YIELD AND QUALITY OF SWEET POTATO AS AFFECTED BY NUMBER OF NODES BURIED AND POTASH FERTILIZERS

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CROP SCIENCE OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

A study was conducted from January 2013 to June 2013 at Hombolo Agricultural Research Institute in Dodoma, Central Tanzania. The aims were to evaluate response of three sweet potato varieties in productivity and quality to four levels of nodes buried and three potash fertilizer sources. A Split-split plot designs was employed and treatments were applied. Main plot were three sweet potato varieties, *Kiegeya*, *Mataya,* and *Ukerewe*. Sub plot were, nodes burring levels: four buried nodes, (two above ground), five buried nodes (three above ground), seven buried nodes (three above ground) and eight buried nodes (four above ground). The sub - subplot treatments were potash fertilizer sources: Control no fertilizer used, Potassium chloride (KCl), Potassium nitrogen phosphate (NPK) and Farm yard manure (FYM). Results indicated total yield were not affected by varieties planted. There were significant differences among number of nodes on the total yield, the lowest total yield (11.68 t ha^{-1}) was from four buried nodes whereas the highest yield of (15.91 t ha^{-1}) was from eight buried nodes. The application of fertilizers at the rate 120 kg ha^{-1} significantly influenced the yield components ($P < 0.05$). The lowest number of tuber roots (2.81) was from control treatment while the highest number of tuber roots (6.03) was from KCl treatment. The indicators of tuberous root quality such as diameter (4.81 cm), length (19.03 cm) and weight (0.42 kg $plant^{-1}$) were from KCl. The total tuber roots yield (18.84 t ha^{-1}) from KCl, (17.51 t ha^{-1}) from NPK, (11.33 t ha^{-1}) from FYM and (8.82 t ha^{-1}) with control treatment. Seven and eight buried nodes with KCl and NPK fertilizers appeared appropriate for optimum sweet potato growth, yield and tuberous root quality in the study area and are therefore recommended.

DECLARATION

I, **John Kalaye** do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	Percent
BD	Bulk density
C	Carbon
Ca^+	Calcium ion
CO_2	Carbon dioxide
CEC	Cation exchange capacity
CIP	International potato center
cm	Centimeter
$cmol_c\ kg^{-1}$	Centimol per kilogram
COSTECH	Commission of Science and Technology
CV (%)	Coefficient of variation (in percentage)
DAP	Days after planting
DM	dry matter
e.g.	for example
FAO	Food and Agriculture Organization
Fig	Figure
FYM	Farm yard manure
g	Gram
H_2O	Water
ha	Hectare
i.e.	that is
IFA	International fertilizer industry association

IITA	International Institute of Tropical Agriculture
IPI	International Potash Institute
K^+	Potassium ion
kg	Kilogram
K_2O	Di-potassium oxide
KCl	Potassium chloride
LA	Leaf area
LAI	Leaf area index
M	Metre
MAFC	Ministry of Agriculture, Food and Cooperatives
masl	metre above sea level
Max.	Maximum
Mg	Milligram
Mg^+	Magnesium ion
Min.	Minimum
mm	millimetre
N	Nitrogen
Na^+	Sodium ion
NH_3	Ammonia
NH_4^+	Ammonium ion
ns	no significant difference
^oC	degree of Celsius
OC	Organic carbon
OM	Organic matter

P	Phosphorus
P_2O_5	Di-phosphorus pentaoxide
pH	Hydrogen ion concentration
R	correlation coefficient
RCBD	Randomized complete block design
RH	Relative humidity
S	South
s.d	standard deviation
SOM	Soil organic matter
SUA	Sokoine University of Agriculture
t	Tonne
T	Time
TMA	Tanzania Metrological Agency
TSP	Triple super phosphate
USA	United State of America
NR	Number of roots
NT	Number of tubers
VL	Vine length
TD	Tuber diameter
TL	Tuber length
TDW	Tuber dry weight
TFW	Tuber fresh weight
VFW	Vine fresh weight
VDW	Vine dry weight

CGR	Crop growth rate
NRT	Nate assimilation rate
LAD	Leaf area duration

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Sweet potato (*Ipomoea batatas* [L.] Lam) is an important staple crop in many parts of the tropics. It is known for its drought resistance, being grown under various environments. The crop ranks the world's seventh most significant food crop after maize (*Zea mays* L.), wheat (*Triticum aestivum* L.) rice (*Oryza sativa* L.), round potato (*Solunum tuberosum* L.), barley (*Hordeum vulgare* L.) and cassava (*Manihot esculentum* L.) (FAO, 2009).

The potential of sweet potato to guarantee food security is under-estimated as its use is often limited to a substitute food in African countries. Sweet potato is valued for its tuber roots which are 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, and used as raw material for industrial starch and alcohol (Uwah *et al.*, 2013).

The leaves are used as vegetables and are rich in proteins, vitamins and various minerals. Sweet potato tubers are rich in vitamins A, B, and C; significant amounts of essential minerals are also found in sweet potato including manganese, copper, iron and potassium (Mtunda *et al.,* 2007). 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 (Uwah *et al.*, 2013).

World production of sweet potato is within the range of 107 million tons per annum. Most of this production comes from China (more than 80 million tons) and other Asian countries, including Indonesia, Japan and Korea as indicated in appendix 1. The crop is an important supplementary staple in the eastern and southern part of Africa (Tumwegamire *et al.*, 2004).

In Tanzania, sweet potato reported to be the third most significant tuberous root crop after cassava and round potato and is mainly produced by women as a food security crop as well as a source of income (Gibbson *et al.*, 2011). The crop is important in the western, lake, central, eastern and southern highland zones of the country (Kapinga, 2007).

Though sweet potato crop is easy to cultivate, it is faced with several production and economic constraints. Crop yields remain poor on account of low fertility status of the over-cropped soils, while post-harvest losses and low purchase prices have reduced production. Sweet potato yield is presently restricted by many factors among which is low soil fertility, varietal selection, planting dates, weather conditions, soil type, weeds, insects, disease pressure and crop management practices (Onunka *et al.*, 2012). The crop thrives in marginal soils but improved soil fertility increases its growth and yield performance. The crop is similar to sugarcane and other roots and tuberous crops that have high demands for K since leaves, vines, stems and tubers habitually remove considerable amount of K from the soil (CFFA, 2011). Sweet potato yield is significantly depressed if K is deficient. In Japan, it was anticipated that a tuberous yield of 13 t ha^{-1} removes about 70 kg N ha^{-1}, 20 kg P ha^{-1} and 110 kg

K ha^{-1} from the soil depending on the variety, crop duration and agro-climatic region. Comparisons of this kind are rare for tropical countries including Tanzania (Degras, 2003). In the Hubei province of China, the most advantageous K rate varied from 150-300 kg K_2O ha^{-1} (Jian-wei *et al.*, 2001), whereas in India, the mean optimum requisite was 120 kg K ha^{-1} and the highest was 160 kg K ha^{-1} with a yield response (16.7 t ha^{-1}) (Trehan *et al.*, 2009). Sweet potato response to applied K is considerably influenced by the variety grown (Uwah *et al.*, 2013). The varietal response to applied K is often related to its yield potential and the number of large sized tuber roots it can produce. Generally, rapid bulking varieties producing large sized tubers respond more to K than do the varieties with small tubers (Trehan and Grewal, 1990).

Sweet potato planting methods and fertilization differ from zone to zone in Tanzania. These differences are mainly in land preparation, number of nodes buried at planting depth, amount and rates of fertilizers (Kanyeka *et al.*, 2007). In western zone farmers prepare land by plowing followed by ridging. This is contrary in the other regions such as Dodoma where farmers practice zero tillage "*kubelega*". Some farmers however, plough back where by crop residues are buried in the soil during ridging and mould preparation then planting. Cuttings shorter than 30 cm and planting on flat land result in poor yield (Nyambok, 2011).

Therefore this study was conducted to access number of nodes of vines at planting when the crop is applied with fertilizers under field conditions in Dodoma on productivity and quality of sweet potato tubers. Apart from the inadequate use of organic manure in sweet potato production actual yield levels normally range from 3 to 6 t ha^{-1} and are considered to be relatively low compared to the experimental yields that ranges between 17- 23 t ha^{-1} (Kuoko, 2007). The total amount of phosphorus, nitrogen and potassium in organic manure is further as low as 0.18%, 1-5% and 1-2 % respectively (Kimbi and Semoka, 2004). In order to meet plant requirements of 120 kg K ha^{-1}, 10 - 12 t ha^{-1} should be applied depending on the type of soil and nutrients availability in a particular soil. Kuoko *et al.* (2007) conducted a research based on nitrogen and phosphorus at rate of 50 kg N ha^{-1}, 150 kg P_2O_5 ha^{-1} and found positive response on sweet potato yield (23 t ha^{-1}). However, information on the recommended use of inorganic fertilizers rich in potassium as well as the number of buried nodes per vine at planting in Tanzania are limited (Kuoko *et al.*, 2007). The study conducted by Hatibu *et al.* (1995) and Kabanza (2003) in some parts of Dodoma reveals the declining of potassium from high > 0.8 cmol$_c$ kg^{-1} to medium < 0.8 cmol$_c$ kg^{-1} which is low for the sweet potato requirement.

The low yield of 4.5 t ha^{-1} in Tanzania compares well with Africa's sweet potato yield averaging 6 t ha^{-1} that is below the global yield that averages 14 t ha^{-1} (Mukhtar *et al.*, 2010). In Tanzania sweet potato seed systems is poor such that obtaining planting materials is difficult and costly during growing seasons (Low, 2010). In general the crop is planted using vine cutting, but there is limited information on the specific number of nodes to be buried during planting. Usually farmers use vine of 30 cm length with variable number of nodes depending on the internodes length of the variety (Belehu, 2003). Little attention has so far been given to crop yield improvement of sweet potato leading to low tuber roots yield in Tanzanian. In order to obtain good yield, research must be conducted on improved varieties of crops which normally do require higher quantities of fertilizers with corresponding higher yield compared to the local varieties (Kapinga, 2007). There are new sweet potato varieties released in Tanzania; however, these varieties have not been tested widely on a number of relevant agronomic characteristics important for the crop such as planting methods fertilizer and manure requirements, irrigation, pest and disease control. Therefore this study was conducted to establish the effect of number of buried nodes of vines at planting and when the crop is applied with fertilizers under field conditions in Dodoma on their productivity and quality.

1.2 Objectives

1.2.1 Overall objective

To enhance sweet potato productivity and quality in Dodoma region, central Tanzania

1.2.2 Specific objectives

i To determine the influence of number of buried nodes on sweet potato growth and development

ii To evaluate the effect of three different fertilizers (FYM, KCl, NPK) on sweet potato performance

iii To determine the effect of different fertilizers and number of buried nodes of sweet potato vines on physical characteristics of sweet potato tubers

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Crop Botany, Origin and Distribution

The sweet potato (*Ipomoea batatas* L.) is a dicotyledonous plant that belongs to the family convolvulaceae. The crop is reported to have its center of origin in America or northwestern South America, with early cultivation beginning about 3000 to 2000 BC. The common name for this plant in Latin America is *batata*. The crop was brought to Europe by Columbus and Europe described this species using the Latin binomial system as a *convolvulus's batata.* However, in (1791) Lamarck reclassified the species within the genus *Ipomoea* on the basis of stigma, shape and the surface of pollen grains changing the name to its current form *Ipomoea batata L.* (Huamaan, 1997). Sweet potato was subsequently introduced to Africa and Asia by Portuguese and Spanish traders (Mukhtar *et al.*, 2010). The crop is widely grown in Peru and Mexico (Stephen, 2004).

Sweet potato has long and thin stem that runs along the soil and put roots into the soil at the nodes. Roots, normally develop from the stem cutting within (1-2) days after planting and grow rapidly to form the fibrous root system of the plant. The roots can go as deep as 2m that is what make sweet potato to be a drought resistant crop (Huamaan, 1999).

As the vines grow along the soils, roots are produced at various nodes. These are produced as a result of secondary growth of the roots within the top soil height of 20-

25 cm which are assimilated and structured to form tubers. Tuber formation and their quality are normally affected by environmental conditions (Nyambok, 2011).

2.2 Significance of Sweet Potato

Sweet potato is the world's most important root and tuber crop (Lenne, 1991). The crop is mainly grown in developing countries as a valuable source of food, feed, and industrial raw material. In Africa sweet potato is mostly grown for human consumption. The tuber roots are made into numerous food types; boiled, steamed, baked and fried. Sweet potato tuber roots are also made into flour and canned; the flour is further used in sweet dishes such as pies, biscuit and cakes (Woolfe, 1992). In some countries example China, South Africa, Mexico and Peru the tuberous roots are processed into starch, glucose, syrup and alcohol for industries. Depending on sweet cultivars grown, in some parts of Tanzania such as Dodoma consumers utilize both tuber roots and leaves as vegetables especially during the dry seasons. The fresh vines are used to feed animals such as cattle, goat, sheep and swine's in their Kraals (Maniyam *et al.*, 2012). Furthermore, non alcoholic beverages and vinegar can be derived from microbial fermentation of alcohol from starch in sweet potato. In the United States sweet potato are best known for their use in vegetable and Thanksgiving dinner (Woolfe, 1992). The use of sweet potato has been diversified beyond their classification as subsistence food security and famine relief crop. The nutritional composition of the tubers is as follows: Water 70- 80% Carbohydrates 10-30% Protein 1-3 % Crude fiber 2-3% Fats 0-1%, Vitamin A and C varies depending on the varieties (Nyambok, 2011).

2.3 Climate Requirements of the Crop

Varied climatic conditions, including frequent droughts and sporadic rainfall, affect the yields of sweet potato as in poor soil. Enhancing crop productivity in poor and infertile soil is a major task and of primary concern. Sweet potato is a reliable crop that could meet the requirements of the poor farming community in terms of nutrition and food security (Nyambok, 2011). The crop is highly adaptable and is able to grow in a wide range of agro-ecological zones. It grows best in the tropics between 40° north and 32° south. Temperature, light, rainfall, soil and altitude are the main environmental factors that affect the growth and development of the plant. Optimum growth requires mean temperatures of 20 to 30 °C and well distributed annual rainfall from 500 to 1 200 mm (Nyambok, 2011).

The plant is better adapted to seasonal variations characterized by wet and dry seasons rather than by warm and cold seasons (Kapinga, 2007). The crop cannot withstand waterlogged conditions therefore clay soils should be avoided. Well drained sandy loam soil is the best. It requires moderate soil pH of 6.0 -7 for optimum production (Kapinga, 2007). Clay and water logged soils affect negatively tuber formation. Inadequate water especially during the stage of tuber development retards development of the tubers (Maniyam, *et al.*, 2012).

