KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF CROP AND SOIL SCIENCES

YIELD AND TUBER QUALITY OF WHITE YAM (*DIOSCOREA ROTUNDATA* POIR) AS INFLUENCED BY FERTILIZER APPLICATION AND TIME OF HARVESTING.

BY

ASIEKU YAHAYA

MARCH, 2012.

Yield and Tuber Quality of White Yam (*Dioscorea Rotundata* Poir) as Influenced by

Fertilizer Application and Time of Harvesting.

A thesis submitted to the School of Graduate Studies , Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, in partial fulfillment of the requirement for the award of MSc. AGRONOMY DEGREE.

Asieku Yahaya

(B.Ed Agriculture)

March, 2011

DECLARATION

I hereby declare that this research work presented in this thesis is my own work and that, to the best of my knowledge, it contains no material previously published by another person for the award of a degree in any other University, except where acknowledgement has been made in the text.

Asieku Yahaya ……………………… ……………………
(Student) Signature Date

Certified by:

Dr. Eric Asare …………………….. ……………………
(Supervisor) Signature Date

Dr. Emmanuel Otoo …………………….. ……………………
(Co-Supervisor) Signature Date

Dr. Joseph Sarkodie-Addo ……………………… ……………………
(Head of Department) Signature Date

DEDICATION

I dedicate this work to my lovely Mum and Dad, Madam Asara and Mr. Yahaya

To my uncle Mr. Ilyas Yakubu; My dear wife Aminatu; My late grandfather, Mr. Yakubu Salifu; and to all my siblings.

ABSTRACT

A field trial was conducted at the CSIR-Crops Research Institute (CRI) experimental fields to evaluate the effects of organic and inorganic fertilizers, and time of harvesting on the yield and quality of white yam (*Dioscorea rotundata*). The experiment was a 4x3 factorial arranged in a Randomised Complete Block Design (RCBD) with three replications. The treatments consisted of four fertilizer rates [(i) No fertilizer (ii) 4t poultry manure per hectare (iii) 300kg NPK 15:15:15/ha (iv) 2t poultry manure + 150kg NPK 15:15:15/ha and three harvesting times [(i) milking at 20 weeks after planting (WAP) (ii) milking at 24 WAP and (iii) harvesting at 32 WAP].

The combined application of organic and inorganic fertilizer gave significantly higher ($p<0.05$) total yield of yam than their sole application. All treated plots had higher ($p<0.05$) yields than the control. Harvesting yam early at 20 WAP yielded more seed yam and total yield than at 24 and 32 WAP. The combination of PM+NPK gave higher number of tubers of 2.12 per stand. Tuber length of 37.9cm was significantly higher ($p<0.05$) in PM treatment than 29.23cm for the PM+NPK amended treatment while at 24 WAP, PM+NPK was better in terms of tuber length than the control. The sole NPK amended treatment recorded higher yam mosaic virus (YMV) infection at 4MAP than all other treatments whereas leaf spot infection rate was greatest (20.1%) in the PM+NPK treatment as compared to in the control (7.3%).

The study also revealed significant tuber weight loss of 23.8%, 19.0% and 16.7% for PM, PM+NPK and the control respectively, over a three month storage period. Yam harvested at 20 WAP had the greatest ($p<0.05$) weight loss. The interaction of fertilizer PM treatment and harvesting at 24WAP gave significant ($p<0.05$) weight loss compared to the control. Tuber weight was 36% and 41% higher at 32WAP than at 24 and 20WAP, respectively. Higher rotting rates were recorded under PM+NPK amended treatments compared to the other amended treatments and the control. The sensory evaluation showed that there was equal preference for boiled yam from PM+NPK amended treatments and the control at 20 WAP. The PM+NPK treatment yam was similar to the control in taste, aroma, sogginess and hardness at 20 WAP. At 24 WAP, only sole NPK treatment was slightly worse than control in taste. The treatments did not differ in mealiness. Sole NPK and PM were similar to the control in aroma and mealiness at 32 WAP. Proximate analysis showed that fertilizer amendment did not improve ash contend of yam at 20 WAP. Significantly higher level of carbohydrates was realized in PM treatment compared to the other fertilizer treatments at 20 WAP. Applying sole PM and NPK increased crude fibre content compared with the control and PM+NPK treatments. Significantly higher crude protein level (12.23%) was realized under PM+NPK treatment at 24 WAP. Highest moisture (66.1%) and fat (2.0%) contents were recorded under the NPK treatment plot at 24 WAP. The PM+NPK treatment gave the highest protein content of 11.7% than the other amended treatments but recorded lower fat content than sole PM and NPK at 32 WAP. However, moisture and potassium levels did not vary significantly at 32 WAP with fertilizer application. The application of PM+NPK was most profitable at all harvest times. It was profitable to harvest at 32 WAP and 20WAP under sole PM and NPK, respectively.

ACKNOWLEDGEMENT

I am sincerely thankful to the West African Agricultural Productivity Programme (WAAPP) for providing financial support for this work. I also thank the Council for Scientific and Industrial Research (CSIR) for granting me study leave to undertake this study programme.

To my main supervisor Dr Eric Asare and co-Supervisor Dr. Emmanuel Otoo (Crops Research Institute, CRI), I owe you a debt of gratitude for your unanimous support, guidance and contributions

Special thanks also go to the Director of Savanna Agricultural Research Institute, Dr. Stephen Nutsgah without whose strong backing this study programme would not have materialized.

I am also grateful to Mr. Adrews Opoku of the Department of Crops and Soil Sciences (KNUST) for his immense technical assistance and invaluable inputs made to this research work.

My deep gratitude goes to Dr. Faustina Dufie Baah of the Department of Food Science and the Head of Department Prof (Mrs) Ibok Oduro for allowing me to use their facilities for sensory evaluation and other laboratory activities. Mr. William Ofori Appaw and the final year students of the Department of Food Science are acknowledged for their participation as sensory panel members.

The remarkable role played by Mr. Kwabena Acheremu of the Savanna Agricultural Research Institute (SARI) in assisting me with seed yam at that critical time of the season is highly appreciated

The field staff of CRI Yam section led by Mr. Luke Opoku-Amankwah are duly appreciated for their immeasurable assistance throughout the field activities of this research. Also, Ms Numafo Mavis of CRI yam section is thanked for all the assistance offered me in the course of this work.

My appreciation also goes to Mr. Larry Essilfi (T.A.) of Agricultural Economics Department, Miss Kwara Bintu and Kofi Amponsah (students, Crop and Soil Sciences Department, KNUST) for their assistance in analyzing the results.

Special thanks go to Drs. J Sarkodie-Addo and Charles Kwoseh for their technical advice in this write-up.

It gives me great pleasure to thank Mr. Samuel Joe-Acquah of the Soil Science Laboratory for his support during all my laboratory analyses.

