**KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY (KNUST)**

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**DEPARTMENT OF CROP AND SOIL SCIENCES**

# EFFECT OF TILLAGE, VINE LENGTH AND FERTILIZER APPLICATION ON THE GROWTH, YIELD AND QUALITY OF SWEET POTATO (*Ipomoea batatas* (L) Lam).

**BY**

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**SEPTEMBER, 2015**

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# EFFECT OF TILLAGE, VINE LENGTH AND FERTILIZER APPLICATION ON THE GROWTH, YIELD AND QUALITY OF SWEET POTATO (*Ipomoea batatas* (L) Lam).

**A thesis submitted to the Department of Crop and Soil Sciences, Faculty of Agriculture, College of Agriculture and Natural Resource, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana in partial fulfillment of the requirement for the award of Master of Philosophy Degree in Agronomy**

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**DECLARATION**

I Gibrilla Dumbuya declare that the work presented in this thesis entirely my own and has not been submitted for a degree to any other University and all references used have been duly acknowledged.



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# DEDICATION

This work is dedicated to my lovely mother, Mrs. Ramatu Conteh for her love and encouragement throughout the duration of the course.

## ACKNOWLEDGEMENT

Glory and honour to the Almighty God for the love, guidance, protection and strength He granted me to complete my course. My profound gratitude goes to my supervisor, Dr. Joseph Sarkodie-Addo of the Department of Crop and Soil Sciences, Faculty of Agriculture, KNUST for his assistance, patient and support in the execution of this research.

I am very grateful to Dr. Charles Kwoseh, WAAPP- SL coordinator and senior lecturer, Department of Crop and Soil Sciences, Faculty of Agriculture, KNUST for his patient and fatherly love shown throughout the course. I thank all my lecturers at the Kwame Nkrumah University of Science and Technology for their knowledge, which laid a strong foundation for this work. I express my sincere gratitude to my sponsor, the West Africa Agricultural Productivity Programme (WAAPP) Sierra Leone for the financial assistance given throughout my studies. Special thanks to the Sierra Leone Agricultural Research Institute (SLARI) for choosing me as a beneficiary of this scholarship.

Heartfelt thanks to my dear friend, Louisa N. Banfo for her support and encouragement given me throughout the period of the studies. Indeed, you are a definition of true friendship. I greatly appreciate the tireless efforts of all the staff of the Plantation Section. Thanks to all my friends, Mr. Moses A. Daramy, Mr. Milton S. Kanneh, Mr. Alex Tamu, Mr. Aloysius B. Bangura and the rest for their support during my studies.

## ABSTRACT

Sweet potato (*Ipomoea batatas* L.) is becoming the most widely distributed root crops in most developing countries. However, production of the crop in Africa is faced with several constraints among which are tillage method used by farmers, the type of planting material farmers used and lack of knowledge on the appropriate rate of fertilizer the crop need. Two field experiments were carried out at the Plantation Section of the Department of Crop and Soil Sciences, KNUST, to evaluate the effect of tillage, vine length and fertilizer application on the growth, yield and quality of sweet potato.

The first experiment was conducted during the major season of 2014 to evaluate the effect of tillage method and phosphorus fertilizer on sweet potato growth, yield and quality. Two tillage methods (ridge and mound) and five phosphorus fertilizer rates (0, 30, 60, 90 and 120 kg $P_2O_5$/ha) in the form of triple superphosphate (46 % $P_2O_5$) were applied in a factorial experiment with treatments arranged in a Randomized Complete Block Design (RCBD) with three replications. A 30 kg N/ha in the form of urea (46 % N) was applied to all the treatments. Sweet potato variety Okumkom was used for the study. The results showed no significant tillage effect on growth, the ridge tillage produced the greatest sweet potato root yield. Phosphorus fertilizer at the rate of 60 kg $P_2O_5$/ha recorded the greatest growth and yield. Both tillage method and phosphorus fertilizer did not significantly influence sweet potato quality characters.

The second experiment which evaluated the effect of vine length and potassium fertilizer on sweet potato growth and yield was carried out during the minor season in 2014 – 2015. Vine length (15, 22.5 and 30 cm) and four rates of potassium fertilizer (0, 60, 120 and 180 kg $K_2O$/ha) in the form of muriate of potash (60% $K_2O$) were used. The treatments were arranged in a Randomized Complete Block Design (RCBD) with three replications. A 30 kg N/ha in the form of urea (46 % N) was equally applied to all the treatments and Okumkom variety was also used. Results showed that vine length of 30 cm had the greatest growth and sweet potato yield components. Application of potassium fertilizer at 60 kg $K_2O$/ha showed the greatest response as indicated by the production of longer vine, greater number of leaves, branches, tuber roots and marketable root yield.

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| **FAO** | Food and Agriculture Organization |
| **FAOSTAT** | Food and Agriculture Organization statistics |
| **BC** | Before Christ |
| **CSIR** | Council for Scientific and Industrial Research |
| **CRI** | Crops Research Institute |
| **GD** | Gross Domestic Product |
| **IITA** | International Institute of Tropical Agriculture |
| **CIP** | International Potato Center |
| **CGIAR** | Consultative Group on International Agricultural Research |
| **CACC** | Central Agricultural Census Commission |
| **DAFF** | Department of Agriculture, Forestry and Fisheries |
| **NGMC** | New Guyana Marketing Corporation |
| **NARI** | National Agricultural Research Institute **C:** |
| **N** | Carbon-to-Nitrogen ratio |
| **m** | meter **cm** |
| centimeter | **mm** |
| millimeter **g** | gram |
| **kg** | kilogram |
| **ml** | milliliter |
| **mg** | milligram |
| **nm** | nanometer |
| **ha** | Hectare |
| **kg/ha** | Kilogram |

per hectare **t/ha**

tonnes per hectare

**$cm_3$** centimeter cube

**$g/cm^3$** gram per centimeter cube **kgai/ha**

kilogram active ingredient per hectare

**M** Molarity

**$P_2O_5$** Phosphorus pentoxide

**$K_2O$** Potassium oxide

**$NH_3$** Ammonia

**NaOH** Sodium Hydroxide

**TSP** Triple Superphosphate

**DNA** Deoxyribonucleic acid

**RNA** Ribonucleic acid

**ATP** Adenosine triphosphate

**RCBD** Randomized Complete Block Design **ANOVA**
Analysis of Variance

**CV** Coefficient of variation

**LSD** Least significant difference

**DAF** Days after fertilizer application

**WAP** Weeks after planting

**GMT** Greenwich Mean Time

**% RH** Percent Relative Humidity

# CHAPTER ONE

## INTRODUCTION

Sweet potato (*Ipomoea batatas* (L) Lam) is a tuber root bearing vegetable species grown in tropical areas for either domestic or industrial uses. It is an herbaceous plant with creeping perennial vines and adventitious roots (Belehu and Hammes, 2004). According to Loebenstein *et al*. (2009), sweet potato is ranked seventh in the world as the most important food crop after rice, wheat, potatoes, maize, yam and cassava.

The Food and Agriculture Organization (FAO, 2012) reported that 115 countries produced 108,274,685 tonnes of sweet potato in 2010 with China producing the largest, 82,474,410 tonnes, followed by Indonesia, 2,083,623 tonnes. Far behind, but ranked second in the world after Asia, is Africa with its contribution of up to 14 % of global production put at 14,441,099 tonnes in 2010. Nigeria ranks second in Africa after Uganda with the production figure of 2,883,408 tonnes which has shown an increasing trend over the years (FAOSTAT, 2012). In Ghana, annual production is 90,000 tonnes from an area of 65,000 ha (FAOSTAT, 2006).

Sweet potato root is a rich source of vitamin A, B6 and C, riboflavin, copper, pantothenic and folic acid. It can, therefore, be a high value-added food particularly for children and pregnant women who are more often exposed to vitamin A deficiency in sub-saharan Africa (Degras, 2003). The tubers have great food quality and they qualify as an excellent source of anti-oxidants and carotenes (Woolfe, 1992). Sweet potato has a high production yield of biomass; accordingly, it could have superior impact as industrial material for application in medicinal purposes (Berberich *et al*., 2005). The consumption of sweet potato is in different forms. It can be consumed as vegetable, boiled, fried as chips, baked, roasted or often fermented into food and beverages, therefore, it can be considered as a food crop that can be used to reduce the shortage of food and defeat hunger (Kassali, 2011).

Despite these values, its potential to guarantee food security is under-estimated. The production of sweet potato in Ghana is left in the hands of peasant farmers that produce far below the expected yield of the crop estimated around 2 tonnes/ha (FAOSTAT, 2012).

Tillage systems, which include ridges and mounds, optimize infiltration and facilitate root expansion, vary in respective areas depending on environmental conditions (Andrade *et al*., 2009). There are divergent views on the most appropriate tillage method to be used for planting sweet potato. Janssens (2001) reported that planting sweet potato on mounds favours the formation of tuberous root and that growing on mound is preferable to growing on ridges particularly on heavy soil while Ennin *et al*. (2003) reported that planting on ridges has been shown to increased sweet potato yields by 38% over mounding, mainly as a result of increased plant population density on ridges which help to suppressed weed and reduced the possibility of the crop competing with weeds for available nutrients. Smallholder farmers also plant sweet potato on flat land. But based on survey conducted by Ahiabor (2010), planting sweet potato on flat land resulted in drastic yield reductions of 28%.

Sweet potato is normally propagated from vine cuttings (Belehu and Hammes, 2004). In many places, farmers use any length of cuttings which are available or convenient to handle. Some farmers use short cuttings for planting just because they are easy to handle or in order to economize on the planting materials. Others also take very long cuttings, fold them several times and insert them in the soil. In other places, after harvesting the previous crop, the vines are left on the field to grow again without any organized propagation (Amoah, 1997).

According to Onunka *et al*. (2012) low soil fertility is a major factor accounting for low production of sweet potato. The crop thrives in marginal soils but improved soil fertility increases its growth and yield performance (Uwah *et al*., 2013). Fertilizer use has gained quick and tremendous importance in most developing nations of the world as high yields of improved crop cultivars depend on high growth rate which is dependent on optimum nutrition (Issaka *et al*., 2003). Unfortunately, sweet potato production in Ghana is done under minimal or no fertilizer input which always result in the low yield of crop. Root yields as low as 7 tonnes per hectare compared with potential of 18 to 24 tonnes per hectare of improved varieties have been recorded in Ghana, due to low soil fertility (CRI, 2002).

The above constraints provide the need to promote its growth and utilization by reviewing some of these agronomic practices. The best practices for the production of the crop in Ghana for increasing yield is yet to be ascertained. Proper land preparation, improved planting material and the appropriate fertilizer dosage in crop production is a pre-requisite for achieving yield of good quality (Abd El-Baky *et al*., 2009). Agricultural practices based on combined use of the most appropriate tillage, vine length and the optimum P and K fertilizer rate would promote vigorous growth and sustainable yields.

The main objective of this study was:

To determine the appropriate tillage method, vine length and optimum phosphorus and potassium fertilizer that will increase the yield and improve root quality of sweet potato.

The specific objectives were;

1. To determine the effect of P and K on sweet potato growth, yield and root quality.
2. To evaluate the effect of tillage method on root yield of sweet potato.
3. To evaluate the effect of vine length on growth and yield of sweet potato.
4. To determine the net benefit value of applying P and K fertilizers in sweet potato production.

The above objectives were formulated to test the null hypothesis that:

1. Tillage method has no effect on sweet potato growth and yield.
2. Vine length has no effect on the growth and yield of sweet potato.
3. The application of appropriate rates of phosphorus and potassium fertilizers does not increase sweet potato growth, yield and quality.
4. The application of appropriate rates of phosphorus and potassium fertilizers is not profitable for sweet potato growers.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 CROP DESCRIPTION

Sweet potato (*Ipomoea batatas* (L) Lam) is in the botanical family Convolvulaceae along with common plants, such as bindweed and morning glory. The number of chromosomes in the sweet potato plant is 2n = 90. This indicates that it is a hexaploid plant with a basic chromosome number x = 15 (Huamán and Zhang, 1997). The plant is herbaceous and perennial, but mostly grown as an annual plant by vegetative propagation using either storage roots or stem cuttings. Its growth habit is predominantly prostrate with a vine system that expands rapidly on the ground. The types of growth habit of sweet potatoes are erect, semi- erect, spreading, and very spreading. The foliage and the roots are the two main parts of the plant.

The foliage consists of numerous trailing stems, often called vines, which is cylindrical and its length, like that of the internodes depends on the growth habit of the cultivar and of the availability of water in the soil. The erect cultivars are approximately 1 m long, while the very spreading ones can reach more than 5 m long (Huaman, 1992). Some cultivars have stems with twinning characteristics. The internode length can vary from short to very long and stem diameter can be thin or very thick. Depending on the sweet potato cultivar, the stem colour varies from green to totally pigmented with anthocyanins (red-purple color) (Huaman, 1992).

The leaves are simple and spirally arranged alternately on the stem in a pattern known as 2/5 phyllotaxis. The total number of leaves per plant varies from 60 – 300 (Somda *et al*., 1991). The number of leaves per plant increases when plant density decreases, increasing irrigation and N application (Nair and Nair, 1995). Depending on the cultivar, the edge of the leaf lamina can be entire, toothed or lobed. The base of the leaf lamina generally has two lobes that can be almost straight or rounded. The shape of the general outline of sweet potato leaves can be rounded, reniform (kidney- shaped), cordate (heart-shaped), triangular, hastate (trilobular and spear-shaped with the two basal loves divergent), lobed and almost divided. Lobed leaves differ in the degree of the cut, ranging from superficial to deeply lobed. The number of lobes generally range from 3 to 7 and can be easily determined by counting the veins that go from the junction of the petiole up to the edge of the leaf lamina (Huaman, 1992).

The sweet potato root system consists of fibrous roots which develop mainly from tetrarch, thin adventitious root (Chua and Kays, 1981). Fibrous roots are branched with lateral roots forming a dense network throughout the root zone absorbing nutrients, water, and anchor the plant (Belehu, 2003). Sweet potato also consists of storage roots that are lateral roots, which store photosynthetic products. The root system in plants obtained by vegetative propagation starts with adventitious roots that develop into primary fibrous roots, which are branched into lateral roots. As the plant matures, thick pencil roots that have some lignification are produced. The edible tuberous root is long and tapered, with a smooth skin whose color ranges between yellow, orange, red, brown, purple, and beige. Its flesh ranges from beige through white, red, pink, violet, yellow, orange, and purple. Sweet potato varieties with white or pale yellow flesh are less sweet and moist than those with red, pink or orange flesh (Loebenstein *et al*., 2009). Plants grown from true seed form a typical root with a central axle with lateral branches. Later on, the central axle functions as a storage root.

**2.2 ORIGIN AND DISTRIBUTION**

Sweet potato is thought to be originated either in Central or South America (Geneflow, 2009). According to Austin and Gregory (1988), the 'cultigen' had most likely been spread by local people to the Caribbean and South America by 2500 BC. Strong supporting evidence was provided that the geographical zone postulated by Austin is the primary center of diversity (Zhang *et al*., 1999). In Africa it was introduced by explorers from Spain and Portugal during the 16th century (Zhang *et al*., 2004). Based on the presence of large numbers of varieties, East Africa is one of the areas suggested as secondary centres of diversity (Gichuki *et al*., 2003).