2.4 Sweet Potato Growth and Development

The sweet potato plant has three growth phases which are more or less distinct (Jahan *et al*, 2001). The initial phase is characterized by slow vine growth and rapid growth of adventitious roots (CIP, 2006). The first 20 days of this initial phase are important as they determine the total number of storage roots formed (Jahan *et al,* 2001). An intermediate phase follows where there is the rapid growth of vines and an increase in leaf area as well as storage root initiation. In 100 days after planting (DAP), the leaf area is at its maximum and any further increase in biomass is due to storage root formation (Lawrence, 2010). The deposition of starch within storage roots can occur as early as 8 DAP and storage root formation can be visible as early as 28 DAP and by 49 DAP, 80% of the storage roots can be identified (Lisinska and Leszczynski, 1989). At the final stage there is bulking of the storage roots, which can reach a maximum growth after 90 days. Storage roots enlarge throughout the life of the plant but after 120 days enlargement peaks. It should be noted that most of the growth phases are controlled genetically (i.e. variety) and environmentally (i.e. agro ecological conditions of the area where the crop is established) (CIP, 2006).

2.5 Sweet Potato Production in Africa

Sweet potato is a co-staple in East Africa in the densely populated intensively cultivated mid elevation areas. The principal sweet potato producers include Uganda Kenya, Tanzania, Rwanda, and Burundi. It is an important secondary food in many other countries like Nigeria, South Africa, Mozambique, Zambia, and Malawi (Kapinga *et al.*, 2005). The challenge however is to maintain sweet potato's status as a food security crop, and, at the same time, stimulate its transition into a market oriented commodity that local people can use to generate cash income and improve family welfare. Its production across the region is constrained by acute shortage of healthy planting material, pests and diseases and unreliable markets during surplus production. Other many underlying factors include prolonged drought that leave planting materials required by farmers at the onset of planting period. This has resulted into rapid, wide and massive deployment of improved sweet potato varieties in the region that partly accounts for the increases in Sweet potato tonnages in the different countries over the recent past years (Kapinga *et al.*, 2005).

2.5.1 Sweet potato propagation and field establishment in Tanzania

In Tanzania the crop is grown locally in western, lake, southern highland, eastern and central zones and the Common cultivars are *sinia, ukerewe, simama, mavuno, jitihada* and *vumilia,* (Kanyeka *et al.*, 2007). Sweet potato can reproduce asexually by: a) colonizing an area by production of storage roots which subsequently sprout to give new plants, b) reproducing vines which may form roots at the nodes, producing daughter plants. The sweet potato can also reproduce sexually by production of seed, but seed is used only in research for breeding. Sweet potato is a perennial dicot, but it is cultivated as an annual for vines and storage roots (Ames, 2002).

2.5.2 Sweet potato nursery preparation

2.5.3 Sweet potato primary nursery

Nursery preparation starts three months prior to planting in the main field. For planting one hectare of land, about 100 m^2 of primary area and about 100 kg of medium size weevil free vine cuttings are required. The roots are planted at spacing of 20 cm in ridges formed 60 cm apart. To ensure quick growth of vines they are top-dressed with 1.5 kg urea in 100 m^2 at 15 days after planting. The nursery is irrigated every alternative day for the first 10 days and thrice in a week; thereafter, 45 DAP the vines are cut to a length of 20-30 cm for further multiplication in the second nursery.

2.5.4 Sweet potato secondary nursery

To produce enough planting material to plant one hectare of land, vines obtained from the primary nursery are further multiplied in the secondary nursery to an extent of 500 m^2. Farmyard manure (FYM) or compost of 500 kg is applied at the time of nursery preparation in ridges at a spacing of 60 cm apart. Vines obtained from the primary nursery, or from freshly harvested crop, are planted in the secondary nursery at a spacing of 20 cm within ridges. To ensure enough vegetative growth, 5 kg of urea is applied in two splits at 15 and 30 DAP. For better establishment of vines in the nursery, irrigations are provided every alternate day for the first 10 days and thrice in a week thereafter. The vines will be ready for planting in the main field within 45 days (Maniyam *et al.*, 2012).

Vines are used as planting material for propagation; Cuttings shorter than 30 cm with short internodes length of < 2cm result in poor yield. Seed beds are prepared before the beginning of the rains. Sweet potato is mainly grown on ridges or on flat land. Planting on flat land leads to low yield. Ridges are encouraged because they give high yields. Ridges can be up to 30cm high; the ridges give high yield because it allows good root penetration for proper water and nutrient absorption, tuber enlargement, aeration and it control water logged conditions, the higher the ridge the higher the yield (Kanyeka *et al.*, 2007).

2.5.5 Sweet potato seed system

In Tanzania, lack of efficient seed systems for multiplication, improper management of nurseries, lack of techniques for easy and rapid multiplication, and the lack of availability of improved varieties are just some of the causes for declined yields (Kapinga *et al.*, 2005). Nevertheless, there is a lack of information on the specific number of nodes to be buried, the current recommendation of planting cutting size is 30 cm but does not tell the number of nodes and their internodes length (Low, 2010). Maniyam *et al.* (2012) indicated that cuttings of 40 cm with five buried nodes give the optimum yield in India than cuttings of 30 cm with three buried nodes.

2.5.6 Sweet potato vines and branches

Sweet potato has long thin stems that trail along the soil surface and can produce roots at the nodes the stem is called a vine (Lisinska and Leszczynski, 1989). Stem length varies with varieties, internodes length is also highly variable (Zana and Stanley, 1990). Planting density has a pronounced effect on the internodes length as well as vine length. Branches vary in number and length; normally sweet potato plants produce three types of branches primary, secondary and tertiary at deferent periods of growth. The total number of branches varies between 3 and 20 among varieties. Spacing, photoperiod, soil moisture and nutrient supply influence the branching (Belehu, 2003).

2.6 Site Selection and Preparation for Planting

A well drained sandy loam is preferred and heavy clay soils should be avoided because they retard root development resulting in growth cracks and poor root shape.

Lighter soils are more easily washed from the roots at harvest time. Wet season green manure cropping with sterile forage sorghum is recommended and should be thoroughly incorporated and decomposed during planting time (Traynor, 2005). Soil pH should be adjusted to about 6.0 by applying lime or dolomite. Rates of 240 kg and 400 kg ha^{-1} respectively will raise the pH by 0.1 of a unit (McLean 1982). The soil should be deep ripped and then disc cultivated to break up any large clods and provide enough loose soil for hilling of beds.

2.6.1 Variety selection

Selection of sweet potato variety to grow should be based on a number of parameters including tolerant to drought, salt, pest and diseases. However plant vigour, high yielding, tubers shape, skin, flesh attractiveness and tuber roots uniformity is the essential characteristics to be considered. But most significant parameter farmers do prefer is market demand (Traynor, 2005).

2.6.2 Cutting collection and buried number of nodes

Tip cuttings about 30 to 40 cm are collected from the nursery bed or the last established planting. Tip cuttings should be taken from crops that are old enough to provide material without excess damage (Kanyeka *et al.*, 2007). Avoid "back cuts" as these will have variable maturity and result in significant yield reduction, the lower leaves should be cut away as tearing them off may damage the nodes that will produce the roots (Abd *et al.,* 2009). Cuttings can be left under moist cloth in the shade for 3 days to promote nodal rooting before planting in the field (Stephen, 2004). Cuttings should be planted at about 45° angle into the hills as this promotes good root development. Half of the cutting or two third (3 to 4) nodes of planting material should be buried at a spacing of 30 cm between plants (Traynor, 2005 and Maniyam, *et al.*, 2012).

2.7 Crop Yield, Nutrients and Water Requirements

Fertilizer requirements vary depending on soil type, native fertility, previous cropping, cultural practices and cultivar grown. Nutrient elements have specific function in crop growth and development. Nitrogen fertilizers have been found to increase tuber yield, tuber dry matter and starch content in most sweet potato varieties (Stephen, 2004).

Potassium is one of the principal plant nutrients supporting crop yield production and quality determination (Liu *et al.*, 2013). Investigation has shown that potassium can improve crop yield with different application rates and is involved in many physiological processes. Potassium impacts on photosynthesis and assimilates transport can have direct consequences on crop productivity (Akram *et al.*, 2009). Pathirana (1998) advised that farmers producing sweet potato may obtain the maximum yield by Appling 80 kg N ha^{-1}. Whereas Uwah *et al.* (2013) recommended the optimum level of 120 kg K ha^{-1} will increase tuber roots yield.

2.8 Factors Affecting Sweet Potato Growth

2.8.1 Sink-source relations

Morphologically, leaves, stems and roots are vegetative parts of the sweet potato plant. These organs are developed relatively in the same period and use energy from the same sources, namely photosynthesis and respiration (Soenarto, 1994). Functionally, sweet potato plant organs can be divided into aerial and underground parts. The aerial parts, which consist of stem and leaves, function either as sink or as source of photoynthates. The source is mainly limited to leaves which are photosyntetically active. Stems and shaded leaves act primarily as the sink because these organs receive photosynthates from the source (Stephen, 2004). The underground roots and tuberous roots represent the sink. For roots and tuber crops, source-sink relation refers mainly to the relation of the above ground and the underground parts. During their period of growth and development competition between the aerial and the underground parts of a plant occurs in the allocation of carbohydrates (Egbe, 2012). The process of dry matter allocation is determined by many factors, including both internal and external factors.

The different activities among individual plants in photosynthate allocation are shown by their different growth models, pertaining to different activities in source-sink relation. In addition, the variations in tuber yields among varieties are considered as the result from their different activities in allocating dry matter from leaves to tubers (Egbe, 2012). This difference begins with the onset of tuberous root formation. It can be inferred that tuber initiation is also determined by the relation of the source and the sink activities. As an internal factor, the sink is considered to be more important than the source in determining dry weight of tuber yield (Stephen, 2004). Tuber initiation is possible since both photosynthetic activity and active translocation depend on the sink capacity. In addition, increase in net assimilation rate (NAR) may stimulate the increase in tuberous root development (Tsuno and

Fujise, 1998). This means that if the sink capacity is high it promotes photosynthetic rate because most of the photosynthates can be translocated from leaves to tubers. However, low tuber growth may decrease the photosynthetic activity (Stephen, 2004). Concerning their growth and development, the aerial parts and the tubers require different environmental conditions which may cause contradictory effects occurring on both organs.

2.8.2 Importance of leaf area index on sweet potato growth

Leaf area index (LAI) is an important structural property of crop canopy (Sokoto *et al.*, 2014). Leaf area index is defined as the ratio of total upper leaf surface of vegetation divided by the surface area of the land on which the vegetation grows. LAI is used to predict the photosynthesis capacity of a crop and as a reference tool for crop growth (Sokoto *et al.*, 2007). High correlations were found between reflectance factor and LAI and biomass by Ahlrichs and Bauer (1983). By definition, any LAI below 1 will allow some light energy to fall onto the soil.

Due to the natural display of leaves, however, the LAI must be considerably above 1 before most of the light will be intercepted. The leaf area (LA) is important for the interception of solar radiation and for the biomass production. The light extinction coefficient (k) is related to the leaf inclination angle, leaf arrangement, regarding the LAI, providing an indication of the plants efficiency on intercepting the solar radiation. Studies with this emphasis provide important answers about the use of solar radiation by the plants (Ahlrichs and Bauer, 1983). Leaf area index varies widely among sweet potato varieties and at different growth periods, depending on the number of leaves retained on the stem and their size (Belehu, 2003). Shorter photoperiod, increasing N application and decreasing plant density increases leaf area of individual leaves and leaf area plant^{-1}. Changes in leaf area index during growth occur in three phases. The declining of LAI occurs during the third phase from 90 to 150 DAP and above. The declining of LAI is for the expenses of bulking of tuber roots. Maximum LAI of between 2 and 11 for sweet potato have been reported (Ahlrichs and Bauer, 1983).

2.8.3 Factors affecting sweet potato tuber roots growth and development

2.8.3.1 Light

Sweet potato is a tropical plant which requires a high light intensity throughout the period of its growth. This plant has a high solar radiation fixing efficiency (Maniyam *et al.*, 2012). A study on sweet potato shows that solar radiation significantly affected root growth rate through crop growth rate (CGR) and net assimilation rate (NAR) when LAI was over 3.0 (Maniyam *et al.*, 2012). In addition, in the first half of the growing period, CGR was significantly influenced by temperature and LAI. However, in the second half of the growing period, CGR was more significantly affected by both NAR and solar radiation than it was by temperature and LAI (Kuhlase *et al.*, 2009). It was suggested that root development be promoted by interactions between low light intensity and relatively low temperature, short light, long light and long dark periods (Somasundaram and Santhosh, 2008). On the contrary, aerial part development is affected by a combined effect of high temperature level with high light intensity, long light and short dark periods (Somasundaram and Santhosh, 2008).

2.8.4 Temperature

Air and soil temperature affect root and tubers growth differently. Low night temperature tends to promote tuber growth. Besides that, thermoperiodism having a day and night temperature (30 and 20°C) enhances tuber formation (Somasundaram and Santhosh, 2008). These conditions also increase tubers weight, number of tubers and ratio of ground and top growth compared with that having a constant temperature of 29°C. Tubers formation is also promoted by root temperature between 25 and 30°C (Mukhtar *et al.*, 2010). At 35°C much less tuber roots and more fibrous roots tend to be formed.

Tubers roots are also produced much less at 20°C or below, but in such environment more fibrous tuber roots are formed than that at 35°C. Furthermore, at 10°C no tuber roots are produced (Maniyam *et al.*, 2012).

2.8.5 Soil moisture

Forty days after planting is the most critical period of sweet potato growth (Edmond and Ammerman, 1971). This period represents the onset of tubers bulking (Mukhtar *et al.*, 2010). Reduction in tubers yield results from insufficient water during the period of vine growth, especially during the critical period (Edmond and Ammerman, 1971).

On the other hand, excessive water, as in waterlogged soils, inhibits tubers formation; also this condition promotes fibrous development and increase leaf and petiole weight (Soenarto, 1994).

2.8.6 Nitrogen

The yield is generally low without N application, while a high level N- application also decreases yield (Mukhtar *et al.*, 2010). A negative correlation exists between N content in leaf lamina and the ratio of dry matter content in tubers to that in the whole plant (Tsuno and Fujise, 1998). Further, the effect of N on yield is determined by leaf area. Plants having a small leaf area require high N supply, while in plants having a large leaf area the N supply must be decreased (Mojtaba, 2013). Increase in N supply not only increase leaf area index (LAI) but also increases leaf duration (LAD) although increases in LAI builds up the weight of the arial parts, which increases mutual shading of lower leaves and in turn decreases the net assimilation rate (NAR) (Soenarto, 1994).

