EFFECT OF MANURE SOURCES AND PROPAGULE NODE NUMBER ON THE PRODUCTIVITY OF ORANGE-FLESHED SWEETPOTATO (*IPOMOEA BATATAS* L.) IN OWERRI NIGERIA.

BY

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CERTIFICATION

This is to certify that this work "Effect of Manure Sources and Propagule Node Number on the Productivity of Orange-Fleshed Sweetpotato (King-J) in Owerri Nigeria" was carried out by Nwankwo, Uchenna MaryJane (20154940268) in partial fulfilment of the requirement for the award of the degree of Master of Science (M.Sc) in Horticulture, Department of Crop Science and Technology, Federal University of Technology Owerri, Imo State, Nigeria.

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DEDICATION

This work is dedicated to the Ancient of days, the Almighty God who loves and cares for me, and who has not yet finished His work with and through me.

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My immense gratitude goes to my mother, Mrs. E.N. Nwankwo whose love, care and prayers have kept me so far.

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ABSTRACT

The effects of Manure sources and propagule node number on the productivity of orange fleshed sweetpotato (king-J) was investigated at the Teaching and Research Farm of Federal University of Technology, Owerri Nigeria in 2016 and 2017 planting seasons respectively. Three (3) vine nodes: 2, 4 and 6 as well as three (3) sources of manure: 0 (control), poultry manure 10 t ha^{-1} and NPK 15:15:15 400 kg ha^{-1} respectively were combined in a 3 x 3 factorial experiment fitted into Randomized Complete Block Design (RCBD) giving a total of 9 treatment combinations replicated 3 times and it gave 27 treatment plots. Data on soil at the beginning and at the end of each of the experiments were collected and analyzed. Data on the growth and yield parameters of sweetpotato were also collected and statistically analyzed using Genstart software. Analysis of variance (ANOVA) at 5% level of probability was used to test treatment effect. The result showed that the study site was slightly acidic (P^H 4.99 and 5.19) and low in nitrogen (0.13 and 0.12) in 2016 and 2017. At the end of the experiment the acidity was raised from 4.99 to 5.72, and 5.19 to 6.22 in 2016 and 2017 respectively. Result of the investigation revealed that manure sources were statistically significant on sweetpotato vine length, branch formation, leaf production, leafspot and bacterial blight disease severity as well as yield in kg ha^{-1} at 5% probability level in 2016 and 2017 planting seasons respectively. Propagule with 4 nodes applied with 400kg ha^{-1} NPK had the longest vines 100.40cm and 109.40cm, the highest number of leaves 104,30, 134.90, number of branches 9.00, 12.00, as well as lowest leaf spot and bacteria blight disease severity 1.15, 1.48; 1.19, 1.49 in 2016 and 2017 planting season respectively. However interaction of propagule with 4 nodes and 10 t ha^{-1} poultry manure produced the highest total fresh tuber yield 29.79 t ha^{-1} and 38.79 t ha^{-1} in 2016 and 2017 respectively. Sweetpotato production is a good and profitable enterprise. For successful sweetpotato production in Owerri Nigeria, the following recommended practices are made; Farmers can adopt the use of propagule with 4 nodes for high growth and yield of sweetpotato. However further studies is recommended.

Keywords: Manure, Propagule Node, Productivity, Sweetpotato, Yield

CHAPTER ONE

1.1 Introduction

Crop production is dependent on the soil and its fertility stability, the supply of adequate nutrients and quality of plant material used for optimum crop yield. Inadequate nutrient supply and poor soil structure in most cases are some of the major constraint in our agricultural production system. These constraints seriously affect the resource poor farmers that practice low-input agriculture. Thus the use of organic manures to meet the nutrient requirement of crops would be an inevitable practice in the years to come for sustainable low input agriculture. Organic manures usually enhance the soil's physical, chemical and biological characteristics, while preserving the soil's moisture holding ability, leading in increased crop productivity and retaining plant quality. (Eghball *et.al,* 2002).

Although organic manures contain plant nutrients in tiny amounts compared to inorganic fertilizers, the existence of development promoting principles such as enzymes and hormones makes them vital to improve soil fertility and productivity in addition to plant nutrients (Dileep, 2005). Despite the beneficial qualities of poultry manure, rates as high as 20 t ha^{-1} may be needed to guarantee appropriate soil coverage, particularly in low fertility areas and those that have been inorganically fertilized for many years. Under intensive agriculture, inorganic fertilization is often associated with reduced crop yield, soil acidity enhancement and nutrient imbalance (Kang and Juo, 1980; Ojeniyi, 2000).

Many studies have shown that application of inorganic and/or organic fertilizers increase productivity mainly because they contain considerable quantities of plant nutrients including micro nutrients which have benefits for plant growth (Ibeawuchi *et al*, 2006). Inorganic fertilizers are generally easy chemical compounds produced in the factory and or acquired

through mining, such as rock phosphate, which supplies vital plant nutrient phosphorus. Organic fertilizer is important because it includes little or no soluble salt and it can be applied in big quantities without the danger of harming the roots of the plant. Microorganisms in the soil also assist to split organic materials into inorganic water-soluble plant forms (Hignette., 1999).

Currently in Nigeria, sweetpotatoes are increasingly recognized as foods for both humans and livestock, and this has led to enhanced demands for enhanced manufacturing at both national research institutes and universities. Sweetpotato (*Ipomoea batatas* L.) belongs to family *Convolvulaceae* and order *Polemoniales* (Oggema *et al*., 2007). The manufacturing region and sweetpotato productivity are growing worldwide. It is cultivated in different settings in many areas of the globe, often by small farmers in marginal soils, with low inputs (Amare *et al.*, 2014).

It is commonly known as 'Misti Alu' in Bangladesh; "Sakarkand Alu" in India and yam in the United States of America (Rashid, 1999) and it is one of the most important root crops of the world. Today, sweetpotato is extensively grown throughout the tropics between latitude 40^0S and 40^0N of equator (Ghosh *et al*., 1988).

Sweetpotato is generally a herbaceous, perennial vine in nature but usually cultivated as an annual crop. It has a lengthy slender stem that runs along the surface of the soil and continues its vegetative development. Some of the adventitious roots owing to starch accumulation are irregularly swollen to form tuber. Vine cutting is generally used to propagate sweetpotato. Although sweetpotato is frequently grown through vine cuttings, many farmers are not fully conscious of cutting material quality and grow this crop according to their own method of decision owing to the lack of conventional production technique.

Orange-Fleshed Sweetpotato (OFSP) is an improved breed of sweetpotato (*Ipomea batatas* [L.] *Lam.*) Cultivated in tropical and sub-tropical regions of the world for food, fodder and source of

income especially among the rural dwellers (Adebisi, *et al.,* 2015; Mitra, S., 2012). It can be cultivated in a broad spectrum of agro-ecological areas and kinds of soil. Orange-fleshed sweetpotatoes are simple to grow, with enormous capacity to grow in marginal areas (Afuape, *et al*., 2014). It can be propagated vegetatively and once developed it has a relatively drought-resistant capacity. Compared to other root and tuber plants, it has a brief maturity period (3-4 months). These features make Orange-Fleshed Sweetpotato an outstanding crop in sub-Saharan Africa for food safety (Low, *et al*., 2007a). However, timely access to appropriate quality planting materials was quoted as one of the main limitations for realizing the complete potential of Sub-Saharan African Orange-Fleshed Sweetpotato production (Coomes *et al.,* 2015; McGuire and Sterling, 2016; McEwan *et al*., 2017). This hideous situation is exacerbated by the failure of the official seed delivery system and the perishable, voluminous nature of the Orange-Fleshed Sweetpotato vines. The institutional seed sector's restricted function in supplying farmers with timely and high-quality vines has provided rise to a thriving informal decentralized and local multiplication scheme (Kimenye and McEwan, 2014; McEwan *et al.,* 2017). It is therefore essential to reinforce and leverage efforts for timely dissemination of healthy and quality vines to farmers on the casual vine multiplication to assist enhance the output of OFSP. Climate, biological and soil variables influence the output of sweet potato like other plants (Udo *et al.,* 2005; NRCRI, 2008). Fertility is the most significant factor in the production of sweetpotatoes. Recently, despite its countless financial and nutritional values, the production rate of sweet potato has been declining. The decrease can be ascribed mainly to a reduction in the status of soil nutrients, resulting in a reduction in yield. Because of its beneficial impact on soil and crop, organic manure may be helpful in the production of sweetpotato, but its bulkiness, slow release of nutrients and hard handling pose severe difficulties, particularly in commercial production.

Although inorganic fertilizer is comparatively costly, its rapid nutrient release and simple handling makes it a better choice for business manufacturing in particular. Manure use is a traditional technique of boosting soil fertility, although inorganic fertilizers such as NPK (Mg) are becoming progressively essential in the country. Udo *et al.,* (2005) noted that plant nutrient deficiency was a significant factor in traditional farming's low crop yield, whereas Njoku *et al.,* (2001) discovered that sweetpotato production was critical to nitrogen and potassium. In addition, Elmundo *et al.,* (2009) clarified that the sweetpotato output with fertilizer implementation increased significantly. In addition, sweet potato is a short-lived crop requiring inorganic fertilizer to release nutrients in the soil for quicker use by plants. Therefore, it is very true that inorganic fertilizer use will be more efficient in growing output. The response of different sweetpotato varieties (improved and local) to inorganic fertilizer may as well vary.

Because of the low demand for agricultural inputs, high productivity per unit region, excellent dietary value and increased demand for food due to the country's elevated population growth, sweetpotato is one of the country's perfect starch staples for food safety (Laban *et al.,* 2015). Although most sweet potato varieties contain elevated carbohydrates, varieties of Orange Fleshed Sweet Potato (OFSP) also contain vitamins A and C (Laban *et al.,* 2015). Despite this notable crop potential, vitamin A deficiency (VAD) is prevalent in the developing world and the most prevalent cause of child blindness (Low *et al.,* 2007a).

The majority of sweet potato varieties presently cultivated by farmers are poorly adjusted and have low root yields, less nutritious and white flesh with no beta-carotene, a precursor to vitamin A (Wariboko and Ogidi, 2014). But among the cheapest and wealthiest sources of vitamin A are the types of orange-fleshed sweetpotato (OFSP) that are wealthy in beta-carotene and well adopted by young kids (Low *et al.,* 2007a). The intensity of orange colored flesh in the root of

sweetpotatoes shows the amount of beta carotene (Low *et al.*, 2001). Blindness and death of 250,000 - 500,000 African children annually result in widespread vitamin A deficiency (VAD) (Wariboko and Ogidi, 2014). It is therefore essential and timely to evaluate enhanced orange-fleshed sweetpotato (OFSP) varieties

1.2 PROBLEM STATEMENT

The yield of sweetpotato largely depends on the variety used, production technology and the planting materials. The different vine length used as planting material influence the growth and yield of sweetpotato to a great extent.

Most farmers plant sweetpotato based on the old knowledge of laying a long vine into the soil which can lead to loss, inadequate planting material, deterioration of vines. The use of different node number increase household income and reduce poverty, household food insecurity, improve production through sound agricultural practices.

In our country suitable node number and fertiliser has not yet been standardised for sweetpotato and information regarding the Effect of manure sources and propagule node number on the productivity of Orange-fleshed sweetpotato production. This study therefore was aimed to fill this knowledge gap by examining if the adoption of propagule node number plays a role in contributing to food security.

1.3 OBJECTIVES

The broad objective of this research is to determine the effect of manure sources and propagule node number on the productivity of orange-fleshed sweetpotato in Owerri. The specific objectives include;

- To assess the effects of manure sources on the establishment, growth and yield of orange-fleshed sweetpotato.
- To determine the effect of node number(s) on the establishment, growth and yield of orange-fleshed sweetpotato.

To evaluate the interactive effect of manure sources and node numbers on the establishment, growth and yield of orange-fleshed sweetpotato.

1.4 JUSTIFICATION

Improving sweetpotato productivity and achieving self-sufficiency in sweetpotato production and other food crops has been a major concern to researchers, scholars and majority of farmers who live in the rural areas (Okoye *et al*., 2007). This is more worrisome considering the fact that Nigeria is endowed with rich and abundant species of root, this study will enrich data on fertilizer use and propagule management basis for equitability, effective and better allocation of resources among producers of orange-fleshed sweetpotato products. This study will also add to the already existing literature on orange-fleshed sweetpotato production which may aid other researchers.

1.5 SCOPE OF STUDY

The study will evaluate the effect of manure sources and propagule node numbers on the establishment, growth and yield of Orange-fleshed sweetpotato. This study covers a period of two years (2016 and 2017). As a study that focused on manure sources, NPK 15:15:15 and poultry manure was used on different node number cuttings to ascertain there effect on the productivity of sweetpotato and make recommendations. And also to determine the effect of manure sources on the soil physio-chemical properties.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin and distribution of sweetpotato

Sweetpotato (*ipomoea batatas* l.) belongs to the Convolvulaceae family of morning glory and is a reproductive plant consisting of perennial herbs and adventitious roots (Kebede *et al.,* 2008). It is a perennial dicot herb grown annually, with trailing or twining stems up to 4 m long, sending roots at the nodes into the soil. It is usually propagated by the use of roots and stem cuttings and is mainly grown for the edible root which takes about 5 - 6 months to mature. Sweetpotatoes are susceptible with photoperiod duration of 11.5 hours or less encouraging flowering, while flowering ceases at 13.5 hours of daylight, but root yield is not influenced by storage (Kays, 1985). The subterranean stem nodes form large, fleshy, edible storage roots. Latex occurs in all part of the crop.

The systematic classification of the sweetpotato according to Huaman 1992 is as follow:

Family Convolvulaceae

Tribe Ipomoeae

Genus Ipomoeae

Subgenus Quamocllt

Section batatas

Species ipomoea batatas (L) Lam

Sweetpotato thrives well in sandy-loam and clay loam soils, which must be well drained due to the sensitivity of the plant to long-lasting excessive humidity in the soil (Van den Berg and Laurie, 2004). Soil p^H is very useful for crop production between 5.6 and 6.6 (Laurie, 2004).

China is the largest producer of sweetpotato with 80% of annual world supply (FAO, 2008). It is Sub-Saharan Africa's third largest root and tuber crop (Ewell and Mutuura, 1994). Africa generates 11.6 million tonnes per year, with Nigeria being Uganda and Tanzania's biggest producer.

Sweetpotato vine cuttings are used to plant the crop, the duration or amount of nodes per cutting vine cuttings differs from farmer to farmer and from site to site (Belehu, 2003). Vine cuttings in tropical areas are better planting material than tuber sprouts for several reasons. Plants derived from vine cuttings are free from soil borne diseases (Onwueme, 1978; Phills and Hill, 1984). By propagating the entire tuber harvest with vine cuttings for consumption or marketing instead of reserving some of it for planting purposes and vine cuttings yield better than sprouts and generate roots of more uniform size and shape.

There are conflicting results regarding the optimum length of vine cuttings. Onwueme (1978) stated that tuber yield tends to improve as the length of the vine cuttings used increases and suggested a length of approximately 30 cm (9-node numbers per cut). Cuttings longer than 30 cm tend to be wasteful of planting material, while cuttings much shorter slowed down and yielded less. Also suggested by Ravindran and Mohankumar (1982) and Bautista and Vega (1991) to use 20 to 40 cm long vine cuttings for better root output storage. Hall (1986) found that 40 to 45 cm cuttings produced higher total marketable root yield than 20 to 25cm cuttings. The three cutting lengths of Hwassa-83 cultivar in Melkassa and Hawassa (20 cm regarded 5 – node numbers, 25 cm considered 6 - node numbers and 30 cm considered 9 - node numbers) did not vary in

complete, marketable, medium, big, root returns under size and over size storage. The cuttings of 30 cm (9-node numbers per cut) led in the largest yield of tiny storage roots compared to the cuttings of 20 cm (5 - node numbers per cut) and 25 cm (6 -node numbers per cut). No important yield variations between the 20 cm and 25 cm cuttings of tiny storage roots were observed (Belehu, 2003). Choudhury (1979) got more tuberous roots using cuttings with four nodes from the top part of the trees. It has also been noted that the terminal vine cuttings yielded greater than cutting produced from the center part of the vine regardless of the amount of nodes in cutting. Appropriate planting material guarantees proper growth, optimal plant standing and tuberization that eventually affected crop yield. The distinct sections of the vine used as planting material have a significant impact on the development and yield of sweet potato. Using excellent planting materials could improve the yield of sweet potato. Using vine cuttings (Edmond, 1971) is the most prevalent technique of sweet potato propagation. Farmers use any cutting length accessible or easy to manage in many locations. For planting, some farmers use brief cuttings just because they are simple to handle or save on planting equipment. Others also take lengthy cuttings, fold them multiple times and insert them into the soil. In other locations, the vines left on the ground to grow again without any structured propagation after harvesting the earlier crop (Amoah, 1997). Vine cuttings stored in the primary area for 3 days produced crops with the largest marketable root yield followed by cuttings of 4 days (Hammett, 1983). Two days before planting in the primary field, cut trees with intact leaves are placed under shade to encourage better root initiation, easier vine establishment and greater root yield (Ravindran and Mohankumar, 1989; Biswal, 2008). Sweetpotato is a vegetable wealthy in starch that is essential and common. Its tuberous roots are edible and consumed boiled, baked, roasted or fried forms (Onweme, 1978). They also eat the young stems and leaves as vegetables. Both the tuberous root and leaf and

plants are rich in calorie and carotene, and in Bangladesh it is known as the food of the poor man. As a root crop, it compares favorably with other root crops such as 18 - 35% carbohydrate cassava and 1500 IU carotene per 10 g edible root (Rashid, 1999). In addition to food products, sweetpotato has diversified use for processing sectors as animal feeds and raw materials. Sweetpotato is grown in a region of about 50,000 hectares with an annual manufacturing of about 70,000 tons of tuberous root (Ahmed *et al.,* 1998). Increasing recognition of the sweetpotato crop's excellent potential as a nutritious food for humans and livestock has led in increased study attempts in latest decades to improve its output and consumption (Woolfe, 1992; Yamakawa and Yoshimoto, 2002).