Sweet potato is now cultivated throughout tropical and warm temperate regions wherever there is sufficient water to support their growth. According to FAOSTAT (2012), Asia produces the greatest amount of sweet potato with China being the largest producer accounting for about 80 % of annual world supply between 2006 and 2010, followed by Indonesia, Vietnam, India, Japan and Philippines. Africa produces 11.6 million tonnes annually with Uganda being the largest producer followed by Nigeria and Tanzania. In Uganda, sweet potato is a major food crop grown throughout the country as a subsistence and food security crop (Yanggen and Nagujja, 2006).

## 2.3 SWEET POTATO PRODUCTION IN GHANA

Root and tuber crops contribute the most to Ghana‟s agricultural growth. Current information available from Ghana‟s CSIR – CRI shows that roots and tubers account for approximately 40 % of Ghana‟s GDP whilst cereals account for 7 % (CORAF, 2006**)**. Sweet potato has been cultivated in Ghana for many years, but mostly by small-holder farmers scattered around the Northern and Coastal belts where sweet potato is used as both food and cash crop (Missah *et al*., 1996; Otoo *et al*., 2000). Yields of sweet potato recorded in Ghana at the subsistence level are quite low. The crop is still not very well integrated into average Ghanaian diet (Adu-Kwarteng *et al*., 2001). Eight sweet potato varieties (Six white fleshed and two orange fleshed) have been released in Ghana by CSIR - Crops Research Institute between 1998 and 2005. An additional four varieties from IITA and CIP were released in 2012 which are now being used as parents in a crossing block established in CRI. Sweet potato annual production in Ghana was 90,000 tonnes (FAOSTAT, 2006). The characteristics of some common Ghanaian cultivars as reported by Asafo-Agyei (2010) are shown in **Appendix 1.**

## 2.4 ECONOMIC IMPORTANCE OF SWEET POTATO

Sweet potato is an important crop in many parts of the world. It is a root crop that provides food to a large segment of the world population, especially in the tropics where the bulk of the crop are cultivated and consumed (Opeke, 2006). The crop is mainly grown for its edible storage roots mostly by low-income, smallholder farmers predominantly women for household consumption and it is sometimes refers to as "a poor man's food" or survival crops in many parts of Latin America, Africa and Asia (Watson 1989). Over 50 % of sweet potato produced in Asia is fed to livestock while in contrast those produced in Africa are for human consumption (CGIAR, 2000). Sweet potato is one of the main staple crops in the food systems of Uganda, Rwanda, and
Burundi with a per capita consumption of 72.6, 73.0 and 88.9 kg, respectively
(FAOSTAT, 2010) and it is the second most important food crop after cassava in Uganda.

Fresh sweet potato contains on the average 70 % moisture and is therefore bulky and perishable. It has to be processed into a stable form for optimum utilization as food or feed. In the dry areas of Uganda, sweet potato storage roots are processed by slicing and drying. The dried chips are eaten during periods of food scarcity (Kapinga and Carey, 2003). The carbohydrate rich tuber can be boiled, fried, baked or roasted for humans or boiled and fed to livestock as a source of energy. The tubers can also be processed into flour for bread making, starch for noodles as well as used as raw material for industrial starch and alcohol (Ukom *et al*., 2009). In Nigeria, the flour is also utilized in sweetening local beverages like *Kunu-zaki*, *burukutu*, and for fortifying baby foods (Tewe *et al*., 2003). The leaves are a source of protein, containing 2.7 – 3.4 g/100g of raw fresh leaves and are an important vegetable for most rural household in Malawi and other Africa countries (Kanju, 2000). The leaves also contain substantial amount of betacarotene (-800 mg/100g) and can contribute as much as 86 % of the daily dietary requirement in Asia and 80 % in Africa (Oke 1990).

Sweet potato also has many industrial applications (Lin *et al*., 2007). It is an industrial source of starch and alcohol (Rahman *et al*., 2003), yielding 30 – 50 % more starch than rice, corn and wheat sources measured under the same conditions (Wang, 1984). Its high grade starch is suitable for food and pharmaceutical industries, and has been used in textile, paper, cosmetics, insulating and adhesive industries (Rahman *et al*., 2003; Veeraragavathatham *et al*., 2007) and has great potential for biofuel production (Mays *et al*., 1990).

## 2.5 ENVIRONMENTAL CONDITIONS OF SWEET POTATO

Sweet potato is widely grown between latitude 40º N to 40º S and altitude as high as 2500 m at the equator (Hahn and Hozyo, 1984). The crop generally requires a growth season of 4 to 5 months with optimum temperatures of 20°C - 25°C. It can, however, grow at a wide range of temperatures between 15°C and 35°C. The greatest root yields are obtained during day time temperatures of 25 to 30ºC and night temperatures of 15 to 20ºC. Temperature and the number of sunny days strongly affect sweet potato yields. If temperatures are low the growing period has to be extended to 6 – 7 months, and if lots of overcast days occur the yield will be reduced and root quality will be poorer (Stathers *et al*., 2013). The length of growth period affects the size of roots, a short growth period will result in a high percentage of medium and small storage roots, while the average mass of the roots will be higher if they are harvested later. Adventitious roots emerge from pre-formed root primordial at the nodes after planting, and become fibrous roots, which under good water, air and mineral conditions have the potential to differentiate into storage roots, within the top 20 – 25 cm of the soil. Under unfavourable conditions roots may fail to differentiate into storage roots and become lignified pencil roots. Most of the storage roots develop from the initial adventitious root system of the plant.

Storage root differentiation may begin as early as two to three weeks after planting, and on average between 4 – 6 weeks, depending on the variety and the environmental conditions. Therefore, favourable conditions during the first month after planting are of vital importance for storage root initiation and will strongly influence yield potential of a plant (Stathers *et al*., 2013).

Sweet potato is very sensitive to frost, and due to this fact, cultivation of the crop in the temperate regions is restricted within a minimum frost-free period of 4 to 6 months. Annual rainfall of 750 – 1000 mm is considered most suitable, with a minimum of 500 mm in the growing season. The crop is also sensitive to drought at the tuber initiation stage after planting, and it is not tolerant to water-logging, as it may cause tuber rots and reduce growth of storage roots if aeration is poor (Peter, 1993). Sweet potatoes are grown on a variety of soils, but well-drained, light- and medium-textured soils with a pH range of 4.5 – 7.0 are more favorable for the crop (Woolfe, 1992). High soil pH invites pox and scurf diseases in sweet potato, whereas at low pH, the crop suffers from aluminium toxicity (Nedunchezhiyan and Ray, 2010).

## 2.6 CULTIVATION ASPECTS

### 2.6.1 TILLAGE AND SEEDBED PREPARATION

Tillage has been an integral component of crop production systems since the beginning of agriculture. The process of tilling or preparing the soil was greatly refined with the invention of the first plow by the Chinese in the sixth century B.C., and since then, various types of tillage equipment and systems have been developed for seedbed preparation and cultivation (Mohammadi and Shamabadi, 2012).

Tillage system comprises tillage operations performed in a certain sequence/combination to promote crop production (Gajri *et al*. 2002). Tillage improves aeration, water transmission and enhances root growth and nutrient uptake. It induces soil nutrients to be released faster (Ojeniyi, 1992). In general, root and tuber crops do not produce satisfactory yields on compacted or shallow soils. The advantageous aspects of seedbed preparation in root and tuber crops cultivation is that, it optimizes infiltration, enhance rooting depth, and improve soil-water management (FAO, 2000). Studies in the Alfisol of Southwest Nigeria have proven that tillage is very essential for good growth and yield of cowpea (*Vigna unguiculata* (L.)Walp) (Ojeniyi, 1989), tomato (*Lycopersicon lycopersicum*, mill) (Adekiya and Ojeniyi, 2002), rice (*Oryza sativa* L.) (Ogunremi *et al*., 1989) and cassava (*Manihot esculenta*, crantz) (Agbede, 2007). Due to the fact that, the crop cannot withstand water logging condition and on the basis of soil type, mounds, ridges and sometime flat bed methods are practiced in sweet potato cultivation in different localities (Belehu, 2003).

Planting of sweet potato on mound is the most common practice in traditional agriculture (Belehu, 2003). Hoes with wide blades are used for making mound traditionally. Mechanically, it can be constructed using tractor with hilling discs. The size of each mound, the mean distance between mound, and the number of cuttings planted on each mound vary from place to place (Belehu, 2003). Mounds should be approximately 30 cm high and 40 cm wide at the base and spaced at 1.5 – 2 m apart. The main consideration is that the developing roots remain under the soil within the hill (Traynor, 2005). In some parts of Southeastern Nigeria, mounds may attain heights of up to 1 m and the space between mounds can be as much as 3 m. 6 – 10 cuttings can be planted at various points of the sloping side on mound of this size (Onwueme, 1978). Janssens (2001) reported that, planting on mounds favours the formation of tuberous root and that growing on mound is preferable to growing on ridges particularly on heavy soil. One of the factors that may contribute to high yield on mound planting is that the process of mound making collects the rich topsoil and the entire depth of the mound consists of the more fertile topsoil. In India, Ravindran and Mohankumar (1985) compared the effect of ridge, bed and furrow, flat and mound tillage practices on the yield of sweet potato grown under upland conditions. They found that tilled soils, especially mound significantly increased sweet potato root yield compared with planting on flat. According to Ennin *et al*. (2009), mounding is a very tedious and expensive operation that limits the scale of root crop production.

Ridge planting is the most common method of growing sweet potato, the higher the ridge, the greater the yield; up to a height of 36 cm (Belehu, 2003). The optimum height of the ridge will depend on the soil type and the cultivar being grown. Many farmers believe that, high yields are produced from very high ridges, yet Dhliwayo and Chiunzi (2004) observed that, small to medium sized ridges that are easy to make may produce good yields as long as fertility is present. Ridges should also be high enough to prevent water logging (Gomes, 1999). Ridge planting is advantageous as it help in erosion control. Ridging can be mechanized to reduce drudgery and increase the scale of production of root crops. Ridging has been shown to result in increased sweet potato yields by 38 % (Ennin *et al*., 2003) over mounding, mainly as a result of increased plant population density and better weed suppression on ridges. The major disadvantage of ridging is that during the course of heavy rain, the rains tend to wash soil from the ridgetop result in a decreasing height of the ridge to an extent that the tubers growing within the soil become exposed leading to attacked by rodents and insects (Onwueme, 1978).

Sweet potato may be planted on flat beds particularly in household farming where there are labour shortages, although this typically results in lower yield than when ridges or mounds are used (Kimber, 1970). In Nigeria, planting crops on ridges, mounds and occasionally on flat are used by farmers as standard procedures in crop husbandry (Aina, 2002). Igwilo and Ene (1982) in their study on planting yam on ridges, mounds and flats, concluded that there was no significant yield difference among the different planting methods. Kalu (1989) and Ijoyah (2004) however, reported that planting yam minisetts on beds resulted in significant greater quantities of heavier tubers than from ridges.

### 2.6.2 PLANTING MATERIALS AND PLANTING METHOD

Sweet potato is commonly propagated through vine cuttings obtained from either freshly harvested plants or from nursery. However, intermittent use of vines can cause increased weevil infestation (Nair, 2006). According to Wilson (1988), cuttings from the tips of the vine are the best planting material. Cuttings from the middles and the bases of the vine can be used, but they usually produce lower yields because they more often carry weevils. Long vine cuttings tend to produce higher yields than short ones, but generally cuttings 30 to 40 cm long are recommended. If the internodes (distances between leaves) are short or average, cuttings that are 30 cm long are recommended. If the internodes are long, cuttings should be about 40 cm long (Wilson, 1988). Generally, vine cuttings taken from young plants (2 to 3 months of age) produce higher yields than cuttings taken from old plants (4 to 5 months of age). This is because; old plants are putting most of their energy into tuber production, and therefore their vine tips are weak and growth is slow while vine tips of young plants are vigorous and growing rapidly (Wilson, 1988). According to Traynor (2005), tip cuttings about 30 – 40 cm long with approximately 8 nodes should be used for planting, and stressed that tip cuttings should be taken from crops that are old enough to provide material without excess damage. Onwueme (1978) indicated that tuber yield tend to increase with increase in the length of vine cutting used and recommended 30 cm. Bautista and Vega (1991) recommended that 20 – 40 cm long vine cuttings should be used for better storage yield. Hall (1986) found that 40 – 45 cm cutting produced higher total marketable tuber yield than 20 – 25 cm cuttings. Sweet potato can also be propagated by means of sprouts or slips obtained by planting 20 to 50 g of healthy tuber at a depth of 3 cm (Ikemoto, 1971), but however, this method is not widely used. Propagation by seed is more often done in breeding work (Purseglove, 1972).

During planting, cuttings are planted at about $45^{o}$ angle into the hills and half of the cutting (about 3 to 4 nodes) buried at a spacing of 30 cm between plants as this promotes good and even root development (Traynor, 2005). Where sweet potato is grown on mounds, farmers usually plant 3 vines per mound with some space between the vines. At a spacing of 1 m x 1 m between mounds, 30,000 cuttings are required per hectare if 3 cuttings per mound are used. While on ridges 33,333 cuttings are required to plant a hectare at spacing of 30 cm between plants and 1 m between ridges (Stathers *et al*., 2013). According to (Nair, 2000), horizontal planting resulted in higher transplant survival and better development of the root system than other methods though it is laborious. Dhliwayo and Chiunzi (2004) specified that, planting at an angle or horizontally produce more yields while Onwueme (1999) recommends vertical

orientation.

Time of planting has been identified as a constraint affecting growth and quality of the root (Nedunchezhiyan and Byju, 2005). Sweet potato requires adequate soil moisture for high yields (Onwueme, 1977). Therefore, the crop is best adapted to regions with well distributed rainfall because of the moisture requirement for tuber initiation and development (Martin, 1988). Sweet potato weevil is a problem wherever the crop is grown and often worse during dry times. Studies carried out in various parts of the world on sweet potato weevil management, revealed an influence on yield and damage by different seasons or periods. According to Bourke (1985) the weevil caused economic damage in areas with a marked dry season or in unseasonably dry years. High levels of weevil incidence generally correspond with lower rainfall levels because weevils generally fail to penetrate wet soils but can penetrate dry soils. In Keravat, where rainfall spread is high, weevil damage is usually not a problem (Wijimeersch, 2000).

### 2.6.3 FERTILIZER APPLICATION IN SWEET POTATO

Sweet potato is often considered as a crop that is adapted to grow on poor soils; as such most farmers in Ghana do not apply mineral fertilizer to their crops but rather rely on natural bush fallow to restore soil fertility (Buri and Issaka, 2003). Nevertheless, improved soil fertility, such as high but balanced nutrition, increases the growth and yield performance of sweet potato because it has been reported that the crop responds to varying regimes of nitrogen, phosphorus and potassium fertilizers (Dapaah *et al*., 2004).

As with most root crops, sweet potato has high demands for potassium relative to nitrogen and phosphorus because leaves, vines, stems and tubers usually remove substantial quantity of potassium from the soil. In Japan, it was estimated that a tuberous yield of 13 t/ha, removes about 70 kg N/ha, 20 kg $P_2O_5$/ha and 110 kg $K_2O$/ha from the soil depending on the variety, crop duration and agro-climatic region (Degras, 2003).

Small-holder farmers in Ghana often cited high cost or non-availability of inorganic fertilizers as reasons for not applying recommended dosage.