I appreciate all those who contributed in various ways during my entire postgraduate programme but whose names could not be mentioned here.

Above all, I say thank you to the Almighty Allah for seeing me through every step.

TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
Cm	Centimeter
cmol/kg	Centimole per kilogram
CSIR	Council for Scientific and Industrial Research
CRI	Crops Research Institute
^{o}C	Degree Celsius
FAO	Food and Agriculture Organization
g	Gramme
Hrs	Hours
HCl	Hydrochloric acid
CIMMYT	International Maize and Wheat Improvement Center
Kg	Kilogram
Lsd	Least Significant Difference
µg/ml	Microgram per milliliter
µgK/ml	Microgram potassium per milliliter
mg/kg	Milligram per kilogram
ml	Millilitre
mm	Millimeter
MOFA	Ministry of Food and Agriculture
M	Molar
MAP	Months after planting
OC	Organic carbon
%	Percentage

PPMED	Policy Planning Monitoring and Evaluation Department
PM	Poultry manure
p-value	Probability value
SARI	Savanna Agricultural Research Institute
WAE	Weeks after emergence
WAP	Weeks after planting
WP	Wettable powder
YMV	Yam mosaic virus

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

Yam belong to the genus *Dioscorea* which consists of about 600 species of which only six are important as staples in the tropics (Coursey, 1967; Hahn *et al*., 1987). Yam is an important food crop in the tropical countries including East Africa, the Caribbean, South America, India and the South East Asia (Okonkwo, 1985) and a staple crop in West Africa (Asiedu *et al*., 1992). The bulk of global yam production is concentrated in West Africa, with Nigeria producing the largest proportion followed by Ghana and Cote d'Ivoire (FAOSTAT, 2004). The dominant production zone stretches from the Côte d'Ivoire through Ghana, Togo, Benin, Nigeria, Cameroon, Gabon, Central African Republic and the western part of Democratic Republic of Congo. The Guinea yams (*Dioscorea rotundata* Poir and *D. cayenensis* Lam.) of African origin, account for most of the yam production in Africa. Yam is also said to constitute a multispecies crop important for food, income and socio-cultural activities (Ekanayake and Asiedu, 2003).

Major yam growing areas in Ghana include the Northern, Ashanti and Brong Ahafo regions. About 80% of the principal commercial yam produced in Ghana is D. *rotundata* (Tetteh and Saakwa, 1991).

The most important edible product prepared from yam is that which is known throughout Africa as fufu or in parts of francophone West Africa as foutou (Coursey, 1967) or boiled yam sometimes broken up and mixed with oil, meat or fish and spices to form yam pottage ("etoh", as it is called in Ghana). In Ghana, yam is boiled or pounded into fufu. Dioscorea *dumetorum,* is however not adaptable for fuotou preparation but is used for various industrial products and as a useful animal feed (Degras, 1993). Yam is an excellent source of carbohydrate energy (Trech and Agbor-Egbe, 1995), high protein and dry matter than cassava (Degras, 1993) and provides vitamin C and minerals Yam contributes more than 200 dietary calories per day for over 60 million people in the yam zone (Nweke *et al*., 1991). Yam also plays an important role in the cultural lives of certain communities in the yam belt as production activities and arrival of new yam are accompanied by certain ritualism, tradition and fanfare (Tetteh and Saakwa, 1991).

Yam production rate in Ghana has been estimated at 8 percent from 1994 – 2000 and is ranked second to cassava globally as a root and tuber crop in terms of production. Yam contributes about 16 percent of Agricultural GDP in Ghana with a 53.38% increase in production due to increase in area cultivated between 1981 to 2005 (FAO, 2006). Total yam production in Ghana was estimated to be about 4 million metric tons in 2005.

The production of yam in Ghana is however, failing to meet increasing demand for local consumption and export market, due to lack of planting material (MiDA, 2009).

1.2 Problem statement and Justification

Yam is propagated vegetatively by small whole tubers or pieces (>200g) cut from large tubers (Okoli and Akoroda, 1995). The cost of planting material is over 33% of the total cost outlay for yam production (Okoli and Akoroda, 1995). Orkwor *et al*. (1998) reported that in the traditional cropping systems for yams, farmers put aside as much as 30% of the harvest (average size of 200-1000g) as seed yams for the next cropping season because of the scarcity and high cost of purchasing seed yam.

A major constraint in yam production has been the requirement of large quantities of planting material on a per hectare basis (Orkwor *et al*., 1998). The traditional method of seed yam production which was basically through selection of sizeable tubers as seed yams was reported to give a low multiplication ratio of 1:5 tuber-to-setts. Partial sectioning technique by Nwosu (1975) doubled the multiplication rate to 1:10 per seed yam tuber of 300-400g. The minisett technology was successfully developed (Okoli *et al*.,

1982) for rapid, high volume seed yam production at a higher ratio of 1:30 at a reduced cost of seed yam production.

D. rotundata is said to be able to produce two separate products in one season. Tubers are harvested at immature stage ("milking") for consumption or harvested as seed yams for replanting. For early maturing varieties of *D. rotundata*, harvesting of tubers about two-thirds into the growing season without destroying the root system (known as "milking") provides early yams for home consumption and market (Anchirinah *et al*., 1996). This also allows the regeneration of fresh and small tubers from the base of the vine. These are harvested at the end of the season and used as planting materials for the next season. Bencini (1991) reported that harvesting is done first at 5-6 months after planting and then 3-4 months later. Milking results in regenerated tubers that are used as setts. It is reported that yams produced in Ghana are mainly double harvested D. *cayenensis-rotundata*, with puna being the most popular variety (MiDA, 2009).

The most serious constraints identified in yam growing areas in Africa include high costs of planting materials, labour for field operations (land preparations, planting, staking, weeding and harvesting), and pests damage in the field and storage (Robin *et al*., 1984; Nweke *et al*., 1991; Baudoin and Lutaladio, 1998). On-farm survey conducted in Ghana revealed that the main problem encountered in yam production and marketing was declining soil fertility resulting in increasing cultivation of the crop in remote areas with its negative effects on transport and marketing (Anchirinah *et al*., 1996).

Yam is a very demanding crop in terms of soil fertility especially for organic matter content and fertilization is thus required due to its significant nutrient uptakes (FAO, 1999).

A study by IITA shows that supplying nitrogen alone alters the taste of yam and above all, its texture but that balanced fertilization (NPK-Mg) has no negative effects (Adeniji, 1998). Yield increases of 10.7 and 15.6 percent were obtained in 1980 and 1981 respectively with the application of 35kg N/ha to white yam (D. *rotundata*). Phosphorus and potassium had no effects on yield and none of the three had effect on starch content (Kayode, 1985). Lyonga (1984) reported that the application of 120 and 240 units of K improved yield by 13.4 and 21 percent respectively. Response to fertilization is highest when applied at time of greatest vegetative growth and yields are significantly increased at 8 WAP (weeks after planting) fertilization.