In addition, NAR is also reduced by the increase in LAD and since the most of photosythates are used for developing the aerial parts, the ratio of tubers to the above parts is reduced when N content of the leaf blade is larger than 2.2% (Mojtaba, 2013). The effect of N on the photosynthetic activity is promoted by the K content of the leaf blade on contrary the photosynthetic activity is decreased with a lower N content (Soenarto, 1994).

2.8.7 Phosphorus

Stephen (2004) working on sweet potato found that the effect of P on the crop was low. This was probably due to the ability of sweet potato plant to absorb large quantities of natural P. Plants treated with P produce tuber which are longer in shape, sweeter and drier (Stephen, 2004). Furthermore, since P is an essential element in glucose- monophosphate, by which starch is formed, starch accumulation might be related to the P content (Stephen, 2004).

2.8.8 Farm yard manure (FYM)

Farmyard manure (FYM) is an important source of essential plant nutrients and organic matter for crop production in the small-holder sector and can help farmers reduce inputs of commercial fertilizers and increase enterprise profitability (Mubonderi *et al.,* 1999). The FYM contains a broad range of plant nutrients although at a lower concentration than inorganic fertilizers (Miles *et al.,* 2002). Current information showed that FYM of 20 t ha^{-1} resulted into high yielding dry weight of sweet potato (11.11 t ha^{-1}) (Teshome and Nigussie, 2012). Quality of FYM research conducted by Kimbi and Semoka (2004) in Dodoma region central Tanzania, reported low FYM nutrient contents with the following trend (N, 1.05 %, P, 0.47 % K, 1.52%, Ca, 0.3 % and Mg, 0.5 %).

2.9 Potassium and Potato Production

2.9.1 Role of potassium in plants

Potassium is one of the essential nutrient elements needed by plants (Young 2010). This element is the major inorganic constituent of plants, besides the concentration of K in a plant is higher than that in soil solution (Stephen, 2004). This element is found in a concentration level than other cations in plants. This plant nutrient has a vital function in many physiological processes in plant cells. Potassium is a univalent cation and is always found in an ionic form (Young 2010). This form facilitates K ions to move from one tissue to another such as meristematic tissue, where K is required to support their growth. Sweet potato like sugarcane, round potato and cassava are crops with high demands for K because leaves, vines, stems and tubers usually remove 60 to 80 % of K ha^{-1} from the soil (Maniyam *et al.*, 2012). Potassium appears to be the most important nutrient in the production of sweet potato as its application increases yield by the formation of larger sized tubers (Bishnu and Krishna, 2006). Potassium also 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 (Degras, 2003).

Sweet potato yield is significantly depressed if K is deficient, but eliminating P does not seem to affect the yield as the crop is well adapted to low levels of available P on account of its mycorrhizal association which makes P available to it. In Japan, it was estimated that a tuberous yield of 13 t ha^{-1}· removes about 70 kg N ha^{-1}, 20 kg P ha^{-1} and 110 kg K ha^{-1} from the soil depending on the variety, crop duration and agro-climatic region (Degras, 2003). Comparisons of this kind are rare for tropical areas including Tanzania. Common recommendations in most tropical countries are 65-80 kg N, 50-100 kg P and 80-170 kg K $^{-1}$ (IFA, 1991). In the Hubei province of China, the optimum K rate varied from 150-300 kg K ha^{-1} (Jian-wei *et al.*, 2001). Sweet potato response to applied K is considerably influenced by the variety grown (Trehan, 2007). The varietal response to applied K is often related to its yield potential and the number of large sized tubers it can produce. Generally, rapid bulking varieties producing large sized tubers respond more to K than do the varieties with small tubers (Trehan and Grewal, 1990).

2.9.2 Function of potassium in plants

The functions of potassium in plants are enzyme activation, water relations, energy relations, translocation of assimilates nitrogen uptake, protein synthesis and starch synthesis (Stephen, 2004). Apart from outlined roles of K, also the nutrient may increase the number of root crops including sweet potato (Uwah *et al.*, 2013).

2.9.3 Water relation

There are three important roles of potassium dealing with plant water relations; these include Osmotic regulation, stomata functioning and transpiration rate (Stephen, 2004). When water supply is short, K is pumped out of the guard cells. The pores close tightly to prevent loss of water and minimize drought stress to the plant. If K supply is inadequate, the stomata become sluggish slow to respond and water vapor is lost. Closure may take hours rather than minutes and is incomplete. Plants with insufficient supply of K are much more susceptible to water stress (Bishnu and Krishna, 2006). Accumulation of K in plant roots produces a gradient of osmotic pressure that draws water into the roots. Plants deficient in K are thus less able to absorb water and are more subject to stress when water is in short supply (CFFA, 2011).

2.9.4 Enzyme activation

Enzymes serve as catalysts for chemical reactions, being utilized but not consumed in the process. They bring together other molecules in such a way that the chemical reaction can take place. Potassium "activates" at least 60 different enzymes involved in plant growth. The K changes the physical shape of the enzyme molecule, exposing the appropriate chemically active sites for reaction (Stephan, 2004) Potassium also neutralizes various organic anions and other compounds within the plant, helping to stabilize pH between 7 and 8 optimum for most enzyme reactions (CFFA, 2011). The amount of K present in the cell determines how much enzymes can be activated and the rates at which chemical reactions can proceed. Thus, the rate of a given reaction is controlled by the rate at which K enters the cell.

2.9.5 Photosynthesis

The role of K in photosynthesis is complex, the activation of enzymes by K and its involvement in adenosine triphosphate (ATP) production is probably more important in regulating the rate of photosynthesis than the role of K in stomatal activity. When the sun's energy is used to combine CO_2 and water to form sugars, the initial high-energy product is ATP. The ATP is then used as the energy source for many other chemical reactions. The electrical charge balance at the site of ATP production is maintained with K ions. When plants are K deficient, the rate of photosynthesis and the rate of ATP production are reduced, and all of the processes dependent on ATP are slowed down. Conversely, plant respiration increases which also contributes to slower growth and development. In some plants, leaf blades re-orient toward light sources to increase light interception or away to avoid damage by excess light (CFFA, 2011).

2.9.6 Stomatal activity

Plants depend upon K to regulate the opening and closing of stomatal pores through which leaves exchange carbon dioxide (CO_2), water vapor, and oxygen (O_2) with the atmosphere. Proper functioning of stomata is essential for photosynthesis, water and nutrient transport and plant cooling (Stephan, 2004). When K moves into the guard cells around the stomata, the cells accumulate water and swell, causing the pores to open and allowing gases to move freely in and out in effect assisting to regulate the rate of photosynthesis. These movements of leaves are brought about by reversible changes in turgor pressure through movement of K into and out of specialized tissues similar to that described above for stomata (Soenarto, 1994).

2.9.7 Transport of sugars

Sugars produced in photosynthesis must be transported through the phloem to other parts of the plant for utilization and storage (IPI, 1999). The plant's transport system uses energy in the form of ATP. If K is inadequate, less ATP is available, and the transport system breaks down. This causes photosynthates to build up in the leaves, and the rate of photosynthesis is reduced. Normal development of energy storage organs, such as grain, is retarded. An adequate supply of K helps to keep all of these processes and transportation systems functioning normally (IPI, 1999).

2.9.8 Water and nutrient transport

Potassium also plays a major role in the transport of water and nutrients throughout the plant in the xylem (Young, 2010). When K supply is reduced, translocation of nitrates, phosphates, calcium (Ca), magnesium (Mg), and amino acids is depressed. As with phloem transport systems, the role of K in xylem transport is often in conjunction with specific enzymes and plant growth hormones. An ample supply of K is essential to efficient operation of these systems (IPI, 1999).

2.9.9 Crop quality

Potassium plays significant roles in enhancing crop quality (Sood *et al.*, 2008). High levels of available K improve the physical quality, disease resistance, and shelf life of fruits tuber roots and vegetables (Soenarto, 1994). Quality can also be affected in the field before harvesting such as when K reduces lodging of grains or enhances winter hardiness of many crops. (Latha and Indirani, 2004). The effects of K deficiency can cause reduced yield potential and quality long before visible symptoms appear (Sood *et al.*, 2008). This "hidden hunger" robs profits from the farmer who fails to keep soil K levels in the range high enough to supply adequate K at all times during the growing season (Latha and Indirani, 2004). Even short periods of deficiency, especially during critical developmental stages, can cause serious losses (Bishnu, 2006).

Storage roots vary in shape and size according to the cultivar, type of soil where the plant is grown, fertilizers applied and other factors (Huaman, 1999). The outline of their shape can be round, round-elliptic, elliptic, ovate, obovate, oblong, long oblong, long elliptic, and long irregular or curved. Growing sweet potato in soils rich in K produces quality tuber roots (Soenarto, 1994). The storage root skin color can be whitish, cream, yellow, orange, brown-orange, pink, red-purple, and very dark purple. The intensity of the color depends on the environmental conditions where the plant is grown. The flesh colour can be white, cream, yellow, or orange. However, some cultivars show red-purple pigmentation in the flesh in very few scattered spots, pigmented rings or, in some cases, throughout the entire flesh of the root (Huaman, 1999).

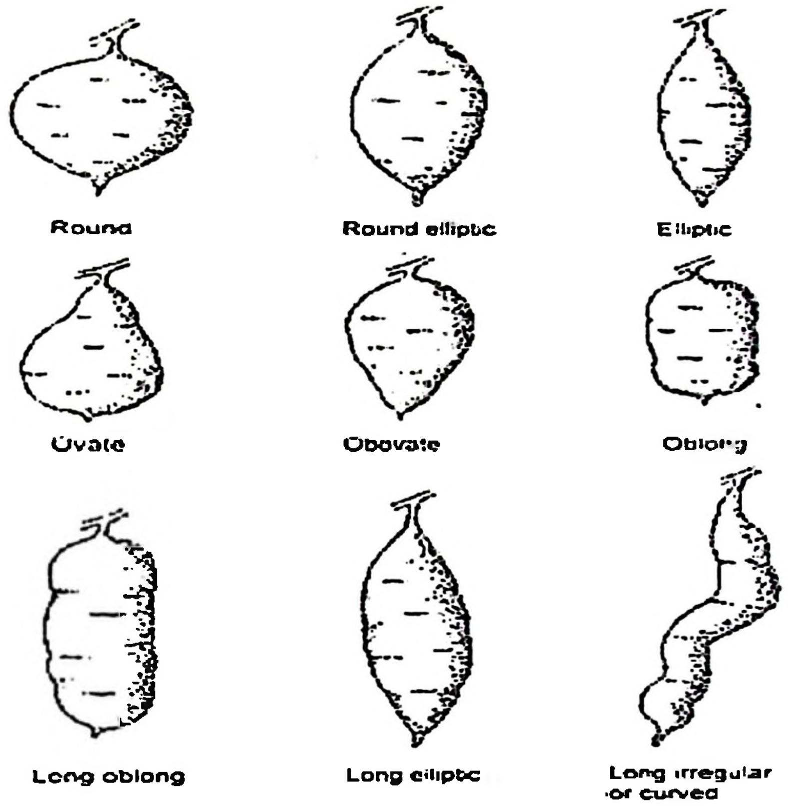

Figure 1: Types of storage root shapes adopted from Huaman (1999)

2.10 General Sweet Potato Agronomic Practices

2.10.1 Weed management

If weeds are not controlled during plant establishment and within the first two months after planting, they compete with sweet potato plants for nutrients and water as well may harbour pests and diseases. Weeds are typically removed manually, once the vines have grown together and covered the ridges; there is little need for further weeding. However, in very wet regions, further selective weeding may be required to remove stubborn or vigorous growing weeds. If these are few and scattered hand pulling can be practiced otherwise a hoe is used gently ensuring that any storage roots remain covered by soil (Stathers *et al.*, 2005).

2.10.2 Sweet potato mulching and crop rotation

Mulches can be described as organic materials which are placed on the top of the soil to provide a blanket effect. Good mulch will increase the soil's water-holding capacity, reduce evaporation, keep the soil structure soft and open, increase the organic matter content, suppress weeds and provide slow-release nutrients. Mulches are generally applied during the warm and active growing season to keep soil temperatures in balance and reduce stress to the crop (Smith *et al.*, 2009).

2.10.3 Vine lifting and hilling-up

If the soil is moist and the stem of a vine touches it, roots will grow from the nodes. Some producers lift these vines to prevent roots forming into small non-marketable storage roots. If this is done, care should be taken to just lift the vines and not to turn them over (Smith *et al*, 2009). Hilling-up is done to ensure the developing storage roots are well covered and not exposed to sun or attack by weevils. Soil is hoed up around the base of the plant, closing cracks in the soil caused by expansion of storage roots, or erosion of the ridge or mound away from the crown of the plant (Stathers *et al*,. 2005).

2.10.4 Irrigation of sweet potato crops

Irrigation is rarely used on sweet potato crops in Sub-Saharan Africa with the exception of South Africa. Although sweet potato is considered to be fairly drought tolerant, water is one of the most limiting factors for sweet potato production and drought causes serious yield losses (Smith *et al.,* 2009). The effect of drought conditions depends on when during the growth stage the water shortage occurs.

A well-distributed rainfall of 500 to 1 200 mm during the growth cycle is sufficient for high productivity. Irrigation can also be used to reduce soil temperature. Most irrigation methods are furrow, drip, flood, and sprinkler. Furrow irrigation can be used when the crop is planted on ridges. Drip irrigation is currently practiced under some research environments, and is the most water efficient method. The 5 mm water day^{-1} is said to be appropriate for sweet potato growth and yield (Maniyam *et al.*, 2012).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 General Description of Study Area

This study was conducted at Agricultural Research Institute (ARI) Hombolo in Dodoma region, Tanzania. The Institute lies between latitude 2° 54' S and longitude 35°.57' E at an elevation of 1062 meter above sea level (masl) (Hatibu *et al.* 1995). The area experiences short rainfall and rains usually start during the second week of December to the end of January. Normally there is no rain in February up to second week of March to the end of April with a mean annual rainfall ranging between 500 and 610 mm. Mean annual temperature ranges from 20 to 32 °C (TMA, 2013). The main part of the experimental area is comprised with sand clay loam soil, bushes with short trees. Short grasses can be seen during rainy season, although such grasses survive for a short time from December to April. The long period of eight months from May to December the type of vegetations at Hombolo is dried bushes, and shrubs (Hatibu *et al.* 1995).