Sweetpotato is particularly essential in developing nations as it is an extremely adaptable crop that produces big quantities of food per unit region and time per unit during comparatively brief rainy periods, offering it an edge over significant staples (Muhammad *et al.,* 2011). It also has flexible planting and harvesting times, tolerates elevated temperatures and low soil fertility, and above all is tolerant of drought and simple to propagate. In addition, sweetpotato needs less input and labor compared to other plants, making it particularly appropriate for migration-threatening homes or illnesses such as HIV / AIDS (Jayne *et al.,* 2004).

Sweetpotato yields are mainly dependent on the variety, manufacturing technology and the equipment used for planting. The distinct number of nodes used as planting material greatly influences sweetpotato development and yield. Appropriate planting material guarantees proper growth, optimal plant standing and early tuberization that eventually affect crop yield. Sweet potato is a significant food crop together with cassava, with the benefit of being resistant to drought. Has low nutrient requirement and is capable of delivering decent returns in seasons

where other plants fail, another benefit is that the daily new food for the family can be harvested piecemeal (Karyeija *et al.,* 1998).

The main issue of increasing sweetpotato is the shortage of planting materials, pests and illnesses, especially viral diseases (Moyo *et al.,* 1999). Diseases are of excellent significance in the manufacturing of sweet potatoes, viruses being the largest issue in the world because sweet potatoes are highly prone to viral diseases (Bolton and du Plooy, 1984 ; Owour, 2000). During a 1997 ARC Vegetable and Ornamental Plant Institute baseline study on cassava and sweetpotato, viral illnesses were listed high based on symptom expression in the field and the outcomes of indexing the trees to the indicator plant, *Ipomoea setosa* Kerr. (Van der Mescht *et al., 1997*). Sweetpotato production is severely restricted by illnesses that reduce yields by up to 98 percent (Mukasa, 2001), and viruses significantly restrict sweet potato production in tropics and Africa, accounting for over 50 percent of Nigeria and Uganda's yield decrease (Mukiibi, 1977). The crop is susceptible to viral diseases in warm tropical areas in South Africa, such as the low output of Mpumalanga and the province of Limpopo (Coertze *et al.,* 1996). There is usually a lack of data on the yield loss induced by viruses in the globe and in some other fields where the crop is cultivated owing to the practice of harvesting piece-meal which makes it hard to assess yield (Jericho, 1999). Unlike most other main staple food plants, under relatively negative circumstances, sweetpotato can generate a comparatively elevated yield; however, the crop is affected by a number of pests, illnesses and dietary illnesses._Among the pest and disease limitations, sweetpotato weevils (Cylas spp.) and virus illnesses may lead most to yield losses, although leaf feeding insects such as sweetpotato butterfly (*Acraea acerata*) may cause important losses during outbreaks. Nutritional illnesses can also cause slight loss of yield to

finish, and are the major limiting factor for most unfertilized plants. They can also decrease pest and disease tolerance.

The sweet potato virus disease (SPVD) that is caused by mixed infection with sweet potato chlorotic stunt virus by whiteflies and sweet potato feathery mottle virus by aphids is the most severe sweetpotato disease in Africa (Karyeija *et al.,* 1998; Gibson *et al,.* 2004). Sweet potato weevil (*C. formicaries* complex) is regarded the world's largest pest attacking sweet potatoes both grown and stored (Allemann *et al.,* 2004). Weevil infestation severity relies on variation and rises as the harvest of mature roots is delayed (Stathers *et al.,* 2003b). Integrated crop management is the foundation for effective management of sweetpotato pests, illnesses, and dietary disorders. This involves preventing insect infestation and pathogen infection by using appropriate cultural methods and preserving natural enemies. Adequate cultural practices include the selection of healthy planting material from well-adapted varieties, rotation, good field sanitation, and maintenance of soil fertility. Natural enemy conservation includes avoiding pesticide use, enhancing natural enemy action through favorable cultivation methods, and introducing natural enemies where appropriate.

Sweetpotato is very rich in vitamins A, B and C and minerals such as phosphorus, iron and calcium (Woolfe, 1992). The sweetpotato is an ancient crop created in Central and South America's prehistoric cultures with early cultivation starting around 3000 B.C. (Lewthwaite, 2004). The modern crop version is cultivated across cultures and continents throughout the world's tropical and subtropical areas (Huaccho and Hijmans, 2000; Lewthwaite, 2004).

Sweet potato is among the oldest crops in the world, especially in the wet tropics, and was among the first staple crops before the introduction of cereals. Today it is counted among other root crops such as cassava, sweet potato and yam, which in developing nations are the second

most significant carbohydrate collection of food plants, closely following cereal crops (Lebot, 2009). In Gush's view (2003), usually the most misunderstood vegetable is sweet potato, often confused with yams. It is thought that Portuguese explorers brought sweet potato in the 16th century to Africa (Woolfe, 1992; Allemann *et al.,* 2004; Laurie, 2004; Lebot, 2009). From there, Spanish explorers took it to the east and west areas of the globe in the form of storage roots. Because of low temperatures, it was carried back to Africa until it failed to produce in European nations and was planted in Africa's hot coastal areas where it spread quickly (Lebot, 2009). Due to the tropical origin of sweet potatoes, they adapt well to hot environments and grow best in summer. Sweet potatoes are susceptible to cold and should not be cultivated until there is no risk of frost. The optimum temperature to achieve the best growth of sweet potatoes is between 21 and 29^0C, although they can tolerate temperatures as low as 18^0C and as high as 35^0C.

Depending on the point of root growth, storage roots are susceptible to modifications in soil temperature. Orange-fleshed sweetpotato includes carotenoids responsible for their dietary value and positive impacts on the health of consumers. Increasing orange fleshed sweetpotato consumption, which includes more beta carotene than white or yellow fleshed ones, can assist to relieve the deficiency of vitamin A (Anderson *et al.,* 2007). Vitamin A is essential to rural poor people's diet and its deficiency creates night blindness, a severe public health issue in many developing nations (WHO, 1995).

Low soil fertility is a significant constraint on the manufacturing of sweet potato in south-eastern Nigeria (Njoku *et al.,* 2001; Okpara *et al.,* 2011). Research has shown that the use of inorganic fertilizer improves root output but hampers the quality of sweet potatoes and exacerbates soil degradation (Nedunchezhiyan *et al.,* 2003). Research reports on orange fleshed type sweet potato

reaction while little is known about orange-fleshed sweet potato nutrient management (Njoku *et al.,* 2001; Okpara *et al.,* 2011).

Many studies have shown that the use of inorganic and or organic fertilizers improves plant growth primarily because they contain substantial amounts of plant nutrients, including micro nutrients with elevated plant development advantages (Ibeawuchi *et al.,* 2006). Recently, the need for inorganic fertilizer has risen without comparable rises in the fertilizer product supply to satisfy farmers demand for earnings. Second, the cost is very exorbitant when available that resource poor farmers cannot afford even a bag to apply to their plants.

2.2 Climatic and Soil Requirements of Sweetpotato

Sweet potato needs moderate temperature (21 - 26^0c) and well-distributed 75 - 150 cm precipitation, requires plenty of sunlight, not shade, which causes yield decrease, and is intercropped with seasonal plants such as pea pigeon, corn, etc. (Nedunchezhiyan *et al.,* 2010). It is also cultivated as an intercrop in plantation/orchard plants with the objective of intensifying plants and maximizing profit (Nedunchezhiyan *et al.,* 2007). Sweet potato can tolerate drought to some extent but cannot withstand waterlogging (Nedunchezhiyan and Ray, 2010). The crop has a short growing season and can therefore avoid long dry seasons (Kapinga *et al.,* 1995) and is widely grown in the equator at 40 ° N and 40 ° S and above 2500 m above sea level (Hahn and Hozyo, 1984). The crop is highly adaptable, but under favorable circumstances the yield is greater. In warm, humid areas, growth and manufacturing are better. However, at the start of its development, the plant only needs elevated humidity, once the tubers have developed, any surplus humidity in the soil may cause rotting. Tuberisation is supported by brief days of sunlight (11 hours) and cool evenings but is inhibited if daylight lasts 14 hours or longer (Degras, 2003). Temperatures below 10° C can be harmless to sweetpotato plants as growth starts at 15° C and is

optimal between 21° C and 28° C (Janssens, 2001). Leaf shading is a main determinant of soil temperature, and comparatively tiny soil temperature increases can have a direct impact on the quality of tuber. Bourke (1985) recorded yields as high as 20 to 30 tons per hectare in 8 months at an altitude of 1600-2000 m, with temperatures typically 16 ° C to 18 ° C, while *Ngeve et al.*, (1992) reported yields as high as 20 to 30 tons per hectare, Stressed that output declines with rising altitude in the tropics, while Goodbody and Humpfreys (1986) stated a delay in maturity with rising altitude. Sweetpotato requires plenty of sunshine, but shade causes yield reduction, however, sweet potato can tolerate drought to some extent but cannot resist water logging (Nedunchezhiyan and Ray 2010). Sweetpotato can colonize marginal soils as it generates easily adventitious roots and has trailing vines. As a result, soil type is not very challenging. It requires a light, friendly, relatively permeable loam, without surplus oxygen, which would otherwise boost aerial parts growth at the cost of root tubers (Raemaekers, 2001). Well drained loam and clay loam soils are good for sweet potato cultivation. Heavy clay soil restricts the growth of the storage root owing to compactness while lengthy cylindrical pencils like roots are encouraged by sandy soils (Nedunchezhiyan and Ray, 2010). Sweet potato is cultivated mostly in acidic soils, but the optimum soil pH is discovered to be 5.5 - 6.5. High soil p^H induces sweet potato pox and scurf disease, while low p^H aluminum toxicity of sweet potato (Nedunchezhiyan and Ray, 2010). Sweetpotato has excellent tolerance to soils rich in aluminum, poor in phosphorus acid. Growth at p^H 4.0 can still be achieved. It readily adjusts to extremely organic soils. Compact soils, on the other hand, must be prevented. The crop will not tolerate continuous hydromorphic conditions for more than three days. The development of fibrous roots promotes excess nitrogen and hydromorphic conditions (Janseen, 2001). Also susceptible to saline and alkaline conditions is sweet potato (Dasgupta *et al.,* 2006; Mukherjee *et al.,* 2006).

Planting time has been recognized as one of the most significant variables influencing root development, yield and quality (Nedunchezhiyan and Byju 2005). Higher root yields were observed in Malaysia during the drier increasing season (January to July) compared to the humid season (August to December) (Zaharah and Tan 2006). From May to August, sweet potato is cultivated in Nigeria. Studies on the impacts of sweet planting dates in Puerto Rico stated that the vine weight at harvest during the rainy season was the largest maturing. Heavy rainfall encouraged vegetative growth high temperature accelerated growth process and cloudiness, reduced the net photosynthetic production (Martin, 1988).

2.3 Environmental Requirements

2.3.1 Light

Light duration has been recorded as one of the critical environmental variables influencing sweetpotato development and yield (Bouwkamp, 1985; Mortley *et al.*, 1996) and most cultivars are day-sensitive (Ngailo *et al.*, 2013). For instance, stimulated storage root formation under long days has been reported (Kim, 1957; Mortley *et al*., 1996). Higher storage root yields were also recorded when growing sweetpotato under 12 hour light periods than when growing crops under shorter (8-hour) or longer (18 - hour) light periods (McDavid and Alamu, 1980; Mortley *et al.*, 1996). These suggestions are augmented by reports of higher yields when sweetpotato was grown under 14 hour light periods compared to 8 hour light periods (Mortley *et al*., 1996). Even under controlled settings, the importance of light periods on sweetpotato development has been noted. Mortley (1996) showed that when using the Nutrient Film Technique (NFT) in a hydroponics scheme, sweetpotato physiological reactions, development and yield varied with light.

2.3.2 Water

Abiotic constraints which significantly affect sweetpotato production include low soil fertility and drought (Kapinga *et al*., 1995; Mwololo *et al*., 2007; Mihale *et al*., 2009; Pareek *et al*., 2010; Ngailo *et al*., 2013). The quantity, timing and distribution of water affects the storage root yields (Ravi *et al.,* 2009). During the growing season, the crop's water requirement is between 360 and 800 mm (Gomes and Carr, 2003; Belehu, 2003). Normally, the crop requires 500 mm water over 16-20 weeks growth period (King, 1985; Kays, 1985; Onyekwere and Nwinyi, 1989; Ravi *et al*., 2009).

2.4 Sweetpotato Morphology/Anatomy

The sweetpotato plant mainly consists of apical shooting, leaves, flowers, fruits, nodes, internodes, main stem, secondary stem, pencil roots, fibrous roots and storage roots (Huaman, 1992). Characteristic of the growth of the plant is a predominantly prostrate vine system that can either be erect or spreadingIt has a vine structure that extends quickly and horizontally along the floor, varying from erect and semi-erect to spreading, although primarily prostrating in its growth habit (Rossel *et al.,* 2000). The root system of the plant consists mainly of fibrous roots absorbing nutrients, water and anchoring the plant (Huaman, 1992). As the crops mature some of the roots that have some lignification are created, the roots of pencils are fleshy and thicken a lot while others have no lignification (Huaman, 1992). These are the roots of storage that store photosynthesis products. The storage root includes the proximal end that connects it to the stem, the more extended core portion, and the reverse distal end to the root stalk. The central and distal components, adventitious buds generally sprout later than those in the proximal end (Huaman, 1992). The stem, whose color may differ from green to red-purple (pigmented with anthocyanins), depending on the cultivar, is cylindrical and maybe 1 to 5 meters long. The

hairiness in the apical shoots ranges from glabrous (without hairs) to very pubescent (Huaman, 1992) in some cultivars in the stems.

2.5 Crop Description

2.5.1 The Root System

When sweet potato is planted from stem cuttings, adventitious roots arise from the cutting in a day or two. These roots are quickly growing and forming the plant's root system. Research has shown that sweet potato roots can penetrate the soil to an amount of more than 2 m, the precise depth reached depending on the situation of the soil (Onwueme, 1978 and Kays, 1985). The root system of sweet potato is split into the adventitious roots resulting from the underground nodes of a vine cutting and lateral roots resulting from current roots based on its origin. The adventitious roots were split into storage, fibrous and pencil roots by Kays (1985). Subdividing the lateral roots into main, secondary and tertiary roots. They are often divided into two groups, i.e. slender and dense roots, during the early ontogeny of youthful adventitious roots emerging from the stem. In the structure of their main vascular tissue, i.e., four xylem and phloem poles discovered within the vascular cylinder, slender roots are typically tetrarch, according to Wilson (1982) and Kays (1985). The dense roots in structure are pentarch or hexarch. Thick roots are reported to give rise to string roots (main fibrous roots) and pencil roots under negative circumstances depending on the main change activity and the quantity of stele cell lignification (Hahn and Hozyo, 1984; Du Plooy, 1989). The most important functional differences between these root types are their capacity for storage root initiation in a specific region of the thick roots. Several factors such as exposure of potential storage roots to long photoperiod (Bonsi *et al*., 1992), water logged soil conditions (Kays, 1985), high level of nitrogen supply (Wilson, 1973; Chua and Kays, 1981), gibberellic acid application (McDavid and Alamu, 1980), as well as

exposing the plant to long days (McDavid and Alamu, 1980; Du Plooy, 1989) encourage lignification and inhibit storage root development. Alternatively elevated supply of potassium (Tsuno, 1971; Hahn and Hozyo, 1984), lack of light (Wilson, 1982), as well as aerated soil circumstances, low temperature and brief days were shown to encourage the development of root storage (Du Plooy, 1989).