Nitrogen (N) plays a vital role in the plant biochemistry as an essential constituent of cell wall, cytoplasmic proteins, nucleic acid, chlorophyll and other parts of the cell (Hay and Walker, 1989). In sweet potato cultivation, the contribution of nitrogen to storage root which is the most economic part of the plant and the above ground biomass yield is still not fully understood. Nitrogen fertilizer responses are variable. According to Stathers *et al*. (2013), nitrogen if present in high concentrations can result in abundant vine growth but poor root development. This is particularly damaging if nitrogen is applied after the middle of the crop‟s growth period. In India, research on nitrogen application in sweet potato production indicated that, when nitrogen is applied beyond 56 kg/ha, the yield of the crop tend to decline (Nandpuri *et al*., 1971). Similarly, in Puerto Rico, an application rate beyond 94 kg/ha (Landrau and Samuels, 1951) resulted in root yield decline. Application of manure as a nitrogen source has been found to have significant impact on growth and root yield of sweet potato (Salawu and Mukhtar, 2008). Usually farm yard manure/cow dung, compost or green manure is used as organic manure for sweet potato (Kaggwa *et al*., 2006). According to Nedunchezhiyan and Reddy (2004), 5 to 10 tonnes/hectare of organic manure should be supplied to soil that is low in organic matter content to ensure proper development of storage root.

Phosphorus (P) is an important nutrient for many plant species including sweet potato, making up to about 0.2 % to 0.4 % of plant"s dry matter (Nyle and Ray, 1999). Phosphorus is an essential component of deoxyribonucleic acid (DNA), the seat of genetic inheritance, and of ribonucleic acid (RNA), which directs protein synthesis in both plants and animals, phospholipids, which play critical roles in cellular membranes and ATP, and consequently, plants cannot grow without a reliable supply of this nutrient. Adequate phosphorus nutrition enhances many aspects of plant physiology, including the fundamental process of photosynthesis, nitrogen fixation, flowering, fruiting (including seed production), and maturation. The necessity of phosphorus as a plant nutrient is emphasized by the fact that it is an essential constituent of many organic compounds that are very important for metabolic processes, blooming and root development (Purekar *et al*., 1992). Phosphorus concentration in the soil solution is much lower and ranges from 0.001 mg/L to 1 mg/L (Brady and Weil, 2002). Plants generally absorb phosphorus in the form of orthophosphate, but can also absorb certain forms of organic phosphorus. Phosphorus moves to the root surface through diffusion. However, the presence of mycorrhizal fungi, which develop a symbiotic relation with plant root and extend threadlike hyphae into the soil, can enhance the uptake of phosphorus as well, especially in acidic soils that are low in phosphorus. In many agricultural systems in which the application of phosphorus to the soil is necessary to ensure plant productivity, in spite of the considerable addition of P-fertilizers, the amount available for plants is usually low since it is converted to unavailable form by its reaction with the soil constituents (Marschner, 1995). This explains why very little mention has been made in literature on the use of phoshatic fertilizers to sweet potato and why FAO (2005) indicated that, when phosphorus is eliminated in sweet potato cultivation, the yield of the crop is not affected. However, despite P fixation in the soil, EI-Morsy *et al*. (2002) and Hassan *et al*. (2005) found that increasing applied P- rate to sweet potato significantly increased plant length, plant leaf area, canopy dry weight, total chlorophyll and carotenoids. Were *et al*. (2003), also reported favourable responses to phosphorus fertilizer by sweet potato. Spence and Ahmad (1967) indicated that deficiency symptom appears on the crop once the P content in the lamina fall below 0.12 %. In an experiment carried out by Issaka *et al*. (2014), absence of P even though when other nutrients (45 kg/ha N, and 45 kg/ha $K_2O$) were present, both tuber and vine production were significantly reduced. Phosphorus at 45 kg/ha gave significantly higher tuber and vine yield/ha. When P was not applied the number of tubers/ha were significantly reduced.

Of the essential elements, potassium (K) is the third most likely, after nitrogen and phosphorus, to limit plant productivity (Brady and Weil, 2002). It plays a critical role in lowering cellular osmotic water potentials, thereby reducing the loss of water from leaf stomata and increasing the ability of root cells to take up water from the soil (Havlin *et al*., 1999) and maintain a high tissue water content even under drought conditions (Marschner, 2002). Potassium is essential in the synthesis and translocation of carbohydrate from the tops to the root (Byju and Nedunchezhiyan, 2004), activating over sixty (60) enzymes and promotes photosynthesis, controls stomata opening, improves the utilization of N, promotes the transport of assimilates and consequently increases crop yields. It influences the microbial population in the rhizosphere and plays key roles in the nutrition and health of man and livestock (Romheld and Neumann, 2006). Sweet potato like sugarcane, Irish potato and cassava are crops that have high demands for K because leaves, vines, stems and tubers usually remove substantial quantity of K from the soil. The nutrient appears to be the most important in the production of sweet potato as its application increases yield by the formation of larger sized tubers. Potassium affects the number, size, quality and the unit weight of tuberous roots produced, while the minimum levels of K suggested for healthy growth and yield are twice those recommended for N, although three times as much may be applied and occasionally even more (Degras, 2003). The quality characters like starch and protein content were found to increase with increased K levels (Biswal, 2008). A moderate dose of 75 – 100 kg/ha $K_2O$ is recommended for sweet potato (John *et al*., 2001). However, in China, the crop responded to optimum K rate of 150 – 300 kg $K_2O$/ha (Jian-wei *et al*., 2001). According to Trehan (2007), sweet potato response to applied K is considerably influenced by the variety grown. Generally, rapid bulking varieties producing large sized tubers respond more to K than those producing small tubers (Trehan and Grewal, 1990).

Research in Ghana has showed no response of sweet potato to potassium fertilizer. Increasing K rates showed a decreasing trend of both tuber and vine yield. At 45 and 60 kg K/ha, number of tubers/ha fell significantly. Tubers sizes were significantly smaller when K was applied at 60 and 90 kg/ha (Issaka *et al*., 2014).

### 2.6.4 CROPPING SYSTEMS

Sweet potato can be grown in rotation with other crops or intercropped with crops such as soybean, maize, cassava, okra, sorghum and bean (P‟Obwoya, 1995). As with any crop, it is advisable to rotate sweet potato with other crops, or to have a fallow period between crops, in order to reduce the buildup of diseases, such as viruses, and pests such as weevils and nematodes. Sweet potato does well following cereals or legumes, but it is not recommended for it to follow other root and tuber crops, particularly cassava, due to their similar nutrient requirements (Stathers *et al*., 2013). Rotating crops like sweet potato or cassava with legumes have been shown to be generally beneficial to the soil by preservation of organic matter, increasing soil nitrogen, improving soil physical properties and could also break the cycle of soil-borne diseases (Imai, 1990).

In some areas sweet potato is intercropped with other crops, this occurs particularly in areas where land pressure is high or labour for constructing ridges is limited. Intercropping using improved varieties of crops and improved agronomic practices remain the most feasible approach to optimizing crop production and maximising the use of available land (Adetunji, 1993). Njoku *et al*. (2010) reported that intercropping was the dominant cropping system in West Africa and that farmers did not only aim at multiplying the net returns per unit area by growing extra crops; but making a better use of available space, and also maximising the cost of production. Other advantages include soil protection, greater yield stability, variability of food supply, and insurance against crop failures (Beets, 1982).

Intercropping in addition to improving crop and food diversity, can also improve labour efficiency, increase soil fertility if nitrogen fixing intercrops are used, and reduce weed growth.

As with all intercropping, the cropping pattern should try and minimize the competition for light and nutrients between the two or more crops being intercropped. If intercropping sweet potato with beans, soybeans or peas, sweet potato can be planted along the ridge and a row of beans on either side of the ridge. Relay cropping of sweet potato with maize, with sweet potato planted as the maize is nearing harvest, has also been used successfully by some commercial producers in Ghana‟s Central Region (Stathers *et al*., 2013).

## 2.7 OTHER CULTURAL PRACTICES

### 2.7.1 WEEDING

Weeds are a major problem in all types of farming system. Weed control has been observed as one of the most important practice in crop production because good weed control will ensure maximum yield and high quality of farm produce (Njoroge, 1999). According to Gianessi and Williams (2011), broadleaf weeds and grasses dominate the weed spectrum, whereas sedges are minor. Weed problems are more severe in African tropical regions than in Europe and North America because weeds grow more vigorously and regenerate more quickly because of the heat and higher light intensity (Gianessi and Williams, 2011).

Sweet potato is an aggressive crop that can quickly form canopy which cover the soil, shading out weeds. It suppresses most of the weeds when grown closely by reducing availability of light (Ravindra *et al*., 2010) and physical interference (Tesdale and Mohler, 1993). However, weeds may be a problem in the early growth stage of the crop before vigorous vine growth covers the beds as plants become established (Traynor, 2005). According to CACC (2003), weeds account for 11.64 % of the total damages of sweet potato production. A yield loss of 87 to 98.9 % was recorded if sweet potato is left unweeded; even early or late weeding reduced the yield (Awassa progress report, 1991). According to Nedunzhiyan and Satapathy (2002), the crop – weed competition set at early for water and nutrients due to initial slow growth of the crop. The critical period of crop – weed competition is between 30 and 45 days after planting in India (Nedunzhiyan *et al*., 1998), between 14 and 28 days in the Philippines (Talata *et al.*, 1978).

Hand weeding is the predominant weed control practice on smallholder farms (Vissoh *et al*. 2004). The method is the oldest of weed control and consists of pulling and slashing weeds by hand and hoeing, but deep penetration of the soil by tool such as hoes, cutlass etc must be avoided to ensure no damage to the superficial roots or tubers. Additionally, weed control in sweet potato can be done by increasing the plant population density and cultivar selection. High plant density can slow down crop growth rate and reduce leaf area index that has a relation in enhancing the competitiveness of the cultivar (Lisson *et al*., 2000). Some varieties have been identified to better compete and suppress weeds due to their canopy structure (Taye and Tanner, 1997).

The use of chemicals is an alternative to hand weeding. Herbicides can be sprayed before planting to remove weeds from a field, applied directly to soil at planting for residual control of germinating weed seeds, and applied to weeds during the growing season. Residual herbicides applied to the soil before the crop and weeds emerge from the ground remain active in controlling germinating weed until the critical period of weed competition has passed (Gianessi and Williams, 2011). Where the stubborn spear grass weed (*Imperata cylindrica*) is predominant, a mixture of Glyphosate + Prometryn/S-metolachlor at the rate of 3.5 + 2.0 kg ai/ha was found to control it when applied at 4, 8, and 12 weeks after planting (Stathers *et al*., 2013). However, availability, costliness, efficacy, and its effect on human health are problems to consider when using herbicides.

### 2.7.2 MULCHING

Mulching is the process of covering the soil with a thin layer of biomass (mulch material) to help maintain soil moisture and protect the crop from excessive sun burn. It is a common practice in rain-fed ecosystem in small holder farming. Mulching is an effective method of manipulating crop growing environment to increase yield and improve product quality by controlling weed growth, reducing soil temperature, conserving soil moisture, reducing soil erosion, improving soil structure and enhancing organic matter content of the soil (Opara-Nadi, 1993). In yam cultivation, studies by Inyang (2005) and Gbadebor (2006) revealed that mulch materials improved soil physico-chemical properties, suppressed soil temperature, reduced evaporation and increased the soil moisture, thereby, creating enabling soil microclimatic condition for early yam sprouting. The type of material used as mulch determines its impact on soil physical and chemical properties, and crop yield (Awodun and Ojeniyi, 1999). Some mulch with low C: N ratios provide nutrients for crop growth through rapid decomposition (Unger 1994). According to Aregheore and Tofinga (2004), the application of poultry manure as mulch have tremendous potentials for the control of root nematodes and increase both growth rate and yield of crops. Mulched soil retained more moisture and enhanced mineral N (29 – 87 %), P (1.4 – 12.6 %) and K (16 – 36 %) availability when applied for dry season sweet potato (Kundu *et al*., 2006).

### 2.7.3 DISEASES AND PESTS OF SWEET POTATO

#### 2.7.3.1 DISEASES

Viral diseases are of major economic importance in most production areas around the globe. Viruses from different taxa occurring individually and in combination are known to infect sweet potato worldwide (Aritua *et al*., 2003). The most important and devastating viral disease affecting sweet potato worldwide is sweet potato virus disease (SPVD) (Mwanga, 2001). The disease is mainly caused by dual infection with an aphid-transmitted Sweet potato feathery mottle potyvirus (SPFMV) and a whitefly-transmitted Sweet potato chlorotic stunt crinivirus (SPCSV) (Aritua *et al*., 2003). A mixed infection by several viruses causes degeneration and subsequent yield loss of more than 70 % in sweet potato (Janssens, 2001). SPVD occurrence has been documented from several countries including Rwanda, Burundi, Kenya and Tanganyika (Sheffield, 1953), Nigeria (Schaefers and Terry 1976), Togo, Liberia, Sierra Leone, Sao Tome, Ivory coast (Thottappilly and Rossel, 1988), Cameroon (Ngeve and Bouwkamp, 1991), Madagascar, Zambia (Gibson *et al*., 1998), Benin and Gabon (Lenne, 1991), and most recently from Peru (Gutierrez *et al*., 2003). Most of the local landraces and some of the introduced material are degenerated because of sweet potato virus disease (Low *et al*., 2009), thus, the use of vegetative cuttings as a principal propagation method provides virus an efficient way to perpetuate and disseminate between growing seasons as well as growing area (Salazar and Fuentes, 2001). Although single infections by East African isolates of

SPFMV in sweet potato causes no symptoms, SPCSV infection can cause mild symptoms such as slight stunting and purpling or yellowing of lower leaves and mild chlorotic mottle in the middle leaves of sweet potato plants (Sim and Valverde, 1999). Depending on the type of cultivar and stage of infection, SPVD infection leads to the development of various symptoms, including vein clearing, severe stunting, chlorosis, leaf strapping, excessive branching, short internodes, indistinct vein banding, indefinite mosaic, mottling, and purpling on lower leaves in some varieties (Aritua *et al*., 2002).

Several fungal diseases including storage rot has been reported to affect sweet potato production especially in Nigeria (Echerenwa and Unechuruba, 2004). The fungi observed to be associated with rottening of sweet potato include, *Fusarium oxysporum*, *Ceretocysts fimbriata*, *Fusarim solani, Monilochaetes infuscans, Macrophomina phaseolina* and *Botryodiplodia theobromae* (Clark and Hoy, 1994). Onuegbu (2002) implicated *Penicillium sp*., *Cerocystis fimbriata*, *Diaporthe batatalis*, *Aspergillus flavus* and *Aspergillus niger,* as fungi responsible for decay of sweet potato tuber. These fungi create local discoloration of the surrounding tissues of infected tubers (Snowdor, 1991), resulting in changes in appearance, deterioration of texture and possibly flavour or taste.

In East Africa, the Alternaria blight disease has been ranked as the most important fungal disease (Rees *et al*., 2003). Alternaria blight disease of sweet potato was first recorded from subsistence food garden in the Nebilyer valley of the Western Highlands province in Papua New Guinea in early 1987 (Lenne, 1991), then it was reported in the southern and western highlands of Papua New Guinea, Brazil, South America and in New Caledonia (Lenne, 1991). The disease affects the shoots destroying the leaf, petiole and stem causing brown lesions that enlarge and become dark grey or black due to the abundance of spores

(Osiru, 2008). Yield losses due to Alternaria disease range from 2.5 – 10 t/ha (Turyamureeba *et al*., 1999).

