treatment recorded the greatest value of 166.10 cm and this was significantly different from NPK only and the control treatments. All other treatment effects were statistically similar.

Table 5. Effect of seedbed type and fertilizer application on fresh vine length, percent ground cover and number of plants harvested of sweetpotato

Treatments	Fresh vine length(cm)	Ground cover (%)	Number of plants harvested
Seedbed			
Ridge	153.10	80.00	11.67
Mound	136.20	76.20	7.58
Lsd (5%)	19.45	4.82	0.58
Fertilizer			
Control	136.70	67.50	9.50
Chicken manure	166.10	88.30	9.83
NPK	133.60	73.30	9.67
Chicken manure + NPK	142.40	83.30	9.50
Lsd (5%)	27.50	6.82	0.82
CV (%)	15.30	7.1	1.15

4.1.5 Percent ground cover

Results of percentage ground cover recorded at 3 months after planting are shown in Table 5. Seedbed type did not significantly affect ground cover. Among the fertilizer treatments, sole chicken manure and the combined chicken manure and NPK were not statistically different (P>0.05) but were significantly different from the control and sole NPK fertilizer. The sole NPK treatment did not show any significant difference from the control treatment.

4.2 YIELD PARAMETERS

4.2.1 Number of plants harvested

Table 5 shows mean number of plants harvested. The number of plants harvested from the ridges was significantly higher than those from the mounds. Fertilizer application did not significantly affect the number of plants harvested.

4.2.2 Number of plants with roots

The number of plants with roots at harvest is shown in Table 6. Number of plants with roots on ridges were significantly ($P<0.05$) different from that of mounds. Among the fertilizer treatments, sole NPK fertilizer effect was significantly different from sole chicken manure only and the combined fertilizer treatment effect. The control treatment effect was significantly different from sole chicken manure.

4.2.3 Fresh vine weight

Table 6 shows the fresh vine weight at harvest. Fresh vine weight from mounds was significantly different ($P<0.05$) from that of ridges. Among the fertilizer treatments, chicken manure treatment recorded the greatest value of 44.20 kg compared with 19.80 kg for the control treatment. Chicken manure treatment effect was significantly different from that of the control. The combined fertilizer treatment was also significantly different from the control treatment effect.

4.2.4 Number of marketable roots

The results of the number of marketable roots are shown in Table 6. Seedbed type significantly affected number of marketable roots as the ridge seedbed supported greater number of marketable roots than mound seedbed. Among the fertilizer treatments, sole NPK resulted in the greatest number of marketable roots with a mean

value of 8.50, which was significantly different from that of sole chicken manure treatment only. All other treatment effects were similar

Table 6. Effect of seedbed type and fertilizer application on number of plants with roots, fresh vine weight and number of marketable roots of sweetpotato

Treatments	Number of plants with roots	Fresh vine weight (kg)	Number of marketable roots
Seedbed			
Ridge	9.67	26.70	8.75
Mound	5.08	39.30	5.50
Lsd (5%)	1.09	9.76	2.03
Fertilizer			
Control	8.00	19.80	7.17
Chicken manure	6.17	44.20	5.00
NPK	8.50	30.80	8.50
Chicken manure + NPK	6.83	37.20	7.83
Lsd (5%)	1.54	13.81	2.88
CV (%)	16.90	33.80	32.60

4.2.5 Number of non-marketable roots

Table 7 shows the number of non-marketable roots. The difference between the numbers of non-marketable roots from the two seedbed types was significantly ($P<0.05$) different from one another. The ridge seedbed produced greater non-marketable roots than from the mounds. Among the fertilizer treatments, the chicken manure only treatment had the lowest (5.17 roots), and this was significantly lower than those from the control and NPK only treatments. Non-marketable roots from the combined fertilizer treatment were also significantly lower that of the control and NPK only. The number of non-marketable roots for sole chicken manure and combined fertilizer treatments were statistically not different.

4.2.6 Marketable roots weight

The results of marketable roots weight are shown in Table 7. From the table, there was significant difference between marketable roots weight of the two seedbed types. The ridge produced higher weights than the mound. Fertilizer application did not significantly ($P>0.05$) affect the weight of marketable roots.

