UNIVERSITY FOR DEVELOPMENT STUDIES

ROOT QUALITY OF FOUR SWEETPOTATO *[Ipomoea batatas (L)* Lam] CULTIVARS AS AFFECTED BY DAYS AFTER PLANTING

BY

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DECLARATION

CANDIDATE'S DECLARATION

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this University or elsewhere.

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SUPERVISORS' DECLARATION

I hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University for Development Studies.

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ABSTRACT

Time to harvest sweet potato is paramount in determining the yield and nutritional composition. Establishing an appropriate period to harvest non-white fleshed sweet potato *[Ipomoea batatas* (L) Lam] cultivars introduced in Ghana as food crops is relevant to their promotion for human health. However, there is insufficient scientific information on the root quality (root yield, fresh foliage weight, (3-carotene, dry matter, starch, fructose, glucose, sucrose, zinc, iron and protein) of these orange and purple-fleshed sweet potato cultivars as affected by days after planting (DAP), hence this study. Four cultivars, orange-fleshed (TUO) and purple-fleshed (TUP) were the newly the introduced ones from the Tuskegee University. Apomuden (APD), a released orange-fleshed in Ghana and Voggu (VOG) a landrace were used to investigate the effect of DAP: 65, 95, 125 and 155 on the root quality. Randomized complete block design was used. Nutrients were determined using Near-Infrared Reflectance Spectroscopy in Kumasi while, root yield and fresh foliage weight were quantified gravimetrically. The highest root yield was 28.20 t/ha observed at 125 DAP and the least was 6.30 t/ha observed at 65 DAP. Among the cultivars, APD gave the highest root yield of 19.50 t/ha, VOG had the lowest root yield of 15.80 t/ha. Fresh foliage weight was 30.40 t/ha high at 125 DAP and the least was 6.44 t/ha at 155 DAP,, The highest 13-carotene content was 18.50 mg/100 g observed at 155 and the least was 12.60 mg/100 g obtained at 65 DAP. Among the cultivars, it was only the OFSP cultivars that contained I3-carotene content, the pattern was APD > TUO > VOG. TUP was. devoid of 13-carotene, it was rather the highest cultivar in dry matter and starch. Starch and dry matter contents were high at 95 and 125 DAP respectively. They were both low at 155 DAP. Fructose and glucose declined from 65 to 155 DAP but sucrose was rather the reverse. Once 125 DAP recorded the highest root yield and had good 13-carotene content, it is concluded that 125 DAP is the appropriate time to harvest these cultivars for maximum root quality.

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DEDICATION

I dedicate this work to my lovely wife, Salome Akonde Assigri and to my children:

Josephine Nelly Awinbune Assigri,

Augustina Awinpang Assigri

And

Jeremiah Awinguri Assigri.

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LIST OF ACRONYMS AND ABBREVIATIONS

APD: Apomuden

CIP: International Potato Center

CSIR: Council for Scientific and Industrial Research

DAP: Days after planting

FAO: Food and Agricultural Organization

IITA: International Institute for Tropical Agriculture

MO: Months

MAP: Months after planting

OFSP: Orange-fleshed sweet potato

PFSP: Purple-fleshed sweet potato

RAE: Retinol Activity Equivalent

SSA: Sub-Saharan Africa

SARI: Savanna Agricultural Research Institute

TU: Tuskegee University

TUO: Tuskegee University Orange

TUP: Tuskegee University Purple

VAD: Vitamin A Deficiency

VOG: Voggu

UNICEF: United Nations Children's Fund

WHO: World Health Organization

INTRODUCTION

1.1 Organization of chapters

Chapter one consists of the background of the study, problem statement, objectives, relevance of the topic and scope of the research. Chapter two contains the review of relevant literature related to the study. Chapter three explains the methodology employed -for the study.; emphasizing on the study location, specifications of tools used and data analysis. Chapter four consists of all the findings of the investigation presented in graphs and tables. Chapter five is made up of the discussion of the results, both agronomic and nutritional data generated from the study. Chapter six contains the summary, conclusions, recommendations for future study and the limitations drawn from the research.

1.2 Background

In an effort to address vitamin A deficiency (VAD) in Ghana and Africa as a whole, harvesting time has been identified as an important agricultural practice that could be used to improve upon the root quality of sweet potato to reduce VAD and increase food security in Ghana and beyond (Alcoy, Garcia, Baldos, Robles, & Cuyno, 1993; Richardson, 2011; Rukundo, Shimelis, Laing, & Gahakwa, 2013). Sweet potato *[Ipomoea batatas (L)* Lam] is cultivated all over the world due to the fact that it has the ability to adapt and grow well in a wide range of environmental conditions (Lim *et al.*, 2013; Woolfe, 1992). Sweet potato may be considered as a dessert in the Western world, in Africa it is one of the major staple food crops (Adu-Kwarteng *et al.*, 2014). Sweet potato contributes effectively to improving food availability as a result of its high yielding potential (Alcoy *et al.*, 1993; Wayo, 2002).

It is capable of giving a significant amount of root yield even when planted on marginalized soils with very low level of soil fertility (Attaluri *et al.*, 2010; Truong, Avula, Pecota, & Yencho, 2011; Woolfe, 1992). According to Attaluri *et al.* (2010) and Maniyan and Ray (2010), the spreading nature of the sweet potato vines coupled with its broad leaves, facilitates its good canopy formation a few weeks after planting. This helps in suppressing weed growth. Sweet potato is capable of producing high root yield even when exposed to minimal drought (Degras, 2003). More especially, when root initiation is completed (Rukundo *et al.*, 2013). It could be cultivated with few labour, limited lands and a little amount of capital (Attaluri *et al.*, 2010). Sweet potato could produce more yield per unit area with reasonable amount of protein, vitamin and mineral content as compared to cassava, a major food crop in Africa (Griineberg, Mwanga, Andrade, & Dapaah, 2009).

According to Carey *et al.* (1999), the indigenous sweet potato cultivars in Sub-Saharan Africa (SSA) are predominantly the white and yellow-fleshed types which are significantly low in most of the nutrients needed by the human body for good growth and development. (3-carotene, a precursor of vitamin A, is an example of nutrients needed mostly by children under five, pregnant and lactation mothers for good growth (Griineberg *et al.*, 2009; Low, Walker, & Hijmans, 2001; World Health Organization, 2008). It has been reported that (3-carotene is responsible for improving human sight and could prevent xerophthalmia in children and also in pregnant women (Carey *et al.*, 1999; Low *et al.*, 2001; Ssebuliba, Nsubuga, & Muyonga, 2001; World Health Organization, 2009). In the 1990s scientists at the International Potato Center (CIP) identified a group of orange-fleshed sweet potato (OFSP) cultivars with a good 13-caroten6 and dry matter content to satisfy consumer preference and taste (K'osambo, Carey, Misra, Wilkes, & Hagenimana, 1999) to complement the supplementation of the vitamin A capsules distribution by United Nations Children's Fund (UNICEF) (Wagt, 2001).

Consumption of the OFSP cultivars improves the vitamin A status and could play a significant role in developing countries as a viable and long term food-based strategy for reducing VAD in children (Christian *et al.*, 2000 ; Jaarsveld *et al.*, 2005). Previous studies have demonstrated that consumption of about 100 g of boiled deep orange-fleshed sweet potato roots can provide the daily vitamin A requirements of young children and adults thereby preventing or reducing VAD (Attaluri & Campilan, 2010; Mukherjee, 2010). The OFSP cultivars are good and promising food crops and could be used for fighting VAD especially in low-income countries (Low *et al.*, 2001).

The purple-fleshed sweet potato (PFSP) cultivars contain a high amount of polyphenolic compounds, mainly anthocyanins that is being used as functional food and source of natural food colourants (Lim *et al.*, 2013; Steed & Troung, 2008). Thus inhibits oxidation of other molecules that plays a vital role in human health (Lim *et al.*, 2013; Woolfe, 1992). Antioxidants are mostly found among the PFSP cultivars (Mario, Ogasawara, Sato, Higo, & Minobe, 2007). Lim *et al.* (2013) reported that the anthocyanins contained in the PFSP cultivars is effective in inhibiting SW480 cancer cells growth in human colon by inducing cell-cycle arrest with no significant side effect. Additionally, it has been shown to reduce blood glucose level in diabetic patients (Jawi, Satirta-Yasa, Suprapta, & Mahendra, 2012).

Thus, the OFSP and PFSP could contribute significantly to improving the quality of life of Ghanaians when well-studied, adopted and included in our diet.

1.3 Problem statement

Notwithstanding the health benefits of the OFSP and the PFSP cultivars as mentioned above, the harvesting period to obtain good root quality of these newly introduced sweet potato cultivars in Ghana is yet not known. Therefore, establishing an appropriate harvesting time for these new cultivars is warranted since root quality of sweet potato associated with time of harvest (Alcoy *et al.,* 1993; Richardson, 2011). According to Richardson (2011) and Woolfe (1992), root quality of sweet potato could be reduced when harvesting is done early or become fibrous when harvesting is delayed. Delayed harvesting increases the buildup of weevils on the root of the crop as a result of increases in sucrose (Mitra, Tarafdar, & Palaniswami, 2010). This means that, root quality of the OFSP and PFSP cultivars could be improved if appropriate harvesting period is established. Additionally, other factors reported to have affected root quality include planting materials (Alcoy *et al.,* 1993), root age (Carey *et al.,* 1999), intercropping and mixed farming (Attaluri *et* al., 2010) and planting dates (Etela & Anyanwu, 2011).

DAP could be a significant factor that may possibly influence the quality of these OFSP and PFSP cultivars been introduced to Ghana. Mostly, harvesting of the sweet potato roots is also at the discretion of the farmer depending on their concerns such as targeted market prices, personal economic circumstances and types of cultivar that is been cultivated (Mwanga & Ssemakula, 2011). Depending on maturity stages, some sweet potato cultivars could be classified as being early or late maturing type (Richardson, 2011; Woolfe, 1992). Some of the late maturing cultivars could have their roots remain in the soil for about eight months before they are harvested (Woolfe, 1992). However, this may only be possible when good environmental conditions are met with relatively few natural enemies such as pest and diseases (Woolfe, 1992).

This study seeks to investigate root quality of four sweet potato *[Ipomoea batatas* (L) Lam] cultivars, three being OFSP cultivars (TUO, VOG, and APD) and one PFSP cultivar (TUP) as influenced by four different days after planting (65, 95, 125 and 155) in the savanna agro-ecological zone of Ghana. APD is the only released OFSP variety in **Ghana** with deep orange colour of the flesh. TUO and TUP are pale orange and purple-fleshed sweet potato variants introduced to Ghana on the STOPS project. VOG is a farmer variety grown in the Kumbungu District, Northern Region Ghana. its flesh colour is yellow with deep orange patches.

1.4 Justification

The high rate of VAD in Africa have caused about 250, 000 to 500, 000 children to become blind every year and about half of them do die within the year (World Health Organization, 2000) VAD patients have low resistance to infectious diseases such as diarrhoea and measles (World Health Organization, 2011), it also causes high maternal mortality, unsustainable pregnancies and poor lactation (Christian *et al.,* 2000; WHO, 2000). The prevalence of VAD in Ghana among children under five years is as high as 76% (WHO, 2009) which is almost four-fold more than the WHO classification of being a severe public health issue, Over 3, 000 lives of children who are less than five years of age are lost in some sub-Saharan African countries including Ghana each year mainly due to VAD (Humphrey, West, Sommer, 1992).

VAD patients who are fortunate to escape death, face a lot of health challenges such as night blindness (visual impairment), corneal ulceration and undesirable changes in the skin such us being dry, scaly and rough known as xeroderma (WHO, 2000). Poor growth and development as well as abnormal epithelial differentiation which may disturb the normal functioning of the body are also as a result of VAD (Humphrey *et al.,* **1992; Kennedy & Oniango, 1993).** This phenomenon therefore makes it very necessary to carry out investigation on when to harvest these newly introduced OFSP and PFSP cultivars for high 0-carotene content, a precursor for vitamin A and other nutrients to improve human health. According to Aguayo, Baker, Crespin, Hamani, & MamadoulTalbou (2005), the control of VAD can avert over 25,000 children deaths per year in Sub-Saharan African.

Food insecurity is an issue in Ghana (Kuwornu, Suleyman, & Amegashie, 2013) and other countries in the developing world (Low *et al.*, 2001) as a result food with little amount of 0-carotene is consumed (K'osambo *et al.;* 1999; Low *et al.*, 2007). Sweet potato is one of the root crops that play a major role as a food security crop in Sub-Saharan Africa (Kapinga *et a/.*, 2005). Sweet potato is a high yielding crop and the roots are of different colours depending on the cultivar (Hagenimana & Low, 2000; Hagenimana *et al.*, 2001). Once the OFSP cultivars contain 0-carotene (Carey *et al.*, 1999; Crissman *et al.*, 2007; Low *et al.*, 2001) and the PFSP cultivars also contains anthocyanins (Lim *et a/.*, 2013) and many other valuable nutrients, then there is the need to study on how to establish an appropriate DAP to maximize root quality to complement the effort of improving food and nutrition security in Ghana.

In Ghana, there is only one OFSP variety, Apomuden (denoted as APD), is this thesis.

The Sustainable Technology for Orange and Purple Sweet potatoes (STOPS) project, led by researchers from Tuskegee University, USA, identified the gaps in the value chain from production, processing, product development to consumption of OFSP and PFSP aimed at addressing VAD and improving the health and nutritional status of the vulnerable population in rural communities of Ghana. Detailed description of the STOPS project is beyond this scope and can be found elsewhere: http://hortcrsp.ucdavis.edu/main/35 sweetpotato.html. This project introduced OFSP and PFSP denoted as (TUO and TUP) cultivars to Ghana, but they are yet to be evaluated and released as varieties in Ghana.

Hence, this study will assess the root quality of these introduced sweet potato cultivars to set the background information required- for extensive research for their evaluation for released as varieties in Ghana

1.5 Objectives of the study

The main objective of this study is to establish an appropriate time of harvesting sweet potato cultivars for optimum root quality.

Specific objectives of the research are:

1) To assess the appropriate time to harvest four sweet potato cultivars (**APD, TUO, TUP** and **VOG**) for a desirable root yield.
2) To investigate the effect of harvesting time on nutrients especially 13-carotene content of roots of the four sweet potato cultivars listed above.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter contains relevant literature of the study. It begins with a review of the origin and distribution of sweet potato, its production and role in improving food security in Ghana. Days after planting and its effects on root quality such as root yield and foliage weight, [3 carotene, dry matter, sugars, starch, minerals and protein have been reviewed in detail as being the main aspect of this study.

2.2 Origin and distribution of sweet potato

Sweet potato *[Ipomoea batatas* (L.) Lam] is believed to have come from the northwestern part of South America, where it had a lot of common names such as batata, camote, bonlato, batatdoce, apichu and kumara (Huaman, 1992). In 1753, Linnaeus described the sweet potato plant as *Convolvulus batatas* due to the shape of the stigma as well as the surface of the pollen grains (Huaman, 1992) and in 1791 Lamarck also categorized it into the genus *Ipomoea* hence the *name Ipomoea batatas* (L.) Lam (Huaman, 1992; Nedunchezhiyan & Ray, 2010). According to Truong *et al.* (2011), sweet potato is not to be confused with "yam", which is a crop that is grown outside the United States. Sweet potato is sometimes called "yams", due to the moist nature of the roots and for marketing purposes.

Yam belongs to the family *Dioscorea* (Ennin, Otoo, & Tetteh, 2009; Kuepper Freeman, 2012) but sweet potato belongs to *Convolvulaceae,* the morning glory family and is a true root crop (Wireko-Manu, Oduro, Ellis, Asiedu, & Maziya-Dixon, 2013; Woolfe, 1992). According to Degras (2003) and Woolfe, (1992), more than 400 species of *Ipomoea batatas* exist around the world and are known in different languages.