**2.7.3.2 PESTS**

Sweet potato production suffers considerable damage from insect and nematode pests both in field and in storage (Ferdu *et al*., 2009). The stem and root feeders like sweet potato weevils, *Cylas puncticollis*, (Coleoptera: Curculionidae); sweet potato butterfly, *Acraea acerata* (Lepidoptera: Nymphalidae), sweet potato hornworm, *Agrius convolvuli* (Lepidoptera: Sphingidae), tortoise beetles, *Aspidomorpha spp*., Laccoptera spp. (Coleoptera: Chrysomelidae); and virus transmitters *Aphis gossypii* (Homoptera: Aphididae) and *Bemisia tabaci* (Homoptera: Aleyrodidae) are the major ones (Shonga *et al*., 2013).

Sweet potato weevil (*Cylas sp*.) is the cosmopolitan insect and most serious insect pest of sweet potato in Central America, Africa and Asia; causing up to 90 % of losses to the crop (Theberge, 1985). The adult weevils are ant-like that feed on leaves and vine as well as storage roots, but the most severe damage are caused by the larvae which tunnel the roots and deposit frass within tunnels during feeding making them unfit for human consumption and unmarketable (Horton, 1989). They can pupate in the stems and be transferred in planting material. Even small weevil populations can reduce sweet potato root quality. In respect to the root feeding weevil, the pest feeds on storage roots, produce bitter tasting and toxic sesqui-terpenes that render them unfit for human consumption (Shonga *et al*., 2013). The bitterness resulting from sweet potato weevil damage makes even the partially damaged tubers unsuitable for human consumption. Yield losses due to sweet potato weevil are much higher towards the dry season due to low soil moisture, low biomass yield and possibly high soil crack (Ashebir, 2006), because the insect can reach the root more easily through the cracks that appear as the soil dries out.

Other pests such as millipedes and nematode of which *Meloidogyne spp*. (root- knot) and *Rotylenchulus reniformis* are the most common in the tropics (Mohandas, 2006) have been found to reduce sweet potato yield. Millipedes are normally regarded as saprophytes, living in moist soils containing large amount of organic matter or surface litter. They burrow through the soil and litter or penetrate underneath surface objects using the force of their legs. At night many become active on the soil surface (Marshall and Williams, 1977). Their importance in West Africa is related to the amount of damage they cause to crops as reported by Abidin (2004). Millipedes injured sweet potato by eating the root of the plant, causing tunnel into the tuber root. Nematodes attack the fibres as well as fleshy roots of sweet potato and reduce the yield and quality. They also allow other pathogens to penetrate through the wounds.

Virus diseases on sweet potato can be managed through field tolerant varieties, use of virus free planting materials as well as meristem cultured pest (Prasanth *et al*., 2006). The weevil can be effectively managed by following the integrated pest management (IPM) strategy developed by International Potato Centre, Peru (CIP) (Nedunchezhiyan *et al*., 2012). The IPM is as follows: dip the vine cuttings in fenthion or fentrothion 0.05 % solution for 10 minutes before planting, re-ridge the crop two months after planting, install synthetic sex pheromone traps at 1 trap/100 $m^2$ area to collect and kill the male weevils and lastly, destroy the crop residues after harvesting by burning. IPM practice reduced 50 – 60 % weevil infested storage roots and increased more than 20 % storage root yield

(Sethi *et al*., 2003). Nematodes can be controlled by application of neem cake at 500 kg/ha in the last ploughing before ridge and furrow making (Nedunchezhiyan *et al*., 2012).

### 2.7.4 HARVESTING, CURING AND STORAGE

#### 2.7.4.1 HARVESTING

In sweet potato, single and double (progressive) harvesting can be practiced as root yields are not affected by delaying few days after maturity. Staggered harvesting facilitates marketing and realizing reasonable price for the produce. However, varieties and environment play a significant role in deciding the time of harvest in sweet potato (Nedunchezhiyan *et al*., 2012). Generally, sweet potato is harvested when the tuber has reached physiological maturity. Based on the period of maturity, sweet potato is classified into early maturing (3 – 4 months after planting), medium maturing (4 – 6 months after planting) and late maturing varieties (more than 6 months after planting) (Golokumah, 2007). Maturity is often indicated by the yellowing of the leaves, by that time, the roots would have reached marketable sizes. In some part of Africa, due to lack of adequate storage capacity, in-ground storage is often practised by leaving the roots in the ground and harvested in piecemeal (depending on home consumption needs and market demand) (Smit, 1997). In these regions, harvesting is often spread over a period of 8 – 12 months to maintain supply of roots for the longest possible period (Smit, 1997). In some other areas within the tropics, most varieties are harvested as soon as the roots reach marketable size, often in 3 – 8 months after planting (Lebot, 2009). Sweet potato continues to enlarge if left in the ground, but root diseases and insect damage typically increase with the amount of time the roots remain in the soil (NGMC and NARI, 2004).

Harvesting can be carried out in two ways: manual or mechanical. The sweet potato vines should be cut off at the soil level prior to the intended harvest date. During the dry season, the vines should be removed three to seven days before digging and during the rainy season, the vines should be left intact until just prior to harvest. Vine removal helps to toughen the skin of the root and facilitates harvesting (NGMC and NARI, 2004). After vine removal, the sweet potato roots can be dug by hand or by machine. Manual harvesting of sweet potato typically involves the use of a metal spade, pick, or fork which is used to loosen the soil and undercut the roots, but care must be taken to avoid cutting or injury to the roots. After cutting, the roots are then lifted out of the ground, separated from the main stem, and temporarily left on top of the soil or put directly into a field container. Mechanical harvesting involves the use of mouldboard plows, middle buster plows, and single or multiple row diggers (NGMC and NARI, 2004). Mouldboard plows turn the soil and roots over on top of the ground and produce the least amount of physical damage to the roots. However, they leave many roots covered by soil that makes them difficult to recover.

#### 2.7.4.2 CURING

Curing is a process in which the skin thickens and new tissue forms beneath the surface of injured areas in the root. This process involves the forced hot air treatment of roots at 30ºC with 90 % relative humidity for between 4 to 6 days. This must be done immediately after harvest, and will result in the formation of a wound skin, which heals any mechanical damage suffered during harvesting (DAFF, 2011). Root curing is not a standard commercial practice, but is worth considering if roots need to be stored for a prolonged period. Subsequently, harvested roots are placed in buildings to cure (30 – 35 °C, 90 %

RH) and then stored (10 – 15 °C; 85 – 90 % RH) until needed for the market (DAFF, 2011). The purpose of curing is to heal the skin scratches and wounds inflicted during harvest and handling, reduce water loss during storage, and minimize decay.

Curing also increases the storage life, and increase the sugar content of sweet potato (Nelson and Elevitch, 2011), thus improved the eating quality.

**2.7.4.3 STORAGE**

Storing sweet potato is a major challenge to post-harvest handling because the crop is bulky and once harvested it has a short shelf life. In Ghana and other parts of tropical developing countries, sweet potato tuberous roots have storage duration of only up to three (3) weeks (Rees *et al*., 2003; Teye, 2010). Research conducted by Birago (2005) and Golokumah (2007), revealed that sweet potato farmers in the Cape Coast Metropolis do not store their harvested sweet potato because of high deterioration in storage and inappropriate storage technology. Farmers therefore, practice in-situ storage or piece meal harvesting. This practice ties the land down to the crop, increases infestation of weevil (Cylas sp.) and roots become fibrous and are therefore offered at give-away prices (Agbemafle *et al*., 2013). However, under controlled atmosphere, the storage roots can be stored up to a year (Rees *et al*., 2003). Sweet potato roots are sensitive to chilling injury and should not be stored below 12ºC. Storage at freezing temperatures will severely damage sweet potato; the damage usually does not show until the product is returned to a warmer temperature.

Traditional storage of harvested tubers is done in baskets covered with banana leaves. Tubers can also be stored in a dug pits lined with a layer of dried grass followed by another layer and at least 5 cm of top soil. Traditional barns and other forms of storage structures used extensively in tropical countries to protect the integrity of the crop have not yielded the desired results (Amoah *et al*., 2011).

Generally, storage temperature is between 12 and 15 °C. Relative humidity should be maintained between 75 to 80 % to prevent excessive water loss from the roots. Some ventilation should be provided to prevent carbon dioxide buildup (DAFF, 2011).

## 2.8 SWEET POTATO PRODUCTION CONSTRAINTS IN GHANA

The potential yield of sweet potato is up to 45 t/ha (PRAPACE, 2003). However, yields in Ghana are still as low as 2 t/ha (FAOSTAT, 2012) which is far less than the average for Kenya (9.5 t/ha) and Ethiopia (7.7 t/ha) (PRAPACE, 2003). Ghana is ranked 35$^{th}$ among the producer countries of sweet potato (FAOSTAT, 2010). Based on the study carried out by Bidzakin *et al*. (2014) on the needs assessment of sweet potato production in Northern Ghana, the major constraints to sweetpotato production have been identified as:

a) lack of planting materials,
b) pest infestation such as weevils and termites,
c) poor rainfall,
d) poor market/prices and
e) poor storage facilities

## 2.9 NUTRITIONAL COMPOSITION

Sweet potato is a nutritious food and has a unique and huge potential as an affordable source of energy and nutrients. The leaves are a source of protein, containing 2.7 – 3.4

g/100 g of raw fresh leaves (Kanju, 2000) and it also contain substantial amount of betacarotene (-800 mg/100g) contributing as much as 86 % of the daily dietary requirement in Asia and 80% in Africa (Oke 1990).

In many countries in sub-Saharan Africa (SSA) the preferred types of sweet potato are those that are higher in dry-matter content (28 – 30 %) and have little to no sweetness (Mwanga *et al*., 2007a). The high dry matter and low sugar cultivars are not as nutritious as the orange-fleshed types because they tend to be low in carotenoid content (Low *et al*., 2007). Orange-fleshed sweetpotato (OFSP) varieties that have high levels of βcarotene have the potential to alleviate vitamin A deficiency (VAD) in children and lactating mothers (Low *et al*., 2007). Depending on the variety, 100 g of sweet potato can provide β-carotene quantities that are sufficient to yield from 0 to 100 % of the recommended daily vitamin A requirement, which is at least 350□g per day for infants and 400□g per day for young children (1 – 6 years) (Tumwegamire *et al*., 2004). Sweet potato root also contain carbohydrates constituting the bulk (approximately 80 – 90 %) of the dry matter of the crop and consist of various proportions of starch and soluble sugars, with lesser amounts of pectins, hemicelluloses and cellulose (Woolfe, 1992). According to Duke (1983) the fresh root contains 25.6 – 3.0 g of total carbohydrates per
100 g. Total dietary fibre of raw sweet potato sample from the Solomon Islands and Papua New Guinea ranged between 1.2 – 2.62 % on fresh weight basis (Bradbury *et al*., 1984). The total protein is referred to as crude protein. Every 100 g of the fresh root of sweet potato is reported to contain 1.0 – 1.7 g of protein (Duke, 1983).

Like most foodstuffs, sweet potato roots are sources of some minerals and trace elements. The predominant minerals in the sweet potato tuber are potassium (K), sodium

(Na), chloride (Cl), phosphorus (P), and calcium (Ca) (Onwueme and Charles, 1994). They are a good source of P and though not having outstanding contents of iron (Fe) and (calcium (Ca), they can make modest contributions to the recommended daily intakes of these minerals in a quantity as little as 100 g, which also provide part of the daily allowance of magnesium (Mg), copper (Cu) and manganese (Mn) (Palaniswami and Peter, 2008). 100 g of root is noted to contain 21 – 36 mg of Ca, 38 – 56 mg of P, 0.7 – 2.0 mg of Fe, 10 – 36 mg of Na, 210 – 304 mg of K, and 24 g of Mg.

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.1 EXPERIMENTAL SITE

Two field experiments were carried out at the Plantation Section of the Crop and Soil Sciences Department, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi. The first experiment was done from June to October 2014 to evaluate the effect of tillage and phosphorus fertilizer and the second was conducted from September to January 2014 - 2015 on a separate field to evaluate the effect of vine length and potassium fertilizer. Kumasi is located in the semi-deciduous forest vegetation zone of Ghana. It is about 356 m above sea level on latitude 06° 43‟N and longitude 01° 33‟W (Asiamah, 1998).

The rainfall pattern is bimodal [with major (Mid-March to July) and minor (September to November) rainy seasons]. The average annual rainfall of the area is 1422.4 mm. The average relative humidity varied from 83.88 % (09 hours GMT) during the major and minor rainy seasons to 58.42 % (15 hours GMT) during the dry season for 2014 (Meteological Department, KNUST, 2014). Annual average maximum and minimum temperatures were 31.59$^{o}$ C and 22.09$^{o}$ C respectively. The mean daily maximum and minimum temperatures during the period of the experiment were 29.01$^{o}$ C and 21.32$^{o}$ C, and 31.85$^{o}$ C and 22.34$^{o}$ C for the major and minor season, respectively. Total rainfall recorded during the experiment were 466.55 mm and 317.85 mm (major and minor season) and relative humidity varied from 77.84 % (09 hours GMT) to 51.34 % (15 hours GMT) during the major season and 83.67 % (09 hours GMT) to 59.17 % ( 15 hours GMT) during the minor season (Meteological Department, KNUST, 2014).

## 3.2 SOIL CHARACTERISTICS

Before the start of the experiment, soil samples were taken randomly from the experimental site at a depth of 0 – 15 and 15 – 30 cm using soil auger, mallet and core sampler. The samples were taken to the laboratory for soil physio-chemical properties determination. At the lab, the samples were sieved using a 2 mm mesh and air dried. After this process, each composite sample was analyzed separately for organic carbon, total nitrogen, exchangeable potassium, available phosphorus, soil pH and bulk density.

### 3.2.1 ORGANIC CARBON

The organic carbon was determined using the Walkley and Black (1934) method. Potassium dichromate (acidified) at 1.0 M was used to oxidize the carbon in the soil. The unreduced dichromate was then titrated with 1.0 M ferrous sulphate (acidified solution).

The percentage organic matter content was then calculated by multiplying the percentage organic carbon by the conventional Van Bemmelen factor of 1.724.

### 3.2.2 TOTAL NITROGEN (N)

The total nitrogen was determined using the Modified Kjeldahl method described by Jackson (1967). 10 g of soil sample (< 2 mm in size) was digested with a mixture of 100 g potassium sulphate, 10 g copper sulphate and 1g selenium with 30ml of concentrated sulphuric acid. This was followed by distillation with 10 ml boric acid (4 %) and 4 drops of indicator and 15 ml of 40 % NaOH. It was then titrated with ammonium sulphate solution. Based on the relation that 14 g of nitrogen is contained in one equivalent weight of $NH_3$, the percentage of nitrogen in the soil was calculated as:

$$\text{Total N in the sample} = \frac{14\,(A - B) \times N \times 100}{1000 \times W}$$

Where,

A = Volume of standard acid used in the titration.

B = Volume of standard acid used in blank titration.

N = Normality of the standard acid.

W = Weight of soil sample used.

### 3.2.3 EXCHANGEABLE POTASSIUM (K)

The exchangeable K was determined by the flame photometer method. Soil was extracted with neutral (pH 7.0) ammonium acetate and K was measured in a flame photometer.

### 3.2.4 AVAILABLE PHOSPHOROUS (P)

The available phosphorus was extracted with Bray-1 solution (Anderson and Ingram., 1993). Colour developed with a mixture of molybdenum and a reducing agent to a blue phospho-molybdonate complex was measured by spectronic 20 at 520 nm wave length.

