EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON PERFORMANCE OF SWEET POTATO (*Ipomoea batatas* (L.) LAM) VARIETIES IN NYANYA ABUJA, NIGERIA.

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M.Tech/SAAT/2018/7893

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FEDERAL UNIVERSITY OF TECHNOLOGY

MINNA, NIGERIA

JANUARY, 2022

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF DEGREE OF MASTER OF TECHNOLOGY IN CROP PRODUCTION.

JANUARY, 2022

ABSTRACT

Field trials were carried out in the 2019 and 2020 cropping seasons at the experimental station of the National Root Crops Research Institute Nyanya Out-Station to assess the effects of integrated nutrient management on the performance of sweet potato varieties in Nyanya, Nigeria as well as their residual effects on soil properties. Treatments consisted of factorial combinations inorganic (NPK) and Organic (poultry manure) fertilizer (Control, 400 kg ha^{-1} NPK, 3t ha^{-1}Poultry Manure (PM), 200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM, 300 kgha^{-1} NPK + 0.75 tha^{-1} PM,100 kgha^{-1} NPK + 2.25 t ha^{-1} PM) with two varieties of sweet potato (Butter milk and Umuspo1) laid in a Randomized Complete Block Design (RCBD) with three replications. Results indicated that the application of 200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM and 300 kg ha^{-1} NPK + 0.75 t ha^{-1} PM in 2019 and all the fertilizer applications in 2020 recorded highest establishment count than the control which had the lowest establishment count in both years. The application of 200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM consistently gave higher number of leaves and longer vines than the control which had the lowest in 2019 and 2020 respectively. Number of branches was highest with the application of 100 kg ha^{-1} NPK + 2.25 t ha^{-1} PM in 2019 and application of 3.0 t ha^{-1} PM in 2020 than the control which consistently recorded lower number of branches in both years. The application of sole and integrated fertilizer applications recorded significantly similar highest number of tubers and tuber yield (6.52 t ha^{-1}) and (11.0 t ha^{-1}) than the control which had the lowest (2.05 t ha^{-1}) and (2.25 t ha^{-1}) in 2019 and 2020 respectively. The application of 400 kg ha^{-1} NPK supported higher residual phosphorus and organic carbon content than the control which had the lowest. The application of 3.0 t ha^{-1} PM recorded higher residual total nitrogen content in the soil than the control which had the lowest nitrogen content in the soil. The variety Butter milk recorded increased growth, tuber yield and supported higher residual soil chemical properties than Umuspo 1 sweet potato variety. It is therefore recommended that farmers in this agro-ecological zone of Nigeria should apply 200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM and Butter milk variety for optimum growth and tuber yield of potato, applications of 400 kg ha^{-1} NPK and 3.0 t ha^{-1} PM for highest residual chemical properties in the soil of the study area.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Sweet potato (*Ipomoea batatas* (L.) Lam) is a perennial storage tuber crop usually grown as an annual and a starchy staple food crop in tropical, sub-tropical and frost-free temperate climatic zones of the world (Kivuva *et al.*, 2014). The crop is known for its resistance to drought, vigorous early growth and low input requirement. It also does well in areas of high rainfall and requires very little labor and care compared to other crops. Sweet potato is grown in several agro-ecological zones of Nigeria and usually plays a significant role in the farming and food sustainability systems of the country. It is commonly grown by farmers in complex and mixed cropping systems. Several varieties with different characteristics (yield, maturity, palatability, time to maturity, root size and shape, root color, storability in the ground, pest and disease tolerance, drought tolerance and sweetness) are grown in mixtures (Assefa *et al.*, 2007). As a food security crop, it can be harvested piecemeal as needed, thus offering a flexible source of food and income to rural households that are mostly vulnerable to crop failure and consequently fluctuating cash income. Sweet potato has several advantages within the context of Africa cropping systems. It produces food in a relatively short time, and gives a reliable yield in sub-optimal growth conditions. It requires lower labor inputs (appropriate for vulnerable households) than other staple, and serves as an alternative food source for urban populations facing increasing prices of cereals (Andreas *et al.*, 2009).

It ranks fifth as the most important food crop after rice, wheat, maize, cassava, in developing countries (Som, 2007). The potential of sweet potato to guarantee food security is under estimated as its use is often limited to a substitute food in Africa countries. Sweet potato is valued for its roots which are boiled, fried, baked or roasted for human consumption or boiled and fed to livestock as source of energy. The roots can also be processed into flour for bread making; starch for nodules and can be as well used as raw material for industrial starch and alcohol (Ukom *et al*., 2009). The flour is utilized also in sweetening local beverages like *kunu-zaki*, *burukutu*, and for fortifying baby foods and *fufu* /*pounded yam* in Nigeria (Tewe *et al*., 2003). The leaves are used as vegetables in yam and cocoyam porridge and are rich in proteins, vitamins and various minerals. Sweet potato roots are rich in vitamins A, B and C, and minerals such as K, Na, Cl, P and Ca.

The crop thrives in marginal soils but improved soil fertility increases its growth and yield performance. Manure encompasses the use of chicken dropping, cow-dung, wood ash and other plant and animal residues in soil. Use of organic fertilizer in the production of sweet potato and other food crops is on the increase (FAOSTAT,2011). Ojiako (2009) reported that sweet potato yield per hectare in Nigeria in 2009 in farmers' fields was approximately 3.0t/ha which is a significant decline from 11.73t/ha recorded between 1960 and 1970. This lowering yield per unit area could be attributed to inappropriate field management by farmers. While it is true that many sweet potato farmers still plant old land races with low productivity most sweet potato farmers through their associations have accessed improved cultivars from the National Root Crops Research Institute (NRCRI), Umudike. However, the production of these new sweet potato varieties developed under high inputs (fertilizer) system in a low input system resulted in little or no yield gain in farmer's field. Fertilizers are made to supplement soil nutrients inadequacy which presents a current problem amidst farmers. Plants do not know the differences between organic and inorganic fertilizer. For obvious reasons researchers advocate the use of combined organic and inorganic fertilizers for increased production. Organic manures and compost discharge their nourishing content only when they break down slowly through the intricate ecology of living organisms in the soil at that time they steadily discharge contents. Organic manure is known to be effective in maintenance of adequate supply of organic matter in soils with attendant improvements in soil physical and chemical conditions and enhanced crop performance (Ikpe and Powel, 2003; Ano and Agwu,2005). Sweet potato like any other root tuber crop is a heavy feeder exploiting greater volume of soil for nutrients and water (Osundare, 2004).

1.2 Statement of the Research Problem

Multiple nutrient deficiencies related to severe soil fertility depletion have emerged as the major constraints to the sustainability of agriculture on the global scale. The use of animal manure from different sources has been proposed asan option for improving soil fertility and restoring degraded land. Organic manure to soil is particularly important for tropical soils, which provides a better environment for roots and plant growth: this includes the improvement of soil structure and water holding capacity (Reed, 2007). Furthermore, a better soil texture and better root growth avoids soil degradation during heavy rains. Organic amendments also help in aeration, drainage, usable water holding capacity, nutrient holding capacity (Reed 2007; GIZ, 2010) So far, farmers in Nigeria, make use of animal manure such as cow-dung, poultry manure, goat droppings etc. Inadequate use of organic manure by farmers is as a result of non-availability and high cost to resources poor farmers. Also yields remain poor on account of low fertility status of the over-cropped soils and crop management. In recent times, the production rate of sweet potato has been on the decrease despite its numerous economic and nutritional values. Onunka *et al.* (2012) confirmed that yield of sweet potato is presently restricted by many factors among which are low soil fertility, varietal differences, planting date, weather conditions, soil type,weeds,insects, disease pressure and crop management practices among others.

The concept of integrated nutrient management utilizing all available organic and inorganic resources has become dominant for improved or increased yields in small holder agriculture system of Sub-Saharan African (SSA) to ensure both efficient and economic use of scarce nutrients resources (Vanluawe *et al*., 2001). Therefore, the use of organic manure to supplement inorganic fertilizer use, as an integrated management strategy, is of paramount importance to reducing the cost of soil mineral input, maximizing yields and sustaining sweet potato as well as other food crops production. [The differences in the use of varieties is attributed to the quality of the sweet potato varieties. Varieties of sweet potato could be of immense contribution in production, because of certain attributes that these varieties possess, high yielding, needs low amount of water put unit of food and energy (drought and other abiotic stresses) (Hijmans *et al.*, 2002)]. Sweet potato provides relatively good yields under poor inputs and marginal soil conditions, and also exhibits wide adaptability to climates, farming systems and uses (Jiang *et al.,* 2004)

1.3 Justification of the Study

Organic manure to soil is particularly important for maintenance of tropical soils. Despite the importance of sweet potato as a food crop, the productivity of these crops is becoming low mainly due to poor soil fertility of the most arable field. Fertilizer is one of the most important inputs either as organic or inorganic in increasing the productivity of crops (Ali *et al*., 2009). The role of organic fertilizer according to Lingga and Marsono (2007) is to improve soil structure, increase soil water absorption, improve the living conditions of soil micro-organism and also act as a source of nutrients for plant growth and development. In general, the application of organic fertilizer will increase some of the soil chemical properties and will also affect positively the physical properties of soil. Inorganic fertilizer when applied to crop usually has a quick release formula making nutrients rapidly available to plants. It is however costly and its long time adverse effect on soil chemical properties makes organic fertilizer being recommended for use, due to its environmental friendliness and its ability to supply both macro and micro nutrients to the soil (Negassa *et al*., 2001; Tirol-padre *et al*., 2007) and also improve physical and chemical properties of the soil. Low soil fertility and poor genotypes could be among the major production constraints for sweet potato crop (Ndunguru *et al*., 2009). Low soil fertility is the major production constraint in the tropics. Soils are 80 – 90% sand with low fertility (Nyadzi *et al*., 2003). They are mostly low in organic carbon, phosphorous, total nitrogen and cation exchange capacity (CEC) and pH 4-6 (Nyadzi *et al*., 2003; Majule *et al*., 2011). Low yield of sweet potato is caused by many factors, including the use of local varieties, which are susceptible to diseases and are of poor genetic traits. Sweet potato production also depends on genetic and environmental factors. The use of organic and inorganic fertilizer has become necessary for soil enrichment according to (Lingga and Marsono 2007). The role of organic fertilizer is to improve soil structure, increase soil water absorption, improve the living conditions of soil micro-organism and also act as a source of nutrients for plant growth and development. [The reason for using orange-fleshed sweet potato and butter milk varieties is to compare their productivity level and create awareness among farmers in the locality, as orange fleshed varieties are believed to be least expensive source of dietary vitamin A available to poor families (Stathers,2005; Laurie*et al*., 2013). It is estimated that over 95% of sweet potato produced in Nigeria are white or creamed fleshed (Chipungu, 2008). These varieties are low in beta-carotene content, vines and tuber yield (Chipungu *et al.*, 2009). One of the alternatives is the replacement of high-cost mineral fertilizers by plants and animal origin products that are available in the field. It is necessary to consider that global consumers are increasingly demanding products obtained from crops cultivated with less synthetic fertilizers (Kikuchi-Uehara *et al*.,2016; Khan and Moshin,2017).

1.4 Aim and Objectives of the Study

The aim of the study was to identify appropriate rates of combined inorganic and organic fertilizer that will increase the production of sweet potato varieties.

The objectives were to determine:

i. the effect of NPK fertilizer and poultry manure amendments on growth and yield of two sweet potato varieties.

ii. the residual effects of NPK fertilizer and poultry manure on growth and yield of two sweet potato varieties and some soil properties.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Botanical Description of Sweet Potato

The sweet potato (*Ipomoea batatas* (L.) Lam) is an herbaceous dicotyledonous plant that belongs to the family Convolvulaceae. It is a perennial vine that is usually grown as an annual through any of its vegetative parts which could either be root or stem cuttings. Sweet potato is characterized by a long edible tuberous root tapered with a smooth skin whose color ranges between yellow, orange, red, purple and beige. It bears alternate heart-shaped or palmately lobed leaves with medium-sized sympetalous flowers. Sweet potato is a short duration crop that is adaptable to a wide range of growing conditions. It exhibits no strict seasonality, making it suitably combined with other crops in a mixed cropping system (Pandey, 2007).

There are several varieties of sweet potatoes with varying and dynamic growth habits. Generally, the growth habit of many sweet potatoes are predominately prostrate with a vine system that rapidly expands horizontally on the ground, though some are erect, semi-erect, spreading and very spreading. The most dominant forms have twining and trailing long stems of slender to moderate thickness with leaves that are moderately or widely spaced.

2.2 Production and Distribution of Sweet Potato

Sweet Potato (*Ipomoea batatas* (L) Lam) ranks the fourth most important food crop in Nigeria after yam, cassava and cocoyam in terms of production and hectarage. It is a staple food for many developing countries (FAO, 2008). In Nigeria, about 3.4 metric tons of sweet potatoes are produced annually (FAO, 2012). Sweet potato is grown in several Agro-ecological zones of Nigeria and usually plays a significant role in the farming and food sustainability systems of the country.