Today, sweet potato is grown in most parts of the tropical regions including Ghana, as one of the world's most important food crops (Walker, Thiele, Suarez, & Crissman, 2011).

The total annual production of the crop as at 1990 to 2006 was between 120 - 140 million tons across the globe and China contributed 80.00% being the leading producer (Truong *et al.*, 2011) Africa 6%, U.S. 0.80% and the remaining 13.20% for the rest of the world (Truong *et* al., 2011; Woolfe, 1992). This low production level of the crop in Africa suggests that the people know little about the health benefits and its potential to reduce food insecurity. Another possible reason could be that it is mainly grown by peasant and small-holder farmers (Carey *et al.*, 1999). In Ghana, sweet potato is becoming a commercial crop. A large area of land, estimated to be 9,622 hectares were cultivated during the 2012 cropping season which yielded 131,990 t/ha (Ministry of Food and Agriculture (MoFA) & Statistics Research and Information Directorate (SKI)), 2012).

According to Ofori *et al.* (2009), the crop is mainly grown by few farmers scattered around the three Northern regions and some parts of Volta region of Ghana. Nedunchezhiyan *et al.* (2012) reported that warm sunny days and cool nights with moderate rainfall are good conditions for sweet potato to produce well.

2.3 Sweet potato production in Ghana

Ghana is located on the southern coast of West Africa, between latitudes 4^{e} 44' N and 11 11' N and longitudes 3 11' W and 1 11' E with a total population approximately, 24.70 million in the year 2010 (Ghana Statistical Service, 2013). It is one of the West African countries with its economy largely driven by agriculture (Dittoh, Bhattarai, & Atosiba, 2013; Wayo, 2002).

Nearly 60% of the Ghanaian population are in the rural sector and are predominately farmers (New Partnership for Africa's Development (NEPAD), Comprehensive Africa Agriculture Development Programme (CAADP) Investment Centre Division, & Food and Agriculture Organization (FAO) of the United Nations, 2005; Wayo, 2002).

There are six agro-ecological zones in Ghana are: Sudan Savannah, Coastal Savannah, Rain Forest, Deciduous Forest, Guinea Savannah and the Transitional Zone as shown in Figure 1 (Fold, 2008; FAO, 2005; Wayo, 2002).

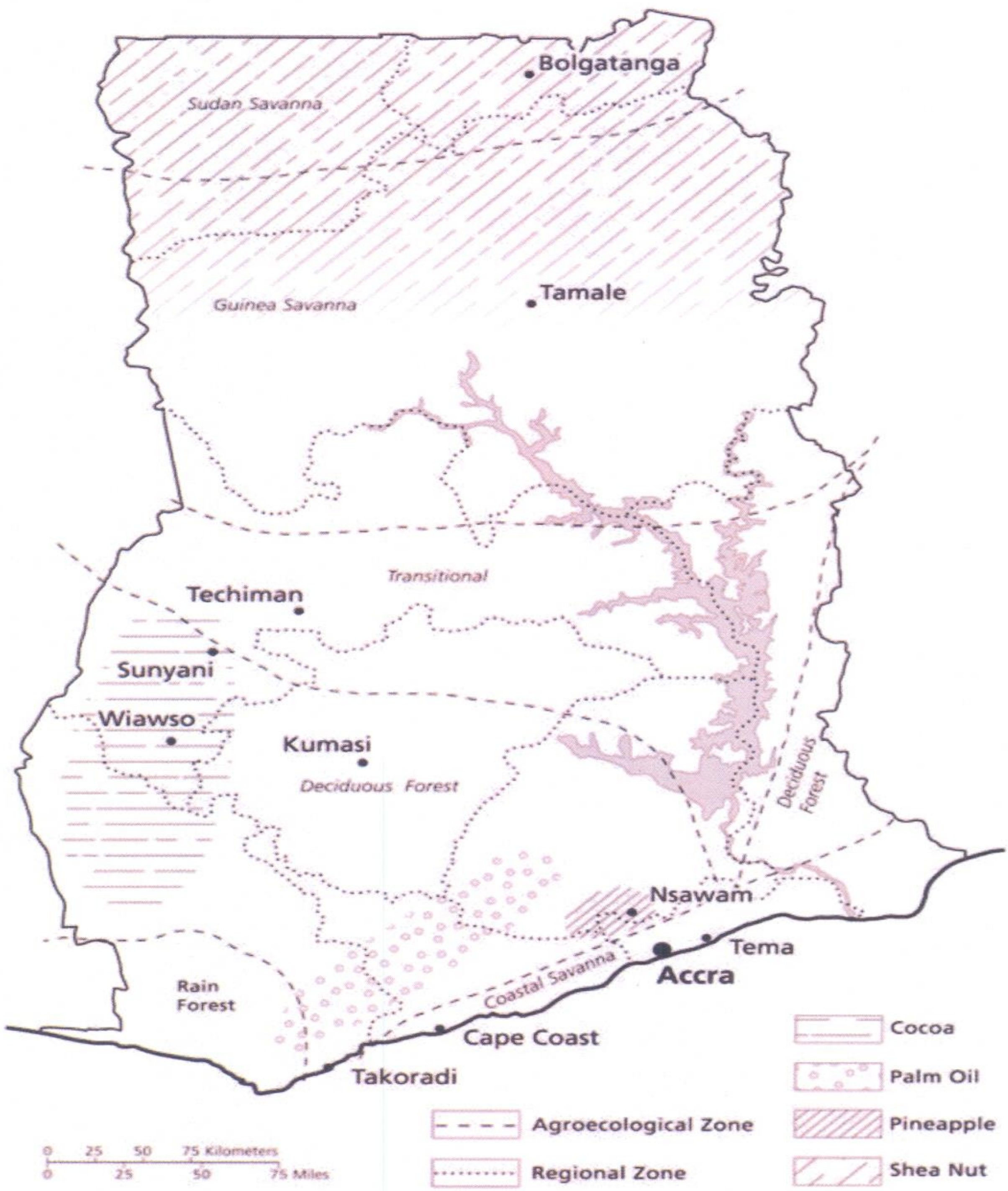

Figure 1: agro-ecological zones in Ghana showing the major economic crops

Source Fold,(2008)

According to Wayo (2002), some of the food crops mainly grown in these zones include: cereals, legumes, root and tuber crops such as sweetpotato, yam, and cassava **(Table 1)** which are use for food and raw materials for industries.

Table 1: Crops grown in Ghana

Group	**Crop**
Cereals	Maize, Millet, Sorghum, Rice
Industrial crops	Cocoa, Oil-palm, Coffee, Cotton, Tobacco, Sheanut, Cola nut
Legumes	Cowpea, Bambara nut, Groundnut, Soybean
Fruits	Papaya, Avocado, Mango, Cashew, Watermelon, Plantain, Banana
Vegetables	Tomato, Eggplant, Onion, Pepper, Okra, Cabbage, Lettuce, Carrot
Roots and Tubers	Yam, Cassava, Cocoyam, Sweet potato

Source: FAO (2005)

Sweet potato, which is the fifth most important food crop in the world after rice, wheat, maize and cassava (Low *et al.*, 2001; Nelles, 2009) ranks fourth in Ghana after cassava, yam and cocoyam (Ennin, Dapaah, & Asafu-Agyei, 2007). Sweet potato is often regarded as an inferior crop that is consumed by the poor and therefore has not being given the necessary attention it deserves as a staple food crop (Walker *et a/.*, 2011). About 78,000 household farmers are into the **production** of sweet potato, this is still expected to increase due to the recent research and extension intervention currently going on in Ghana (Ennin *et a/.*, 2007). This is because many people in Africa and for that matter Ghana are beginning to know the essence of the crop relative to human health and food security (Low *et a/.*, 2007).

The high productivity level (Walker *et a/.*, 2011), wide adaptability and most importantly the health benefits of sweet potato especially the OFSP and PFSP cultivars (Low *et al.*, 2001). Some international organizations such as International Institute for Tropical Agriculture (IITA) and CEP have intensified research to develop the crop (Mwanga & Ssemakula, 2011; Walker *et al.*, 2011).

In Ghana, almost all the regions cultivate sweet potato in larger quantities except the Western region which is in the southern sector of the country. It is mainly planted in pure stand in the southern sector whilst in the northern sector; it is sometimes intercropped with yam or estimated that, a total of 9,622 hectares of sweet potato was cultivated during the 2012 cropping season in Ghana (MoFA & SRID, 2012).

Table 2: Sweet potato production in Ghana

Region	Area	%	Production	%
Central	371	3.90	6,490	4.90
Volta	880	9.10	15,340	11.60
Eastern	1,030	10.70	34,910	26.40'
Gt. Accra	38	0.40	640	0.50
Ashanti	37	0.40	620	0.50
Brong	145	1.50	2,390	1.80
Northern	414	4.30	6,070	4.60
Upper	5,550	57.70	46,000	34.90
Upper	1,157	12.00	19,530	14.80
Total	**9,622**	**100.0**	**131,990**	**100.0**

Sourte: MoFA & SRID, (2012)

The highest sweet potato production region in Ghana is Upper East, contributing 34.90% and the least production regions are Greater Accra and Ashanti Regions respectively contributing 0.50% each (Table 2). The reason for the differences in root yield observed between the southern and northern part of the country could be due to environmental differences that exist in these agro-ecological zones such as rainfall, sunshine and temperatures that may affect the crop growth and development (West Africa Agricultural Productivity Programme (WAAPP) & Council for Scientific and Industrial Research (CSIR), 2012).

Ghana is one of the African countries with good sweet potato production potential (Ofori *et al.,* 2009) and this study on the newly introduced OFSP and PFSP cultivars will help improve upon the root quality which could possibly help fight diseases related to VAD, improve and sustain livelihoods for the poor and vulnerable people in the country and the world at large.

2.4 Importance of sweet potato production in Ghana

Ghana has been fairly stable in terms of food security on national basis, even though there are few pockets of food insecurity situations that exist in the three Northern Regions and the Central Region (Kuwomu *et al.*, 2013). Kuwomu *et al.* (2013) reported that majority (60%) of the farmer households were food insecure in Central region of Ghana. According to Kuwomu *et al.* (2013) this situation could be due to the fact that most of the farmer households (85%) were into tree crop production and only (13%) went into food crop production. These few farmers who went into food crop production were unable to produce enough to satisfy the population in the region, hence food shortages.

The major causes of food insecurity in Africa include: very low or erratic rainfalls, floods and political instability resulting into poor yield production (Kapinga *et al.*, 2005). According to Kapinga *et al.* (2005), drought affected farm families in Uganda from 1994 to 1995 were given healthy OFSP planting materials rich in 13-carotene content to establish their own farms and increase food availability and vitamin A levels in their diet. The OFSP could improve upon food security and also provide very useful nutrients such as (3-carotene which is good for body functioning (Hagenimana & Low, 2000; Jaarsveld *et al.*, 2005). The OFSP has the potential to reduce food shortages and malnutrition in our communities since it is able to produce high quality roots per unit area (Nedunchezhiyan *et al.*, 2012). According to Kapinga *et al.* (2005), OFSP also contribute to high income generation and improving the nutritional level of the rural poor.

This means that, sweet potato has the potential to fight food insecurity and improve human health by reducing VAD, hence the need to investigate on the appropriate time to harvest these OFSP and PFSP cultivars to meet the maximum root yield and nutritional content needed by Ghanaians.

2.5 Sweet potato production for food, income and health

Even though Cereals, legumes and fruits provide good yield and nutrients, roots and tubers are still needed to meet the dietary requirement in Africa and other parts of the world at large (Dayal, Scott, Ktuup, & Balagopalan, 1997). Cassava, yam and sweet potato are notably the major root and tuber crops produce in Sub-Saharan Africa in fighting hunger and improving the income level of farmers (FAO, 2005). Root yield of sweet potato in Sub-Saharan Africa appears to be static, between 4 and 5 t/ha and more than 80% of the total production is consumed by man directly and the rest is processed into starch, glucose syrup or use as animal feed (Dayal *et al.*, 1997; Kenyon, Anandajayasekeram, & Ochieng, 2006). According to Kenyon *et al.* (2006); Padmaja (2009) and Woolfe (1992), the crop is mostly eaten as boiled or roasted. It is also be processed into flour for bread baking (Low & Jaarsveld, 2008), ice-cream or chips which is widely consumed in Asia (Padmaja, 2009).

In Japan, 5% of the total production of sweet potato starch is fermented and distilled into a spirit called "shochu" (Woolfe, 1992) and in Uganda, it is being processed into juice, cake; chapattis and also chips as it is done in Japan (Padmaja, 2009). According to Ezeano (2010), 70.80% of sweet potato farmers in Nigeria use the crop for the preparation of *foo-foo* (pounded yam), flour and other beverages like *kuru* and *burukutu*. Additionally, sweet potato could also be used to prepare complementary foods for infants, mostly those in the low income countries (Amagloh *et al.*, 2012). It could also be processed into *gari* which many people prefer in Ghana

(Amoaful, 2001). Due to the attractive colour of the crop, especially the PFSP a lot of people around the world consume it (Steed & Troung, 2008; Woolfe, 1992).

Culturally, countries like the United States uses the crop as festive foods and when it i; absent, their Thanksgiving meal would be incomplete (Woolfe, 1992). In Tonga, it is also used in the traditional feasts for high ranking personalities (Woolfe, 1992). All these suggest that, sweet potato is not only used as food to combat hunger in Africa, but also relevant traditionally across the globe. According to Padmaja (2009), sweet potato roots and vines together with its waste products from starch and alcohol are used to feed livestock in China, Japan, and Taiwan.

Economically, sweet potato plays a significant role in improving upon the living standard of people across the world. According to Degras (2003), even though sweet potato has not gained much popularity in the international trade, it has by far boosted the economy of some countries. For example, a Chinese province have experienced a tremendous economic transformation due to the relatively high production level of sweet potato and have been elevated from subsistence farming to agro-industrial level of production. In Japan, there have been major changes in the usage of the crop as a forage and consumption on the farm to starch production (Degras, 2003). Agro-industrialization is not the same in all parts of the world. In most parts of the Sub-Saharan Africa, sweet potato is mainly consumed directly from the farm and does not undergo any industrial processing before use (Degras, 2003). There is high consumption of sweet potato in Africa (Degras, 2003). This means that, the crop is capable of improving food securifi. However, harvesting period, good storage practices and processing the roots of most cultivars are not known, hence low root yield (Pillai, 1997).

Even though sweet potato is yet to be given much industrial attention in Africa, it does not in any way mean that Africans are not enjoying its economic fortunes. Many sweet potato farmers have being able to improve their income level through the sale of sweet potato planting materials (Mwanga & Ssemakula, 2011): A single farmer can earn 400 US$ per month from the sale of planting materials and sweet potato products at the beginning of the rainy season (Mwanga & Ssemakula, 2011). According to Kenyon *et al.* (2006), root crop production including sweet potato in the developing world's economy, is estimated annually to- be more than 41 billion US$. The income these farmers gain helps them meet their household obligations such as their children educational and medicinal needs as well as clothing and providing shelter for them.

In terms of human health, the contribution of sweet potato cannot be over-emphasized. The human nutritional need is paramount and has been improved significantly due to the 0-carotene content, the precursor for vitamin A availability of the OFSP cultivars. Millions of children under five years of age have been saved from death as a result of consuming the OFSP cultivars of the required quantities (Carey *et al.*, 1999; Low *et al.*, 2001; Low & Jaarsveld, 2008; Mwanga & Ssemakula, 2011). According to Woolfe (1992), sweet potato is a good medicinal crop and has been very effective in preventing kidney problems, constipation, and its consumption increases blood platelet levels, reduces blood sugar level thereby stimulating the immune system to function effectively. Due to the high nutritional content of the crop, it is also used in the oral rehydration therapy to improve upon children nutritional level (Woolfe, 1992).