2.5.1.1 Storage Roots

Storage roots arise from pentarch or hexarch thick young roots if the cells between the protoxylem points and the central metaxylem cell do not become lignified (Wilson and Lowe, 1973). The rise in the size of the storage root is ascribed to the vascular change activity as well as the anomalous cambia activity (Wilson, 1982). The original sign of the formation of storage root is the accumulation of predominantly starch photosynthates (Chua and Kays, 1982). Storage root initiation is reported to occur between the period 35 to 60 days after planting (Enyi, 1977; Agata, 1982; Wilson, 1982). But Du Plooy's (1989) research stated that the initiation of the storage root could take place as soon as 7 days after planting. These conflicting findings indicate that further study on the formation of root storage in sweet potatoes is needed.

Agata, (1982) reported that storage root formation started about 30 to 35 days after planting and the root dry weight increased linearly until harvest. Wilson and Lowe (1973) revealed that the amount of storage roots created reached a maximum of 49 to 56 days after planting, but some cultivars may take up to 112 days to form the highest amount of storage roots after planting. The mean numbers of storage roots per plant at week 7 varied from 1.2 to 5.5 depending on cultivar.

2.5.1.2 Pencil Roots

Pencil roots are generally between 5 and 15 mm in diameter, they are the least well defined of the adventitious roots emerging from the subterranean node of the cutting. Under circumstances

not conducive to the growth of storage roots, they grow primarily from young dense adventitious roots. Lignification in pencil roots is not complete, but results in a uniform thickening of the whole root (Wilson and Lowe, 1973).

2.5.1.3 Fibrous Roots

According to Chua and Kays (1981) fibrous roots develop mainly from tetrarch, thin adventitious roots. The fibrous roots are generally less than 5 mm in diameter and are branched with lateral roots forming a dense network throughout the root zone constituting the water and nutrient absorbing system of the plant. Fibrous roots have heavily lignified steles and very low levels of vascular cambial activity. High nitrogen and low oxygen within the root zone favor their formation (Chua and Kays, 1981).

2.5.1.4 Lateral Roots

The lateral roots of sweet potato emerge from existing roots. Adventitious roots (storage, pencil and fibrous) have a profusion of lateral roots at varying densities along their axis. From adventitious roots arise the main lateral roots. Laterals that emerge from the main laterals are called secondary laterals, and those that emerge from the secondary laterals are called tertiary laterals (Kays, 1985).

2.5.2 Above Ground Plant Organs

2.5.2.1 Vines

Sweet potato has long slender stems trailing along the surface of the soil and producing node roots. Based on the length of their vines (Yen, 1974; Kays, 1985), sweet potato genotypes are categorized as erect, bushy, medium or spreading. With cultivar, the length of the stem ranges from about 1 m to over 6 m. The size of the internode is also very variable, varying from a few

centimeters to a length of 10 cm. The planting density has a marked impact both on the length of the internode and on the length of the vine (Somda and Kays, 1990a). The stem is slightly angular or circular. Stem color is predominantly green, but there is often a violet pigmentation. Branching is dependent on cultivar (Yen, 1974) and the amount and length of branches differ. Sweet potato crops generate three kinds of branches at distinct growth phases, primary, secondary and tertiary. The complete amount of branches between cultivars ranges between 3 and 20. The branching intensity of sweet potato plants is affected by spacing, photoperiod, soil moisture and nutrient supply (Kays, 1985; Somda and Kays, 1990a; Sasaki *et al.,* 1993).

2.5.2.2 Leaf and Petiole

The leaves of sweet potato occur spirally on the stem. The total number of leaves per plant varies from 60 to 300 (Somda *et al*., 1991). The number of leaves per plant increases with decreasing plant density (Somda and Kays, 1990b), increasing irrigation (Indira and Kabeerathumma, 1990; Holwerda and Ekanayake, 1991; Nair and Nair, 1995), and N application (Nair and Nair, 1995). The length of the petiole differs extensively with genotypes, ranging from about 9 to 33 cm (Yen, 1974). In order to expose the lamina to full light, the petiole maintains the capacity to grow in a curved or twisted way. The canopy petiole length is at its minimum in the early phases of growth, but with a rise in canopy size, the petiole length rises significantly towards the center and latter portion of the growing season. At its intersection with the stem, the petiole is swollen, and at the intersection it bears two tiny nectaries. The lamina, even for leaves on the same plant, is highly variable in size and shape. The color of the lamina is green, with purple coloring at times. Stomata are present on both the leaves ' top and bottom surfaces. Kubota *et al.,* (1993) discovered that high producing cultivars had more stomata on the abaxial surface and reduced

numbers on the abaxial surface than low producing cultivars, although this is likely not a universal occurrence.

2.6. Flower

The flowers of sweet potato are born solitarily or on cymose inflorescences that grow vertically upward from the leaf axis (Purseglove, 1972; Onwueme, 1978). Each flower has five united sepals, and a funnel-shaped corolla tube is formed by five petals. Stamens differ in height with regard to style duration. This tube is the most noticeable component of the flower and is purple in color. In most cultivars the two longest stamens are about the same length as the style. The filament is white and hairy; the anther is white as well and on the surface includes countless rounded pollen grains. The ovary is made up of two carpels with one locule each. Each locule includes two ovules so that in each ovary there are no more than four ovules (Onwueme, 1978). Each flower opens on a specific day before dawn, remains open for a couple of hours, then closes and wilts the same day before midnight. If the weather is cool and cloudy, the length of time the flower remains open is slightly longer. Insect pollination, especially bees. The sweet potato flower's physiology is complicated. First, environmental control, particularly photoperiodical control, is subject to flower formation. Second, for an incredibly short time, the flower is open and receptive. Third, there are complexes of incompatibility. Fourth, the presence of stamen length variation with regard to style brings another morphological complication into the mechanism of pollination. All these characteristics make it hard to produce seeds (Onwueme, 1978).

2.7 Sweetpotato Growth, Development and Yield

The sweetpotato plant identifies three growth stages. The first stage is defined by slow development of the trees and fast development of adventitious roots, followed by the

intermediate stage of fast development of the trees and an increase in the region of the leaves and the initiation of the storage root. At 100 days after planting (DAP), the leaf area is at its maximum and any further increase in biomass is due to storage root formation (CARDI, 2010). Because they determine the total number of storage roots formed, the first 20 days of the initial phase are important. Storage root formation can be seen as soon as 28 DAP and 49 DAP, identifying 80% of storage origins (CARDI, 2010). In the final development stage, storage roots bulking may achieve a maximum of 90 DAP or may increase to 120 DAP throughout the plant's lifetime (CARDI, 2010).

Sweetpotato roots grow as adventitious roots (Belehu, 2001) and are usually derived from the underground stem part of a vine cutting used as planting. From the nodal portion of the stem these adventitious roots evolve (Belehu, 2001). Accordingly, Bangladesh studies have shown that increasing the amount of nodes per vine has increased the amount of plants per plant, the length of the vine and the root yield (Nedunchezhiyan *et al.*, 2012a). There are two procedures involved in root growth; initiation and extension (Eguchi, 2000). The origins originate from main cambia activation, along with abnormal changes in secondary and vascular cambia (Tsu *et al.*, 2008). The procambial ring gradually aligns outwardly during the secondary-thickening development meanwhile, parenchyma cells within are extremely proliferated and ultimately distinguish into starch-storage cells (Tsu *et al.,* 2008). It should be noted that most of the growth phases are controlled genetically (i.e. variety) and environmentally (i.e. agro - ecological conditions of the area where the crop is established) (CARDI, 2010). Organized growth initiation is a complicated morphogenetic phenomenon that plays significant roles with extrinsic and inherent variables. Inputs from environmental indications, hormone signals and nutrient status are therefore driving variables during organogenesis (Tsu *et al.*, 2008). In addition, the internal

balance of plant hormones such as abscisic acid (ABA) and cytokinins is crucial to the phase transition and root development (Wang *et al*., 2005; Tsu *et al*., 2008). It is suggested that the first two growth stages may happen faster under tropical circumstances, after which a lengthy period of root bulking occurs (Wilson and Lowe 1973b; Lewthwaite, 2004).

2.8 Importance of Sweet Potato

The starchy roots and immature leaves are the most significant plant components of sweet potato. These are used for human consumption, feed for animals and for industrial purpose (Laurie *et al.,* 2004, Mukhopadhyay *et al.,* 2011). China, the world's leading producer of sweet potatoes, utilizes 40% for its animal feed products, while Brazil and Madagascar, respectively, use 35% and 30% (Laurie *et al.,* 2004).

Due to its flexibility in a number of manufacturing elements, sweet potato is considered to be the tropics most significant root crop (Mukhopadhyay *et al.,* 1990). At any moment of the year, it can be planted and harvested, particularly in freezing fields. It has a brief crop season, utilizes non-edible components as planting material, and has a non-trellising growth habit and low soil nutrient requirement (Martin, 1985). Woolfe (1992) also indicated producing more edible energy than any other significant crop of meat. It is more productive on marginal lands within brief periods of time and plays a major part in bad household's economies (Mukhopadhyay *et al.,* 2011).

Laurie (2004) and Manamela (2009) indicated that starchy plants like sweet potato are the staple food in some African nations, while other nations use it as an extra crop or food safety crop. The latter use is consistent with previous Ebregt *et al.,* (2007) claims that sweet potato storage roots have often been held in the ground and harvested when necessary. This is an indication that sweet potato has no necessity for costly storage infrastructure to provide a constant supply of

food during off season. It becomes seasonally essential in the diet, typically one or two months before the significant grain harvest or when the past year's grain inventory was exhausted. It also offers a food reserve if the main grain crop fails owing to drought and infestation with pests. Orange-fleshed sweet potato (OFSP) flour has been used to enrich infant meal, the misola, with microbiological parameters being monitored. The newly acquired bio-fortified flour formulation provided dietary characteristics that contribute to the regeneration of protein-energy and enhancement of the immune status of mild malnourished children.

2.9 Nutrient Requirements of Sweetpotato

Sweet potato is often regarded a bad soil-related crop. This is likely because it is well suited for often infertile sandy soils and because the output of tuber in very fertile soils is sometimes low. However, excellent yield can only be achieved under elevated but balanced nutritional circumstances. Sweet potato, like other root crops, has a strong potassium requirement relative to nitrogen.

2.9.1 Nitrogen

Various study findings stated that the root output improved with N implementation (George and Mitra, 2001). High N, however, promotes vine growth rather than root storage. For sweet potato root production, a moderate dose of 50-75 kg N ha^{-1} is optimal (Nair *et al.*, 1996; Sebastiani *et al.,* 2006; Biswal, 2008). Sometimes higher N concentrations depress root yield (Hartemink, 2003). The combined use of fertilizer N and any of the organic manures to supply 50% of each of the suggested N generated the highest output of plant and root storage compared to other N management methods (Nedunchezhiyan and Reddy, 2002). Azospirillum (free-living bio-fertilizer) inoculation was found to enhance root yield storage (Desmond and Hill, 1990) quality (Nedunchezhiyan *et al.,* 2004) and soil fertility status in sweetpotato fields (Nedunchezhiyan and

Reddy, 2004). Azospirillium replaces requirements of one-third N and decreases farming costs (Nedunchezhiyan and Reddy, 2002).

Sweetpotato cultivars differ significantly in the nitrogen level needed to maximize output, and in their tendency to lower yields at greater nitrogen concentrations. Specifically, adverse nitrogen reactions are more prevalent in cultivars produced in fields with low fertility where soil amendments are not traditionally used. Use of 60 kg N ha^{-1} improved yields of three U.S. cultivars but reduced yields of three African cultivars. Positive nitrogen reactions are often acquired in West African soils on soils that have been strongly cultivated in the past, or on soils that are subject to severe leaching. However, if other nutrient deficiencies such as potassium are ignored and left untreated, the reaction to nitrogen may be poor (Hill and Bacon, 1984). Sweetpotato tends to react better to plant material composts that contain elevated potassium relative to nitrogen than to potassium-lower animal manures. This, however, relies on the soil's nutrient equilibrium (Halavatau *et al.*, 1996).

When root tubers and vines are harvested, a 20 t ha^{-1} sweet potato crop removes about 87 kg N ha^{-1}. The optimum fertilization speed will rely on the quantity of plant nitrogen available in the soil and the yield potential that can be dictated by the water and rainfall available in the soil. Reported nitrogen fertilizer suggestions for sweetpotato are usually between 30 and 90 kg N ha^{-1} (De Geus, 1967). Over fertilization with nitrogen can result in lower yields as it can encourage excessive development of the vine at the cost of the root tubers. Deficiency in nitrogen is sometimes associated with soil waterlogging. Soil bacteria rapidly transform soil nitrate into nitrogen gas (N_2) under anaerobic conditions, which is lost to the atmosphere. Improved drainage can be accomplished by raising the height of ridges or mounds, maintaining clear of weeds the troughs between them, and offering appropriate channels for surplus water to leave the field.

Sweetpotato is susceptible to waterlogging, and the crop tends to perform badly if waterlogging happens even for a short time, especially in the early phases of plant development. Good drainage is therefore needed irrespective of the supply of nitrogen. Improved plant nutrition with nitrogen also contributes to greater protein levels in root tubers, and this can be of significant importance in societies that get much of their protein from plants (sweetpotatoes). For development, reproduction and photosynthesis, plants need nitrogen. Nitrogen (N) was not as efficient in growing sweetpotato yields in most fields studied as other fertilizers (potassium or phosphorus). Too much nitrogen could lead to excessive development of the vine, cracked skin tubers and bad storage properties (Masciancia *et al.*, 1985; Walker and Woodson, 1987).

2.9.2 Phosphorous

Phosphorus (P) as a major plant nutrient is generally essential for plant respiration, photosynthesis, cell division, energy storage and early crop maturity. Phosphorus is vital for transferring energy to crops and helps to grow early and mature crops, including flowering. Phosphorus tends to boost starch synthesis, but rather than delay maturity, in comparison to N. Sweetpotato crops with phosphorus deficiency typically generate tubers with reduced specific gravity compared to those with sufficient P nutrition. Adequate P can assist counteract the low specific gravity of elevated N concentrations. Like nitrogen, phosphorus during the yield boost period increases the carotene content of tuberous roots and also impacts the unit weight of root tubers (Degras, 2003). The reaction of sweet potato to phosphorus is very small. A dose of 25 - 50P_2O_5 per ha^{-1} is considered optimum for sweet potato (Akinrinde, 2006; Sebastiani *et al.*, 2006). The comparative efficacy of rock phosphate as a source of P to sweet potato was in direct impact equivalent to single super phosphate but in residual value higher than that (Kabeerathumma *et al.,* 1986). Most studies have shown that there is no important impact of

phosphorus on growing sweetpotato output. For example, Degras (2003) reported using N and K at all rates, adding P did not lead to improved yield increases.

2.9.3 Potassium

Potassium is a main component of carbohydrate synthesis and translocation from top to root (Byju and Nedunchezhiyan, 2004). Like all other tuber plants, sweet potatoes have elevated potassium fertilizer requirements (Raemaekers, 2001). K is needed for effective use of water in the crop, reduces its sugar content and disease tolerance, and adds to early development, water and nutrient use, protein manufacturing, and enhanced disease resistance, according to Foth (1978). It is also very important in the status of plant energy, translocation and storage of assimilates and maintenance of tissue water relationships (Marschner, 1995). Sweetpotatoes are recommended for a moderate dose of 75 - 100 kg K_2O (Mukhopadhyay *et al.*, 1990; Nair *et al.*, 1996; John *et al.*, 2001). It has been shown to be an important fertilizer for sweetpotatoes. In Ghana, potassium applications significantly improved sweetpotato yield Applications were produced at 30 -30 - 0, 30 -30 -30 and 30 – 30 - 60 NPK ratios, with 8.75, 12.3 and 14.4 respectively enhanced returns in t / ha (CRI-CSIR, 2003). In China, however, sweetpotato reacts to very high K2O ha-1 levels of 300 kg (George *et al.*, 2002). With enhanced concentrations of K, quality attributes such as starch and protein content have been discovered to improve (Biswal, 2008). Total root output with K supply has been reported to rise, but the magnitude depends on the original K rate (Hammett *et al.*, 1984). Nicholaides *et al.*, (1981) demonstrated that distinct concentrations of K fertilizer had no important impact on both the weight of the vine and the length of the vine. In a field research on K impact on yield, Zhi (1991) found that with enhanced K implementation, complete root yields were important. The 120 kg K_2O ha^{-1} therapy yielded the largest output of 21.4 t ha^{-1} while O kg K2O ha^{-1} (control) yielded 17.7 t ha^{-1}. However,

Constantin *et al.,* (1977) did not establish any important distinction between the concentrations of K fertilizers in harvest index and dry matter. According to the study, differences however exist among varieties. Villareal (1982) advocates for a far higher K level compared to N for maximum sweetpotato yield as increasing N rates tend to decrease root yield. Increased starch content reduced firmness of canned root and enhanced crude fiber content was accomplished through K implementation, according to Hammett and Miller (1982). Hammett and Miller (1982) further noted that K application did not influence the carotene content, ascorbic acid concentrations and soluble sweetpotato carbohydrate concentrations. Perrenoud (1993) have indicated that K nutrition influences tuber quality, tuber size, specific gravity, susceptibility to black spot bruises, after cooking darkening, reducing sugar level, fry color and storage quality. Perrenoud (1990) indicated that K increases plant resistance to disease through enhancing the health and vigor of the plant. According to him, around infected locations of resistant crops, K improves the production of disease inhibitory compounds such as phenols, phytoalexins and auxins. Perrenoud (1993) also discovered potassium fertilizers to reduce the incidence of illnesses such as late blight. Bergmann (1992) stated that K encourages the thickening of the cell wall and the development of meristematic tissues thus stopping the epidermis from penetrating parasites. Its deficiency according to Kiraly, (1976), increases inorganic N accumulation and the breakdown of phenols that have fungicidal properties. To avoid excessive potash requests in the late season is essential. Starch synthesis and specific gravity boost to an optimum tuber concentration of 1.8 percent with growing K concentration. However, specific gravity declines at greater levels of K as root tubers start to absorb more water because of the osmotic impacts of enhanced levels of tissue salt (Dahnke *et al.,* 1992).