Tanzania is the second largest producer of sweet potato in east Africa (after Uganda) with an annual production of just 1,000,000 million tons (URT, 2011). In India, sweet potato area, production and productivity were 0.11 million hectares,1.45 million tons and 13.06 tons per hectare, respectively. In Argentina, Venezuela, Puerto Rico and Dominican Republic sweet potato is called batatas. In Mexico, Peru, Chile, central America and the Philippines, the sweet potato is known as camote (alternatively spelled kamote in the Philippines, sweet potatoes became a staple in japan because they were important in preventing famine when rice harvests were poor.

2.3 Soil and Climatic Requirement of Sweet Potato

Sweet potato requires moderate temperature (21-26^{o}C) hence it is planted and harvested every month in one part or other in the world, temperatures above 37.9^{o}C slow down growth of sweet potato (Hartemink *et al.*, 2003). A well distributed rainfall of 750-1000mm is sufficient for its cultivation. Sweet potato requires plenty of sunshine, but shade causes yield reduction. However, Sweet potato is intercropped with other seasonal crops like pigeon pea, maize etc. (Nedunchezhiyan *et al.*,2010) and also grown as intercrop under plantation/orchard crops with the aim of crop intensification and profit maximization (Nedunchezhiyan *et al.*, 2007). Sweet potato can tolerate drought to some extent but cannot withstand logging, too shallow or stony soils, poorly aerated and bulky soils retard tuber formation and reduced yields (Nedunchezhiyan and Ray, 2010). Yields are drastically reduced if drought occurs in the first 6 weeks after planting and also during root formation and development well drained loam and clay loam soil are good for sweet potato cultivation. However, sandy loam with clay subsoil is ideal. Heavy clayey soil restricts the storage root development due to compactness whereas, sandy soils encourages long cylindrical pencil like roots (Nedunchezhiyan and Ray, 2010). Sweet potato is mostly grown in acidic soils however, soil pH of 5.5-6.5 is found to be optimum. High soil pH invites pox and scurf diseases in sweet potato, whereas at low pH sweet potato suffers from aluminum toxicity (Nedunchezhiyan and Ray, 2010). Sweet potato is also sensitive to saline and alkaline conditions (Dasgupta *et al*., 2006; Mukherjee *et al*., 2006). Too high fertility may result in excessive vegetative growth at the expense of tuber and starch formation. The crop is sensitive to drought at the tuber initiation stage 50-60 days after planting and it is not tolerant to water-logging, as it may cause tuber rots and reduce growth of storage roots if aeration is poor, depending on the cultivar and conditions, tuberous roots mature in two to nine months with care, early maturing cultivars can be grown as an annual crop in temperate areas. Sweet potato rarely flowers when the daylight is longer than 11hours, as is normal outside of the tropics. They are mostly propagated by stem or root cuttings or by adventitious shoots called "slips" that grow out from the tuberous roots during storage. It is important to select high quality planting materials to ensure the production of a good crop. Sweet potato can be propagated in a variety of ways; tissue culture, sprouting, vine cuttings and seeds. Vine cuttings and sprouts and, to a lesser extent, tissue culture are the most commonly used propagules. True seeds are used for breeding only. Sweet potato grows well in many farming conditions and have few natural enemies; pesticides are rarely needed. Traditionally, many growers utilize the cuttings from the previous crop to establish new cultivations of sweet potato. As with most vegetative propagated crops the quality of the planting material impacts growth and resultant yield. It is critical in the establishment of new cultivations that high quality planting material be used. Generally, vine cuttings/slips ranging in length from 30cm to 40cm should be planted. The apical region of the plant should be used as it is more likely to be free of pest infestations and it gives better yields than cuttings from the middle or base of the plant. The implement to be used to cut the vine should be sharp and clean. The lower leaves of the vines/slips should be cut as tearing may damage the nodes that could eventually produce roots. Sweet potatoes are relatively easy to plant, because the rapidly growing vines shade out weeds, little weeding is required. When vine cuttings/slips cannot be planted immediately, they can be stored under damp/shaded conditions for up to 7 days, if the vine cuttings are being stored the majority of leaves should be removed with only a few leaves being left at the tip. The cuttings should be tied in a bundle and the cut ends covered at the base with a damp cloth, during this period, roots will begin to grow at the nodes and the cuttings will become more resistant to the "shock" of planting. Under rain fed conditions, it is best to plant sweet potatoes early in the rainy season so that establishment can take place quickly. In areas, where the rainy season is prolonged, planting may be timed so that the crop matures just as the rainfall begins to decline. Vine cuttings should be planted at about 45^{o} angle, as this promotes even root development. Half of the cutting or three to four nodes should be buried at a spacing of 25-30 cm. The sweet potato plant has three growth phases which are more or less distinct. The initial phase is characterized by slow vine growth and rapid growth of adventitious roots. The first 20 days of this initial phase are important as they determine the total number of storage roots formed. An intermediate phase follows where there is the rapid growth of vines and an increase in leaf area as well as storage root initiation. By 100 days after planting (DAP), the leaf area is at its maximum and any further increase in biomass is due to storage root formation. The deposition of starch within storage roots can occur as early as 8 DAP and storage root formation can be visible as early as 28 DAP. By 49 DAP 80 % of the storage roots can be identified. At the final stage there is bulking of the storage roots, which can reach a maximum after 90 days. Storage roots enlarge throughout the life of the plant but after 120 days' enlargement peaks. It should be noted that most of the growth phases are controlled genetically (variety) and environmentally (Agro-ecological conditions of the area) where the crop is planted.

2.4 Nutritional Importance of Sweet Potato

Sweet potato (*Ipomoea batatas* (L.) Lam) is a vegetable used as human diet component. It is a source of mineral, vitamins, some hormones precursors, proteins and energy. Its leaves are used to accompany the dishes of yam and cocoyam in some parts of Nigeria, namely among the Efik-Ibibio people of south-Eastern Nigeria (Anita *et al*., 2006). It also contains chlorogenic acid, a phenolic compound responsible for suppressing obesity in humans (Williams *et al*., 2013). The vines can be used in feeding goat and cattle and contains protein and minerals required in the livestock feeding diet (Kebede *et al*., 2008; EPAR, 2012). Recent studies found that animals that are fed sweet potato vines actually produce less methane gas than animals given other types of feed, suggesting that sweet potato animals feed can help contribute to reducing global emissions Sweet potato vines have crude protein contents ranging from 16 to 29 % on dry matter basis which is comparable to leguminous forage (An *et al*., 2003). Feeding the vines to cows as a supplement to basal

diet of other forage increases milk yield (Etela *et al.,* 2008). The tuberous roots are used a s food by human whereas the vines are used as supplementary feeds for goats (Getachew *et al*., 2000; Tesfaye *et al*., 2008). Sweet potato varieties meant for both fodder and food (tuberous roots) allow a low number of toppings which enable spreading of fodder availability over the years without significantly affecting tuberous root yields (Leon-velarde, 2000). Increasing recognition of the potential of sweet potato crop as a nutritious food for humans and animals has resulted in intensified research efforts to enhance its production and consumption. In recent decades (Yamakawa and Yoshimoto, 2002) previous research showed that vine harvesting of sweet potato reduced the yield of tuberous roots (Kiozya *et al*., 2001; An *et al*., 2003). Age at harvest is an important management factor that affects sweet potato fodder and tuberous root yield as well as quality (An *et al*., 2003). Sweet potato is also processed industrially into fried snacks like sweet potato fries (chips), candy, starch, noodles, flour and crisps and can also be exploited for ethanol and bio-fuel production (EPAR, 2012).

In Sub–Saharan Africa, vegetable are necessary dietary components for soup or sauces that accompany carbohydrates. It tuber crops provide carbohydrates while it’s leaves are major sources of vitamins, dietary fibers, essential amino acids and antioxidants (Fasuyi, 2006; Nkongho *et al*., 2014) because sweet potato tops can be harvested several as nutritional consumption of orange fleshed sweet potato a year, their annual yield is much higher than many other vegetables and available on low cost. The content of these nutrient differs according to harvesting period and variety, oxalic acid poses a problem when using sweet potato leaves as food, but its content does not change greatly according to the harvesting time and is less than one fifth that of spinach. Tewe *et al*. (2003) reported that in some part in Nigeria, sweet potato leaves were preferred as soup ingredient in terms of flavor, appearance, palatability, softness and acceptability. Ishida *et al*. (2000) studied two kinds of sweet potatoes and reported that the leaves contained high amount of protein (3.8 and 3.7g $100g^{-1}$), total dietary fiber (5.9 and 6.9g $100g^{-1}$) and ash (1.9 and 1.5g $100g^{-1}$) Potato has been highlighted such as carbohydrate, protein, vitamins and minerals and a good source of energy. Emphasis was more on vitamin A which makes our body strong and healthy. Consumption of orange fleshed will boast our body immunity due to its vitamin A content, it also improves our eye sight and reduces diseases such as malaria, measles, chicken pox and small pox and reduces mortality in children (Kapinga *et al*., 2009). Emerging health benefits of the OFSP are substantial, making it an even more important food-especially for populations in danger of malnutrition (Away *et al*., 2013; Kaspar *et al*., 2017).

Several improved sweet potato varieties have been developed, which gain their importance through the provision of carbohydrate, protein, vitamins (Gibson, 2006). It also contains good quantities of vitamin A, vitamin B, calcium and iron (Helen Keller International Tanzania, 2012). It is often a good source of the secondary elements, and micronutrients necessary for plant growth and contributes a modest quantity of the primary nutrients (N, P and K) requirements (Onunka *et al*., 2012). The major economic part of this plant is starchy tuberous roots (Anita *et al*., 2006). It is the cheapest source of calories. It produces highest food calories among the roots and tuber crops. Sweet potato is also used to feed livestock's. Sweet potato roots can be included in pullet chick diet up to 25 kg per 100 kg of diet, while sweet potato tops can replace wheat offal to a level of 50 % or 9.20 kg per 100 kg of diet (Akoroda, 2003) Sweet potato is high in nutritional value, with the exception of protein and niacin. It provides over 90 % of nutrients per calorie required for most people. The main nutritional material in sweet potato's tubers are carbohydrates (starches and simple sugars), protein, fats and fat soluble vitamins. Moreover, cultivars with a yellow flesh also contain significant amount of carotene (Allen *et al*., 2012). Maloney *et al*. (2012) pointed out that potentially valuable proteins can be extracted from the peel during the processing of sweet potatoes. Sweet potato is used in the treatment of tumors of the mouth and throat, decoctions of the leaves can be used as an aphrodisiac, astringent, laxative, energizer, bactericide and fungicidal agents, sweet potato has also been found to be beneficial in treating asthma, bug bites, burns, and catarrh. Sweet potato tubers have anti-diabetic, anti-oxidant and anti-proliferative properties due to the presence of valuable nutritional and mineral components (Jaarsveld *et al*., 2005; Abubakar *et al*., 2010). Tubers are used in starch and industrial alcohol production. In south America, the juice of red sweet potatoes is combined with lime juice in varying proportions to make a dye for cloth (pink to black) The crop sweet potato protects cigarette smokers from emphysema, it also alleviates muscle cramps due to their high potassium content, it contains magnesium, a crucial mineral which promotes relaxation, calmness, mood and nerve health. Furthermore, sweet potato tubers which are steady item in the American's diet, appear to be very beneficial in the diet of diabetics and consumers with an insulin resistance, because they have a low glycemic index (Ludvik *et al.*,2004; Allen *et al*., 2012). Knowledge of the glycemic index (GI) diet for diabetes may help to predict their daily diet in order to control a blood glucose level. The cultivation of these vegetables as raw material with excellent nutritional values, mainly for the food and pharmaceutical industries. Sweet potato gives high amount of energy per unit area per unit time and is expected to bridge the food shortages and malnutrition. The comparative short duration coupled with its innate power for tremendous dry matter production has enabled sweet potato to rank as the foremost root crop. Sweet potato varieties exist in many colors of skin and flesh, ranging from white to deep purple, although white and yellow, orange flesh are the most common (Adam, 2005). The sweet potato varieties commonly grown by farmers in southern guinea savanna zone of Nigeria are characterized with low yields (3000-9000 kg/ha) (BNARDA, 2007). The nutritional value of sweet potato, like most crops, depends greatly on climatic and soil conditions (Away *et al*., 2013; Kidmos *et al*., 2007). Variations are also present between and within varieties depending on the stage of maturity and growing conditions.