Yam has the potential to enhance food security as food production cannot keep pace with population growth in West Africa. It has a comparative advantage over other crops like cassava due to its nutritional diversity and long storage life. White Guinea yam (Orkwor and Asadu, 1998) is the most widely grown and eaten species in West Africa. *Dioscorea rotundata* Poir alone constitutes about 80% of the principal commercial yam produced in Ghana (Tetteh and Saakwa, 1991). The most cultivated rotundata mostly preferred by both domestic and export market is 'pona' (or puna). Yam production could improve if farmers had access to readily available and affordable seed yams (MiDA, 2009).

1.3 Objectives of the study

The overall objective of the study was to improve the yield and quality of yam through soil amendment and appropriate harvesting techniques

The specific objectives were to:

- evaluate the yield of yam under different levels of fertilizer treatments.
- determine best method for producing yam planting material.
- evaluate the culinary quality of yam tuber.
- evaluate the effects of fertilizer application on the storability of yam.
- evaluate the effect of fertilizer on the mineral composition of yam

CHAPTER TWO

2.0: LITERATURE REVIEW

2.1 Origin and distribution

Yams (*Dioscorea* spp.) belong to the family *Dioscreaceae* and the genus *Dioscorea*. The genus *Dioscorea* was reported as comprising about 600 species (Burkill, 1960). The six most economically important species grown as staple foods in Africa are: *D. rotundata* Poir (white guinea yam), *Dioscorea cayenensis* Lam. (yellow yam), *Dioscorea alata* L. (water yam), *D. esculenta* (Lour) Burk. (Chinese yam), *D. dumetorum* (Kunth) Pax (bitter yam), and *D. bulbifera*, L (aerial yam) (Onwueme, 1978). These species also constitute over 90% of the food yams produced in the tropics (Hahn *et al*., 1987).

Yams are among the oldest recorded food crops. The family *Dioscorea* is probably one of the oldest groups among the angiosperms and seems to have originated in Southeast Asia (Burkill, 1960). Food yams are believed to have originated in the tropical areas of three separate continents:- Africa, Southeast Asia and South America. Ayensu and Coursey (1972) reported that Asiatic yam, *D. alata*, probably originated in tropical Burma and Thailand. In South America, *D. trifida* is believed to date back to pre-Columbian times. *D. rotundata*, *D.cayenensis*, and *D. dumetorum* are believed to have originated in West Africa (Coursey, 1969; Watt, 1961; Lagemann, 1977; Onwueme, 1978; Diehl, 1981; Hahn, *et al*., 1987). According to Coursey (1976) *D. rotundata* is cultivated throughout the West African yam belt and this zone has the oldest yam culture and the largest repository of yam biodiversity.

2.2 Botany/Morphology of Yam

Yams are angiosperms or flowering plants and are monocotyledons. The genus *Dioscorea* is by far the largest genus within this family. The *Dioscoreaceae* are predominantly tropical plants and are distributed throughout the tropics except in the most arid areas. A few species inhabit the warmer parts of the temperate zones, but these are mostly of comparatively little economic importance.

Yams are rhizomes producing annual shoots which are twining except in dwarf species, the direction of twining being specific. They have storage organs that are commonly enlarged or modified into a cormous structure from which one or more annual tuberous organs develop. The tuber size and shape are variable depending on the species and growing conditions and may range from 2-3 m in length and over 50kg in weight. The tubers of most important cultivars are cylindrical in shape, with some root 'hairs'. The stems consist of a main stem and branches, leaves petiolate, usually cordate either simple, palmate lobed or compound. The seeds are usually winged, but wingless in *Trichopus* and in a few species of *Dioscorea*, consisting of hard endosperm and embryo in marginal pocket. (Coursey, 1967).

2.3 Production levels

Generally, the area referred to as the West African yam belt or yam zone stretches from west of the Cameroon mountains to the Bandama river in central Côte d'Ivoire (Coursey 1967, 1976, and Hahn *et al*., 1987). The yam zone comprises Nigeria the Republic of Benin, Togo, Ghana, Cameroon and Côte d'Ivoire. Statistics show that the West African yam belt produces 95% of the world's output of 34 million metric tons (mmt) of yam in 2001 (www.cgiar.org/impact/research/yam, accessed on 28/09/2011)

The bulk of yam production is concentrated in West Africa, with Nigeria producing the largest proportion followed by Ghana and Côte d'Ivoire (FAOSTAT, 2004). FAO statistics show that 48.7 million tones of yams were produced worldwide in 2005, and 97% of this was in sub-Saharan Africa. West and central Africa account for 94% of world production. According to GEPC (2009), Ghana produced approximately 4 million metric tonnes of yam in 2005 and was the leading yam exporter in 2008 (exporting 20,842 metric tonnes)

In Ghana, variety of yams are grown, but the white yams, especially the Pona (sometimes Puna) variety, are preferred by both the domestic and export market by virtue of its taste (MiDA, 2009).

The Asiatic yams especially D. *alata* and *esculenta* are now widely distributed in Africa and D. *alata* has become a staple food in Côte d'Ivoire and constitutes about 65% of yams grown in the country. D. *alata,* however, is placed second to D. *rotundata* in production and consumption in Nigeria. In Papua New Guinea, New Caledonia and the West Indies, D. *alata* is the major food yam grown and consumed. In the Caribbean, it is the African food yams, D. *cayenensis* and D. *rotundata* that are widely grown (Hahn *et al*., 1987). According to Orkwor *et al*. (1998) yams are produced and consumed in West Africa than any part of the world and this has led to the erroneous impression that yam is an African crop.

Table 2.1: Yam area cultivated, yield, production and consumption in various regions.

	Africa			Asia	Pacific	Caribbean	Latin America
	WCA	ESA	ALL Africa				
Area ('000 ha)	4,136	81	4,273	15	22	65	68
Yield (t/ha)	8.0	4.3	7.9	13.8	14.0	8.6	9.6
Production ('000 tonnes)	37,584	347	38,069	204	343	557	682
Consumption (kcal/capita/day)	108.0	4.5	82.0	2.0	70.0	33.0	7.8

Source: FAOSTAT (2005) WCA = West and Central Africa; ESA = East and Southern Africa.

2.4 Economic and Social Importance

Harvested tubers are preserved for use as planting materials, for household consumption or preserved for market when prices are high. Yam is better than cassava from a nutritional point of view i.e. higher vitamin C and crude protein levels (Opara, 1999) but second to it as the most important root crop. The ability of yam to store for some months after harvest ensures food security.