### 3.2.5 SOIL pH

The soil pH was measured in 1:2.5 soils to water suspension by the use of a pH meter.

### 3.2.6 BULK DENSITY

The bulk density was determined using the formula of Cresswell and Hamilton (2002) as:

$$\text{Bulk density } (g/cm^3) = \frac{\text{Dry soil weight (g)}}{\text{Soil volume } (cm^3)}$$

**3.3 EXPERIMENT ONE:** To evaluate the effect of tillage method and phosphorus (P) fertilizer application on the growth, tuber yield and quality factors of sweet potato.

The first experiment was a 2 × 5 factorial experiment with the treatment combinations arranged in a Randomised Complete Block (RCBD) design with three replications. The factors were tillage method and P fertilizer (triple superphosphate) application. The tillage methods used were Ridges and Mounds and the triple superphosphate was applied at 0, 30, 60, 90 and 120 kg $P_2O_5$/ha.

### 3.3.1 RIDGE AND MOUND PREPARATION

The site for the experiment was manually cleared by slashing using cutlass, ploughing and harrowing was done with a tractor. The field was then levelled and 30 plots of ridges and mounds each measuring 2 × 5.5 m were laid out using meter rule and pegs. Ridges and mounds were constructed using hoe and spade. Four ridges measuring 2 m long, 1 m wide and 0.3 m high each and 24 mounds, measuring 0.3 m high and 0.5 m wide at the base were made for each plot as per treatment. Ridges and mounds within each plot were spaced at 0.5 m. Blocks were spaced 1 m apart with 0.5 m spacing between plots.

### 3.3.2 VINE CUTTING PREPARATION AND PLANTING

Tip cuttings of about 30 cm long with six (6) nodes are collected from the Crops Research Institute (CRI) for planting. Early maturing variety, Okumkom was used for the experiments.

Each of the four ridges accommodated a total of six plants at a spacing of 1 m × 0.8 m according to Amoah (1997) to give 24 plants per plot. There were 24 mounds per plots and each mound was accommodating one plant at a spacing of 1 m × 0.5 m. On the planting method, the 30 cm vine lengths were inserted into the soil inclined at an angle of about $45^{o}$ with half to two-thirds of the length buried in the soil with the nodes pointing upwards.

### 3.3.3 FERTILIZER APPLICATION

The different rates of triple superphosphate (46 % $P_2O_5$) were applied using side band placement method 2 weeks after planting. 30 kg N/ha in the form of urea (46 % N) was applied equally on all the treatments together with the triple superphosphate at 0, 30, 60, 90 and 120 kg $P_2O_5$/ha.

### 3.3.4 WEED CONTROL

Hand weeding was done before fertilizer application 2 weeks after planting and at 3 weeks interval after fertilizer application to keep the experimental sites free from weeds.

### 3.3.5 IRRIGATION

Irrigation was done when necessary. The operation was carried out with the use of watering can. Two watering cans full of water were used for each plot when irrigating to ensure that the plots were adequately wet.

### 3.3.6 PEST MANAGEMENT

Pest management was done by spraying lambda master at 3 weeks interval after planting. This operation was carried out using knapsack sprayer. Following the label instruction on the chemical, 11 litres of water was filled in the knapsack sprayer and 0.10 ml of the lambda master was mixed with the water and stirred at each spraying time.

### 3.3.7 HARVESTING

Harvesting was done at 120 days after planting. At harvesting, the ridges and mounds were scattered and the tubers dug out of the soil with the use of hand hoe.

**3.4 EXPERIMENT TWO:** To evaluate the effects of vine length and potassium (k) fertilizer application on growth, tuber yield and quality factors of sweet potato.

The second experiment was a 3 × 4 factorial experiment with the treatment combinations arranged in a Randomised Complete Block (RCBD) design with three replications. The factors were vine length and potassium fertilizer (muriate of potash) application. The vine lengths used were 15, 22.5 and 30 cm and the muriate of potash was applied at 0, 60, 120 and 180 kg $K_2O$/ha.

### 3.4.1 LAND PREPARATION

Prior to planting, the land was manually cleared by slashing using cutlass. Ploughing and harrowing were followed using tractor. The field was then levelled and plots laid out using meter rule and pegs. The plots were designed into ridges using hand hoe, spade and garden line. There were 36 plots in the whole experiment each measuring 1.8 × 5 m. Six ridges measuring 1.8 m long and 0.3 m high were made per plot. 1 m spacing was maintained between ridges in a plot. Blocks were spaced 1.5 m apart with 1 m spacing between plots.

### 3.4.2 VINE CUTTING PREPARATION AND PLANTING

Okumkom variety was also used for this experiment. The planting materials were obtained from Crops Research Institute (CRI). Cuttings were prepared at different length for planting as per treatment, each with different number of nodes. The 15 cm vine was having two (2) nodes, the 22.5 cm with four (4) nodes and the 30 cm with six (6) nodes. Cuttings planted on ridges were spaced at 1 m × 0.3 m and each ridge was accommodating six plants to give a total of 36 plants per plot. The cuttings were also inserted into the soil inclined at an angle of about 45° with half of the length buried in the soil.

### 3.4.3 FERTILIZER APPLICATION

The different rates of muriate of potash (60 % $K_2O$) were applied using side band placement method 3 weeks after planting. 30 kg N/ha in the form of urea (46 % N) was applied equally on all the treatments together with the muriate of potash at 0, 60, 120 and 180 kg $K_2O$/ha

### 3.4.4 WEED CONTROL

Hand weeding was done at 3 weeks interval after planting until before harvesting time.

### 3.4.5 IRRIGATION

Because the second experiment was carried out in the minor season, irrigation was done at one day interval until when the sproutings have emerged. After sprouting, irrigation was done when necessary. This operation was done using three watering cans full of water per plot to ensure that the plots were adequately wet.

### 3.4.6 PEST MANAGEMENT

Pest management was done at 2 weeks interval after planting. The same quantity of water and concentration of the lambda master as in the first experiment was used at each time of spraying.

### 3.4.7 HARVESTING

Harvesting was done at 120 days after planting when the tuber has reached physiological maturity. Physiological maturity was determined by yellowing of the leaves. Hand hoe was used for this operation. The ridges were scattered and the tuber removed from the soil with the hand hoe.

### 3.5 DATA COLLECTION

The following data were collected on both experiments. Their methodologies are described also. Five (5) plants were selected at random from each plot and tagged for data collection on both experiments. Two sets of growth data were collected at one month interval after fertilizer application for the first and second experiment. Percentage sprouts was determined one and two weeks after planting.

### 3.5.1 GROWTH DATA

#### 3.5.1.1 Percentage sprout

Percentage sprouts as affected by vine length was determined for each plot as total number of cuttings sprouted divided by the total number of cuttings planted multiply by 100.

#### 3.5.1.2 Vine length per plant

Vine length was measured on the five tagged plants in centimeter (cm) from the ground level to the apical bud of the plant using meter rule. The longest vine of each plant was used to collect this parameter.

#### 3.5.1.3 Vine girth per plant

The vine girth from each of the five (5) tagged plant was measured at 15 cm from the base of the plant. This was done with the use of vernier caliper at the various sampling periods.

#### 3.5.1.4 Number of branches per plant

The number of primary and secondary branches was determined by counting from each of the five (5) tagged plants on every plot. The mean value was estimated and expressed as number of branches per plant for each plot.

#### 3.5.1.5 Number of leaves per plant

Number of leaves on each of the five (5) tagged was determined by counting and mean value calculated and expressed as number of leaves per plant.

**Fig. 3.1: Spraying operation at 6 WAP**

**Fig. 3.2: Growth data collection at 6 WAP**

### 3.5.2 YIELD AND YIELD COMPONENTS

The yield data were collect at 120 days (4 months) after planting for the both experiments. At harvesting, the following data were taken into consideration:

#### 3.5.2.1 Total number of roots per plant

The total number of roots per plant was determined by counting the harvested roots from the five (5) tagged plants on every plot.

#### 3.5.2.2 Root yield per plant

Root yield per plant was determined by weighing in kilogram (kg) the combined harvested roots of the five (5) tagged plants on each plot using a weighing scale.

#### 3.5.2.3 Total number of marketable roots per plant

Total number of marketable roots per plant was determined by counting from the five (5) tagged plants on each plot for every treatment and the average number of marketable root per plant calculated. Marketable roots were determined by the size of the root.

Roots that are medium to large were considered to be marketable roots.

#### 3.5.2.4 Total number of non-marketable roots per plant

The total number of non-marketable roots per plant was determined from the five (5) tagged plants by counting. Roots that were ranging from small to very small were considered to be non-marketable roots.

#### 3.5.2.5 Marketable root yield per plant

Marketable root yield per plant was determined by weighing in kilogram (kg) the combined medium to large roots of the five (5) tagged plants on each plot using a weighing scale.



#### 3.5.2.6 Non-marketable root yield per plant

Non-marketable root yield per plant was determined by weighing in kilogram (kg) the combined small to very small roots of the five (5) tagged plants on each plot using a weighing scale.

#### 3.5.2.7 Dry matter content

Selected root samples from the five (5) tagged plants for each treatment were washed, peeled and chopped into smaller fragments. 50 g of the chopped samples were weighed using an electronic balance and deep frozen. The freezed samples were taken to the freeze drying machine for 72 hours. After 72 hours, samples were removed and the dry weight was taken. From this, the dry matter content was computed for each treatment as:

$$\text{Dry matter content } (\%) = \frac{\text{Dry weight (DW)}}{\text{Fresh weight (FW)}} \times 100$$

#### 3.5.2.8 Root yield per hectare

Root yield per hectare was determined for the first experiment by mapping a net plot. All the plants were collected on the net plot, weighed in kilogram (kg) with a weighing scale and the figures were extrapolated in per hectare basis (tonnes/hectare). Root yield per hectare was not determined for the second experiment because of the sprout percentage of the 15 cm length of vine cuttings.

### 3.5.3 QUALITY TRAITS

After collecting the yield data, six representative root samples (2 large, 2 medium and 2 small roots) were collected at random from each treatment, put in a paper bag previously labeled with the corresponding identification code of the field plots and taken to the laboratory for determination of the following quality trait:

1. Protein %
2. Starch %
3. Total sugar %(Fructose, glucose and Sucrose)
4. Zinc (mg/100 g)

At the laboratory, the samples were prepared for nutrients scanning using procedures recommended by Porras *et al*. (2014).

The samples were washed with abundant tap water in order to remove all soil residues, rinsed with distilled water and dried with paper towel. The washed roots were put in a clean and labeled paper bag and stored in a well ventilated room. After one day of storing, the samples were placed in white plastic trays and sorted in a correct order for each treatment. The sorted roots for each sample were peeled carefully with minimum removal of the flesh using a high-grade stainless steel (or ceramic peeler), washed again with distilled water, dried using paper towel and each root was cut longitudinally in four

(4) sections with a ceramic knife. From these four sectioned roots, two (2) sides were selected for each root in every treatment. The two selected roots were then sliced using a ceramic slicer. 100 g of each sample was weighed using an electronic balance. The weighed samples were taken to the deep freezer to be well frozen for at least 24 hours. Samples were freeze because they will be taken to a freeze drying machine (vacuum freeze dryer). This machine works on the principle of freezing. If samples are not well frozen, it will take a long time for the machine to dry them. The freezed samples were placed in a freeze drying machine for 72 hours. The machine uses low pressure and low temperature to force the liquid from the samples. After 72 hours, the samples were taken out of the machine, milled using a stainless steel wiley mini mill and stored in sealed transparent bags. The milled samples were then scanned for nutrients using the Near Infrared Reflectance Spectrophotometer (NIRS) technology. During scanning, the corvette in the NIRS machine is filled with approximately 2 g of the milled samples of each treatment and placed in the Irish Adaptor. Infrared light went through the samples and displayed the nutrient levels in the sweet potato samples on the computer which is connected to the machine.

### 3.6 ECONOMIC ANALYSIS

The net benefit value was determined after harvest for all the treatments as:

Net benefit value = Total revenue – Total input cost.

Where;

Total revenue = the price per kilogram value of the roots for each treatment

Total input cost = cost and transportation of fertilizer, and labour used in applying the fertilizer.

### 3.7 DATA ANALYSIS

The data collected were subjected to Analysis of Variance (ANOVA) based on factorial using GenStat statistical package. Treatment differences were determined using Least Significant Difference (LSD) method at 5 % level of probability.

# CHAPTER FOUR

# RESULTS

## 4.1 EXPERIMENT ONE

### 4.1.1 SOIL CHARACTERISTIC OF THE EXPERIMENTAL FIELD

The physico-chemical characteristics of the experimental soil are shown in Table 4.1. The soil was observed to be low in N and P. It was a sandy loam soil with an average of 82.60 % sand, 3.98 % silt and 13.41 % clay. The soils were slightly acidic with moderate K content, inadequate organic carbon (< 2 %) and bulk densities of 1.45 and 1.46 g $cm^{-3}$.

**Table 4. 1: Physico- chemical properties of soil of the experimental field**

| Soil property | 0 – 15 cm | 15 – 30 cm |
|---|---|---|
| pH (x:y, $H_2O$) | 5.98 | 5.92 |
| Total nitrogen (%) | 0.09 | 0.05 |
| Available phosphorus (mg/kg) | 3.19 | 2.20 |
| Exchangeable potassium ($cmol_c$/kg) | 0.14 | 0.20 |
| Organic carbon (%) | 1.48 | 0.61 |
| Bulk density (g $cm^{-3}$) | 1.45 | 1.46 |
| Sand (%) | 84.30 | 80.90 |
| Silt (%) | 3.90 | 4.07 |
| Clay (%) | 11.80 | 15.03 |
| Texture | Sandy loam | Sandy loam |

## 4.2 GROWTH PARAMETERS

### 4.2.1 VINE LENGTH

Effects of tillage method and Phosphorus fertilizer application on vine length of sweet potato at two (2) sampling periods are shown in Table 4.2. Tillage method did not have significant effect ($P > 0.05$) on vine length. Phosphorus fertilizer application also did not significantly affect vine length.

**Table 4. 2: Effects of tillage method and phosphorus fertilizer application on vine length of sweet potato at two (2) sampling periods**

| | Vine length (cm) | |
|---|---|---|
| Treatments | 30 DAF | 60 DAF |
| **Tillage** | | |
| Mound | 276.2 | 323.5 |
| Ridge | 288.1 | 332.9 |
| **LSD (5%)** | **NS** | **NS** |
| **P fertilizer (kg $P_2O_5$/ha)** | | |
| Control | 265.0 | 304.5 |
| 30 | 279.2 | 323.3 |
| 60 | 292.8 | 344.2 |
| 90 | 288.8 | 339.5 |
| 120 | 284.9 | 329.3 |
| **LSD (5%)** | **NS** | **NS** |
| **CV (%)** | **8.9** | **8.8** |

**NS – not significant** **DAF – days after fertilizer application**

### 4.2.2 NUMBER OF BRANCHES

The differences in the number of branches for both tillage and phosphorus fertilizer were not significant ($P > 0.05$) on the two sampling periods (Table 4.3).