3.2 Experimental Materials

Three sweet potato varieties: *Kiegeya, Mataya* and *Ukerewe* were used in the experiment. These were obtained from Kibaha Agricultural Research Institute in Coast Region, which has the mandate to conduct research on sweet potato. Inorganic fertilizers used were potassium chloride (60% K), NPK (10 % N, 18 % P, 24 % K) bought from agrochemical supplier Balton in Arusha Tanzania whereas Farm yard manure used was collected from farmers' *bomas* close to ARI– Hombolo.

3.3 Methods

3.3.1 Soil sampling and analysis

Soil sampling was done as suggested by Okelebo *et al.* (1993) and Bremner (1982) at the depth of 0–25 cm and one composite soil was organized and taken to Sokoine University of Agriculture (SUA) soil laboratory for physical and chemical analysis. The 2 mm sieved composite soil sample was analysed for soil particle size distribution and bulk density. The soil chemical properties analysed were pH, organic carbon, cation exchange capacity (CEC), total N, available P, exchangeable bases namely K, Ca, Na, and Mg as (Table 1).

Table 1: Soil characterization for sweet potato experiment

Soil characteristics	Method used	Reference
Physical		
Soil texture		
Clay (%)		
Silt (%)	Bouyocous hydrometer-	
Sand (%)	Kettler (2001).	Landon (1991)
Bulk density (g cm^{-3})	Core method – Blake and Hartge (1986).	Landon (1991)
Chemical		
pH(H_2O)	pH in water: soil to water suspension (1:2.5) - Thomas (1982).	Landon (1991)
Total N (%)	Micro Kjeldahl method - Bremner (1965)	Landon (1991)
Extr P(mg/kg)	Bray and Krutz 1 method- Olsen and Somners (1982).	Landon (1991)
CEC ($cmol_c$/kg)	Extraction with NH_4-Ac saturation – Issam (2007).	Landon (1991)
Exch Ca^{2+}($cmol_c$/kg)	Ammonium Acetate by	
Exch Mg^{2+}($cmol_c$/kg)	Atomic absorption	
Exch K^{+}($cmol_c$/kg)	spectrometer- Issam (2007).	
Exch Na^{+}($cmol_c$/kg)		Landon (1991)

3.3.2 Farm yard manure analysis

Nutrient contents of FYM were analysed for chemical characteristics such as pH, total K, P, N, Mg, Ca and Na before planting. Farm yard manure pH was determined in water: manure to water suspension 1:2.5. Total nitrogen was determined using Micro Kjeldahl method. Phosphorous extract was determined using Bray and Krutz 1method and exchangeable bases were determined using Atomic Absorption Spectrometer, all methods for FYM determination were described by Peters (2003). The results are well presented in Table 3.

3.3.3 Land preparation, experimental layout and treatment application

3.3.3.1 Land preparation

Land preparation was done as described by Kanyeka *et al.* (2007). Land preparation process included cleaning and plouwing. Cleaning was done by using machete where leaves and trees were slashed. A four wheel tractor was used to plough to a depth of 25 cm, followed by land leveling was done by using hand hoe and racks.

3.3.3.2 Experimental layout and treatment applications

A split–split plot experiment in randomized complete block design (RCBD) as described by Gomez and Gomez (1984) was applied. The main plot size of 453 m^2, sub plot size of 36 m^2 and sub–subplot size of 9 m^2 were used. Before ridge construction, 15.3 kg farm yard manure was early spread and incorporated into soil in sub-subplots using hand hoe. Ridges were constructed and the treatments applied accordingly where the main treatments factor (a) was three sweet potato varieties (*Kiegeya Mataya* and *Ukerewe*). The sub treatments were decided following recommendation given by Parwada *et al.* (2011) meant burring two third of the total number of nodes per vine used. Therefore, in this study sub treatments were applied as follows; four nodes buried (two above ground), five nodes buried (three above ground), seven nodes buried (three above ground) eight nodes buried (four above ground). The sub- sub treatments (c) were K fertilizers sources (i) potassium chloride (KCl) (ii) nitrogen potassium phosphate (NPK) (ii) Farm yard manure and (iv) control no fertilizer used. All were applied at 120 kg K ha $^{-1}$ with the exceptional of the control plots.

3.3.3.3 Irrigation method

A furrow of 30 cm diameter and 15cm depth was constructed 3 DAP to facilitate irrigation. Water was applied twice per week up to 115 DAP and the quantity of water supplied was calculated using the following formula as described by Anton (1982).

$$WQ\,(m^3) = FCS\,(m^2) \times \frac{\text{Water distance covered(m)}}{\text{Time (min)}} \times \text{Irrigation time (min)} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where; WQ = Water quantity, FCS = furrow cross section

3.3.4 Data collection

3.3.4.1 Weather data

Daily rainfall (mm), minimum and maximum temperature (^{o}C) and percentage relative humidity (RH %) were recorded from the Tanzania Meteorology Agency (TMA) at ARI–Hombolo station.

3.3.4.2 Data collected during vegetative growth phase

Crop vegetative growth and developmental stages from sprouting to vine formation were recorded at interval of 45 DAP as described by Maniyam *et al.* (2012). Data collected included vine length (cm), number of leaves, number of roots formed and vine fresh and dry weight (kg), tuber root diameter and length (cm). All data were collected on per plant basis.

Leaf area index (LAI) determination

Leaf area index was determined by taking five plants from the middle ridges of each plot and LAI was determined using graph paper as described by Gregory *et al.* (2003). Leaf area index was then calculated using the following ratio relationship.

$$\text{Leaf area index} = \frac{\text{Total leaf area (m}^2\text{)}}{\text{Total ground area (m}^2\text{)}} \quad \text{...(2)}$$

Number of branches

Number of branches was determined by counting branches from five plants of the central ridge and average recorded.

Vine length per plant (cm)

Vine length was measured by using a tape measure, five plants from the central ridges measured then an average recorded.

Number of roots per plant

Number of roots per plant was determined by uprooting and counting roots from five plants in the middle ridges and average taken. The following relationship was used to calculate roots average

$$\text{Average number of roots} = \frac{\text{total number of roots/five plants}}{\text{number of plants sampled}} \quad \text{.....................(3)}$$

3.3.4.3 Data collected at physiological maturity stage

The experiment was harvested 120 DAP when two third of sweet potato leaves turned yellow. Harvesting process involved uplifting plants from the central rows (1.125 m^2) per plot using hand hoe to determine the yield components.

Number of tuber roots per plant

Number of tubers was determined by counting tuber roots from each plant among five randomly selected plants per plot and the average was taken.

Marketable tuber roots per plant

Marketable tubers was determined by measuring diameter (cm) using a ruler, greater or equal to 3 cm were regarded as marketable and those with less than 3 cm diameter were regarded as non marketable tubers as described by Uwah *et al.* (2013). This was similar to farmers classification used at Hombolo for the same characteristic.

Yield (kg) per m^2

Tuber roots yields from $1.125m^2$ of the five plants harvested from each plot was determined by weighing all marketable tubers using Tough AKB balance with capacity 20 kg manufactured in China.

3.3.4.4 Sweet potato tuber physical quality characteristics determination

Ten tubers were sampled from each sub- sub plot and used for physical quality determination. Variables analysed were weight (kg), diameter (cm) and length (cm). The shape, colour, texture, skin and flesh colour were determined as described by Abong *et al.* (2010). Tuber roots chemical characteristics such as vitamin A, starch and vitamin C were not determined because of inadequate funds for the analyses required.

3.3.5 Data analysis

Data collected were subjected to analysis of variance (ANOVA) using GENSTAT statistical model.

$$Yijk = \mu + R_i + Vj + (Ea)_{ij} + (F)k + (VF)_{jk} + (Eb)_{ik} + (N)_l + (VN)_{jl} + (FN)_{kl} + (VFN)_{jkl} + (Ec)_{ijkl} \quad (4)$$

Where;

Y_{ijkl} = Response,

μ = General mean,

R_i = Replication effect (ith)

$(V)_j$ = jth effect of varieties, (factor a)

$(Ea)_{ij}$ = Main plot error (error a)

$(F)_k$ = ith effect of number of nodes, (factor b)

$(VF)jk$ = Interaction of varieties and number of nodes (a*b)

$(Eb)_{ik}$ = sub–plot error (error b)

$(N)i$ = number of fertilizers (factor c)

$(VN)_{jl}$ = interaction of varieties and fertilizers (a*c)

$(FN)_{kl}$ = Interaction of fertilizer and number of nodes (b*c)

$(VFW)_{jkl}$ = Interaction of varieties, Fertilizer and number of nodes (a*b*c)

$Ec)_{ijkl}$ = Experimental error.(error c)

The mean separation tests were done using Tukeys Test at $P \leq 0.05$.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Soil Characteristics

4.1.1 Physical characteristics

The results on soil physical and chemical analysis of samples collected from the experimental area at a depth of 0 – 25 cm are presented in Table 2. According to Landon (1991), soils have textural class of sand clay loam. Further, following procedures described by Issam (2007), Frank and Knudsen (1974), the bulk density of 1.3 g/cm^3 has medium porosity and soil compaction. Such soil is recommended for sweet potato production as it allows soil aeration for root growth, penetrations, water and nutrients uptake. The availability of pore space resulted into good and quality tuber roots formation (Maniyam *et al.*, 2012).

4.2 Soil Chemical Properties

4.2.1 Soil pH

The soil pH was found to be medium with a value of 6.01 at depth of 0 – 25 cm, according to Landon (1991). The optimum soil pH for sweet potato ranges between 6 and 7 (Benny 2013). Based on these, soils at Hombolo are suitable for sweet potato cultivation because such soil (pH) fovours availability and uptake of macro nutrients required by the crop. Also it allows root cell division, elongation and growth (Nyambok, 2011).

4.2.2 Total nitrogen (N)

The percentage of total nitrogen (N) recorded was 0.07%, which is equivalent to 2.275 kg ha^{-1}. According to Landon (1991) this value is very low. Sweet potato requires 65-80 kg N ha^{-1} as recommended for optimized tuber yield (Pathirana (1998) and Uwah *et al.*, 2013). Total N reported in this study may be associated with environmental factors such as low rainfall as a limit for organic material decomposition and poor agronomic practices that leads to soil mining due to crop removal without replacement of nutrients. Nitrification, di-nitrification, overgrazing, vegetation burning and limited addition of soil amendments such as the use of organic or inorganic fertilizers also usually result into low N.

4.2.3 Available phosphorus (P)

The available P in the soils at the site was 3.09 mg kg^{-1} (equivalent to 6.18 kg P ha^{-1}). This value is rated as low P according to Landon (1991). Sweet potato P requirements in east Africa including Tanzania is 60 kg P ha^{-1} (Kuoko *et al.*, 2007). The low P at the experimental area may have been caused by surface water runoff, soil attached P, erosion and leaching (Frank and Knuden, 1974). Therefore, the current results indicate that soils used would not satisfy the P requirement by the crop. Such condition calls for additional P to such soils for enhancing sweet potato crop growth and yield.

4.2.4 Potassium (K)

The exchangeable K in the soil was found to be 0.057 $cmol_c^{(+)}$ kg^{-1} this amount is equivalent to 44.46 kg K ha^{-1} which is rated as low Landon (1991).

The recommended amount of K ha^{-1} for sweet potato tuber formation in tropical countries such as Nigeria, Malawi, Zimbabwe, Ethiopia and Egypt has been reported to be 100-132 kg K ha^{-1} (Uwah *et al.,* 2013). In Tanzania there is a limited of document on K recommended rate for sweet potato (Kuoko *et al.,* 2007). Thus the soil K value of 44.46 kg K ha^{-1} soil at the experimental site is low in relation to sweet potato requirements.

The low K at the investigational area may have been caused by soil mining through sweet potato vegetative removal with 70 kg K $ha^{-1}$from the soil, fixation by clay minerals and leaching which have been probably caused by rain fall and irrigation (Osmond *et al.,* 2005). Therefore there is a need to use potash fertilizers for sweet potato growing at Hombolo especially at the area of an irrigation scheme.

4.2.5 Organic carbon (OC)

The organic carbon content in the soil was found to be 0.67 %, equivalent to 21.78 kg OC ha^{-1}. This value is rated as very low (Landon, 1991). This amount of OC is an indicator that at the experimental area has deficiency of organic matter as resulted in low CEC.

The low OC determined from this study may have been caused by low rate of organic matter decomposition because of inadequate rainfall vegetation burning and over grazing. To improve soils condition for crop production, amendment of the soils should be done through incorporating manure and plants residuals in the soil.

4.2.6 Cation exchange capacity (CEC)

Cation exchange capacity (CEC) of the experimental area was 6.8 $cml_c^{(+)}$ kg,$^{-1}$ the values is rated as being low according to Landon (1991). The low CEC of the soils recoded in this study could have been due to the low organic matter content. The results recorded from the experimental area call for addition of organic matter by incorporating soil with vegetation and minimizing crop soil mining by crop removal and vegetation burning.

Table 2: Some of the physical and chemical properties of the soils 0 – 25 cm depth at Hombolo

Soil characteristic	Method	Value	Remarks*
Physical characteristics			
Soil particle analysis			
Sand %	Bouyocous hydrometer-	63	Textural class
Silt %		5	Sand clay loam
Clay %		32	
Bulk density	Core Method	1.3 g $cm^{3\ -1}$	medium
Chemical characteristics			
Soil pH	Electrometrical in 1:2.5 soil H_2o	6.01 (H_2O)	Medium
Total Nitrogen	Micro Kjeldhl	0.07 %	Very Low
Available Phosphate	Bray 1	3.09 mg kg $^{-1}$	Low
Potassium (K^+)	Flame photometer	0.057 cmolc kg $^{-1}$	Low'
Organic carbon		0.67 %	Very low
Cation exchange capacity	Buffer ammonium acetate	6.8 cmolc $^{(+)}$ kg $^{-1}$	Low
Exchangeable Bases			
Calcium (Ca^{2+})	Atomic absorptionspectrophotometer (ASS)	3.26 cmolc $^{(+)}$ kg $^{-1}$	high
Magnesium (Mg^{2+})		1.3 $cmol_C$ $^{(+)}$ kg $^{-1}$	Medium
Sodium (Na^+)	Flame photometer	0.14 $cmol_C^{(+)}$ kg $^{-1}$	Low

* According to Landon (1991)

4.2.7 Exchangeable bases (Ca, Mg and Na)

Calcium Ca^{2+} availability at the experimental site was 3.26 $cmol_c^{(+)}$ kg^{-1} which rated as high according to Landon (1991). The exchangeable Mg in the soil was 1.3 $cmol_c^{(+)}$ kg^{-1} these values are rated as medium according to Landon, (1991). The medium value for Mg^{2+} and appropriate Ca^{2+} had no negative effect on sweet potato growth and yield because no any symptoms of Ca and Mg deficiencies such as leaf necrosis, sweet potato growth failure in the early stage and chrolosis of young and older leaves were recorded. However, no Na deficiency symptoms such as sweet potato stunted growth due to inappropriate uptake of K were detected therefore Na in such soil had no negative effect. (Subbarao *et al.,* 2003).