A few commercial products such as dry yam tuber flakes or flour from the tuber are marketed especially in Nigeria and Côte d'Ivoire or are exported outside Africa. In 2000, nearly 4 million hectares were planted with yam throughout the world (FAOSTATS, 2000). More than 69% of this total area was located in Nigeria. Babaleye (2003) observed that yam contributes more than 200 dietary calories per capita daily for more than 150 million people in West Africa while serving as an important source of income for the people. Orkwor and Ekanayake (1998) reported that, in Nigeria, yams could constitute up to 32% of gross income derived from annual cropping. In 2008, Ghana exported nearly 21,000 metric tons of yam valued at 14.89 million USD (Ghana Export Promotion Council, 2009).

Eka (1985) noted that yam contains a major pharmacologically active substance, *Dioscorine*, which is medicinally a heart stimulant. Yam is also reported to be a good source of industrial starch and quality depends on the species. In the Philippines, crude tuber extract of *D. hispida* has proved to be as effective as malathion in protecting cassava cuttings from scale insects (Vasquez and Platino, 1995). The same crude extract is apparently extremely toxic to aphids and rice bugs (De Pedro *et al.*, 1989).

Yam also has ritual, medicinal and socio-cultural significance. Across the yam zone, a wide variety of beliefs and taboos exist that govern the planting, harvesting and consumption of yam**.** Orkwor (1998) and Hahn *et al*. (1987) reported that pounded yam is the food for royalty, special guests and festive occasions.

2.5 Food value

Yam is primarily a food crop which is usually cooked or less commonly, dried (chips) and ground into flour (Orkwor *et al*., 1998). The most preferred method of preparation of tubers from *D. rotundata* cultivars in West Africa is boiling and pounding into a thick paste ("called pounded yam") that is usually consumed with soup. Tubers could as well be cooked into yam pottage with added protein sources and oils or consumed directly after boiling. In Ghana, boiled yam is sometimes broken up, and mixed with oil meat or fish and spices to form what is known as yam pottage and popularly called "etoh". In the yam zone in West Africa, pieces of peeled yam could be fried in any convenient cooking oil especially palm oil just as potatoes chips are usually prepared.

The nutritional value of yam is linked to its starch content. According to Degras, (1986) one third of daily energy needs can be provided by 1 kg of yam. The tubers have generally high protein content (1-2%), but are relatively poor in some essential amino acids.

The major food component in yam is carbohydrate, which constitutes the major dry matter part of the tuber. Asiedu (1986) noted that even though water and carbohydrate form the bulk of the tuber, it also contains non-carbohydrate components. Differences in growing environment, maturity stage, method of storage and species may also affect variation in the tuber composition. The ash content of yam gives an indication of its mineral status (Osagie, 1992).

Yam tubers have high moisture contents, dry matter and starch and are relatively good sources of some minerals. They are recommended for people with high blood pressure but not suitable for those with renal failure (Osagie and Eka, 1998) due to the presence in appreciable levels of potassium, a mineral that helps to control blood pressure (Osagie, 1992).

Some species contain appreciable quantities of crude protein e.g. *D. dumetorum* which is also high in alkaloids and thus has to be washed in salt water and boiled for a long period before consumption. The texture of *D alata* is too soft thus making it unsuitable for making pounded yam (Hahn *et al*., 1987). Small tubers are sometimes boiled whole without peeling which serves to conserve a greater proportion of the vitamin content (Coursey, 1967).

Degras (1987) noted that cooking improves the digestibility of starch in all species but eliminates the vitamin C in the yam. Bell and Favier (1980) reported that boiling leads to loss of amino acids and essential minerals and yams should therefore be fried. According to Bell (1983) yams could supply the entire vitamin C requirement in areas where yam daily per capita consumption is up to one kilogramme. It is also reported that *Dioscorea* has steroids that are being utilized as starting material in the industrial sector for the preparation of cortisone and other drugs. All edible yams compose of carbohydrate (mainly starch with small amounts of sugar of <1%), and high water content of 65-70% about ($^{2}/_{3}$ of fresh tuber), protein content of 1-2%, crude fibre and ash content distinctly variable 0.7-2.6 (Onwueme and Sinha, 1991). According to Romain (2001) the starch content of matured yam tubers ranges between 15-23 %. Yam peels and waste from yam being used in the home can be usefully fed to livestock. According to Touré (1986), yam peel is an excellent source of energy for sheep, but that the protein digestibility is inhibited by the high lignin concentration.

The flesh colour of several *D. alata* and *D. trifida* cultivars is pale pink through to dark red due to the presence of anthocyanins. The yellow colouration of *D. cayanensis* is due to caratenoid (Coursey, 1967).

Table 2.2: Some reported values of nutrient composition of white yam (*D. rotundata*)

Nutrient	Ash (%)	Fat (%)	Crude fibre(%)	Crude protein(%)	Carbohy-drate (%)	Moisture (%)	Potassium (%)
g/100g	0.68-2.56	0.05-0.12	1.0-1.7	1.09-1.99	22-31	58-80	1.15

Source: Coursey 1967

Crude protein for D. *alata* ranges between 4.7 – 15.6g/100g (Trech and Agbor-Egbe, 1995).

2.6 Growth requirements

Yams generally do well on deep, porous, moderate to well-drained, loamy soils with high organic matter and a pH range of 5.0 – 7.0 (Purseglove, 1972). In Nigeria, application of appropriate organic and inorganic fertilizers and timely weed control measures improved yam yields.

The typical yam growing ecozone in Nigeria extends from the rainforest to the Guinea savanna vegetations where 20 to over 30t/ha are obtained from 90% of the fields sampled (Nweke *et al*., 1991; Ohiri *et al*., 1985). These ecozones have been described by Obigbesan (1981) Ohiri *et al*. (1985) Asadu (1990), Ohiri (1995) and Orkwor and Asadu (1998).

Soils in these areas have pH ranging from 4.2 to 6.7 at the surface. They are also characterized by low effective cation exchange capacity of 2.14-8.83 me/100g, total N (0.02-0.17%) and base saturation ranging from 26.3 to 99.7%. The soil mineralogy is dominated by kaolinites which are not expansive, with low absorptive capacity and dominated by permanent charges. The bulk density of the soils ranges from 1.20 to 1.62kg/m^3 but particle density ranges from 2.45 to 2.57kg/ m^3. Total porosity ranges from 46-62%. Ohiri *et al*. (1985) classified the soils as typic Haplustalfs, Ustic Haplustalfs, Oxic Haplustalfs and Ustoxic Dystropepts in the USDA soil Taxonomy.

Yam is a calendar crop and this guides the field preparation and planting of other crops in the West African yam zone. In an intercropping system, yam is always grown as the base crop as is common in the humid and sub-humid zones in the tropical West African yam belt. Climatic factors such as water (soil moisture), temperature, light, and photoperiod affect the growth and performance of yams.