**Table 4.**

**3: Effects of tillage method and phosphorus fertilizer application on number of branches of sweet potato at two (2) sampling periods**

| | Number of branches | |
|---|---|---|
| Treatments | 30 DAF | 60 DAF |
| **Tillage** | | |
| Mound | 5.59 | 9.12 |
| Ridge | 6.11 | 10.67 |
| **LSD (5%)** | **NS** | **NS** |
| **P fertilizer (kg $P_2O_5$/ha)** | | |
| Control | 4.20 | 5.97 |
| 30 | 5.10 | 9.10 |
| 60 | 7.50 | 13.33 |
| 90 | 6.40 | 10.33 |
| 120 | 6.03 | 10.73 |
| **LSD (5%)** | **NS** | **NS** |
| **CV (%)** | **37.5** | **40.5** |

**NS – not significant** **DAF – days after fertilizer application**

### 4.2.3 VINE GIRTH

The results of tillage method and Phosphorus fertilizer application on vine girth of sweet potato are shown in Table 4.4. Vine girths were not statistically significant ($P > 0.05$) for all the treatments.

**Table 4.**

**4: Effects of tillage method and phosphorus fertilizer application on vine girth of sweet potato at two (2) sampling periods**

| | Vine girth (cm) | |
|---|---|---|
| Treatments | 30 DAF | 60 DAF |
| **Tillage** | | |
| Mound | 0.471 | 0.596 |
| Ridge | 0.481 | 0.632 |
| **LSD (5%)** | **NS** | **NS** |
| **P fertilizer (kg $P_2O_5$/ha)** | | |
| Control | 0.407 | 0.553 |
| 30 | 0.453 | 0.623 |
| 60 | 0.517 | 0.653 |
| 90 | 0.507 | 0.620 |
| 120 | 0.497 | 0.620 |
| **LSD (5%)** | **NS** | **NS** |
| **CV (%)** | **13.9** | **9.1** |

**NS – not significant** **DAF – days after fertilizer application**

#### 4.2.4 NUMBER OF LEAVES

The results of tillage method and Phosphorus fertilizer application on number of leaves of sweet potato at two (2) sampling periods are presented in Table 4.5. Tillage effect was not significant ($P > 0.05$) on both sampling periods. Phosphorus fertilizer showed significant differences ($P < 0.05$) among the treatments at 30 DAF. The greatest number of leaves was recorded in the 60 kg $P_2O_5$/ha treatment, which was significantly higher than those of 30 kg $P_2O_5$/ha and the control treatment only. The control treatment effect was significantly lower than those of 90 and 120 kg $P_2O_5$/ha treatments as well. At 60

**Table 4.**
DAF, Phosphorus application effect was not significant (P > 0.05).

**5: Effects of tillage method and phosphorus fertilizer application on number of leaves of sweet potato at two (2) sampling periods**

| | Number of leaves | |
|---|---|---|
| Treatments | 30 DAF | 60 DAF |
| **Tillage** | | |
| Mound | 116.3 | 147.9 |
| Ridge | 131.1 | 177.2 |
| **LSD (5%)** | **NS** | **NS** |
| **P fertilizer (kg $P_2O_5$/ha)** | | |
| Control | 93.0 | 121.6 |
| 30 | 111.6 | 170.9 |
| 60 | 151.3 | 193.1 |
| 90 | 133.5 | 174.5 |
| 120 | 129.1 | 152.8 |
| **LSD (5%)** | **32.5** | **NS** |
| **CV (%)** | **21.7** | **28.4** |

**NS – not significant** **DAF – days after fertilizer application**

## 4.3 YIELD AND YIELD COMPONENTS

### 4.3.1 TOTAL NUMBER OF ROOTS PER PLANT

Effect of tillage method on total number of roots was not significant (P > 0.05) (Table 4.6). Phosphorus fertilizer showed significant difference (P < 0.05) on the total number of tuber. The 60 kg $P_2O_5$/ha treatment produced the greatest number of tuber (5.70) and this was significantly higher than the 120 kg $P_2O_5$/ha and the control treatment only. The control

**Table 4.**

treatment effect was significantly lower than those of 30 and 90 kg $P_2O_5$/ha treatment as well. Other treatment differences were not significant.

### 4.3.2 ROOT YIELD PER PLANT

Table 4.6 shows root yield of sweet potato at different tillage method and levels of phosphorus fertilizer application. The response to the different tillage methods was not significant ($P > 0.05$). Phosphorus fertilizer application, however, affected root yield. The treatment effect of 60 kg $P_2O_5$/ha was the greatest, and this was significantly higher than those of 30 kg $P_2O_5$/ha and control treatment only. The control treatment effect, which was the lowest, was significantly lower than those of 90 and 120 kg $P_2O_5$/ha treatments. Treatment differences between the control and 30 kg $P_2O_5$/ha was, however, not significant at 5% level of probability.

**Table 4. 6: Effects of tillage method and phosphorus fertilizer application on total number of roots and root yield per plant of sweet potato**

| Treatment | Total Number of roots per plant | Root yield per plant (kg) |
|---|---|---|
| **Tillage** | | |
| Mound | 4.73 | 0.651 |
| Ridge | 4.72 | 0.752 |
| **LSD (5%)** | **NS** | **NS** |
| **P fertilizer (kg $P_2O_5$/ha)** | | |
| Control | 3.77 | 0.525 |
| 30 | 5.10 | 0.590 |
| 60 | 5.70 | 0.858 |
| 90 | 4.90 | 0.782 |
| 120 | 4.17 | 0.753 |
| **LSD (5%)** | **0.94** | **0.194** |
| **CV (%)** | **16.4** | **22.8** |

**NS – not significant**

### 4.3.3 TOTAL NUMBER OF MARKETABLE AND NON- MARKETABLE ROOTS PER PLANT

Tillage methods did not significantly affect number of marketable roots (Table 4.7). Phosphorus fertilizer treatments were highly significant ($P < 0.001$) as 60 kg $P_2O_5$/ha supported the greatest number of marketable roots, but this was significantly higher than those of the control and 120 kg $P_2O_5$/ha treatments only. The control treatment effect was the lowest, and it was significantly lower than those of 30 and 90 kg $P_2O_5$/ha treatments.

Tillage and Phosphorus fertilizer application did not significantly affect ($P > 0.05$) number of non- marketable roots (Table 4.7).

**Table 4. 7: Effects of tillage method and phosphorus fertilizer application on total number of marketable and non- marketable roots per plant of sweet potato**

| Treatment | Total number of marketable roots per plant | Total number of non- marketable roots per plant |
|---|---|---|
| **Tillage** | | |
| Mound | 3.89 | 0.840 |
| Ridge | 3.87 | 0.853 |
| **LSD (5%)** | **NS** | **NS** |
| **P fertilizer (kg $P_2O_5$/ha)** | | |
| Control | 3.20 | 0.567 |
| 30 | 4.30 | 0.800 |
| 60 | 4.63 | 1.067 |
| 90 | 4.03 | 0.867 |
| 120 | 3.23 | 0.933 |
| **LSD (5%)** | **0.68** | **NS** |
| **CV (%)** | **14.7** | **55.2** |

**NS – not significant**

#### 4.3.4 MARKETABLE AND NON- MARKETABLE ROOT YIELD PER PLANT

Table 4.8 indicates results of marketable and non- marketable root yield. Tillage method was not significant ($P > 0.05$). However, Phosphorus fertilizer effect was significant on marketable root yield. The greatest marketable root yield (0.833 kg) was recorded from the treatment that received 60 kg $P_2O_5$/ha and this was significantly higher than those of the control and 30 kg $P_2O_5$/ha treatments only. The control treatment effect was significantly lower than those of 90 and 120 kg $P_2O_5$/ha treatments also.

Non- marketable root yield was not affected by both tillage and Phosphorus application at 5% level of probability.

**Table 4. 8: Effects of tillage method and phosphorus fertilizer application on marketable and non- marketable roots yield per plant of sweet potato**

| Treatment | Marketable roots yield per plant (kg) | Non- marketable roots yield per plant (kg) |
|---|---|---|
| **Tillage** | | |
| Mound | 0.621 | 0.0307 |
| Ridge | 0.729 | 0.0227 |
| **LSD (5%)** | **NS** | **NS** |
| **P fertilizer (kg $P_2O_5$/ha)** | | |
| Control | 0.508 | 0.0167 |
| 30 | 0.570 | 0.0200 |
| 60 | 0.833 | 0.0267 |
| 90 | 0.748 | 0.0333 |
| 120 | 0.717 | 0.0367 |
| **LSD (5%)** | **0.195** | **NS** |
| **CV (%)** | **23.9** | **64.1** |

**NS – not significant**

### 4.3.5 ROOT YIELD PER HECTARE

The root yields per hectare of sweet potato as affected by tillage and phosphorus fertilizer are presented in Table 4.9. The results revealed that root yields per hectare varied significantly ($P < 0.05$) due to tillage method and phosphorus fertilizer. Ridge had the greatest root yields per hectare and mound had the lowest for the two tillage methods. The greatest root yield (15.82 t/ha) was when Phosphorus was applied at 60 kg $P_2O_5$/ha, which was significantly higher than those of the control and 30 kg $P_2O_5$/ha treatments only. The control treatment effect was also lower than those of 90 and 120 kg $P_2O_5$/ha treatments. All other treatment effects were similar.

### 4.3.6 DRY MATTER CONTENT OF TUBER ROOT

Tillage method did not significantly ($P > 0.05$) affect dry matter content of sweet potato (Table 4.9). Phosphorus fertilizer application, however, affected root dry matter content with the 60 kg $P_2O_5$/ha treatment recording the greatest effect, and this was significantly higher than all other treatment effects, except the 90 kg $P_2O_5$/ha treatment. The control treatment effect was not statistically significant from all P applied treatments, except at 60 kg $P_2O_5$/ha.

**Table 4.**

**9: Effects of tillage method and phosphorus fertilizer application on root yield per hectare and dry matter content of sweet potato**

| Treatment | Root yield per hectare (tonnes/ha) | Dry matter content of tuber roots (%) |
|---|---|---|
| **Tillage** | | |
| Mound | 11.48 | 34.51 |
| Ridge | 14.17 | 35.01 |
| **LSD (5%)** | **2.20** | **NS** |
| **P fertilizer (kg $P_2O_5$/ha)** | | |
| Control | 9.47 | 33.70 |
| 30 | 12.18 | 33.97 |
| 60 | 15.82 | 36.42 |
| 90 | 13.70 | 35.00 |
| 120 | 12.97 | 34.72 |
| **LSD (5%)** | **3.48** | **1.67** |
| **CV (%)** | **22.4** | **4.0** |

**NS – not significant**

## 4.4 QUALITY CHARACTERS

### 4.4.1 PERCENT PROTEIN AND STARCH CONTENT

Result in Table 4.10 show that, percent protein and starch content of sweet potato plants were not significantly affected ($P > 0.05$) by both tillage methods. Furthermore, Phosphorus fertilizer application did not affect both starch and protein contents of the sweet potato roots.

**Table 4.**

**10: Effects of tillage method and phosphorus fertilizer application on the protein and starch content of sweet potato**

| Treatment | Protein content (%) | Starch content (%) |
|---|---|---|
| **Tillage** | | |
| Mound | 5.07 | 65.29 |
| Ridge | 5.41 | 65.75 |
| **LSD (5%)** | **NS** | **NS** |
| **P fertilizer (kg $P_2O_5$/ha)** | | |
| Control | 5.15 | 64.73 |
| 30 | 5.30 | 65.11 |
| 60 | 5.70 | 66.37 |
| 90 | 5.13 | 66.26 |
| 120 | 4.92 | 65.12 |
| **LSD (5%)** | **NS** | **NS** |
| **CV (%)** | **11.0** | **1.9** |

**NS – not significant**

### 4.4.2 ZINC AND SUGAR CONTENTS

The differences on the zinc content of sweet potato roots were not significant (P > 0.05) for both tillage method and phosphorus fertilizer application. Also, both tillage and Phosphorus fertilizer application did not significantly affect root sugar content of sweet potato (Table 4.11).

**Table 4.**

**11: Effects of tillage method and phosphorus fertilizer application on the iron and zinc content of sweet potato**

| Treatment | Zinc content (mg/100 g) | Total sugar (%) (sucrose, glucose and fructose) |
|---|---|---|
| **Tillage** | | |
| Mound | 1.833 | 12.52 |
| Ridge | 1.872 | 12.95 |
| **LSD (5%)** | **NS** | **NS** |
| **P fertilizer (kg $P_2O_5$/ha)** | | |
| Control | 1.803 | 11.66 |
| 30 | 1.900 | 12.31 |
| 60 | 1.903 | 14.18 |
| 90 | 1.855 | 13.42 |
| 120 | 1.802 | 12.11 |
| **LSD (5%)** | **NS** | **NS** |
| **CV (%)** | **7.1** | **16.5** |

**NS – not significant**

**4.5 ECONOMIC ANALYSIS**

Results of the economic analysis of sweet potato to determine the net benefit value of tillage method and different rate of phosphorus fertilizer are presented in Table 4.12. From the results, tillage method shows significant difference ($P < 0.05$) with ridging had the highest benefit value of GHc 19,150.00 and mounding had the lowest benefit value of GHc 15,265.00. There were no significant differences on the different rates of phosphorus fertilizer. Notwithstanding, the treatment that received 60 kg $P_2O_5$/ha had the highest

**Table 4.**
benefit value of GHc 21,251.00 and the control treatment had the lowest benefit value of GHc 13,654.00.

**12: Effects of tillage method and phosphorus fertilizer application on the net benefit value of sweet potato**

| Treatment | Net benefit value (GHc) |
|---|---|
| **Tillage** | |
| Mound | 15,265.00 |
| Ridge | 19,150.00 |
| **LSD (5%)** | **3178.1** |
| **P fertilizer (kg $P_2O_5$/ha)** | |
| Control | 13,654.00 |
| 30 | 16,119.00 |
| 60 | 21,251.00 |
| 90 | 18,090.00 |
| 120 | 16,924.00 |
| **LSD (5%)** | **NS** |
| **CV (%)** | **24.1** |

**NS – not significant GHc – Ghana cedis**

## 4.6 EXPERIMENT TWO

### 4.6.1 SOIL CHARACTERISTIC OF THE EXPERIMENTAL FIELD

The results of the physico-chemical characteristics of the soil at the experimental site are presented in Table 4.13. The texture of the soil at the experimental site was sandy loam. From the results, available phosphorus (8.52 mg/kg) was moderately low and total

**Table 4.**
nitrogen (0.09 %) was low. Exchangeable potassium (0.21cmol/kg) was classified as moderate and the soil organic carbon was low (< 2 %).