All sweet potatoes contain important vitamins and minerals, especially vitamins C, B6, folic acid, potassium and manganese. The orange-fleshed sweet potato in particular is an important source of beta carotene, a precursor to vitamin A (Stather *et al*., 2013). It is the only starchy staple, which contains appreciable amounts of b-carotene, ascorbic acid and amino acid, lysine which is deficient in cereals-based diets. Jaarsveld *et al*. (2005) observed that the incorporation of beta-carotene sources, mainly orange-fleshed sweet potato into the meal significantly increased serum retinol concentration. Researchers in North Carolina, Louisiana, Mississippi, California, Texas and Alabama are contributing to the value of sweet potato by finding new uses. Sweet potato has many uses in addition to that of food crop. It is also an important industrial raw material for producing starch, sugar and alcohol. The leaves of sweet potato are a physiologically functional food that offers protection from diseases linked to oxidation such as cancer, allergies, aging, HIV, and cardiovascular problems (Islam, 2006).

2.5 Effects of Organic Manure on Soil Quality and Performance of Sweet Potato

Plant nutrients are essential for the production of qualitative crops that provide healthy food for world expanding population. Plant nutrients are therefore, a vital component for sustainable agriculture. Increase in crop production largely relies on the type of fertilizer used to supplement essential nutrients for plants and ensuring soils rarely have sufficient nutrient for crops to reach their potential yield. Applying organic fertilizers without prior knowledge of their properties may cause yield decline under low application or pollute the environment with excessive application. Understanding the nutrient variability and release pattern of organic fertilizers is crucial to supply plants with sufficient nutrients to achieve optimum productivity, while also rebuilding soil fertility and ensuring protection of environmental and natural resources. In an effort to reduce over and under application as well as establishing an appropriate rate of fertilizer that will enhance both nutrient availability to plant and soil. In recent times, the production rate of sweet potato has been on the decrease despite its numerous economic and nutritional values. This decrease in production of sweet potato has been traced to the poor nutrient status of the soil where the crop is grown. High rainfall, crop removal, rapid mineralization of SOM and excessive cultivation of land due to increase in human population are responsible for this decrease. In the past decades, intensive use of chemical fertilizer was advocated for crop production in the tropics in order to alleviate these nutrient deficiencies (Anonymous, 2000). Presently the use of chemical fertilizers as soil amendment has become cost intensive and beyond the reach of peasant farmers. In view of these problems, the use of organic manure as a substitute for chemical fertilizers or in combination with chemical fertilizers at a reduced rate has become vital especially in this era of organic agriculture that reduces the negative effect of chemical fertilizers on climate change.

The sustainable productivity of agricultural systems is needed for the level of soil organic matter and the optimization of nutrient cycling to be maintained (Odendo *et al*., 2004; Khan *et al*., 2013). Organic manure can be used to replace mineral fertilizer (Togun and Akanbi, 2003;Naeem *et al*., 2006) in order to enhance soil structure (Dauda *et al*., 2008) microbial biomass (Suresh *et al*., 2004). Hence, the use of manures produced by vegetables may improve crop yield and reduce the use of chemical fertilizers.

Farmers participation in the advanced stages of sweet potato variety selection has been reported to be successful in Ethiopia, Kenya and Uganda (Ndolo *et al*., 2001; Abidin, 2004; Laurie and Faber, 2008). Sweet potato contributes highly to the diet of many people in the tropics, but its production is seriously affected by poor soil fertility. The use of poultry manure as an organic amendment to restore worn–out soils can thus be encouraged (Sanchez-Monedero *et al*., 2004). The green manure such as *Eichhornia Crassipes* can also be used to replace soil nitrogen and other elements, and to build up soil organic matter content (Hammad *et al*., 2011; Wamba *et al*., 2012).

Physical and chemical properties of soil such as water retention, erodibility, cation exchange capacity and nutrients availability are affected by their organic matter amount (Rice, 2002; Deksissa *et al*., 2008). Moreover, these systems are beneficial for the overall health Agro-environment, development and management of effective fertilization practices like the manipulation of the quantity and type of organic amendments, thus improving soil ecosystems and fertility (Nzguheba *et al*., 2004; Manqiang *et al*., 2009).

The productivity of these crops is becoming low mainly due to poor soil fertility of the most arable field. Fertilizer is one of the most important inputs either as organic or inorganic of increasing the productivity of crops (Ali *et al*., 2009). Leytem and Wester Mann (2005) reported the important effects of fertilizer on the yield of potatoes. Although inorganic fertilizer when applied to crop usually has a quick release formula making nutrients rapidly available to plants, but because of the high cost and its long time adverse effect on soil chemical properties, organic fertilizer is recommended for use, organic fertilizer is environmentally friendly and it supplies both macro and micro nutrients to the soil (Negassa *et al*., 2001; Tirol-padre *et al*., 2007) and also improves the physio-chemical properties of the soil. There is growing concerns about soil health and productivity and contamination of food and the environment, due to the increased consumption of chemical fertilizers. Organic production technologies are adopted with a main objective of producing safe food and maintaining a pollution free environment. The interest in organic agriculture is increasing rapidly and its market is growing not only in developed countries but in many other developing countries also; but organic farming does not hold good for all crops in all situation, tuber crops in general are very much suited for organic production system. Sweet potato removes appreciable quantities of plant nutrients, hence incorporation of considerable amount of organic manure at the time of planting is recommended to main soil productivity. Application of manures has significant impact on growth and root yield of sweet potato (Salawu and Mukhtar, 2008) used as organic manure for sweet potato (Kaggwa *et al*., 2006). Sweet potato grown in fertile soils generally do not reduce dressing of organic manure while soils low in organic matter content have to be supplied with organic manure at 5 to 10 tons ha^{-1} to ensure proper development of storage root (Nedunchezhiyan and Reddy, 2004). Application of green manure(legume)is found to be an alternative to farmyard manure (Kaggwa *et al*., 2006). On unit nitrogen basis pig manure, cow-dung and poultry manure are equally effective sources of organic manure (Nedunchezhiyan, 2001). Various research results indicated that application of N increased the root yield (George and Mitra 2001; Satapathy *et al*., 2005). However, high amount of N application encourages vine growth rather than storage root development. Yield of crops has been significantly affected by adding organic manure. Plants grow better in soils amended with organic manure (Ouda and Mahadeen, 2008). According to their research, organic manure seemed to be less effective in increasing the yield of crops than inorganic fertilizer. Organic manure could be used to produce crops with similar or better growth or yields than crops grown from the use of inorganic fertilizers (Russo, 2005; Treadwell *et al*., 2007; Zhao *et al*., 2009). It has also been observed that the effect of organic manures on plant growth seem varied and some studies showed decreased plant growth or yields when using organic fertilizers compared with conventional fertilizers (Peet *et al*., 2004). This variation could be the result of the differences in organic fertilizer source being used and application rates and timing (Rossen and Allan, 2007). Excessive organic manure depresses plant growth compared with lower fertility levels (Carpio *et al.*, 2005; Kelley and Biernabaum, 2000).

Organic manure significantly enhances growth and yield of crops. The use of organic manure enhances fertilizer use efficiency of crops (Muneshwar *et al.*, 2001; Nevens and Reheul, 2003). Growth promoting substances like enzymes and hormones present in organic manures make them useful for improvement of soil fertility and productivity (Singh *et al*., 2008). Sanwal *et al*. (2007) observed that application of organic manure produces high and sustainable crop yields. Attarade *et al.* (2012) also reported that organic manure increase can enhance the nutrient status of fruits.

However, it was revealed that animal manure is useful in improving the efficiency of fertilizer recovery thereby resulting in higher crop yield (Gedam *et al.*, 2008). Bayu *et al*. (2006) also reported the possibility of saving up to 50 % of the recommended NP fertilizers due to amendment with 5-15 t/ha of farmyard manure to sorghum crop without significantly affecting the optimum possible yield that can be obtained with the application of full dose of inorganic NP fertilizer alone. The results of an experiment conducted by Ambecha (2001) showed that sweet potato fresh weight is highly responsive to increase levels of farmyard manure. According to his results, as the rate of farmyard manure increased, the development of green top at the expense of production of tuberous root yields was promoted. Also, Tesfaye *et al.* (2008) observed that if sweet potato is produced for livestock feed, application of the maximum farmyard manure helps for better fresh foliage production since increasing farmyard manure application and foliage development are positively correlated. The effect of farmyard manure on average vine length was reported to be statistically significant (Teshome *et al.,* 2012). However, Parwada *et al.* (2011) in an experiment found insignificant root counts per plant of sweet potato in response to poultry manure applied at planting.

Najm *et al.* (2010) found a highly significant vine development of potato in response to application of cattle manure. According to Halvin *et al.* (2003), the increase in vine length in response to increase rate of farmyard manure may be ascribed to increase availability of nutrients in the soil for uptake by plant roots that may have enhanced vegetative growth through increasing cell division and elongation. It has also been noticed that plants grown in soils amended with organic fertilizer shows vigorous vegetative growth and high yield comparing with application of chemical fertilizer alone.

2.6 Effects of NPK on Soil Quality and Performance of Sweet Potato

Plant nutrients are essential for the production of quality crops. Plant nutrients are a vital component of sustainable agriculture: increase in crop production relies on the type of fertilizer used to supplement essential nutrients for plant growth. Intensive use of chemical fertilizers was advocated for crop production in the tropics in order to alleviate these nutrient deficiencies (Anonymous, 2000). A major constraint to crop production in Nigeria savanna zone is nitrogen and phosphorus nutrient deficiencies (Osunde *et al.*, 2003). The yield of sweet potato like other crops is influenced by climatic, biological and soil factors (Udo *et al*., 2005;NRCRI, 2008). Among the soil factors fertility is the most important for sweet potato production. Inorganic fertilizers are used in modern agriculture to correct known plant-nutrient deficiencies: to provide high levels of nutrition, which aid plants in withstanding stress conditions; to maintain optimum soil fertility conditions and to improve crop quality. Adequate fertilization programs supply the amounts of plant nutrients needed to sustain maximum net returns. NPK fertilizers play key roles in the vegetative growth and yield development of crops. Nitrogen stimulates the plant growth and essentially needed for root development of the plant (Dan, 2010). A moderate dose of 50-75 kg N ha^{-1} is optimum for root production in sweet potato (Sebastiani *et al*., 2006; Biswal, 2008) of fertilizer N and any of the organic manure to supply 50 % each of recommended N produced the maximum vine and storage root yield compared to other N management practices (Nedunchezhiyan and Reddy, 2002). Inoculation of Azospirillum (free-living N2-fixing bio-fertilizer) is also found in storage root yield quality (Saikia and Borah, 2007;Nedunchezhiyan *et al.*, 2004) and soil fertility status in sweet potato field. Potato is found to be influenced by nitrogen application (Nedunchezhiyan and Ray, 2010). Continuous use of fertilizer N may, in some situation have detrimental effects on root quality. Sweet potato scarcely reacts to the mineral fertilization carried out during the harvest year. It should be planted in rotation with more demanding cultures such as green vegetables, to take advantage of the residual effect of the previous fertilization. Production can improve with the use of organic or green fertilizer (Soares *et al.*, 2002). Therefore, use of organic source of N is essential to improve the quality characters. However, in the present day situation, per ha yield of starch, vitamin C, β-caroteneare more important than percentage content. Nedunchezhiyan *et al.* (2003) noticed discernible variation in the quality characters due to different sources of N and their combinations. Sweet potato's response to phosphorus (P) is very low. A dose of 25 – 50kg P_2O_5 is considered optimum for sweet potato (Mohanty *et al*., 2005; Akinrinde, 2006; Sebastiani *et al.*, 2006). The relative efficiency of rock phosphate as source of P to sweet potato was equal to single superphosphate in direct effect but superior to it in residual value. While phosphorus is an essential nutrient that stimulates root development, increase stem strength, improved flower formation and tuber/seed production (Bill, 2010). Potassium (K) is a major key element essential in the synthesis and translocation of carbohydrates from the tops to the roots (Byju and Nedunchezhiyan, 2004). A moderate dose of 75-100 kg k_2O is recommended for sweet potato Similarly, potassium is one of sixteen essential nutrients required for plant growth and reproduction. Potassiumplays a vital role in photosynthesis, translocation of photosynthates, protein synthesis, control ionic balance, regulation of plant stomata and water use, activation of plant enzymes and many other processes (Bob, 2010).

Soil fertilization is one of the main factors increasing the yield of plants (Kolodzie, 2006). The amount of fertilizers introduced into the soil, including mineral fertilizers affects the amount of mineral nitrogen available to the plant and the organic carbon content of the soil. Inorganic fertilization improves light textured soil physical properties and water. Fertilization not only increases crop yield but also alter its quality and results in the higher buildup of nutrients in the yield. Crop yield and mineral fertilizer efficacy depend on the content of available phosphorus, potassium and nitrogen in the soil. It has been found that nutrient present in fertilizers are more effective than the equivalent amount of these nutrient present in Farmyard Manure (FYM). Depending on fertilizer forms, rates and nutrients ratios, the content of dry matter, starch, protein and other substance may either increase or decrease. Excessive nitrogen application reduces starch, dry matter and sugar contents in tubers and go bad more rapidly. Nitrogen promotes growth of potato vines and over the years the use of fertilizer application at different level has improved agriculture. Therefore, inorganic fertilizer is considered a major source of plant nutrients. Yield of crops are significantly affected by adding inorganic fertilizers (Adediran *et al*., 2004). According to Sanwal *et al*. (2007), Nitrogen, phosphorus and potassium influence vegetative and reproductive phase of plant growth. Replenishment has depended largely on the addition of inorganic fertilizers which rank first among the external inputs to maximize output in agriculture but in turns, contributes substantially to environmental pollution.