The PFSP cultivars contain anthocyanins which have been found to be effective in inhibiting cancer cell growth in mice and humans (Jawi *et al.*, 2012; Lim *et al.*, 2013). People who are diabetic could reduce it through the consumption of anthocyanins concentrated food8 like the PFSP (Jawi *et al.*, 2012). Additionally, the excess production of free radicals such as superoxide anion radical, hydroxyl radical and alkylperoxyl, induces damage such as aging, cancer and other lifestyle related diseases to human (Suda *et al.*, 2003). These diseases could be prevented through regular consumption of these anthocyanin rich-foods such as the PFSP (Jawi *et al.*, 2012; Suda *et al.*, 2003; Tokusoglu & Yildirim, 2012).

2.6 Cultivation of sweet potato

2.6.1 Cultivation period of sweet potato

There is no specific time for planting sweet potato (Rukundo *et al.*, 2013). This is due to the fact that, different locations with different rainfall patterns (Woolfe, 1992). However, it is always good to plant within the early rains to enable the crop meet maximum rains in the season for proper growth, development and yield production (Woolfe, 1992). Degras (2003) stated that the season for planting sweet potato depends largely on the "ecosystem" and that within the tropical zone, the crop is planted once in a year unless of course the specific geographical area experiences two rainy seasons or being irrigated.

2.6.2 Harvesting of sweet potato

Root quality of sweet potato just like any other food crop cannot be improved after harvest, it can only be maintained (Richardson, 2011). It is therefore very important to identif3 an appropriate harvesting period in other to meet the optimum root quality in terms of agronomic and nutrient characteristics. In some crops, single harvesting is done as soon as the crop gets to its maturity stage, else they are shattered in the case of soybeans, spoiled or eaten by birds for example rice and sorghum (Nedunchezhiyan *et al.*, 2012). In root and tuber crops, for example sweet potato, single and multiple harvesting could be carefully practiced since root yield may not immediately be affected when harvesting is delayed for a week or two (Nedunchezhiyan *et al.*, 2012; Richardson, 2011) they neither ripen nor mature like fruits (Purcell, Walter, & Wilson, 1989).

Traditionally, there is no specific time for harvesting sweet potato due to cultivar and environmental differences, also it is harvested when needed for consumption (Woolfe, 1992). Sweet potato roots may continue to enlarge as long as they remain in the ground with relatively good environmental conditions such as rainfall and temperature, but when over delayed, will become fibrous (Purcell *et al.*, 1989). According to Ebregt *et al.* (2007), who researched into piecemeal harvest versus one time harvest, explained that even though root yield could be increased as the crop is left in the ground, yield and quality levels may be compromised after 135 DAP as a result of weevil infestation, sprouting and fibre development. Appropriate time for harvesting the newly introduced OFSP and PFSP cultivars in Ghana to meet good root quality it's relevant to maximize root quality to feed the fast growing population in the country.

2.6.3 The interactive effect of DAP on root yield and size

The formation of sweet potato root is a complex process which involves a lot of steps such as: stopping the root elongation, initiation of the vascular cambia and increasing of radial growth through cell-proliferation and expansion (Rukundo *et al.*, 2013). Mostly, roots that are harvested during their elongation period may be less in weight than those that are allowed to undergo a complete radial growth to expand in size (Rukundo *et al.*, 2013; You *et al.*, 2003). According to Alcoy *et al.* (1993) and Mitra *et al.* (2010), root yield were observed to be high at 120 DAP than those harvested earlier at 90 and 105 DAP. Etela and Kalio (2011) and Reynolds *et al.* (1994) also revealed that root yield were high when **19**harvested around at 140 DAP than those harvested earlier (Table 3).

Table 3: Root yield and fresh foliage weight (kg) of three sweet potato varieties

Table 3: Root yield and fresh foliage weight (kg) of three sweetpotato varieties

Sweetpotato variety	Days after planting					
	84		112		140	
	Foliage (kg)	Root yield (kg)	Foliage (kg)	Root yield (kg)	Foliage (kg)	Root yield (kg)
TIS-87/0087	2.54	6.29	1.25	6.92	0.99	8.32
TIS-8164	2.60	9.08	1.71	10.16	1.42	10.57
TIS-2532.OP1.13	2.72	7.90	2.24	8.64	1.95	9.55

Source: Etela & Kalio (2011)

Contrary to these findings of good yield around 120 and 140 DAP, it was also demonstrated that, OFSP and PFSP root yield were observed to be high at 190 DAP (Noda, Talcahata, Sato, Ikoma, & Mochida, 1997). These variations confirms that sweet potato have different maturity stages among the cultivars (Woolfe, 1992). The latter may be late maturing, cultivars whilst the former are early maturing cultivars. When harvesting is delayed, the quality of the root may be reduced since most of them could become fibrous (Woolfe, 1992) and have high weevil infestation (Mitra *et al.*, 2010). Thus, significant differences existed among cultivars studied at different harvesting stages and that root yield may increase with root age.

DAP may also have an effect on sweet potato root size. It was reported that root size was 15.95 cm at 121 DAP, which was higher than 12.05 cm at 87 DAP respectively (Reynolds *et al,*, 1994). This agrees with the findings of Alcoy *et al.* (1993) that, the size of the roots were comparatively 16 cm higher after 120 and 105 DAP as compared to those harvested at 90 DAP. This could mean that, sweet potato root needs some period of time that could allow high dry matter accumulation which leads to an increase in root size (Alcoy *et al.*, 1993; Rukundo *et al;* 2013).

2.6.4 Effect of DAP on number of sweet potato roots

According to Alcoy *et al.* (1993) who considered different planting materials and time of harvesting, number of root was 2.45 at 90 as compared to 1.86 and 1.89 at 105 and 120 DAP respectively **(Table 4).** Number of roots could also be increased by the use of mounds or ridges instead of planting them on the flat (Ennin *et al.*, 2009).

Table 4: The influence of number of roots on root yield

DAP	Number of roots	Root yield (kg)
90	2.45	0.24
105	1.86	0.30
120	1.89	0.38
Mean	2.06	0.31

Source: Alcoy *et al.* (1993)

2.6.5 Effect of DAP on sweet potato fresh foliage weight

Fresh foliage comprises the leaves and vines of a crop which is an excellent source of feed for animals (Nedunchezhiyan *et al.*, 2012). It has been a delicacy not only for animals but for people across Africa and China (Etela & Kalio, 2011; Huang, Song, Qiao, & Fuglie, 2003). According to Etela and Kalio (2011), fresh foliage weight of sweet potato was 2.62 t/ha higher at 84 DAP as compared to 1.73 and 1.45 t/ha observed at 112 and 140 DAP respectively. This suggests that fresh foliage weight could 'decrease when DAP are increased. This component of the crop is mostly consumed in Africa as food or fodder but there is no information on it in fresh weight basis. It is important to investigate the newly introduced OFSP and PFSP cultivars to establish when to meet maximum fresh foliage weight in Ghana.

2.7 Effect of DAP on the nutritional composition of sweet potato

2.7.1 a-carotene content

13-carotene is a pro-vitamin A, noted to be associated with some plant product in larger quantities including the OFSP cultivars (K'osambo *et al.*, 1999; Low *et al.*, 2001). This J3-carotene of the OFSP cultivars may be influenced by different days after planting: Accumulations of 13-carotene among the OFSP cultivars have been shown to increase as long as their maturity stages are prolonged (K'osambo *et al.*, 1999; Mitra *et al.*, 2010). Additionally, it has been reported that 13-carotene as well as 13 amylase content of sweetpotato roots varies relative to days after planting (Dziedzoave, Graffham, Westby, Otoo, & Komlaga, 2010). Cultivar differences may also be possible factor that might have accounted to this variation. It has been reported that the white and cream-fleshed cultivars had lesser amount of (3-carotene as compared to the OFSP cultivars (K'osambo *et al.*, 1999; Walker *et al.*, 2011). It is also being speculated that, 3-carotene content could be influenced by root size, plant development and the locations where the cultivars were grown (K'osambo *et al.*, 1999).

Thus, the newly introduced OFSP cultivars with different colours and PFSP cultivar to Ghana warrant an investigation to ascertain its 13-carotene content level relative to DAP.

2.7.2 Dry matter content

Moisture content of sweet potato roots is as high as 70% with relatively low dry matter content depending on the cultivars, soil types and climate (Abubakar, Olayiwola, Sanni, & Idowu, 2010; Woolfe, 1992). Sweet potato cultivars with dry matter content greater-than 30% are considered as cultivars with high dry matter (Grace *et al.*, 2014). Dry matter content of the sweet potato root may differ with DAP. It has been reported that dry matter content increased from 22.76% to 26.52% from 90 to 120 DAP respectively (Mitra *et al.*, 2010). Thus, it could be speculated that dry matter content increase with an increase in root age. According to Mitra *et al.* (2010), the variation in dry matter content might be as a result of the different cultivars used, the traditional OM cultivars are known to have low dry matter content as compared to the improved cultivars. Another possible reason for this phenomenon could be due to the increase in DAP, as dry matter content was high at 120 DAP as compared to 90 DAP (Alcoy *et al.*, 1993; Mitra *et al.*, 2010).

2.7.3 Sugars

Total sugars include glucose, fructose and sucrose (Adu-Kwarteng *et al.*, 2014) and their levels may vary between cultivars (Adu-Kwarteng *et al.*, 2014; Mitra *et al.*, 2010; Woolfe, 1992). The most dominant among these sugars is sucrose, followed by glucose and fructose (Padmaja, 2009). According to Adu-Kwarteng *et al.* (2014), fructose and glucose content were high at 90 DAP and declined at 120 and 150 DAP among the cultivars. However, sucrose assumed a different trend. It rather increased as the plant aged and was high at 150 DAP (Adu-Kwarteng *et al.*, 2014). Fructose and glucose are both simple sugars which could be converted t. sucrose (a complex sugar) as the roots advances in age (Adu-Kwarteng *et al.*, 2014) hence the increase in sucrose content at 150 DAP.

2.7.4 Starch content

Days after planting may also influence starch content in some root crops such as sweet potato. Mitra *et al.* (2010) reported that starch content increased significantly from 5.90% to 17.40% during root growth period from 90 to 120 DAP respectively. This suggest that starch content increases along with increases in DAP (Mitra *et al.*, 2010). This confirms previous findings that starch content of sweet potato roots accumulates as harvesting time is prolonged and was high during the late harvest than the earlier harvest (Noda *et al.,* 1997; Noda *et al.,* 2004; Woolfe, 1992).

The general trend observed is that starch accumulation increases with root age. Previous studies attributed this phenomenon to an enzymatic activity that might have been active at the latter, part of the crop growth, hence the increase in starch accumulation (Noda_et *al*., 1997). Contrary to these findings, Reynolds *et al.* (1994) who worked on two sweet potato cultivars in three separate years in Ontario and Mitra *et al.* (2010) both reported that the increase or decrease in starch content is attributed to the fact that the crops might have been grown in a warmer area causing starch to metabolize into sugars, hence the decrease at the latter harvest. There is little information on the starch content of these newly introduced OFSP and PFSP cultivars in Ghana, hence the need to investigate on the relationship between starch and days after planting.

2.7.5 Mineral content

Zinc and iron are vital micro-nutrients required by humans for healthy growth and body development. Their deficiency could lead to growth retardation, skin disorders, eye lesions and anaemia (WHO, 2000). These minerals may be found in crops like sweet potato. Woolfe (1992) reported a range of 0.16 to 0.94 mg/100 g of iron and 0.27 to 1.89 mg/100 g of zinc frog sweet potato root in fresh weight basis. Similarly, Abubakar *et al.* (2010) also reported that boiled sweet potato roots contains 1.15 mg/100 g of iron and 0.25 mg/100 g of zinc respectively. The mineral content in the soil where the crops were grown could lead to the variations of iron and zinc (Reynolds *et al.,* 1994).

Additionally, it has been demonstrated that peeling of the roots leads to a significant reduction in zinc and iron content (Woolfe, 1992). However, boiled sweet potato leaves may contain as much as 8.82 mg/100 g of iron and zinc (Abubakar *et al.*, 2010).

2.7.6 Protein content

Sweet potato could provide some amount of protein for many people in most of the developing world. Even though this amount of protein may be less as compared to the animal products such as eggs, fish and meat, they are expensive (Low *et al.*, 2001; Woolfe, 1992). The protein content of sweet potato root is 2.27% being low as compared to the amount in leaves which is 12.21% (Abubakar *et al.*, 2010; An, Frankow-Lindberg, & Lindberg, 2003) This seems to agree with Woolfe (1992) report, that protein content of sweet potato root was 1.50%, being lower than that of yam (1.80%) and potato (2.10%). However, the protein content of sweet potato is higher as compared to other root crops such as cassava and giant swamp taro that recorded 1.00% and 0.50% respectively.

Protein content among sweet potato cultivars could vary due to the soil fertility level, pests diseases infestations (Woolfe, 1992). Additionally, cultivar differences and location of crop growth c also lead to the variations of protein content (An *et al*., 2003). The researcher however, did not highl on days after planting as a factor that could influence the protein content of the roots, hence, the need further investigations, considering the newly introduced OFSP and PFSP cultivars.

2.8 Chemical composition of fresh sweet potato roots

The roots and leaves of sweet potato are the main food components of the crop mostly used as food or fodder (Etela & Anyanwu, 2011; Etela & Kalio, 2011). These parts are known to have a variety of chemical components which are useful to the plant and humans (Woolfe, 1992). Though the sweetpotato is not the best in terms of nutrients, it competes very well among other root and tuber crops (**Table 5**).

Table 5: Chemical composition of sweetpotato root and other tuber crops

	Sweetpotato	Cassava	Taro	Yam	Irish potato
Water	70	63	72	76	78
Protein (%)	1.5	1.0	1.7	1.8	2.1
Glucose (%)	26.1	32.4	23.1	21	18.5
Iron (mg)	0.7	1.1	1.2	0.5	0.8

Source: Woolfe (1992).

In terms of the major vitamins needed by the human body for growth and development, sweetpotato competes well with the other root and tuber, recording from 0 - 20,000 β-carotene whiles cassava recording 0 – 120 β-carotene (**Table 6**).

Table 6: Major vitamins of fresh sweetpotato root and other root and tuber crops

	Sweetpotato	Cassava	Irish potato	Cocoyam	Yam
β-carotene (μg)	0-20,000	0-120	Nd	43	108
Thiamin (mg)	0.09	0.05	0.11	0.03	0.05
Riboflavin (mg)	0.03	0.04	0.04	0.03	0.03
Niacin (mg)	0.60	0.60	1.20	0.76	0.41
Pantothenic acid (mg)	0.59		0.30		0.13
Pyridoxine (mg)	0.26		0.25	0.08	nd
Folic acid (μg)	14		24		nd
Ascobic acid (mg)	24	20	30	15	20

Source: Woolfe (1992).

2.9 Orange and purple-fleshed sweet potatoes for health

Sweet potato *[Ipomoea batatas* (L)] have different cultivars with diverse root colours including orange, yellow, white and cream fleshed roots (Low *et al.*, 2001; Woolfe, 1992) purple (Yoshimoto, Nkuno, Yamaguchi, & Yamakawa, 2001) pink and red (Pathleen, 2008) and the skin colours may also be white, cream, yellow, orange and purple. All these variety of cultivars contains reasonable amounts of 13-carotene (Kapinga *et al.*, 2007; Low *et al.*, 2001), Low *et al.* (2001), points out that the common sweet potato cultivars in the USA are mainly the orange types whilst those commonly grown in Sub-Saharan Africa are predominantly white.

The white varieties do not contain any significant amount of 13-carotene content and are mostly preferred by the Africans (Kapinga *et al.*, 2007). This suggest that further work should be done, especially on the newly introduced OFSP and PFSP cultivars to identify an appropriate DAP in relation to yield and 0-carotene content to aid in addressing VAD in Ghana.