4.2.8 Farm yard manure chemical characteristics

Results of chemical characteristics of FYM sampled at ARI - Hombolo the pH was 8.3 as shown in Table 3. The total N was 0.9%, total P was 0.48 % total K was 0.69 %. According to Kimbi and Semoka (2004) the FYM pH is rated as medium, while the rest of the nutrient contents were rated as low. This study indicates that 17 tons of FYM will supply 91 kg N ha^{-1}, 30 kg P ha^{-1} and 120 kg K ha^{-1}. The low nutrients observed from FYM may have been caused by types of animal breeds, low food quality used for livestock feeding and inappropriate FYM handling and storability as resulted in loss of essential plant nutrients such as N, P and K (Ogendo *et al.,* 2008).

Table 3: Farm Yard Manure Chemical Characteristics

Characteristic	Value	Remarks*
Farm yard manure pH (H_2O)	8.3	Slightly alkaline
Total Nitrogen (%)	0.9	Low
Organic carbon (%	0.87	Low
Total phosphate (%)	0.48	Low
Calcium (%)	2.87	Low
Magnesium (%)	0.4	Low
Total potassium (%)	0.69	Low
Sodium (%)	0.9	Low

*According to Kimbi and Semoka (2004)

4.3 Weather Data During Growing Season

4.3.1 Weather data collection

Weather data on rainfall (mm), temperature (°C) and relative humidity (%) were collected from Tanzania Meteorology Agency (TMA) at ARI- Hombolo as indicated in Table 4. However, solar radiation data could not be recorded because there was no instrument for recording this variable.

4.3.2 Rainfall (mm)

Sweet potato crop was planted on February 1, 2013 total monthly rainfall was 4.2 and 0.8 mm during January and February 2013 respectively. The rainfall distribution had low impact on crop growth and establishment in all treatments. However, the situation got worse in March 2013 when total monthly rainfall recorded was 0 mm. Sweet potato grows and develops well to the optimal yield when supplied with well distributed rainfall of 500 to 1 200 mm (Nyambok, 2011). This situation call for addition amount of water to supplement the quantity required, which was done through irrigation of which the average of 16 mm was supplied per day and irrigation was done twice a week. This amount was enough to support plant growth and development.

4.3.3 Temperature (°C)

Weather data at the experimental site during the entire period of the study is presented in Table 4. The average temperature ranged from 19.6 to 31.9 °C. The highest temperature was recorded in February, 2013 where it averaged 31.3 °C with the month's minimum value being 20.4 °C as presented in Table 3. From the data minimum and maximum temperature values recorded during the growing season was within the range of the crop requirement. Nyambok (2011) described that the crop grows and yield well when minimum and maximum temperature is 20 to 32 °C respectively. Low temperature (20 °C) is suitable during the night for tuber roots formation and high temperature (30 °C) is appropriate during the day for sweet potato vegetative growth (Stephen, 2004).

4.3.4 Relative humidity (%)

The RH at the research site for the whole research period ranged from 73.4 to 79.9 %, with the average of 76.9 % as depicted in Table 4. The highest RH value was 79.9 %, recorded in January 2013. Such results may have probably been influenced by the rainfall availability in terms of its amount and distribution for this month as compared with the months of March, 2013. The values of RH recorded during this research had no negative effect on the sweet potato growth and development since no signs of fungal disease infection were recorded. Bello *et al.* (2012) described that sweet potato fungal diseases which are rust *(Coleosporium ipomoeae)*, white rust *(Albugo ipomoeae)*, leaf sport *(Alternaria spp)*, stem rot *(F. oxysporum)*, grow optimally at very high RH between 85 and 100 %, the values that were not recorded during this study.

Table 4: Weather data for 2013 growing season at ARI- Hombolo

Month/Year		Temperature (°C)		
	Rainfall (mm)	Max	(Min)	RH (%)
Jan 2013				
Week 1	9.31	29.9	20.1	84.6
Week 2	0	30.4	20.0	77
Week 3	6	30.9	20.7	80.6
Week 4	1.6	33.2	20.9	77.4
Sub-total	**16.9**	–	–	–
sub Mean	**4.2**	**31.1**	**20.4**	**79.9**
Feb 2013				
Week 1	2.5	29.3	19.3	82
Week 2	0.01	32.1	20.8	72.9
Week 3	0.7	31.2	19.7	83.4
Week 4	0	32.6	19.8	72
Sub-total	**3.21**	–	–	–
sub Mean	**0.8**	**31.3**	**19.9**	**77.6**
Mar 2013				
Week 1	0	32.6	20.6	66.8
Week 2	0	31	20.5	73
Week 3	0	29.5	18.9	87
Week 4.	0	30.6	19.4	67
Sub Total	**0**	–	–	–
Sub Mean	**0**	**30.9**	**19.8**	**73.4**
Apr 2013				
Week 1	6	30	20.1	82.5
Week 2	2.3	28	18.5	84.4
Week 3	0.04	30.4	20.7	73
Week 4	1.6	30.6	19.4	67
Sub Total	**9.94**	–	–	–
Sub Mean	**2.5**	**29.7**	**19.6**	**76.7**
Grand total	**30.05**	-	-	-

4.4 Sweet Potato Growth and Development

4.4.1 Growth of sweet potato crop

Growth and development phases were accounted from planting to 90 DAP when the crop had attained the maximum development, the crop growth attributes included number of roots (NR), number of branches (NB), number of leaves (NL), vine length (VL), vine fresh weight (VFW), tuber length (TL), and tuber diameter (TD). Data for relevant variables are shown in Tables 5 and 6.

4.4.2 Effect of sweet potato varieties on growth components at 45 DAP

There was no significant difference in number of roots, vine length and number of leaves among varieties at 45 DAP, but there was a significant difference ($P<0.05$) on number of branches at 45 DAP. Variety *Ukerewe* recorded with the highest number of branches (5.82) compared to those recorded from the other varieties (Table 5). More number of branches for *Ukerewe* variety may have been associated with rapid growth, probably influenced by the genetic characteristic of the variety and high adaptability. Maniyam *et al.* (2012) described sweet potato growth as being controlled by genetic characteristics and environmental conditions. Also agronomic practices influence crop variables.

4.4.3 Effect of number of nodes on sweet potato growth components at 45 DAP

Number of buried nodes showed significant differences ($P<0.05$) on the NB, NL and vine fresh weight (VFW). The lowest NB (4.44) was in four buried nodes and the highest NB (5.67) was from eight buried nodes (Table 5). The lowest number of leaves (92.4) was from four buried nodes and the highest number of leaves (112.9) was from eight buried nodes. Further, the lowest VFW (0.13 kg) was recorded from four buried nodes whereas the highest VFW (0.18 kg) was observed from eight buried nodes.

The results presented in this study on the effect of buried nodes on the growth components mentioned indicated that eight buried nodes (four above ground) must have initiated roots and shoots at early stage, which also must have increased water and nutrients absorption for rapid growth, than those with four buried nodes (two above ground) which sprouted with difficulty because of late roots and shoot formation. The number of buried nodes with higher numbers of buds acts as a source of hormones which stimulate early rooting and rapid shoot growth (Belehu, 2003).

4.4.4 Effect of fertilizers on sweet potato growth components at 45 DAP

The types of fertilizers applied resulted into significant differences on the NR, NB, NL, VL, and VFW at 45 DAP. The lowest NR (5.75) was observed in control treatment while the highest (7.53 and 7.5) was recorded with KCl and NPK treatments. The lowest NB (4.5) was recorded in control treatments and the highest (5.6) in KCl treatment. The lowest NL (94.4) was recorded in control treatment and the highest (115.2) in KCl treatment. The lowest VL (19.97) was recorded from control treatment and the highest (22.48) in KCl treatment. The lowest VFW (0.12 kg) was observed in control treatments and the highest (0.18 kg) in KCl treatment. The increase in NR, NB, NL, VL and VFW could have been associated with the effect of potash fertilizer applied which resulted in physiological processes of the crop. These processes include cell division, elongation, growth, respiration and photosynthesis. All the physiological processes mentioned above initiated by K may have been resulted in high sweet potato vegetative growth and development. These findings are similar to those reported by Bishnu and Krishna (2006) and Stephen (2004) working in Nigeria and Cuba confirmed that, VL, NL, NB and fresh biomass of the sweet potato crop were found to increase when K was applied at the rate of 100 kg ha^{-1}.

Table 5: Growth components at 45 DAP as affected by treatments applied

Treatments	NR	NB	NL	VL (cm)	VFW (kg)
Varieties					
Kiegeya	7.29a*	4.79a	101.60a	22.06a	0.18a
Mataya	6.75a	5.02a	106.20a	22.06a	0.15a
Ukerewe	6.85a	5.79b	109.20a	20.79a	0.15a
CV (%)	10.2	14.3	7.60	6.20	14.70
SE±	0.581	0.18	6.54	1.08	0.02
Fpr	0.645	0.012	0.559	0.486	0.279
Buried nodes					
4	6.47a	4.44a	92.40a	20.38a	0.13a
5	6.44a	5.08ab	105.10b	21.14a	0.15ab
7	7.44a	5.61b	112.30b	21.83a	0.17b
8	7.50a	5.67b	112.90b	21.60a	0.18b
CV (%)	7.10	6.10	3.90	3.10	10.10
SE±	0.403	0.26	3.39	0.53	0.01
Fpr	0.063	0.01	0.003	0.122	0.014
Fertilizers types					
Control	5.75a	4.5a	94.9a	19.97a	0.12a
KCl	7.53b	5.6b	115.2c	22.48c	0.18b
NPK	7.5b	5.5b	110.9bc	21.83bc	0.17b
FYM	7.08b	5.25ab	101.7ab	20.67ab	0.15ab
Mean	6.96	5.20	105.67	21.23	0.15
CV (%)	3.1	7.2	4.0	2.50	9.60
SE±	0.17	0.30	3.48	0.44	0.01
Fpr	<.001	0.044	0.004	0.005	0.008

*Means followed by the same letter in the same colum are not significantly different at P< 0.05 Tukeys' Test. Where NR =Number of roots, NB= Number of branches, NL= Number of leaves, VL= Vine length, VFW = Vine fresh weight, CV= variation of coefficient, SE = Standard error.

4.5.3 Effect of sweet potato varieties on growth components at 90 DAP

The sweet potato varieties used in this study showed no significant differences (P< 0.05) on the NR, NB, NL and NT at 90 DAP. Significant difference among varieties was only observed on VL. The lowest VL (50.97 cm) was observed from *Ukerewe* variety and the highest (54.25 cm) was recorded from *Kiegeya* variety (Table 6). This difference may be due to genetic characteristics of the varieties, probably influenced by the environment. Variety *Kiegeya* at the experimental site grows with long vines whereas the other varieties grow with short vines.

4.4.4 Effect of nodes on sweet potato growth components at 90 DAP

Number of buried nodes showed no significant differences on NR, NT, and NL; however significant differences ($P<0.05$) were noted on VL. The shortest VL (47.31 cm) was recorded from four buried nodes and longest (56.36 cm) was determined from eight buried nodes as presented in (Table 6). These findings are similar with those reported by Maniyam *et al.* (2012) working in India who concluded that the vine cuttings with five buried nodes sprouted and vine developed earlier than cuttings with three buried nodes.

4.4.5 Effect of fertilizers on sweet potato growth components at 90 DAP

The sources of potash fertilizers applied resulted into highly significant difference ($P<0.001$) on the variables analysed (NR, NT, NB, NL and VL). The lowest NR (10.67) was recorded from the control treatment and the highest (14.11) was observed with NPK treatment. The lowest NT (2.33) was determined in the control treatments while the highest (3.19) in KCl treatment. The lowest NB (9.31) was observed in control treatments and the highest (13.42) in KCl treatment. The lowest NL (264.3) was from control treatments and the highest (410) in KCl treatment. The lowest VL (48.07 cm) was from control treatments and the highest (55.59 cm) in NPK treatment as depicted in Table 6. The positive response of crop growth may have been caused by the effect of K functioning on water regulation, enzyme activation, assimilation and translocations of the photosynthesis products to the cells and tissues of the plant as resulted into sweet potato growth and development (Soenarto, 1994). These findings are similar with those reported by Tishome and Nigusie (2012). The author found that the application of farm yard manure

(20 t ha^{-1}) resulted into the increase of growth components such as NB, VL and NL. On the other hand, the similar findings were reported by Mukhtar *et al.* (2010) who found that, application of 150 kg NPK ha^{-1} resulted into the highest growth and development of sweet potato crop.

Table 6: Effect of varieties, number of nodes and fertilizers on sweet potato growth and development at 90 DAP

Treatments	NR	NT	NB	NL	VL(cm)
Varieties					
Kiegeya	12.69a*	2.7a	11.19a	390.00a	54.25b
Mataya	12.79a	2.81a	11.77a	354.90a	51.37ab
Ukerewe	13.19a	2.5a	13.10a	344.30a	50.97a
CV%	10.80	12.40	9.80	11.40	8.70
SE±	6.30	0.17	0.9	23.37	1.43
Fpr	0.742	0.193	0.142	0.152	0.089
Buried nodes					
4	11.11a	2.59a	11.44a	388.60a	47.31a
5	13.47a	2.77a	11.75a	346.79a	50.95ab
7	12.94a	2.77a	12.19a	377.79a	54.36b
8	14.03a	2.63a	12.69a	389.29a	56.36b
CV%	9.20	10.90	8.40	10.10	4.70
SE±	1.18	0.29	1.04	36.76	2.40
Fpr	0.909	0.627	0.501	0.356	0.016
Fertizers types					
Control	10.67a	2.33a	9.31a	264.30a	48.07a
KCl	13.86b	3.19b	13.42b	410.80b	54.38c
NPK	14.11b	2.60ab	13.19b	402.30b	55.59c
FYM	12.92b	2.50ab	12.17b	375.00b	50.74b
Mean	12.89	2.67	12.02	363.10	52.19
CV%	6.10	10.10	6.30	5.10	1.50
SE±	0.78	0.26	0.76	18.57	0.80
Fpr	0.006	0.034	0.002	<0.001	<0.001

*Means followed by the same letter in the same colum are not significantly different at (P<0.05) Where NR= number of roots, NT= Number of tubers, NB = number branches, NL = number of leaves, VL = Vine length

4.5 Effect of Varieties Planted on LAI

The sweet potato varieties at the experimental area showed no significant difference ($P<0.05$) on leaf area index (LAI) at 45, 90 and 120 DAP. The LAI increased from (1.02) at 45 DAP to (3.14) at 90 DAP and thereafter declined and remained constant at the time of harvesting (2.87) as shown in Table 7. Kuhlase *et al*, (2009) showed that regardless of sweet potato varieties planted, the LAI increased sharply from the time of planting to 90 DAP and thereafter declined. Similar observations were made by Mayisela (2010) and Soenarto (1994) who found that, sweet potato attained maximum LAI at 112 DAP. The decline in the LAI from 90 DAP was probably due to bulking of the tubers as photosynthates are partitioned to the tuber at the expense of the production of leaves and vines (Soenarto, 1994). At 90 DAP two third of the crop had attained the maximum growth so that subsequently formed carbohydrates would be translocated to the sinks.

