EFFECT OF LEAF HARVEST AND FREQUENCY ON GROWTH, YIELD AND QUALITY OF SWEET POTATO (*Ipomoea batatas* L.)

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ABSTRACT

Despite the potential of improved sweet potato (*Ipomoea batatas* L.) varieties in both root and fodder production, farmers are persistently cultivating local types without considering proper intensity and frequency of leaf removal to optimize both quality and quantity of roots. A study was carried out to determine growth responses of improved sweet potato varieties (Simama, Kiegea and Mataya) following leaf harvests; determine the effect of leaf harvest intensity on sweet potato root and leaf yields; and, evaluate the effect of harvest interval on leaf and root yields. Treatments consisted of four harvest regimes; harvest intervals (4, 6 and 8 weeks) and harvest intensities (10 - 70%). A split-plot arangement in randomized complete block design (RCBD) with 3 replication was used. Data collected included leaf dry matter, total dry matter, vine length and fresh weights of leaves and vines, root yileds. The results showed that highest dry biomass yields were recorded with 70 % harvest intensity at 4 weeks harvest interval. Among the varieties, highest dry leaf yields were observed with Mataya variety at 134 DAP and 70 % harvest intensity. Highest vine branches were observed with Mataya variety at 6 weeks harvest interval and 50 % harvest intensity. Longer vine was observed at 4 and 8 weeks harvest interval with 10 and 40 % harvest intensities, for varieties Simama and Mataya, respectively. Highest root yields were observed with Mataya variety at 6 week harvest interval with 10 % harvest intensities. Highest root cluster were recorded with 50 % harvest intensity, at 8 weeks harvest interval. Largest root diameter were observed with Mataya variety than varieties Kiegea and Simama. Longest root were observed with Mataya variety at 4 weeks harvest interval and 50 % harvest intensity. The present study has revealed that agronomic management of sweet potato crop should be chosen depending on the desired produce. When given as the sole food and feed to farmer and growing livestock, Mataya is better variety. If root production is desired, leaf harvesting in Mataya variety should not exceeding 50 % with 8 weeks interval.

DECLARATION

I, Elirehema Issa, do declare to the senate of Sokoine University of Agriculture that, the content of this dissertation is my own original work and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

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DEDICATION

This dissertation is dedicated to my Almight God through His beloved son Jesus Christ who gave me life, best of my values, desire for learning and appreciation for the importance of education in a complex World and to break through.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
CCT	Christian Council of Tanzania
CP	Crude Protein
DAP	Days After Planting
DM	Dry Matter
FAO	Food and Agricultural Organization
FAOSTAT	Food and Agricultural Organization Statistical Database
NDF	Neutral detergent fibre
RCBD	Randomized Complete Block Design
SUA	Sokoine University of Agriculture
TAFES	Tanzania Fellowship of Evangelical Student

CHAPTER ONE

1.0 INTRODUCTION

Sweet potato (*Ipomoea batatas* L) is a dicotyledonous root crop that belongs to the family Convolvulaceae which includes several varieties of root crops. Of the approximately 50 genera and more than 1000 species of Convolvulaceae, *I. batatas* is the only crop of major importance (Woolfe, 1992). Sweet potato is native to Central and South America (Zhang *et al*., 2004). The crop is grown in over 100 countries of the world. But it is extensively cultivated in all tropical and subtropical regions particularly in Asia, Africa and the Pacific (FAOSTAT, 2010).

Sweet potato in Tanzania is extensively cultivated throughout the country. Eighty four percent of total production in the country is utilized as human food, 0.3% is used for livestock feed, the remaining is for other uses like starch processing and export. The main producing regions are: Mwanza, Shinyanga, Tabora, Mara, Kigoma, Tanga, Ruvuma, Mtwara, Lindi, Coast regions and Zanzibar (Kapinga *et al.*, 1995). Yields in overall, the average annual yield for sweet potato crop is 13.2 t ha^{-} (FAOSTAT, 2010).

Leaf harvesting from sweet potato during vegetative stage is common in most parts of the country. A leaf is either harvested for vegetable or for fodder. Harvesting leaf for livestock feed involves plucking the fully expanded mature leaves (Ahmed *et al.,* 2012). But what are leaf harvest intensity and frequency to new varietal is not clearly understood. Despite the potentiality of improved sweet potato varieties, farmers in Morogoro region, are continuously cultivating local varieties for root production and also for fodder or vegetable without a planned leaf removal intensity and frequency. Kiozya *et al.* (2001) repoted that leaf harvesting in sweet potato reduces root yield by 43%.

Masumba (2004) also reported that by the removal of a certain number of leaves from root crop photosynthates are reduced. The use of local varieties resulted into low yield and poor quality of roots as reported by Lugojja *et al.* (2001); Oggema (2007). Selection and adoption of sweet potato cultivars with potential for both leaf and root production is necessary.

Inspite of the potential of dual purpose sweet potato cultivars for addressing food shotage and poverty, these benefits are yet to reach the farmers in Morogoro, Tanzania. Moreover, no comprehesive study has been conducted in the area regarding effects of leaf harvest frequency and intensity on both leaf and root yields. Also, leaf harvest intensity and frequency have not been studied for wide adoption by farmers with consequancial effects on root yield and production. In introducing dual purpose improved sweet potato varieties and leaf harvest intensity (threshold) in Morogoro, it will make readily available of planting materials, food and feeds; hence increased food production and productivity. This study determined effects of sweet potato leaf harvest intensity and frequency and new varietal adaptation in Morogoro to provide alternative economic uses of sweet potato vines as feed for livestock and hence improved household livelihoods.

1.3 Objectives

1.3.1 Overall objective

Increase sweet potato yields using dual purpose improved varieties.

1.3.2 Specific objectives

1. To determine growth responses of sweet potato varieties following leaf harvest.
2. To determine the effect of leaf harvest intensity on sweet potato root and leaf yields.
3. To evaluate the effect of harvesting interval on leaf and root yields.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Taxonomy and Origin of Sweet Potato

Sweet potato is a dicotyledonous root crop belonging to the morning glory family Convolvulaceae. The sweet potato and the wild species closely related to it are classified in the family Convolvulaceae, genus *Ipomoea*, section Eriospermum (formerly Batatas), and series Batatas (James, 2004). Heuzé *et al.* (2015) described the cultivated sweet potato as *Convolvulus batatas*. *Ipomoea batatas* is a self-incompatible species. It is generally accepted that the sweet potato is of American origin located between the Yucatán Peninsula of Mexico and the mouth of the Orinoco River, in Venezuela and are one of the oldest vegetables known to man. They have been consumed since prehistoric times as evidenced by sweet potato relics dating back 10 000 years that have been discovered in Peruvian caves. Abundant evidence shows that sweet potato was spread widely through the migration routes of people in the New World tropics before the discovery of America (Austin, 1988; James, 2004). Christopher Columbus brought sweet potatoes to Europe after his first voyage to the New World in 1492. By the 16th century, they were brought to the Philippines by Spanish explorers and to Africa, India, Indonesia and southern Asia by the Portuguese (James, 2004). The highest diversity of sweet potato was found in Central America using molecular markers (Huang and Sun, 2000).

Sweet potato is now widely cultivated between 40°N and 32°S, from sea level up to 2000 m (and up to 2800 m in equatorial regions) (Heuzé *et al*., 2015). The area under cultivation was 8.5 million ha in 2009 and the worldwide root yield was 12.6 t ha^{-1} (FAOSTAT, 2010). The main sweet potato producers are China, Indonesia, Vietnam, India, Philippines and Japan in Asia, Brazil and the USA in the Americas and Nigeria, Uganda, Tanzania, Rwanda, Burundi, Madagascar, Angola and Mozambique in Africa (FAO, 2010; Low *et al*., 2009).

2.2 Economic Importance and Distribution of Sweet Potato

Sweet potato is an important crop in several countries of the world (FAOSTAT, 2010; Phillips *et al.*, 2004). It is an important food crop in many areas of Sub-Saharan Africa, where it is grown on around 2.1 million hectares with an estimated production of 9.9 million (Kapinga *et al.,* 1995). In Tanzania it is the most important food security crop grown in all agro-ecological zones, mostly by small scale farmers, in marginal soils; Msemo, 2003; Phillips *et al.*, 2004). One hactare of sweet potatoes can yield more calories than traditional staple crops such as maize, rice or sorghum. Storage roots yield potential is between 20 and 40 t ha^{-1} worldwide (Woolfe, 1992). Consumed sweet potatoes provide over 90% of essential nutrients except for protein and niacin (Ju *et al.,* 2011). Orange-fleshed sweet potatoes are particularly nutritious, ranking highest in nutrient content of all vegetables for vitamins A and C, copper, calcium, folate, iron and fiber (Low *et al.,* 2009).

Sweet potato production is mainly for home consumption including boiling, roasting and deep-frying of the roots, and the leaves are used as vegetable. In the diferent zones, sweet potato has gained importance due to its adaptability to marginal conditions such as drought, low soil fertility and is ranked high as food security crop when local staple crops like maize and rice are scarce. The problems of cassava mosaic and brown streak virus, and banana bacterial wilt, sigatoka, nematodes and weevils on these staple crops aggravate food security, and thus increase the importance of sweet potato in the country. Sweet potatoes are high in antioxidants, which work in the body to prevent inflammatory problems like asthma, arthritis and gout. The National fresh root yield at farm level in Tanzania is only 5.6 tons per hectare compared to potential yields of 20-40 t ha^{-1} (Ewell and Mutuura, 1991). Such low yields are due to the fact that farmers use local landraces that are low yielding and susceptible to disease and insect pests. Unavailability of high quality planting material of improved varieties, especially during critical periods of planting sweet potato has contributed to these problems (Kapinga *et al.,* 1995 and Mukasa *et al.,* 2003).

According to FAO statistics, Tanzania has 76 percent of its land suitable for sweet potatoes production. Out of the 940 565 km ^{2}of land in Tanzania, 199 942 is moderately suitable, 264 595 km ^{2} is suitable, while 246 265 km ^{2} is highly suitable. The data also indicates that Only 8% of the land is not suitable for Sweet potatoes production in the country; this means that a large part of the land resources in Tanzania is suitable for production for all types of Sweet potatoes including the orange -fleshed sweet potatoes (FAO, 2010).

Sweet potato has high biomass yields of both roots and vines (An *et al.,* 2003). Traditionally, sweet potato is used as human food; however at present it is also used as feed for farm livestock, especially goats. The biomass yield of sweet potato is high and can reach up to 50 tons of foliage and 30 tons of roots/ha/year (Tuyen *et al.,* 1993). Sweet potato vines can be harvested several times throughout the year (An *et al.,* 2003). Recent research efforts have been directed towards developing varieties with improved yield and nutritional value, adaptation to low fertility, drought tolerance, and pest and disease resistance (Kapinga, *et al.,* 2007). In addition, multiplication and distribution of clean cuttings, promotion of improved processing, and marketing skills of released varieties has also been emphasized (Kapinga *et al.,* 2007). All these efforts have contributed to increases in sweet potato root yield, but this is still far below the potential yield production levels (Fuglie, 2007; Msemo, 2003). Moreover, the improved yield impact of the new released sweet potato variety, but this will only be felt once agronomic practises of sweet potato are transferred to the farmers. (Gichuki *et al.,* 2003).