2.10 Potential of OFSP

Large quantities of sweet potato produced in Africa are predominantly white varieties which have little amount of 0-carotene for addressing VAD (Carey *et al.*, 1999; Low *et al.*, 2001) and to ensure good growth and development (Christian *et al.*, 2000 ; Hagenimana & Low, 2000; Tumwegamire, Kapinga, Zhang, Crissman, & Agali, 2004). Vitamin A intake also improves the weight and height of consumers (Hadi *et al.*, 2000). The OFSP cultivars contain reasonable amount of 0-carotene content, less expensive and readily available in the rural areas where crop could be grown (Low *et al.*, 2001; Tumwegamire *et al.*, 2004). The OFSP cultivars are steadily replacing the predominately white cultivars in Africa dispelling the notion that "the African taste for the white-fleshed cultivars cannot be erased" (Tumwegamire *et al.*, 2004).

The introduction and consumption of OFSP cultivars in Africa have a substantial impact on the dietary intake among women and pre-school children (Hagenimana *et al*., 2001; Hotz eit *al.,* 2012; Katz *et al.*, 2000). The production and consumption of OFSP have increased in Africa tremendously not because of "colour per se" but due to taste, texture and the dry matter content (Carey *et a/.*, 1999; Low *et al.*, 2001; Tumwegamire *et al.*, 2004). Similarly, Mwanga and Ssemakula (2011) reported that the replacement of the white cultivars with the OFSP cultivars shows that VAD could be brought down from 44% to 22% in 17 Sub-Saharan African countries. Furthermore, it has been reported that 35 - 100 g of cooked OFSP, depending on the cultivars able to meet the dietary requirement of vitamin A for little children between the ages of 1 to 3 years while a reasonable amount of 3,636 g/100 g of the white **and** yellow cultivars **(Table 7)** would be required to achieve the same purpose (Carey *et al.*, 1999; Low *et al.*, 2001).

Table 7: Quantity of roots to consume to meet daily vitamin A requirement

Human age or gender group and daily vitamin A requirement (µg) retinol equivalent per 100 g fresh weight)	Sweet potato variety and pro-vitamin A content (µg) retinol equivalent per 100 g fresh weight)			
	TIS 2534 (11)	KEMB 10 (151)	SPK 004 (515)	Japones (1152)
1 to 3 years (300)	3,636	265	78	35
4 to 6 years (400)	4,545	331	97	43
7 to 10 years (600)	6,364	463	136	61
Females over 10 years (700)	7,273	530	155	69
Males over 10 years (900)	9,091	662	194	87

Source: Carey *et al.* (1999)

2.11 Potential of PFSP

The red, purple or blue types of colouration found in most parts of plants are mostly due to the presence of acylated anthocyanins and in sweet potato the flesh becomes purple when it is very high (Woolfe, 1992). The PFSP cultivars are well noted for its colour due to the large amount of anthocyanins it contains (Steed & Troung, 2008). This might be due to genetical influence that causes the high accumulation of the anthocyanin in some varieties while others do not have. According to Yoshimoto *et al.* (2001), the presence of anthocyanins in the roots of the PFSP makes it very useful as physiologically functional foods. The types of anthocyanins off sweet potato are acylated glucosides of cyanidin, acyl groups and peonidin (Islam *et al.*, 2002; Steed & Troung, 2008) and that the level of anthocyanins is influenced by root size (Woolfe, 1992). Larger roots contains more anthocyanins than the smaller roots if they are of same cultivar and grown from the same geographical location (Woolfe, 1992)

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

Materials and methods constitute the framework for the investigation. It comprises all the materials and methods used during the data collection and the procedures involved in analyzing these data. The chapter explains the materials used and their specifications, study location, the experimental design used and data collection procedures for both the agronomic and the compositional data of the study.

3.2 Materials used for the experiment both in the field and in the laboratory

These are the materials that were used in gathering the data during the study both in the field and in the laboratory.

Cutlasses: These were used to clear all the grasses and shrubs on the land.

Mould board plough: The land was ploughed using a mould board plough to make the soil loose enough to facilitate easy penetration of sweet potato root.

Harrow: After ploughing, the land was harrowed to break the lump soil particles to make ridges preparation easier.

Hoes: The hoes made up of a metal plate and wooden handle were used for preparing the ridges, clearing of weeds and digging out the roots during harvesting.

Sweet potato cultivars studied: Four cultivars were used for the study are stated below. These cultivars were the Tuskegee University orange-fleshed (TUO), Tuskegee University purple-

Fleshed (TUP) being newly introduced cultivars. The other two are Apomuden, a nationally released orange-fleshed cultivar (APD) and Voggu-orange being a landrace were obtained from Council for Scientific and Industrial Research-Savanna Agricultural Research Institute (CSIIk.-SARI). The vines of these cultivars were used as a planting materials and each vine contained four internodes. Two internodes were buried into the soil during planting.

Tape measure: This was used to measure the area cultivated. It was *also* used to measure the length of sweet potato roots longitudinally.

Nylon rope: The rope was used to obtain straight lines for pegging the area. It was also used te demarcate the actual area to be harvested at each harvest.

Weighing scale: Top pan weighing scale of 100 kg (Caney TNO 1215169) was used to measure the weight of root yield and fresh foliage weight at each harvest. The weighing scale was always set to zero before the sweet potato roots or fresh foliage could be put into the top pan for weighing.

Vernier caliper: The manual type of vernier caliper was used to measure the girth of sweet potato roots at each harvest. The sweet potato roots were measured by placing the roots in-between the external jaws, one at a time.

Plastic containers: Medium plastic containers were used for conveying the sweet potato roots harvested.

Wooden pegs: The pegs were obtained from trees around and used to demarcate the area total cultivated, units and furrows.

Brown paper envelopes: Samples for nutritional analysis were always packaged in the size A4 brown envelopes at each harvest and transported to the laboratory at Fumesua, Kumasi for the analysis.

Sweet potato peeler: Stainless steel peeler with a plastic handle was used to peel the sweet potato roots.

Deionised water: After peeling the roots, they were washed with deionised water and dried at room temperature.

Kitchen knife: A stainless steel kitchen knife was used for halving and quartering the roots longitudinally.

Slicer: The slicer, made up of stainless steel was used to slice the quartered sweet potato samples into smaller size.

Digital weighing scale: This was used to weigh the sliced samples to about 50 g at the laboratory.

Zip lock plastic bags: Each sweet potato sample weighed to 50 g was packed into these plastic bags. The plastic bags were first tested to confirm whether some of them leaks by filling them with tap water.

Deep freezer: All samples contained in the zip lock plastic bags were put into the deep freezer to get frozen.

Vacuum Freeze-Dryer: TK-118 Vacuum Freeze-Dryer (True Ten Industrial Company Limited Taichung, Taiwan was used to dry the frozen samples. At each time, samples were placed in the Vacuum Freeze-Dryer for about 72 hours for it to get well dried for milling.

Milling of samples: A stainless steel mill (3383-L70, Thomas Scientific, Dayton Electric Manufacturing Company Limited, Niles, IL 60714, USA) was used for milling the dry samples from the vacuum freeze dryer. The milled samples (flour) were sieved through a 60 mm mesi screen (a component of the milling machine) to obtain a uniform particle size. Various parts of the mill used in milling a sample were always clean properly before milling another sample.

Cuvette: About 5 g of the milled samples were loaded into this cuvette ready for the nutrient analysis.

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XDS Rapid Content Analyzer: The XDS rapid content analyzer (Hoganae, Sweden) was used to scan various nutrients contained in the sweet potato samples. Each sample in the cuvette was placed into the XDS Rapid Content Analyzer to scan nutrients with an instruction.

Minitab®: Data generated were analyzed using software, Minitab® 16.2.2 (Minitab Inc., State College, PA, USA, 2012).

Camera: HP camera was used to take photos during the study.

3.3 Methodology

3.3.1 Side description

Field work was carried out at the Council for Scientific and Industrial Research-Savanna Agricultural Research Institute (CSIR-SARI) farm, Nyankpala, Tamale in the savanna ago ecological zone of Ghana.

Laboratory work was carried out at the Sweet potato Quality and Nutrition Laboratory for post-harvest technology at Council for Scientific and Industrial Research (CSIR)-Crops Research Institute (CRI), Fumesua, Kumasi.

3.3.2 Field work

3.3.2.1 Land preparation, planting and experimental design

The research was carried out on a total plot size of 343 m^2 measured by tape measure. The land used for the trial was cleared, ploughed and harrowed and ridges were then prepared using hoes. Planting materials of the four cultivars, namely TUO, TUP, APD and VOG (Appendix B, Plate 1) were obtained from SARI farms Tamale. Planting was done on August 7, 2013. Vine cuttings with four nodes of each cultivar were used for planting by burying two of the nodes, with a distance of 30 cm between plants.

Randomized complete block design (RCBD) was used for the field trial. There were 12 treatments in all, with each of the four sweet potato cultivars appearing three times. Within each of the three blocks, there were four rows of each cultivar. Between blocks, a distance of 1.50 m separated the cultivars; and within block the cultivars were spaced by 1.00 m. The two middle rows of each cultivar were further were divided transversely into 4 equal parts, and each of this subplots were randomly assigned to the scheduled harvesting times, which were 65, 95, 125 and 155 DAP. During harvesting, vines were first pulled off by hands and then hoes were used in digging out the roots. All the agronomic parameters below were taken at each harvest. It was a rain-fed and no fertilizer in any form was used.

3.3.2.2. Root yield (t/ha)

The total weight of the roots harvested from the 0.75 m^2 in each treatment per cultivar were weighed using the standing weighing scale of 100 kg as shown in (Appendix B, Plate 3). Yield was later computed into kilograms per hectare (kg) and metric tons per hectare (t/ha) using
10,000
the formulae below.

A. Kilogram per hectare (kg) = $\frac{1000}{Area\ Harvested} * Root\ yield$ (kg)

B. Metric ton per hectare (t/ha) $= \frac{Kilogram\ per\ hectare}{1{,}000}$

3.3.2.3 Root girth and length

The girth and length of 6 selected roots of varying size per treatment were measured using a vernier caliper and a tape measure respectively **(Appendix B, Plates 4 and 5).** The girth was measured transversely and the length, longitudinally.

3.3.2.4 Number of roots harvested

The total number of roots was established by counting all the roots harvested from each treatment for all the cultivars at each harvest.

3.3.2.5 Fresh foliage weight (t/ha)

The foliage (vines and leaves) of each sample was weighed using a top pan weighing scale during each harvest. The fresh foliage was folded, tight together and then placed on scale and then record the weight **(Appendix B, Plates 6 and 7).**

3.4 Nutritional analysis in the laboratory

Near Infrared Reflectance Spectroscopy (NIRS) method was used for compositional analysis. Harvested roots packed into well coded brown paper bags **(Appendix B, Plate 8)** from the field were sent to the laboratory on each harvesting day for the analysis. A maximum of 6 roots were purposively selected for the compositional analysis. Two roots each were selected based on size namely small, medium and big. The selected roots were washed with ordinary water and allowed to dry at room temperature. Roots were later peeled and washed again with deionised water before cutting into halves, quartering longitudinally and slicing it into pieces. About 50 g of sliced roots were placed in zip lock plastic bags each before putting it into a freezer to get them frozen.

The samples were freeze-dried for 72 hours using the Vacuum Freeze-Dryer as shown in **Appendix B, Plate 11.**

Freeze-dried samples were crushed into small size and then milled into flour using **a** stainless steel mill as shown in **Appendix B, Plate 12a** and sieved through a 60 mm mesh screen. The flour from the mill was collected using zip lock plastic bags which were duly locked after putting samples in it. About 5 g of flour of each sample was put into the cuvette and placed into the XDS Rapid Content Analyzer as shown in **Appendix B, Plate 12b** to scan for all the various nutrient compositions.

3.5 Data analysis

The data were analyzed using Minitab® 16.2.2 (Minitab Inc., State College, PA, USA, 2012). Significant differences were considered at 95.00% confidence level. Regression analysis was employed for a test of association of root yield.

CHAPTER FOUR

RESULTS

4.1 Introduction

The results of this work are outlined in two fold. The agronomic data collected during the field trial and the nutrient composition of the sweet potato roots. All the results are presented in graphs and a table.

4.2 Agronomic data

The results of the agronomic data, namely; sweet potato root yield, root girth, root length, number of roots, fresh foliage weight were analyzed and have been presented in **Figure 2 to 6** and **Table 8.**

4.2.1 Effect of DAP on sweet potato fresh root yield

The study showed that there were significant differences ***(p*** = 0.01) in root yield with respect to **DAP (Figure 2).** Root yield increased from 6.30 to 28.20 t/ha from 65 to 125 DAP. It then declined from 125 to 155 DAP being 19.60 t/ha. However, among the OFSP and PFSP cultivar studied, there was no significant differences ***(p*** = 0.63) in root yield. APD recorded the maximum root yield of 19.50 t/ha at 125 DAP. The next high yielding cultivars were TUO and TUP both recorded 18.00 t/ha. The least root yielding cultivar was VOG which had 15.80 t/ha.

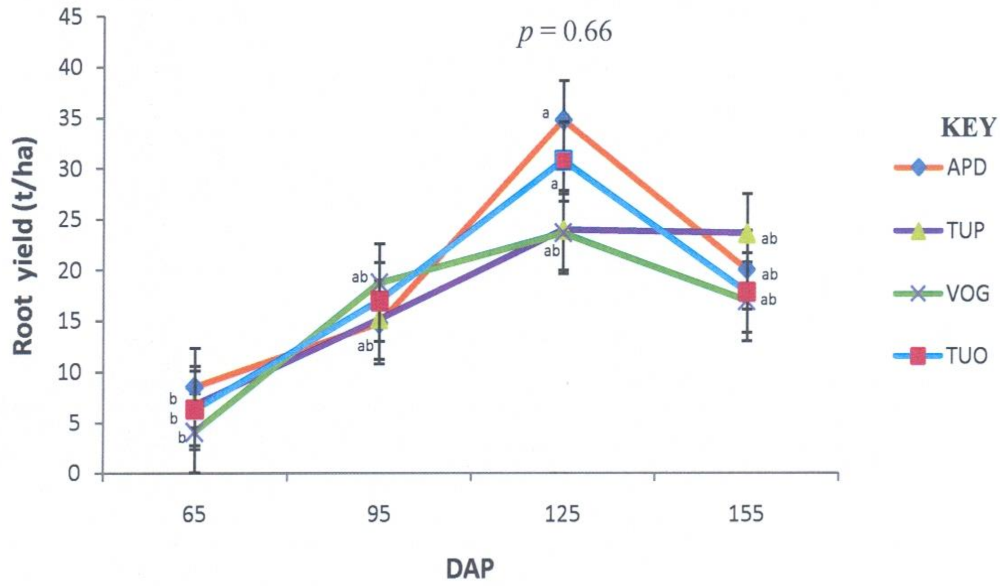

Figure 2: Effect of DAP on sweet potato fresh root yield (t/ha)#.

Values are means of triplicate ± standard error of means

4.2.2 Effect of DAP on sweet potato root girth

The results indicated that root girth was significantly different *(p = 0.01)* with regards to the four DAP **(Figure 3).** The highest root girth of 4.80 cm was observed at 155 **DAP.** Root girth was 4.00 and 4.50 cm observed at 95 and 125 DAP respectively. At 65 DAP, root girth was two-fold less than 155 DAP being the least. Among the cultivars, there was no significant differences (p = 0.13) in root girth, TUO and TUP averagely recorded 4.20 and 4.10 cm and were the highest in root girth. APD and VOG both obtained 3.80 cm and were the least cultivars.