4.2.7 Non-marketable roots weight

Table 7 shows the results of non-marketable roots weight. From the results, the difference of non-marketable roots weight between ridge and mound was significant ($P<0.05$) with the ridge seedbed recording the greater effect than the mound. Among the fertilizer treatments, the combined fertilizer treatment recorded the greatest non-marketable roots weight with a mean value of 1.32 kg and was significantly higher than both the chicken manure only and the control treatments. Other treatment differences were not significant at 5% level of probability.

Table 7. Effect of seedbed type and fertilizer application on number of non-marketable roots, marketable roots weight and non-marketable roots weight of sweetpotato

Treatments	Number of non-marketable roots	Marketable roots weight (kg)	Non-marketable roots weight (kg)
Seedbed			
Ridge	10.92	3.59	1.19
Mound	7.58	2.02	0.71
Lsd (5%)	2.26	1.06	0.34
Fertilizer			
Control	11.17	2.15	0.77
Chicken manure	5.17	2.32	0.65
NPK	13.17	3.28	1.07
Chicken manure + NPK	7.50	3.48	1.32
Lsd (5%)	3.20	1.50	0.48
CV (%)	27.90	43.2	41.00

4.2.8 Weight per root

From Table 8, the results showed that, there was no significant difference between weight per root of the two seedbed types (P>0.05). The combined fertilizer treatment recorded the greatest weight per root which was significantly different from the control treatment. All the other treatment differences were not significant.

4.2.9 Total root yield

The results of the total root yield are shown in Table 8. The treatment effect of the ridge seedbed was significantly higher than that of the mound seedbed (P<0.05). Among the fertilizer treatments, the combined fertilizer treatment effect was the greatest (4.80 kg), and this was significantly different from the control and sole chicken manure. All other treatment effects were statistically not different.

4.2.10 Harvest index

The results of harvest index shown in Table 8 indicated that there was significant difference between the two seedbed types (P<0.05). Plants from ridges had significantly higher harvest index than those on mounds. The NPK only treatment recorded the greatest harvest index value of 0.15 and this was significantly greater than the chicken manure treatment effect only. All the other treatment differences were not significant.

Table 8. Effect of seedbed type and fertilizer application on weight per root, total root yield and harvest index of sweetpotato

Treatments	Weight per root (kg)	Total root yield (kg)	Harvest index
Seedbed			
Ridge	0.50	4.78	0.17
Mound	0.51	2.73	0.07
Lsd (5%)	0.15	1.17	0.04
Fertilizer			
Control	0.38	2.92	0.14
Chicken manure	0.50	2.97	0.08
NPK	0.55	4.35	0.15
Chicken manure + NPK	0.60	4.80	0.12
Lsd (5%)	0.21	1.65	0.06
CV (%)	32.90	35.50	41.6

4.2.11 Commercial harvest index

Table 9 shows the results of the commercial harvest index. The results indicated that, there was no significant differences between commercial harvest index under the two seedbed types (P>0.05). Among the fertilizer treatments, the control treatment recorded the highest commercial harvest index value of 0.82 and was significantly

different from the combined fertilizer treatment which recorded the lowest commercial harvest index value of 0.57. The treatment effect of sole chicken manure was significantly higher than that from the combined fertilizer treatment.

4.3 DISEASES AND PESTS

4.3.1 Virus score

The results of virus scores are shown in Table 9. Virus incidence was not significantly affected by seedbed type and fertilizer application on both occasions.

Table 9. Effect of seedbed type and fertilizer application on commercial harvest index and virus score at two recording periods of sweetpotato

Treatments	Commercial harvest index	Virus score-1	Virus score-2
Seedbed			
Ridge	0.73	1.00	1.83
Mound	0.73	1.00	1.50
Lsd (5%)	0.14	-	0.95
Fertilizer			
Control	0.82	1.00	1.67
Chicken manure	0.78	1.00	1.67
NPK	0.75	1.00	2.00
Chicken manure + NPK	0.57	1.00	1.33
Lsd (5%)	0.20	-	1.34
CV (%)	22.20	-	64.80

4.3.2 Cracks

The results of severity of cracks on roots are shown in Table 10. The results indicated that there was no significant difference between the scores of cracks for roots from the two seedbed types ($P>0.05$). Among the fertilizer treatments, the combined fertilizer treatment had the highest score of 2.67, which was significantly different from sole NPK treatment. All other treatment effects were significantly not different.