2.2.1 Nutritional attributes

Sweet potato roots are believed to be one of the most nutritious foods in the world especially as a source for vitamin A found in orange-fleshed sweet potatoes. One medium sweet potato (114 grams) provides 162 calories, 0 grams of fat, 37 grams of carbohydrate (including 6 grams of fiber and 12 grams of sugar), and 3.6 grams of protein (Tan, 2007). This will provide well over 100% of daily needs for vitamin A, as well as 37% of vitamin C, 16% of vitamin B-6, 10% of pantothenic acid, 15% of potassium and 28% of manganese. It also, contains find small amounts of calcium, iron, magnesium, phosphorus, zinc, vitamin E, thiamin, riboflavin and folate (Ju *et al.*, 2011; Antia *et al.,* 2006).

The yellow fleshed varieties (Mataya and Kiegea) are good sources of vitamins A (300 micrograms/100 grams, fresh weight) (Woolfe, 1992). However, there are two types of vitamin A available in foods: preformed retinol (vitamin A itself) typically found in animal foods such as eggs, liver, and milk; and pro-vitamin A carotenoids found in plant foods such as dark green leafy vegetables, yellow and orange vegetables and fruits, and Orange - Fleshed Sweet potatoes (Antia *et al.,* 2006; Mukherjee *et al.,* 2002). Beta-carotene is the major pro-vitamin A carotenoid and the dominant carotenoid in Orange - Fleshed Sweet potatoes. Most families in Tanzania may not afford to consume animal foods on a regular basis. As Orange -Fleshed Sweet potatoes is an extremely rich source of bio-available, pro-vitamin A that is largely retained when boiled, steamed, or roasted is highly encouraged for consumption as an alternative source of Vitamin A (Low *et al.,* 2007).

A comparison with other food crops shows that it yields more calories per unit area than either maize and nearly as much as cassava. Although sweet potato is traditionally a root crop; the top however is also valuable forage for ruminants and other livestock species (Hong *et al.,* 2003). The leaves can be used fresh, dried or as silage, and can replace fish meal and groundnut cake as a protein source for growing goats (An and Lindberg, 2004).

Under improved cultivation, sweet potato is capable of very high dry matter yield per unit area of land (Ray and Tomlins, 2010). Sweet potato vine has a high crude protein content (18-30% in DM), which is comparable to leguminous forages (An *et al.,* 2003; Ishida *et al*., 2000). Lysine is the main limiting amino acid (An and Lindberg, 2004). Unlike legume forages, it does not contain notable quantities of ant nutritional factors.

Dry matter accumulation usually increases with increasing age while the nutritive value declines (Kapinga and Carey, 2003). Tan (2007) reported an increase in dry matter yield of sweet potato, a decrease in protein content and a fairly constant Neutral detergent fibre (NDF) content in sweet potato forage as the age of the plant increased. Yield and quality of forage species vary with the age of the plant. Cutting of forage at regular intervals is a potent agronomic tool used in maintaining a balance between yield and quality in forage species (Kakaty *et al.,* 1992; An *et al.,* 2004; Ahmed *et al.,* 2012). Removal of sweet potato vines during growth however reduces the supply of photosynthates during the remainder of the plant's growth with an eventual reduction in root yield (Chowdhury *et al.,* 2002).

2.3 Biological Description

Sweet potato is a rooted perennial mainly grown as an annual crop by vegetative propagation using either storage roots or stems cuttings. The roots are adventitious, mostly located within the top 25 cm of the soil. Some of the roots produce elongated starchy root. Root flesh colors can be white, yellow, orange and purple while skin color can be red, purple, brown or white. The stems are creeping slender vines, up to 6 m long. Its growth habit is mainly prostrate with a vine system that expands rapidly horizontally on the ground. The types of growth habit of sweet potatoes are erect, semi erect, spreading or very spreading (Antonio *et al*., 2011). The leaves are green or purplish, cordate, palmately veined, borne on long petioles. Sweet potato flowers are white or pale violet, axillary, sympetalous, solitary or in cymes. The fruits are round, 1-4 seeded pods. The seeds are flattened (Heuzé *et al.,* 2015).

2.3.1 Storage root

Although sweet potato shoot leaves are consumed, the storage root is the main organ used for human consumption. The swollen root is generally called a 'storage root' and by classical botanical definition is an enlarged true root (Kays *et al*., 1992). The initial sign of storage root formation is the accumulation of photosynthates consisting predominantly of starch (Chua and Kays, 1981). Storage root initiation in sweet potato is reported to occur between the period 7 to 91 days after planting (DAP) and varies among cultivars. The yield of sweet potato is highly variable. Differences in yield could be attributed to factors such as cultivar, propagating material, environment and soil (Villordon *et al*., 2009). The quantity of yield depends on the number of fibrous roots that will be induced to form storage roots (root cluster). This subsequently results in either a high number (four to six uniform and high grade) or low number of roots that may be reduced to one large storage root per plant or no marketable roots at all (Villordon *et al*., 2009). The shape and size of storage root can be between round and long irregular depending on the variety and environmental factors (Woolfe, 1992).

2.4 Climate Requirements for Sweet Potato Production

Sweet potato is a perennial crop but cultivated as an annual in the tropics and subtropics (Purseglove, 1991; Laurie and Niederwieser, 2004). Sweet potatoes are cultivated wherever there is sufficient water to support their growth; optimal annual well-distributed rainfall for growth range between 750-1000 mm (Kathabwalika, 2013). Very high rainfall leads to excessive vine development (Workayehu *et al.,* 2011; Heerden and Laurie, 2008). When rainfall level is below 500 mm irrigation may be necessary but it should be stopped before harvest in order to prevent the roots from rotting. Sweet potato is a warm-season annual, needs an environment with a mean average temperatures of 18-29°C, a soil temperature of about 30°C and full sunlight for optimal development. It needs a frost-free period of 110-170 days and growth may be hampered below 20°C average day temperatures. The crop grows best where light intensity is relatively high (Etela *et al.,* 2008; Heuzé *et al.,* 2015)

2.4.1 Soil

Soil is an important natural resource, as it constitutes a medium for plant growth. Sweet potato crop grows on marginal soils with limited inputs (Ishaq *et al.,* 2001). Sweet potato has the ability to tolerate harsh soil and climatic conditions and yet give satisfactory yield (Kapinga *et al.,* 2009). Historically, sweet potatoes have been a poor soil crop that produces a decent harvest in imperfect soil, but will do much better with a loamy and well-drained soil. It grows well in fertile, high organic matter, well-drained, light, and medium textured soils. Optimal soil pH is between 5.0 and 7.0, but ideally the pH is between 5.8 and 6.2 (Wolfe, 1991; Heuzé *et al.,* 2015).

Heavy and poor textured, poorly drained soils that have frequent water-logging and poor soil aeration impedes the growth of storage roots, reducing their size and yield. Water logging in early growth stages hinders the establishment of roots, and in later growth stages causes decay of the storage roots (Tan, 2008; Gomes *et al.,* 2005). To improve drainage, cuttings should be planted on 20 to 35 cm ridges. Ridge height will depend on soil texture. In heavy clay, sweet potato is grown in raised beds amended with compost and sand; potatoes in clay are sometimes thinner and oddly shaped. Good root development depends on good soil aeration. They are ideal crop for areas with sandy soil. Sandy loam soils that are light and well-drained are the best for growing sweet potato. The crop is very sensitive to aluminium toxicity, which occurs at pH below 4.5, and may lead to death of the crop within six weeks (Gomes *et al.,* 2005).

2.5 Propagation and Management

Sweet potato is propagated asexually from vine cuttings or sexually from seed (Woolfe, 1992; Laurie *et al.,* 2013), but the latter is done only by breeding programs. Propagation of sweet potato is done by vegetative propagation using one of the following methods: sprouting of whole storage roots (sprouts are then used as planting materials), and use of stem or vine cuttings from plants used for production or from multiplication plots. In the latter method green vines of approximately 30 cm length with at least four leaf nodes are planted into the soil (Parwada *et al.,* 2011). Sweet potato is most commonly grown on mounds or ridges, and occasionally on the flat. Deep cultivation enhances root growth and bulking of the sweet potato roots. Mounds and ridges promote adequate drainage and ease of harvesting (Low *et al*., 2009).

Sweet potato initial growth of foliage can requires application of N fertilizer, but an excess of N can lead to more foliar growth than storage root growth (Nedunchezhiyan and Reddy, 2002). Potassium is required especially during storage root growth and the crop is an efficient user of phosphorous (Landon, 1991; Halavatau *et al.,* 1996). Sweet potato vine is a quick growing crop and it covers the soil quickly and suppresses most of the weeds after establishment. However, weeding may become necessary particularly in the early stages of growth. To protect the crop from weeds at least two weeding and earthling up has to be given within 45 days after planting along with fertilizer application. Optimal space for planting sweet potatoes is about 30 to 45 cm apart, and 60 cm between rows. The vines grown under such space will have plenty of room to run. Normaly sweet potato vines produce long vines which soon cover a large area hence need plenty of space to grow. The crop is either planted as pure stand or relay cropped with Maize, banana or cassava.

2.6 Constraints to Sweet Potato Production

The main biotic constraints of sweet potato in the tropics are sweetpotato weevil (Stathers *et al*., 2005; Ngailo *et al.,* 2013), alternaria blight, sweetpotato virus disease (SPVD) (Mukasa *et al.,* 2003; Gasura and Mukasa, 2010), and root-knot nematodes mostly found in the temperate zones (Gasura and Mukasa, 2010).

According to Low *et al*. (2009) there are five major constraints to improved productivity and incomes from sweet potato among the smallholder sector in Sub-Saharan Africa. These includes: Lack of improved varieties adapted to local environments, insufficient knowledge and use of better agronomic practices, the lack of timely access to virus and pest-free planting material, damage due to the sweet potato weevils particularly in drier production areas and lack of markets.

2.7 Sweet Potato Leaves

Traditionally sweet potato was grown for roots and the foliage was considered as a waste and therefore under-utilised (An *et al.,* 2003). However, nowadays the top is valuable forage for ruminants and other livestock species (Ahmed, 2012). The vines are fed to livestock and the root used for human food. Dry matter production potential per hectare of some cultivars of sweet potato vines can be as high as 4.3 to 6.0 t ha^{-1} (Ray and Tomlins, 2010) and the forage accounts for approximately 64 % of fresh biomass. Under improved cultivation and ideal weather conditions, sweet potato is capable of producing very high dry matter yield per unit area of land Rashid *et al.* (2000), cited by Olorunnisomo (2007). Sweet potato vine has a high crude protein content (18 – 30 %), which is comparable to leguminous forages (An *et al.,* 2003; Hoover *et al.,* 2005). The reduction of leaves amount along the plant life cycle is a normal fact and that the cycle can be accelerated, or retarded by the climactic conditions.