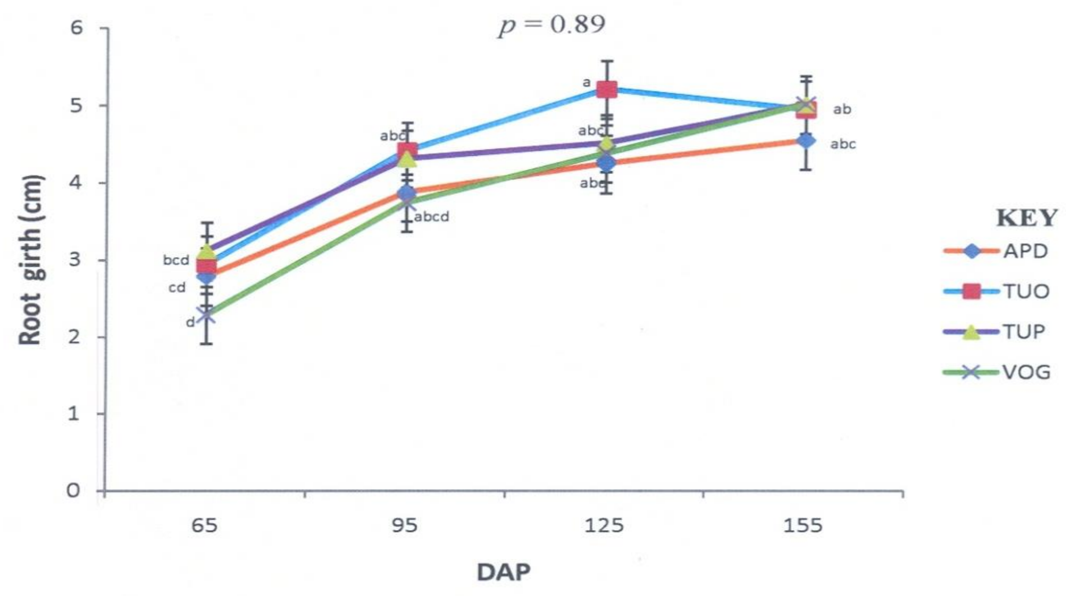

Figure 3: Effect of DAP on sweet potato root girth (cm)#.

Values are means of triplicate ± standard error of means.

4.2.3 Effect of DAP on sweet potato root length

Figure 4 shows that there was no significant differences (p = 0.49) in root length among DAP. The longest roots length was 19.60 cm observed at 155 DAP. The shortest roots length was 1.30 and 2.00 cm observed at 65 and 125 DAP. There was significant differences (p = 0.02) among the cultivars in root length. VOG recorded 20.90 cm in root length and was the longest. It was 1.80 and 3.50 cm longer than that of the APD and TUP. TUO was noted to be the cultivar with the shortest root length; it was 4.00 cm less than that of VOG, the cultivar with the longest root length.

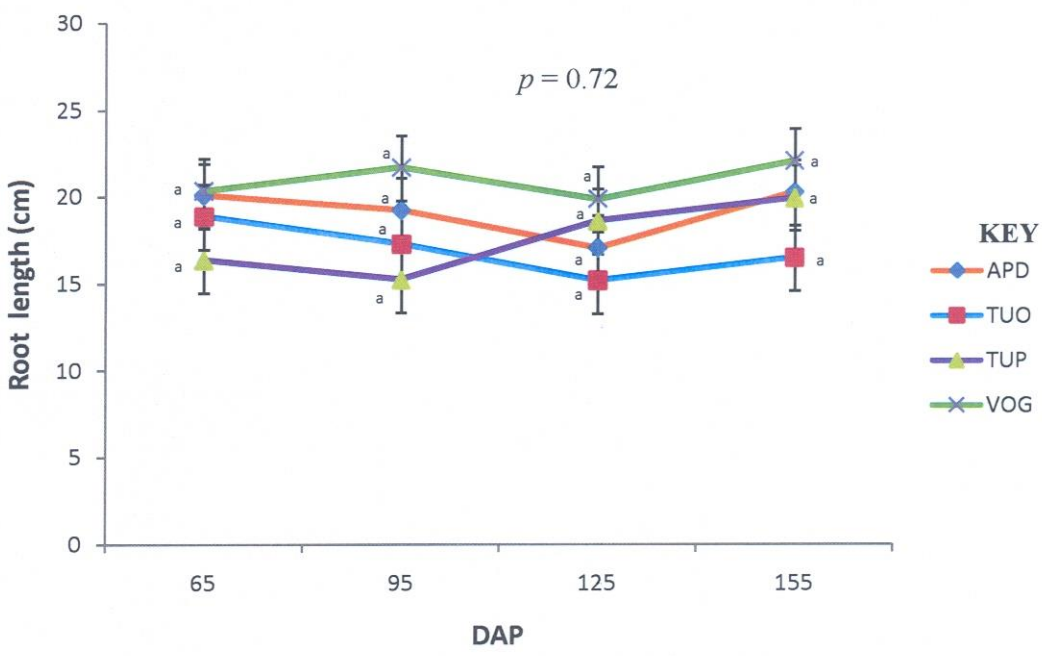

Figure 4: Effect of DAP on sweet potato root length (cm)[#].

Values are means of triplicate ± standard error of means.

4.2.4 Effect of DAP on number of sweet potato roots

There was significant differences *(p = 0.01)* in number of roots between the DAP (Figure 5). Number of roots was observed to be 1.30 log of count being the maximum at 125 DAP. Number of roots at both 65 and 95 DAP was 1.20 log of count and the least number of roots was 1.10 log of count observed at 155 DAP. Among there was also significant differences *(p = 0.02)* cultivars, TUO had the highest number of roots (1.30 log of count), it was 0.10 and 0.19 log of count higher than VOG and APD. The cultivar that had the least number of roots (1.10 log of count) was TUP.

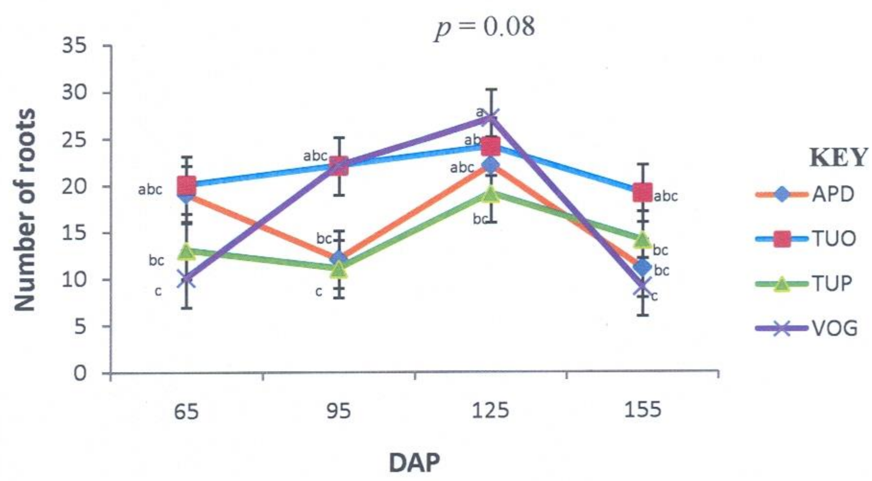

Figure 5: Effect of DAP on number of sweet potato roots (log of count)#

Values are least square means of triplicate t standard error of means

4.2.5 Sweet potato fresh foliage weight

With regards to the fresh foliage weight, the study showed that it was significantly different at *(p* = 0.01) relative to DAP **(Figure 6).** The highest fresh foliage weight was 30.40 t/ha observed at 125 DAP. Fresh foliage weight declined to 19.70 t/ha as observed at 65 DAP. At 95 **DAP,** it further decreased to 18.00 t/ha the fresh foliage weight was 6.43 t/ha at 155 DAP being four-fold low as compared to 125 DAP. Similarly, there were significant differences *(p* = 0.02) among the cultivars, TUO obtained the maximum fresh foliage weight of 23.90 and was 4.60 and 7.60 t/ha and higher than VOG and APD respectively. TUP had 1.10 t/ha fresh foliage weight and was the least.

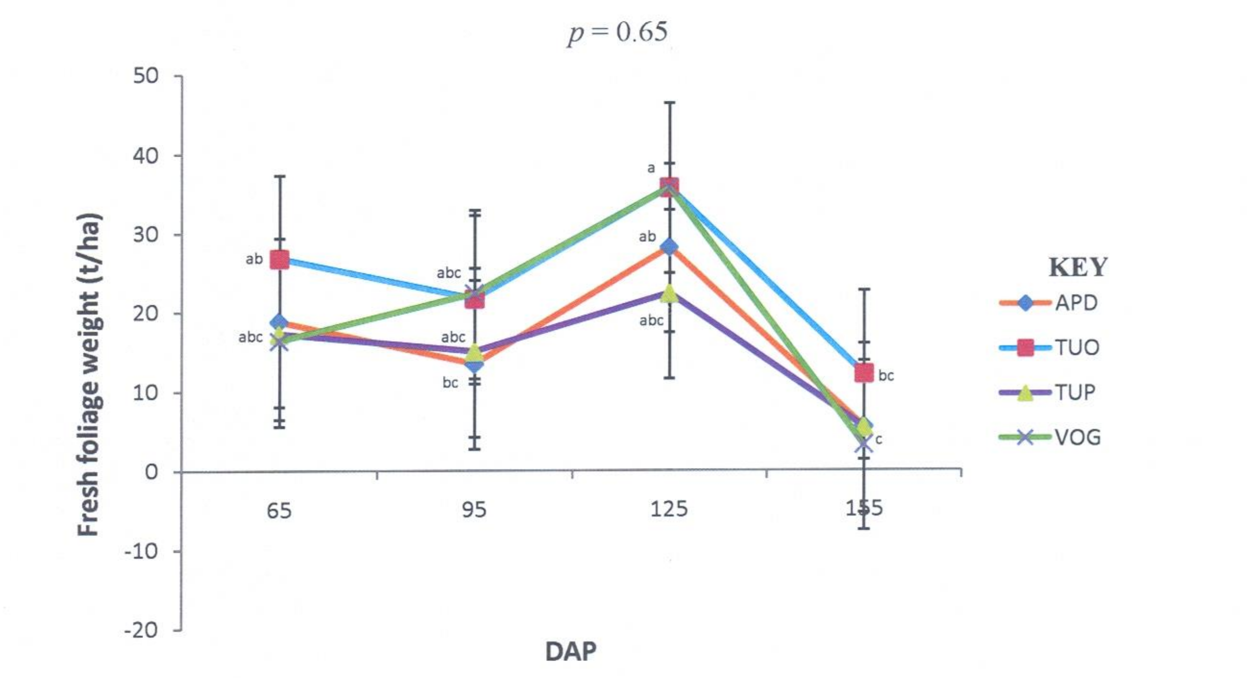

Figure 6: Effect of DAP on sweet potato Fresh foliage weight (t/ha).

Values are means of triplicate t standard error of means.

4.3 Effect of fresh foliage weight and number of roots on root yield

The results of the regression analysis on number of roots and foliage weight enabled the prediction of root yield (Table 8). This finding indicates that number of roots significantly *(p* = 0.04) influenced root yield a unit change in number of roots results 0.89 t/ha gain in root yield. Fresh foliage weight was not significant *(p* = 0.17) and did not influence root yield in any way. A unit change in fresh foliage weight results 0.15 t/ha gain in root yield being insignificant.

Table 8: Root yield prediction variables

Variable.	Coefficient (sem)*	p-value
Intercept	**-8.844(1.97)**	**0.000**
Foliage weight (kg)	**0.1536(0.11)**	**0.169**
Number of root (log)	**0.8861(0.42)**	**0.040**

#Regressing model = 0.15 (Foliage) + 0.89 (Number of roots) — 8.84. Significant level was (p < 0.001), and it explained that any unit change in foliage weight or root number loads to an increase in root yield. *Values in pm-Mimes are standard error of means.

4.4 Effect of DAP on nutritional composition of sweetpotato roots

The results of the nutritional composition of sweetpotato roots; β-carotene content, dry matter, fructose content, glucose content, sucrose content, starch content, zinc content, iron content and protein content were analyzed have been presented in **Figure 7 to 15.**

4.4.1 Beta-carotene content

The results indicates that accumulation of β-carotene content in the sweetpotato roots was significantly (p = 0.01) increased with DAP (**Figure 7**). The highest β-carotene content of 18.50 mg/100 g was observed at 155 DAP. The β-carotene content 15.60 and 16.00 mg/100 g at 95 and 125 DAP respectively. At 65 DAP, β-carotene content was 12.60 mg/100 g being least as compared with the 95, 125 and 155 DAP. Similarly, there was significant variations (p = 0.01) in β-carotene content between the cultivars studied. The TUP was devoid of β-carotene content. Among the three OFSP cultivars, β-carotene content ranged between 10.70 and 31.50 mg/100 g. The cultivar with the highest β-carotene content of 31.50 mg/100 g was APD. TUO was next with β-carotene content of 20.60 mg/100 g. The least cultivar with β-carotene content of 10.60 mg/ 100 g was VOG.

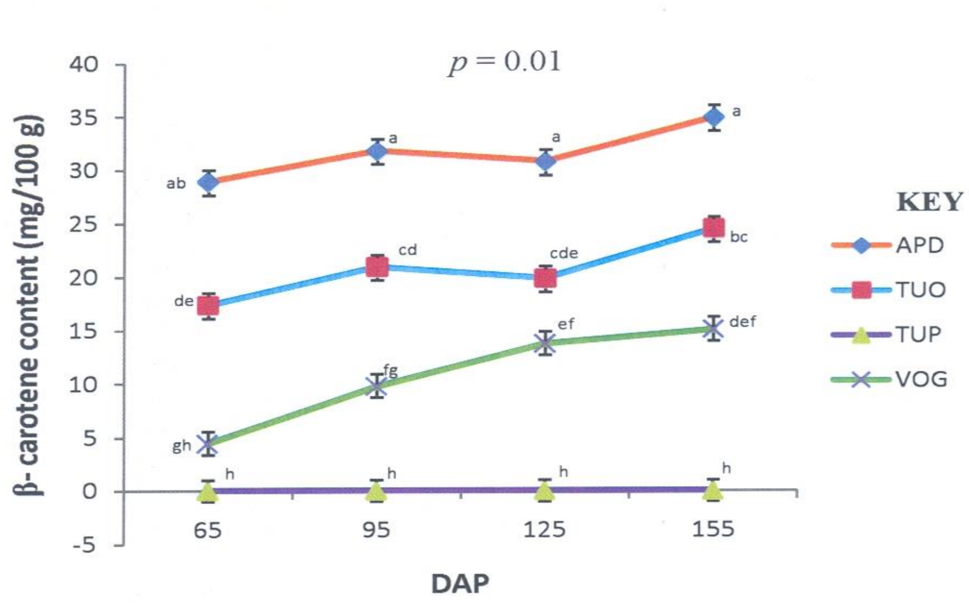

Figure 7: Effect of DAP on a-carotene content sweet potato roots (mg/ 100 g)*.

Values are means of triplicate ± standard error of means; values followed by different lowercase superscript letters are significantly different

4.4.2 Dry matter content

The findings of this study showed that dry matter content was significantly different at *(p* = 0.01) among the DAP (Figure 8). Dry matter content was 33.90% at 125 DAP being the highest. Dry matter content was 30.60 and 33.20% at 65 and 95 DAP respectively. At 155 DAP, dry matter content declined to 29.10% being the least among the DAP. The dry matter content was also significantly different *(p* = 0.01) among the cultivars. TUP was the cultivar identified with the maximum dry matter content of 38.90%. VOG and TUO recorded 35.90 and 28.00% of dry matter content respectively. The cultivar with the least dry matter content of 23.90% was APD.