4.3.3 Cylas damage

The extent of cylas damage recorded at harvest is shown in Table 10. The result shows a significant higher cylas damage of roots from ridges than mounds ($P<0.05$). Among the fertilizer treatments, the roots from the control and sole NPK treatments gave highest cylas damage. Both effects were significantly different from the sole chicken manure which supported the lowest damage. All other treatment differences were not significant.

4.3.4 Alcidodes damage

Table 10 shows the extent of alcidodes damage recorded at harvest. Seedbed type did not significantly affect ($P>0.05$) alcidodes damage. Among the fertilizer treatments, the combined fertilizer treatment had the greatest alcidodes damage score of 4.50 which was significantly different from that of the sole chicken manure. Additionally the combined fertilizer treatment effect was significantly higher than that of the chicken manure treatment effect. All other treatments did not have any statistical differences.

Table 10. Cracks, Cylas and Alcidodes damages on sweetpotato as affected by seedbed type and fertilizer application

Treatments	Cracks Score (1-5)	Cylas damage Score (1-5)	Alcidodes damage Score (1-5)
Seedbed			
Ridge	1.75	3.17	4.08
Mound	2.08	2.25	4.33
Lsd (5%)	0.83	0.73	0.62
Fertilizer			
Control	2.00	3.33	4.17
Chicken manure	1.67	2.00	3.83
NPK	1.33	3.17	4.33
Chicken manure + NPK	2.67	2.33	4.50
Lsd (5%)	1.17	1.03	0.41
CV (%)	49.50	30.70	16.90

4.3.5 Millipede damage

The results of millipede damage are shown in Table 11. Both seedbed type and fertilizer application did not significantly affect millipede damage (P>0.05).

4.3.6 Exposed roots

The results of harvested roots that were exposed are shown in Table 11. Both seedbed type and fertilizer application did not significantly affect number of exposed roots (P>0.05)

Table 11. Millipede damage and exposed roots of sweetpotato as affected by seedbed type and fertilizer application

Treatments	Millipede damage Score (1-5)	Exposed roots Score (1-5)
Seedbed		
Ridge	1.25	1.33
Mound	1.17	1.25
Lsd (5%)	0.41	0.32
Fertilizer		
Control	1.33	1.33
Chicken manure	1.00	1.33
NPK	1.17	1.17
Chicken manure + NPK	1.33	1.33
Lsd (5%)	0.57	0.54
CV (%)	38.30	33.80

4.4 ROOT QUALITY FACTORS

4.4.1 Root fresh weight

The results of fresh weight of roots are shown in Table 12. Seedbed and fertilizer types did not significantly affect the root fresh weight. .

4.4.2 Root dry weight

Table 12 shows the results of root dry weight. Seedbed type significantly affected the root dry weight ($P<0.05$). Root dry weights from the ridges were statistically different from that of mounds. Among the fertilizer treatments, sole NPK and the control were significantly different from the combined fertilizer and sole chicken manure treatments. There was no difference between these two fertilizer treatments ($P>0.05$)

4.4.3 Percent root dry matter

The result of percentage root dry matter is as shown in Table 12. The ridge seedbed recorded significant difference in percentage root dry matter compared to that of mounds (P<0.05). Among the fertilizer treatments, the control and NPK only treatment had similar effects. Both treatments were significantly different from chicken manure and combined fertilizer treatments.

Table 12. Effect of seedbed type and fertilizer application on root fresh weight, root dry weight and percent dry matter of sweetpotato root

Treatments	Root fresh weight (g)	Root dry weight (g)	% Root dry matter
Seedbed			
Ridge	50.35	18.33	36.41
Mound	50.44	16.99	33.66
Lsd (5%)	0.25	0.82	1.61
Fertilizer			
Control	50.27	18.47	36.73
Chicken manure	50.34	16.89	33.56
NPK	50.56	18.53	36.64
Chicken manure + NPK	50.40	16.77	33.20
Lsd (5%)	0.35	1.16	2.27
CV (%)	0.60	5.30	5.20

4.4.4 Zinc content of root

The zinc content of roots is shown in Table 13. There was significant difference between the two seedbed types (P<0.05). Mound seedbed recorded the greater zinc content value of 1.36. Among the fertilizer treatments, the control treatment effect was lowest and this was significantly lower than all other treatment effects except the NPK only treatment. The NPK only treatment effect was also significantly lower than that of the chicken manure only treatment.