2.9.4 Temperature

Although sweetpotato is cultivated in the world's tropical, subtropical and hot temperate areas, it is mainly a hot climate plant (Onwueme, 1978; Belehu, 2003) and therefore susceptible to low temperatures. The crop is revealed to have been unable to sustain temperatures below 12^{o} C, to survive at 15^{o} C but not to develop (Harter and Whitnet, 1962; Belehu, 2003). Growth risen above 15^{o} C to 35^{o} C at 38^{o} C (Harter and Whitnet, 1962; Belehu, 2003). The thermal optimum is recorded to be above 24^{o} C (Kay, 1973; Belehu, 2003) and ordinary root production was recorded for 5 months from sweetpotato elevated to 27^{o} C in the growth chamber (Liu and Cantliffe, 1984; Schultheis *et al.,* 1994). Higher temperature (> 28^{o} C) diverts photosynthate partitioning to fibrous roots compared to root storage (Eguchi *et al.,* 2003; Ravi *et al.,* 2009).

2.10 Sweet potato utilization

Both the storage root and the leaves are edible to humans as one of the most nutritious food safety plants. Storage roots can be cooked, cooked or cooked with some individuals eating them raw (Laurie and Niederwieser, 2004). The leaves are used as vegetables and are rich in vitamins and other essential minerals also includes chromogenic acids, a phenolic compound that suppresses human obesity (Williams *et al.,* 2013). Due to the polyphenol-rich green extracts reported to have a function in decreasing prostate cancer, sweet potato leaves may potentially have some medicinal characteristics (Karna *et al.,* 2011). According to reports from China, the world's leading producer of sweet potatoes, they also use sweet potato for starch production and as raw material for biofuel manufacturing (Woolfe, 1992; Liu, 2011). Red sweet potato plant sap (juice) has also been revealed to play a crucial role in South America's manufacturing of dye for cloth. Another non-nutritious use of sweet potato owing to its appealing foliage is its esthetic value (Anon, 2011).

2.11 Nutritional value

The root of sweetpotato storage offers on its own a balanced diet. It can supply nearly all the nutrients the human body needs. Woolfe (1992) reported containing important quantities of carbohydrates relative to other starchy plants such as rice, corn and porridge sorghum, although the protein content is slightly smaller than in vegetables and other grain plants. It includes nearly all the macro and micro nutrients, significant amounts of vitamin C, mild amounts of complicated vitamin B (Vitamin B_1, B_2, B_5 and B_6) and folic acid, as well as adequate amounts of vitamin E (Walter *et al.,* 1983; Laurie, 2004). Several writers have reported that orange-fleshed sweet potato contains elevated quantities of vitamin A and are presently being promoted as a complementary food by the Food and Agriculture Organization (FAO) and other in-country programs to combat childhood vitamin A deficiencies (Kulembeka *et al.*,2004; Ebregt *et al.,* 2007, Amagloh *et al.,* 2011).

Also nutritious are sweet potato leaves, which are a decent source of protein and vitamins A, C and B2 (riboflavin). Sweet potato leaf protein content is twice that of the storage roots, according to Laurie (2004). Khachatryan *et al*., research (2003) found the leaves to be an outstanding source of lutein. Lutein is accountable for the human eye's core vision and helps protect the eyes from oxidative stress and high-energy blue light photons. Sweetpotato is also popular in low fat diets and is recommended as a low glutamate index (GI) food (Podsedek, 2007). Therefore, sweet potato dietary content and the role it can play in addressing the present low nutrition status in Nigeria's agro-ecological areas positions sweet potato in a very significant food production category.

2.12 Sweetpotato as a Food Security Crop

The world is estimated to generate enough food to feed all its individuals, but about 30% of the inhabitants of Sub-Saharan Africa (218 million people) are still suffering from acute starvation and malnutrition (Mbabu and David, 2012). Food security is based on three pillars, food accessibility, food access and food use (use and stability), according to the World Health Organization (WHO, 2013). Increasing food prices, especially maize and wheat, which are the staple diet for the poor in most of the African region, pose severe issues and danger of hunger to urban and rural poor individuals who are net food buyers (Altman *et al.,* 2009).

On the other side, sweet potato is regarded an outstanding crop for food safety as it often survives where other plants (e.g. corn) fail (Low *et al.,* 2007). It contributes to food security by improving rural livelihoods (Yngve *et al*., 2009), especially those involved in small scale agriculture. It contributes to food availability by providing high output per unit of land (yields about 3.9 – 9.5 t ha^{-1} under communal agriculture compared to 3 t ha^{-1} reported for maize under similar management) and can produce on marginal soils. The fact that it has greater power (Woolfe, 1992) than corn derivatives also contributes to its potential role as a plant for food safety. Good health is regarded an outcome indicator for food use in the measurement of food safety (FAO, 2013), and the elevated dietary status of sweet potato qualifies the crop as an option to food safety. Improved early cultivars are often prepared for harvest within 3 to 5 months and can be harvested over several months as required (Mbabu and David, 2012). The benefit of harvesting early and consuming over several months implies that there is a quick turn over and lasting source of food, therefore improved food access, availability and stability. The food security benefits of sweet potato mentioned above can also lead to the crop being removed from

the ‘underutilized’ category since it would have caught the eye of the consumers and will be utilized accordingly.

It is also easy to access sweet potato because it is easy to store or multiply the vines and roots. Storage roots can be sprouted in drought-prone fields to generate vines in order to give communities access to planting material. Sweet potato was often a life-saver, according to Lebot (2009), when typhoons demolished all their rice fields just before the First World War, it saved the Japanese nation. During the early 1960s, China was attacked by famine and sweet potato saved millions of the population from starvation. When cassava was attacked and destroyed by an unknown virus in the 1990s, sweet potato provided food for the Ugandan rural communities (CIP, 2012a).This is proof that, as many writers have mentioned, sweet potato is indeed a food safety crop (Ebregt *et al.,* 2007 ; Amagloh *et al.,* 2011 ; CIP 2012b).

2.13 Orange Fleshed Sweetpotato and Vitamin A Deficiency

There is increasing consensus that lowering undernutrition and micronutrient deficiencies in specific is an immediate concern for growth that affects more than one-third of the worldwide population (Allen *et al.,* 2006). Micronutrient deficiencies have a huge impact on human health and well-being and hamper financial efficiency (Haddad, 2013). As part of attempts to accelerate the decrease of undernutrition across a spectrum of industries, specific interest is placed in ways to reshape agricultural and food systems, acknowledging that agricultural development has failed to drive increased dietary diversity among the poor in many nations (Headey, 2012). In reaction, a body of proof emerges on ' linking agriculture and nutrition ' through a variety of approaches, including introducing fresh crop varieties, enhancing circumstances for farm employees, and raising awareness of government nutrition (Ruel and Alderman, 2013). Prominent among these

strategies is bio fortification: the breeding of new crop varieties with enhanced micronutrient profiles, along with efforts to increase their production and consumption.

Although vital to preventing disease, disability and death among vulnerable populations, interventions that focus on increasing micronutrient intake through a single mechanism, such as supplementation, are tenuous if not paired with complementary approaches such as food fortification and dietary diversification In nations where chronic malnutrition is widespread food-based approaches that emphasize a broad range of vitamin-rich foods are critical to decreasing life-changing and often deadly micronutrient deficiencies (Jenkins, *et al.*, 2015). The most commonly cultivated sweetpotato varieties in Nigeria are white and yellow/orange-fleshed and in most of Sub-Saharan Africa, white-fleshed varieties dominate and contain no beta-carotene. Initiatives have been launched to encourage the development and consumption of beta-carotene-rich orange-fleshed sweetpotato varieties (a carotenoid or plant pigment responsible for the orange colour of some tuber varieties) and to assist combat vitamin A deficiencies (EPAR, 2012). About 80% of individuals consume diets that provide less than half of the RDA (Recommended Dietary Allowance) for iron and vitamin A (NNMB, 2000). Orange-fleshed sweetpotato (OFSP) as a staple food has an advantage over most vegetables in that it can supply significant amounts of vitamin A and energy simultaneously, thus helping to address both Vitamin A deficiency and undernutrition. OFSP is an example of a bio-fortified crop where the micronutrient status of staple foods is enhanced by plant breeding to the point where impact can be achieved on micronutrient status (Bouis, 2002). Since the poorest households typically obtained over 60% of their energy needs from food staples, this strategy is particularly suited to poor rural households that cannot access purchased fortified food products but could grow OFSP. Since the implementation of Vitamin A for Africa (VITAA) from 2001 to 2006, OFSP

interventions have focused on women and children as target beneficiaries due to their vulnerability to Vitamin A Deficiency and due to women's role in the production and marketing of sweet potato. Based on its sensory and agronomic features, OFSP has not only been shown to be extremely acceptable to humans, but its implementation into societies has shown that vitamin A consumption among children has increased dramatically (Low *et al.,* 2007a). The intensity of the orange color reflects the amount of beta-carotene present in the sweetpotato. On a fresh weight basis, light orange varieties contain at least 250 Retinol Activity Equivalent RAE/100gms (30 μg/g), medium-intensity varieties at least 458 RAE/100 gms (55 μg/g) and dark orange varieties at least 833 RAE/100 gms (100 μg/g). The recommended daily intake for healthy children aged two and five is 400 RAE and 500 RAE, respectively, to bring stuff into view (Institute of Medicine, 2001, Low *et al.,* 2009). The intake requirements of a young kid are met by 1/4 to 1 cup of boiled and mashed sweetpotato, depending on the color intensity of the OFSP type used and taking into account losses during cooking (about 20 percent through boiling).

Vitamin A is an important micronutrient for human health and its deficiency in developing nations or the world is common among young kids. It is estimated that around 127 million kids under the age of six are impacted globally (West, 2002). Sub-Saharan Africa (SSA) and India have the highest estimated prevalence rates of sub-clinical vitamin A deficiency. Deficiency of vitamin A can reduce development, weaken immunity, because blinding exophthalmia, and boost mortality (Low *et al.,* 2009). There are two kinds of vitamin A available in foods: preformed retinol (vitamin A itself) typically found in animal foods such as eggs, liver and milk ; and pro vitamin A carotenoids found in plant products such as dark green leafy vegetables, yellow and orange vegetables and fruits, and orange fleshy sweet potatoes (McLaren and Frigg, 2001). The major pro vitamin A carotenoid is β-carotenoid, and is the dominant carotenoid in orange-fleshed

sweetpotato. Low income families typically cannot afford to consume the highly bioavailable animal foods on a regular basis. High deficiency levels of significant micronutrients (vitamin A, iron [Fe], and zinc [Zn]) are prevalent among bad people who eat plant-based diets (Hess *et al.*, 2005). One possible solution for addressing vitamin A deficiency in this area is through a food based approach, using orange-fleshed sweet potato as an inexpensive source of beta-carotene (the pre-cursor to vitamin A). The development and use of beta carotene rich OFSP roots deserves unique consideration in any sweetpotato project due to the pressing need to tackle extensive vitamin A deficiency in Sub Saharan Africa.

Compelling evidence is available of the potential contribution of OFSP to improved nutrition. To evaluate potential health and economic impact, economists estimate the number of vitamin A deficiency (VAD) related to Disability Adjusted Life Years (DALYs) that could potentially be saved through the use of bio fortified sweetpotato. Results show that the VAD burden could be lowered in 17 nations where sweetpotato is commonly cultivated only by replacing white-fleshed with orange-fleshed variants (Stein *et al.,* 2005). Depending on the beta-carotene content of the variety, the amount of orange-fleshed sweet Potato root needed to meet the recommended daily allowance for vitamin A in adults and children is about 100 grams per day. The quantity required for yellow-fleshed varieties is 100-120 grams per day. Some of the CIP-tested varieties contain up to 8,000 micrograms of beta-carotene/100 grams, almost four times the quantity needed (Sreenkanth and Dindo, 2010). Semba and Bloem (2002) showed a beneficial impact of vitamin A supplements or vitamin A-fortified foods in kids, pregnant females and lactating females. There is significantly less evidence of interactive impacts between vitamin A and zinc (Hess *et al.,* 2005).

2.14 Sweet Potato for Combating Vitamin A Deficiency

Highly nutritious (Woolfe, 1992; Kruger *et al.,* 1998; Laurie, 2010) are its storage roots (raw and boiled). In addition, elevated quantities of β-carotene, a precursor to vitamin A, are reported to contain orange-fleshed sweetpotato. The content of β-carotene rises with the depth of sweetpotato flesh in orange color (Laurie, 2004).

Low, *et al.,* (2007a) indicated studies in sub-Saharan Africa have shown that consumption of cooked orange-fleshed sweetpotato has enhanced children's vitamin A status. A distinct research by Amagloh *et al.,* (2011) verified that orange-fleshed sweet potato is high in vitamin A and can be used in infant feeding as a supplementary food. In order to enhance the consumption of this wealthy form of sweetpotato vitamin A, Laurie *et al*., (2012) further prepared different kinds of food (chips, doughnuts, sweets and a leafy green plate) from orange-fleshed sweetpotato to determine the acceptability of the customer.

2.15 Constraints to Sweetpotato Production

2.15.1 Biotic constraints

Many biotic limitations such as viral diseases, insect pests and weeds affect sweetpotato manufacturing (Harrison and Jackson, 2011; Lou *et al.,* 2010; Ndunguru *et al.,* 2009; Schafleitner *et al.,* 2010). Diseases and insects of paramount importance are sweetpotato virus diseases and sweetpotato weevils, respectively (Kivuva *et al*., 2014b). Sweetpotato virus disease (SPVD) induced by dual infection and synergistic interaction of chlorotic sweetpotato stunt virus and feathery sweetpotato mottle virus is spread globally (Gibson *et al.,* 1998; Mukasa *et al.,* 2006). It is the most destructive disease that causes plant growth and root returns to be reduced (Gibson, 2005; Gibson *et al.,* 2004; Gibson *et al.,* 1997; Kapinga *et al.,* 2009; Karyeija *et al.,* 2000). Also SPVD limits the length of time the roots can be kept in the ground and shorten the

storage duration of the harvested crop (Engoru *et al*., 2005; Tsakama *et al*., 2010). SPVD harm varies from 50% to 98% (Gibson *et al.,* 1998; Njeru *et al.,* 2004; Tairo *et al.,* 2004). On the other side, Cylas spp., sweetpotato weevils, is another significant restriction of sweetpotato manufacturing (Kapinga *et al.,* 2003b; Munyiza *et al.,* 2007, Stathers *et al.,* 2003). The weevils tunnel and feed on vines and storage roots thereby reducing the quality and yield of the crop (Stathers *et al*.,1999). The yield losses from weevils ' infestation can be as large as 100 percent, according to Stanthers *et al.,* (1999). In addition, under dry circumstances, infestation rates are highest owing to many cracks that appear when the soil dries (Muyinza *et al.,* 2007). Other biotic limitations such as millipedes, *Alternaria* leaf spot, stem blight, black rot, *fusarium* rot, bacterial rot, nematodes and vertebrate pests such as rats are also a threat to the manufacturing of sweetpotatoes (Ebregt *et al.,* 2004; Johanson and Ives, 2001; Kapinga *et al.,* 1995). Additionally, when elevated rainfall happens early in the growing season, weeds can cause serious yield losses (Harrison and Jackson, 2011).