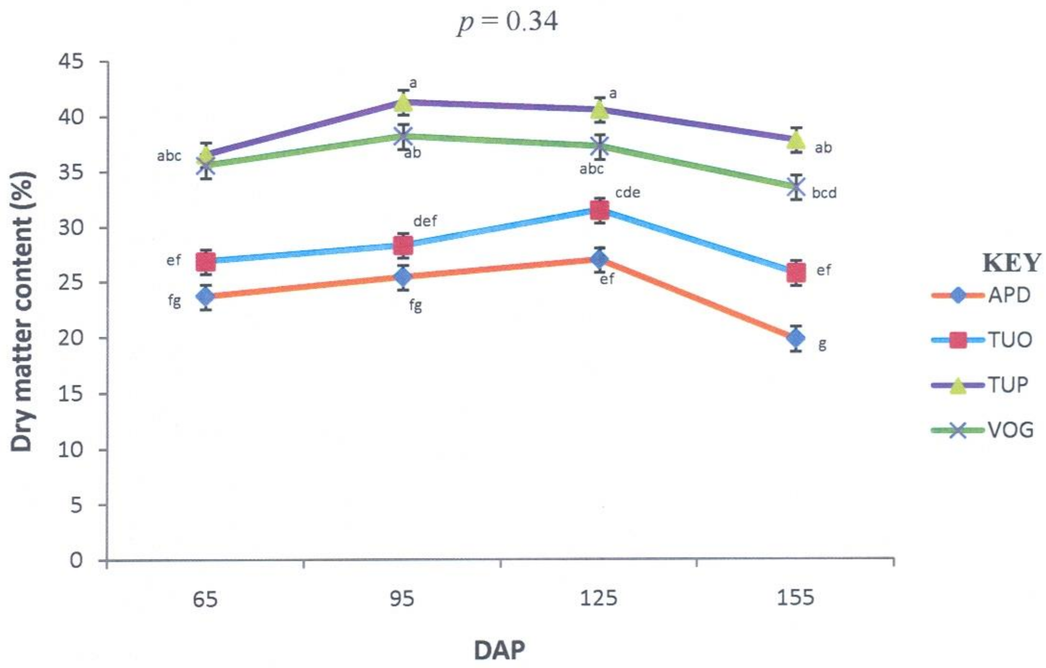

Figure 8: Effect of DAP on dry matter content of sweet potato root (%)#.

Values are means of triplicate ± standard error of means.

4.4.3 Fructose content

The study showed that fructose content was significantly affected *(p* = 0.01) among DAP as presented in Figure 9. It was 4.20 and 3.00 mg/100 g high at 65 and 155 DAP. It than decreased afterwards to 2.10 and 2.30 mg/100 g being low at 95 and 125 DAP. Among the cultivars, fructose was significantly different at *(p* = 0.01). TUO and APD recorded 5.10 and 4.60 mg/100 g being the highest fructose cultivars. VOG and TUP both had the least fructose content of 1.50 and 1.20 mg/100 g.

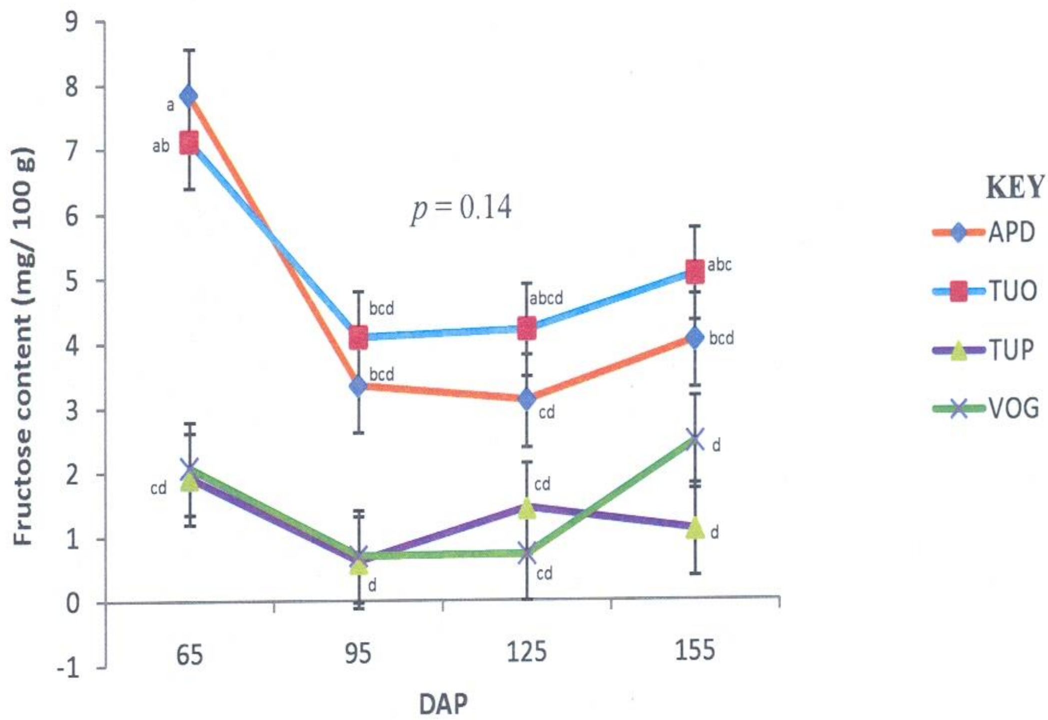

Figure 9: Effect DAP on Fructose content of sweet potato roots (mg/ 100 g)#.

Values are means of triplicate ± standard error of means.

4.4.4 Glucose content

The study indicates that glucose level was significantly different *(p = 0.01)* among the DAP as shown in **Figure 10.** Glucose content was 8.00 mg/100 g being high at 65 DAP. It then declined to 5.80 mg/ 100 g at 155 DAP. The least glucose content of 3.70 was observed at 95 DAP. Similarly, glucose content was significantly different *(p = 0.01)* among the cultivars. TUO and APD recorded the highest glucose content of 7.60 and 7.30 mg/100 g respectively. The lowest cultivars, TUP and VOG both recorded glucose content of 3.90 and 3.40 mg/100 g respectively.

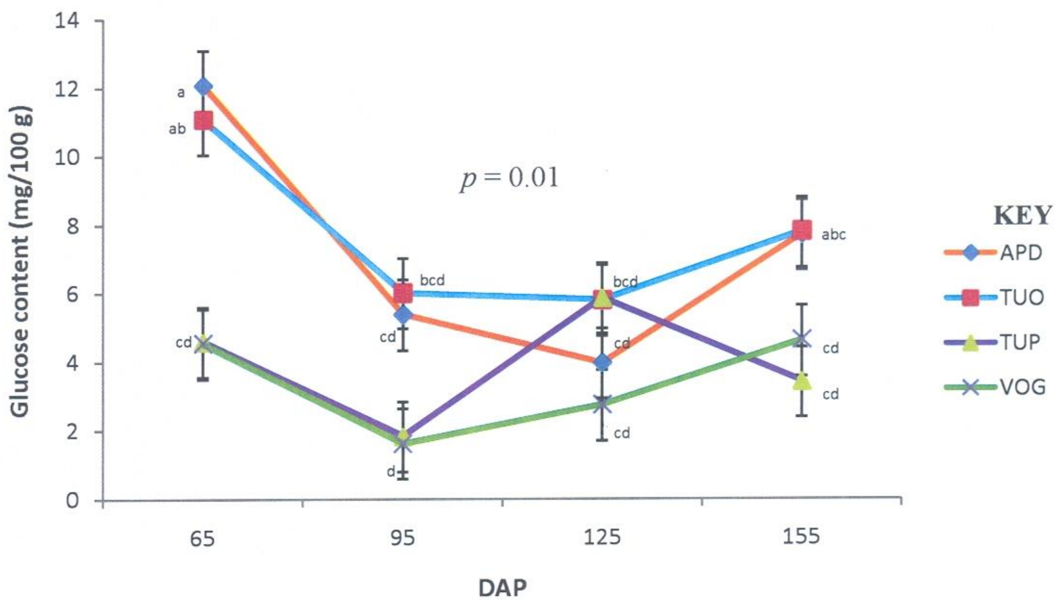

Figure 10: Effect of DAP on glucose content of sweet potato root (mg/ 100 g)#.

Values are means of triplicate ± standard error of means; values followed by different lowercase superscript letters are significantly different

4.4.5 Sucrose content

The result of this work showed that sucrose content was significantly different (p = 0.02) among DAP (Figure 11). The highest sucrose content was 16.20 mg/100 g observed at 155 DAP. The sucrose content at 125 and 95 DAP were 14.20 and 12.50 mg/100 g respectively. At 65 DAP, sucrose content was 7.90 mg/100 g been two-fold lower as compared with 155 DAP. Similarly, the content of sucrose was significantly different (p = 0.01) among the cultivars. APD recorded the highest sucrose content of 15.40 mg/100 g. TUO and VOG recorded 12.30 and 11.99 mg/100g respectively. The cultivar with the least sucrose content was TUP recording 11.20 mg/100 g.

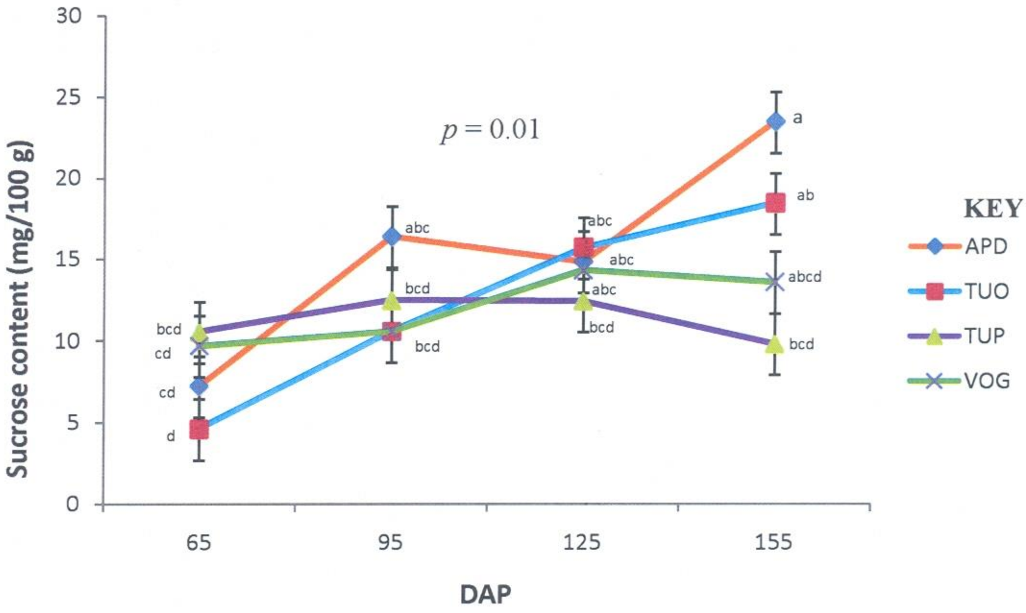

Figure 11: Effect of DAP on sucrose content of sweet potato root (mg/ 100 g)[#].

Values are means of triplicate ± standard error of means; values followed by different lowercase superscript letters are significantly different

4.4.6 Starch content

The results demonstrated that there were significant differences at *(p* = 0.01) in starch content among the DAP as shown in Figure 12. Starch content ranged from 57.60% to 65.40% among DAP. The highest starch content was observed at 95 DAP. At 65 and 125 DAP, starch content was 62.14 and 63.29% respectively. The least starch content of 57.55% was recorded at 155 DAP. Among the cultivars were significant differences at *(p* = 0.01), TUP recorded the highest starch content of 67.90%. VOG and TUO, both recorded 66.39 and 59.58% respectively. The cultivar with the least starch content was APD being 13.40% lower than that of TUP.

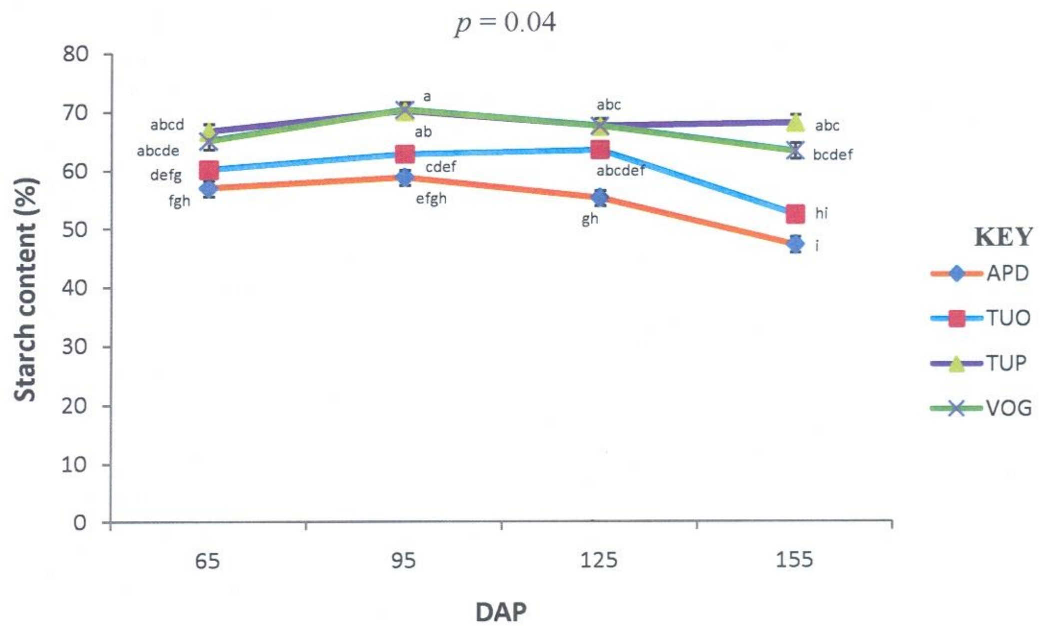

Figure 12: Effect of DAP on starch of sweet potato root *(%)#*.

Values are means of triplicate ± standard error of means; values followed by different lowercase superscript letters are significantly different

4.4.7 Zinc content

From the findings, zinc content was significantly different *(p = 0.01)* among the **DAP.** The highest zinc content of 1.20 mg/100 g was observed at 155 DAP **(Figure 13).** At 125 and 65 DAP were 1.10 and 1.00 mg/100 g respectively. The lowest zinc content 0.88 mg/ 100 g observed at 95 DAP. Similarly, among the cultivars, there were significant differences *(p = 0.01)*. APD recorded the highest zinc content of 1.30 mg/100 g. The zinc content was 1.00 mg/100 g found in VOG. TUO and TUP both recorded 0.95 mg/100 g of zinc content being the least cultivar.

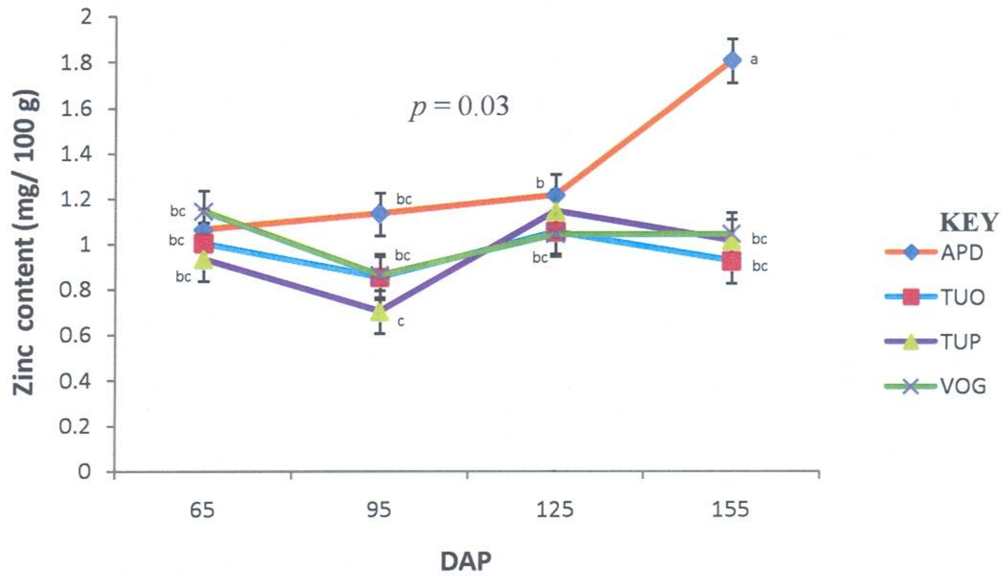

Figure 13: Effect of DAP on Zinc content sweet potato roots (mg/ 100 g)".