Yams can be produced in nearly all-tropical countries, provided water is not a limiting factor. Ideal conditions include: at least 1 000 mm of rain, spread over 5 to 6 months; and deep, friable, well-drained soils to allow for proper tuber growth and development (Hahn *et al.*, 1987). The ideal soil should be deep, loose, soft-textured, free-draining and fertile to enhance root growth and support large tuber formation (Coursey, 1967). Annual rainfall of 1000-1500mm well distributed over a period of 6-7 months of the cropping season is required for yams to do well (Onwueme 1975). Yams generally require well drained deep profile soils with stable structures (Orkwor and Asadu, 1998). Sometimes shallow soils that have less than 50% effective depth could be used by making ridges and mounds as is the case in southeastern Nigeria (Abakaliki). In terms of texture loamy soils appear to be the best for yam. Nwinyi (1981) reported that the composition of soils in the major yam zones of Nigeria is dominated by sandy-clay-loam. According to Ezumah (1986) yam requires well pulverized, loose soil consistence with high organic matter levels for the easy penetration and swelling of the tubers. Yams do well under temperatures around 30^{o}C with a sharp demarcated dry season of two to five months, and a total rainfall of some 150cm evenly distributed throughout the remainder of the year.

Yams require rainfall for at least five of their eight month of growth in the field. Most forms of *D. alata* and *D. rotundata* require a seven or eight month growing period to complete their life cycle even though some can survive with as little as six months (Coursey, 1967).

According to Koné, (1987) and Dumont and Jeanteur (1988) optimal rainfall for *D. alata* is around 900 mm for a seven-month vegetative cycle. Some forest species such as *D. cayanensis* cannot tolerate a rain-free period of more than 2 or 3 months and grow almost continuously through the year. Yams can withstand periods of severe drought during their growing season due to the large reserves of water and nutrients stored in their tubers. But severe drought in the early stages of their growth at just the emergence of young shoots, when reserves in setts are exhausted, can result in death of plants (Coursey, 1969). Yams are reasonably tolerant to drought once germinated and Onwueme (1978) noted that young plants have a remarkable ability to survive drought after sprouting due three factors;

(i) the planted sett contains an enormous amount of food reserves and moisture; during early development, the young plant can absorb sufficient moisture and food from the parent sett.

(ii) the first phase of growth is mainly the development of an extensive root system; consequently, the plant is well equipped to exploit the available soil moisture.

(iii) the vine (young plant) is a xerophyte, often covered with a waxy bloom, and it is virtually without expanded leaves with their large transpiring surfaces.

Yam requires water throughout its active growth period for vine and leaf development; the most critical stage being tuber initiation and bulking. Onwueme (1975) noted that moisture stress has been reported to delay tuber initiation in water yams. The optimum temperature range for growing yams is between 25-30^{o}C (Orkwor and Asadu, 1998) and this range during the 6 month active growth stage resulted in good crop growth and yield (Orkwor, 1990). Njoku (1963) noted that short day length of about 12hours was found to promote tuberisation in the tropics. Trenbath (1976) observed that light is an essential factor after water and nutrients for growth in the production of yams. Yam is reported to require a day-length of more than twelve hours at the beginning of the growing season and the later part with a shorter day-length. (Coursey, 1969). Daily sunshine of 4-5 hours during the active growth period of yams (6^{th} – 13^{th}) WAP is required for higher tuber yields (Orkwor and Ekanayake, 1998). Studies indicate that day lengths greater than twelve hours favour the development of the vines while satisfactory tuber formation only takes place during shorter daily periods of illumination (Coursey, 1969). Yam production as reported by Manyong *et al*. (1996) has moved from the humid forest area into the guinea savanna zones where disease problems are less acute and land is available.

2.7 Planting

Yam is propagated vegetatively by small whole tuber or pieces (>200g) cut from large tubers (Okoli and Akoroda, 1995). The cost of planting material is over 33% of the total cost outlay for yam production (Okoli and Akoroda, 1995). Orkwor and Asadu (1993) reported that in the traditional cropping systems for yams, farmers put aside as much as 30% of the harvest (usually small sized tubers of 200-1000g) as seed yams for the next cropping season because of the scarcity and high cost of purchasing seed yam.

2.8 Staking

Staking is done to help yam stems to twine and display their leaves to attract adequate solar energy for efficient photosynthesis. Stakes up to 4 meters are used to support the growing vines from the ground (Ekanayake and Asiedu, 2003). This enables the yam canopy to spread out for better light interception and aeration thus reducing foliar disease problems. Ndegwe *et al*. (1990) reported that there was an increase in yield of between 34 and 105% due to variations in number of stakes per hectare when yams were grown as a sole crop. Yams not staked are particularly susceptible to weed infestation especially between 60 and 120 days after emergence (Onochie, 1974) whilst Orkwor *et al*. (1994) give this period as the third to the sixteenth week of vegetative cycle. In a humid climate, where clouds can greatly limit the hours of sunshine, staking serves to improve the photosynthesis activity of the plants, prevent foliage diseases and allows the cultivation of interim crops (FAO, 1999). In many parts of West Africa, staking is normally only used with two-harvest *D. rotundata* grown in the climatic belt on the northern border of the distribution area of yams. Staking is less important when there is greater solar radiation. In many savannah regions in Africa (Benin, Nigeria) as well as in the West Indies, manual cultivation is often done without staking. Hahn *et al.* (1987) in a research conducted in Nigeria reported there was no significant increase in yield with staking north of latitude 8°30'

2.9 Mulching

Soil moisture conservation is necessary in dry season planting of yams, hence the importance of mulching. Mulching is reported to be a common practice in both West (Antwi *et al*., 2000) and East (Osiru and Hahn, 1994; Wanyera *et al*., 1996) Africa. According to Asadu (1995), "earth mulching" or mound-remolding helps to improve mound soil infiltration rates, cover exposed roots and tubers of yams, prevents pests and pathogens from damaging these tubers and also keeps down weeds. Mulching reduces the caking of soils caused by the high absorption of heat/solar radiation. It also prevents the tubers from rotting prior to germination and the young vines from being scorched by soil heat. Lal (1978) reported that under mulch, soil bulk density reduced from 1.54 to 1.40 g/cm^3 at 0-10cm depth and from 1.70 to 1.42g/cm^3 at 11.20 depth of an oxic paleustalf soil in Nigeria. Yams that were mulched in the semi-humid area in Nigeria performed well while an almost total crop failure was the case of the un-mulched field. The beneficial effects of mulching on soil moisture and temperature, growth and yield of yam have been reported by Maduakor *et al*. (1984) and Opara-Nadi and Lal (1987). Toyohara *et al*. (1997) also reported of increase in biomass and tuber weight in yams due to mulching.