4.4.5 Iron content of root

Results in Table 13 show the nutritional component of iron. The mound plants recorded significantly higher effect than the ridge seedbed. Fertilizer application also significantly affected the iron content of the root. The greatest effect was recorded in the chicken manure treatment, which was significantly higher than those of the control and NPK treatment only. The combined fertilizer treatment effect was also significantly higher than the control treatment effect.

4.4.6 Protein content of root

The results of nutritional component protein in roots are as shown in Table 13. Among the seedbed types, the mound recorded significantly higher protein value than those from the ridge seedbed ($P<0.05$). Among the fertilizer treatments, the chicken manure recorded the highest protein value of 7.10 which was significantly higher than those of the control and NPK only treatments. The control treatment effect was also significantly lower than those of the combined fertilizer and NPK only treatments.

Table 13. Effect of seedbed type and fertilizer application on zinc, iron and protein of sweetpotato root

Treatments	Zinc (mg/100g)	Iron (mg/100g)	Protein (mg/100g)
Seedbed			
Ridge	1.17	1.81	4.97
Mound	1.36	2.17	6.43
Lsd (5%)	0.17	0.22	0.96
Fertilizer			
Control	1.06	1.68	4.05
Chicken manure	1.46	2.25	7.10
NPK	1.22	1.92	5.59
Chicken manure + NPK	1.33	2.11	6.06
Lsd (5%)	0.24	0.31	1.36
CV (%)	15.50	12.50	19.30

4.4.7 Sucrose content of root

Table 14 shows the results of root sucrose content, and seedbed type did not significantly affect ($P>0.05$) sucrose content of roots. Among the fertilizer treatments, the chicken manure treatment effect was the greatest, and this was significantly higher than those of NPK only and control treatments. All other treatment differences were not significant.

4.4.8 Fructose content of root

Table 14 shows the results of the root fructose content. Seedbed type did not significantly affect fructose content. The control treatment effect was the greatest, but this was higher than that of the chicken manure treatment. Other treatment differences were not significant.

4.4.9 Root glucose

The results of root glucose content are shown in the Table 14. Glucose content did not vary in the different seedbeds. Fertilizer application significantly affected root glucose content. The effect of the control treatment was significantly higher than that of the chicken manure treatment. All other treatment effects were similar.

Table 14. Effect of seedbed type and fertilizer application on sucrose, fructose and glucose of sweetpotato root

Treatments	Sucrose (mg/100g)	Fructose (mg/100g)	Glucose (mg/100g)
Seedbed			
Ridge	10.09	0.94	2.61
Mound	10.87	1.22	2.80
Lsd (5%)	1.07	0.33	0.47
Fertilizer			
Control	9.82	1.33	3.18
Chicken manure	11.39	0.77	2.18
NPK	9.73	1.06	2.70
Chicken manure + NPK	10.98	1.16	2.76
Lsd (5%)	1.51	0.47	0.66
CV (%)	11.60	35.30	19.70

4.4.10 Starch content of root

From the results in Table 15, the starch content of the root from the ridges was significantly higher than that from mounds. Among the fertilizer treatments, the control had the greatest root starch content which was also significantly higher than those from the chicken manure only and the combined fertilizer treatments. The two latter treatment effects were not different from one another.

4.4.11 Betacarotene content of root

The betacarotene content of the roots from the ridges was significantly higher than that from the mounds (Table 15). Indeed the difference was more than 100%. Among the fertilizer treatments, the control treatment effect was very low, and was significantly lower than all other treatment effects. All other treatment differences were not significant.