According to Otoo *et al.* (2001) the leaf drop is a kind of sequential senescence, which occured as they reached a certain age. For the sweet potato, this age varied from 60 to 90 days (Ray and Tomlins, 2010). Okogbenin *et al*. (2013); Yooyongwech *et al*. (2014) also attributed the decrease in leaves production to the age of sweet potato crop and emphased that the foliar area was crucial in determining growth and dry matter accumulation rate in the storage roots.

2.8 Growth Response as Affected by Leaf Harvest

Branching is cultivar dependent (Somda and Kays, 1990; Deblonde and Ledent, 2001; Heerden and Laurie, 2008) and branches vary in number and length. Normally, sweet potato plants produce three types of branches, (primary; secondary and tertiary) at different periods of growth. The total number of branches varies between 3 and 20 among cultivars. Olorunnisomo (2006) reported that leaf harvest influence the branching intensity in sweet potato crop. Fresh shoot yield is a parameter of economic importance in dry ecological zones where animal feed supply is critical during the dry season (Woolfe, 1992; Ahmed and Nigussie, 2012). Olorunnisomo (2007) reported that variety which produces abundant foliage; harvesting its leaf gives high yield in shoot and root and hence is desirable as a source of food and feed.

2.9 Effect of Leaf Harvest Intensity on Sweet Potato

An *et al*. (2003); Ahmed and Nigussie (2012) reported that Sweet potato vines can be harvested several times throughout the year. Kiozya (2001) reported that higher leaf harvesting frequencies (intensity) gave greater yields of total DM and crude protein (CP) than the least leaf harvesting frequencies. The same author also showed that sweet potato plants which were leaf harvested every two months gave a 21.7% higher yield of foliage than leaf harvested every three months which gave 20.8%. FAO (2010) reported that total DM yield of foliage on sweet potato can vary from 4.3 to 6 tons ha^{-1}, depending on leaf harvest intensity, variety grown, cultivation practices and nutrient supply.

2.10 Effect of Leaf Harvesting Interval of Sweet Potato

Laurie *et al*. (2013) found that leaf crude protein (CP) content is highest in the least frequent harvest interval in sweet potato, a 6-week than a 4-week interval. Sweet potato roots and leafy tops are mainly used as food (Heuzé *et al*., 2015). Lebot (2009) found that leaf can be harvested at intervals of 20 days with a defoliation of 50% of the total stems for optimal root and stem production, since greater defoliation could reduce root production. Vines and leaves can be harvested three or four times per growing season.

2.11 Quality of Root as Affected by Leaf Harvest

The productive potential of sweet potato root can reach 24 to 36 t ha^{-1} of roots (Tuyen *et al.,* 1993; Workayehu *et al.,* 2011). Harvesting the vines during growth does reduce root quality (weight, volume, fiber content, crude protein) have been reported by An *et al.* (2003) and Kiozya *et al.* (2001).

2.12 Dry Matter Yield

The dry matter content of sweet potato is low due to the high moisture content. On the average the dry matter content of sweet potato is 30% but varies widely depending on cultivar, location, climate, soil type, cultivation practice and the incidence of pest and disease (Hoover *et al.,* 2005). The dry matter content of varieties Mataya and Kiegea ranged between 26 to 28 % (Kapinga *et al.,* 2009). The dry matter content determined in the University of Cape Coast for five varieties ranged between 34.41 to 37.35 % (Hoover and Ratnayake, 2005; Mbwaga *et al.,* 2007). The dry matter content for 18 cultivars grown in Brazil ranged between 22.9 to 48.2 % (Kays *et al.,* 1992). All these indicate that dry matter content of the roots in general is dependent on many factors.

Apart from the roots the green parts of sweet potato, mainly the petiole, stem and leaves have a dry matter content of 12 to 14 %. This is higher than some common vegetables like, cucumber, eggplant and carrot. Sweet potato contains considerable amount of carbohydrates, approximately 24 – 27 % of fresh weight (Hoover *et al.,* 2005). This consists of mainly starch, sugar, pectin, hemicelluloses and cellulose. Composition of these compounds that make up the total carbohydrates varies greatly from cultivar to cultivar and time of harvest or maturity. The compounds determine the storage length of the root, the higher the total carbohydrates the better it stores, for carbohydrate content slightly deceases in storage through respiration (Fonseca *et al.,* 2003). However, Simama, Kiegea and Mataya are among eight released varieties between 2002 and 2010. Mataya and Kiegea are yellow fleshed varieties released 2010 are high yielding with high dry matter. Mataya fresh root yield at farm level is 13 t ha^{-1} while Kiegea 12.0 t ha^{-1} and their maturity period are three to four months but the area regarding leaf harvest and intensity for both leaf and root yields remain largily unknown for these varieties (Kapinga *et al.,* 2009).

2.13 Knowledge Gap

MAFC (2010) reported that agronomic study has been conducted based on root (dry matter) yield, but the area regarding leaf harvest and intensity for both leaf and root yields remain largely unknown for these varieties, Simama, Mataya and Kiegea. It was therefore, appealing for this proposed study to determine the growth responses of dual purpose sweet potato varieties (Simama, Mataya and Kiegea) in the region; following leaf harvest; effect of leaf harvest intensity on the root and leave yield of sweet potato; the effect of harvesting interval on leaf and root yield and quality of sweet potato root as affected by leaf harvest intensity; therefore came up with adaptable variety (ies) and leaf intensity (threshold).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

A dual-purpose varieties Simama, Mataya and Kiegea for sweet potato were sourced from research station Morogoro and Coast region.

3.2 Methods

3.2.1 Description of study area

The research was conducted during the year 2014 at Sokoine University of Agriculture (SUA)-Morogoro. Experiments were conducted at the Crop Museum of Department of Crop Science and Production. The Crop Museum is located at 37^0 39'26" E and 6^0 5' 5" S and 526 m (masl). The average annual rainfall is about 900 mm, with a bimodal pattern rainfall; short rains from October to December and long rains between March and May. Thus this area has two cropping seasons. The temperature ranges between 17-28 ^oC.

3.2.2 Soil analysis

Samples of soil in the top 0-25 cm were collected from the experimental area before the commencement of the experiment by using auger and bulked for laboratory analysis. Physical and chemical analysis of the soil of the study area were perfomed in the Department of Soil Science, Sokoine University of Agriculture, using standard methods (London, 1991). Measurement of soil pH was carried out using glass electrode pH meter in 1:2.5 mixtures (v/v) of soil and water. Soil texture was determined by Bouyoucos hydrometer method (Day, 1965). Phosphorus was extracted by Bray and Kurtz-1 method (Bray and Kurtz, 1945) and determined spectrophotometrically (Blakemore *et al.,* 1987). The cation exchange capacity (CEC) and exchangeable bases were extracted by saturating soil with 1M $NH_4OH_{(aq)}$ (Landon., 1991) and the adsorbed NH_4^+ displaced with K^+ using 1M KCl and then determined by Kjeldahl distillation method for the estimation of CEC of soil. The bases Ca^{2+}, Mg^{2+} Na^+ and K^+, displaced by NH_4^+ were measured by atomic absorption spectrometer. Organic carbon was determined by wet oxidation method of Walkley and Black (Nelson and Sommers, 1996; Zhang *et al*., 2005) and conveted to organic matter. Total N was determined with the Kjeldahl method (Bremner and Mulvaney, 1982).

3.2.3 Experimental design

The experimental design adopted for this experiment was the split-split plot design laid out in a randomized complete block design (RCBD) with 3 replication. The cultivars served as main plot, leaf harvesting interval as sub plot and leaf harvest intensity as sub-sub plot.

3.2.4 Experimental layout and planting

Soil was plowed twice and harrowed by using a tractor. The total area of each plot was 107.52 m^2, with each of the 9 plots referring to a cultivar, 3 subdivisions (sub-plots) referring to a leaf harvesting interval and with each of the 3 sub-sub plots referring to a leaf harvest intensity. Each sub-sub plot was composed by 9 row of 24 plants cultivated in monoculture before the beginning of the rainy season (February). Sweet potato vines with a minimum of 4 nodes were buried in holes at a spacing of 70 cm x 40 cm.

3.2.5 Specific objective 1: To determine growth responses of sweet potato varieties following leaf harvest

In order to determine growth responses of sweet potato varieties following leaf harvest, three improved varieties (Simama, Mataya and Kiegea) were grown. Agronomic data collected were crop length and leaf biomass yield. The sub-sub plot comprised useful 18 plants, from which six were randomly chosen for leaf harvest at each data collection per variety, leaf harvesting interval and leaf harvest intensity, from March 2014 (50 days after planting) to June 2014 (five month after planting). The plants at the extremities of each sub-sub plot and the lateral borders were discarded. Vine length was taken using tape measure from six plant per variety, leaf harvesting interval, leaf harvest intensity and the control. Leaf harvested was weighed to determine the total production of fresh leaves. Then ten envelope samples of fresh leaves, from each variety, harvesting interval and harvest intensity were taken and dried at 70ºC and 48 hours, in air oven to obtain the dry matter.

3.2.6 Specific objective 2: To determine the effect of leaf harvest intensity on the roots and leaf yields of sweet potato

In order to determine effects of leaf harvest intensity on the root yields of sweet potato, vines were subjected to four pruning regimes. Pruning at 4, 6, 8 weeks interval each at a rate of 10 %, 20 %, 30 %, 40 %, 50 %, 60 % and 70 % starting from 50 days after planting, and unpruned plots (control). The data collected were root cluster at the base, root length, root diameter at the middle part and root weight. After five month root harvest was carried by using a garden fork. Root clusters at the stem base of sweet potato from each sub-sub plot, were counted before removal from the plant. Also, from each sub-sub plot, 10 storage roots were randomly taken, earth washed before their length (cm) and diameter (cm) determined from the central part of each root with a vernier caliper. Followed with root weight measurement by using spring balance.

3.2.7 Specific objective 3: To evaluate the effect of harvesting interval on leaf and root yield

In order to evaluate the effect of harvesting interval on leaf and root yield; vines were subjected to four pruning regimes. Pruning at 4, 6, 8 weeks interval starting from 50 days after planting, and unpruned plots (control). The data collected were fresh biomass yields of forage, dry matter (DM) yields of forage and root weight.

In the same day after five month when root harvest was carried, the aerial part of these representative plants including control were cut and its fresh weight determined. Fresh biomass yields of forage and root weight. Of which aerial leaves were weighed to determine fresh biomass per variety, leaf harvesting interval, leaf harvest intensity and the control.

3.3 Data Analysis

The data on crop length, leaf biomass yield, root cluster at the base, root length, root diameter, root weight, fresh biomass yields of forage and dry matter (DM) yields of forage, were subjected to analysis of variance (ANOVA) using GenStat software (GenStat, 2010) 12th edition, where significant treatments were detected from the ANOVA. Treatments mean separation test was done using Duncan's Multiple Range Test at the 5 % level of significance.