**13: Physico- chemical properties of soil of the experimental field**

| Soil property | 0 – 15 cm | 15 – 30cm |
|---|---|---|
| pH (x:y, $H_2O$) | 6.00 | 5.97 |
| Total nitrogen (%) | 0.10 | 0.08 |
| Available phosphorus (mg/kg) | 8.44 | 8.60 |
| Exchangeable potassium ($cmol_c$/kg) | 0.20 | 0.22 |
| Organic carbon (%) | 1.61 | 0.74 |
| Bulk density (g $cm^{-3}$) | 1.40 | 1.42 |
| Sand (%) | 82.63 | 79.05 |
| Silt (%) | 4.05 | 3.85 |
| Clay (%) | 13.32 | 17.10 |
| Texture | Sandy loam | Sandy loam |

### 4.7 GROWTH PARAMETERS

#### 4.7.1 PERCENTAGE SPROUT

Effects of vine length on percentage sprout of sweet potato vines are shown in Table 4.14. The result obtained for percentage sprout was highly significant ($P < 0.001$) for both sampling period. The percentage sprout recorded at both weeks increased with increasing number of nodes. The 30 cm vine length recorded the greatest sprouting percentage of 49.03 % and 76.80 % for the first and second weeks after planting respectively. The lowest sprouting percentage was obtained from the 15 cm vine length with a numerical value of

**Table 4.**
21.27 % and 33.30 % for the first and second weeks after planting respectively (Table 4.14).

**14: Effects of vine length on percentage sprout of sweet potato at two (2) sampling periods**

| | Percent sprout (%) | |
|---|---|---|
| Treatments | 1 WAP | 2 WAP |
| **Vine length (cm)** | | |
| 15 | 21.27 | 33.3 |
| 22.5 | 40.70 | 66.6 |
| 30 | 49.03 | 76.8 |
| **LSD (5%)** | **4.408** | **10.52** |
| **CV (%)** | **5.3** | **7.9** |

**WAP – Week after planting**

### 4.7.2 VINE LENGTH

Effects of vine length and potassium fertilizer application on vine length of sweet potato at two (2) sampling period are presented in Table 4.15. At 30 DAF, vine length and potassium fertilizer had significant effect on sweet potato plants. The greatest vine length was recorded on the 30 cm vine length which was significantly higher than the other treatment effects. The other treatment effects were similar. Among the fertilizer treatment, the greatest effect was recorded in the 60 kg $K_2O$/ha treatment and this was significantly higher than the control and 180 kg $K_2O$/ha treatment only. The 180 kg $K_2O$/ha treatment which recorded the lowest effect was significantly lower than the 120 kg $K_2O$/ha treatment effect.

**Table 4.**

At 60 DAF, vine length from the 30 and 22.5 cm treatments were similar, but either effect was greater than the 15 cm vine length treatment. Vine length from the 60 kg

$K_2O$/ha plots was the greatest, and this was greater than those of the control and 180 kg $K_2O$/ha treatments only.

**Table 4. 15: Effects of vine length and potassium fertilizer application on vine length of sweet potato at two (2) sampling periods**

| | Vine length (cm) | |
|---|---|---|
| Treatments | 30 DAF | 60 DAF |
| **Vine length (cm)** | | |
| 15 | 191.3 | 280.9 |
| 22.5 | 218.0 | 315.2 |
| 30 | 249.4 | 316.8 |
| **LSD (5%)** | **31.1** | **24.8** |
| **K fertilizer (kg $K_2O$/ha)** | | |
| Control | 207.5 | 295.1 |
| 60 | 255.0 | 332.8 |
| 120 | 228.2 | 315.2 |
| 180 | 187.7 | 274.0 |
| **LSD (5%)** | **35.9** | **28.7** |
| **CV (%)** | **16.7** | **9.6** |

**DAF – days after fertilizer application**

#### 4.7.3 NUMBER OF BRANCHES

Table 4.16 shows the effect of vine length and potassium fertilizer on the number of branches of sweet potato at two (2) sampling periods. The result shows that, number of branches was greatest on the plots planted with 30 cm cuttings on both days of sampling, which was significantly higher than vines of 15 and 22.5 cm long at 30 DAF, and only that of 15 cm at 60 DAF. Potassium fertilizer application also had significant effect on number of branches on both days. At 30 DAF, treatment effect of the 60 kg $K_2O$/ha was greatest, and this was significantly higher than those of the control and 180 kg $K_2O$/ha treatments. Treatment effect of the 120 kg $K_2O$/ha was also greater than those of the control and 180 kg $K_2O$/ha treatments. At 60 DAF, number of branches from the 60 kg $K_2O$/ha was the greatest, and this was greater than the control and 180 kg $K_2O$/ha treatment effects. Other treatment effects were similar.

**Table 4. 16: Effects of vine length and potassium fertilizer application on number of branches of sweet potato at two (2) sampling periods**

| | Number of branches | |
|---|---|---|
| Treatments | 30 DAF | 60 DAF |
| **Vine length (cm)** | | |
| 15 | 2.50 | 3.42 |
| 22.5 | 4.30 | 6.68 |
| 30 | 5.64 | 7.72 |
| **LSD (5%)** | **0.88** | **2.16** |
| **K fertilizer (kg $K_2O$/ha)** | | |
| Control | 3.78 | 5.09 |
| 60 | 5.19 | 7.69 |
| 120 | 4.59 | 6.91 |
| 180 | 3.03 | 4.07 |
| **LSD (5%)** | **1.02** | **2.49** |
| **CV (%)** | **25.2** | **43.0** |

**DAF – days after fertilizer application**

#### 4.7.4 VINE GIRTH

Results on vine girth of sweet potato as affected the vine length and potassium fertilizer at two (2) sampling periods are presented in Table 4.17. From the result, at 30 DAF, vine girth was highly significant ($P < 0.001$) with vine girth of plants from 30 cm cuttings being significantly higher than the other treatment effects. Potassium fertilizer did not show significant difference on vine girth at 30 DAF. At 60 DAF, both vine length and potassium fertilizer had significant effect ($P < 0.05$). Treatment effect from the 30 cm cutting was significantly higher than from the other cuttings. Also, the 60 kg $K_2O$/ha treatment effect was significantly higher than those from the control and 180 kg $K_2O$/ha treatments only. All other treatment effects were not significantly different from one another.

**Table 4. 17: Effects of vine length and potassium fertilizer application on vine girth of sweet potato at two (2) sampling periods**

| | Vine girth (cm) | |
|---|---|---|
| Treatments | 30 DAF | 60 DAF |
| **Vine length (cm)** | | |
| 15 | 0.324 | 0.493 |
| 22.5 | 0.343 | 0.534 |
| 30 | 0.407 | 0.575 |
| **LSD (5%)** | **0.039** | **0.052** |
| **K fertilizer (kg $K_2O$/ha)** | | |
| Control | 0.350 | 0.519 |
| 60 | 0.382 | 0.586 |
| 120 | 0.366 | 0.548 |
| 180 | 0.334 | 0.483 |
| **LSD (5%)** | **NS** | **0.060** |
| **CV (%)** | **12.9** | **11.7** |

**NS – not significant** **DAF – days after fertilizer application**

### 4.7.5 NUMBER OF LEAVES

Table 4.18 shows the results of number of leaves. Both vine length and K fertilizer application affected leaf production at 30 DAF. Plants from the 30 cm cuttings produced the greatest number of leaves, which was significantly higher than those from the 15 cm cuttings. Also, the 60 kg $K_2O$/ha treatment produced the greatest effect, which was significantly higher than those from the control and 180 kg $K_2O$/ha treatments.

At 60 DAF, number of leaves from the 30 cm cuttings was the greatest, but this was greater than that of the 15 cm cuttings only. Potassium application did not affect leaf production at 60 DAF.

**Table 4. 18: Effects of vine length and potassium fertilizer application on number of leaves of sweet potato at two (2) sampling periods**

| | Number of leaves | |
|---|---|---|
| Treatments | 30 DAF | 60 DAF |
| **Vine length (cm)** | | |
| 15 | 97.0 | 149.0 |
| 22.5 | 147.0 | 178.0 |
| 30 | 191.0 | 233.0 |
| **LSD (5%)** | **55.4** | **59.3** |
| **K fertilizer (kg $K_2O$/ha)** | | |
| Control | 120.0 | 170.0 |
| 60 | 196.0 | 229.0 |
| 120 | 159.0 | 200.0 |
| 180 | 105.0 | 147.0 |
| **LSD (5%)** | **63.9** | **NS** |
| **CV (%)** | **45.2** | **37.5** |

**NS – not significant** **DAF – days after fertilizer application**

## 4.8 YIELD COMPONENTS

### 4.8.1 TOTAL NUMBER OF ROOTS PER PLANT

Results in Table 4.19 shows that vine length had significant effect on the total number of roots per plant. From the result, 30 cm vine length had the greatest number of roots, which was significantly higher than that from the 15 cm cuttings only. Potassium fertilizer did not show significant difference on the total number of roots.

### 4.8.2 ROOT YIELD PER PLANT

Table 4.19 shows root yield of sweet potato as affected by different vine length and rates of potassium fertilizer application. The 30 cm cuttings produced the greatest root yield, and this was significantly higher than that of 15 cm cuttings only. Potassium application significantly affect root yield, with 60 kg $K_2O$/ha treatment effect being the greatest, and this was significantly higher than all other treatment effects. All other treatment differences were not significant at 5% level of probability.

**Table 4. 19: Effect of vine length and potassium fertilizer application on total number of roots and root yield per plant of sweet potato**

| Treatment | Total number of roots per plant | Root yield per plant (kg) |
|---|---|---|
| **Vine length (cm)** | | |
| 15 | 1.57 | 0.143 |
| 22.5 | 2.13 | 0.218 |
| 30 | 2.68 | 0.280 |
| **LSD (5%)** | **0.69** | **0.068** |
| **K fertilizer (kg $K_2O$/ha)** | | |
| Control | 2.18 | 0.180 |
| 60 | 2.62 | 0.369 |
| 120 | 2.18 | 0.189 |
| 180 | 1.53 | 0.118 |
| **LSD (5%)** | **NS** | **0.079** |
| **CV (%)** | **38.4** | **38.0** |

**NS – not significant**

### 4.8.3 TOTAL NUMBER OF MARKETABLE AND NON- MARKETABLE ROOTS PER PLANT

Result on the number of marketable roots (Table 4.20) shows no significant differences ($P > 0.05$) for both vine length and potassium fertilizer. Potassium fertilizer application did not significantly affect number of non- marketable roots. For vine cuttings, the 30 cm cuttings produced the greatest number of non- marketable roots, but this was significantly higher than that of the 15 cm cuttings only.

**Table 4. 20: Effect of vine length and potassium fertilizer application on total number of marketable and non- marketable roots per plant of sweet potato**

| Treatment | Total number of marketable roots per plant | Total number of non-marketable roots per plant |
|---|---|---|
| **Vine length (cm)** | | |
| 15 | 0.600 | 0.967 |
| 22.5 | 0.783 | 1.350 |
| 30 | 0.983 | 1.700 |
| **LSD (5%)** | **NS** | **0.446** |
| **K fertilizer (kg $K_2O$/ha)** | | |
| Control | 0.911 | 1.267 |
| 60 | 1.067 | 1.556 |
| 120 | 0.689 | 1.489 |
| 180 | 0.489 | 1.044 |
| **LSD (5%)** | **NS** | **NS** |
| **CV (%)** | **62.9** | **39.4** |

**NS – not significant**

### 4.8.4 MARKETABLE AND NON- MARKETABLE ROOT YIELD PER PLANT

Table 4.21 indicates the effect of vine length and potassium fertilizer application on marketable root yield of sweet potato. Vine length was statistically significant ($P < 0.05$) with 30 cm treatment recording the greatest marketable root yield which was significantly higher than the 15 cm cutting treatment only. The 60 kg $K_2O$/ha treatment effect was also the greatest, and this was significantly higher than all other treatment effects. All other treatment effects were statistically similar.

Non- marketable root yield was not significantly ($P > 0.05$) affected by cuttings length or potassium fertilizer application.

**Table 4. 21: Effect of vine length and potassium fertilizer application on marketable and non- marketable roots yield per plant of sweet potato**

| Treatment | Marketable roots yield per plant (kg) | Non- marketable roots yield per plant (kg) |
|---|---|---|
| **Vine length (cm)** | | |
| 15 | 0.080 | 0.063 |
| 22.5 | 0.153 | 0.065 |
| 30 | 0.183 | 0.096 |
| **LSD (5%)** | **0.065** | **NS** |
| **K fertilizer (kg $K_2O$/ha)** | | |
| Control | 0.113 | 0.066 |
| 60 | 0.256 | 0.113 |
| 120 | 0.124 | 0.064 |
| 180 | 0.062 | 0.055 |
| **LSD (5%)** | **0.075** | **NS** |
| **CV (%)** | **55.4** | **60.7** |

**NS – not significant**

# CHAPTER FIVE

# DISCUSSION

## 5.1 EXPERIMENT ONE 5.1.1 EFFECT OF TILLAGE METHOD ON GROWTH PARAMETERS OF

## SWEET POTATO.

Growth parameters were not significantly influenced by tillage methods (i.e., ridges and mounds) at both sampling periods. The non- significant difference observed in the study could be as a result of the same height of 30 cm that was maintained for both tillage methods. Parwada *et al*. (2011) and Traynor (2005) reported that, at an appreciable height of 30 cm for either ridge or mound, favourable conditions are available around the planting zones which are necessary for normal growth of sweet potato. Proper seedbed preparation for root crops as in ridges and mounds has been confirmed by FAO (2000) to loosen the soil, optimize infiltration, enhance rooting depth and improve soil- water management. Indeed, Taylor and Klepper (1978) reported that, tillage system that loosens the soil improve aeration, increases the rooting depth and thus enables roots to proliferate and penetrate unexploited zones.

### 5.1.2 EFFECT OF PHOSPHORUS FERTILIZER APPLICATION ON GROWTH PARAMETERS OF SWEET POTATO.

Phosphorus fertilizer did not show any significant increase on vine length, number of branches and vine girth as presented in Table 4.2, 4.3 and 4.4 respectively for the two sampling periods. However, numerically greatest values for these parameters were obtained from plots treated with 60 kg $P_2O_5$/ha. The result is in line with what was reported by Kareem (2013), who found no significant difference for vine production though the treated plots had the greatest vine production as compared to the control plot. It was also observed in the present study that, there was a fall in vine production at an application rate above 60 kg $P_2O_5$/ha which agrees with the findings of Rashid and Waithaka (2009) that phosphorus did not significantly increase vine production in sweet potato and that higher level of phosphorus application produced shorter vines.

In spite of the above observations, application of phosphorus fertilizer had significant effect on number of leaves of sweet potato at 30 days after fertilizer application. It was evident in this study that leaf production was directly related to vine length and number of branches. That is, the longer the length and greater number of branches, the more number of leaves produced. The significant increase on number of leaves at 30 DAF may be attributed to the beneficial effect of P-element on the activation of photosynthesis and metabolic processes of organic compounds in plants which increases plant growth (Purekar *et al*., 1992).

At 60 days after fertilizer application, there was no significant increase in leaf production among the various treatments. The non- significant difference in leaf production may be due to bulking of the storage roots at this stage. It has been reported by Van de Fliert and Braun (1999) that, from the ninth week of sweet potato growth cycle till maturity, vine growth normally reaches a maximum. At this stage, the foliage and vine density decreases because the plant uses more energy to fill the storage roots rather than to form and maintain leaves. Moreover, the photosynthates produced in the vegetative part are partitioned to the roots for bulking.

### 5.1.3 EFFECT OF TILLAGE METHOD ON YIELD COMPONENTS OF SWEET POTATO.

The trend of the result on yield components as total number of roots, root yield per plant, total number of marketable and non- marketable roots, marketable and non- marketable root yield and dry matter content of sweet potato presented in Table 4.6 – 4.9 showed no significant differences due to tillage methods. The non- significant difference of tillage method on these components of yield could be due to both ridge and mound created favourable conditions for sweet potato growth; both loosened the soil, optimized infiltration and facilitated root expansion. Akinboye *et al*. (2015) reported that mound planting increased sweet potato yield due to the fact that, the process of mound making collects the top rich soil and the entire depth of the mound consist of more fertile topsoil while high ridge provides ample depth of loose fertile soil for root development. The result on sweet potato yield is similar to what was observed by Ennin *et al*. (2014) on yam, who reported no significant different between yam planted on ridges and those planted on mounds.