2.15.2 Abiotic constraints

Low soil fertility and drought include abiotic limitations that have a significant impact on sweetpotato manufacturing (Kapinga *et al.,* 1995; Mihale *et al.,* 2009; Mwololo *et al.,* 2007; Pareek *et al.,* 2010). Declining soil fertility restricts the production of sweetpotatoes as their replenishment is limited by inorganic fertilizer prices that are not affordable (Elliott and Hoffman, 2010; Mudiope *et al.,* 2000). In addition, degraded and depleted soils reduce the effectiveness of applied fertilizers. Continuous cultivation without adding organic and inorganic manures has resulted in a decrease in soil fertility and subsequently a decrease in productivity (Saleh and Zahor, 2007).

Drought is a major abiotic constraint that limits the productivity of not only sweetpotatoes but also many other plants and impacts both yield quality and yield amount (Balouchi, 2010; Collins *et al.,* 2008). Kivuva *et al*. (2014b) reported that, 28% of 345 farmers interviewed identified drought as a major constraint in sweetpotato production in Kenya. Although sweetpotato is reported to be tolerant of drought, prolonged and frequent dry periods and erratic rainfall causes significant decrease in yields (Johanson and Ives, 2001; Liwenga and Kangalawe, 2009; Schafleitner *et al.,* 2010). Drought impacts not only plant growth and development, but also root yield, content and structure of dry matter, and incidence of pests and disease incidence (Ekanayake and Collins, 2004 ; Masumba *et al.,* 2005 ; Mcharo and Carey, 2001). In the case of drought, Mwololo *et al.,* (2007) recorded an enhanced incidence and severity of viral sweetpotato diseases. For example, in addition to low dry matter content and susceptibility to viral diseases, the freshly introduced orange fleshed sweetpotato (OFSP) has been unable to resist drought, resulting in low productivity and farmers being unacceptable (Mwanga and Ssemakula, 2011). Sweetpotato varieties less tolerant to drought significantly retard the efforts invested by farmers making them unpopular and subsequently rejected. Gibson (2005) reported that the participatory sweetpotato breeding and selection trials were ruined by drought and farmers rejected the less drought tolerant varieties. Therefore, together with other constraints, the production of sweetpotato is also significantly affected by drought leading to low productivity.

2.15.3 Socio-economic constraints

There are several socio-economic limitations affecting the production of sweetpotatoes. These include insufficient accessibility of high yields, disease resistant materials for planting, poor or no fertilization and weeding, and absence of post-harvest techniques (Kulembeka *et al*., 2005;

Mpagalile *et al*., 2003; Mudiope *et al*., 2000; Mwololo *et al*., 2007; Ndunguru *et al*., 2009; Rees *et al*., 1998; Schafleitner *et al*., 2010; Tairo *et al*., 2005). Using infected, low yielding planting materials substantially contributes to the persistence of viral sweetpotato illnesses (Mwololo *et al.,* 2007, Opiyo *et al.,* 2010). Inadequate extension services limits dissemination and adoption of improved husbandry practices. As a result, farmers continue to grow informally disseminated inferior planting materials that not only cause disease persistence but also adversely impact crop efficiency and profit (Kapinga and Carey, 2003 ; Fugile, 2007). Similarly, the bad connection between farmers and other stakeholders combined with undeveloped and fragmented rural infrastructure considerably reduces crop efficiency (Kapinga and Carey, 2003; Waddington *et al.,* 2010). In addition, insufficient post-harvest techniques such as storage and processing techniques have a serious impact on crop investment, manufacturing and sustainability (Fugile, 2007; Hu *et al.,* 2011; Mpagalile *et al.,* 2003; Waddington *et al.,* 2010).

Furthermore, the absence of high yield sweetpotato varieties with preferred characteristics of farmers leads to low manufacturing (Karuri *et al.,* 2009). High yield and preferred varieties of farmers are the foundations for enhanced productivity and sustainable crop growth. Presently, most farmers use local landraces. Though adapted to local agro-ecologies, the landraces are low yielding and late maturing (Gibson *et al*., 1998; Masumba *et al*., 2005). Likewise, sweetpotato is one of the most under-exploited plants and there are comparatively early breeding initiatives relative to other plants such as corn, rice and cassava (Gasura *et al.,* 2010; Kriegner *et al.,* 2003). In the past, attempts were made to use exotic varieties in various agro-ecologies to address low productivity and circumvent pest and disease damages (Gasura *et al*., 2010; Kapinga *et al*., 2009). However, the exotic varieties showed comparatively bad performance relative to the well-adapted landraces to the farming schemes (Gasura *et al.*, 2010). Mwanga *et al*. (2007) and

Mwanga and Ssemakula (2011) reported almost 100% failure of the newly introduced orange-fleshed sweetpotato in Uganda. On the other side, comparatively comparable local unimproved performance has been recorded and improved varieties have been introduced for both yield and adaptability to various agro-ecologies (Mbwaga *et al.*, 2007). This underpins the need for further sweetpotato research and development.

2.16 Management of SweetPotato Viruses

The perception of sweetpotato in Africa as a crop for the poor, predominantly cultivated by females, has many consequences for crop cultivation (Karyeija *et al.*,1998a; Owour, 2000). Traditional cultivation procedures such as piecemeal harvesting and the free exchange of planting material between adjacent landowners ensure that virus infected material is distributed and perpetuated (Karyeija *et al.*, 1998a). Farmers obtain planting materials from mature crops which are normally not virus free and on which pesticides are rarely used (Karyeija *et al.*, 1998a; Owour, 2000).

Managing sweet potato viruses will involve understanding of the viruses ' etiology and ecology. Information is missing among resource-poor farmers on virus control and how viruses infect crops (Jericho, 1999). African farmers use three primary control methods to restrict SPFMV impacts: (a) selection of SPVD-resistant crops, (b) use of disease-free planting material and (c) removal of all infected crops (Clark and Moyer, 1988 ; Karyeija *et al.*, 1998a). There has been no success in managing the spread of sweet potato viruses by regulating the vectors (Clark and Moyer, 1988). Both SPFMV and SPCSV and other sweet potato viruses can be controlled using virus free material and controlling weeds, which may serve as alternative hosts of insects and viruses, especially wild *Ipomoea* spp. in and around fields (Joubert *et al., 1974;* Bolton and du Plooy, 1984; Thompson and Mynhardt, 1986; Karyeija *et al.*, 1998a). The removal of fresh

plants from ancient mature plants will decrease the incidence of viruses and result in elevated yield plants (Gibson and Aritua, 2002). By delaying the initiation and buildup of SPVD vectors (Ndunguru and Alyoce, 2000), the use of intercropping to decrease the number of infectious vectors attacking the sweetpotato crop can assist to decrease SPVD incidence. A sweetpotato/maize cropping pattern was found to have a lower SPVD incidence and it can be an option to reduce SPVD damage in the traditional sweetpotato farming system (Ndunguru and Alyoce, 2000). By removing voluntary sweetpotato plants that may have survived from prior crops and planting resistant varieties, viral diseases may be minimized (Joubert *et al.,* 1974; Bolton and du Plooy, 1984; Thompson and Mynhardt, 1986 ; Karyeija *et al.,* 1998a).

The development of transgenic sweetpotato plants can be another method of controlling sweetpotato viruses (Owour, 2000). Although the transgenic lines can still be affected by SPFMV-RC through grafting with SPFMV-RC infected.

2.17 Pest Control

A fallow period should follow each crop to prevent build-up of soil-borne pests and diseases. Planting a green manure crop after harvest helps to suppress any regrowth and weeds as well as improving soil structure, and is essential for the long-term health of the soil.

2.17.1 Sweetpotato Weevil

This is the most serious pest of sweet potato. Adults are ant-like and lay eggs on stems and roots. The larvae burrow into the roots, making them unmarketable. They can pupate in the stems and be transferred in planting material. Once established in a crop, this pest is difficult to control. Research (1993 Soil insect control trial) has shown that a pre-plant treatment of cuttings with chloropyrifos combined with foliar applications of chloropyrifos at 5 and 10 weeks from planting provides significant control. Planting material collected from an infected crop would require

insecticide dipping before planting. Destroying all crop residues after harvest and crop rotations are the best ways to keep weevil numbers down.

2.17.2 Giant Termite

Termites can be a major problem, especially on newly cleared ground where the activity of established colonies has not been identified. Avoiding known termite-infested areas may be successful in the short term. Aggregation techniques to locate and concentrate termite activity followed by a baiting programmer is the best way to clear future planting areas of this pest.

2.17.3 Other pests

Leaf-feeding caterpillars may cause problems if infestation is severe enough to cause significant leaf reduction. At the start of the wet season, hungry and destructive birds such as magpies and geese can cause serious damage by trampling crops and eating the roots. Black-footed tree rats are also a problem.

2.18 Disease Control

Mycoplasma (little leaf disease)

Infected plants have small, pale-yellow, stunted leaves and stems. The infection is spread by leafhoppers and if plants are infected while young, yields are greatly reduced. Control is by regular monitoring for symptoms and the removal and destruction of infected plants.

2.18.1 Fungal diseases

Soil-borne fungal diseases can infect the roots but are not a large problem on well-drained, sandy soils. Any organic matter added to the soil should be well decomposed before planting.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Location

The experiment was conducted at the Teaching and Research Farm of the School of Agriculture and Agricultural Technology, Federal University of Technology Owerri Imo state, Nigeria in April 2016 and repeated in 2017 cropping seasons. The site is located between latitudes $07^0$02'N and longitude $06^0$29'E at a height of 55m above sea level Hand-held Global Positioning System (GPS) receiver. Owerri is within the rainforest zone of Nigeria which ecologically is characterized with more than 2500mm annual rainfall, 27^0C – 32^0C average minimal and maximum annual temperatures and 86% - 91% relative humidity. The soil of the study area is infertile and therefore termed an ultisol (Onweremadu, *et al.,* 2007).

3.2 Agronomic Practices

3.2.1 Soil sample collection before and after the experiment

Random soil samples were taken from different locations in the experimental field to the depth of 25cm with soil auger in 2016 and 2017 planting seasons respectively. These samples were bulked and thoroughly mixed together to obtain a uniform soil sample. The collected soil samples were air dried in the laboratory, and sieved using a 2mm-mesh sized sieve pan. From the soil samples, physical and chemical analysis was performed. After the experiment soil samples were collected on plot by plot basis. Plots carrying the same treatments were collected from different blocks, bulked, thoroughly mixed together and prepared for analysis.

3.2.2 Land preparation

The experimental field was manually cleared, stumped using the available traditional implements such as machetes, rakes and spades and the trash packed. The area was mapped out using meter tape and sticks of 1m length. Experimental plots measured 3.0m x 3.0m with 2m alleys between blocks, plots and guard area round the experimental field. Experimental field measuring 15m x 39m was used

3.3 Experimental Design

The experiment was a 3 x 3 factorial fitted into a randomized complete block design (RCBD) giving 9 treatments and replicated 3 times. With the three (3) replicates i.e. blocks, ridges were made in each block for planting of the sweetpotato vines and placements of the fertilizer treatments. The 9 treatments were randomized within each block among the plots within the 3 blocks giving a total of 27 treatment plots.

3.3.1 Treatments

The treatments comprised of factors A and B. Factor A being orange fleshed sweetpotato propagules cuttings of 2, 4 and 6 nodes respectively while factor B represents 3 manure sources which include No manure (control),NPK 15:15:15 kg ha^{-1} fertilizer and Poultry manure 10 t ha^{-1}.

3.3.2 Planting Materials

The Orange-fleshed sweetpotato variety (king-j) cultivar were used in the experiment in 2016 and 2017 planting seasons respectively. The vines were obtained from the sweetpotato multiplication farm of the National Root Crop Research Institute, Umudike Abia State. (NRCRI)

3.3.3 Planting

The vines were cut at 2, 4 and 6 nodes intervals. The vine cuttings were planted 30cm within rows and 100cm between ridges in 2016 and 2017 respectively.

Table 3.1 Field Layout

Block 1	T1	T2	T3	T4	T5	T6	T7	T8	T9
Block 2	T6	T7	T1	T9	T4	T3	T2	T5	T8
Block 3	T3	T8	T5	T2	T6	T1	T7	T9	T4

TI 2 nodes + control
T2 4 nodes + poultry manure
T3 6 nodes + control
T4 2 nodes + NPK
T5 6 nodes + poultry manure
T6 2 nodes + poultry manure
T7 6 nodes + NPK
T8 4 nodes + NPK
T9 4 nodes + control

3.3.4 Weeding

Weeding was done manually at 2 and 4 weeks after planting in 2016 and 2017 planting seasons.

3.3.5 Fertilizer Application

Organic fertilizer (poultry manure 10 t ha^{-1}) and inorganic fertilizer (NPK 15:15:15 400 kg ha^{-1}) was incorporated into the soil after ridge making. Planting of vines was done one week after manure incorporation in 2016 and 2017 respectively.

3.4 Soil Sample Analysis

Soil pH was determined in a 1:1 soil/water suspension using a glass electrode pH meter (Udo *et al*., 2009). Particle size analysis was done by Buoyoucos (Hydrometer) method reported by Udo, *et al*., (2005), for the determination of percentages of sand, silt and clay respectively.

Organic carbon determination was done on 2g samples by the dichromate wet oxidation method of Walkley and Black as out lined by Udo, *et al*., (2005). The macrokjeldahl method (Udo, *et al*., 2005) was used to determine the % nitrogen (N) in soil samples which was air-dried and sieved through 0.5mm mesh. The bray P-I method was used to extract available phosphorus. The exchangeable cation was determined on extracts obtained after leaching the samples with IM neutral ammonium acetate (IM NH_4OA P^H 7.0) solution. Exchangeable potassium and sodium contents were estimated on flame photometer, while calcium and magnesium were determined by versenate (0.1 M) Ethylene diamine tetra acetate (EDTA) titration method. Effective cation exchange capacity (ECEC) was obtained by summation of exchangeable cations and acidity (IITA, 1993) while base saturation was estimated by expressing the sum of exchangeable cation as a percentage of ECEC values.

3.5 Data Collection

Data were collected in 2016 and 2017 planting seasons respectively, based on the following parameters:

3.5.1 Stand count: The stand count was determined by taking physical count of surviving and dead plants per plot at 2 and 4 weeks after planting and at harvest.

3.5.2 Vine length (cm): The sweetpotato vine length was measured using a measuring tape placed from the ground to the tip of the vine at 6, 8 and 10 weeks after planting.

3.5.3 Vine girth (mm): The vine girth was measured using a veneer caliper placed round the girth and read off at 6, 8 and 10 weeks after planting.

3.5.4 Number of leaves: The number of leaves was obtained by counting the number of leaves at 6, 8 and 10 weeks after planting.

3.5.5 Number of branches: This was determined by physical counting of the secondary branches on the vine at 6, 8 and 10 weeks after planting.

3.5.6 Disease Severity Assessment: This is the measurement of the proportion of the roots affected by a disease in a sample/plot. This was done at 4, 8 and 12 weeks after planting to make sure there was a significant disease appearance. Disease severity for sweetpotato root was estimated using the observation and scoring (The proportion of sweetpotato root affected by disease was measured by counting the number of roots with symptom divided by the total number of roots, both healthy and unhealthy roots multiply by 100) according to the method described by Ford and Hedwitt (1980) and recorded in 2016 and 2017 planting seasons respectively.

3.5.7 Number of Tubers: At the final harvesting (4 Months), all plants from the net plot area were harvested. The number of unmarketable tuberous roots was determined by counting the number of tuberous roots having the weight of less than 100 g as well as those that were blemished. Similarly, the number of marketable tuberous roots was determined by counting those having the weight of 100 g and above. The number of total tuberous roots was determined by adding up the values of the two tuberous root categories (Mohammed *et al*., 2011).

3.5.8 Total Fresh Tuber Yield kg ha^{-1}: The total fresh yields of tuberous roots were determined by combining the weights of the marketable and the unmarketable tuberous root fresh yields.

3.5.9 Weight of Marketable Tuber Yield (kg ha^{-1}): The marketable fresh yields of tuberous roots were determined by weighing the marketable tuberous root categories separately. (Mohammed *et al*., 2011)

3.5.10 Weight of Unmarketable Tuber Yield (kg ha^{-1}): The unmarketable fresh yields of tuberous roots were determined by weighing the tuberous root number categories separately (Mohammed *et al*., 2011)

3.5.11 Statistical Analysis

Growth and yield data of sweetpotato were statistically analyzed using analysis of variance (ANOVA). Means were separated using Fishers Least Significant difference at $LSD_{0.05}$ at 5% probability level.

Table 3.2: Disease Severity Assessment

Severity (%)	Scale	Interpretation
0	0	No infection
1-20	1	Slight infection
21-40	2	Moderate infection
41-60	3	Extensive infection
61-80	4	Very extensive infection
81-100	5	Roots completely infected

The proportion of sweetpotato root affected by disease was measured by counting the number of roots with symptom divided by the total number of roots, both healthy and unhealthy roots multiply by 100 (Ford and Hedwitt., 1980).