2.10 Cropping system

Yams require fertile lands and are thus planted as the first crop on cleared land or after fallow. Land clearing by slash and burn precedes manual clearing of burnt tree trunks and other vegetation (Ekanayake and Asiedu, 2003) and production in the sub Saharan-Africa still largely depends on hoe-cutlass labour. Most indigenous farmers in the yam belt rotate yam with cassava and or vegetables or left fallow for 2-5 years. Vernier *et al*. (1998) however observed that yams are grown on large commercial farms in the region of Nigeria.

In monoculture system, farmers keep separate fields of *D. rotundata* and *D. alata* due to their difference in growth habits and maturity. *Dioscorea praehensilis* is either semi-domesticated or found in the wild as undergrowth in the forest areas of Eastern, Ashanti, Brong Ahafo, central and Western regions of Ghana where the trees are used as live stakes by the yam vines (Ekanayake and Asiedu, 2003). According to Manyong *et al*. (1996) the production zone of yam (particularly in Nigeria) has moved from the forest zone through the derived Guinea savanna to the southern Guinea savanna.

2.11 Weed control

When yam grows in association with weeds, the total amount of nutrients removed by the yam crop were 6% N, 6.5% P and 6% K when compared to about 94% of the N, P and K respectively taken up by weeds (Unamma, 1981). Two weed control methods have been identified with yam production i.e. the traditional hand pulling or hoeing and use of herbicides. Two to three weeding regimes at 3, 8, 12, and 16 WAP have been found to be effective for weed control in both ware yams and seed yams production (Orkwor and Asadu, 1998). Weed interference is most critical at 12 to 16 WAP for seed yams using the minisett technique (Unamma and Melifonwu, 1986) and 4 to 16 WAP for ware yams (Ezumah and Akobundu, 1991).

2.12 Organic fertilizer application

The need for nutrient elements for growth by plants calls for the application of organic or inorganic fertilizer. This is to correct serious deficiencies, prevent smaller losses and thus maintain or increase output per land area. (http//.www.ohioline.osu.edu/hyg-fact, assessed on 01/11/11)

Organic fertilizers are generally by-products from animals or vegetables and minerals such as rock phosphates. Organic fertilizers release nutrients much more slowly than synthetically produced ones. They improve soil structure for plant roots to reach moisture and absorb nutrients, by breaking up heavy clay soil, improving air circulation and drainage and increase the capacity for sandy soils to retain moisture (www.torontomastergardeners.ca, retrieved on 5th April, 2010).

Organic matter in the soil is derived from animal and plant residues and it is a mixture of these materials at various stages of decomposition (Alexandra and Jose, 2005). Organic manure falls into 3 classes:

(i) farmyard manure (FYM) made by various kinds of stock either indoors or on the land

(ii) plant residues, either fresh as green manures, or rotted in the form of compost

(iii) concentrated organic manure of commerce such as poultry manure which is much richer in N and other plant nutrients, and contain less carbon than bulky manure. Orkwor and Asadu (1998) stated the various sources of organic manure used in yam culture as compost, farm yard/animal manure, green manure, organic mulch crop residue incorporated after harvest and fallow crop.

The continued application of organic manure is observed to increase soil organic matter content (Rasmussen and Collins, 1991) and release rate of P and K from organic matter is slow thus protecting plant nutrients from leaching (Yayock *et al*., 1988). Organic manures release nutrients slowly and usually have longer residual effects than mineral fertilizers.

But organic fertilizers are not available in the quantity needed for large scale use, and are also bulky and the rate of application is not uniform (Orkwor and Asadu, 1998). Nambiar *et al*. (1989) reported that organic fertilizers contain little or no soluble salts and can be applied at large rates without risk of damage to their roots as would occur if inorganic fertilizers were used to supply corresponding quantities of plant nutrients. Use of organic manure is reported to increase the absorptive capacity (i.e. CEC) of low activity clay soils like Kaolinite. Poultry manure has about 11% N, 11% P and 5%K and averagely, 30% of both N and P_2O_5, and 50% of K_2O in poultry manure are available to crop plants in the first season after application under field conditions (Leonard, 1995). Asadu and Akamigbo (1990) observed that organic matter contributes about 71% of CEC in oxisols, 70% in ultisols, 58% in alfisols and 52% in inceptisols in the A horizons of the soils in southwestern Nigeria. Young (1976) reported that a reduction in organic matter content from 3 to 5% caused a drop on water holding capacity (WHC) from 37 to 57%. Generally organic matter acts as a binding material and prevents erosion and leaching in sandy soils by holding sand particles together.

2.13 Inorganic fertilizer application

The increased pressure on land, increasing human population and the use of agricultural land for other human activities has drastically reduced the fallow period which ultimately results in declining soil fertility and the lost of its ability to support the regional biodiversity (Ojating, 1997). Due to the higher yields usually obtained from fertilizer fields, the use of chemical fertilizers in yam production is now common in yam production areas in Nigeria especially where long fallow is no longer tenable as an integral part of the cropping system (Ferguson and Hayness 1970; Azih, 1987; and Asadu, *et al*., 1998).

It is reported that application rates of 400-500kg ha^{-1} compound fertilizer 15:15:15 is recommended for acid sandy loam soils in Southern Nigeria for seed yam production

(NRCRI 1985). Fertilizer is applied at 10-12 WAP in band rows and covered. Better response to fertilization is achieved when the fertilizer is applied at the time of greatest vegetative growth. Fertilization at eight weeks after planting significantly increased yields (Okwuowulu, 1995).

In West Africa there is a strong reluctance to utilise chemical fertilisers as it would alter the taste of pounded yam and would increase losses during storage of the tubers. Ohiri *et al*. (1996) reported that during a survey in the root crop belt of Nigeria, majority of the farmers (70%) interviewed in the Southwestern Nigeria believed that fertilizer reduced the pounding quality of yam. The use of inorganic fertilizer is strongly believed by farmers to be a major factor causing rot of yam tubers in storage (Chukwu *et al*., 2000). As a consequence, some yam farmers refuse to use inorganic fertilizer in the production of seed yams meant to be stored beyond six months after harvest (Chukwu *et al*., 2000). Akanbi *et al*. (2007) reported that farmers are sceptical about the use of inorganic fertilizers because they believe that it affects the nutritional quality of the crop and the rising costs of inorganic fertilizers make it unaffordable by the resource poor small-scale farmer. According to Okpon and Aduayi (1988) application of 80kg N/ha irrespective of source (Urea, sulphate of Ammonia and Calcium Ammonium Nitrate) increased starch, glucose and N contents of yam tuber but decreased K content. However, results from fertilizer trial on Alfisols of Southwestern Nigeria involving N at 0, 35 and 70kg/ha; P at 0, 25 and 50kg/ha and K at 0, 25 and 50kg/ha (Kayode, 1985) revealed that neither N, P and K nor their interaction had any significant effect on starch content of yam. He rather found that dry matter content was significantly influenced by P and K during the four years of the study.