Table 15. Effect of seedbed type and fertilizer application on starch and betacarotene of sweetpotato root

Treatments	Starch (mg/100g)	Betacarotene (mg/100g)
Seedbed		
Ridge	68.13	1.59
Mound	65.53	3.68
Lsd (5%)	1.72	1.34
Fertilizer		
Control	68.71	4.05
Chicken manure	64.83	0.33
NPK	68.09	2.32
Chicken manure + NPK	63.81	3.84
Lsd (5%)	2.43	1.90
CV (%)	2.90	58.20

CHAPTER FIVE

DISCUSSION

5.1 GROWTH PARAMETERS

5.1.1 Percentage crop establishment

Optimum plant population is influenced and achieved by high percentage of crop establishment. High percentage crop establishment on ridge recorded might be due the use of active vine growing portions, optimum planting depth, spacing and good land preparation as well as reduction in weed competition for growth resources as reported by Dapaah *et al*. (2004).

5.1.2 Leaf size

Leaf size varied significantly between seedbed types and among the fertilizer treatments as well. Between the two seedbed types, the mound recorded greater leaf size and this might be influenced by the preparation and height of the mound which heaped the topsoil and made nutrients available in the early stages of vegetative growth. Onwueme (1978) reported that, one of the factors which may contribute to high growth and yield of mound grown plants is that, the process of mound making collects the rich topsoil and the entire depth of the mound consists of fertile soil. Secondly, from the results, all the amended fertilizer treatments had greater leaf size than the control treatment. This might be due to the availability of nutrients to the plants. Additional observation was that the effects of the chicken manure treatment were higher than the NPK fertilizer alone. This may be due to the fact that the manure was providing nutrients as well as supplying organic matter, improving drainage and aeration of which resulted in greater leaf size (Blake, 2001)

5.1.3 Petiole length and fresh vine length

Petiole length and fresh vine length varied significantly among the fertilizer treatments. From the results, all the amended treatments recorded greater petiole length and high fresh vine length than the control treatment, with the chicken manure recording the highest value. This might be probably due to the supply of nitrogen and other nutrients by the amendments. AVRDC (1975) had reported that, the nitrogen fertilizer encourages growth in sweetpotato. According to Yen (1974), petiole and vine length vary widely with genotypes, but this could not be verified in this study as only one genotype was used.

5.1.4 Percent groundcover

Percent groundcover varied significantly among the fertilizer treatments. All the amended treatments recorded high percent groundcover than the control treatments. Borke (2003) reported that, nitrogen application has a profound influence on leaf area index (LAI) and leaf area duration (LAD). This means the higher groundcover achieved might be influenced by the high nitrogen, supplied by the chicken manure and the NPK. High percentage crop establishment might have also accounted for the high percent groundcover and this is in an agreement with Tucker and Dahniya (1998) who reported that, early establishment of crop provides an optimum photosynthetic canopy for a longer period of the growing season hence high percent groundcover.

5.2 YIELD PARAMETERS

5.2.1 Number of plant harvested and number of plant with roots.

The trend in the number of plants harvested and number of plants with roots followed the trend of crop establishment. The number of plants harvested depends on the number of established crops. High percentage crop establishment might have led to the high number of plants harvested on the ridge. From this, it can be deduced that, number of plant harvested and number of plants with roots might have been influenced by the use of active vine growing portions, optimum planting depth and spacing and good land preparation as stated by Dapaah *et al.* (2004).

5.2.3 Storage root yields at harvest

The main components of storage root yields are the root number and weight. Therefore differences in these parameters may affect the total root yield. All the amended treatments, except the chicken manure significantly out-yielded the control treatment in terms of the entire storage root yields. Although the chicken manure recorded low values in terms of number and weight of marketable and weight of non-marketable root, these figures were better than the control treatment in other root yield parameters especially total root yield. The combined fertilizer treatment produced the highest values of storage root yields than the NPK fertilizer only treatment as both soil chemical and physical factors might have been improved with the former treatment (Yeng *et al.*, 2012).

Similar reports have been made by other authors who stated that positive interaction between organic and inorganic inputs is observed when applied simultaneously (Giller *et al.*, 1998; Palm *et al.*, 1997).