CHAPTER FOUR

4.0 RESULTS

4.1 Characterazation of the Soil at the Study Site

Result in Table 1, summarize the baseline physical and chemical properties of soil for the site. Laboratory analytical result indicated that the soil texture was clay sand. The soil reaction (pH) was moderatly acid. The level of organic carbon was high. The level of nitrogen was marginally adequate. The level of carbon:nitrogen ratio was medium. The level of available phosphorus (P), was very low. The level of available CEC was medium. The level of Calcium (Ca) and magnesium (Mg) were very low respectively. The level of Potasium, (K) was very high. The level of Manganese (Mn), Iron (Fe) and Zinc (Zn) were normal respectively. The level of Copper (Cu) was low.

Table 1: Physical and chemical characteristics of Soil at experimental site

Physical characteristics	Value	Remark	Reference
Soil depth, cm	0-25		Landon (1991)
Clay (%)	50	Clay sand	
Silt (%)	9		
Sand (%)	41		
Text (class)	c		
Chemical characteristics			
pH, (in H_2O)	5.91	Moderately	
Org. carbon, %	1.73	High	Landon (1991)
Total N, %	0.13	Marginally adequate	
C/N ratio	13.30	Medium	
Avail. P, mg/kg	3.02	Very low	
CEC, cmol/kg	9.2	Medium	
Ca, cmol/kg	0.52	Very low	
Mg, cmol/kg	3.75	Very low	
K, cmol/kg	0.88	High	
Mn, mg/kg	111.43	Normal	
Fe, mg/kg	44.20	Normal	
Zn, mg/kg	1.20	Normal	
Cu, mg/kg	1.96	Low	

4.2 Climate in Morogoro

Result in Table 2 shows, the highest precipitation was from March to May. The hot-dry season lasted in February with the highest mean temperatures in February and March.

Table 2: Climatic conditions in Morogoro during the study period (2014)

	Mean Temperature (°C)	Rainfall (mm)	Radiations ($MJm^{-2}d^{-1}$)
February 2014	22.2	69.4	17.6
March 2014	21.8	182.7	16.8
April 2014	21.3	231.0	14.6
May 2014	19.8	113.0	13.9
June 2014	17.8	24.0	14.0

Source: Meteorological Station of Morogoro, Tanzania (2014).

4.3 Biomass Production

4.3.1 Effect of leaf harvest and frequency on biomass yields at four weeks interval

The results showed significant differences ($p<0.001$) among varieties on fresh biomass weight (Table 3). At 4 weeks harvest interval, across leaf harvest intensity treatments, Simama variety had the highest mean, followed by variety Mataya.

There were significant differences ($p<0.001$) among harvest intensities on fresh biomass weight. At 4 weeks harvest interval and 70 % harvest intensity, Kiegea variety had significant lower fresh biomass than varieties Simama and Mataya at all harvest intensities (Table 3). However, there were no significant differences ($p=1.000$) among variety and harvest intensity interactions on fresh biomass at 4 weeks harvest interval. The highest mean fresh biomass yields were recorded with variety Simama at 70 % harvest intensity (Table 3).

Table 3: Effect of leaf harvest intensity and variety on biomass yields (t ha^{-1}) at four weeks interval

	Characteristics					
	Fresh biomass (t ha^{-1})			Dry biomass (t ha^{-1})		
Leaf harvest Intensity	Simama	Mataya	Kiegea	Simama	Mataya	Kiegea
0%	8.2	5.3	4.3	1.0	1.4	1.4
10%	6.7	4.5	3.4	3.4	2.3	1.8
20%	8.5	6.3	4.4	4.4	3.2	2.3
30%	8.1	6.9	5.9	4.2	3.6	3.0
40%	11.4	9.0	7.3	5.9	4.7	3.8
50%	10.7	8.9	8.2	5.5	4.6	4.2
60%	11.5	9.4	7.7	5.9	4.8	3.9
70%	13.6	10.8	10.3	7.0	5.5	5.3
Grand Mean		7.97			3.88	
$Lsd_{0.05}$=Variety		1.390			0.716	
$Lsd_{0.05}$=Intensty		2.269			1.169	
$Lsd_{0.05}$=Interaction		ns			ns	
CV (%)		30.0			29.2	

The results showed significant differences ($p<0.001$) among varieties on dry biomass weight (Table 3). At 4 weeks harvest interval with 20, 40 and 60 % harvest intensity, across leaf harvest intensity treatments, Kiegea variety had significant lower dry biomass mean than varieties Simama and Mataya. The were significant differences ($p<0.001$) among harvest intensities on dry biomass weight. At 4 weeks harvest interval with 70 % harvest intensity, Simama variety had the highest mean dry biomass than varieties Mataya and Kiegea. However, varieties Mataya and Kiegea had high and same mean of dry biomass in unpruned (control) than Simama variety (Table 3). Also, there were no significant differences ($p=1.000$) among variety and harvest intensity interactions on dry biomass at 4 weeks harvest interval. Moreover, there were no significant differences ($p\leq0.05$) among variety and harvest intensity interactions on aboveground biomass yield among harvest interval. The highest dry biomass yields were recorded with 70 % harvest intensity (Table 3).

4.3.2 Effect of leaf harvest and frequency on biomass yields at six weeks interval

The results showed significant differences ($p=0.011$) among varieties on fresh biomass weight (Table 4). At 6 weeks harvest interval and 70 % harvest intensity, Kiegea variety had significant higher mean, followed by varieties Mataya and Simama. There were significant differences ($p<0.001$) among harvest intensities on fresh biomass weight. At 6 weeks harvest interval and 70 % harvest intensity, Kiegea variety had significant high fresh biomass than varieties Mataya and Simama. At 10 % harvest intensity, Kiegea variety had low fresh biomass than varieties Simama and Mataya or the control (0 %) for all the varieties (Table 4).

However, there were no significant differences ($p=0.247$) among variety and harvest intensity interactions on fresh biomass weight at 6 weeks harvest interval. The highest mean fresh biomass yields were recorded with variety Kiegea at 70 % harvest intensity (Table 4).

The results showed significant differences ($p=0.011$) among varieties on dry biomass weight (Table 4). At 6 weeks harvest interval and 70 % harvest intensity, Kiegea variety had high dry biomass than varieties Mataya and Simama. However, Kiegea variety had the lowest dry biomass for Unpruned plot than varieties Mataya and Simama. The results showed significant differences ($p<0.001$) among harvest intensities on dry biomass weight. At 6 weeks harvest interval and 70 % harvest intensity, Kiegea variety had significant high dry biomass than either 10 to 60 % harvest intensities or the control for all the varieties (Table 4).

Table 4: Effect of leaf harvest intensity and variety on biomass yields (t ha^{-1}) at six weeks interval

	Characteristics					
	Fresh Biomass (t ha^{-1})			Dry Biomass (t ha^{-1})		
Leaf harvest Intensity	Simama	Mataya	Kiegea	Simama	Mataya	Kiegea
0 %	5.6	3.5	4.3	1.6	1.6	1.4
10 %	2.9	3.9	2.8	1.5	2.0	1.5
20 %	3.6	5.7	3.6	1.9	2.9	1.9
30 %	3.9	6.4	5.0	2.0	3.3	2.6
40 %	5.3	7.4	7.6	2.7	3.8	3.9
50 %	7.1	8.6	8.2	3.6	4.4	4.2
60 %	7.2	9.0	9.5	3.7	4.6	4.9
70 %	8.0	9.0	10.2	4.1	4.7	5.3
Mean	5.4	6.7	6.4	2.6	3.4	3.2
Grand Mean		3.181			3.066	
$Lsd_{0.05}$=Variety		0.722			0.3722	
$Lsd_{0.05}$=Intensty		1.180			0.6078	
$Lsd_{0.05}$=Interaction		ns			ns	
CV (%)		23.0			22.8	

Also, there were no significant differences (p=0.247) among variety and harvest intensity interactions on dry biomass at 6 weeks harvest interval. Moreover, there were no significant differences ($p \leq 0.05$) among variety and harvest intensity interactions on aboveground biomass yield among harvest interval. The highest dry biomass yields were recorded with 70 % harvest intensity while the lowest with unpruned; both for Kiegea variety (Table 4).

4.3.3 Effect of leaf harvest and frequency on biomass yields at eight weeks interval

The results showed no significant differences (p=0.134) among varieties on fresh biomass weight (Table 5). At 8 weeks harvest interval and 20 % harvest intensity, Simama variety had low fresh biomass than varieties Mataya and Kiegea (Table 5).

However, there were significant differences ($p<0.001$) among harvest intensities on fresh biomass weight. At 8 weeks harvest interval and 70 % harvest intensity, Simama variety had significantly high fresh biomass than Mataya variety. At 10 % harvest intensity, Kiegea variety had low fresh biomass than varieties Mataya and Simama (Table 5).

Also, there were no significant differences ($p=0.888$) among variety and harvest intensity interactions on fresh biomass at 8 weeks harvest interval (Table 5). The highest fresh biomass yields were recorded with variety Simama at 70 % harvest intensity (Table 5).

However, the results showed no significant differences ($p=0.134$) among varieties on dry biomass weight (Table 5). At 8 weeks harvest interval and 20 % harvest intensity, Simama variety had lower dry biomass than varietis Mataya and Kiegea. At 60 % harvest intensity, Kiegea variety had high dry biomass than varieties Mataya and Simama. At 70 % harvest intensity, Simama variety had high dry biomass than varieties Mataya and Kiegea (Table 5).

The results showed significant differences ($p<0.001$) among harvest intensities on dry biomass weight. At 8 weeks harvest interval and 60 % harvest intensity, Kiegea variety had high dry biomass than varieties Mataya and Simama. At 10 % harvest intensity, Kiegea variety had low dry biomass than varieties Mataya and Simama (Table 5).

Also, there were no significant differences ($p=0.888$) among variety and harvest intensity interactions on dry biomass at 8 weeks harvest interval. Moreover, there were no significant differences ($p\leq0.05$) among variety and harvest intensity interactions on aboveground biomass yield among harvest interval. The highest dry biomass yields were recorded with 70 % harvest intensity (Table 5).

Table 5: Effect of leaf harvest intensity and variety on biomass yields (t ha^{-1}) at an interval of eight weeks

	Characteristics					
	Fresh biomass (t ha^{-1})			Dry biomass (t ha^{-1})		
Leaf harvest Intensity	Simama	Mataya	Kiegea	Simama	Mataya	Kiegea
0 %	4.2	2.6	3.6	0.9	1.26	1.83
10 %	4.5	3.7	3.4	2.30	1.91	1.73
20 %	4.1	4.9	5.0	2.09	2.51	2.58
30 %	5.9	6.4	7.0	3.05	3.28	3.58
40 %	6.1	5.6	6.7	3.14	2.90	3.45
50 %	7.1	6.7	7.5	3.66	3.45	3.87
60 %	8.2	7.6	8.8	4.24	3.92	4.51
70 %	9.1	7.3	8.6	4.67	3.78	4.43
Grand Mean		6.02			3.0	
$Lsd_{0.05}$=Variety		ns			ns	
$Lsd_{0.05}$=Intensty		1.345			0.6930	
$Lsd_{0.05}$=Interaction		ns			ns	
CV (%)		20.7			20.7	

4.4 Leaf Biomass Production

The results showed significant differences ($p<0.001$) among varieties on dry weight of leaves (Table 6). At 4 weeks harvest interval 50 DAP with 10 to 70 % harvest intensities, Kiegea variety had low dry leaf biomass than Mataya and Simama. Also, among varieties on dry weight of leaves. At 78 and 106 DAP across leaf harvest intensity treatments, Simama variety had significant ($p<0.001$) higher mean, than varieties Mataya and Kiegea.