CHAPTER FOUR
RESULTS AND DISCUSSIONS

4.1 Results

4.1.1 Characterization of poultry manure

Results revealed that poultry manure used in the experiment contained 36.4cmolkg^{-1} of calcium, 4.80cmolkg^{-1} phosphorus, 15.50cmolkg^{-1} potassium, 4.5% of nitrogen and P^{H} was 8.12.

4.1.2: Weather records

Weather records for 2016 and 2017 cropping season presented in Table 4.1 revealed that temperature during planting time was 31.40^{o}C and 31.60^{o}C in April and during harvesting of sweetpotato was 29.95^{o}C and 29.50^{o}C, in August 2016 and 2017 respectively. Lowest and highest temperature of 29.80^{o}C and 32.60^{o}C was recorded in July and January and 0.00^{o}C and 32.50^{o}C in December and March 2016 and 2017 respectively. Highest rainfall of 293.00mm and 295.00mm was recorded in October 2016 and 2017 respectively.

Table 4.1: Weather data for Owerri in 2016 and 2017 respectively.

MONTHS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
(2016)												
Temp (^{o}C)	32..60	32.50	32.60	31.40	31.00	30.50	29.80	29.95	30.00	30.50	30.60	32.00
Rainfall (mm)	0.00	2.60	96.30	93.00	192.80	276.00	276.40	279.60	284.00	293.00	186.00	0.00
Raindays	2.00	4.00	5.00	7.00	16.00	22.00	20.00	21.00	25.00	24.0	10.00	3.00
(2017)												
Temp (^{o}C)	32.30	32.40	32.50	31.60	31.3	30.20	29.70	29.50	30.50	30.30	30.80	0.00
Rainfall (mm)	0.26	11.00	101.50	171.60	188.30	283.30	279.80	293.60	290.60	295.00	186.00	0.00
Raindays	2.00	5.00	6.00	8.00	18.00	24.00	22.00	20.00	27.00	26.00	14.00	0.00

Source: ADP (2016 and 2017)

4.1.3: Evaluation of the physio-chemical properties of the soil at the beginning and end of the experiment for the two planting seasons.

4.1.3.1 Soil pH

The results obtained from the evaluation of the physio-chemical properties of the soil at the beginning and the end of the experiment for the two seasons are presented in Table 4.2 and 4.3 respectively. The results showed that the experimental site before the commencement of the experiment was acidic with p^H of 4.99 and 5.91 and at the end of the experiments, the p^H value of the soil became slightly acidic 5.72 and 6.22 in plots where NPK. The lowest value of 5.14 and 5.59 were obtained from plots treated with 4 nodes + control during the 2016 and 2017 planting season experiments respectively.

4.1.3.2 Organic carbon (%)

Organic carbon was drastically reduced in the plots where sweetpotato 6 node cuttings was fertilized with poultry manure 10 t ha^{-1} from (1.35, 1.28) before the commencement of the experiment to the lowest value of (0.94, 0.57) while the highest value of (1.28, 0.78) was obtained from plots treated with 4 nodes + NPK after the 2016 and 2017 planting season experiment respectively.

4.1.3.3 Organic matter (%)

Organic matter build up at the commencement of the experiment was 2.32, 1.62 which was depleted at the end of the 2016 and 2017 season plantings in the range of (2.20 - 1.67) and (1.62 – 1.19) respectively

4.1.3.4 Total Nitrogen (%)

Total nitrogen at the beginning of the experiment was (0.13, 0.12) which was depleted to the lowest value of (0.09, 0.07) obtained from plots treated with 6 nodes + poultry manure while the

highest value of (0.12, 0.09) was obtained from 4 nodes + NPK treated plots at the end of the 2016 and 2017 planting season experiment. The control however had 0.089% total nitrogen.

4.1.3.5 Potassium (meq/100g soil)

The initial value of Potassium at the commencement of the experiment was 0.02meq/100g soil which was depleted to the lowest value of 0.008meq/100g soil in plots treated with 6 nodes + control, although plots treated with 6 nodes + NPK had the value of 0.014%, while the highest value of 0.03% was obtained from the plots that were treated with 4 nodes + NPK. The result obtained from the 2017 planting season experiment revealed further depletion of Potassium. The lowest value of 0.004 was obtained in plots treated with 6 nodes + control.

4.1.3.6 Available phosphorus (ppm)

There was an increase in phosphorous from 7.21 ppm to 8.68 ppm in plots that were treated with 6 nodes + NPK, 8.40ppm with 2 node cuttings + poultry manure and 8.19 ppm with 4 nodes cutting + NPK during the 2016 planting season experiment. At the end of the 2017 planting season, plots treated with 4 nodes + NPK had the highest value of 3.45ppm while the control had the lowest value of 1.07ppm.

4.1.3.7 Exchangeable acidity

The initial value of Exchangeable acidity at the beginning of the experiment was (0.432, 1.28) in 2016 and 2017 respectively, the highest value of (1.28, 1.29) was obtained from the plots that were treated with 4 nodes + NPK in 2016 and 2017 respectively.

4.1.3.8 ECEC

ECEC at the beginning of the experiment was 3.95, 3.03 which were depleted to the lowest value of 1.87,1.47 obtained from plots treated with 4 nodes + control while the highest value of 4.29, 4.09 was obtained from 4 nodes + poultry manure treated plots in 2016 and 2017 respectively.

4.1.3.9 Soil physical properties

The % sand in the experiment showed a build up from 91.16% before the experiment to 93.16% at the end of experiment in 4 nodes cuttings + NPK and 6 nodes + NPK. The lowest % of sand (90.16) was observed with 2 nodes + control and 4nodes + control. Also at the end of the 2017 planting season, the % sand was further depleted to the lowest value of 90.16 in plots treated with 4 nodes + poultry manure while the highest value of 92.16 was obtained from 4 nodes + NPK treated plots. The percentage clay increased by 1% in soils that received 4 nodes + poultry manure, 6 nodes + control, 2 nodes +NPK, and 6 nodes + NPK. There was a decrease by 1% (3.64) in the treatment with 4 nodes + control while the other treatments did not affect the clay content of the soil. During the 2017 planting season, the treatments did not influence the % clay. The initial value of % silt at the beginning of the experiment was 4.20% which was depleted to the lowest value 2.20% with treatment 2 nodes + control while the highest value of 5.20% was obtained from the plots that were treated with 4 nodes + NPK.

Table 4.2: Evaluation of the physiochemical properties of the soil before treatment application and at harvest (2016)

SAMPLE	PH H_2O	O.C %	O.M %	N %	AP %	Ca++ (meg/100g) Soil	Mg++ (meg/100g) Soil	Na++ (meg/ 100g) Soil	K+ (meg/ 100g) Soil	Exchangeable Acidity	ECEC	SAND PSD %	CLAY	SILT PSD %
Before treatment application														
	4.99	1.347	2.322	0.130	7.21	2.00	1.47	0.030	0.018	0.432	3.95	91.16	4.64	4.20
At Harvest														
T_1	5.31	1.137	1.960	0.110	6.93	1.44	1.60	0.039	0.010	0.672	3.761	90.16	4.64	2.20
T_2	5.23	1.127	1.943	0.118	3.71	2.16	1.60	0.030	0.016	0.480	4.286	91.16	5.64	3.20
T_3	5.66	1.197	1.926	0.118	3.57	1.32	1.20	0.023	0.008	0.432	2.983	91.16	5.64	3.20
T_4	5.17	1.77	2.029	0.115	6.51	0.48	0.73	0.028	0.015	0.864	2.117	92.16	5.64	3.20
T_5	5.55	0.938	2.201	0.099	6.58	0.88	0.67	0.030	0.014	0.848	2.382	92.16	4.64	4.20
T_6	5.35	1.177	2.029	0.105	8.40	2.48	1.07	0.042	0.023	0.448	4.006	92.16	4.64	3.20
T_7	5.72	1.117	2.064	0.112	8.68	0.52	0.47	0.037	0.014	1.152	2.193	93.16	5.64	4.20
T_8	5.19	1.277	1.617	0.124	8.19	1.76	0.67	0.047	0.028	1.280	3.033	93.16	4.64	5.20
T_9	5.14	1.257	2.167	0.120	5.25	0.40	0.13	0.034	0.021	0.512	1.865	90.16	3.64	3.20

Key: AP -Available Phosphorous, BF-Before the Experiment, AF-After experiment, EA- Exchangeable Acidity, ECEC-Effective Cation Exchange Capacity, Tmts- Treatments, PM- Poultry Manure, NPK- NPK15:15:15, Control =0, T_1-2 nodes + control, T_2-4 nodes + poultry manure, T_3-6 nodes + control, T_4-2 nodes + NPK, T_5- 6 nodes + poultry manure, T_6- 2 nodes + poultry manure, T_7- 6 nodes + NPK, T_8- 4 nodes + NPK, T_9- 4 nodes + control

Table 4.3: Evaluation of the physio chemical properties of the soil at harvest (2017)

SAMPLE	PH H_2O	O.C %	O.M %	N %	AP Ppm	Ca++ (meg/100g) Soil	Mg++ (meg/100g) soil	Na++ (meg/ 100g) Soil	K+ (meg/ 100g) Soil	Exchangeable Acidity	ECEC	SAND PSD %	CLAY	SILT PSD %
Before treatment application														
	5.91	1.28	1.62	0.12	8.19	1.76	0.67	0.050	0.030	1.28	3.033	93.16	4.64	5.20
At harvest														
T_1	5.78	0.73	1.188	0.088	1.07	0.84	2.34	0.034	0.010	0.682	3.261	90.26	4.54	3.22
T_2	5.69	0.71	1.618	0.094	1.53	1.25	2.34	0.029	0.006	0.490	4.086	90.16	5.34	3.10
T_3	6.16	0.76	1.517	0.094	1.47	0.77	1.19	0.021	0.004	0.462	2.383	91.26	5.34	3.22
T_4	5.63	1.08	1.491	0.092	2.68	0.28	0.72	0.025	0.013	0.874	2.017	92.06	5.34	3.10
T_5	6.03	0.57	1.441	0.079	2.70	0.51	0.66	0.025	0.013	0.898	2.082	91.16	4.44	4.21
T_6	5.82	0.72	1.491	0.084	2.83	1.44	1.06	0.040	0.023	0.458	3.006	92.06	4.34	3.10
T_7	6.22	0.68	1.416	0.089	3.37	0.30	0.45	0.031	0.013	1.192	2.093	91.16	5.34	4.21
T_8	5.64	0.78	1.428	0.099	3.45	1.02	0.65	0.043	0.024	1.290	2.033	92.16	4.34	2.22
T_9	5.59	0.77	1.593	0.096	2.16	0.23	0.11	0.031	0.020	0.552	1.465	91.16	3.34	5.10

Key: AP -Available Phosphorous, BF-Before the Experiment, AF-After experiment, EA- Exchangeable Acidity, ECEC-Effective Cation Exchange Capacity, Tmts- Treatments, PM- Poultry Manure, NPK- NPK15:15:15, Control =0, T_1-2 nodes + control, T_2-4 nodes + poultry manure, T_3-6 nodes + control, T_4-2 nodes + NPK, T_5- 6 nodes + poultry manure, T_6- 2 nodes + poultry manure, T_7- 6 nodes + NPK, T_8- 4 nodes + NPK, T_9- 4 nodes + control

4.1.4 Effects of manure sources and propagule node number on sweetpotato stand count at 2 and 4 weeks after planting and at Harvest in 2016 and 2017.

The results obtained from the evaluation of the effects of manure sources and propagule node number on sweetpotato stand count in 2016 and 2017 planting seasons respectively are presented in Table 4.4. The result showed that sources of manure did not have significant ($p>0.05$) effect on the number of sweetpotato stand count at 2 and 4 weeks after planting and at harvest during the 2016 and 2017 planting seasons. There was also no ($p>0.05$) significant interaction effect of number of nodes x manure source on sweetpotato stand count. Furthermore, Table 4.4 revealed that at harvest, manure source, number of nodes per cutting and number of node per cutting x manure interaction showed no significant effect on number of sweetpotato stand. At 4 weeks after planting, 2, 4 and 6 nodes with 10 t ha^{-1} poultry manure produced 27.67, 30.00 and 27.00 stands which on the average was higher than the number of stands obtained in 2016. 2 nodes with 400 kg ha^{-1} NPK had 27.67 sweetpotato stands while 4 and 6 nodes with 400 kg ha^{-1} NPK had 30.00 sweetpotato stands each. Also 2 and 4 nodes with zero manure application had 25.00 stands each while 6 nodes without manure application had 24.00 stands which were slightly higher than the values obtained in 2016.

The stand count at harvest showed that 4 nodes with 10 t ha^{-1} poultry manure had the highest value of 28.33 while 6 and 2 nodes with 10 t ha^{-1} poultry manure had 27.33 and 26.33 stands slightly higher than the number of stands produced in 2016 planting season. .

Table 4.4: Effect of manure sources and propagule node number on sweet potato stand count at 2 and 4 weeks after planting and at harvest in 2016 and 2017.

Number of nodes	Manure sources 2016			Mean	Manure sources 2017			Mean
	Poultry manure 10,000 t ha^{-1}	NPK 400 kg ha^{1}	Control 0		Poultry manure 10,000 t ha^{-1}	NPK 400 kg ha^{1}	Control 0	
Stand count at 2 WAP								
2	25.33	26.67	22.00	**24.67**	27.33	28.67	25.00	**27.00**
4	29.67	29.33	23.33	**27.44**	30.00	30.00	25.00	**28.33**
6	28.67	29.33	22.67	**26.89**	30.00	30.00	24.00	**28.00**
Mean	**27.89**	**28.44**	**22.67**		**29.11**	**29.56**	**24.67**	
Stand count at 4 WAP								
2	25.67	25.67	22.67	**25.67**	27.67	27.67	25.00	**26.78**
4	29.33	28.67	23.00	**27.00**	30.00	30.00	25.00	**28.33**
6	25.00	29.00	22.00	**25.33**	27.00	30.00	24.00	**27.00**
Mean	**26.67**	**27.78**	**22.55**		**28.22**	**29.22**	**24.67**	
Stand count at harvest								
2	24.33	26.33	21.33	**23.10**	26.33	28.33	25.00	**26.55**
4	26.33	24.33	20.00	**23.55**	28.33	26.33	25.00	**26.55**
6	25.33	27.33	20.00	**24.22**	27.33	29.33	25.00	**27.22**
Mean	**25.33**	**25.10**	**20.44**		**27.33**	**27.10**	**25.00**	
$LSD_{0.05}$ Number of node	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	
$LSD_{0.05}$ Manure	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	
$LSD_{0.05}$ Number of node x manure	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	

4.1.5 Effect of manure sources and propagule node number on Number of Sweetpotato Leaves at 6, 8 and 10 weeks after planting in 2016 and 2017.

The result obtained from the evaluation of the effect of manure sources and propagule node number on number of sweetpotato leaves at various stages of growth in 2016 and 2017 planting seasons of the experiment are respectively represented in (Table 4.5). The number of nodes and the manure interaction did not significantly influence the number of leaves of sweetpotato at 6, 8 and 10 WAP in 2016 and 2017, while the different manure sources significantly influenced the sweetpotato leaves at 6, 8 and 10 weeks after planting in 2016 and 2017 respectively.

Result also revealed that 400 kg ha^{-1} NPK recorded the highest number of sweetpotato leaves 124.90, 134.90 followed by plots applied with 10 t ha^{-1} poultry manure 104.30, 114.30 while control (no manure) had the lowest number of sweetpotato leaves 17.00, 25.00 in 2016 and 2017 respectively.

Table 4.5: Effect of manure sources and propagule node number on sweet potato leaves at 6, 8 and 10 weeks after planting in 2016 and 2017.