2.7 Effects of Integrating NPK Fertilizer and Organic Manure on Soil Quality and Performance of Sweet Potato

Integrated plant nutrition involving the combined use of organic and inorganic fertilizers increases crop yields more than either used alone (Quansah, 2000). Integrated plant nutrient system (IPNS) emphasizes the need to develop fertilizer management practices for maintenance of proper soil health. The basic concept underlying the IPNS is to provide an ideal nutrition for a crop through a proper combination of various nutrient resources and their optimum utilization along with maintenance of soil productivity. Soil fertility replenishment for sustaining crop productivity should use all possible sources of plant nutrients in an integrated manner. Integrated nutrient management implies the maintenance or adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop productivity on one hand and to minimize nutrient losses to the environment on the other hand. It is achieved through efficient management of all soil nutrient sources. Nutrient sources to a crop growing on a soil include soil minerals and decomposing soil organic matter, mineral and synthetic fertilizers, animal manure and plant composts, plant residues and biological N-fixation (Singh *et al.*, 2002) for sustainable crop production, integrated use of inorganic and organic fertilizer has to be highly beneficial. Several researches have demonstrated the beneficial effect of combined use of inorganic and organic fertilizer to mitigate the deficiency of many secondary and micronutrients in fields that continuously received only N, P and K fertilizers for a few years, without any micronutrients or organic fertilizer. A field experiment was conducted by (Chand *et al*., 2006) for seven years continuously to evaluate the influence of combined applications of organic and chemical fertility build-up and nutrient uptake in mint (*Mentha arvensis*). Based on the evaluation of soil quality indicators, Dutta *et al.* (2003) reported that the use of organic fertilizers, together with inorganic fertilizer, compared to the addition of organic fertilizers alone, had an effect on microbial biomass and hence soil health. Application of organic manure in combination with inorganic fertilizer has been reported to increase absorption of N, P and K in sugar leaf tissue in the plant and ratoon crop, compared to inorganic fertilizer alone (Bokhtiar and Sakurai, 2005). Kaur *et al*. (2005) compared the change of chemical and biological properties of soil receiving farm yard manure and poultry manure. Increase in microbial biomass C and N was observed in soils receiving organic manures only or with the combined application of organic manure and inorganic fertilizers compared to soils receiving inorganic fertilizer. Studies have shown that balanced fertilization using both organic and inorganic fertilizers is important for maintenance of Soil Organic Matter (SOM) content and long-term soil productivity in the tropics where soil organic matter is low. The effects of organic fertilization and combined use of inorganic and organic fertilizer on crop growth and soil fertility depends on the application rates and the nature of fertilizer used. In general, the application rates of organic fertilizer mostly are based on crop nitrogen need and estimated rates of organic fertilizer N supply, but do not consider the amount of P and K provided with organic fertilizer.

However, the nitrogen to phosphorus ratio of organic fertilizer usually is significantly lower than the nitrogen, phosphorus uptake ratio of the crop. Therefore, basing organic fertilizer on nitrogen supply typically results in phosphorus addition in excess of the crop's needs.

2.8 Residual Effect of NPK and Organic Manure on the Performance of Sweet Potato

When farming is continued on the same field for several years, residual effects of fertilizer treatment may considerably affect the soil chemical properties and also crop yield. Studies shows that previous manuring with animal manure and inorganic fertilizers keeps residues of nitrogen, phosphorus and potassium in soil that benefits the following crops. The residues of inorganic fertilizer usually last only for a season, but the residual effects of continuous manuring with phosphorus and potassium may last for many years. Akande *et al.* (2003) reported an increase in soil available P of between 112 and 115 % and 144 and 153% respectively for a two-year field trial, after applying rock phosphate with poultry manure on okra. Residual effects of organic manure on soil properties can contribute to improvement in soil quality for several years after residual effect of organic matter added to the soil by the manure refers to carry over benefit of the application on succeeding crop. Nutrient present in organic matter are not fully available to the crops in the season of its application.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Site

Field trials were carried out at the experimental site of the National Root Crops Research Institute, Nyanya Abuja, (Latitude 906°.733° E and Longitude 7.62 318°N) during the 2019 and 2020 rainy seasons. Nyanya is located in the Southern Guinea Savanna ecological zone of Nigeria. The mean annual rainfall of the location in the 2019 raining season was 1,404 mm, with mean annual temperature of 26.74 °C, while during the rainy season in 2020 annual rainfall was 1,449mm with mean annual temperature of 30.08°C

3.2 Sources of Experimental Materials

Two varieties of sweet potato (Butter milk and Umuspo 1) were collected from the National Root Crops Research Institute (NRCRI) Nyanya Out–Station. Cured poultry manure was sourced from Ojay Royal farms limited Nyanya Maraba, NPK 15-15-15 was also sourced from National Root Crops Research Institute, Nyanya Out-Station. Umuspo 1 also known as King-J is a semi-erect plant with thick vine very vigorous growth, leaves are triangular in shape with very sparse flowering habit. It is orange-fleshed in color with high dry matter and is high yielding. It is widely adapted across agro-ecologies from the humid forest in Southern Nigeria to the Northern Guinea Savanna of Nigeria. Days to maturity is 3-4 months after planting, with an average root yield of 35-40 t ha^{-1} (Afuape, 2014). Butter milk is a spreading plant type with green thin vines, the leaves are triangular in shape and it is widely adapted across agro-ecologies within the Southern Guinea savannah to the Northern Guinea Savannah of Nigeria. Days to maturity is 3-4 months after planting.

3.3 Treatments and Experimental Design

The treatment consisted of factorial combination of sole and combined inorganic (NPK 15:15:15) and Organic (poultry manure) fertilizer (Control, 400 kg ha^{-1} NPK, 3 tha^{-1} Poultry Manure (PM), 200 kg ha^{-1} NPK + 1.5 tha^{-1} PM, 300 $kgha^{-1}$ NPK + 0.75 tha^{-1} PM, 100 $kgha^{-1}$NPK + 2.25 tha^{-1} PM) and two sweet potato varieties (Butter milk and Umuspo1). Arranged in a Randomized Complete Block Design (RCBD) with three replicates are shown in Table 3.1

3.4 Agronomic Practices.

3.4.1 Land preparation

The land was cleared manually, then ploughed using a tractor; ridges were constructed with hoe. Gross plot size was 2 m x 2 m (4 m^2) having 12 plots in each replication with an inter row spacing of 1m, total experimental land area was 41 m × 8 m (328 m^2).

3.4.2 Fertilizer application and planting

Poultry manure was applied to the field by incorporating it into the soil at 2 weeks before planting using hoe. Sweet potato vines of 25 cm length with 2-4 nodes were planted 2 weeks after incorporating the manure. The potato vines were planted at a spacing of 30 cm intra row. NPK 15:15:15 fertilizer was applied at 4weeks after planting (WAP) in 2019 and planting was done in 2020 without the treatment application for the residual effects. First planting was done 9th August,2019, while the second planting was carried out on 14th June,2020.

3.4.3 Weeding

Manual weeding was done at intervals of 3 Weeks After Planting (WAP). Weeding was carried out twice (2) times. Herbicide was applied before planting using 15 liters of water with 250 mils in a knapsack and then sprayed as blanket application.

Table 3.1: Treatment Combinations of organic and inorganic fertilizer with sweet potato varieties

S/No	Treatment Combinations
1	Control + Butter milk (variety 1)
2	400 kg ha^{-1} NPK+ Butter milk
3	3 t ha^{-1}PM+ Butter milk
4	200 kg ha^{-1} NPK+ 1.5 t ha^{-1}PM+ Butter milk
5	300 kg ha^{-1} NPK+ 0.75 t ha^{-1}PM+ Butter milk
6	100 kg ha^{-1} NPK+ 2.25 t ha^{-1}PM + Butter milk
7	Control + Umuspo1 (variety 2)
8	400 kg ha^{-1} NPK+ Umuspo1
9	3 t ha^{-1}PM+ Umuspo1
10	200 kg ha^{-1} NPK+ 1.5 t ha^{-1}PM + Umuspo1
11	300 kg ha^{-1} NPK+ 0.75 t ha^{-1}PM + Umuspo1
12	100 kg ha^{-1} NPK+ 2.25 t ha^{-1}PM + Umuspo1

PM- poultry manure

3.5 Soil Sampling and Analysis

The soil was sampled from the field before land preparation at the depth of 15cm with soil auger a composite sample was collected from different parts of the field. Soil samples were air-dried and passed through a 2 mm sieve to determine some physical and chemical properties. The soil samples were analyzed using standard methods as described by Agbenin (1995). Particle size distribution was determined by Bouyocous hydrometer method. Soil pH was determined in a 1:2.5 soil to water and 0.1 M $CaCl_2$ using a glass electrode pH meter. The organic carbon was determined using Walkley-Black method of wet combustion involving oxidation of organic matter with potassium dichromate ($K_2Cr_2O_7$) and sulphuric acid (H_2SO_4). Total Nitrogen was determined by micro Kjeldahl method. Exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+) was extracted with 1N neutral ammonium acetate (NH_4OAc) solution and amounts of potassium and Na in solution was determined using a flame photometer while calcium and magnesium by sodium – EDTA titration. Exchangeable acidity (H^+ and Al^{3+}) was determined by titrimetric method with standard sodium hydroxide (0.5N NaOH). The poultry manure used was analyzed for nitrogen, phosphorous and potassium. After the harvest soil sample was collected per plots to determine some soil chemical properties (Soil pH, organic carbon, total nitrogen, exchangeable bases, and available phosphorus) was done at the on-set of the experiment and at harvest in the 2020 farming season.

3.6 Data Collection

3.6.1 Crop establishment count

The crop establishment count was calculated by:

$$\text{Establishment count: } \frac{\text{Number of sprouted vines}}{\text{Total vines planted}} \times 100$$

3.6.2 Vine length

The vine length was measured from the base of the soil to the tip of the vine using meter rule at 4,6, 8 and 10 weeks after planting (WAP) on the tagged plants.

3.6.3 Number of leaves

The number of leaves of sweet potato on tagged plants were counted and the average was calculated and recorded at 4, 6, 8 and 10 weeks after planting (WAP)

3.6.4 Number of branches

The number of branches of sweet potato on tagged plants were counted and the average was calculated and recorded at 4, 6, 8 and 10 weeks after planting (WAP)

3.6.5 Number of tubers

The number of tubers were determined by counting the tubers after harvest and recorded.

3.6.6 Tuber yield

The harvesting was done by removing the vine of the sweet potato with cutlass. Five centimeters of the stem was attached to the storage root for easy removal of the tuber to avoid damages. The tubers were dug out carefully using a digger.

3.6.7 Number of damaged tubers

After the harvest, the number of damaged tubers was observed and recorded.

3.7 Data Analysis

The data collected were subjected to analysis of variance (ANOVA) using statistical analysis system (SAS, 2013) version 9.2. Means were separated using Student-Newman Keuls(SNK) at 5% level of probability.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Physical and chemical properties of the soils

Selected physical and chemical properties of soils of the study site are shown on Table 4.1. The soil was sandy loam in texture with a slightly acidic pH (6.8), organic carbon; total N and available phosphorus were low with values of 8.13, 0.78 and 7.31 g kg^{-1} respectively. Exchangeable bases were 0.92, 0.54, 0.58 and 1.55 for Ca^{2+}, Mg^{2+}, K^{+} and Na^{+} respectively. Exchangeable acidity and ECEC were 0.14 and 3.73 cmol kg^{-1} respectively and a base saturation of 96.25 %.

4.1.2 NPK content of the poultry manure in the experiment

The nitrogen, phosphorus and potassium content of the poultry manure used as source of amendment is presented on Table 4.2. Poultry manure had 27.3, 0.91 and 1.31 % total N, total available P and total K respectively.