Studies carried out in Côte d'Ivoire showed that fertilization, while increasing the unit weight of the tubers also led to losses during storage, depending on the species. Large tubers, which respond well to fertilization, are preserved better in the case of *D. alata*, while for *D. cayenensis-rotundata* it is the opposite (Dumont *et al.*, 1997). A later study at IITA shows that supplying N alone alters the taste of yam and, above all, its texture, but that balanced fertilization (NPK-Mg) has no negative effects (Adeniji, 1998). Eze and Orkwor (2010) argue that the effects of either NPK fertilizer or organic manure on weight loss, sprouting and rotting of tubers in storage was partly dependent on cultivar and perhaps soil fertility status. According to Obigbesan (1993) yam grown with 125kg/ha Ammonium sulphate darken on cooking. Martin (1979) also noted that application of fertilizer could influence the starch content of tubers.

Different cultivars of *D. rotundata* gave varied responses to manure treatments and post-harvest behavior. Generally, tubers from no manure treatment appear to show reduced rotting compared to those treated with organic manure or NPK fertilizer. Murwira and Kurchman (1993) noted that fertilization did not necessarily influence number of tubers per plant but use of NPK was observed to significantly influence the growth of primary vines and number of secondary vines. The widest leaf was observed with the use of inorganic fertilizer thus indicating that the ratio of release was fast compared to organic fertilizer, and may be responsible for the same treatment having the highest number of leaves.

Lyonga (1984) observed that chemical fertilization with 160 units of nitrogen produces 18.25 and 21% in D. *cayanensis*, *dumetorum* and *rotundata* varieties while rates of 120 and 240 units of potassium improve the yield of *D. rotundata* by 13.4 and 22.5%. Degras (1986) estimated the mineral elements uptake per tonne of fresh tuber as 4kg N, 0.4kg P_2O_5, 4.4 kg K_2O, 0.1 Ca and 0.2kg Mg. **L**e Buanec (1972) in Côte d'Ivoire reported mineral needs for *D. cayenensis-rotundata* and *D. alata*; the production of a ton of yam tubers exports 3.9 kg of nitrogen, 0.7 kg of P_2O_5 and 5.0 kg of K_2O.

Based on the respective amounts of nutrient absorption from the soil by yams during growth, N and K are the critical nutrient elements (Sobulo, 1972; Okigbo, 1980). For instance, a yam yield of 29 t/ha is reported to have removed 133, 10 and 85 kg/ha of N, P and K from the soil (Sobulo, 1972). Similarly, Okigbo (1980) reported that an average yield of 11 t/ha removed 36 kg N, 3.06 kg K and 0.7 kg Ca/ha. At the peak period of nutrient supply, nutrient content of *D. rotundata* lamina was found to be 3.20-3.45%N, 0.28-0.30% P, 2.20-2.50% K, 0.45-0.70% Ca and 0.27-0.37% Mg (Obigbesan and Agboola, 1978). Based on soil test result Kayode (1985) could not obtain yield response to fertilizers on Alfisols at Ibadan when the total N ranged from 0.33-0.38%, available P from 4.98-11.4mg/kg and exchangeable K from 0.15-0.18mg/100g. Similarly, on Alfisols at Otobi in Southern Guinea savanna, Ohiri (1990) obtained highest tuber yield consistently in 1985 and 1989 with the application of 90kg N, 10kg P and P(<15 mg/kg) but medium in K (0.20-0.30mg/100g). Under the same soil Ohiri and Chukwu (1991) found that application of 4.0t/ha of cow dung could replace 50% of the inorganic fertilizer requirements for yam.

Inorganic fertilizer use is however reported to lead to increase in the population of yam nematode *Scutellonema bradys* (Obigbesan and Adesiyan 1981); poor tuber storability (Aduayi and Okpon 1980, Asadu 1995); profuse weed growth (Onochie 1974); increased carbon organic matter breakdown (Agboola 1981); nitrogen eutrophication and acidification low residual effects as well as high fertilizer costs.

In a study by Okpon and Aduayi (1988) to evaluate the effect of different levels and sources of N on the nutrient composition of yam flour, it was found that applying N in the form of ammonium sulphate fertilizer (NH_2SO_4) and urea up to 160 kg/ha increased N content of yam while 160 kg N/ha applied in the form of Calcium Ammonium Nitrate (CAN) depressed N content. Application rate of between 80 and 160 kg N/ha as

$(NH_4)_2SO_4$ or urea to improve the quality of yam grown in the humid soils of Southwestern Nigeria was thus recommended

A combination of organic and inorganic fertilizer had the best influence on tuber yield and tuber characteristics and this might increase nutrient use efficiency (Murwira and Kurchman, 1993).

2.14 Milking

Yams must be harvested in a relatively short period and then stored once they have reached maturity compared to cassava (FAO, 1999). Yam tubers are dormant after complete senescence of vine, for 1-5 months, depending on storage conditions and species. Tubers harvested earlier in the full maturity tend to have extended dormancy period (Okoli, 1980). Yams have the longest dormancy period among the tropical root crops making it possible to store the harvested tubers for 6 months or longer (FAO, 1999). The small scale farmer in Ghana grows yam using traditional methods for seed yam production i.e. milking or harvesting the yam tubers (ware yams) early and using the resulting seed yam for planting (MiDA, 2009). *Dioscorea rotundata* comprises two harvest varieties that produce two separate products in one season; tubers for consumption are harvested when yam reaches economic maturity ("milking"), and seed yams for replanting and ware yams harvested at physiological maturity. According to Andreas (2003), most farmers in Ivory Coast grow multitude of yam genotypes to satisfy their culinary preferences and seasonal needs. In double harvest, non mature tubers are dug out at approximately 5 months after planting leading to the formation of a second tuber with a different more lobed shape and serves almost exclusively as planting material. *D. cayenensis* and *D. alata* however are grown with only one harvest period. Martin (1979) reported that the amount of starch in yam tubers depends on the age of the tuber at harvest. Tubers are stored following harvest during which time losses occur.

2.15 Storage losses

The most serious losses in the yam production process occur at storage when traditional methods are used and are mainly due to physiological and pathological factors. Passam *et al*. (1978) noted three main factors as being responsible for storage loses:

1) Catabolic activity increases 3.5 times after the breaking of dormancy i.e. 2 to 4 months after the beginning of the storage period resulting in loss in weight and decrease in nutritional quality of the tuber (Trèche, 1979; Onayemi and Idowu, 1988).