### 5.1.4 EFFECT OF PHOSPHORUS FERTILIZER APPLICATION ON YIELD COMPONENTS OF SWEET POTATO.

Phosphorus fertilizer rates produced significant effect on total number of roots, root yield per plant, total number of marketable roots, marketable roots yield and dry matter content of sweet potato. Components of yield were increased with increasing phosphorus fertilizer rates from 0 kg $P_2O_5$/ha up to 60 kg $P_2O_5$/ha and began to fall at an application rates of 90 and 120 kg $P_2O_5$/ha. The significant effect showed on sweet potato yield components due to phosphorus fertilizer application might be as a result of the very low level of native phosphorus in the experimental site (Table 4.1). Obigbesan *et al*. (1976) stated that, soil with less than 10 mg/kg P could be considered deficient and may show positive response to P fertilizer application. Another possible explanation for these significant effects could be as a result of the importance of phosphorus on sweet potato. Adequate phosphorus nutrition enhances many aspects of plant physiology, including the fundamental process of photosynthesis, flowering, fruiting (including seed production), and maturation. According to Marschner (1995), phosphorus is an essential component of many organic compounds in plant, such as phosphor-proteins, phospholipids, nucleic acids and nucleotides, which indirectly reflect positively on yield. The result of this study agrees with early workers, who reported significant effect of phosphorus fertilizer on total and marketable tuber yield, tuber dry matter, average tuber root weight and tuber root diameter (Hassan *et al*., 2005).

### 5.1.5 EFFECT OF TILLAGE METHOD ON YIELD PER HECTARE OF SWEET POTATO.

Tillage methods had significant effect on roots yield per hectare of sweet potato with ridging producing the greatest yield than mounding (Table 4.9). Ridging has been shown to result in increased sweet potato yields by 38% over mounding (Ennin *et al*., 2003). Similar result was reported by Ennin *et al*. (2009) on cassava where significant difference was obtained between cassava planted on ridge, mound and flat ground.

According to these authors, cassava planted on ridges result in greatest root yield compared to those planted on mounds and flat ground. A possible explanation for increasing yield on ridges over mounds could be as a result of increased plant population density of ridges which help to suppress weeds and reduced the possibility of the crop competing with weeds for available nutrients. According to Ennin *et al*. (2009), mounding apparently had a greater exposed soil surface area for evapotranspiration and greater weed infestation, making weed control most difficult on mounds, and possibly contributing to the lower root yields on mounds compared to ridges. The result is also in line with Brobbey (2015) who investigated the influence of seedbed type on sweet potato yield, and concluded that planting sweet potato on ridge is better than planting on mound since ridge planting in totality resulted in greater growth and yield of sweet potato.

### 5.1.6 EFFECT OF PHOSPHORUS FERTILIZER APPLICATION ON YIELD PER HECTARE OF SWEET POTATO.

Result showed that phosphorus fertilizer significantly influenced sweet potato root yield with 60 kg $P_2O_5$/ha produced the greatest (Table 4.9), acknowledging that the P fertilizer applied favoured tuber roots growth of sweet potato. The observed increment in sweet potato yield can be explained on the basis that the native phosphorus of the experimental field was very low, indicating the need of increasing the phosphorus level of the field through phosphorus fertilizer application. Root yield of sweet potato generally increased with phosphorus application, stressing the important of phosphorus as an essential constituent of many organic compounds that are necessary for metabolic processes, blooming and root development (Purekar *et al*., 1992). The result of this study contradicts what was reported by MacDonald (1963) and FAO (2005) that, phosphorus does not appear to be an important nutrient for sweet potato production although phosphorus is usually recommended in the fertilizer mixture and that when phosphorus is eliminated, the yield of sweet potato is not affected. Issaka *et al*. (2014) evaluated the effect of missing nutrient on sweet potato yield and observed that in the absence of P (45-0-45 kg/ha N, $P_2O_5$, $K_2O$) both tuber and vine production were significantly reduced. It was observed from this study that, root yield of sweet potato was depressed at an application rates above 60 kg $P_2O_5$/ha, that is, at 90 and 120 kg $P_2O_5$/ha indicating that optimum phosphorus fertilizer level was exceeded, supporting what was stated by FAO (1994) that, high phosphorus level in the soil suppressed tuber development of sweet potato and other root and tuber crops.

### 5.1.7 EFFECT OF TILLAGE METHOD ON QUALITY CHARACTERS OF SWEET POTATO.

Root quality characters; crude protein (%), starch content (%), zinc (mg/100g) and total sugar (%) were not significantly influenced by the different tillage methods. This could be as a result of ridge and mound looses and gathered rich top soil around the planting zone (Akinboye *et al*., 2015, Parwada *et al*., 2011), making better use of production elements (water, light, nutrient solution) in the soil leading to better photosynthesis and increasing carbohydrate storage in the roots.

### 5.1.8 EFFECT OF PHOSPHORUS FERTILIZER APPLICATION ON QUALITY CHARACTERS OF SWEET POTATO.

The different rates of phosphorus fertilizer did not significantly affect crude protein (%), starch content (%), zinc (mg/100g) and total sugar (%) of sweet potato roots. The non-significant effect of phosphorus on the above mentioned quality characters could be as a result of the variety used for this study (Okumkom – white flesh). Some of these quality characters are genetic trait and varies from variety to variety. Some sweet potato varieties like the orange flesh have inherently superior quality than the white types and there is little fertilizer application can do to improve on these characters. For instance, orange flesh sweet potato had been identified to be very high in carotenoids and βcarotene (Jakahata *et al*., 1993). Ingabire and Hilda (2011) investigated the nutrient composition of four sweet potato varieties and concluded that the yellow flesh variety was found to be more nutritious compare to the white fleshed varieties.

### 5.1.9 NET BENEFIT VALUE ASSESSMENT OF TILLAGE METHOD AND FERTILIZER TREATMENTS IN SWEET POTATO PRODUCTION.

Economic analysis was done using the partial budget to assess the costs and benefits of the various treatments. The yield extrapolated in per hectare basis (t/ha) obtained was used for this analysis. The farm gate price of sweet potato was used to calculate the gross field benefits (value in Ghana cedis) of the extrapolated yield for each treatment. The total input costs include fertilizer (triple superphosphate), cost of transporting fertilizer to the farm and cost of applying fertilizer. The most economical treatment for tillage method (Table 4.12) was the ridge method. Ridge method gave an average return of GHc 19,150.00 and mound gave GHc 15,265.00.

Concerning P- fertilizer rates, the 60 kg $P_2O_5$/ha had the greatest average economic return of GHc 21,251.00 and the lowest was the control treatment with GHc 13,654.00. Deducting the control treatment„s net benefit value from the greatest net benefit, the 60 kg $P_2O_5$/ha gave an extra benefit of GHc 7,597.00.

### 5.2 EXPERIMENT TWO 5.2.1 EFFECT OF VINE LENGTH ON GROWTH PARAMETERS OF SWEET

### POTATO.

Percentage sprouting was highly significant with the 30 cm length had the greatest sprout and the 15 cm had significantly lesser sprouting percentage. Cuttings began to establish at 1 week after planting and about 3 weeks after planting, most cuttings were fully established. According to lrivine (1969), cuttings require between 4 and 14 days to get established. The delayed on the number of days cuttings took to fully establish may be due to the poor rainfall during the minor season when the experiment was conducted. The highly significant difference in the percentage sprout of cuttings might be due to the fact that, since the 30 cm vines had more number of nodes, more nodes will be buried at planting leading to more root initiation from the nodes for better establishment. Also, with more number of nodes, number of bud increases which serve as a source of growth for rooting and sprouting. The result of this study is similar to the findings of Amoah (1997), who established that cuttings with 5 and 7 number of nodes took significantly less number of days to achieve 100 percent establishment than cuttings with 3 number of nodes. The result also corroborates early findings of Iddrisu (1979) and Adu-Baffour (1977) who reported that the percentage of cuttings established increased with increasing node number per cutting in sweet potato, yam and cassava propagation.

Length of cuttings also had significant effect on other growth parameters as vine length, vine girth, number of branches and number of leaves with 30 cm length having consistently the greatest values and the 15 cm with the lowest. The significant difference on these growth parameters could be as a result of the more number of nodes which were present on the 30 cm vine might have resulted in more roots development thereby enhancing better and early establishment of cuttings leading to rapid vine development, more number of branches and more leaf production. The result is similar to what was reported by Amoah (1997), who found significant difference on number of branches with the cuttings having more number of nodes (5 and 7) produced significantly the greatest number of branches per cutting as compared to those with 3 nodes.

### 5.2.2 EFFECT OF POTASSIUM FERTILIZER ON GROWTH PARAMETERS OF SWEET POTATO.

Potassium fertilizer had significant effect on vine length, number of branches, vine girth and number of leaves. The result is in line with Uwah *et al*. (2013), who reported significant increase in vine length, number of leaves and branches per plant following potassium fertilizer application. The significant effect shown might be attributed to the importance of K nutrition to sweet potato. It has been reported that K increases the photosynthetic rates of crop leaves, $CO_2$ assimilation and facilitates carbon movement (Sangakkara *et al*., 2000) and that increasing potassium in the soil enhances nitrogen uptake by plant. Marschner (1995) and Mengel (1997) explained that, with a shortage of potassium, many metabolic processes like rate of photosynthesis, rate of translocation and enzyme systems are affected which result in reduction of plant growth. Marschner (1995) reported significant increase in vegetative growth and yield of sweet potato in response to potassium fertilizer. Trehan *et al*. (2009) observed that K increased vine length, crop vigor, leaf expansion particularly at early stages of growth. It was also observed from this study that, at an application rate above 60 kg $K_2O$/ha, growth parameters decreases. This might be as a result of the toxic effect of excess fertilizer and that the 60 kg $K_2O$/ha was sufficient for sweet potato growth on the experimental site. However, there was no significant difference on number of leaves at 60 days after fertilizer application. This might be as a result of bulking of the tuber roots. It has been observed that, as tuber roots begin to bulk, more photosynthates will be partitioned to the tuber for bulking at the expense of more leaf production (Van de Fliert and Braun,

1999).

### 5.2.3 EFFECT OF VINE LENGTH ON YIELD COMPONENT OF SWEET

**POTATO.**

Vine length significantly affects total number of roots, root yield, total number of nonmarketable roots and marketable roots yield. The significant influence of vine length on total number of roots, roots and marketable roots yield could have been as a result of the more number of nodes which were present on the 30 cm vine might have resulted in more nodes to be buried in the soil giving more points for tuber root initiation.

According to Amoah (1997), tuber initiation and bulking begins earlier on cuttings with more nodes than those with fewer nodes as a result of the early rapid growth which translocated into higher roots yield and greater marketable yield on cuttings with higher number of nodes. Also, the positive effect showed on the number of non- marketable roots may be due to the fact that the 30 cm vine length produced considerable greater quantity of roots than the 15 cm cuttings. As a result of that, some quantity of roots will be marketable while others will be non-marketable with the 30 cm vine length than the 15 cm length. Vine length did not significantly increase both total number of marketable roots and non- marketable roots yield in this study. However, there was a general trend towards an increase in the total number of marketable roots and that of non-marketable roots yield with increasing node number per cutting. This might be due to the development of more roots on cuttings with more number of nodes. This however, may affect tuber roots size due to competition among the roots for available nutrients and assimilate resulting to some small to medium tuber roots.

### 5.2.4 EFFECT OF POTASSIUM FERTILIZER ON YIELD COMPONENT OF SWEET POTATO.

Potassium fertilizer rates had significant effect on roots yield and marketable roots yield, but there was no significant increase on the total number of roots, total number of marketable and non- marketable roots and non- marketable roots yield. This showed that potassium fertilizer application increases the size of sweet potato roots but not the total number of tuber roots. The significant response shown by some of these yield components could be due to the beneficial effect of K in activating more than 60 enzymes, which are necessary for essential plant processes such as energy utilization, starch synthesis, N metabolism and respiration (Wallingford, 1980). The result agrees with what was reported by previous workers (Uwah *et al*., 2013; Njoku *et al*., 2001) that potassium fertilizer increases the yield of sweet potato through the formation of large sized tuber roots. Abd El-Baky *et al*. (2010) reported significant effect on sweet potato yield with increasing potassium fertilizer rate from 60 to 150 kg $K_2O$. According to these authors, the greatest sweet potato yield was obtained from plants received 150 kg $K_2O$. In this study, it was observed that, all the components of yield were decreased with increasing potassium fertilizer rates above 60 kg $K_2O$/ha, suggesting that the 60 kg $K_2O$/ha is sufficient for sweet potato yield. The low response of sweet potato to potassium fertilizer could be due to the initial moderate level of soil K (0.21cmol/kg). However, K could become limiting with continuous cultivation. It was also observed that, the treatment whose effect recorded the greatest growth produced the greatest yield, indicating that there was a positive influence of growth on sweet potato yield.

# CHAPTER SIX

## CONCLUSIONS AND RECOMMENDATIONS

## 6.1 CONCLUSIONS

The results of this study revealed that tillage method did not have significant effect on growth, but significantly influenced yield of sweet potato. Phosphorus fertilizer had significant effect on yield and its components of sweet potato. All the quality characters studied were not significantly influenced by both tillage method and phosphorus fertilizer application. It was observed from the result that ridging had the greatest net benefit return, and that application of phosphorus fertilizer had a positive net return in sweet potato production. It was also observed that application of phosphorus fertilizer at a rate of 60 kg $P_2O_5$/ha could be the maximum rate for enhanced sweet potato growth and yield.

The result of this study also revealed that cutting vine length of 30 cm produced the greatest growth and yield of sweet potato, and that application of potassium fertilizer has the potential of increasing the growth and yield in sweet potato production. Finally, it was observed that application of muriate of potash at 60 kg $K_2O$/ha produced the greatest growth and yield of sweet potato.

## 6.2 RECOMMENDATIONS

Due to the fact that ridge produced the greatest yield per hectare and had the greatest net benefit return, it is recommended that sweet potato should be cultivated on ridges.

For greater growth and yield, sweet potato growers should apply both phosphorus and potassium fertilizer at 60 kg/ha.

Since the 30 cm vine length resulted in greater growth and yield, it is recommended for farmers to cut their vines to this length.

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# APPENDIX

**Appendix 1: SOME SWEET POTATO CULTIVARS IN GHANA; THEIR CHARACTERISTICS AND USES**

| Name of Cultivar | Root skin colour | Flesh colour | Root yield (t/ha) | Dry matter (%) | Uses and production in Ghana and sub- region |
|---|---|---|---|---|---|
| Apomuden | Orange | Reddish | 30 | 21.9 | High beta-carotene; preferred by exporters; baby foods |
| Otoo | White | Light orange | 23 | 32.2 | Medium beta-carotene; boiled and deep-fried; export crop |
| Ogyefo | Pink | White | 20 | 40.1 | Boiled and fried as chips; good for starch extraction |
| Hi starch | Dark cream | Cream | 18 | 40.0 | High starch content (21%); mild sweetness; good for flour |
| Sauti | White | Yellow | 19 | 40.2 | Boiled and fried as chips; low sugar content |
| Faara | Pink | White | 22 | 36.1 | Excellent for fried chips and boiled as ampesi |
| Okumkom | Light pink | White | 20 | 30.7 | Early maturing; good for ampesi |
| Santom pona | Dark cream | Light yellow | 17 | 34.4 | Early maturing; tastes like yam; good for ampesi |
| Jukwa orange | Dark cream | Light orange | 30 | 35.0 | High dry matter; highly preferred for ampesi and chips |

**Source**: Asafo-Agyei (2010)