Storage root yields of sweetpotato depend on the photosynthetic capacity of the leaf canopy, the capacity of the crop to translocate assimilates from the leaf (source) to the root (sink) and the capacity for the sink to accept assimilates. Though leaf area index were not measured in the experiment, inferences can be made from the data on leaf size and percent groundcover to give some idea of solar radiation interception potentials of the crop since the combined fertilizer treatment recorded very appreciable leaf size and percent groundcover. It is therefore possible that assimilates of photosynthesis translocated to the roots might have contributed to the high storage root yields of the combined fertilizer treatment.

Yields of sweetpotato are reduced if severe water stress occurs at the time of tuberization (Degras, 2003). Singer and Munns (1987) had reported that moisture status of the soil affects the plant growth and yield. Chicken manure in combination with NPK has the capacity to hold and conserve water which improves the moisture status of the soil at the crucial time of tuberization and this might have contributed to the high storage root yields of the combined fertilizer treatment.

Another serious factor that may influence storage root yields is diseases and pests attacks. At harvest, it was observed that some roots were seriously damaged by *Cylas spp*, cracks and alcidodes. This might have contributed to the reduced storage root yields especially marketable roots and the total root yields of the sole chicken manure and the control treatments.

5.2.4 Harvest and commercial harvest indices

Harvest index represents the efficiency of the storage root production and is usually determined by ratio of storage root weight to the total plant weight or total biomass

while commercial harvest index is determined by ratio of marketable storage root weight to the total storage root weight.

Harvest index (HI) did show significant differences among the fertilizer treatments as well as between the seedbed types while commercial harvest index (CHI) did show significant differences among the fertilizer treatments only. The present results indicated that harvest index was low. This might be due to poor partitioning or low translocation of dry matter to the storage roots as stated by Yeng *et al.* (2012). The commercial harvest index was quite high for both seedbed types and fertilizer treatments (except the combined fertilizer treatment), indicating a very small percentage of non-marketable root yield production. From the results, the higher fresh vine weight at harvest might have contributed to the lower root yield and in turn lowered the harvest index since higher fresh vine weight could be influenced by high translocation of assimilates to vegetative biomass at the expense of storage roots.

5.3 DISEASES AND PESTS

From the results, the severity of SPVD (virus score) was low based on the sweetpotato descriptor. The presence of this disease might have been contributed by the use of infested vines used as planting material. Foliar diseases reduce the photosynthetic capacity of crop as well as storage root size and this may lead a long way to affect growth and yield of sweetpotato (CIP/AVRDC/IBPGD, 1991).

Three different pests were studied in the experiment which included *Cylas spp*, alcidodes and millipedes. From the results, the severity of cylas damage was moderate-damage according to the sweetpotato descriptor especially on the ridges and in the control among the fertilizer treatments. The presence of this pest might have

been influenced by the dry season where temperatures were high. Onwueme (1978) reported that temperatures at or below freezing can kill the adult in 7 days, the larvae in 15 days and the pupae in 21 days. Also it was observed that the heaped soil was reduced at harvest thereby reducing the depth of the roots in the soil and leaving some roots exposed. This observation might contributed to the damage by the weevil since the weevil is less likely to attack roots found deep in the soil and according to IITA (1975).

Alcidodes damage was generally severe in the study especially among the fertilizer treatments with the combined fertilizer treatment recording the highest severity of alcidodes damage. Alcidodes damage might be influenced by the use of infested planting vines and alternative weed hosts. Millipede damage was insignificant in the study (CIP/AVRDC/IBPGD, 1991).

Cracked and exposed roots were also studied. From the results, incidence of cracks was significant especially most crack roots were recorded in the combined treatment. Incidence of cracks may be influence by weather conditions where the dry season is immediately followed by rains and also high nitrogen fertilization may cause cracks since nitrogen encourages rapid growth and can cause uneven growth rate in the roots (CIP/AVRDC/IBPGD, 1991). Even though exposed root case was observed but was not significant. Exposed root may result from reduced soil levels on ridge and mound.

5.4 QUALITY FACTORS

Percentage root dry matter was determined by ratio of dry root weight to fresh root weight. From the results, the ridge recorded a higher percentage root dry matter than the mound, whereas in the fertilizer application, the control had the highest percentage

root dry matter among the fertilizer treatments. Interestingly there was no positive effect of fertilizer on root dry matter and this might be due to high nitrogen in the soil which encourages continuous vegetative growth and this is in line with the result of Hill *et al.* (1990) who reported no effect on root dry matter following nitrogen addition. In general the percentage root dry matter recorded in this study was slightly low compared to the percentage root dry matter of Sauti recorded in the CSIR-CRI sweetpotato varietal release brochure, 2012 (Appendix 2) and this may due to time of harvest and high vegetative growth as observed in treatments where nitrogen was high.