Number of nodes	Manure sources 2016			mean	Manure sources 2017			Mean
	Poultry manure 10,000 t ha^{-1}	NPK 400 kg ha^{-1}	Control 0		Poultry manure 10,000 t ha^{-1}	NPK 400 kg ha^{-1}	Control 0	
Number of leaves at 6 WAP								
2	36.30	42.40	17.00	**31.90**	46.30	52.40	25.00	**41.23**
4	54.30	74.90	19.80	**49.67**	64.30	84.00	27.80	**58.70**
6	70.30	46.00	17.50	**44.60**	80.30	56.00	25.50	**53.93**
Mean	**53.63**	**54.43**	**18.10**		**63.63**	**64.43**	**26.10**	
Number of leaves at 8 WAP								
2	25.00	29.00	27.00	**26.66**	35.00	39.00	35.00	**36.33**
4	79.30	99.90	34.80	**71.30**	89.30	109.90	42.80	**65.03**
6	61.30	71.00	34.50	**55.60**	71.30	81.00	42.50	**64.93**
Mean	**55.20**	**66.63**	**32.10**		**65.20**	**76.60**	**40.10**	
Number of leaves at 10 WAP	25.33	27.33	25.00	**25.89**	35.33	38.33	33.00	**35.55**
2	104.30	124.90	59.80	**96.30**	114.30	134.90	67.80	**105.67**
4	86.30	96.00	59.50	**80.60**	96.30	106.00	67.50	**89.93**
6	**71.10**	**82.74**	**48.10**		**81.10**	**92.74**	**56.10**	
Mean								
$LSD_{0.05}$ Number of node	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	
$LSD_{0.05}$ Manure	**20.02**	**20.02**	**19.46**		**25.01**	**22.50**	**21.01**	
$LSD_{0.05}$ Number of node x manure	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	

4.1.6 Effect of manure sources and propagule node number on Number of Sweetpotato Branches at 6, 8 and 10 weeks after planting in 2016 and 2017.

The result obtained from the evaluation of manure sources and propagule node number on sweetpotato branches at various stages of growth in 2016 and 2017 planting season experiments represented Table 4.6. Results of the investigation showed that manure sources was statistically significant on the number of sweetpotato branches at 5 % probability level in 2016 and 2017 respectively. However, propagule node number as well as its interaction with manure sources was not statistically significant at 5 % probability level in 2016 and 2017 respectively.

Result also revealed that 400 kg ha^{-1} NPK recorded the highest number of sweetpotato branches 9.00, 12.00 followed by plots applied with 10 t ha^{-1} poultry manure 8.67, 11.52 when control (no manure) had the lowest number of sweetpotato branches 0.00, 1.00 in 2016 and 2017 respectively.

Table 4.6: Effect of manure sources and propagule node number on sweetpotato branches at 6, 8 and 10 weeks after planting in 2016 and 2017.

Number of nodes	Manure sources 2016			Mean	Manure sources 2017			Mean
	Poultry manure 10,000 t ha^{-1}	NPK 400 kg ha^{1}	Control 0		Poultry manure 10,000 t ha^{-1}	NPK 400 kg ha^{1}	Control 0	
Number of branches at 6								
WAP	1.47	3.00	1.73	**1.73**	3.47	4.50	1.73	**3.23**
2	1.33	2.73	0.00	**1.36**	3.33	4.23	1.00	**2.85**
4	2.67	1.73	0.00	**1.47**	4.67	3.23	1.00	**2.10**
6	**1.82**	**2.49**	**0.24**		**3.82**	**3.99**	**1.24**	
Mean								
Number of branches at 8								
WAP	4.00	6.00	2.73	**4.24**	6.00	7.50	3.73	**5.74**
2	4.33	5.73	1.40	**3.82**	6.33	7.23	2.40	**5.32**
4	5.67	4.73	2.87	**4.42**	7.67	13.46	3.87	**8.33**
6	**4.67**	**5.49**	**2.33**		**6.67**	**9.40**	**3.33**	
Mean								
Number of branches at 10								
WAP	7.33	7.73	5.40	**7.30**	10.01	10.53	7.30	**9.84**
2	7.47	9.00	4.40	**6.82**	10.23	12.00	6.20	**9.15**
4	8.67	8.73	5.87	**7.42**	11.52	11.23	6.76	**9.60**
6	**7.82**	**8.49**	**5.22**		**10.59**	**11.25**	**6.75**	
Mean								
$LSD_{0.05}$ Number of node	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	
$LSD_{0.05}$ Manure	**1.93**	**1.94**	**1.74**		**2.17**	**2.05**	**1.72**	
$LSD_{0.05}$ Number of node x manure	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	

4.1.7: Effect of manure sources and propagule node number on Number of Sweetpotato Vine Length (cm) at 6, 8 And 10 weeks after planting in 2016 and 2017.

Result on effect of manure sources and propagule node number on vine length (cm) of sweetpotato showed that manure sources as well as propagule node number were statistically significant on sweetpotato vine length at 5% probability level in 2016 and 2017 respectively. However, interaction of manure sources with propagule node number was not statistically significant at 5 % level of probability. Table 4.7.

Propagule with 6 nodes recorded highest vine length 99.90, 109.90 followed by propagule with 4 nodes 92.40, 84.60 while propagule with 2 nodes recorded lowest 77.10, 81.30 at 6 WAP in 2016 and 2017 respectively. 400 kg ha^{-1} NPK had the highest vine length 100.40, 109.40 while control (no manure) recorded the lowest 23.30, 31.30 in 2016 and 2017 respectively.

Table 4.7: Effect of manure sources and propagule node number on sweet potato vine length (cm) at 6, 8 and 10 weeks after planting in 2016 and 2017.

Number of nodes	Manure sources 2016			Mean	Manure sources 2017			Mean
	Poultry manure 10,000 t ha^{-1}	NPK 400 kg ha^{1}	Control 0		Poultry manure 10,000 t ha^{-1}	NPK 400 kg ha^{1}	Control 0	
Vine length at 6 WAP								
2	27.10	34.10	23.30	**28.10**	37.10	43.10	31.30	**37.17**
4	42.40	50.40	26.60	**39.80**	52.40	59.40	34.60	**48.80**
6	49.90	53.80	33.50	**45.70**	59.90	62.80	41.50	**54.73**
Mean	**39.80**	**46.10**	**27.80**		**49.80**	**55.10**	**35.80**	
Vine length at 8 WAP								
2	52.10	59.10	43.30	**60.50**	62.10	68.10	51.30	**60.50**
4	67.40	75.40	51.60	**73.80**	77.40	84.40	59.60	**73.80**
6	74.90	78.80	58.50	**79.73**	84.90	87.80	66.50	**79.73**
Mean	**64.80**	**71.10**	**51.13**		**74.80**	**80.10**	**59.13**	
Vine length at 10 WAP								
2	77.10	84.10	73.30	**78.10**	87.10	93.10	81.30	**87.17**
4	92.40	100.40	76.60	**89.80**	102.40	109.40	84.60	**98.80**
6	99.90	95.70	83.50	**93.03**	109.90	104.70	91.50	**102.03**
Mean	**89.80**	**93.40**	**77.80**		**99.80**	**102.40**	**85.80**	
$LSD_{0.05}$ Number of node	**10.83**	**9.30**	**10.83**		**12.01**	**11.50**	**11.02**	
$LSD_{0.05}$ Manure	**10.83**	**9.30**	**10.83**		**11.23**	**10.50**	**10.90**	
$LSD_{0.05}$ Number of node x manure	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	

4.1.8: Effect of manure sources and propagule node number on sweetpotato vine girth (mm) at 6, 8 and 10 weeks after planting in 2016 and 2017.

Table 4.8 shows the effect of manure sources and propagule node number on sweetpoato vine girth showed that there was no statistical differences existing on manure source, propagule node number as well as its interaction with manure source at 5% probability level in 2016 and 2017 respectively at 6, 8 and 10 weeks after planting.

Table 4.8: Effect of manure **sources and propagule node number on sweet potato vine girth (mm) at 6, 8 and 10 weeks after planting in 2016 and 2017.**

Number of nodes	Manure sources 2016			Mean	Manure sources 2017			Mean
	Poultry manure 10,000 t ha^{-1}	NPK 400 kg ha^{1}	Control 0		Poultry manure 10,000 t ha^{-1}	NPK 400 kg ha^{1}	Control 0	
Vine girth at 6 WAP								
2	1.80	1.70	1.00	**1.50**	3.80	3.20	2.00	**3.00**
4	1.86	1.76	1.86	**1.83**	3.86	3.26	2.86	**3.33**
6	2.16	2.16	2.23	**2.18**	4.16	3.66	3.23	**3.68**
Mean	**1.94**	**1.87**	**1.70**		**3.94**	**3.37**	**2.70**	
Vine girth at 8 WAP								
2	2.50	2.33	1.90	**2.24**	4.50	3.83	2.90	**3.74**
4	2.50	2.33	2.50	**2.44**	4.50	3.83	3.50	**3.94**
6	2.66	2.73	2.90	**2.76**	4.66	4.23	3.90	**4.26**
Mean	**2.55**	**2.46**	**2.43**		**4.55**	**3.96**	**3.43**	
Vine girth at 10 WAP								
2	2.66	2.50	0.16	**1.77**	4.66	4.00	1.16	**3.27**
4	2.50	2.33	0.66	**1.82**	4.50	3.83	1.66	**3.33**
6	2.66	2.73	0.90	**2.10**	4.66	2.90	1.90	**3.15**
Mean	**2.61**	**2.52**	**0.57**		**4.61**	**3.58**	**1.57**	
$LSD_{0.05}$ Number of node	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	
$LSD_{0.05}$ Manure	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	
$LSD_{0.05}$ Number of node x manure	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	

4.1.9: Effect of manure sources and propagule node number on the bacterial blight disease severity of sweetpotato at 4, 8 and 12 weeks after planting in 2016 and 2017.

The result obtained from the evaluation of effect of manure sources and propagule node number on the bacterial blight disease severity of sweetpotato is presented in Table 4.9. Result on blight disease severity revealed that node number, manure source as well as interaction of node number and manure source were statistically significant on leaf blight disease severity at 5% probability level in 2016 and 2017 respectively.

Propagule with 6 nodes recorded statistically significant lowest blight severity (1.69, 1.99) followed by propagule with 2 nodes (2.06, 2.36) while propagule with 4 nodes had highest (2.18, 2.48) in 2016 and 2017 respectively. 400 kg ha^{-1} NPK recorded lowest blight severity (1.19, 1.49) followed by poultry manure (1.90, 2.20) while control (no manure) had the highest (2.83, 3.13) in 2016 and 2017 respectively.

Interaction of NPK kg ha^{-1} consistently recorded low leaf blight disease severity when compared with any other interaction. Interaction of propagules with 2 nodes with control had high leaf blight (3.23, 3.53) followed by 2 nodes with poultry manure (1.07, 2.17) while 2 nodes with NPK had (1.87, 1.37). Also interaction of propagules with 4 nodes with control had (3.47, 3.77) which was high followed by 4 nodes with poultry manure (1.80, 2.23) and 4 nodes interaction with NPK was low 1.13, 1.43 in 2016 and 2017 respectively.

Propagule with 6 nodes interaction with control was also high (1.80, 4.89) followed by 6 nodes interaction with poultry manure (1.90, 2.20) while 6 nodes interaction with NPK was low (1.37, 1.67) in 2016 and 2017 respectively. The result showed that interaction of 4 nodes with 400 kg ha^{-1} NPK had lowest blight severity (1.13, 1.43) of all the interaction while interaction of propagules with 4 nodes and control (no manure) (3.47, 3.77) had statistically highest blight severity of all other interactions in 2016 and 2017 respectively. Result also showed that blight disease severity increased with plant age.

Table 4.9: Effect of manure **sources and propagule node number on the bacterial blight disease severity of sweetpotato at 4, 8 and 12 weeks after planting in 2016 and 2017.**

Number of nodes	Manure sources 2016			Mean	Manure sources 2017			Mean
	Poultry manure 10,000 t ha^{-1}	NPK 400 kg ha^{-1}	Control 0		Poultry manure 10,000 t ha^{-1}	NPK 400 kg ha^{-1}	Control 0	
Bacteria blight at 4 WAP								
2	1.20	0.70	2.50	**1.47**	1.50	1.00	2.80	**1.77**
4	1.10	0.70	2.30	**1.37**	1.40	1.00	2.60	**1.67**
6	0.90	1.00	1.40	**1.10**	1.20	1.30	1.70	**1.40**
Mean	**1.07**	**0.80**	**2.07**		**1.37**	**1.10**	**2.37**	
Bacteria blight at 8 WAP								
2	1.70	1.00	2.90	**1.87**	2.00	1.30	3.20	**2.17**
4	1.90	1.20	3.50	**2.20**	2.20	1.50	3.80	**2.50**
6	1.80	1.30	1.60	**1.57**	2.10	1.60	1.90	**1.87**
Mean	**1.80**	**1.17**	**2.67**		**2.10**	**1.47**	**2.97**	
Bacteria blight at 12WAP								
2	2.70	1.50	4.30	**2.83**	3.00	1.80	4.60	**3.13**
4	2.80	1.50	4.60	**2.97**	3.10	1.80	4.90	**3.27**
6	3.00	1.80	2.40	**2.40**	3.30	2.10	2.70	**2.70**
Mean	**2.83**	**1.60**	**3.76**		**3.13**	**1.90**	**4.06**	
$LSD_{0.05}$ Number of node	**0.82**	**1.52**	**0.25**		**1.12**	**1.82**	**0.55**	
$LSD_{0.05}$ Manure	**0.74**	**1.65**	**0.65**		**1.04**	**1.95**	**0.95**	
$LSD_{0.05}$ Number of node x manure	**0.71**	**1.45**	**0.55**		**1.01**	**1.75**	**0.85**	

4.1.10: Effect of manure sources and propagule node number on sweet potato leafspot disease severity in 2016 and 2017.

The result obtained from the evaluation of manure sources and propagule node number on leafspot disease severity is presented in Table 4.10. Result revealed that manure source, node numbers as well as interaction of manure sources with node numbers were statistically significant at 5 % probability level in 2016 and 2017 planting season respectively. Result on propagule node number revealed that 2 nodes recorded the highest leafspot disease severity (2.08, 2.37) followed by propagules with 4 nodes (2.18, 2.48) while that of 6 nodes (1.69, 1.99) had the lowest leafspot disease severity in 2016 and 2017 respectively.

Plots applied with 400 kg ha^{-1} NPK recorded the lowest leafspot disease severity (1.19, 1.48) followed by poultry manure applied plots (2.23, 2.23) while control (no manure) (2.76, 2.97) was the highest. Interaction of 4 nodes with control had the highest leafspot disease severity while propagule with 4 nodes interaction with 400 kg ha^{-1} NPK had the lowest leafspot disease severity in 2016 and 2017 respectively. Investigation also revealed that leafspot disease severity increased with age of the plant.

Table 4.10: Effect of manure sources and propagule node number on the leafspot disease severity of sweetpotato at 4, 8 and 12 weeks after planting in 2016 and 2017.

Number of nodes	Manure sources 2016			Mean	Manure sources 2017			Mean
	Poultry manure 10,000 t ha^{-1}	NPK 400 kg ha^{1}	Control 0		Poultry manure 10,000 t ha^{-1}	NPK 400 kg ha^{1}	Control 0	
Leaf spot at 4 WAP								
2	1.20	0.70	1.70	**1.20**	1.50	1.00	2.00	**1.50**
4	1.30	0.70	1.80	**1.27**	1.60	1.00	2.10	**1.57**
6	1.10	0.80	1.20	**1.03**	1.40	1.10	1.50	**1.33**
Mean	**1.20**	**0.73**	**1.57**		**1.50**	**1.03**	**1.87**	
Leaf spot at 8 WAP								
2	1.80	1.20	3.50	**2.17**	2.10	1.50	3.80	**2.47**
4	1.70	1.10	3.30	**2.03**	2.00	1.40	3.60	**2.33**
6	1.90	1.40	1.60	**1.63**	2.20	1.70	1.90	**1.93**
Mean	**1.80**	**1.23**	**3.07**		**2.10**	**1.53**	**3.10**	
Leaf spot at 12WAP								
2	3.70	1.60	4.20	**2.87**	3.10	1.90	4.50	**3.17**
4	2.90	1.40	3.90	**2.73**	3.20	1.70	4.20	**3.03**
6	2.70	1.70	3.70	**2.40**	3.00	2.00	3.10	**2.70**
Mean	**3.70**	**1.50**	**3.63**		3.10	1.87	3.93	
$LSD_{0.05}$ Number of node	**0.31**	**0.65**	**0.05**		**0.61**	**0.95**	**0.35**	
$LSD_{0.05}$ Manure	**0.71**	**1.22**	**0.09**		**1.01**	**1.52**	**0.21**	
$LSD_{0.05}$ Number of node x manure	**0.90**	**1.03**	**0.05**		**1.20**	**1.33**	**0.25**	

4.1.11: Effect of manure sources and propagule node number of sweet potato on number of tubers, total marketable and unmarketable tuber in 2016 and 2017.

The result obtained from the evaluation of the effect of manure sources and propagule node number on sweetpotato number of tubers, total marketable and unmarketable tubers is presented in Table 4.11. Results showed that there was no statistically significant effect on the manure source, propagule node number as well as interaction of manure source and propagule node number at 5 % probability level in 2016 and 2017 respectively.