However, the results showed no significant differences ($p=0.087$) among varieties on dry weight of leaves (Table 6). At 134 DAP with 10 to 70 % harvest intensities. Among the varieties, highest leaf yields were observed with Mataya variety at 134 DAP and 70 % harvest intensity. The results showed significant differences ($p<0.001$) among harvest intensities on dry weight of leaves (Table 6). At 4 weeks harvest interval 50, 78 and 106

DAP respectively with 10 to 70 % harvest intensities, across leaf harvest intensity treatments, Simama variety had the highest mean on dry weight of leaf than varieties Mataya and Kiegea.

Also, the results showed significant differences ($p<0.001$) among harvest intensities on dry weight of leaves (Table 6). At 134 DAP with 10 to 70 % harvest intensities, Kiegea variety had lower dry weight of leaf than varieties Simama and Mataya. Among the harvest intensities, highest leaf yields were observed at 78 DAP and 70 % harvest intensity.

Also, there were significant differences ($p<0.001$) among variety and harvest intensity interactions on dry weight of leaves (Table 6). At 4 weeks harvest interval 78 DAP with 30 to 70 % harvest intensities, across leaf harvest intensity treatments, Mataya variety had the lowest mean on dry weight of leaf, than varieties Simama and Kiegea. However, the results at 4 weeks harvest interval 50 DAP showed no significant differences ($p=0.165$) among variety and harvest intensity interactions on dry weight of leaves.

At 4 weeks harvest interval 106 DAP, had no significant differences ($p=0.871$) among variety and harvest intensity interactions on dry weight of leaf. Also, there were no significant differences ($p=0.645$) among variety and harvest intensity interactions on dry weight of leaf (Table 6). At 4 weeks harvest interval 134 DAP.

Table 6: Effect of variety and harvest intensity (%) on dry leaf yields (t ha^{-1}) of sweet potato at four weeks interval

	50 DAP			78 DAP			106 DAP			134 DAP		
	V1	V2	V3	V1	V2	V3	V1	V2	V3	V1	V2	V3
0 %	-	-	-	-	-	-	-	-	-	-	-	-
10 %	0.07	0.03	0.02	0.11	0.01	0.03	0.12	0.04	0.03	0.06	0.10	0.05
20 %	0.26	0.15	0.10	0.30	0.07	0.07	0.34	0.19	0.20	0.54	0.25	0.17
30 %	0.65	0.36	0.17	0.60	0.14	0.17	0.65	0.39	0.42	0.47	0.45	0.35
40 %	1.03	0.54	0.44	0.97	0.25	0.32	0.98	0.76	0.58	0.73	1.03	0.69
50 %	1.23	0.68	0.49	1.38	0.39	0.45	1.46	1.07	1.08	1.17	1.53	1.02
60 %	1.28	1.16	0.56	1.32	0.55	0.76	1.47	1.26	1.26	1.32	1.20	1.10
70 %	1.55	1.14	0.81	1.96	0.70	0.99	1.56	1.55	1.45	1.45	1.79	1.30
Grand Mean		0.530			0.480			0.702			0.702	
$Lsd_{0.05}$=V		0.073			0.109			0.094			ns	
$Lsd_{0.05}$=I		0.119			0.178			0.154			0.297	
$Lsd_{0.05}$=VxI		ns			0.309			ns			ns	
Cv (%)		47.6			39.1			23.1			44.6	

Key: VI=Simama, V2=Mataya, V3=Kiegea; V=Variety, I=Intensity, VxI=Interaction

The results showed significant differences ($p=0.002$) among varieties on dry weight of leaves (Table 7). At 6 weeks harvest interval 50 DAP with 10 % harvest intensities, Kiegea variety had low dry weight of leaf than varieties Mataya and Simama. Also, showed significant differences ($p<0.001$) among varieties on dry weight of leaves. At 92 DAP with 70 % harvest intensities, Kiegea variety had the highest mean, than varieties Simama and Mataya on dry weight of leaf.

However, the results showed no significant differences ($p=0.440$) among varieties on dry biomass weight. At 134 DAP with 60 % harvest intensities, Kiegea variety had high dry weight of leaf than Simama and Mataya. Among the varieties, highest leaf yields were observed with Kiegea variety at 92 DAP and 70 % harvest intensity (Table 7).

The results showed significant differences ($p<0.001$) among harvest intensities on dry weight of leaves (Table 7). At 6 weeks harvest interval 50, 92 and 134 DAP respectively. Among harvest intensities, the lowest leaf yields were observed with Kiegea at 50 DAP and 10 % harvest intensity.

Also, there were significant differences ($p<0.002$) among varieties and harvest intensity interactions on dry biomass weight (Table 7). At 6 weeks harvest interval 92 DAP with 10 % harvest intensities, Kiegea variety had the lowest mean, than varieties Simama and Mataya on dry weight of leaf. Of which the mean of dry weight of leaves were the same for varieties Simama and Mataya at 10 % harvest intensities. However, the results at 6 weeks harvest interval 50 DAP showed no significant differences ($p=0.457$) among varieties and harvest intensity interactions on dry weight of leaves. At 6 weeks harvest interval 134 DAP. Also, at 92 DAP there were no significant differences ($p=0.939$) among varieties and harvest intensity interactions on dry weight of leaves.

Table 7: Effect of variety and harvest intensity (%) on dry leaf yields (t ha^{-1}) of sweet potato at an interval of six weeks

Leaf harvest Intensity	50 DAP			92 DAP			134 DAP		
	V1	V2	**V3**	**V1**	V2	V3	V1	V2	V3
0 %	-	-	-	-	-	-	-	-	-
10 %	0.09	0.05	0.02	0.15	0.15	0.07	0.09	0.06	0.06
20 %	0.26	0.18	0.10	0.20	0.56	0.23	0.25	0.20	0.21
30 %	0.65	0.36	0.17	0.36	0.92	0.40	0.57	0.45	0.54
40 %	0.79	0.54	0.44	0.69	1.31	0.71	0.86	1.11	0.97
50 %	1.08	0.74	0.64	1.00	1.64	1.12	0.93	1.11	1.44
60 %	1.13	1.20	0.92	1.02	1.25	1.35	1.39	1.37	1.55
70 %	1.24	1.32	1.30	1.08	1.46	1.75	1.41	1.17	1.52
Grand Mean		0.551			0.726			0.719	
$Lsd_{0.05}$=V		0.1126			0.1136			Ns	
$Lsd_{0.05}$=I		0.1838			0.1855			0.2903	
$Lsd_{0.05}$=VxI		ns			0.3213			ns	
CV (%)		35.2			26.9			42.6	

Key: VI=Simama, V2=Mataya, V3=Kiegea; V=Variety, I=Intensity, VxI=Interaction

Among varieties and harvest intensity interactions, highest leaf yields were observed with Kiegea at 92 DAP and 70 % harvest intensity (Table 7).

The results showed no significant differences (p=0.019) among varieties on dry weight of leaves (Table 8). At 8 weeks harvest interval 50 DAP with 70 % harvest intensities, Simama variety had high dry weight of leaf than varieties Mataya and Kiegea.

However, the results showed significant differences (p<0.001) among varieties on dry weight of leaves. At 8 weeks harvest interval 106 DAP with 20 to 50 % harvest intensities, Kiegea variety had high dry weight of leaf than varieties Simama and Mataya. Also, there were significant differences (p=0.003) among varieties on dry weight of leaves. At 162 DAP with 40 to 70 % harvest intensities, Simama variety had low dry weight of leaf than varieties Kiegea and Mataya (Table 8). Among the varieties, highest leaf yields were recorded with Kiegea variety at 162 DAP and 60 % harvest intensity (Table 8).

Table 8: Effect of variety and harvest intensity (%) on dry leaf yields (t ha^{-1}) of sweet potato at an interval of eight weeks

	50 DAP			106 DAP			162 DAP		
Leaf harvest Intensity	V1	V2	V3	V1	V2	V3	V1	V2	V3
0 %	-	-	-	-	-	-	-	-	-
10 %	0.06	0.09	0.07	0.06	0.07	0.06	0.07	0.06	0.06
20 %	0.26	0.21	0.17	0.63	0.49	0.76	0.27	0.29	0.25
30 %	0.61	0.36	0.29	0.74	0.37	1.29	0.44	0.40	0.72
40 %	0.68	0.54	0.44	0.77	0.82	0.97	0.62	0.91	0.90
50 %	0.83	0.83	0.58	0.93	0.42	1.18	1.06	1.34	1.34
60 %	1.05	0.86	0.80	1.01	0.59	0.95	1.14	1.36	1.63
70 %	1.35	0.97	1.10	1.15	0.93	1.00	1.33	1.46	1.62
Grand Mean		0.982			0.633			0.719	
$Lsd_{0.05}$=V		0.1232			0.1522			0.1091	
$Lsd_{0.05}$=I		0.2012			0.2485			0.1782	
$Lsd_{0.05}$=VxI		ns			ns			ns	
CV (%)		41.9			41.4			26.1	

Key: VI=Simama, V2=Mataya, V3=Kiegea; V=Variety, I=Intensity, VxI=Interaction

The results showed significant differences ($p<0.001$) among harvest intensities on dry weight of leaves (Table 8). At 8 weeks harvest interval 50, 106 and 162 DAP respectively. Among harvest intensities, the highest leaf yields were observed with Kiegea variety at 162 DAP and 60 % harvest intensity. However, the results showed no significant differences ($p=0.905$) among varieties and harvest intensity interactions on dry weight of leaves. At 8 weeks harvest interval 50 DAP. At 106 DAP had no significant differences ($p=0.119$) among varieties and harvest intensity interactions on dry weight of leaves.

Also, there were no significant differences (p=0.420) among varieties and harvest intensity interactions on dry weight of leaves. At 8 weeks harvest interval 162 DAP with 10 % harvest intensities, varieties Mataya and Kiegea resulted into the same mean. Of which had the lowest mean than Simama variety (Table 8).

However, there were no significant differences ($p \leq 0.05$) among variety and harvest intensity interactions on dry weight of leaves. The highest leaves were recorded with 70 % and 60 % leaf harvest intensity at all harvest intervals (Table 6, 7 and 8).

4.5 Number of Branches Vines

The results showed no significant differences (p=0.830) among varieties on vine branches (Table 9). At 4 weeks harvest interval and 20 % harvest intensity, Mataya variety had lower vine branches than varieties Simama and Kiegea. Also, there were no significant differences (p=0.076) among varieties on vine branches. At 8 weeks harvest interval and 10 % harvest intensity, Mataya variety had lower vine branches than varieties Simama and Kiegea. However, the results showed significant differences ($p<0.003$) among varieties on vine branches**.** At 6 weeks harvest interval and 50 % harvest intensity, Mataya variety had higher vine branches than varieties Simama and Kiegea (Table 9).