The mound recorded a higher iron, zinc and protein contents between the two seedbed type whiles the chicken manure treatment recorded the highest protein as well as iron and zinc contents among the fertilizer treatments. Researchers have cited linear increase of crude protein content with increasing nitrogen rates of several cultivars (Purcell *et al*., 1982; Constantin *et al*., 1984) and also since nitrogen is a major element of protein, it is clear that the high protein recorded was influenced by the high nitrogen content in the fertilizer especially the chicken manure. Greater leaf size recorded on mounds is an indicator of high zinc and iron contents which is in line with Acquaah (2002), who reported that plants with high zinc and iron have increased leaf size and shortened internodes. Aside the fertilizer effect, it can be deduced that, mound preparation which heaped the rich topsoil might have also contributed to the high protein, zinc and iron contents since there was significant difference between the two seedbed types.

The ridge recorded higher starch content between the two seedbed type whiles the control treatment recorded the highest starch content among the fertilizer treatments. It is clear that the trend in starch content followed the trend of percentage root dry

matter and it may be deduced that, percentage root dry matter has influence on the starch content of roots. The starch content recorded in this study was slightly low compared to starch content of Sauti recorded in the CSIR-CRI sweetpotato varietal release brochure, 2012 (Appendix 1) and this might be accounted for by time of harvest, high vegetative growth as observed in treatments where nitrogen was high and poor translocation of photosynthetic assimilates.

In general, betacarotene is not of high levels in the variety Sauti since it is not an orange-flesh. However, the content of betacarotene was higher on mound which may be due to the heaped rich topsoil of the mound.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The results of the study have indicated and confirmed that combination of organic (chicken manure) and inorganic fertilizers use, as an integrated nutrient management strategy in sweetpotato production, is a better alternative than either sole application of organic or inorganic fertilizer.

Under the study, the combined fertilizer type enhanced the growth and development of the crop. Specifically the combined fertilizer resulted in high storage total root yield of 4.80 kg (number of roots and roots weight) on ridges.

The study revealed that, chicken manure which is for sustainable production and cost effective resulted in high vegetative growth. It is therefore important for pastoral farmers to consider the production of sweetpotato using organic fertilizer for vigorous vegetative growth to feed their livestock.

The results of the study showed that, the effect of fertilizer application enhanced some quality factors (protein, zinc and iron) of sweetpotato specifically on mounds.

In general, the study revealed that, planting of sweetpotato on ridge is better than mound planting since ridge planting in totality resulted in high growth and yield of sweetpotato.

It is therefore economically cost-effective and beneficial for farmers to combine organic and inorganic fertilizers in sweetpotato production on ridges.

6.2 Recommendations

The following recommendations were made based on the outcome of the study.

- Further investigations should be made into different rate of combined organic and inorganic fertilizers for high growth and yield of sweetpotato.
- Time of maturity and harvest period should be further investigated at six months since in the study, there was still vegetative growth at the recommended period of four months
- Further studies must be carried out on the number of cuttings per mound for high growth and yield of sweetpotato since in my case one cutting was used.

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APPENDIX 1

Protein, Fe, Zn, Starch, Raw Fructose, Raw Glucose, Raw Sucrose, Raw Maltose and Raw Total Sugars, of roots of Sweetpotato Variety Trial (SPVT) for 13 sweetpotato genotypes at **Pokuase**, one out of the **five locations** (**1=Fumesua, 2=Ejura, 3=Pokuase, 4=Ohawu and 5=Komenda**), major season, 2011