The marketable tuber of sweetpotato produced by 2, 4 and 6 nodes with 10 t ha^{-1} poultry manure are (8.40, 10.90), (8.43, 10.93) and (8.55, 11.05) respectively during the 2016 and 2017 planting seasons respectively. 4 nodes with NPK produced the highest marketable tuber sweetpotato (6.86, 8.86), followed by 2 nodes (6.68, 8.68) and the least was produced from 6 nodes (5.00, 7.00) in 2016 and 2017 respectively. The control without manure application produced total marketable tuber of sweetpotato (6.71, 9.71), (8.42, 11.42) and (8.49, 11.49) from 2, 4 and 6 nodes respectively in 2016 and 2017.

The unmarketable tuber of sweetpotato obtained in 2016 and 2017 season showed that 2 nodes with 10 t ha^{-1} poultry manure produced the highest unmarketable tuber of sweetpotato (7.27, 9.77) higher than 4 and 6 nodes which produced (7.20, 9.70) and (6.97, 9.47) tubers in 2016 and 2017 respectively. Also 6 nodes with NPK produced the highest value of (10.66, 12.66) unmarketable sweetpotato tubers when it was compared with 2 and 4 nodes which produced (8.84, 10.84) and (9.20, 11.20) tubers in 2016 and 2017 respectively. However, 2 nodes without manure application (control) produced (8.60, 11.60), followed by 4 nodes (7.13, 10.13) and 6 nodes (6.99, 9.99) in 2016 and 2017 respectively. Tuber yield was highest with NPK 400 kg ha^{-1} followed by poultry manure 10 t ha^{-1} while 0 (control) was the lowest in 2016 and 2017 planting seasons.

Table 4.11: Effect of manure **sources and propagule node number of sweet potato on number of tubers, total marketable and unmarketable tubers in 2016 and 2017.**

Number of nodes	Manure sources 2016			Mean	Manure sources 2017			Mean
	Poultry manure 10,000 t ha^{-1}	NPK 400 kg ha^{1}	Control 0		Poultry manure 10,000 t ha^{-1}	NPK 400 kg ha^{1}	Control 0	
Total number of tubers								
2	15.67	15.31	15.30	**15.43**	18.17	18.30	17.31	**17.93**
4	15.64	16.06	15.54	**15.75**	18.14	18.54	18.06	**18.25**
6	15.52	15.66	15.39	**15.52**	18.02	18.39	17.66	**18.02**
Mean	**15.61**	**15.68**	**15.41**		**18.11**	**18.41**	**17.68**	
Yield of marketable tuber								
2	8.40	6.68	6.71	**7.26**	10.90	8.68	9.71	**9.76**
4	8.43	6.86	8.42	**7.90**	10.93	8.86	11.42	**10.40**
6	8.55	5.00	8.49	**7.35**	11.05	7.00	11.49	**9.85**
Mean	**8.46**	**6.18**	**7.87**		**10.87**	**8.18**	**10.87**	
Yield of unmarketable tuber								
2	7.27	8.84	8.60	**8.24**	9.77	10.84	11.60	**10.74**
4	7.20	9.20	7.13	**7.84**	9.70	11.20	10.13	**10.34**
6	6.97	10.66	6.99	**8.21**	9.47	12.66	9.99	**10.71**
Mean	**7.15**	**9.57**	**7.57**		**9.65**	**11.57**	**10.57**	
$LSD_{0.05}$ Number of node	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	
$LSD_{0.05}$ Manure	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	
$LSD_{0.05}$ Number of node x manure	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	

4.1.12: Effect of manure sources and propagule node number on total fresh tuber yield, weight of marketable and unmarketable tubers in 2016 and 2017.

The result obtained from the evaluation of the effects of manure sources and propagule node number on total fresh tuber yield, weight of marketable and unmarketable tubers is presented in Table 4.12. This result showed that propagule node number as well as its interaction with fertilizer source was not statistically significant at 5% probability level in 2016 and 2017 respectively. However, manure source was statistically significant at 5 % level of probability in 2016 and 2017 respectively. Investigation revealed that plots applied with 10 t ha^{-1} poultry manure recorded statistically the highest total fresh tuber yield kg ha^{-1} (28.17, 37.17) followed by plots applied with 400 kg ha^{-1} NPK (25.10, 32.10) while control (no manure) had the lowest (9.12, 15.12) in 2016 and 2017 respectively. Further evaluation of the weight of marketable tuber, 2016 and 2017 experiment showed that poultry manure and NPK produced the highest weight of marketable tuber yield of (20.07, 29.07) and (19.15, 26.15) while the lowest was control (4.04, 10.04) in 2016 and 2017 respectively.

The weight of unmarketable tuber in 2016 and 2017 experiment further showed that poultry manure produced highest weight of unmarketable tuber of (5.57,14.57), NPK produced (4.80, 11.80) while control gave (2.82, 8.79) respectively in 2016 and 2017 respectively.

Table 4.12: Effect of manure sources and propagule node number on sweet potato on total fresh tuber yield kg ha^{-1}, weight of marketable and unmarketable tuber kg ha^{-1} in 2016 and 2017.

Number of nodes	Fertilizer sources 2016			Mean	Fertilizer sources 2017			Mean
	Poultry manure 10,000 t ha^{-1}	NPK 400 kg ha^{1}	Control 0		Poultry manure 10,000 t ha^{-1}	NPK 400 kg ha^{1}	Control 0	
Fresh tuber Yield kg ha^{-1}								
2	26.33	20.22	7.54	**18.03**	35.33	27.22	13.54	**25.36**
4	29.79	28.11	7.13	**21.68**	38.79	35.11	13.13	**29.01**
6	28.39	26.96	12.69	**22.68**	37.39	33.96	18.69	**30.01**
Mean	**28.17**	**25.10**	**9.12**		**37.17**	**32.10**	**15.12**	
Weight of marketable tuber								
	19.02	18.53	3.96	**13.83**	28.02	25.53	9.96	**21.70**
2	21.04	20.11	3.40	**14.85**	30.04	27.11	9.40	**22.18**
4	20.14	18.80	4.75	**14.57**	29.14	25.80	10.75	**21.90**
6	**20.07**	**19.15**	**4.04**		2**9.07**	**26.15**	**10.04**	
Mean								
Weight of unmarketable tuber								
2	4.80	3.73	2.83	**3.79**	13.80	10.73	8.83	**11.12**
4	6.50	5.19	3.02	**4.90**	15.50	12.19	9.02	**12.24**
6	5.41	5.19	2.16	**4.50**	14.41	12.46	8.61	**11.83**
Mean	**5.57**	**4.80**	**2.82**		**14.57**	**11.80**	**8.79**	
$LSD_{0.05}$ Number of node	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	
$LSD_{0.05}$ Manure	**1.48**	**1.29**	**5.06**		**5.14**	**3.40**	**6.01**	
$LSD_{0.05}$ Number of node x manure	**NS**	**NS**	**NS**		**NS**	**NS**	**NS**	

4.2 Discussion

4.2.1 Soil Characteristic of the Site at the Beginning and End of the Experiment

The soil acidity level of 4.99 and 5.19 at the beginning of the experiment in 2016 and 2017 respectively shows that growth of sweetpotato is possible. The result obtained from this study is in agreement with the findings of Nedunchezhiyan and Ray, (2010) who reported that the P^H of 5.5-6.5 was ideal. The increase in soil p^H observed in the treated plots might be due to the presence of basic cations contained in the manure which are released upon microbial decarboxylation (Van *et al.,* 1996; Duruigbo *et al.,* 2007). This agrees with the findings of (Allison 1973) that sweetpotato growth is ideal with p^H of 5.5- 5.6 which are associated with benefits such as water infiltration, water holding capacity and retention, in drainage and in water use efficiency

The increase in the organic matter content of the soil might be attributed to direct incorporation a nd subsequent mineralization of organic matter in the soil to provide good environment for decomposing microorganisms in plots receiving poultry manure. It could also be because organic amendments had a major impact on mineralization rate by increasing soil carbon directly (Mutegi *et al.,* 2012).

The low Nitrogen observed in the experimental plot is in agreement with the findings of Hills and Bacon, (1984) who reported that soils of West Africa are heavily depleted in Nitrogen.

4.2.2 Effects of manure Sources and propagule node number on Sweetpotato Stand count at 2 and 4 Weeks after Planting and at Harvest.

High percentage of field establishment showed high adaptability of the seedlings to the field harsh conditions. Lower number of survived stands of sweetpotato with 2 nodes could be attributed to the absence of exposed nodes for leaf emergence since all nodes were buried in the soil. Vine cuttings with 2 nodes remain generally shorter than vines with 4 and 6 nodes, such shorter nodes have been reported to show low establishment. This finding is in agreement with the findings of Ocittin, P.O and Williams, (1987), Ekpe *et al*, (2002) who all reported that shorter vine cutting at planting remained only a few centimeters deep and their inability to establish rapidly might be attributed to low moisture at shallow depths and the soil temperature.

4.2.3 Effect of manure Sources and Propagule Node Number on Sweetpotato Leaves at 6, 8 and 10 weeks after planting.

The number of sweetpotato leaves was more in the sweetpotato treated with and NPK 15:15:15, poultry manure 10 t ha^{-1} than in the control. The increase in the number of leaves might be as a result of efficient mineralization of NPK fertilizer resulting in the quick release of plant nutrients into the soil. Similar results were reported by Atayese, *et al.,* (2013) with application of 400 kg ha^{-1} NPK on sweet potato; Anozie, *et al.,* (2008) with the application of inorganic manure on growth and yield of fluted pumpkin. Low leaf production in sweetpotato planted without any soil amendment was obvious. The study site was generally low in Nitrogen and could have been the reason for the depressed leaf production. This agrees with the findings of Nair and Nair, (1995) who reported increased number of leaves with increasing Nitrogen application.

4.2.4 Effect of manure Sources and Propagule Node Number Sweetpotato Branches at 6, 8 and 10 weeks after planting.

The number of branches in sweetpotato contributed to the vigor of the crop since the branches hold the leaves and keep them in place for photosynthesis using the solar energy. Farmers may prefer a few branches especially when intercropped with other crops, whereas the spreading branches are needed in combating weeds.

The highest number of branches observed in the sweetpotato treated with NPK could be attributed to the effects of N from fertilization and mineralization in the soil (Anozie, *et al*., 2008). Also this might be due to differences in node number as planting material. This result is in agreement with (Mukhopathyay, *et al.,* 1990) that node number is found to be an important factor for getting higher number of sweetpotato branches.

4.2.5: Effect of manure Sources and Propagule Node Number on Sweetpotato Vine Length at 6, 8 and 10 weeks after planting.

Vine length indicates the growth pattern or plant morphological types of orange-fleshed sweetpotato. The longest vine observed are the cuttings with 4 and 6 nodes probably because they had enough time to grow more vegetative tops. This was similar to the findings of Ekpe, *et al.,* (2002) who reported that more number of nodes 4 to 6 induced vigorous growth of vine length. The longest vine length further observed with sweetpotato with vine cutting 4 nodes treated with NPK was attributed to the vine vigor due to length and Nitrogen as a result of NPK source application. This agrees with the report of AVRDC, (1975) that the nitrogen fertilizer encourages growth in sweetpotato. NPK fertilizer applications have also been shown to significantly affect the vine length of orange fleshed sweetpotato (Haliru, *et al.,* 2015; Kumar, *et al.,* 2009 and Zalalem *et al.,* 2009). The longest vine length can be attributed to better climatic

condition experienced during the growing season. The result is in conformity with the report of Rasco, *et al.,* (2000) that field and environmental conditions may influence the relationship between cutting length of sweetpotato and the crop improvement.

4.2.6: Effect of manure Sources and Propagule Node Number on Sweetpotato Vine Girth at 6, 8 and 10 weeks after planting.

The vine girth measures the thickness of the vine. The consistent improvement in vine girth in the propagule with 4 and 6 nodes could also be attributed to improved nutrient reserved due to the thickness of propagule which encourages more growth in those vine girth. This agrees with the observation of Ekpe, *et al*., (2002) that thicker propagule of sweetpotato vine girth was accelerated better than those with lighter girth. The widest girth of sweetpotato vines were in plots treated with soil amendments was as a result of improved nutrient status especially Nitrogen. This was why sweetpotato in the control plots were significantly lower than those with soil amendments. Application of NPK has been widely accepted for crop production due to its ability to improve both soil nutrient and soil texture.

4.2.7: Effect of manure sources and propagule node number on the leafspot disease and bacterial blight disease severity of sweetpotato at 2, 4 and 6 weeks after planting.

The result presented on the effect of number of nodes and manure source on the leafspot disease severity and bacterial blight disease severity showed that the number of nodes, manure source and their interaction significantly influenced Disease severity. This result could be attributed to the growth rate of the plant due to the application of both poultry manure and NPK. The application of nutrients for plant uptake increases the plant ability to resist the attack of pest and diseases. This result is in agreement with the findings of Haber and Grahan, (1999) and Ihejirika *et al*., (2009) who reported that addition of nutrient generally reduces the susceptibility of plant to pathogen up to the level required for optimum growth. However, they stated that beyond

sufficient levels of plant nutrient there is no additional benefit from supplying additional nutrient. Farmers however require sweetpotato vines that are free from diseases.

4.2.8: Tuber Yield

The non-significant effect of sweetpotato number of nodes and manure source on the number of tubers could be attributed to nutrient imbalance in the soil. The improved growth due to application of NPK and Poultry manure failed to give corresponding tuber number probably because potassium reported as the major nutrient needed for tuber production was inadequate. This is in agreement with Brobbey, A. (2015) that that Nitrogen and Potassium is an important factor for improved tuber yield of sweetpotato.

However the significance of total fresh tuber yield was achieved with application of 10 t ha^{-1} poultry manure. Similar results were reported by Agyarkor *et al.*, (2014) with incorporation of organic manure on sweetpotato yield; Nandpuri *et al*., (1971). This also shows that tubers obtained from sweetpotato applied with poultry manure were larger and heavier than those of the control. This is in line with the findings of Yeng, *et al.,* (2012) who obtained larger tuber weight of sweet potato with application of poultry manure which could be as a result of improved soil physicochemical properties leading to the release of nutrients for the uptake by the sweet potato. Again higher total fresh tuber yield of sweetpotato applied with 10 t ha^{-1} of poultry manure than control or no fertilizer indicates the efficacy of poultry manure in conditioning infertile soil for successful sweetpotato production. This agrees with the result obtained by Santhi and Selvakumari, (2000) that the addition of organic manure sources could increase the yield of crops through improving soil productivity and higher fertilizer use efficiency

CHAPTER FIVE

5.0 Conclusion, Recommendation

5.1 Conclusion

Based on the result from this investigation, 400 kg ha^{-1} NPK significantly produced the highest growth parameters as well as lowest leafspot and bacterial blight disease severity of orange fleshed sweetpotato while poultry manure 10 t ha^{-1} gave the highest yield. Also 4 nodes sweetpotato vine equally significantly produced the highest growth parameters and yield but lowest leafspot and bacterial blight disease severity of orange fleshed sweetpotato. The Interaction of manure source and number of node did not have any significant effect on growth parameter and yield of orange-fleshed sweetpotato. However for sweetpotato farmers and researchers interested in growth parameter such as vine multiplication, leaf production etc. sweetpotato that were treated with 4 nodes and 400 kg h^{-1} performed better than other treatment combination, while those that have interest in yield are advised to use 10 t ha^{-1} poultry manure. Fertilizer should be made accessible to sweetpotato farmers at a subsidized rate and on time by government. Sweetpotato farmers should be sensitized and educated on the improved varieties of sweetpotato in Owerri.

5.2 Recommendation

Sweetpotato production is a good and profitable enterprise. For successful sweetpotato production in Owerri Nigeria, the following recommendations are made;

1. The application of 400 kg ha^{-1} NPK improved the growth of sweetpotato.

2. Farmers can adopt the use of propagule with 4 nodes for high growth and yield of sweetpotato.

3. Interaction of propagule with 4 nodes and 400 kg ha $^{-1}$ NPK improved the growth of sweetpotato while interaction of 4 nodes and 10 t ha^{-1} poultry manure improved the yield of sweetpotato.

4. However, further studies is recommended on the use of other manure sources and the use of other node number cuttings.

5.3 Contribution to knowledge

The use of poultry manure at 10 tha^{-1} and 4 node number of the Orange-fleshed sweetpotato is the best for high yield of the sweetpotato variety. Longer vine does not guarantee Large yield, farmers purchase the vines and is of no good wasting them.

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APPENDIX 1

Plate1 : Orange-fleshed sweetpotato (King j)

APPENDIX 2

Plate 2: Newly established orange fleshed sweetpotato at 2 days after planting.

APPENDIX 3

Plate 3: Orange fleshed sweetpotato 2weeks after planting

APPENDIX 4

Plate 4: Sweet Potatoes treated with NPK 15:15:15 at 8weeks after planting

APPENDIX 5

Plate 5: Orange fleshed sweetpotato tubers harvested at 16weeks after planting

APPENDIX 6

Plate 6: Leaf Spot Affected Plant