4.5.1 Effect of number of nodes on sweet potato LAI

The LAI for seven and eight buried nodes depicted significant differences ($P< 0.001$) from the four and five buried node cuttings at 45 and at 90 DAP. The LAI at 45 DAP was (1.03) and at 90 DAP was (3.09). The significant differences in the LAI recorded must have been caused by amount of water, CO_2, light and nutrients absorbed by the crop for the physiological processes such as photosynthesis and respiration. These physiological processes are the key components for sweet potato growth and development. Belehu (2003) found similar findings where by vine cuttings with six buried nodes developed with vigour and had the highest LAI than those with three buried nodes.

4.5.2 Effect of fertilizers on LAI

Leaf area index (LAI) was affected significantly (P < 0.05) by types of fertilizers applied. The lowest value (0.89) was recorded with control treatment at 45 DAP and the highest value (1.1) was observed with NPK treatment. At 90 DAP the lowest LAI value (2.57) was recorded from control treatment and the highest value (3.37) was observed with NPK treatment (Table 7).

Table 7: Effect of treatments applied on Leaf area index at 45, 90 and 120 DAP

Treatments	LAI 45 DAP	LAI 90 DAP	LAI 120 DAP
Varieties			
Kiegeya	1.03a*	3.24a	2.80a
Mataya	1.04a	3.10a	2.91a
Ukerewe	1.02a	3.09a	2.90a
CV (%)	9.10	9.80	5.10
SE±	0.09	0.30	0.16
Fpr	0.970	0.802	0.675
Buried nodes			
4	0.67a	2.59a	2.17a
5	0.82b	3.03ab	2.56b
7	1.26c	3.26ab	3.34c
8	1.37d	3.46b	3.39c
CV (%)	4.00	9.00	3.60
SE±	0.04	0.27	0.09
Fpr	<.001	0.037	<.001
Fertilizers types			
Control	0.89b	2.58a	2.10a
KCl	1.07a	3.36b	3.21c
NPK	1.10b	3.37b	3.05c
FYM	1.06b	3.28b	2.66b
mean	1.02	3.14	2.76
CV (%)	3.60	5.10	3.20
SE±	0.04	0.16	0.09
Fpr	0.002	0.003	<.001

*Means followed by the same letter in the same colum are not significantly different at P< 0.05 Tukeys' Test, LAI= leaf area index, DAP= Days after planting, CV= variation of coefficient, SE = Standard error.

The increase in LAI must have been influenced by physiological processes of sweet potato crop such as solar radiation interception and photosynthesis. The mentioned physiological processes do increase carbohydrate synthesis product of which are translocated and stored in the sinks and lead to high root size and therefore high yield (Mehmet *et al.*, 2007). The LAI increase was influenced by fertilizers types applied. These findings are similar to studies by Mayisela (2010) in which fertilizer application on sweet potato increased size of leaves, NB, VL and VFW. Further, Maniyam *et al.* (2012) showed that fertilizers application increased leaf area index by increasing leaf size, VL, and NB.

4.6 Effect of Sweet Potato Varieties on Yield at 90 DAP

The varieties showed significant differences (P<0.05) in VFW (kg plant^{-1}) and VDW (kg plant^{-1}). The lowest VFW (0.33 kg plant^{-1}) was from *Mataya* variety and the highest (0.38 kg plant^{-1}) was from *Kiegeya* variety. The lowest VDW (0.19 kg plant^{-1}) was recorded from *Ukerewe* variety and the highest (0.24 kg plant^{-1}) was from *kiegeya* variety (Table 7). The differences (0.15 kg plant $^{-1}$ determined on VFW and 0.05 kg plant $^{-1}$ on VDW) among varieties was probably caused by differences on NL, NB and VL (cm) formed from each variety. Also may have been probably caused by varieties differences on water and nutrient uptake and time taken for transportations of photosynthesis products to sinks (Nyambok, 2011).

4.6.1 Effect of number of nodes on sweet potato yield components at 90 DAP

The number of buried nodes used showed no significant difference (P<0.05) on VFW, VDW, TFW and TDW at 90 DAP as per results presented in Table 8. These insignificant differences may probably have been caused by the ability of roots formed by each buried node on water and nutrient uptake. At 90 DAP sweet potato above ground parts attained maximum growth, no variations among variables was observed. Soenarto, (1994) made similar observation that at 90 DAP sweet potato attained maximum growth; hence the above ground parts are insignificant.

4.6.2 Effect of fertilizers on yield components at 90 DAP

The types of potash fertilizers for K sources applied showed significant differences ($P<0.05$) on VFW, VDW, TFW and TDW at 90 DAP. The lowest VFW (0.29 kg plant^{-1}) VDW (0.17) TFW (0.19) TDW (0.07) were respectively the highest values were from KCl treatment as shown in Table 8. The result presented signifies the importance of K functioning on the assimilation and translocation of photosynthesis products to some parts of sources and sinks of the sweet potato crop. These findings are similar with results observed by Uwah *et al.* (2013) in which the VFW, VDW, TFW and TDW increased when 120 kg K ha^{-1} was applied.

Table 8: Effect of sweet potato varieties, number of buried nodes and fertilizers on the fresh and dry biomass of vines and tubers at 90 DAP (kg plant^{-1})

Treatments	VFW	VDW	TFW	TDW	TBDW	HI
Varaeties						
Kiegeya	0.38b*	0.24b	0.17a	0.10a	0.34b	0.29a
Mataya	0.33a	0.21a	0.18a	0.09a	0.29a	0.34a
Ukerewe	0.34ab	0.19a	0.15a	0.08a	0.30a	0.30a
CV%	6.50	8.50	10.70	13.70	7.60	8.10
SE±	0.02	0.01	0.01	0.01	0.01	0.03
Fpr	0.042	0.011	0.367	0.262	0.002	0.243
Buried nodes						
4	0.34a	0.21a	0.17a	0.08a	0.30a	0.31a
5	0.34a	0.21a	0.13a	0.07a	0.30a	0.32a
7	0.36a	0.22a	0.18a	0.09a	0.32a	0.30a
8	0.37a	0.22a	0.17a	0.10a	0.32a	0.31a
CV%	5.90	7.40	7.70	10.80	2.10	5.80
SE±	0.017	0.02	0.02	0.01	0.02	0.02
Fpr	0.34	0.75	0.95	0.93	0.787	0.96
Fertilizers types						
Control	0.29a	0.17a	0.16a	0.07a	0.27a	0.31a
KCL	0.38b	0.24b	0.19b	0.12b	0.34b	0.34a
NPK	0.37b	0.22ab	0.14ab	0.09ab	0.32ab	0.30a
FYM	0.36b	0.21ab	0.17a	0.08a	0.31ab	0.29a
Mean	0.35	0.22	0.16	0.09	0.31	0.31
CV	5.50	4.30	4.40	9.30	2.40	6.70
SE±	0.02	0.02	0.01	0.02	0.01	0.02
Fpr	0.007	0.04	0.009	0.04	0.034	0.167

*Means followed by the same letter in the same colum for each treatment factor are not significantly different at P< 0.05 Tukeys' Test, VFW=Vine fresh weight, VDW =Vine dry weight, TFW =Tuber fresh weight, TDW = Tuber dry weight, HI=Harvesting index CV= variation of coefficient, SE = Standard error

4.6.3 Effect of varieties on yield components at 120 DAP

The results in Tables 9 and 10 show that there were no significant differences among the varieties used on NT, VFW, VDW, TFW, MKT, and non marketable tubers (NMKT) However, significant difference ($P<0.05$) was recorded on TL. The lowest TL (15.31 cm) was recorded from *Mataya* variety whereas the highest (17.66 cm) from *Ukerewe*. The difference in TL may have been caused by genetic characteristic of the varieties and its interaction on the environmental factors (Huaman, 1999).

4.6.4 Effect of number of buried nodes on yield component at 120 DAP

The number of buried nodes showed significant effect (P<0.05) on yield and yield components. Lowest NT (3.47 plant^{-1}), VFW (0.23), VDW (0.14), TDW (0.14), TFW (0.26), MKT (23.31) and total yield (11.68 t ha^{-1}) were noted from four buried node whereas, the highest values were recorded from seven and eight buried nodes as presented in Tables 9 and 10. The effect of yield and yield components increased by seven and eight buried nodes might have been influenced by number of buried nodes. More nodes which were buried resulted into more tuber roots initiation as the tuber root increased from node four (3.47), five (4.27), seven (5.16) and eight (5.2). On the other hand the early rapid growth and development in seven and eight buried nodes, tuber initiation and bulking began earlier than in four and five buried nodes. This finding is similar to that reported by Belehu (2003) showed that six buried nodes resulted into high yield compared to three buried nodes. Maniyam *et al.* (2012) working in India also had similar observation where five buried nodes resulted into high yield of 26 t ha $^{-1}$ than with three buried nodes which resulted into 14 t ha $^{-1}$.

4.6.5 Effect of fertilizers on sweet potato yield and yield components at 120 DAP

The types of fertilizer sources of K applied revealed significant differences (P<0.001) on yield and yield components. Lowest NT (2.81 plant^{-1}) was recorded with control treatment and the highest (6.03 plant^{-1}) with KCl treatment. The lowest

VFW (0.23 kg plant^{-1}) was from the control and FYM treatments while the highest (0.32 kg plant^{-1}) with KCl treatment. The lowest VDW (0.14 kg plant^{-1}) was from the control treatment and the highest VDW (0.18 kg plant^{-1}) with KCl and NPK treatments. The lowest TDW (0.1 kg plant^{-1}) was from control treatment and the highest (0.29 plant^{-1}) with KCl treatment. The lowest TD (3.44 cm) was recorded with control treatment while the highest (4.81 cm) with KCl treatment. The lowest TL (12.86 cm) was from control treatment and the highest (19.03 cm) with KCl treatment. The lowest TFW (0.19 kg) was from control treatment and the highest (0.42 kg) from KCl treatment. The lowest of number of MKT (15.47) was observed in the control treatment and the highest number (47.06) was recorded in KCl. The lowest HI was from control the treatment 42 %. Trends for the other treatments were FYM (49 %), NPK (58 %) and KCl (60 %). Lowest yield (8.82 t ha $^{-1}$) was from the control treatment while the highest yield (18.84 t ha $^{-1}$) was from KCl. All these results are well depicted in Tables 9 and 10.

Potassium application increased both size and total number of tubers at a rate of 120 kg ha^{-1} as recommended in tropical countries. The biological and economic yield differences obtained from this research justify the functions of potash fertilizes (Soenarto, 1994). These findings are similar with that reported by Njoku *et al.* (2001) and Trehan *et al.* (2009) which indicated that the K application increased yield of 24.7 t ha^{-1} most likely through formation of large sized tubers and lustrous appearance of the surface of the tuber roots (indicators of quality). The size of the tuber roots as affected by the application of K is because of its role on water regulation through closure and opening of stomata enzymes activation by changing the active sites for the chemical reactions to take place within plant cells and tissues. Stomata Opening, closure and enzymatic relationship enables appropriate water use efficiency for the functioning of cells and tissue of the crop. The fates of all these physiological processes result into translocations of synthesized carbohydrates to the tuberous roots (Soenarto, 1994).

Table 9: Influence of sweet potato varieties, number of buried nodes and fertilizer types on sweet potato yield components at 120 DAP

Treatments	N T/p	VF W (kg)	VDW(kg)	TDW(kg)	TD (cm)	TL (cm)
Varieties						
Kiegeya	4.81a*	0.24a	0.13a	0.21a	4.17a	17.18b
Mataya	4.52a	0.27a	0.18a	0.19a	4.18a	15.31a
Ukerewe	4.27a	0.30a	0.19a	0.19a	4.45a	17.66b
CV%	5.80	12.10	19.10	9.50	3.50	6.90
SE±	0.21	0.02	0.02	0.01	0.34	0.39
FPr	0.146	0.16	0.153	0.529	0.141	0.008
Buried nodes						
4	3.47a	0.23a	0.14 a	0.14 a	4.2a	16.51a
5	4.27b	0.23a	0.14 a	0.18 b	4.3a	17.03a
7	5.167c	0.31b	0.20b	0.23 b	4.18a	17.00a
8	5.20c	0.30b	0.20 b	0.24 b	4.37a	16.33a
CV%	5.10	11.90	8.00	8.80	3.30	4.60
SE±	0.18	0.01	0.10	0.01	0.11	0.63
Fpr	<.001	<.001	0.001	0.003	0.476	0.631
Fertilizers types						
Control	2.81a	0.23a	0.14 a	0.10a	3.44a	12.86a
KCl	6.03c	0.32b	0.18 b	0.29 c	4.81c	19.03c
NPK	5.67c	0.31b	0.18 b	0.26 c	4.71c	18.87c
FYM	3.64b	0.23a	0.15 a	0.14 b	4.12b	16.11b
Mean	4.53	0.27	0.17	0.19	4.27	16.71
CV%	4.20	10.50	4.40	6.30	2.50	1.70
SE±	0.15	0.01	0.01	0.01	0.21	0.23
Fpr	<.001	<.001	<0.001	<0.001	<.001	<.001

*Means followed by the same letter in the same colum for each treatment factor are not significantly different at P< 0.05 Turkeys' Test, NT= number of tubers, VFW= vine fresh weight, VDW= vine dry weight, TDW= tuber dry weight, TL= tuber length, TD= tuber diameter, CV= variation of coefficient, SE = Standard error.