Values are means of triplicate ± standard error of means; values followed by different lowercase superscript letters am significantly different

4.4.8 Iron content

The study showed that iron content was significantly different *(p* = 0.01) among DAP **(Figure 14).** At 155 DAP, the iron content was noted to be 2.00 mg/100 g being the highest. At 125 DAP, iron content was 1.90 mg/100 g. The least iron content was 1.70 mg/100 g observed at 65 and 95 DAP respectively. Among the cultivars, iron content was significantly different *(p* = 0.01). **APD** had 2.30 mg/100 g of iron content being the highest. The least iron content was 1.60 mg/ 100 g observed in VOG and TUP.

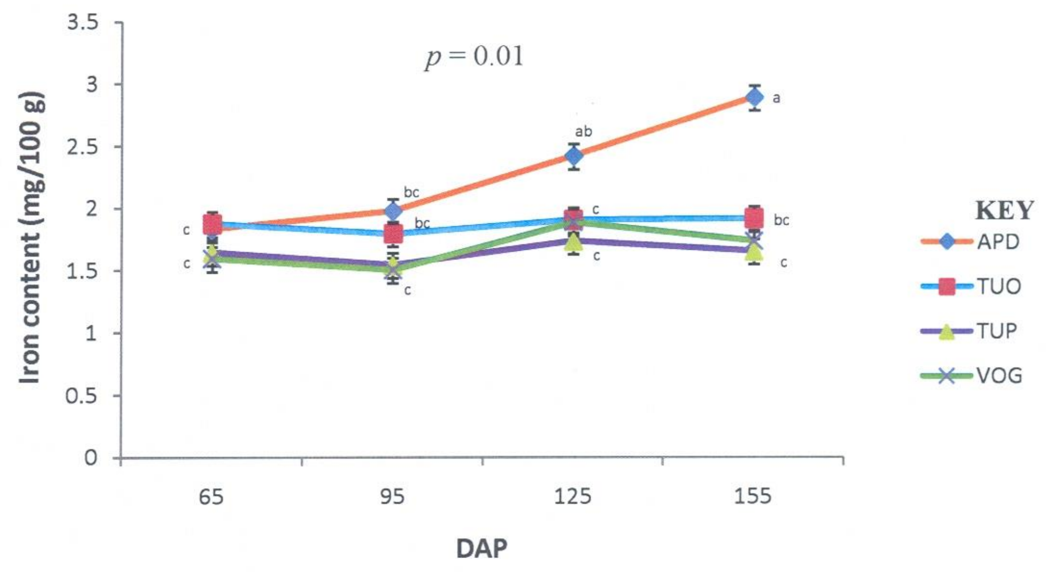

Figure 14: Effect of DAP on iron content of sweet potato roots (mg/ 100 g)#

Values are means of triplicate ± standard error of means; values followed by different lowercase superscript letters are significantly different

4.4.9 Protein content

The investigation indicated that there was significant differences (p = 0.02) in protein content among DAP as showing in **Figure 15.** The highest protein content of 3.70 mg/100 g was observed at 155 DAP. Protein content was 3.50 mg/100 g observed at 125 and 65 DAP respectively. The least protein content of 2.90 mg/100 g was observed at 95 DAP. Similarly, there were significant differences (p = 0.03) among the cultivars. APD recorded 3.70 mg/100 g being the cultivar with the highest protein content. The protein content was 3.50 mg/100 g found in VOG and TUP respectively. TUO recorded 2.90 mg/100 g of protein content been the least protein content cultivar.

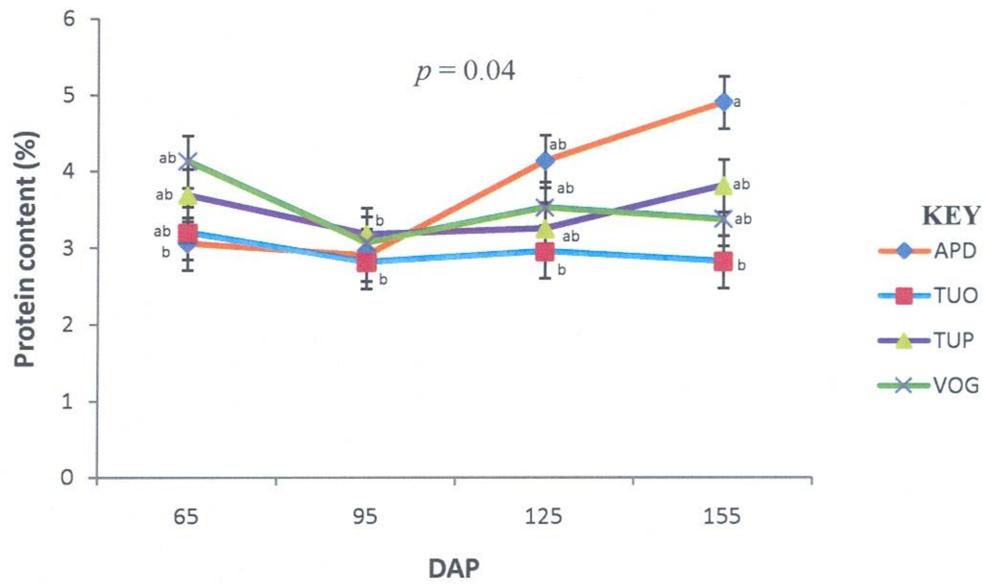

Figure 15: Effect of DAP on protein content of sweet potato root (mg/ 100 O^{m}

***(p* = 0.14)**

Values are least square means of triplicate ± standard error of means; values followed by different lowercase superscript letters are significantly different.

CHAPTER FIVE

DISCUSSION

5.1 Introduction

Discussion of the results was done in two-fold; the agronomic data (root yield, root length, root girth, number of roots and fresh foliage weight) and the nutritional composition (13-carotene, dry matter, starch, glucose, fructose, sucrose, zinc, iron and protein). This study revealed that it is essential to consider DAP of sweet potato as a staple food crop M Ghana.

5.2 Effect of DAP on sweet potato root yield, root size, number of roots and fresh foliage weight

The results obtained from this study, indicated that root yield varied significantly in relation to DAP. It increased from 65 to 125 DAP. This suggests that the sweet potatoes considered are early maturing cultivars. The low root yield from 65 and 95 DAP might have resulted from the immaturity of roots at that period of growth, root development was still in progress. This result agrees with some previous findings that root yield of sweet potato was observed to be high at 120 DAP as compared to 105 and 90 DAP respectively (Alcoy *et* 1993; Mitra *et al.*, 2010). The maximum root yield observed, at 125 DAP for the sweet potato cultivars may be due to the fact that the number of roots were high during that period. Additionally, the 125 DAP was appropriate period for the maximum bulking of the roots. Hence, the increased in root yield. It was also revealed that root yield of sweet potato could have been positively associated with DAP (Alcoy *et al.*, 1993), invariably, accumulation of dry matter (Mitra *et al.*, 2010) and good radial growth and expansion of the roots after the elongation has ceased (Rukundo *et al.*, 2013) which resulted to the high root yield at the 125 DAP. However, the decline in root yield from 125 to 155+ DAP was expected due to the damaged roots observed by weevil infestation even though not considered in this study. This confirms some previous report that weevils damage on sweet potato roots have been found to be directly related with time of harvest (Alcoy *et al.*, 1993).

Prolonging the DAP from 125 to 155 DAP would mean an increase in weevil build up rendering the roots unfit for consumption. Contrary to this result, Noda *et al.* (1997) reported that high root yield was obtained from the OFSP and PFSP cultivars as investigated at 190 DAP compared to those harvested earlier. Different locations with varied environmental condition could be the possible factor that might' have caused this phenomenon. Additionally, cultivar differences might have triggered these variations. Some sweet potato cultivars are early maturing whilst some are late maturing type. Base on the findings of this investigation coupled with other previous findings highlighted, it would be appropriate to harvest these newly introduced OFSP and PFSP cultivars in Ghana around 125 DAP for good root yield.

Root size is one of the yield components that give hope to farmers when seen to be larger (Woolfe, 1992). The investigations showed that root girth was higher at 155 DAP among the cultivars. This suggests that root girth increases as much as DAP are delayed. The low root girth from 65 to 125 DAP could also be as a result of the incomplete radial growth of the roots. The research finding indicates that, root length of sweet potato was not significantly different among DAP.

Root lengths increased slightly from 65 to 155 DAP. A similar trend was observed by Alcoy *et al.* (1993) and Reynolds *et al.* (1994). The short root lengths from 65 to 125 DAP could be attributed to fact that root initiation, radial growth and elongation were still in progress (Rukundo *et al.*, 2013) This suggests that the OFSP and PFSP cultivars could perform better relative to root girth and length when maximum time is given for its full physiological development.

Number of roots sometimes provides the basis for yield determination when considering root crops like sweet potato. The outcome of this study revealed that number of roots were high at 125 DAP as compared 65, 95 and 155 DAP respectively. The reason for this outcome could be that, the cultivars had had reasonable amount of growth period that allowed for much roots initiation coupled with favorable environmental conditions such rainfall and temperatures around the 125 DAP. Contrary to this finding Alcoy *et al.* (1993), reported that number of root was high at 90 DAP more than 105 and 120 DAP. This variation could probably be due to the fertilizer level 45-45-45 kg N. P. K used in that study. The fertilizer application could induce early root initiation (Ennin *et al.*, 2009; FAO, 2005). Additionally, the variation may be as a result of cultivar differences, coupled with different measuring procedures between the two studies. Furthermore, location of the crop growth Philippines versus Ghana, could also lead to these variations.

The vines and leaves of any plant such as sweet potato are known as foliage or fodder when intended to be used as feed for animals (Attaluri *et al.*, 2010; Etela & Kalio, 2011; Woolfe, 1992). The results of the present study indicated that fresh foliage weight of the sweet potato cultivars considered was high at 125 DAP as compared to the 65, 95 and 155 DAP. The low foliage weights from 65 to 95 DAP, may suggest that the sweet potato cultivars were still vegetative growth period, and that more time was needed for the foliage to reach its maximum. The declined in foliage weight observed from 125 to 155 DAP may be due to the unfavourable weather conditions that resulted to the dry up of the foliage. Rains had stopped and harmattan had started.

Contrary to this findings, Etela and Kalio, (2011) demonstrated that foliage weight was observed to be high at 84 DAP as compared to 112 and 140 DAP. The possible reason for this variation could be attributed to cultivar differences as well as the location where the crops were grown. Additionally, at 42 DAP, inorganic fertilizer (N. P. K 15:15:15) was applied as sid0 dressing at the rate 250 kg/ha in the previous study. However, this study did not use any form of fertilizer, be it organic or inorganic. Furthermore, canopy formation could influence foliage weight (Woolfe, 1992).

Regression analysis was carried out on fresh foliage weight and number of roots to determine their potential in contributing to sweet potato root yield. The regression equation used was: Root yield = 0.15 (Fresh foliage) + 0.89 (Number of roots) - 8.84.The outcome of the analysis did indicate that number of roots has significant ($p < 0.04$) effects on sweet potato rook yield. A unit change in change in number of roots leads to 0.89 increase in root yield. Fresh foliage weight was however insignificant ($p < 0.17$). A unit change in change in fresh foliage weight leads to only 0.15 increase in root yield of sweet potato. This suggests that only number of roots that could effectively increase root yield. This result confirms Etela & Kalio (2011), report that foliage weight did not significantly affect root yield. However, the findings disagree with some previous report that number of sweet potato roots has no significant effect the root yield (Alcoy *et al.,* 1993). This variation could be due to the cultivar differences and as well as the different geographical locations involved in the investigations. Additionally, different analytical procedures were employed at both instances, regression against correlation.

5.3 Nutritional analysis

5.3.1 Effect of DAP on a-carotene content of sweet potato root

The result indicates that DAP was a major factor that influenced the β-carotene content

The β-carotene content increased, when DAP increased from 65 to 155. This may suggest that β-carotene content increased with an increase in root age. The outcome however, disagrees with some previous observations that carotenoid concentration declined from 140 -to 160 DAII (K'osambo *et al.*, 1999) and from 105 to 120 (Mitra *et al.*, 2010). These variations may be due to cultivar differences as well as different locations where the crops were grown. Additionally, it could also be as a result of the different analytical procedures employed, NIRS versus HPL method by Ruddat and Will 111, 1985 and AOAC, 1984.

Among the cultivars, β-carotene content varied significantly. APD recorded the highest β-carotene content, followed by TUO. VOG was the least cultivar with β-carotene content. These variations among the OFSP cultivars could be due to their different genetical background: The APD is a national released OFSP, TUO is a new cultivar being introduced to Ghana from the Tuskegee University whilst VOG is landrace. The PFSP cultivar (TUP) did not contain β-carotene at all as observed for the four different harvests. However, Grace *et al.* (2014) reported that PFSP cultivars contain β-carotene which was 1.00 mg/ 100 g. The analytical methods used in detecting β-carotene content level may vary especially when the β-carotene content is at its lowest level. It has been reported that the PFSP contains lbMYB1 gene which is responsible for the accumulation of anthocynins in the roots (Kim *et al.*, 2010; Mano *et al.*, 2007). This gene may suppress the accumulation of β-carotene in these cultivars.

There is an increasing demand for food colourants from natural sources such the PFSP anthocynins relative to those that are chemically synthesized worldwide (Woolfe, 1992).

Additionally, due to the health benefits such as the ability of PFSP anthocynins to arrest cancer cells growth (Lim *et al.*, 2013) and the reduction of diabetics level (Jawi *et al.*, 2012) its cultivation should be intensified as well.

5.3.2 Effect of DAP on dry matter content of sweet potato root

High dry matter content is one of the main aims of recent sweet potato breeding programs (Mwanga *et al.*, 2007; Rukundo *et al.*, 2013). Percentage dry matter of sweet potato roots varies due to a number of reasons including soil types (Woolfe, 1992) and harvesting days (Mitra *et al.*, 2010). According to Grace *et al.* (2014), variations among the sweet potato cultivars could be a possible factor. The outcome of this current investigation points out that dry matter content was maximum at 125 DAP. The low dry matter content observed from 65 to 95 DAP may be as a result of limited time period for the accumulation to attain its maximum level (Rukundo *et al*,, 2013). This findings agrees with Mitra *et al.* (2010) that dry matter content was maximum at 120 DAP as compared to the previous harvests. The reduction in dry matter content from 125 to 15$ DAP may be attributed to the fact that some roots were becoming fibrous and weevil damaged roots had increased, similar situations were observed by Mitra *et al.* (2010) and Alcoy *et* (1993).

Among the cultivars, the PFSP cultivar (TUP) performed better than the OFSP cultivars. Within the OFSP cultivars, VOG was the highest and APD, the national released cultivar was the least. This outcome agrees with previous demonstrations that the PFSP cultivars- exceeded the OFSP cultivars in dry matter content (Grace *et al.*, 2014). The result further confirms Steed and Troung (2008) findings, that the PFSP cultivars have good potential of high dry matter content accumulation as compared to OFSP cultivars. Even the white-fleshed sweet potato (WFSP) also exceed the OFSP in dry matter content (Carey *et al.*, 1999). Dry matter content and 0-carotene concentrations are negatively correlated (Andrade *et al.*, 2009). Since the OFSP cultivars are high in β-carotene, definitely it would be low in dry matter content.