4.1.3 Establishment count

The effect of integrated nutrient management on establishment count of some sweet potato varieties at 2 and 4 WAP in 2019 is shown in Table 4.3.Fertilizer application had no significant effect on establishment count at 2WAP. Establishment count was significantly different among the fertilizer combination at 4WAP only. The application of 200 kg ha^{-1}NPK+1.5 t ha^{-1}PM and 300 kg ha^{-1} NPK + 0.75 t ha^{-1}PM recorded similar highest establishment count though statistically similar with the application

Table 4.1: Physical and Chemical Properties of Soil of the Experimental Site Before planting in 2019

Parameters	Value
Textural classification (gkg^{-1})	
Sandy	662
Silt	225
Clay	113
Textural class	Sandy Loam
Chemical properties	
pH (1:2.5) soil water ratio	6.8
$CaCl_2$	6.0
Organic Carbon (g kg^{-1})	8.13
Total N (g kg^{-1})	0.78
Available P (mg kg-^{1})	7.31
Exchangeable bases (cmol kg^{-1})	
Ca^{2+}	0.92
Mg^{2+}	0.54
K^{+}	0.58
Na^{+}	1.55
Exchangeable acid (cmol kg^{-1})	0.14
ECEC (cmol kg^{-1})	3.73
Base Saturation (%)	96.25

Table 4.2: Nutrient Content of the Poultry Manure used in the Experimental Site

Total N ($g\ kg^{-1}$)	27.3
Total Available P ($mg\ kg^{-1}$)	0.91
Total K **($cmol^{(+)}\ kg^{-1}$)**	1.31

Table 4.3: Effect of integrated nutrient management on establishment count of sweet potato at Nyanya in 2019

Treatments	Establishment count (%) 2 WAP	4 WAP
Fertilizer (F)		
Control	94.00a	89.27b
400 kg ha^{-1} NPK	97.62a	96.43b
3 t ha^{-1} PM	97.62a	96.42ab
200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM	97.62a	97.62a
300 kg ha^{-1} NPK + 0.75 t ha^{-1} PM	97.62a	100.00a
100 kg ha^{-1} NPK + 2.25 t ha^{-1} PM	96.43a	95.23ab
SE±	1.496	1.888
Variety (V)		
Butter milk	96.43a	97.22a
Umuspol	97.22a	94.43a
SE±	0.864	1.090
Interaction		
F x V	NS	**

Means with the same letter(s) in a column and under the same factor are not significantly different from each other at 5 % level of probability by SNK.
NS: Not significant, PM = Poultry manure, WAP = Weeks after planting

3 t ha^{-1}PM and 100 kg ha^{-1} NPK+ 2.25 t ha^{-1}PM compared with the control and 400 kg ha^{-1}NPKwhich recorded similar lowest establishment count in this study.

The interaction effect between fertilizer and variety on establishment count at 4WAP in 2019 is shown in (Table 4.4).Butter milk sweet potato establishment count was not significantly different among the fertilizer applications. While Umuspo 1 sweet potato variety, all the sole and integrated application of fertilizer recorded significantly higher establishment count than the control which recorded the lowest establishment count in this study.

The residual effect of integrated nutrient management on establishment count of some sweet potato varieties at 2 and 4 WAP in 2020 is shown in Table 4.5. The application of fertilizer affected establishment count significantly at 2 and 4 WAP respectively. All the plots with sole and integrated nutrient application recorded statistically similar highest establishment count than the control which recorded the lowest establishment count at each sampling time of the study.

There were no significant interaction effects between the fertilizer and variety on establishment count at each sampling periods of the study.

Table 4.4: Interaction effect between integrated nutrient management and variety on establishment count at 4 WAP in 2019

	Variety	
Treatments	**Butter milk**	**Umuspo 1**
Fertilizer (F)		
Control	95.23a	83.30b
400 kg ha^{-1} NPK	100.00a	92.85a
3 t ha^{-1} PM	100.00a	92.83a
200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM	97.62a	97.62a
300 kg ha^{-1} NPK + 0.75 t ha^{-1} PM	100.00a	100.00a
100 kg ha^{-1} NPK + 2.25 t ha^{-1} PM	90.67a	100.00a
SE±	2.670	

Means with the same letter(s) within a column and row are not significantly different at 5 % level of probability using SNK. PM = Poultry manure, WAP = Weeks after planting.

Table 4.5: Residual effect of integrated nutrient management on establishment count of sweet potato at Nyanya in 2020

	Establishment count (%)	
Treatments	**2 WAP**	**4 WAP**
Fertilizer (F)		
Control	65.47b	28.57b
400 kg ha^{-1} NPK	90.47a	83.33a
3 t ha^{-1} PM	90.47a	85.00a
200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM	92.85a	77.38a
300 kg ha^{-1} NPK + 0.75 t ha^{-1} PM	100.00a	75.00a
100 kg ha^{-1} NPK + 2.25 t ha^{-1} PM	96.43a	83.80a
SE±	5.414	7.475
Variety (V)		
Butter milk	90.08a	73.81a
Umuspol	88.49a	70.55a
SE±	3.126	4.316
Interaction		
F x V	NS	NS

Means with the same letter(s) in a column and under the same factor are not significantly different from each other at 5 % level of probability by SNK.
NS: Not significant, PM = Poultry manure, WAP = Weeks after planting

4.1.4 Vine length

The effect of integrated nutrient management on vine length of sweet potato varieties at 4,6,8 and 10 WAP in 2019 is shown in Table 4.6. Fertilizer application had a significant effect on vine length at 4,6, 8 and 10 WAP respectively. The application of 100kg ha^{-1} NPK+ 2.25 t ha^{-1} PM recorded significantly longer vine though statistically similar with all other plots with fertilizer application than the control which recorded shorter vines at 4 WAP.But that was not the case at 6 WAP,where plots treated with the application of 300 kg ha^{-1} NPK+ 0.75 t ha^{-1} PM recorded significantly longer vine though statistically similar with all the other plots with fertilizer application compared with the control which had shorter vines. At 8 WAP, the application of 3 t $ha^{-1}$and all integrated fertilizer application significantly similar longest vine than the control compared to 400 kg ha^{-1} NPK which recorded shorter vines. At 10 WAP, the application of 200 kg ha^{-1} NPK+ 1.5 t ha^{-1} PM, 300 kg ha^{-1} NPK+ 0.75 t ha^{-1} PM and 100 kg ha^{-1} NPK+ 2.25 t ha^{-1}PM recorded significantly similar longer vines though statistically similar with the application of 400 kg ha^{-1}NPK compared with the control which recorded shorter vines similar with the application of 3 t ha^{-1} PM in this study.

The vine length measured was significantly different among the sweet potato varieties throughout the sampling time in the study. The sweet potato variety butter milk consistently recorded longer vines than Umuspo 1 potato variety which consistently recorded the shortest vine in this study.

The interaction effects between fertilizer and variety on vine length was not significantly different at 4, 6, 8 and 10 WAP respectively in this study.

Table 4.6: Effect of integrated nutrient management on vine length of sweet Potato varieties at Nyanya in 2019

	Vine length (cm)			
Treatments	**4 WAP**	**6 WAP**	**8 WAP**	**10 WAP**
Fertilizer (F)				
Control	43.63b	89.22b	278.17b	631.33c
400 kg ha^{-1} NPK	64.17ab	96.55ab	42.65c	800.33ab
3 t ha^{-1} PM	55.57b	105.32ab	292.63a	700.17bc
200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM	67.80ab	125.92ab	362.73a	913.17a
300 kg ha^{-1} NPK + 0.75 t ha^{-1} PM	75.53ab	138.39a	361.20a	872.67a
100 kg ha^{-1} NPK + 2.25 t ha^{-1} PM	91.58a	129.77ab	393.47a	879.33a
SE±	7.704	10.448	29.710	45.229
Variety (V)				
Butter milk	89.72a	148.97a	497.13a	1007.50a
Umuspol	43.04b	79.42b	179.82b	591.50b
SE±	4.448	6.032	17.153	26.113
Interaction				
F x V	NS	NS	NS	NS

Means with the same letter(s) in a column and under the same factor are not significantly different from each other at 5 % level of probability by SNK.
NS: Not significant, PM = Poultry manure, WAP = Weeks after planting

The residual effect of integrated nutrient management on vine length of some sweet potato varieties at 4,6,8 and 10 WAP in 2020 is shown in Table 4.7. Fertilizer application had a significant effect on vine length throughout the sampling periods in this study. At 4, 6 and 8 WAP, all the plots with sole and integrated application of fertilizer recorded significantly similar longest vine than the control which recorded shorter vine. At 10 WAP, 3 t ha^{-1} PM, 200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM and 100 kg ha^{-1} NPK + 2.25 t ha^{-1} PM recorded significantly similar longest vine than the control, 400 kg ha^{-1} NPK and 300 kg ha^{-1} NPK + 0.75 t ha^{-1} PM which had similar shortest vines.

The sweet potato varieties differed significantly in terms of their production of vine length at each sampling time. Butter milk variety consistently recorded longer vines than Umuspo 1 variety which consistently recorded shorter vines.Therewere no significant interaction effects between fertilizer and variety on number of leaves.

4.1.5 Number of leaves

The effect of integrated nutrient management on number of leaves of some sweet potato varieties at 4,6,8 and 10 WAP in 2019 is shown in Table 4.8. Fertilizer application significantly affected number of leaves at each sampling times of the study. The application of300 kg ha^{-1} NPK + 0.75 t ha^{-1} PMrecorded significantly similar highest number of leaves though statistically similar with all other sole and integrated fertilizer application compared with the control which had lower number of leaves. At 6 WAP, 3.0 t ha^{-1} PM and all plots with integrated fertilizer application recorded significantly similar highest number of leaves than the control and the application of 400 kg ha^{-1} which had similar lowest number of leaves. At 8 WAP, the application of 3.0 t ha^{-1} PM, 100 kg ha^{-1} NPK +

Table 4.7:Residual effect of integrated nutrient management on vine length of sweet Potato varieties at Nyanya in 2020

	Vine length (cm)			
Treatments	**4 WAP**	**6 WAP**	**8 WAP**	**10 WAP**
Fertilizer (F)				
Control	59.50b	105.00b	168.75b	444.08b
400 kg ha^{-1} NPK	145.17a	269.00a	350.50a	516.42b
3 t ha^{-1} PM	137.33a	269.00a	358.83a	752.12a
200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM	134.00a	263.83a	445.50a	575.92a
300 kg ha^{-1} NPK + 0.75 t ha^{-1} PM	127.25a	260.92a	328.83a	522.50b
100 kg ha^{-1} NPK + 2.25 t ha^{-1} PM	138.08a	210.33a	420.08a	565.75a
SE±	26.352	48.115	47.297	70.288
Variety (V)				
Butter milk	169.31a	343.83a	537.36a	905.04a
Umuspol	77.81b	115.53b	153.47b	220.56b
SE±	15.214	27.779	27.307	40.581
Interaction				
F x V	NS	NS	NS	NS

Means with the same letter(s) in a column and under the same factor are not significantly different from each other at 5 % level of probability by SNK.
NS: Not significant, PM = Poultry manure, WAP = Weeks after planting

Table 4.8: Effect of integrated nutrient management on number of leaves of sweet Potato varieties at Nyanya in 2019

	Number of leaves			
Treatments	**4 WAP**	**6 WAP**	**8 WAP**	**10 WAP**
Fertilizer (F)				
Control	33.0b	265.0b	397.0b	708.0b
400 kg ha^{-1} NPK	41.0ab	270.0b	397.0b	793.0a
3 t ha^{-1} PM	39.0ab	318.0a	407.0a	853.0a
200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM	52.0ab	307.0a	393.0b	937.0a
300 kg ha^{-1} NPK + 0.75 t ha^{-1} PM	59.0a	365.0a	487.0a	956.0a
100 kg ha^{-1} NPK + 2.25 t ha^{-1} PM	56.0a	313.0a	414.0a	949.0a
SE±	5.227	30.667	30.452	78.489
Variety (V)				
Butter milk	46.0a	307.0a	394.0a	915.0a
Umuspol	47.0a	305.0a	438.0a	817.0a
SE±	3.018	17.705	17.582	45.316
Interaction				
F x V	NS	NS	NS	NS

Means with the same letter(s) in a column and under the same factor are not significantly different from each other at 5 % level of probability by SNK.
NS: Not significant, PM = Poultry manure, WAP = Weeks after planting

2.25 t ha^{-1} PM recorded significantly similar highest number of leaves than the control, 400 kg ha^{-1} and 200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM which had similar lowest number of leaves. At 10 WAP, all the plots with sole and integrated fertilizer application recorded significantly highest number of leaves than the control which had lower number of leaves. The number of leaves measured was not significantly different among the sweet potato varieties at 4,6,8 and 10 WAP respectively in this study. Therewere no significant interaction effects between fertilizer and variety on number of leaves.

The residual effect of integrated nutrient management on the number of leaves of sweet potato varieties at 4,6,8 and 10 WAP in 2020 is shown in Table 4.9. Fertilizer application had a significant effect on number of leaves throughout the sampling times. At 4WAP, the applicationof 400 kg ha^{-1} NPK, 200 kg ha^{-1} NPK+ 1.5 t ha^{-1} PM and 300 kg ha^{-1} NPK+ 0.75 t ha^{-1}PM recorded significantly similar higher number of leaves statistically similar with the application of 3 t ha^{-1}PM and 100kg ha^{-1} NPK + 2.25 t ha^{-1} PM compared with the control which recorded the least number of leaves. At 6WAP, application of 200 kg ha^{-1} NPK+ 1.5 t ha^{-1} PM recorded higher number of leaves similar with all other plots with sole and integrated application of fertilizer than the control which had lower number of leaves. At 8 WAP, the application of sole and integrated fertilizer application recorded significantly similar highest number of leaves than the control which had lower number of leaves. At 10 WAP, application of 400 kg ha^{-1}, 3 t ha^{-1}, 200 kg ha^{-1} NPK+ 1.5 t ha^{-1} and 100kg ha^{-1} NPK + 2.25 t ha^{-1} PMrecorded significantly similar highest number of leaves than the control and application of 300 kg ha^{-1} NPK+ 0.75 t ha^{-1}PM which had similar lowest number of leaves.