Table 10: Influence of sweet potato varieties, number of buried nodes and fertilizer types on sweet potato yield components at 120 DAP

Treatments	TFW (kg)	MKT/(m^2)	TBDW	HI	T/ha	NMKT/(m^2)
Varieties						
Kiegeya	0.35a*	33.67a	0.34a	0.47a	15.44a	14.25a
Mataya	0.31a	31.50a	0.37a	0.52a	13.65a	13.29a
Ukerewe	0.29a	30.71a	0.39a	0.58a	13.28a	11.6a
CV%	9.10	8.40	8.60	9.60	9.10	15.20
SE±	0.02	1.94	0.03	0.05	1.05	1.62
Fpr	0.205	0.379	0.292	0.134	0.205	0.353
Buried nodes						
4	0.26a	23.31a	0.29a	0.50a	11.68a	11.69a
5	0.29a	28.67a	0.31a	0.52a	13.11a	13.83a
7	0.35b	37.89b	0.43b	0.52a	15.80b	13.97a
8	0.36b	37.97b	0.43b	0.56a	15.91b	12.69a
CV (%)	5.50	7.90	4.50	8.20	5.50	9.80
SE±	0.01	2.24	0.02	0.04	0.63	1.05
Fpr	0.001	<0.001	<.001	0.559	0.001	0.204
Fertizer types						
Control	0.19a	15.47	0.24a	0.42a	8.82a	12.06a
KCl	0.42b	47.06	0.48d	0.60b	18.84b	12.94a
NPK	0.39b	41.11	0.45c	0.58b	17.51b	11.28a
FYM	0.26b	24.19	0.30b	0.49a	11.33a	11.92a
Mean	0.32	31.9	0.37	0.52	14.13	13.05
CV%	5.40	7.00	3.00	6.10	4.00	4.50
SE±	0.02	2.05	0.01	0.03	0.74	0.48
Fpr	<.001	<.001	<.001	0.001	<.001	0.001

*Means followed by the same letter in the same colum for each treatment factor are not significantly different at P< 0.05 Tukeys' Test, TFW= tuber fresh weight, MKT= marketable tubers, T ha= tones per hector, NMKT= Non marketable tubers, TBDW =Total biological dry yield, HI = Harvesting index CV= variation of coefficient, SE = Standard error.

4.7 Tuber Physical Quality Determinations

4.7.1 Effect of varieties on sweet potato tubers physical quality

Effects of varieties on sweet potato tubers physical quality parameters were such that *Mataya* had tuber roots that were round, uniform with smooth skin and white colour no cracks on the surface of the skin, as shown in Plate 1: *Kiegeya* tubers were long, uniform, with smooth skin and no fibers as depicted on Plate 2. *Ukerewe* was characterized by presence of fibers on the skin, irregular tubers and rough skin texture as presented in Plate 3. It has been described by Huaman (1999) that the sweet potato varieties may change in quality because of soil type, environmental condition and fertilizers used. Therefore environmental condition and soil type was appropriate for sweet potato tuber roots physical quality since each variety express its genetic characteristics.

Plate 1: Mataya variety round elliptic shape

Plate 2: Kiegeya variety long elliptic shape

Plate 3: Ukerewe variety long elliptic shape

4.7.2 Effect of number of nodes on sweet potato tubers physical quality

Eight and seven number of buried nodes produced tuber quality in terms of size, weight, uniformity, regularity and appearance than those cuttings with four and five buried nodes. This is because the more number of nodes buried initiated tuber roots early because of absorbing appropriate water and nutrients. Therefore tuber roots bulking started earlier for the first roots formed than those roots initiated later from the four and five buried nodes near the soil surface. The early development of tubers had more time for the tubers to develop into a large size, uniform and regular shape. This is revealed by the TDW (kg plant ha^{-1}) that increased from four nodes (0.14), five nodes (0.18), seven nodes (0.23) and eight nodes (0.24) as presented in Table 9. Nyambok (2011) described that burring 3 nodes resulted into low yield and quality tuber roots.

4.7.3 Effect of fertilizers on sweet potato tubers physical quality

The length of sweet potato tuber roots in this study was positively affected by K fertilizer sources and variety used. *Kiegeya* and *Ukerewe* produced the longest tuber roots of 17.18 cm and 17.66 cm respectively, followed by *Mataya* 15.31 cm as shown in Table 9. The size in TL increased from control (12.86 cm), KCl (19.03), NPK (18.87 cm) and FYM (16.11cm). Furthermore TD increased from control (3.44 cm), KCl (4.81cm), NPK (4.71cm) and FYM (4.12cm). In addition TDW $plant^{-1}$ increased from control (0.10), KCl (0.29), NPK (0.26) and FYM (0.14). These observations may have been caused by the effect of K fertilizer sources functions on chemical reactions within the crop which resulted into cell and tissue growth. These findings are similar to those reported by Njoku *et al.* (2001) and Trehan *et al.* (2009)

whereby application of K improved sweet potato yield through the formation of large sized tuber roots and shiny appearance of the surface of the tubers.

4.8 Interaction Effects of Treatments Involved on Sweet Potato Yield Components

According to various statistics literature, interactions are usually defined as the measure of inter–relationships among two or more different classifications (Gomez and Gomez, 1984). According to Kothari (2011) interaction exist when the graphic lines cross over each other and it is not significant to discuss factors and variables if there is no interaction within treatments involved.

4.8.1 Interactions effect of sweet potato varieties and number of buried nodes on yield and yield components

There was slightly significant influence ($P<0.05$) on when varieties interacted with number of buried nodes. The lowest TFW (0.21 kg $plant^{-1}$) was from *Ukerewe* variety with four buried nodes, the highest TFW (0.39 kg $plant^{-1}$) was from *Kiegeya* with eight buried nodes. This weight difference (0.18 kg $plant^{-1}$) may be caused by the early development and tuber initiation for varieties with eight buried nodes which initiated the early tuber bulking than those cuttings with four buried nodes. However, there were no significant differences ($p< 0.05$) on the NT, VFW, VDW, TDW, TD and TL as shown in Table 11. Therefore it is not important to discuss variables and factors with no significant differences as already stated.

Table 11: Effect of interactions between sweet potato Varieties and Number of nodes on yield and yield components

Treatments	N T	VF W (kg)	VDW (kg)	TDW (kg)	TD (cm)	TL (cm)	TFW
V*BN							
K* 4 BN	3.75ab	0.21a	0.11a	0.15ab	4.11ab	16.5abcde	0.29abcd
K*5 BN	4.67bcde	0.21a	0.12a	0.21bcde	4.15ab	17.41de	0.35cde
K*7 BN	5.508e	0.25abc	0.14a	0.25e	4.15ab	17.58de	0.39e
K* 8 BN	5.25de	0.28cde	0.17abc	0.23cde	4.29abc	17.23cde	0.37de
M*4 BN	3.42a	0.22ab	0.14a	0.16abc	4.17ab	14.68a	0.28abc
M*5 BN	4.25abcd	0.23abc	0.13a	0.17abcd	4.00a	16.21abcd	0.28abc
M* 7 BN	5.250de	0.32ef	0.22bcd	0.23de	4.08ab	15.41bcd	0.35cde
M* 8 BN	5.250de	0.31def	0.21bcd	0.22abcd	4.47bc	14.93ab	0.33bcde
U* 4 BN	3.25a	0.27bcde	0.17abc	0.14a	4.00a	18.36e	0.21a
U* 5 BN	3.92abc	0.25abcd	0.15ab	0.17abcd	4.13 ab	18.00de	0.26ab
U* 7B N	4.83cde	0.35f	0.25d	0.22bcde	4.33abc	18.00de	0.34bcde
U* 8 BN	5.08de	0.34f	0.22cd	0.25e	4.60bc	16.83bcde	0.38e
Mean	4.53	0.27	0.17	0.19	4.27	16.72	0.32
CV%	11.40	8.60	23.20	20.10	5.30	6.90	0.04
SE±	0.42	0.02	0.03	0.04	0.23	1.15	12.60
FPr	0.963	0.050	0.676	0.196	0.022	0.540	0.020

*Means followed by the same letter in the same colum for each treatment factor are not significantly different at P< 0.05 Tukeys' Test, V= Varieties, BN= Buried nodes, VFW= Vine fresh weight (kg), VDW= Vine dry weight, TD= Tuber diameter (cm) Tuber length (cm) TFW= tuber fresh weight, CV= variation of coefficient, SE±= Standard error

4.8.2 Interactions effect of sweet potato varieties and fertilizers on yield and yield components

Sweet potato varieties and types of fertilizers applied showed significant difference ($P<0.05$) on TFW. The lowest TFW (0.16 kg plant^{-1}) was from *Ukerewe* variety with control treatment and the highest (0.47 kg plant^{-1}) from *Kiegeya* variety with KCl treatment. The increase (0.31kg plant^{-1}) in TFW was caused probably by response of varieties on the applied K as it increases size and tuber roots weight (Soenarto, 1994). These results are similar with those reported by Uwah *et al.* (2013) that potash fertilizer applied increases tuber weight. These facts may have been due to assimilation and transportation of synthesized carbohydrate to the sinks. However, there were no significant differences on NT, VFW, VDW, TDW, TD and TL as presented in Table 12.

Table 12: Effect of interactions between Varieties and Fertilizer sources on yield and yield components

Treatments	NT	VF W (kg)	VDW (kg)	TDW (kg)	TD (cm)	TL (cm)	TFW (kg)
V*F							
K* C	3.25abc	0.22a	0.12a	0.09a	3.33a	12.71ab	0.17a
K*KCl	6d	0.25abc	0.15abc	0.31d	4.83ef	19.85c	0.47c
K* NPK	5.83d	0.24abc	0.14abc	0.29cd	4.69ef	19.18de	0.44cd
K* FYM	4.17c	0.24ab	0.12a	0.15ab	3.8bc	16.99c	0.27b
M* C	2.83ab	0.23ab	0.14ab	0.12ab	3.38a	12.23a	0.22ab
M* KCl	6.25d	0.28bcd	0.19bcd	0.27cd	4.64ef	17.07c	0.39cd
M* NPK	5.58d	0.29bcd	0.20cd	0.23c	4.59ef	17.30cd	0.36c
M*FYM	3.42d	0.27abcd	0.17abcd	0.16b	4.12cd	14.63b	0.26b
U* C	2.33a	0.27abcd	0.17abcd	0.08a	3.63ab	13.63ab	0.16a
U* KCl	5.83d	0.32d	0.22d	0.30cd	4.94f	20.16e	0.44cd
U* NPK	5.58d	0.32d	0.22d	0.26cd	4.85ef	20.14e	0.38c
U*FYM	3.33abc	0.29cd	0.18abcd	0.13ab	4.39	16.72c	0.23ab
Mean	4.53	0.27	0.17	0.19	4.27	16.72	0.32
CV%	8.10	12.70	20.00	13.70	4.30	4.10	11.6
SE±	0.37	0.03	0.04	0.02	0.18	0.69	0.03
FPr	0.286	0.812	0.727	0.064	0.273	0.104	0.043

*Means followed by the same letter in the same colum for each treatment factor are not significantly different at P< 0.05 Tukeys' Test, V= Varieties, F =Fertilizers =control, VFW= Vine fresh weight (kg), VDW= Vine dry weight, TD= Tuber diameter (cm) Tuber length (cm) TFW= tuber fresh weight, CV= variation of coefficient, SE= Standard error

4.8.3 Effect of interactions between fertilizer sources and number of buried nodes

Fertilizer types applied and number of buried nodes showed significant interaction

(P<0.001) on NT. The lowest NT (2.67 $plant^{-1}$) was from control with four buried nodes and the highest (7) was recorded from KCl and NPK treatments with seven and eight number of buried nodes respectively. Also the interaction effect was determined on TFW; the lowest weight value (0.16 kg $plant^{-1}$) was recorded in control treatment with 4 buried nodes whereas the highest weight was from KCl and NPK with seven and eight buried nodes. In addition there was interaction effect on TDW; the lowest (0.09 kg $plant^{-1}$) was from control treatments with four buried nodes while the highest value (0.36 Kg $plant^{-1}$) was from NPK with eight buried nodes.

The increase of variables (NT, TFW and TDW) seems to have been caused by early rooting, establishment and development of seven and eight buried nodes which initiated roots early together with early tuber roots formation, bulking and storage of the synthesized carbohydrate (Belehu, 2003). Uwah *et al.* (2013) reported that potash fertilizer increases TFW from 0.08 kg plant $^{-1}$ with control to 0.57 kg plant $^{-1}$ with KCl. These results are similar with those reported by Soenarto (1994) which indicated that potash fertilizers increased NT from (3) with control to (8) with KCl and TFW of (0.09 kg $plant^{-1}$) to (0.21kg $plant^{-1}$) with KCl.