5.3.3 Effect of DAP on sugar content of sweet potato roots

Fructose, glucose and sucrose constitute total sugars. The results of this study showed that the monosaccharides, both fructose and glucose were high at the 65 DAP when the roots were young and declined afterwards to 155 DAP. Contrary to this, sucrose being a disaccharide rather increased from 65 to 155 DAP. This outcome confirms the previous findings that fructose and glucose were both high at 90 DAP as compared to the 120 and 150 DAP (Adu-Kwarteng *et al.*, 2014). This suggests that as the sweet potato roots advances in age, the monosaccharides (fructose and glucose) declines whilst sucrose, a diasaccharide increases (Adu-Kwarteng *et all*, 2014; Reynolds *et al.*, 1994).

Among the cultivars, the OFSP cultivars were high in fructose and sucrose as compared to the PFSP cultivar. The PFSP cultivar had low amounts of sugars but was rather high in dry matter content, being contrary to some previous findings that cultivars with high dry matter tend to be high in sugar content (Adu-Kwarteng *et al.*, 2014).

5.3.4 Effect of DAP on starch content of sweet potato roots

The results of this work indicate that starch content increased from 65 to 125 DAP and declined as DAP advanced to 155. It appears that starch accumulation was more active at the earlier stage of the sweet potato roots when its formation was also very active. This finding agrees with Reynolds *et al.* (1994), that starch content of sweet potato root did not experience any increase as DAP were delayed. The result of this investigation was however contrary to the findings of Mitra *et al.* (2010) and Woolfe (1992) that starch content of sweet potato increases as DAP were delayed.

The PFSP cultivar performed better in terms of starch accumulation as a compared to the OFSP cultivars in this study. This is in line with some earlier report that cultivars with higher dry matter tend to perform so well in starch content accumulation (Mitra *et* al., 2010).

5.3.5 Effect of DAP on mineral content of sweet potato roots

There is evidence that zinc and iron deficiency may cause growth retardation, dermatitis, impaired immune functioning, delay in Sexual maturation, skin and eye lesions (WHO, 2000: Anaemia which affects about 2,000 million people each year is also as a result of iron insufficiency in our diet (WHO, 2000). This study demonstrates that iron and zinc contents were both high at 155 DAP. This may mean that iron and zinc accumulation is directly associated with DAP. Again, it could also be attributed to the soil characteristics (Reynolds *et al.,* 1994).

The OFSP cultivars were higher in iron and zinc content than the PFSP cultivar. These cultivars could be used as source of iron and zinc to help improve upon our health status.

5.3.6 Effect of DAP on protein content of sweet potato roots

Protein, an important nutrient needed by the human body for growth and development is found in both animal and plant products including the sweet potato roots. The outcome of this work indicates that the protein content of the sweet potato roots differs greatly relative to DAP. Protein content was high at 155 DAP as compared to the previous DAP. The increased in protein content from 65 to 155 DAP could be as a result of roots age. Additionally, it has been reported that weevil infestation could influence sweet potato protein content (Alcoy *et al.,* 1993; Woolfe, 1992).

Among the cultivars, the APD recorded the highest protein content and TUO was the cultivar with the least protein content. This suggests that protein content could vary as a result of cultivar differences. Other previous researchers have reported that even between parts of the same sweet potato plant, protein content varies (Abubakar *et al.*, 2010; Woolfe, 1992) and that boiled leaves contains more protein content as compared to the boiled roots (Abubakar *et al.*, 2010; An *et al.*, 2003). Sweet potato leaves contain a lot of protein ranged between 19.50 to 21.00% (An *et al.*, 2003).

CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

Ghana is a West African country that largely depends on agriculture for food, income and raw materials. The major exports crops produce in Ghana include cocoa, oil palm, Shea nut and pineapples. Root and tuber crops such as cassava, yam and sweet potato compete effectively, with the cereal crops being the largest portion of food consumed by most Ghanaians. There is high prevalence of vitamin A deficiency (VAD) in Ghana which is severe and a threat to public health. VAD patients mostly have low resistance to infectious diseases such as diarrhoea and measles. As a result, victims face a lot of challenges such as visual impairment, corneal ulceration and undesirable changes in the skin such us being dry, scaly and rough known as xeroderma. There is also high maternal mortality, unsuccessful pregnancies, poor development and growth rate among the affected people. Many lives of children who are less than five years of age are lost in some Sub-Saharan African countries including Ghana each year mainly due to VAD.

Several efforts have been made to address VAD in Ghana. These are animals and their products such as fish, eggs and liver. Additionally, United Nation Children Education Fund introduced vitamin A capsules which is administered six monthly at the health centres. These strategies even though are good sources of vitamin A, they are not readily available. In the 1990s, the International Potato Center identified orange-fleshed sweet potato (OFSP) to contain I3-carotene which is a pro-vitamin A. Consuming about 100 g of boiled and mashed OFSP is capable of meeting the daily vitamin A requirement of children under five years. The purple-fleshed sweet potato (PFSP) cultivars are well known to contain anthocyanins which could be used to arrest cancer cells growth.

These sweet potato cultivars are available in most Ghanaian communities and could be good materials for improving human health and food security.

The Tuskegee University has introduced OFSP and PFSP in Ghana which could promote hence this study. The trial was carried out at SARI farms in Nyankpala, Ghana. Randomized' complete block design was used. The four sweet potato cultivars studied were TUO, TUP, APD and VOG. Harvesting was done on the following days after planting: 65, 95, 125 and 155. Data collected were in two-fold, agronomic data and nutritional data. Root yield, number of root, root girth and length and foliage weight were the agronomic data gathered. The nutritional data such as β-carotene, dry matter, sugars, starch, minerals and protein were also considered. The nutritional analysis was done in Fumesua, Kumasi using the (NIRS) method on each harvest.

The findings of the agronomic data indicate that root yield, girth, number of roots and foliage weight were all at its maximum at 125 DAP as compared to the 65, 95 and 155 DAP. The parameter that did not vary significantly was root length. Among the cultivars, the OFSP cultivars had better root yield, girth, length, number of roots and foliage weight than the PFSI' cultivar. The newly introduced OFSP and PFSP cultivars could be harvested at 125 DAP, since the parameters considered were better off at this DAP compared with the other periods investigated.

On the nutritional aspect of the study, 13-carotene was high at 155 DAP, as compared t(i) the 65, 95 and 125 DAP. Starch content was high at 95 DAP. In relation to sugars, fructose and glucose were both high at 65 DAP. On the contrary, sucrose was high at 155 DAP. Zinc, iron and' protein were all high at 155 DAP as compared to the rest of the days after planting. The analysis

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APPENDICES

Appendix A: Anova

1: Analysis of variance of sweet potato root yield (kg)

Source	DF	SS	MS	**F**	P
Variety	3	0.4642	0.1547	0.59	0.627
DAP	3	16.5508	5.5169	20.98	0.000
Variety*DAP	9	16.5508	0.1990	0.76	0.656
Error	32	8.4133		0.2629	
Total	47	27.2192			

2. Analysis of variance for sweet potato root girth (cm)

Source	DF	SS	MS	F	P. value
Variaty	3	2.5331	0.8444	2.04	0.127
DAP	3	30.8266	10.2755	24.87	0.000
Variety*DAP	9	1.6954	0.1884	0.46	0.893 4-1
Error	32	13.2220	0.4132		
Total	47	48.2771			

3: Analysis of variance of sweet potato root length (cm)

Source	DF	SS	MS	F	P. value i
Variety	3	27653.1	9217.7	15.27	0.022
DAP	3	6590.2	2196.7	3.64	0.498
Variety*DAP	9	9610.7	1067.9	1.77	0.722
Error	32	19321.6	603.8		
Total	47	63175.5			

4. Analysis of variance for sweet potato root numbers (log)

Source	DF	SS	MS	F	P.value
Variety	3	0.32247	0.10749	3.95	0.017
DAP	3	0.64713	0.21571	7.92	0.000
Variaty*DAP	9	0.47330	0.05259	1.93	0.083
Error	32	0.87188	0.02725		
Total	47	2.31478			

5: Analysis of variance for fresh foliage weight (kg) of sweet potato

Source	DF	SS	MS	F	P. value
Variety	3	3.2354	1.0785	4.01	0.016 ...
DAP	3	19.3675	6.4558	24.02	0.000
Variety*DAP	9	1.8363	0.2040	0.76	0.654
Error	32	8.6000	0.2687		
Total	47	33.0392			

6: Analysis of variance for (3-carotene content of sweet potato roots

Source	DF	SS	MS	F	P.value
Variety	3	6542.70	2180.90	510.78	0.000
DAP	3	212.40	70.80	16.58	0.000
Variety DAP	9	127.23	14.14	3.31	0.006
Error	32	136.63	4.27		
Total	47	7018.96			

7. Analysis of 'variance for dry matter content of sweet potato roots

Source	DF	SS	MS	F	P. value
Variety	3	1739.89	579.96	155.16	0.000
DAP	3	182.71	60.90	16.29	0.000
Variety*DAP	9	39.64	4.40	1.18	0.341
Error	32	119.61	3.74		4.
Total	47	2081.87			c

8: Analysis of variance for fructose content of sweet potato roots

Source	DF	SS	MS	F	P.value
Variety	3	146.419	48.806	31.86	0.000
DAP	3	48.985	16.328	10.66	0.000
Variety*DAP	9	23.175	2.575	1.68	0.135
Error	32	49.017	1.532		
Total	47	267.597			

9: Analysis of variance for glucose content of sweet potatoroots

Source	DF	SS	MS	F	P.value
Variety	3	178.036	59.345	18.80	0.000
DAP	3	129.339	43.113	13.66	0.000
Variety*DAP	9	83.138	9.238	2.93	0.012
Error	32	100.990	3.156		
Total	47	491.503			

19. Analysis of variance for sucrose content of sweet potato roots

Source	DF	SS	MS	F	P. value
Variety	3	120.88	40.29	3.80	0.019
DAP	3	451.58	150.53	14.19	0.000
Variety*DAP	9	342.17	38.02	3.58	0.004
Error	32	339.40	10.61		
Total	47	1254.03			

11. Analysis of variance for starch content of sweet potato roots

Source	DF	SS	MS	F	P. value
Variety	3	1414.10	471.37	89.48	0.000
DAP	3	394.24	131.41	24.95	0.000
Variety*DAP	9	181.31	20.15	3.82	0.002
Error	32	168.56	5.27		
Total	47	2158.21'			

12. Analysis of variance for zinc content of sweet potato roots

Source	DF	SS	MS	F	P. value
Variety	3	0.98405	0.32802	12.09	0.000
DAP	3	0.61440	0.20480	12.09	0.001
Variety*DAP	9	0.91218	0.10135	3.74	0.003
Error	32	0.86826	0.02713		
Total	47	3.37889			

13. Analysis of variance for iron content of sweet potato roots

Source	DF	SS	MS	F	P. value
Variety	3	3.06267	1.02089	33.73	0.000
DAP	3	1.07667	0.35889	33.73	. 0.000
Variety*DAP	9	1.26222	0.14025	4.63	0.001
Error	32	0.96849	0.03027		
Total	47		6.37006		

14: Analysis of variance for protein content of sweet potato roots

Source	DF	SS	MS	F	P. value
Variety	3	4.2039	1.4013	4.01	0.016
DAP	3	3.4655	1.1552	3.30	0.033
Variety*DAP	9	7.4514	0.8279	2.37	0.035
Error	32	11.1913		0.3497	
Total	47		26.3121		

Appendix B: Plates

Plates 1: The sweetpotato cultivars evaluated in the study

Plates 2: Root yield at 65 and 95 DAP

Plates 3: Root yield at 125 and 155 DAP

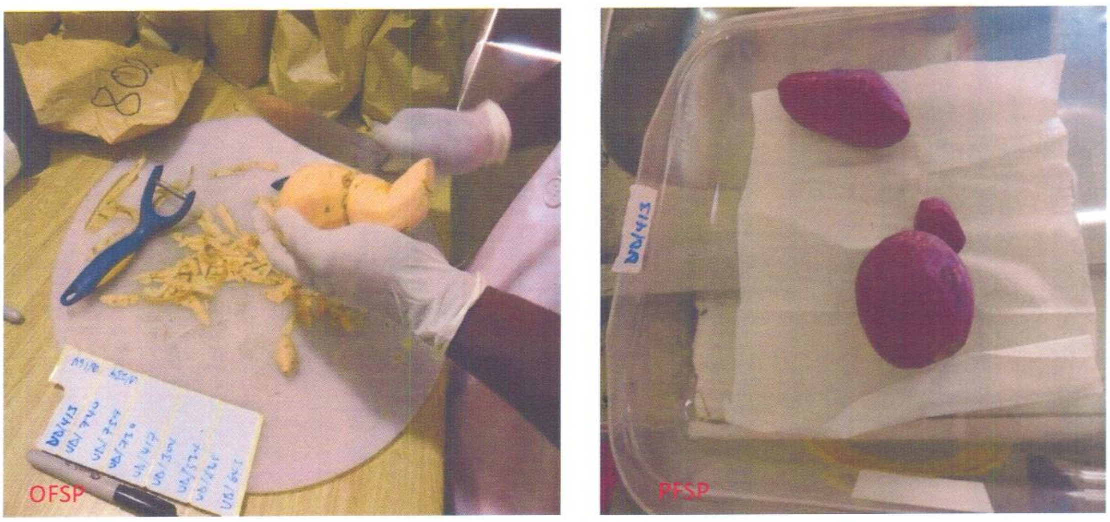
Plates 4: Measuring root girth of OFSP and PFSP using vener caliper

Plates 5: Measuring root length using tape measure

Plates 6: Measuring fresh foliage weight at 65 and 95 DAP

Plates 7: Measuring fresh foliage weight at 125 and 155 DAP

Plates 8: Packaged and coded samples to be transported for compositional analysis

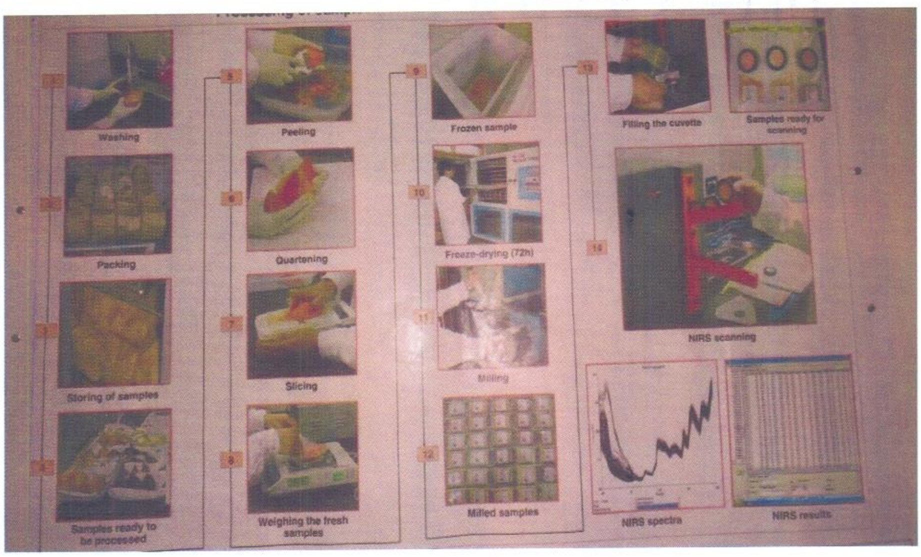


Plates 9: OFSP and PFSP roots being peeled by sweetpotato peeler

Plates 10: Peeled sweetpotato root being quartered and sliced

Plates 11: Samples in a freezer and a freeze-dryer for drying samples

Plates 12: Stainless steel mill (a) and XDS Rapid Content Analyzer (b)



Plates 13: Summary of how roots were processed and analyzed at the sweetpotato laboratory