Table 4.9:Residual effect of integrated nutrient management on number of leaves of sweet Potato varieties at Nyanya in 2020

	Number of leaves			
Treatments	**4 WAP**	**6 WAP**	**8 WAP**	**10 WAP**
Fertilizer (F)				
Control	48.0b	120.0b	318.0a	660.0a
400 kg ha^{-1} NPK	157.0a	327.0ab	705.0a	855.0a
3 t ha^{-1} PM	103.0ab	209.0ab	570.0a	958.0a
200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM	157.0a	355.0a	738.0a	992.0a
300 kg ha^{-1} NPK + 0.75 t ha^{-1} PM	156.0a	324.0ab	653.0a	749.0a
100 kg ha^{-1} NPK + 2.25 t ha^{-1} PM	76.0ab	188.0ab	746.0a	1187.0a
SE±	22.914	49.774	108.669	145.485
Variety (V)				
Butter milk	157.0a	342.0a	777.0a	1194.0a
Umuspol	76.0b	166.0b	466.0a	606.0b
SE±	13.229	28.737	62.739	83.996
Interaction				
F x V	NS	NS	*	NS

Means with the same letter(s) in a column and under the same factor are not significantly different from each other at 5 % level of probability by SNK.
NS: Not significant, PM = Poultry manure, WAP = Weeks after planting

The number of leaves measured was significantly different among the sweet potato varieties at 4,6 and 10 WAP only. Butter milk varieties produced higher number of leaves than Umuspo 1 which produced the lowest number of leaves. The interaction between fertilizer and variety was significant on number of leaves at 8WAP.

The interaction effect between fertilizer and variety on number of leaves at 8 WAP in 2020 is shown in (Table 4.10). Theapplication of 400 kg ha^{-1} NPK and Butter milk variety of sweet potato recorded higher number of leaves than all other combination compared to control with Umuspo 1 which recorded similar lower number of leaves statistically with control and Butter milk, 3 t ha^{-1}PM with Umuspo 1 and 300 kg ha^{-1}NPK+ 0.75 t ha^{-1}PM with Umuspo 1.

4.1.6 Number of branches

The effect of integrated nutrient management on the number of branches of sweet potato varieties is shown on Table 4.11. At 4 weeks after planting (WAP) in 2019 control was significantly lower than other treatment combinations except 400 kg ha^{-1} NPK which was Similar. At 6 WAP, 100 kg ha^{-1} NPK + 2.25 t ha^{-1} PM was not significantly different from 300 kg ha^{-1} NPK + 0.75 t ha^{-1}PM, but was however, significantly higher than other treatment combinations. In 2019 at 8 WAP, plots treated with 100 kg ha^{-1}NPK + 2.25 t ha^{-1}PM was significantly higher than control, plots with 400 kg ha^{-1} and 3 t ha^{-1}PM was significantly similar, plots treated with 200 kg ha^{-1} NPK + 1.5 t ha^{-1}PM and 300 kg ha^{-1}NPK + 0.75 t ha^{-1}PM. At 10 WAP in the 2019 cropping season plots treated with 300 kg ha^{-1} NPK + 0.75 t ha^{-1}PM and 100 kg ha^{-1} NPK + 2.25 t ha^{-1}PM were significantly different from the control.

Table 4.10: Interaction effect between integrated nutrient management and variety on number of leaves at 8 WAP in 2020

	Variety	
Treatments	**Butter milk**	**Umuspol**
Fertilizer (F)		
Control	406.0bcd	229.0d
400 kg ha^{-1} NPK	1200.0a	209.0d
3 t ha^{-1} PM	837.0b	304.0cd
200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM	675.0bc	802.0bc
300 kg ha^{-1} NPK + 0.75 t ha^{-1} PM	812.0bc	494.0bcd
100 kg ha^{-1} NPK + 2.25 t ha^{-1} PM	732.0bc	761.0bc
SE±	153.681	

Means with the same letter(s) within a column and row are not significantly different at 5 % level of probability using SNK. PM = Poultry manure, WAP = Weeks after planting.

Table 4.11: Effect of integrated nutrient management on number of branches of sweet Potato varieties at Nyanya in 2019

	Number of branches			
Treatments	**4 WAP**	**6 WAP**	**8 WAP**	**10 WAP**
Fertilizer (F)				
Control	2.93b	4.17d	5.00d	5.67d
400 kg ha^{-1} NPK	3.52ab	5.68c	6.47c	7.62bc
3 t ha^{-1} PM	4.80a	6.12bc	6.92bc	7.17c
200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM	4.17a	7.35bc	8.15ab	8.88ab
300 kg ha^{-1} NPK + 0.75 t ha^{-1} PM	4.42a	6.37abc	7.17abc	9.07a
100 kg ha^{-1} NPK + 2.25 t ha^{-1} PM	4.47a	7.62a	8.42a	9.13a
SE±	0.400	0.580	0.470	0.570
Variety (V)				
Butter milk	4.55a	6.76a	7.56a	8.62a
Umuspol	3.55b	5.67b	6.47b	7.17b
SE±	0.270	0.360	0.390	0.400
Interaction				
F x V	NS	*	*	NS

Means with the same letter(s) in a column and under the same factor are not significantly different from each other at 5 % level of probability by SNK.
NS: Not significant, PM = Poultry manure, WAP = Weeks after planting

The interaction effect of integrated nutrient management on the number of branches of sweet potato varieties at 6 and 8 WAP in 2019 is shown (Table 4.12).At 6WAP in 2020, the application of 400 kg ha^{-1}NPK in combination with Butter milk variety gave rise to more branches. Sweet potato plants under the control with either variety had the least branches. Also,8WAP in 2020, the application of 100 kg ha^{-1}NPK+ 2.25 t ha^{-1}PM produced plants with more branches that were at par with those of 3 t ha^{-1}PM in combination with butter milk variety.

Table 4.13 shows the residual effect of integrated nutrient management in 2020 cropping season, control and 100 kg ha^{-1}NPK + 2.25 t ha^{-1} was significantly lower than other treatment combinations, Similarly, at 6WAP plots treated with 400 kg ha^{-1}NPK was not significantly different from plots treated with 3 t ha^{-1}PM and 300 kg ha^{-1}NPK+0.75 t ha^{-1}PM but was significantly higher than others.At 8WAP, plots treated with 400 kg ha^{-1}NPK was significantly higher than control and plots treated with 100 kg ha^{-1}NPK+ 2.25 t ha^{-1}PM but was similar to the others.Results on varietal effects shows that butter milk variety significantly performed better than Umuspo 1 in both years across all the weeks of observation. Similar, to fertilizer effects, the varieties performed better in the 2020 cropping season. There was no significant interaction effect of fertilizer and varieties except at 6 weeks after planting in both years and 8 weeks in 2019 only.

The residual interaction effect of integrated nutrient management on the number of branches of sweet potato varieties at 6 WAP in 2020 is shown in (Table 4.14). The application of 100 kg ha^{-1}NPK+2.25 t ha^{-1}PM in combination with Butter milk variety produced more branches compared to the control plots with either variety which had the least branches.

Table 4.12: Interaction effect of integrated nutrient management on the number of branches of sweet potato varieties at Nyanya in 2019

Treatments	Varieties			
	6 WAP		8 WAP	
	Butter milk	Umuspo1	Butter milk	Umuspo1
Control	7.06d	7.13d	4.97d	5.01d
400 kg ha^{-1} NPK	12.29a	8.72bcd	5.30d	7.60bc
3 t ha^{-1} PM	11.09ab	9.39bcd	9.0ab	7. 30bc
200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM	10.29b	7.72cd	8.20d	5.63cd
300 kg ha^{-1} NPK + 0.75 t ha^{-1} PM	9.79bc	8.72bcd	7.70bc	6.6bcd
100 kg ha^{-1} NPK + 2.25 t ha^{-1} PM	7.39d	9.72bc	10.20a	6.55bcd
SE±	0.27		0.29	

Means with the same letter(s) in the same week after planting are not significantly different at 5% level of probability using SNK.

PM = Poultry Manure,

WAP=weeks after planting

Table 4.13:Residual effect of integrated nutrient management on number of

branches of sweet Potato varieties at Nyanya in 2020

Treatments	Number of branches			
	4 WAP	**6 WAP**	**8 WAP**	**10 WAP**
Fertilizer (F)				
Control	5.17b	7.46d	7.62d	9.87c
400 kg ha^{-1} NPK	6.71a	10.51a	11.07a	12.23a
3 t ha^{-1} PM	7.04a	10.24ab	10.57ab	10.82bc
200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM	6.41a	9.01bc	10.80ab	12.05ab
300 kg ha^{-1} NPK + 0.75 t ha^{-1} PM	6.67a	9.26abc	9.82abc	11.07abc
100 kg ha^{-1} NPK + 2.25 t ha^{-1} PM	5.17b	8.56c	9.13c	10. 37c
SE±	0.430	0.560	0.590	0.500
Variety (V)				
Butter milk	6.79a	9.65a	10.21a	11.46a
Umuspol	5.78b	8.56b	9.12b	10. 37b
SE±	0.270	0.390	0.400	0. 370
Interaction				
F x V	NS	*	NS	NS

Means with the same letter(s) in a column and under the same factor are not significantly different from each other at 5 % level of probability by SNK.
NS: Not significant, PM = Poultry manure, WAP = Weeks after planting

4.1.7 Number of tubers

The effect of integrated nutrient management on number of tubers of sweet potato varieties in 2019 and 2020 is shown in Table 4.15. Fertilizer application had a significant effect on number of tubers across the years. All the plots with sole and integrated fertilizer application recorded significantly higher number of tubers than the control which recorded the lowest number of tubers in 2019 and 2020 respectively.

Number of tubers was not significantly different among the sweet potato varieties in both years. There was no significant interaction between fertilizer and variety on number of tubers in both years.

4.1.8 Number of damaged tubers

The effect of integrated nutrient management on number of damaged tubers of sweet potato varieties in 2019 and 2020 is shown in Table 4.15. Fertilizer application had no significant effect on number of damaged tubers in 2019 and 2020 respectively.

Number of damaged tuber was not significantly different among the sweet potato varieties in both years. There was no significant interaction on number of damaged tubers in both years.

Table 4.14: Residual interaction effect of integrated nutrient management on the

number of branches of sweet potato varieties at 6 WAP in 2020

Treatments	**Varieties**	
	Butter milk	**Umuspo1**
Control	4.17d	4.45d
400 kg ha^{-1} NPK	4.5d	6.80bc
3 t ha^{-1} PM	8.20ab	6.50bcd
200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM	7.4b	4.8cd
300 kg ha^{-1} NPK + 0.75 t ha^{-1} PM	6.9bc	5.8bcd
100 kg ha^{-1} NPK + 2.25 t ha^{-1} PM	9.40a	5.8bcd
SE±	0. 32	

Means with the same letter(s) are not significantly different at 5% level of probability using SNK.

PM = Poultry Manure,

WAP=weeks after planting.

4.1.9 Tuber yield (t ha^{-1})

The effect of integrated nutrient management on tuber yield of sweet potato varieties in 2019 and 2020 is shown in Table 4.15. Fertilizer application had a significant a significant effect on tuber yield in both years in. The plots with sole and integrated fertilizer application gave significantly higher tuber yield than the control which recorded lower tuber yield in both years.

Tuber yield was not significantly different among the sweet potato varieties in 2019 and 2020 respectively. There was no significant interaction on tuber yield across the year in the study.

4.1.10 Selected soil chemical properties

The effects of integrated nutrient management on sweet potato varieties on selected soil chemical properties is presented on Table 4.16. Significant differences were observed in the effect of fertilizers on the selected parameters with the exception of exchangeable potassium. Available phosphorus ranged from 8.50 mg ha^{-1} in the control plot to 31.00 mg ha^{-1} in the plot with the application of sole NPK fertilizer. This was followed closely by 25.50 mg ha^{-1} in the plot with 200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM then 3 t ha^{-1} poultry manure gave 18.50 mg ha^{-1}.Available phosphorus,plots treated with 400 kg NPK ha^{-1} was significantly higher than the other treatment combinations.