		Protein (%)	Fe ..... (mg/100g).....	Zn	Starch (%)	Fructose (%)	Glucose (%)	Sucrose (%)	Maltose (%)
1	Santom Pona	4.07	1.42	0.96	70.11	1.44	2.90	8.53	0.08	12.95
2	Otoo	3.47	1.51	0.79	68.03	1.03	2.27	12.36	0.24	15.90
3	HI-starch	3.23	1.25	0.84	75.15	0.47	2.10	7.85	0.09	10.52
4	199062.1	3.44	1.52	0.96	68.09	1.13	2.56	11.22	0.31	15.21
5	Tek Santom	3.39	1.58	0.98	64.82	1.16	2.74	13.98	0.25	18.13
6	Apomuden	4.43	2.26	1.41	47.01	4.67	7.79	23.35	0.86	36.67
7	Cemsa 74-228	3.38	1.27	0.95	69.53	1.19	2.71	10.57	0.22	14.69
8	Ogyefo	2.74	1.25	0.96	74.13	0.20	1.56	8.21	0.09	10.06
9	Faara	3.28	1.45	0.99	70.21	1.39	3.11	9.25	0.15	13.90
10	**Sauti**	**3.87**	**1.38**	**1.00**	**69.26**	**0.70**	**2.30**	**9.56**	**0.15**	**12.71**
11	Mohc	7.53	2.99	1.69	69.35	1.75	4.33	23.45	0.40	14.97
12	Okumkom	3.46	1.68	0.96	65.86	2.50	4.31	10.17	0.32	17.31
13	Kemb 37	4.29	1.73	1.04	68.01	1.68	3.65	9.54	0.24	15.11

*Starch content on dry weight basis
Source: CSIR-CRI Sweetpotato Varietal Release Brochure, 2012.

APPENDIX 2

Percentage dry matter of roots of Sweetpotato Variety Trial (SPVT) for 13 sweetpotato genotypes at **five locations** (**1=Fumesua, 2=Ejura, 3=Pokuase, 4=Ohawu and 5=Komenda**), major season, 2011

		.....DM (%).....					
		Fumesua	Ejura	Pokuase	Ohawu	Komenda	
1	Santom Pona	35.2	36.8	34.5	32.6	35.6	34.9
2	Otoo	36.6	34.8	32.2	34.6	32.3	34.1
3	HI-starch	45.8	46.2	43.7	44.2	44.2	44.8
4	199062.1	33.2	32.9	31.3	30.1	28.7	31.2
5	Tek Santom	-	35.1	34.8	33.7	31.5	33.8
6	Apomuden	21.5	20.3	20.6	17.9	21.2	20.3
7	Cemsa 74-228	38.0	36..5	36.2	33.2	33.4	35.4
8	Ogyefo	42.1	36.7	37.4	40.0	36.6	38.6
9	Faara	40.6	36.9	37.8	38.1	36.9	38.1
10	**Sauti**	**40.4**	**35.5**	**37.1**	**39.8**	**37.9**	**38.1**
11	Mohc	36.0	35.6	34.2	32.9	32.5	34.2
12	Okumkom	34.8	35.2	33.2	28.5	31.3	32.6
13	Kemb 37	38.9	34.4	32.8	33.6	32.8	34.5

Source: CSIR-CRI Sweetpotato Varietal Release Brochure, 2012.

APPENDIX 3

CIP, AVRDC, IBPGR DESCRIPTORS FOR SWEETPOTATO (1991)

PLANT DATA

4.1.3 Ground cover

Estimated percentage of ground cover recorded at 3 MAP

1 Low (<50%)

2 Medium (50-74%)

3 High (75-90%)

4 Total (>90%)

4.1.8 Mature leaf size

1. Small (<8 cm)

2. Medium (8-15 cm)

3 Large (16-25 cm)

4 Very large (>25 cm)

4.1.11 Petiole length

1 Very short (<10 cm)

2 Short (10-20 cm)

3 Intermediate (21-30 cm)

4 Long (31-40 cm)

7 Very long (>40 cm)

6.1.6 Storage root cracking

0 Absent

3 Few cracks

5 Medium number of cracks

7 Many cracks

8. BIOTIC STRESS SUSCEPTIBILITY

Scored on a scale of 1-9

1 Very low

3 Low

5 Intermediate

7 High

9 Very high

Alternatively, score on a scale of 1-5

1 No apparent damage/no present

2 Very little damage/few present

3 Moderate damage/numbers present

4 Considerable damage/high numbers present

5 Several damage/very high numbers present