The results showed no significant differences (p=0.704) among harvest intensities on vine branches (Table 9). At 4 weeks harvest interval and 40 % harvest intensity, Simama variety had higher vine branches than varieties Mataya and Kiegea. There were no significant differences (p=0.060) among harvest intensities on vine branches. At 6 weeks harvest interval and 50 % harvest intensity, Mataya variety had higher vine branches than varieties Simama and Kiegea.

Table 9: Effect of variety and harvest intensity on vine branch number at an interval of four, six and eight weeks

Leaf harvest Intensity	4 Week V1	V2	V3	6 Week V1	V2	V3	8 Week V1	V2	V3
0 %	11	10	11	8	10	9	10	11	9
10 %	11	13	11	9	10	10	11	8	12
20 %	10	8	11	11	11	13	10	10	11
30 %	10	12	9	10	12	10	9	10	12
40 %	13	12	10	9	12	11	9	9	10
50 %	10	11	11	10	14	11	9	9	12
60 %	10	10	11	10	11	10	10	9	9
70 %	11	10	10	10	11	12	9	9	11
Grand Mean		10.75			10.65			9.99	
$Lsd_{0.05}$=Variety		ns			1.019			ns	
$Lsd_{0.05}$=Intensty		ns			ns			ns	
$Lsd_{0.05}$=Interaction		ns			ns			ns	
CV (%)		22.5			16.5			17.6	

Key: VI=Simama, V2=Mataya, V3=Kiegea; V=Variety, I=Intensity, VxI=Interaction

Also, there were no significant differences (p=0.704) among harvest intensities on vine branches. At 8 weeks harvest interval and 10, 30 and 50 % harvest intensity, Kiegea variety had higher vine branches than varieties Simama and Mataya (Table 9). The results showed no significant differences (p=0.940) among varieties and harvest intensity interactions on vine branches. At 4 weeks harvest interval. There were no significant differences (p=0.424) among varieties and harvest intensity interactions on vine branches. At 6 weeks harvest interval. Also, there were no significant differences (p=0.940) among varieties and harvest intensity interactions on vine branches. At 8 weeks harvest interval (Table 9). Morever, there were no significant difference (p≤0.05) among variety and harvest intensity interactions on vine branch among harvest intervals (Table 9). The highest vine branches were recorded with 50 % harvests intensity, at 6 weeks harvest interval. furthermore, among the varieties highest vine branches were observed with Mataya variety at 6 weeks harvest interval and 50 % harvest intensity.

4.6 Vine Length

The results showed significant differences ($p<0.001$) among varieties on vine length (Table 10). At 4 and 6 weeks harvest interval and 10 to 70 % harvest intensities, Mataya variety had shorter vine length than varieties Simama and Kiegea. Also, there were significant differences ($p<0.001$) among varieties on vine length. At 8 weeks harvest interval and 0 to 50 % harvest intensity, Kiegea variety had shorter vine length than varieties Simama and Mataya (Table 10).

The results showed significant differences ($p=0.004$) among harvest intensities on vine length (Table 10). At 4 weeks harvest interval and 10 % harvest intensity, Simama variety had longer vine length than varieties Mataya and Kiegea. However, there were no significant differences ($p=0.061$) among harvest intensities on vine length. At 6 weeks harvest interval and 10 % harvest intensity, Simama variety had longer vine length than varieties Mataya and Kiegea (Table 10).

There were significant differences ($p=0.005$) among harvest intensities on vine length. At 8 weeks harvest interval and 40 % harvest intensity, Mataya variety had longer vine length than varieties Simama and Kiegea (Table 10). There were significant differences ($p<0.001$) among varieties and harvest intensity interactions on vine length (Table 10). At 4 and 6 weeks harvest interval and 10 to 70 % harvest intensities, Mataya variety had the shortest vine length than varieties Simama and Kiegea.

Table 10: Effect of variety and harvest intensity on vine length (cm) at 4, 6 and 8 weeks harvest

Leaf harvest Intensity	V1	V2	V3	VI	V2	V3	V1	V2	V3
	4 Week			6 Week			8 Week		
0 %	484	287	335	412	213	329	479	453	318
10 %	561	268	332	486	279	304	525	442	305
20 %	389	296	346	312	308	328	447	473	390
30 %	393	277	295	321	294	311	438	469	392
40 %	437	284	387	348	343	362	551	561	355
50 %	458	290	308	339	328	346	470	443	340
60 %	515	253	267	405	287	292	436	314	361
70 %	501	277	290	428	285	303	448	397	406
Grand Mean		355.5			331.7			425.5	
$Lsd_{0.05}$=Variety		18.56			20.58			29.97	
$Lsd_{0.05}$=Intensty		30.30			ns			48.94	
$Lsd_{0.05}$=Interaction		52.49			58.21			84.77	
CV (%)		9.0			10.7			12.1	

Key: VI=Simama, V2=Mataya, V3=Kiegea; V=Variety, I=Intensity, VxI=Interaction

Also, there were significant differences ($p=0.005$) among varieties and harvest intensity interactions on vine length. At 8 weeks harvest interval and 60 to 70 % harvest intensity, Simama variety had shorter vine length than varieties Mataya and Kiegea (Table 10). Moreover, there were significant differences ($p \leq 0.05$) among varieties and harvest intensity interactions on vine length. Longer vine was observed at 4 and 8 weeks harvest interval with 10 and 40 % harvest intensities, for varieties Simama and Mataya, respectively. Of which resulted into the same mean (Table 10).

4.7 Root Yield

The results showed significant differences ($p<0.001$) among varieties on fresh root weight (Table 11). At 4, 6 and 8 weeks harvest interval with 10 to 70 % harvest intensities, Simama variety had lower root yields than varieties Mataya and Kiegea.

Table 11: Effect of variety and harvest intensity on fresh root yield (t ha^{-1}) at an interval of 4, 6 and 8 weeks

Leaf harvest Intensity	4 Weeks			6 Weeks			8 Weeks		
	V1	V2	V3	V1	V2	V3	V1	V2	V3
0 %	5.8	18.2	11.9	8.3	17.7	17.9	5	14	17
10 %	3.5	12.1	13.9	5.4	21.6	15.6	6	17	13
20 %	2.9	12.9	7.5	4.1	13.4	13.1	3	15	13
30 %	2.6	12.4	8.0	5.2	16.8	13.1	2	12	11
40 %	2.4	12.4	10.2	3.9	16.5	13.6	2	16	9
50 %	2.4	10.5	8.5	3.4	15.6	11.2	3	15	11
60 %	2.4	8.0	8.5	1.7	14.6	7.3	3	13	14
70 %	2.1	10.3	9.5	1.5	10.2	9.1	2	11	12
Grand Mean		8.20			10.86			9.95	
$Lsd_{0.05}$=Variety		0.723			2.256			2.281	
$Lsd_{0.05}$=Intensty		ns			3.684			ns	
$Lsd_{0.05}$=Interaction		ns			ns			ns	
CV (%)		43.2			36.2			39.0	

Key: VI=Simama, V2=Mataya, V3=Kiegea; V=Variety, I=Intensity, VxI=Interaction

The results showed significant differences (p=0.022) among harvest intensities on fresh root weight (Table 11). At 4 weeks harvest interval and unpruned (0 %) harvest intensity, Mataya variety had higher fresh root weight than varieties Simama and Kiegea. There were significant differences (p=0.001) among harvest intensities on fresh root weight. At 6 weeks harvest interval and 10 and 70 % harvest intensity, Mataya variety had higher fresh root weight than varieties Simama and Kiegea (Table 11). Also, there were significant differences (p=0.005) among harvest intensities on fresh root weight. At 8 weeks harvest interval and 10 to 40 % harvest intensity, Mataya variety had higher fresh root weight than varieties Simama and Kiegea (Table 11).

There were no significant differences (p=0.899) among varieties and harvest intensity interactions on fresh root weight (Table 11). At 4 weeks harvest interval and 20 to 50 %

harvest intensities, Mataya variety had higher fresh root weight than varieties Kiegea and Simama. There were no significant differences ($p=0.911$) among varieties and harvest intensity interactions on fresh root weight. At 6 weeks harvest interval and 0 to 70 % harvest intensity, Simama variety had the lowest fresh root weight than varieties Mataya and Kiegea.

Also, there were no significant differences ($p=0.863$) among varieties and harvest intensity interactions on fresh root weight. At 8 weeks harvest interval and 60 to 70 % harvest intensity, Kiegea variety had higher fresh root weight than varieties Mataya and Simama (Table 11).

Moreover there were no significant differences ($p \leq 0.05$) among varieties and harvest intensity interactions on fresh root weight. Mataya variety at 4, 6 and 8 week harvest interval with 10 to 50 % harvest intensities, had the highest fresh root weight than varieties Kiegea and Simama (Table 11).

4.8 Root Cluster

The results showed significant differences ($p=0.027$) among varieties on root cluster (Table 12). At 4 weeks harvest interval and 50 to 70 % harvest intensity, Kiegea variety had higher root cluster than varieties Simama and Mataya. At 30 to 40 % harvest intensity, Mataya variety had higher root cluster than varieties Simama and Kiegea. There were significant differences ($p<0.001$) among varieties on root cluster. At 6 and 8 weeks harvest interval and 30 to 70 % harvest intensity, Simama variety had lower root cluster than varieties Mataya and Kiegea. Among the varieties, highest root cluster were observed with varieties Mataya and Kiegea at 8 weeks harvest interval with 50 % harvest intensity (Table 12).

Table 12: Effect of variety and harvest intensity on root growth characteristics (no)

Leaf harvest Intensity	4 weeks V1	4 weeks V2	4 weeks V3	6 weeks V1	6 weeks V2	6 weeks V3	8 weeks V1	8 weeks V2	8 weeks V3
0 %	4	4	6	3	4	6	4	7	5
10 %	6	5	6	4	4	5	3	5	7
20 %	4	5	7	3	4	6	3	6	6
30 %	5	6	4	2	5	5	2	4	5
40 %	3	5	3	3	5	4	3	4	6
50 %	2	4	6	3	5	6	4	8	8
60 %	4	5	7	2	4	5	2	4	7
70 %	4	3	6	3	7	5	3	4	7
Grand Mean		4.72			4.20			4.81	
$Lsd_{0.05}$=V		ns			0.763			0.698	
$Lsd_{0.05}$=I		ns			ns			1.139	
$Lsd_{0.05}$=VxI		ns			ns			ns	
CV (%)		37.9			28.6			27.3	

Key: VI=Simama, V2=Mataya, V3=Kiegea; V=Variety, I=Intensity, VxI=Interaction

There were no significant differences (p=0.403) among harvest intensities on root cluster number (Table 12). At 4 weeks harvest interval and 50 % harvest intensity, Simama variety had lower root cluster than varieties Mataya and Kiegea.

There were no significant differences (p=0.289) among harvest intensities on root cluster number (Table 12). At 6 weeks harvest interval and 20 to 70 % harvest intensity, Simama variety had lower root cluster than varieties Mataya and Kiegea.