Table 4.15: Effect of integrated nutrient management on number of tubers, number of damaged tubers and tuber yield of sweet Potato varieties at Nyanya in 2019 and 2020

Treatments	Number of tubers		Number of damaged tubers		Tuber yield (t ha^{-1})	
	2019	2020	2019	2020	2019	2020
Fertilizer (F)						
Control	14.0b	13.0b	3.33a	1.50a	2.05b	2.25b
400 kg ha^{-1} NPK	27.0a	31.0a	2.50a	3.00a	5.42a	8.65a
3 t ha^{-1} PM	34.0a	31.0a	3.33a	3.00a	5.96a	9.67a
200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM	37.0a	35.0a	3.50a	3.17a	6.52a	11.00a
300 kg ha^{-1} NPK + 0.75 t ha^{-1} PM	28.0a	35.0a	2.17a	3.83a	5.91a	10.00a
100 kg ha^{-1} NPK + 2.25 t ha^{-1} PM	33.0a	25.0a	3.00a	1.50a	6.25a	7.00a
SE±	2.993	3.493	0.480	0.720	0.706	1.240
Variety (V)						
Butter milk	30.0a	30.0a	3.22a	3.17a	6.00a	8.23a
Umuspol	29.0a	26.0a	2.72a	2.17a	5.00a	7.86a
SE±	1.728	2.017	0.280	0.420	0.408	0.716
Interaction						
F x V	NS	NS	NS	NS	NS	NS

Means with the same letter(s) in a column and under the same factor are not significantly different from each other at 5 % level of probability by SNK.
NS: Not significant, PM = Poultry manure, WAP = Weeks after planting

However,there was no significant differences among plots treated with 3t ha^{-1}PM and 200 kg ha^{-1}+ 1.5 t ha^{-1}NPK which was also significantly different from control and 300 kg ha^{-1}NPK+0.75 t ha^{-1}PM.

Total nitrogen in 3 t ha^{-1}PM was significantly higher than all other treatments. The other treatments with combinations of organic and mineral fertilizers did not differ significantly. Similarly, the control plot had the least organic carbon content (4.21 kg ha^{-1}). This was however, not significantly different from the other treatments with the exception of 400 kg NPK ha^{-1} which gave the highest organic carbon content of 7.18 kg ha^{-1}. Varietal difference did not affect the nutrient content of the soils after harvest significantly with the exception of available phosphorus. Buttermilk field had 18.17 mg ha^{-1} which was significantly higher than 16.50 mg ha^{-1} obtained with Umuspo l. There was no significant difference in the interaction effect of fertilizers and sweet potato varieties on the selected parameters with the exception of available phosphorus. The Buttermilk variety performed better in the control plots and in plots amended with sole NPK fertilizer of 400 kgha^{-1} NPK. In plots amended with sole poultry manure, the Umuspo l variety had higher available phosphorus in the soils. For 200 kg ha^{-1} NPK + 1.5 t ha^{-1} poultry manure, Buttermilk with 30 mg ha^{-1} performed better than Umuspo l with 21 mg ha^{-1}. However, for plots amended with 100 kg ha^{-1} NPK + 2.25 t ha^{-1} poultry manure, Umuspo l variety had higher available P (14 mg ha^{-1}) than Buttermilk (9 mg ha^{-1}).

The interaction effects of fertilizer and variety on phosphorus content is shown in (Table 4.17). Under Butter milk, the application of 400 kg NPK ha^{-1}resulted in higher phosphorus content than the other fertilizer applications compared with the control,

Table 4.16: Residual effect of treatments on selected soil chemical properties after harvest at Nyanya in 2020

Treatments	Available phosphorous (mg kg^{-1})	Total nitrogen (g kg^{-1})	Organic carbon (g kg^{-1})	Exch. Potassium (cmol$^{(+)}$ kg^{-1})
Fertilizer (F)				
Control	8.50e	0.46c	4.21b	0.13a
400 kg ha^{-1} NPK	31.00a	0.56bc	7.18a	0.20a
3 t ha^{-1}	18.50b	0.96a	4.62ab	0.20a
200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM	25.50b	0.67b	5.77ab	0.18a
300 kg ha^{-1} NPK + 0.75 t ha^{-1} PM	9.00e	0.60bc	4.70ab	0.19a
100 kg ha^{-1} NPK + 2.25 t ha^{-1} PM	12.50d	0.69b	4.70ab	0.24a
SE±	1.32	0.05	0.64	0.042
Variety (V)				
Butter milk	18.17a	0.65a	4.87a	0.19a
Umuspo1	16.50b	0.66a	5.23a	0.18a
SE±	2.16	0.047	0.42	0.024
Interaction				
TxV	*	NS	NS	NS

Means with the same letter(s) in a column are not significantly different at 5% level of probability using SNK.

NS: Not significant

*: Significant

Table 4.17: Interaction effects of fertilizer and varieties on available phosphorous

	Variety	
	Butter milk	Umuspo1
Fertilizer (F)		
Control	9e	8e
400 kg ha^{-1} NPK	35a	27b
3 t ha^{-1}	17cd	20c
200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM	30b	21c
300 kg ha^{-1} NPK + 0.75 t ha^{-1} PM	9e	9e
100 kg ha^{-1} NPK + 2.25 t ha^{-1} PM	9e	14d
SE±	1.54	

Means with the same letter(s) in a column are not significantly different at 5% level of probability using SNK.

application of 300 kg ha^{-1}NPK + 0.75 t ha^{-1}PM and 100 kg ha^{-1} NPK + 2.25 t ha^{-1}which had statistically similar lowest phosphorus content. Under Umuspo 1, the application of 400 kg NPK ha^{-1}resulted in higher phosphorus content than the other fertilizer applications compared with the control and application of 300 kg ha^{-1}NPK + 0.75 t ha^{-1}PM which had statistically similar lowest phosphorus content. Generally, the combination of Butter milk and application of 400 kg ha^{-1}NPK resulted in higher phosphorus content than the other fertilizer applications.

4.2 Discussion

Soils of the experimental site were low in essential plant nutrients when compared with soil fertility ratings by Esu (1991). This is typical of many tropical soils which are highly weathered with little or no weatherable reserve (Aduayi *et al.*, 2002). The slash and burn practice of farmers around these areas coupled with high insolation and rainfall could also be responsible for these low nutrient status (Anjembe, 2004). Other factors responsible for the low nutrient status may include intensive and continuous cropping without corresponding fertilizer application, weathering, and erosion/leaching losses. The low Phosphorus content could be as a result of high P fixing capacity of most tropical soils (Ibrahim, 2015). Senjobi *et al.* (2013) reported that Nigeria soils are deficient in most nutrients. The low nutrient status of the soil indicates a high probability of getting a response to the application of fertilizers when the soil is cultivated, otherwise partial or total crop failure is probable. The soil texture which is sandy loam is optimum for sweet potato production as they require loose soils through which the roots can penetrate. The soils pH of 6.8 is optimum for sweet potato production. According to Samuel *et al.* (2003), soils with pH of 6.5 -7.0 are considered optimum for crop production.

The chemical composition of poultry manure therefore depends very much on the quality and quantity of the feeds the birdswere feed with. This fact agreed with the observation of Oyedeji *et al.* (2014) that the protein constituent in the poultry feeds had a direct relationship with manure nitrogen. The NPK fertilizer had more P and K. this is probably due to the fact that it was made to release these nutrients readily. The N component could have been attributed to losses due to volatilization

There was no significant difference in establishment count. At this stage, the treatments could not have had influence or effect on establishment count. However, the healthy and actively growing vines used as planting material could have been responsible for the high percentage crop establishment.

Vegetative growth of crops is usually associated with nitrogen, soils amended with fertilizers and poultry manure gave longer vines than the control plots. The 200 kg ha^{-1} NPK + 1.5 t ha^{-1} pm gave longer vine lengths. This might be due to differences in soil fertility occasioned by the application of these amendments. Results of this study is in line with the findings of Abdissa *et al*. (2012) who reported an increase in the vine length of sweet potato with application of organic manure. Also Haliru *et al*. (2015) and El-Hlamy (2011) reported a significant increase in the vine length of sweet potato with application of mineral fertilizer The varieties significantly differed in the length of vines produced with the buttermilk variety producing longer vines. Mukthar *et al.* (2010) postulates that two cultivars of sweet potato may behave significantly different in their vegetative growth due to differences in their genetic composition. Raemaekers (2001) also asserts that vine length and growth habit of sweet potato depend on cultivar and environment and the plants nutrition. It was observed that longer vines were produced in

2020 perhaps the environmental factors were responsible given the similarities in the weather data of the location at the various times the experiment was carried out. The slow release as well as initial competition of microbes for mineralized nitrogen may be responsible for shorter vines in the 2019 season as more nitrogen is made available in 2020.

However, no significant differences were observed in most of the weeks of observation. The varieties did not show any significant difference in terms of this trait, indicating that they could be genetically similar in this regard.

The application of3 t ha^{-1} PM, 300 kg $haha^{-1}$ NPK + 0.75 t $haha^{-1}$ PM having on production of more leaves might be attributed to the high nitrogen content obtained from the interactive effect between poultry manure and NPK. The increase in leaves number might be because of better photosynthesis activity in large photosynthesis area. Since, nitrogen is one of the basic minerals associated with synthesis of protoplasm and in primary synthesis of amino acids, components of protoplasm include all elements that are required to synthesize biomass growth. This finding is in agreement with the findings of Cheng-Wei *et al.* (2014), Ouda and Mahadeen (2008) who observed that the combined application of organic and inorganic fertilizers results in the vigorous vegetative growth of plants. Teshome *et al*. (2012) also reported that interactive effect of organic manure and inorganic fertilizers highly influence high canopy formation, vine length and plant height. The increase in the number of leaves might be because of mineralization of organic manure leading to release of organic bound nutrients. Similar results were reported by Atayese *et al*. (2013) with application of 10t/ha poultry manure application on sweet potato and Abou-Hussein *et al*. (2003) with organic fertilization in sweet potato influenced leaves growth.

The greatest number of branches, which is also a vegetative attribute of sweet potato, were obtained from plots where sole mineral fertilizer was applied and where mineral fertilizer was combined with poultry manure. The reasons for this is not quite different from reasons responsible for differences in the other vegetative traits. Mukthar *et al.* (2010) explained that a difference in number of branches of sweet potato cultivars largely depends on differences in genetic composition. However, Djilani and Senoussi (2013) states that fertilizers either organic or inorganic provide adequate plant nutrient for optimum growth and development. Also Havlin *et al.* (2005) reported that an adequate supply of nutrient to plant release nitrogen which is associated with vigorous seedling emergence, vegetative growth and yield. The higher number of branches obtained in 2020 was as a result of the residual effect of the fertilizers. Adenawoola and Adejoro (2005) reported that the cumulative agronomic value of some organic manure applied to agricultural soils could be more than five times greater in the post-application period than the value realized during the year of application. In the interaction effect on number of branches at 6 weeks, Butter milk variety performed better than Umuspo l, this could be attributed to the genetic make-up which made this variety more responsive to fertilizer application at all levels of both sole and combined applications.

There was significant difference in the number of tubers in 2019 and 2020 number of tubers obtained from plots amended with 200 $kgha^{-1}$ NPK + 1.5 t ha^{-1}PM out-numbered what was obtained in the control plots. This is a pointer to the residual effect of fertilizers applied in the first season. However, in 2019 the numbers of tubers obtained were higher than those obtained in 2020 but as can be seen from the yield on per hectare basis, the higher number of tubers in 2019 did not translate into higher yield on hectare basis.

Crop yield is a measurement of the amount of a crop that can be harvested per unit of land usually measured in tons per hectare or kilogram per hectare, and this in most cases is the major interest of the farmer. In both years' yield obtained with other treated plots were higher than what was obtained in the control plots, this might be due to differences in soil fertility as a result of the amendments added in the other plots (Mukthar *et al.*, 2010). These amendments have the ability to correct adverse soil conditions both physical and chemical. In years, 200 $kgha^{-1}$ NPK + 2.25 t ha^{-1}PM gave the best yields.

Both organic and inorganic fertilizers have been reported to be of great importance in increasing the productivity of crops (Ali *et al.*, 2009). Leytem and Westermann (2005) reported the important effects of fertilizer on the yield of potatoes. Also that potato is highly responsive to nitrogen fertilization and that it is usually the most limiting essential nutrient for potatoes growth and development (Sincik*et al.*, 2008). Inorganic fertilizers when applied are readily available for crop uptake and use. This advantage coupled with the fact that organic fertilizer is environmentally friendly and supply both macro and micro nutrients to the soil (Negassa *et al.*, 2001; Tirol-padre *et al.*, 2007) and also improve the physio-chemical properties of the soil, may be responsible for this combination giving the best yield.

The yields in 2020 were generally better than that of 2019 (Chen,2006) reported that decomposition of manure and mineralization of the nutrients contained in it is fairly slow and may take a few months to several years depending on environmental factors. These released nutrients are stored for a longer period in the soil ensuring longer residual effects, improved root development and higher crop yields Rosen and Bierman (2005) reported that organic fertilizers applied to preceding crops had a remarkable residual effect on yield and yield contributing components of succeeding crop because time was needed for the processes of mineralization to take place.