Table 13: Effect of interactions between Fertilizer sources and Number of nodes

Treatments	N T	VF W (kg)	VDW (kg)	TDW (kg)	TD (cm)	TL (cm)	TFW (kg)
F*BN							
C* 4 BN	2.67a	0.23a	0.14ab	0.09a	3.44a	12.71a	0.16a
C* 5 BN	2.78a	0.21a	0.12ab	0.10ab	3.42a	12.78a	0.19ab
C* 7 BN	3.11ab	0.26abcd	0.16abc	0.10ab	3.37a	12.79a	0.18a
C*8 BN	2.67a	0.26abcde	0.16abc	0.11ab	3.54a	13.14a	0.2ab
KCl*4 BN	4.33bcd	0.24ab	0.14ab	0.19cde	4.74def	18.77ef	0.31cde
KCl*5 BN	5.44de	0.24ab	0.14ab	0.25ef	4.78ef	19.67f	0.37ef
KCl* 7 BN	7.11f	0.32cd	0.22cde	0.36g	4.82ef	19.59f	0.51g
KCl* 8 BN	7.22f	0.33e	0.23de	0.35fg	4.88f	18.08cdef	0.49g
NPK*4 BN	3.78ab	0.23ab	0.14ab	0.18bcde	4.68cdef	18.94ef	0.30bcde
NPK*5 BN	5.33cde	0.25abc	0.15abc	0.24def	4.63cdef	18.59def	0.36de
NPK*7 BN	6.56ef	0.33de	0.22cde	0.30fg	4.67cdef	19.28f	0.46fg
NPK*8 BN	7.00f	0.33de	0.24e	0.32fg	4.87f	18.68def	0.46fg
FYM*4 BN	3.11ab	0.22a	0.12a	0.13abc	4.13bc	15.62b	0.24abc
FYM* 5BN	3.56ab	0.22a	0.13ab	0.14abc	4.27bcde	16.71bcde	0.25abc
FYM*7 BN	4.11bc	0.32de	0.20bcde	0.15abcd	3.9ab	16.33bcd	0.26abcd
FYM* 8 BN	3.78ab	0.3bcde	0.17abcde	0.16abcd	4.2bcd	15.79bc	0.26abcd
Mean	4.53	0.27	0.17	0.19	4.27	16.71	0.32
CV%	7.70	7.50	12.80	14.30	7.90	8.70	9.10
SE±	0.34	0.02	0.02	0.03	0.34	1.45	0.02
FPr	<.001	0.0758	0.091	<.001	0.793	0.750	<.001

*Means followed by the same letter in the same colum for each treatment factor are not significantly different at P< 0.05 Tukeys' Test, F= Fertilizers, BN= Buried nodes, VFW= Vine fresh weight (kg), VDW= Vine dry weight, TD= Tuber diameter (cm) Tuber length (cm) TFW= tuber fresh weight, CV= variation of coefficient, SE = Standard error

4.8.4 Interaction effect of sweet potato varieties, number of buried nodes and fertilizers on yield and yield components

There was significant interaction of the treatments (P<0.001) on TDW. Lowest value of TDW (0.07 kg $plant^{-1}$) was recorded from *Kiegeya* with four numbers of buried nodes and no fertilizers treatment. The highest weight (0.32 kg) was from *Kiegeya*, with seven buried nodes in KCl and NPK treatments. The increase in TDW must have been influenced by early bulking of tubers for those roots initiated earlier from seven and eight buried nodes.

Table 14: Interactions effects for Varieties, number of nodes and fertilizers

Treatments	NT	TD	TL	TFW	TDW	T/ha
V*N*F						
K*4*KCl	4abcdef	4.73defghi	19.57klm	0.36bcdefgh	0.2abcdefgh	15.7bcdefgh
K*4*NPK	4abcdef	4.6cdefghi	19.17iklm	0.35bcdefgh	0.2abcdefgh	16bcdefghii
K*4*FYM	4abcdef	4abcdefghi	15.4abcdefghii	0.26abcdef	0.13abc	11.9abcdef
K*4*C	3abc	3.17a	11.8a	0.18ab	0.07a	8ab
K*5*KCl	5.3abcdefg	4.7defghi	20.5m	0.46fghiik	0.3defghii	20.6fghiik
K*5*NPK	5.67defghi	4.8efghi	18.4hiiklm	0.43defghii	0.29cdefghii	19.3defghii
K*5*FM	4.33abcdef	3.9abcdefg	17.9ghiiklm	0.29abcdefg	0.14abcdef	13abcdefgh
K*5*C	3.3abcd	3.2a	12.8abcdef	0.2abc	0.09a	8.89abc
K*7*KCl	7.7i	5hi	20.87m	0.57k	0.4ii	25.5k
K*7*NPK	6.67ghi	4.6cdefghi	20.13lm	0.49hiik	0.32ghii	21.8hiik
K*7*FM	4.3abcdefg	3.7abcd	17defghiiklm	0.27abcdef	0.14abcdef	12abcdef
K*7*C	3.67abcde	3.26a	12.37abcd	0.21abc	0.1ab	9.4abc
K*8*KCl	7hi	4.9fghi	18.47iiklm	0.49hiik	0.32fghii	21.78hiik
K*8*NPK	7hi	4.8efghi	19iklm	0.47ghiik	0.31efghii	21ghiik
K*8*FM	4abcdef	3.8abcdefg	17.6fghiiklm	0.26abcdef	0.16abcdefg	11.85abcdef
K*8*C	3abc	3.6abcd	13.8abcdefghi	0.23abcd	0.11ab	10.5abcd
M*4*KCl	5bcdefg	4.6cdefghi	16abcdefghikl	0.31abcdefg	0.18abcdefg	14abcdefghi
M*4*NPK	3.7abcde	4.56cdefgh	16.8cdefghiikl	0.29abcdefg	0.18abcdefg	13abcdefgh
M*4*FM	2.3a	3.9abcdefg	13.8abcdefghi	0.26abcdef	0.15abcdefg	11.95abcdef
M*4*C	2.7ab	3.6abc	12ab	0.23abcd	0.12abc	10.6abcd
M*5*KCl	6efghi	4.4bcdefgh	18.6iiklm	0.33abcdefg	0.23abcdefg	14.5abcdefg
M*5*NPK	5bcdefgh	4.2abcdefg	17.7ghiiklm	0.29abcdefg	0.18abcdefg	13abcdefgh
M*5*FYM	3.3abcd	4abcdefghi	15.4abcdefghii	0.23abcd	0.13abcd	10.52abcd
M*5*C	2.67ab	3.2a	13abcdefg	0.24abcde	0.13abcd	10.96abcde
M*7*KCl	7hi	4.63cdefgh	17.3efghiiklm	0.47ghiik	0.327ghii	21ghiik
M*7*NPK	6.6ghi	4.6cdefghi	17.4efghiiklm	0.44efghiik	0.29cdefghii	19.56efghii
M*7*FM	4abcdef	3.8abcdefg	15abcdefgghii	0.28abcdefg	0.19abcdefg	12.4abcdefg
M*7*contr	2.7ab	3a	11.9a	0.19ab	0.1267abcd	8.4ab
M*8*KCl	7hi	4.9ghi	16abcdefghiikl	0.44efghiik	0.32fghii	19.7efghiik
M*8*NPK	7hi	4.96ghi	17.2defghiikl	0.4cdefghiik	0.28bcdefgh	17.8cdefghii
M*8*FM	4abcdef	4.6cdefghi	14.3abcdefghii	0.25abcde	0.15abcdef	11abcde
M*8*C	2.66ab	3.4ab	11.93ab	0.22abc	0.113ab	9.52abc
u*4*KCl	4abcdef	5hi	20.67m	0.28abcdefg	0.2abcdef	12.7abcdefg
u*4*NPK	3.66abcde	4.86fghi	20.8m	0.258abcde	0.17abcdefg	11.47abcde
U*4*FM	3abc	4.5abcdefg	17.6fghiiklm	0.19ab	0.0933a	8.7ab
U*4*C	2.2a	3.5abc	14.3abcdefghi	0.13a	0.07a	6a
U*5*KCl	5bcdefg	5.1i	19.87klm	0.32abcdefg	0.22abcdefg	14.2abcdefg
U*5*NPK	5.33cdefgh	4.9ghi	19.63klm	0.34abcdefg	0.24abcdefg	15abcdefghi
U*5*FM	3abc	4.8efghi	17bcdefghiikl	0.22abc	0.12abcd	9.6abc
U*5*contr	2a	3.7abcdef	13.6abcdefgh	0.17ab	0.08a	7.56ab
U*7*KCl	6.7ghi	4.8efghi	20.6m	0.49hiik	0.35hii	22hiik
U*7*NPK	6fghi	4.8efghi	20.3lm	0.44efghiik	0.29cdefghii	19.6efghiik
U*7*FM	4abcdef	4.1abcdefg	17defghiiklm	0.43abcd	0.14abcde	10.6abcd
U*7*contr	2.30a	3.6abc	14.1abcdefghi	0.16ab	0.1abc	7.4ab
U*8*KCl	7.7i	4.9fghi	19.5klm	0.55ik	0.42i	24.44ik
U*8*NPK	7.00hi	4.8fghi	19.8klm	0.5iik	0.35hii	22.52iik
U*8*FM	3.00abc	4.60efghi	17defghiiklm	0.27abcdefg	0.15abcdefg	12.2abcdefg
U*8*C	2a	3.50abc	12.57abcde	0.2ab	0.09a	8.52ab
Mean	**4.50**	**4.27**	**16.70**	**0.32**	**0.20**	**14.29**
CV	**17.30**	**7.90**	**7.70**	**18.80**	**6.80**	**18.80**
SE±	**0.78**	**0.33**	**1.45**	**0.05**	**0.05**	**2.60**
Fpr	**0.70**	**0.83**	**0.94**	**0.95**	**0.001**	**0.9**

*Means followed by the same letter in the same colum for each treatment factor are not significantly different at P< 0.05 Tukeys' Test, V= Varieties F= Fertilizers, FM = Farm yard manure, C= Control, N= Number of nodes, T/ha =tones per hector (kg), TD= Tuber diameter (cm) Tuber length (cm) TFW= tuber fresh weight, TDW = tuber dry weight (kg) CV= variation of coefficient, SE = Standard error

4.9 Simple Correlation Analysis Results on sweet potato Yield and Yield Components

Simple correlations between LAI and its contributing components were performed as indicated in Table 15. Positive correlation was observed between NT and LAI with (r= 0.68***). The results showed that LAI was highly and positively correlated with yield t ha^{-1} and MKT (r = 0.61*** and 0.68***) respectively. There was also positive correlation on LAI and NL (r = 0.82***). Positive correlation was determined on TD and MKT (r = 0.58*) In addition the highly positive correlation was observed on TDW and yield (r = 0.96***). The significant values of correlation observed on LAI with NL, NT, VFW and VDW indicated that the increase of LAI may significantly lead to the increases in MKT $plant^{-1}$, yield in t ha^{-1} and total TDW. Similar results were reported by Afuape *et al.* (2011) reported positive and strong correlation between LAI, tuber root yield and TDW.

Table 15: Correlation coefficient of yield and yield components

	NT	NB	NL	VL	LAI	MKT	TFW	TD	TL	VFW	VDW	TDW
NT	-											
NB	0.50***	-										
NL	0.56***	0.59***	-									
VL	0.57***	0.54***	0.56***	-								
LAI	0.68***	0.69***	0.82***	0.64***	-							
MKT	0.96***	0.59***	0.53***	0.54***	0.68***	-						
TFW	0.87***	0.54***	0.46***	0.55***	0.6***	0.87***						
TD	0.57***	0.32**	0.36***	0.39***	0.4***	0.58***	0.58***	-				
TL	0.58***	0.3*	0.33***	0.4***	0.38***	0.59***	0.57***	0.75***	-			
VFW	0.358***	0.54***	0.7***	0.38***	0.6***	0.36***	0.23**	0.28***	0.29***	-		
VDW	0.37***	0.5***	0.66***	0.3***	0.58***	0.39***	0.27***	0.31***	0.32***	0.95***	-	
TDW	0.85***	0.53***	0.47***	0.57***	0.62***	0.85***	0.96***	0.6***	0.59***	0.29***	0.3**	-
T /ha	0.87***	0.55***	0.46***	0.55*	0.61***	0.87***	0.86***	0.58***	0.57***	0.26***	0.27***	0.96***

NT=Number of tubers, NB= Number of branches, NL =Number of leaves, LAI= Leaf area index, MKT= Marketable tubers, TFW = Tuber fresh weight (kg) TD =Tuber diameter (cm), TL =Tuber length (cm) VFW =Vine fresh weight (kg), VDW = Vine dry weight (kg) , TDW = Tuber dry weight (kg) VL = vine Length (cm)

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

Based on the information obtained from this research, the following conclusions are made:

Sweet potato varieties planted had no significant effect on number of tubers, marketable tubers and total yield. On the other hand seven and eight buried nodes produced a good number of tubers plant^{-1}(5.16 and 5.2), marketable tubers (37.87 and 37.97) and total yield t ha^{-1} (17.51 and 18.84) respectively.

The three fertilizers tested, two among them namely Potassium nitrogen phosphate and potassium chloride recorded with the highest yield and yield components. The components affected positively are vine length, number of branches, leaves, tubers plant^{-1}, marketable tubers and total yield. Furthermore tuberous root quality such as tuber length, tuber diameter and weight were recorded from these two treatments.

5.2 Recommendations

Within the country including Hombolo in Dodoma farmers bury any number of nodes depending on the availability of sweet potato planting materials. Some farmers bury two to three nodes just because such cuttings are easy to handle or in order to economize on the planting materials. Others also bury twelve to fifteen node cuttings, fold them several times and insert them in the soil.

1. Sweet potato vine cuttings with seven or eight buried nodes with internodes' length not less than 2 cm $vine^{-1}$ are suitable for maximum sweet potato growth and yield. The findings made from this research advice farmer in Dodoma to bury recommended number of nodes for improving yield and quality of sweet potato tuberous root.

2. Potassium nitrogen phosphate and potassium chloride at a rate of 120 kg K ha^{-1}, is recommended in soils with low mineral K contents for improving fertility status of the soil. These will enable farmers to increase yield and quality of sweet potato to meet consumers' requirement and consequently raise their income.

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APPENDIX

Appendix 1: Sweet potato production trend of different countries expressed in terms of tones

Countries	2006	2007	2008	2009	2010
Asia, including:	88 430 581	83 124 117	85 702 879	84 182 639	88 511 139
China	81 039 000	75 600 000	78 830 000	76 772 593	81 175 660
Indonesia	1 854 238	1 886 852	1 876 944	2 057 913	2 050 810
Vietnam	1 460 900	1 437 600	1 325 600	1 207 600	1 317 060
India	1 066 500	1 067 200	1 094 000	1 119 700	1 094 700
Japan	988 900	968 400	1 011 000	1 026 000	863 600
Philippines	566 773	573 734	572 655	560 516	541 525
Africa, including	**14 712 718**	**14 098 182**	**15 275 678**	**14 353 091**	**14 213 680**
Ouganda	2 628 000	2 602 000	2 707 000	2 766 000	2 838 800
Nigeria	3 462 000	2 432 000	3 318 000	2 746 817	2 838 000
Tanzania	1 396 400	1 322 000	1 379 000	1 381 120	1 400 000
Angola	684 756	949 104	819 772	982 588	986 563
Kenya	724 646	811 531	894 781	930 784	383 590
Madagascar	869 000	890 000	941 355	910 857	919 127
Mozambique	929 826	875 216	890 000	900 000	920 000
Rwanda	777 034	841 000	826 000	801 376	840 072
Ethiopia	388 814	388 814	526 487	450 763	401 600
Latin America, including:	1 961 714	2 104 017	2 057 497	2 162 830	1 966 398
Brazil	518 541	529 531	548 438	477 475	479 200
Cuba	303 000	414 000	375 000	437 000	384 700
North America, Including:	744 046	819 741	836 662	883 207	1 081 720
United States	743 937	819 641	836 560	883 099	1 081 590
Oceania, including:	719 410	763 716	641 861	680 177	742 554
Papua New Guinea	560 000	580 000	485 181	534 085	576 000