However, there were significant differences (p=0.007) among harvest intensities on root cluster number. At 8 weeks harvest interval and 10, 30 to 40 and 60 to 70 % harvest intensity, Kiegea variety had higher root cluster than varieties Mataya and Simama (Table 12). There were no significant differences (p=0.352) among variety and harvest intensity interactions on root cluster number (Table 12). At 4 weeks harvest interval with 20 and 60

% harvest intensity, Kiegea variety had higher root cluster than varieties Mataya and Simama.

There were no significant differences ($p=0.223$) among variety and harvest intensity interactions on root cluster number (Table 12). At 6 weeks harvest interval and 70 % harvest intensity, Mataya variety had higher root cluster than varieties Kiegea and Simama and other harvest intensities, or the control (0 %).

Also, there were no significant differences ($p=0.079$) among variety and harvest intensity interactions on root cluster number. At 8 weeks harvest interval with 0 to 70 % harvest intensity, Simama variety had the lowest root cluster than varieties Mataya and Kiegea. Moreover, there were no significant differences ($p \leq 0.05$) among variety and harvest intensity interactions on root cluster number among harvest intervals (Table 12). The highest root cluster were recorded with 50 % harvest intensity, at 8 weeks harvest interval.

4.9 Root Diameter

The results showed significant differences ($p<0.001$) among varieties on root diameter (Table 13). At 4, 6 and 8 weeks harvest interval and 10 to 70 % harvest intensity, Simama variety had smaller root diameter than varieties Mataya and Kiegea.

The results showed significant differences ($p=0.001$) among harvest intensities on root diameter. At 4 weeks harvest interval with 10 and 30 to 70 % harvest intensity, varieties Mataya and Kiegea had same size and larger root diameter than Simama variety (Table 13).

Table 13: Effect of variety and harvest intensity on root diameter (cm) at 4, 6 and 8 weeks intervals

		4 Week			6 Week			8 Week	
Leaf harvest Intensity	V1	V2	V3	V1	V2	V3	V1	V2	V3
0 %	6	8	7	3	7	8	3	8	8
10 %	5	7	7	3	7	7	4	7	6
20 %	4	7	8	1	7	6	3	7	6
30 %	4	7	7	3	7	7	2	7	8
40 %	4	7	7	3	6	6	3	7	6
50 %	3	7	7	2	7	6	2	6	7
60 %	2	6	6	2	6	6	3	7	6
70 %	2	4	6	2	6	5	3	6	5
Grand Mean		5.88			5.23			5.43	
$Lsd_{0.05}$=Variety		2.058			0.568			0.538	
$Lsd_{0.05}$=Intensty		1.227			0.928			ns	
$Lsd_{0.05}$=Interaction		ns			ns			ns	
CV (%)		22.0			17.7			18.0	

Key: VI=Simama, V2=Mataya, V3=Kiegea; V=Variety, I=Intensity, VxI=Interaction

However, there were no significant differences (p=0.055) among harvest intensities on root diameter. At 6 weeks harvest interval at 20 % harvest intensity, Simama variety had the smallest root diameter than varieties Mataya and Kiegea. Also, there were no significant differences (p=0.123) among harvest intensities on root diameter. At 8 weeks harvest interval at 30 % harvest intensity, Kiegea variety had lager root diameter than varieties Mataya and Simama (Table 13). The results showed no significant differences (p=0.868) among varieties and harvest intensity interactions on root diameter (Table 13). At 4 weeks harvest interval with 10 to 70 % harvest intensity, Simama variety had smaller root diameter than varieties Mataya and Kiegea. There were no significant differences (p=678) among varieties and harvest intensity interactions on root diameter. At 6 weeks harvest interval with 10 to 70 % harvest intensity, Simama variety had smaller root diameter than varieties Mataya and Kiegea. Also, there were no significant differences (p=0.123) among harvest intensities on root diameter. At 8 weeks harvest interval at 30 % harvest intensity, Simama variety had smaller root diameter than varieties Mataya and Kiegea (Table 13).

Moreover, there were no significant differences ($p \leq 0.05$) among varieties and harvest intensity interactions on root diameter. At 4, 6 and 8 weeks harvest interval and harvest intensity the smallest root diameter was observed with Simama variety. Furthermore, among varieties, the largest root diameter were most observed with Mataya variety than varieties Kiegea and Simama (Table 13).

4.10 Root Length

The results showed no significant difference (p=0.345) among varieties on root length (Table 14). At 4 weeks harvest interval and 20 to 30 % harvest intensity, Kiegea variety had longer root length than varieties Simama and Mataya. At 40 % harvest intensity, varieties Simama and Kiegea had longer root length than Mataya varieties. At 50 to 60 % harvest intensity, Mataya variety had longer root length than varieties Simama and Kiegea. At 70 % harvest intensity, Kiegea variety had shorter root length than Simama and Mataya.

There were significant differences (p=0.014) among varieties on root length. At 6 weeks harvest interval and 60 % harvest intensity, all varieties had similar root length but, shorter root length than control (Table 14).

Also, there were significant differences (p=0.023) among varieties on root length. At 8 weeks harvest interval and 20 to 50 % harvest intensity, Simama variety had shorter root length than varieties Mataya and Kiegea. At 60 to 70 % harvest intensity Mataya variety had longer root length than varieties Simama and Kiegea. Among the varieties the longest root were observed with Mataya variety at 4 weeks harvest interval and 50 % harvest intensity (Table 14).

The results showed no significant differences (p=0.112) among harvest intensities on root length (Table 14). At 4 weeks harvest interval and 50 % harvest intensity, Mataya variety had longer root length than varieties Simama and Kiegea. At 70 % harvest intensity, Kiegea variety had shorter root length than varieties Simama and Mataya. There were no significant differences (p=0.202) among harvest intensities on root length (Table 14). At 6 weeks harvest interval with 10 to 30 % harvest intensity, Mataya variety had longer root length than varieties Kiegea and Simama. At 40, 50 and 70 % harvest intensity Kiegea variety had shorter root length than varieties Mataya and Simama.

Also, there were no significant differences (p=0.080) among harvest intensities on root length (Table 14). At 8 harvest weeks interval with 10 % harvest intensity, Simama variety had smaller root length than varieties Mataya and Kiegea. Among the harvest intensities, the shortest root length was observed with 70 % at 4 and 6 weeks harvest interval (Table 14). The results showed no significant differences (p=0.209) among variety and harvest intensity interactions on root length (Table 14). At 4 weeks harvest interval and 50 % harvest intensities, Mataya variety had the longest root length than varieties Simama and Kiegea. There were no significant differences (p=0.471) among varieties and harvest intensity interactions on root length.

Table 14: Effect of variety and harvest intensity on root length (cm) at 4, 6 and 8 weeks intervals

		4 Week			6 Week			8 Week	
Leaf harvest Intensity	V1	V2	V3	V1	V2	V3	V1	V2	V3
0 %	12	14	15	13	14	14	13	15	16
10 %	11	14	13	14	15	12	14	14	14
20 %	13	12	15	9	14	12	10	15	13
30 %	14	14	16	14	16	13	13	14	15
40 %	12	11	12	15	13	11	13	15	15
50 %	11	17	14	12	13	10	12	13	14
60 %	13	14	13	12	12	12	12	13	11
70 %	14	12	9	9	15	10	13	14	12
Grand Mean		13.13			12.64			13.48	
$Lsd_{0.05}$=Variety		ns			1.159			1.573	
$Lsd_{0.05}$=Intensty		ns			ns			ns	
$Lsd_{0.05}$=Interaction		ns			ns			ns	
CV (%)		18.2			21.4			14.8	

Key: VI=Simama, V2=Mataya, V3=Kiegea; V=Variety, I=Intensity, VxI=Interaction

At 6 weeks harvest interval and 60 % harvest intensity, the mean of root length was the same for varieties Mataya, Simama and Kiegea. Also, there were no significant differences (p=0.467) among varieties and harvest intensity interactions on root length. At 8 weeks harvest interval with 10 % harvest intensity, the mean of root length was the same size for varieties Mataya, Simama and Kiegea.

Moreover there were no significant differences (p≤0.05) among varieties and harvest intensity interactions on root length. Root length development varied among variety and harvest intensity interactions on root length. Longer root length was observed at 4 weeks harvest interval with 50 % harvest intensities, for Mataya variety. The shortest root length was observed at 4 weeks harvest interval with 70 % harvest intensities for Kiegea variety; and at 6 weeks harvest interval with 20 and 70 % harvest intensities for Simama variety.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Above Ground Biomass Yield

Frequent leaf harvesting at 4 weeks harvest interval had higher biomass than at 6 and 8 weeks harvest interval. Leaf harvesting frequency did improve forage yield of sweet potato when compared to least leaf harvesting or control. These results agree with the findings of Kiozya (2001) who observed that leaf harvesting frequencies gave greater yields of biomass than the zero leaf harvesting frequencies. This was reinforced by Lebot (2009) who reported that, leaves can be harvested three or four times per growing season. Also, the same author reported that sweet potato vines can be harvested at intervals of 20 days with a defoliation of 50 % of the total stems for optimal leaf and root production, since greater defoliation could reduce root production.

However, among varieties biomass weight production of sweet potato at 4 and 6 weeks interval were significantly different, at 8 weeks interval were not significantly differenct. Since biomass production among these varieties at 8 weeks interval was not significantly different, it may be inferred that leaf harvesting did not alter biomass production in sweet potato but re-partitioned dry matter accumulation to favour leaf production at the expense of the root. Mataya variety had significantly higher biomass yields than varieties Kiegea and Simama at six week.

The quantity of the biomass was however, least at 8 weeks interval; harvested plants did not improve forage yields of sweet potato, Simama variety, had higher biomass yields than varieties Kiegea and Mataya. Increasing the interval between harvests gave the plant sufficient time to recover from the previous harvest but at the expences of biomass production. This disagrees with the findings of Uddin *et al.* (1994), cited by Olorunnisomo (2007) who reported that forage yield increased with delayed leaf harvesting.

5.1.1 Leaf dry matter yield

In general higher leaf production were registered from each harvest intervals. There were significant effect of variety and harvest intensity interaction on dry leaf yields per hectare when three varieties of sweet potato leaf harvested sequentially 4, 3 or 3 at an interval of 4, 6 or 8 weeks. Among the varieties, highest harvested leaves were observed with highest harvest intensity and closer harvest intervals. This indicate that harvest intensity and harvest intervals improved forage yield at the expense of root yield. The higher leaf yields might be attributed to frequent harvesting of the leaf and sustained moisture availability over the cropping season, leading to more leaf yields at the expense of root yield. This also, could be explained by the fact that the plant tries to maintain a constant shoot:root ratio and probably Leaf Area Index. In turn demonstrates that the sweet potato vine has a high capacity for regrowth, as was observed when a rate of 50 %, 60 % or 70 % were highly harvested especially in a short interval (4 weeks).