The application of amendments increased the moisture content of the amended plots above that of the control. Moisture content is improved through the addition of poultry manure. Organic manure amendment is considered a sustainable strategy in arable systems because apart from addition of essential nutrients, it adds soil organic matter (Saha *et al.,* 2007; Hepperly *et al.,* 2009). The soil organic matter contributed by the manure led to improvement of soil physical properties such as improved soil structure, water infiltration and holding capacity amongst others (Agbede *et al.,* 2013, 2014; Adeleye *et al.,* 2010 and Mbah *et al.,* 2004). The favorable soil physical condition which is attributed to poultry manure is consistent with earlier findings of Akanni *et al.*(2005).

The fertilizers increased the selected chemical properties in plots amended with poultry manure in 2020. The control plots had the least of nutrients; this could be due to crop uptake and leaching. More nutrients in the amended plots is associated with the release of essential nutrients as a result of mineralization of such nutrients from decomposing organic matter. Organic matter is known to be the store house of nutrients and its decomposition is slow and gradual. For instance, the highest total nitrogen of 0.96 kg ha^{-1} was found in plots amended with sole poultry manure application at the rate of 3 t ha^{-1}. Ano and Agwu (2006), reported that poultry manure increased soil pH, organic matter content, available P, exchangeable cations and micro nutrients, reduced exchangeable Al and Fe contents and bulk density. Boateng *et al.* (2006) reported that Poultry manure application increased soil N levels by 53 %, while exchangeable cations contents were increased appreciably. Lima *et al*.(2009) stated that incorporation of organic manures improves soil physical-chemical properties that may have a direct or indirect effect on plant growth and yield attributes. Organic manures have more beneficial effects on soil quality than inorganic fertilizers thereby improving nutrient release and their availability to the plants (Birkhofer *et al*.,2008).

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

From the results of this study, it is concluded that the applications of 200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM and 300 kg ha^{-1} NPK + 0.75 t ha^{-1} PM in 2019 and all the treatments with sole and integrated nutrient management in 2020 had highest establishment count than the control which had the lowest in both years. The application of 200 kg ha^{-1} NPK + 1.5 t ha^{-1} PM consistently gave higher number of leaves and longer vines similar with all other fertilizer applications than the control which had the lowest in 2019 and 2020 respectively. The application of 100 kg ha^{-1} NPK + 2.25 t ha^{-1} PM consistently produced higher number of branches in 2019 and application of 3.0 t ha^{-1} PM produced higher number of branches in 2020 than the control which consistently recorded lower number of branches in both years. The treatments with sole and integration of inorganic (NPK) and organic manure (PM) recorded statistically similar highest number of tubers and tuber yield than the control which had the lowest in 2019 and 2020 respectively. Number of damaged tubers was significantly different among the fertilizer applications in both years. The application of 400 kg ha^{-1} NPK recorded higher residual phosphorus and organic carbon content than the control which had the lowest. The application of 3.0 t ha^{-1} PM recorded higher residual total nitrogen content in the soil than the control which had the lowest nitrogen content in the soil. Exchangeable potassium was not significantly different among the fertilizer applications in this study.

Establishment count was not significantly different among the sweet potato varieties in both years. The variety Butter milk consistently recorded higher number of leaves in 2020 than Umuspo 1 which had the lowest number of leaves. Longer vines were produced by Butter milk sweet potato variety than Umuspo l which produced shorter vines in 2019 and 2020 respectively. Number of tubers, number of damaged tubers and tuber yield were not significantly different among the fertilizer applications in both years. The variety Butter milk supported higher residual available phosphorus in the soil. Total nitrogen, organic carbon and exchangeable potassium were not significantly different among the sweet potato varieties in 2019 and 2020 respectively.

5.2 Recommendations

Based on the context of this study, it is recommended that farmers should plant Butter milk sweet potato variety with the application of 200 kg ha^{-1}NPK 15:15:15 + 1.5 t ha^{-1} poultry manure for higher growth and tuber yield. The application of 400 kg ha^{-1}NPK 15:15:15 and 3.0 t ha^{-1} poultry manure is recommended for improved soil fertility in the study area.

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APPENDIX I

Table 5: Critical limits for interpreting fertility levels of analytical parameters for Nigerian soils

Parameters	Low	Medium	High	Source
Ca^{2+} (cmol kg^{-1})	< 2	2 – 5	> 5	(Esu, 1991)
Mg^{2+} (cmol kg^{-1})	< 0.3	0.3 – 1	> 1	”
K^{+} (cmol kg^{-1})	< 0.15	0.15 – 0.3	> 0.3	”
Na^{+} (cmol kg^{-1})	< 0.1	0.1 – 0.3	> 0.3	”
Cu (mg kg^{-1})	<0.2	0.2-0.5	>0.5	”
Zn (mg kg^{-1})	<0.6	0.6-1.0	>1.0	”
Mn (mg kg^{-1})	<1.0	1.0-5.0	>5.0	”
Fe (mg kg^{-1})	<4.0	4.0-8.0	>8.0	”
CEC (mg kg^{-1})	< 6	6 – 12	> 12	”
Org. C (g kg^{-1})	< 10	10 – 15	> 15	”
Avail. P (mg kg^{-1})	< 10	10 – 20	> 20	”
B.S (%)	< 50	50 – 80	> 80	”
pH:				
Strongly Acid	5.0 – 5.5			(Chude *et al.*, 2011)
Moderately Acid	5.6 – 6.0			”
Slightly Acid	6.1 – 6.5			”
Neutral	6.6 – 7.2			”
Slightly Alkaline	7.3 – 7.8			”

APPENDIX II

Table 6 : Temperature and Rainfall distribution during 2019 and 2020 cropping season

	2019			2020		
	Cropping season			Cropping season		
	Temperature (°C)		Rainfall (mm)	Temperature (°C)		Rainfall (mm)
Month	Max	Min		Max	Min	
Jan	26	78.0	2	33.6	20.5	2
Feb	27.8	81.2	8	34.9	22.3	6
Mar	29.4	84.1	31	25.5	23.8	20
April	29.5	-	82	33.8	24	57
May	27.9	81.4	157	30.6	23	138
June	26.1	78.2	179	28.2	21.7	205
July	25.3	76.2	235	26.3	20.9	269
Aug	24.9	76.0	282	26.2	20.7	326
Sept	25.4	76.9	285	27.6	20.8	290
Oct	26.3	78.5	132	29.1	21.3	144
Nov	26.6	79.1	10	32	21.1	11
Dec	25.7	77.5	1	33.2	20.4	1
	26.74	78.82	117	30.08	21.70	122

Plate I: Field layout

PLATE II:Planting of Sweet Potato Varieties

PLATE III:Planting of sweet potato vines per plot

PLATE IV: Labelled sweet potato plots

PLATE IV: Labelled sweet potato plots

PLATE V:Sweet potato field labelled per plot/replicate

PLATE VI: Data Collection

PLATE VII: Data collection

PLATE VIII: Butter milk variety

PLATE IX: Umuspo 1 variety

PLATE X: Umuspo 1 and Buttermilk Varieties of Sweet Potato

PLATE XI: Umuspo 1 Varieties of Sweet Potato

PLATE XII: Umuspo 1 and Butter milk variety after harvest

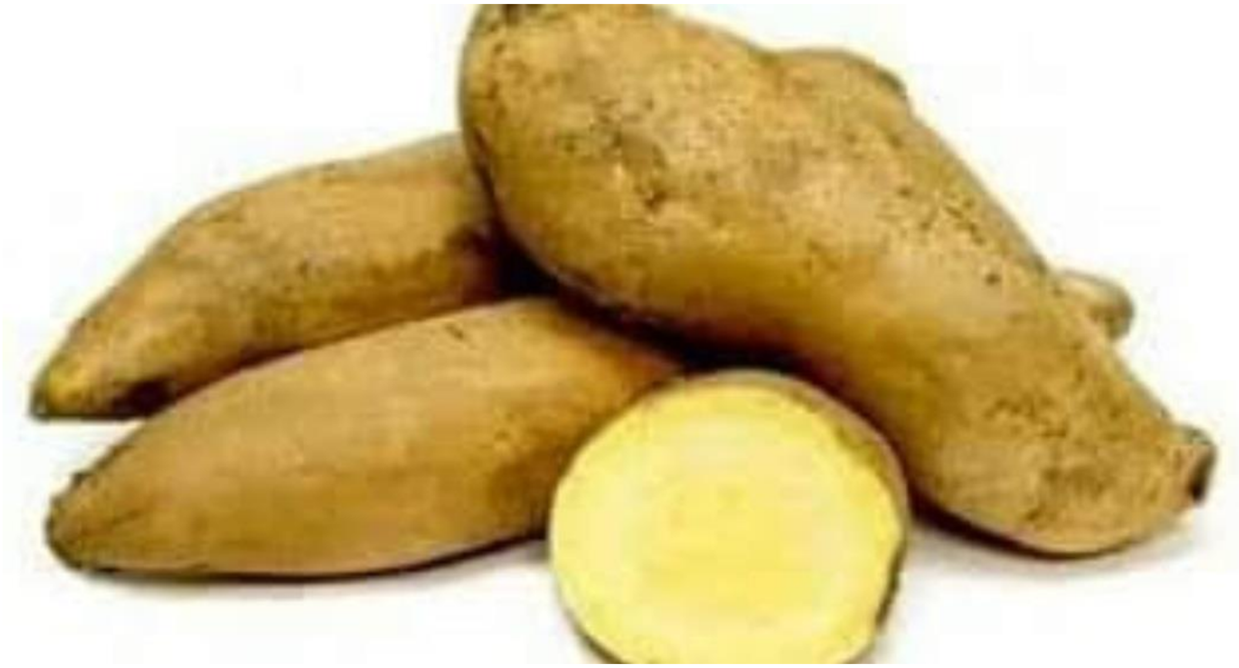

PLATE XIII: Butter milk variety when boiled

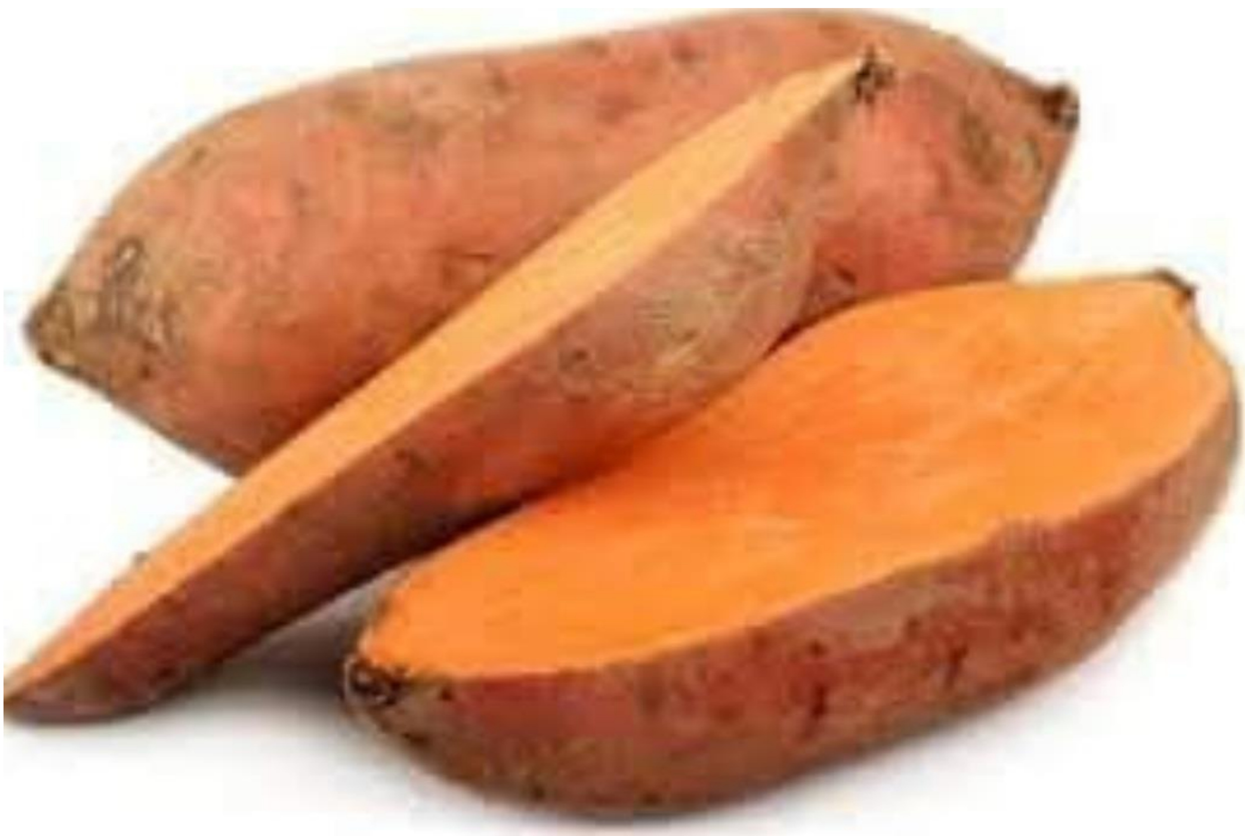

PLATE XIV:Umuspo 1 variety when boiled