The results under four interval support previous records by Nwinyi (1992); Olorunnisomo (2007) and FAO (2010) who observed that leaf dry matter production potential per hectare for some varieties of sweet potato can vary from 4.3 to 6 tons, depending on leaf harvest intensity, variety grown, cultivation practices and fertiliser application. Results under 6 or 8 interval did not support. However, for the present study in any of the harvests the leaf samples taken DM contained old leaves. It was however also, probably that as the closer intervals with high percentage leaf harvest, the chances of being taken young leaves for sample were high due to the short period of time, before the complete aerial part formation in the second life cycle. This fact can explain, therefore, at least in part, the alteration of dry matter in the whole leaf in the sabsequant leaf harvesty.

Another possibility, however, could be related to the fact that, according to Deblonde and Ledent (2001); Parwada (2011); Yooyongwech *et al*. (2014) the size, the morphology, and other agronomical characteristic of the sweet potato leaves varied according to the variety. This result also agrees with the findings of An *et al*. (2003); who reported that sweet potato vines can be harvested several times throughout the year. This was reinforced by Kiozya (2001), who indicated, that the higher leaf harvesting frequencies (intensity) gave greater yields of total DM than the least leaf harvesting frequencies. This disagrees with the earlier findings of Olorunnisomo (2007) who reported that forage yield increased with delayed cutting while root yield was depressed.

However, harvest intensity (50 %, 60 % or 70 %) did not vary significantly among the three sweet potato varieties (Simama, Mataya, Kiegea). This was probably due to the highest humidity. This result support previous records by Hakiza *et al*. (2000); Nedunchezhiyan (2004) who reported the variation in the humidity content of the sweet potato leafy portion. This was due to the high rainfall intensity observed in the period (2014). However, the variations found in this study were not affected by climate, considering that the crops expressed a continuous increase of the dry matter contents, even during the period of most intense vegetative growth. These results also agree with the findings of Lebot (2009) who reported that sweet potato vines can be harvested at intervals of 20 days with a defoliation of 50 % of the total stems for optimal leaf and root production, since greater defoliation could reduce root production. The greatest advantage of high percent harvests is that forage can be supplied at higher amount. Sweet potato leaves were found to be a high quantity feed for livestock.

5.1.2 Number of Branches in Vine

There were significant effect of variety and harvest intensity interaction on branch number in vine when three varieties of sweet potato leaf harvested sequentially 4, 3 or 3 at an interval of 4, 6 or 8 weeks. Among the varieties, neither highest nor least harvest intensity and closer harvest intervals, were observed with branch variation. This indicate that intensity and variety interaction at different, short interval (4 weeks) and at longer intervals (6 and 8 weeks) harvesting of sweet potato leaves did not significantly improve vine branch nor forage yield. These results agree with other reports that, branching is cultivar dependent (Somda *et al*., 1990) and branches vary in number and length. However, these results disagree with Olorunnisomo (2007) who reported that leaf harvest intensity influence the branching intensity in sweet potato crop.

5.1.3 Vine Length

Results showed that vines of each variety had made an extensive growth in vine length; and from each variety did not significant differ of harvest intensity nor frequent harvest. This indicate that harvest intensity improved vine length at the expense of root yield. The longest vines were neither observed in frequently harvested interval nor the least frequently harvested. This disagrees with the findings of Gomes *et al.* (2005) and Olorunnisomo *et al.* (2006) report, who reported that frequency of leaf harvesiting interval has significant influence on vine length. Frequent defoliation of sweet potato plant disrupted the photosynthetic process, leading to a reduced leaf, root and biomass production (Lugojja *et al.,* 2001). These result agree with other reports that; defoliation had a negative influence on root production in sweet potato (An *et al.,* 2003; Kiozya *et al.,* 2001). At high harvesting intensity (50-70 %) yield of sweet potato forage increased significantly when compared to control while the root yield was significantly suppressed. Also at longer harvesting intervals (6 or 8) yield of sweet potato forage increased significantly when compared to control while the root yield was significantly suppressed. This agrees with the findings of Olorunnisomo (2007); Masumba *et al.* (2004) who reported that forage yield increased with increase cutting intervals while root yield was suppressed.

The results of the study suggest that the leaf harvesting in general has an effect on forage and root production. The forage production was higher in crop harvested at an interval of four weeks than in those were harvested at an interval of six or eight weeks. This for the farmers implies that this harvesting system type could favor feeding livestock if resonably high livestock production is to be realised.

The forage production was significantly higher in the Simama variety even when harvested at different intervals, followed by variety Mataya which was not significantly different from Kiegea variety. But since our target is to produce both root and forage for human and livestock respectively. The study has served to confirm that more root were obtaned in Mataya variety than varieties Kiegea and Simama; root in variety Simama was significant lower. From the study, variety Mataya and Kiegea are recommended for the production for both root and forage.

Harvesting of forage at regular intervals is a potent agronomic tool used in maintaining a balance between yield and quality in forage species (Hong *et al.,* 2003). Removal of sweet potato vines during growth however reduces the supply of photosynthates during the remainder of the plant's growth with an eventual reduction in root yield (Nedunchezhiyan *et al.,* 2004). Harvesting the vines during growth does reduce root quality (weight, volume, fiber content, crude protein) by (An *et al.,* 2003). Kiozya *et al.* (2001) found that reduction in root weight amounted to about 33% for plants whose vines were harvested 45 days after planting, 25% for plants whose vines were harvested 75 days after planting and 15% for those whose vines were harvested 105 days after planting. This suggests that most of the photosynthates were not translocated to the storage roots but remained instead in the foliage production. These results further suggests that sweet potatoes grown for root and forage should not be subjected for leaf harvest at a short time of interval such as four weeks of interval; simply because it favor foliage growth at the expense of storage root production.

5.2 Root Yield

In the present investigation it has been experienced that higher root yields were found in the vine harvested at intensities of 50 % and lower one at 8 weeks (least harvested) intervals. The results agree with Lebot (2009) who reported that sweet potato vines can be harvested at intervals of 20 days with a defoliation of 50% of the total stems for optimal leaf and root production, since greater defoliation could reduce root production. Also, the results agree with those of An *et al.* (2003) who reported that defoliation had a negative influence on root production in sweet potato (weight, volume, DM content). Root yield per plant is a function of number of roots per plant, root length, and root diameter (Moyo, 2004; Zuger, 2003). Hence, leaf harvesting rate or intervals could significantly influence root yields per vine.

Although size of the storage roots (diameter and length) were relatively large for Mataya variety compared to the control, the dry matter contents in the storage roots were lower in the high leaf harvest intensities (60 % and, 70 %), especially those under 4 weeks interval. Also, it has been experienced in this experiment for root harvested from this treatment (60 % and, 70 %) harvest intensities, were most with less weight than other lower harvest intensities.

5.2.1 Diameter and length of storage roots

The results of the study suggest that the leaf harvesting in general has an effect on the crop, on root diameter and hence root production. Frequent harvesting of leaves reduces storage roots diameter, but the degree of reduction differs with variety (Brazilian Archives of Biology and Technology, 2006). The storage roots diameter increased considerably when the amount of leaves was higher, indicating the importance of leaf production in the sweet potato root yield. These results agree with the findings of Villordon *et al.* (2009) who reported that radial diameter of storage roots to be the main component of production and that the weight of storage roots were functions of its diameter. This was reinforced by Kathabwalika *et al.* (2013) who reported that who reported that, the existence of cultivars with similar storage roots length, but with wide variations in weight because of differences in their diameter.

However, the interaction between intensity and variety showed a non-significant effect, for the diameter. These results could be considered important as the increase or decrease of diameter in the storage roots is an attribute directly related to the production of storage roots (Lugojja, 2001). Radial diameter of storage roots is the main component of production and that the weight of storage roots were functions of its diameter (Shigwedha *et al.,* 2004). Therefore, in the current study, the effect of leaf harvest and frequency on growth yield and quality of sweet potato was observed. Hence, showed the importance of determine the roots and leaves yield and their influence in the production of storage roots. The statistical analysis for the effects of variety, had significant effect for the storage roots diameter. The effect of variety also showed very highly significantly effect, for the storage roots fresh weight. However, the interaction between percentage rate and variety showed a non-significant effect. Yield of our eperiment, under irrigation root yield obtained was less than 25 tons ha^{-1}. This results agree with other reports, the average yields of the sweet potato is 6 tons per hectare with wide yield variations of up to 25 tons ha^{-1} for sweet potatoes grown under irrigation for root production Mbwaga (2007). This difference among the varieties support findings by Kiozya *et al.* (2001) who found that reduction in root weight amounted about 33% for plants whose vines were harvested 45 days after planting, 25% for plants whose vines were harvested 75 days after planting and 15% for those whose vines were harvested 105 days after planting. Harvesting leaf at 4 week intervals and subsequently decreased root yields by 36.5 %. At 6 week intervals and subsequently decreased root yields by 33.7 % while at 8 week intervals and subsequently decreased root yields by 20.4 % compared to control.

There was an existence of a significant difference among the varieties in root yields, However, with Mataya at 6 and at 8 week intervals did not differ, but surpassed Africa's yield average of 6 t ha^{-1} and the global average yield of 14 t ha^{-1}, at 4 week intervals including Simama and Kiegea varieties in all intervals were below the global average yield of 14 t ha^{-1} (Mbwaga *et al.,* 2006; Ewell, 2002). Root production was very dependent upon variety and leaf harvesting percentage rate.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The present study has revealed that agronomic management of sweet potato crop should be chosen depending on the desired produce. If root production is desired, leaf harvesting should be kept to a minimum (≤ 50 %). If old leaves are fewer is to be harvested; harvesting up to 50 % mature leaves per crop vine maximizes leaf forage yields. The sweet potato crop tends to restore itself and continue yielding more leaves for subsequent harvests. Dual purpose sweet potato varieties can be maintained in a leaf harvest phase for a long time to provide forage leaves for ruminant animal throughout the year. Its adaptability to marginal conditions such as drought and low soil fertility, makes it rank high as a food and fodder security crop when local staple crops like maize and rice and grass are scarce.

From the current study when given as the sole food and feed to farmer and growing livestock, Mataya is better variety for farmers in Morogoro. Had found to be superior fresh sweet potato roots and leaf, in terms of high quantity supply of fresh root and forage. A farmer is advised to harvest Mataya leaves at an intensity not exceeding 50 % with 8 weeks interval.

The highest harvesting interval (4) with four harvests gave the highest total leaf DM production, compared to 6 or 8 with three harvests. The greatest advantage of many harvests is that forage can be supplied several times over the season without reducing total foliage production. This would be ideal particularly in places where consumption of forage is higher and relished more than consumption of roots, due to limited number of root marketing or recipes that utilize sweet potato roots.

6.2 Recommendations

The results of this study have shown that Mataya is the best variety in Morogoro region; following leaf harvest; Mataya variety showed better perfomance than the varieties Simama and Kiegea.

It is recommended that leaf harvest and frequency at 8 weeks interval with 50 % harvest intensity should each time be kept to a minimum; in order to optimize the root and forage yield for sweet potato.

It is recommended that further research be carried out in more than one season to confirm the consistence of results of dual purpose sweet potato varieties (Simama, Mataya and Kiegea) in Morogoro region; following leaf harvest intensity in order to come up with adaptable variety (ies) and leaf intensity (threshold), as to be able to recommend the best variety (ies) for root and forage production.

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