2) Pests cause serious damage to the tubers in storage (Sauphanor *et al.,* 1987). Moths' larvae can severely damage stocks of *D. alata*. Mealybugs (e.g. *Phennococcus sp.* or *Geococcus sp*.) and scale insects (e.g. *Aspidiella hartii*) live as a parasite on both *D. alata* and *D. rotundata*;

3) Rotting which affects mainly D. rotundata mostly occurs after dormancy when the biochemical catabolic activity in the tuber creates a favourable surface for fungi. Pona which is the preferred variety for marketing is reported to be significantly more perishable and susceptible to rotting compared to other varieties of the rotundata species. (Natural Resource Institute).

Pona, stores for a maximum of three months compared to 6-12 months for most other varieties (Kleih *et al.,* 1994). Tuber weight losses are generally up to 25% of the initial weight after 5 months' storage (Osagie, 1992) and can amount to up to 50% or more (Ikotun, 1989). Alhassan (1994) also cites post-harvest losses of yam and cassava in Ghana at 30% of the total crop. In a research conducted in Nigeria post harvest losses due to unfit for sale tubers (9.2%) and tubers absolutely wasted (3.2%) could equate to 10.45% loss of revenue of the affected farmers (Okoh, 1996). Results of surveys conducted in Ghana in 1994 by GTZ and NRI emphasized the importance of the need to improve the post-harvest storage, handling and transportation of yams (Kleih *et al*., 1994). Tubers have a relatively long storage life of 4-6 months at ambient temperature. Different cultivars of white yam were found to vary significantly in their dormancy periods but not same on the effects of manuring on the dormancy period of yams (Eze and Orkwor, 2010). Kpeglo *et al.* (1981) however did indicate that optimum nutrient combination would reduce weight loss and sprouting in storage (Table 2.2a&b). A study in southeastern Nigeria showed that yam tubers grown with organic manure had longer shelf life than those treated with chemical fertilizer in the field (Asadu, 1995).

Table 2.3: Percentage Tuber Weight loss (%) and tuber sprouting (%) in Storage

Tuber weight loss			Tuber sprouting		
8	16	24	11	13	15
Weeks after harvest					
26.7	55.2	63.6	6.1	75.6	96.0
10.7	35.4	55.8	48.6	67.9	83.3
			49.7	-	80.7

Source: Kpeglo *et al.* (1981)

Various methods have been tested to reduce storage losses. Scott *et al.* (2000) noted that tubers in good storage should be kept in their most edible and marketable conditions by preventing large moisture losses, spoilage by pathogens, attack by insects and animals, sprouting and protection from direct rain. Girardin (1996) reports of contradictory results in curing tubers to promote cicatrisation of wounds caused at harvest and to prevent development of subsequent rots.

In resource poor farmer setup, pre-storage 'curing' of yams has been advocated by a number of researchers as a means of diminishing the incidence and forestalling decay and moisture loss in tubers by encouraging the wound-healing of tissues immediately after harvest (Gray, 1996). The necessary conditions required for curing have been reported by many researchers but with mixed results.

Even though there seems to be agreement on the use of high humidity (>70^oC) there is still a wide range in suggested optimum curing temperature (25-40^oC) and curing duration (2-15 days).

i) Pit storage is recommended for pona milk yams (Gray, 1996) and damage has more significant effects on milk yams than on ware yams. Periodic manual de-sprouting of the tubers significantly reduces weight loss in storage (Girardin, 1996) and also improves the seed value of the tuber (Nwankiti, 1988). Yam tubers harvested before physiological maturity have high moisture of 70-80% which favours attacks by microorganisms during storage.

ii) The use of deltamethrine in controlling insect damage has been demonstrated on *D. alata* (Sauphanor *et al.*, 1987); and thiabendazole has reduced rots in *D. cayenensis-rotundata* (Girardin, 1995). Other methods such as the use of chemicals, irradiation and low temperature or controlled atmospheric conditions to suppress or delay sprouting of yams for longer storage, have been reported (Tschannen *et al*., 2003; Swannell *et al*, 2003). Ikotun (1989) suggested that slight improvement in storage can achieve substantial savings of the harvested tubers, with a significant contribution to food security.

iii) Processing techniques have also been developed to increase the length of preservation of the product and make it easier to use (Attaie *et al*., 1998). The process of parboiling and drying of the tubers to produce chips for making yam flour has been observed in Southwest Nigeria, Benin and sometimes Togo. The industrial process entails the production of flakes which are easily re-hydrated. It is sometimes processed into thin dried slices of tubers by frying and served as snacks.

2.16 Pests and Diseases of Yam

Rotting which affects mainly *D. rotundata* mostly occurs after dormancy when the biochemical catabolic activity in the tuber creates a favourable surface for fungi. Pona which is the preferred variety for marketing is reported to be significantly more perishable and susceptible to rotting compared to other varieties of the *rotundata* species (Gray, 1996).

FAO (1999) reported that viruses are normally seen as a major obstacle to yam production but their real effect at the farmer level has not been assessed by research. Viruses which act either singly or in combination are responsible for the suboptimal yields recorded and deterioration in the quality of tubers in storage. *Yam mosaic virus* (YMV) is one of the most important virus infecting yams in sub-Saharan Africa and has since been detected throughout the yam growing regions of Africa (Goudou-Urbino *et al*., 1996), the Caribbean, and the Pacific.

According to Morse *et al*. (2000) most yam rot induced by insect attacks are mainly due to storage beetles (Coleoptra), mealy bug (P*lanococcus* citri) and scale insect (*Aspidiella hartii*) during storage. Controlling insects and fungi is necessary to increase storage shelf life of yam.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

The experiment was conducted on the research field of the CSIR-Crops Research Institute (CRI) at Fumesua, Kumasi – Ghana from April to December, 2010. Fumesua (6^o 41'N 1^o 28'W) is located within the humid forest agro-ecological zone of Ghana with a mean slope of 2-6%. The rainfall pattern is bimodal [with major (April-June) and minor (August-November) rainy seasons], 1190-1650 mm with total annual rainfall of 1345mm/year. Mean annual temperature ranges from 22 - 31^oC. The soil is of the Ferric Acrisol Asuansi series type (Adu and Asiamah, 1992).

3.2 Experimental design and treatments

The trial was conducted using a 4x3 factorial experiment arranged in a Randomized Complete Block Design (RCBD) with 3 replications. Each replication had 12 plots at a spacing of 1.5m apart with 2m alleys between replications. Each plot measured 4m x 7m giving an area of $28m^2$/plot.

The two factors studied were, (i) Rate of fertilizer application (poultry manure and NPK, 15:15:15) and (ii) Time of milking.

The fertilizer treatment (factor A) consisted of four levels namely:

F1= Control (No fertilization)

F2 = Organic fertilizer only (poultry manure) at 4t/ha

F3 = Inorganic fertilizer only (i.e. NPK 15:15:15 at 300kg/ha i.e. 45kgN, 19.80kgP, 37.35kgK)

F4 = Inorganic fertilizer ($^1/_2$ rate – 150kg/ha i.e. 22.5kgN 9.9kgP, 18.7kgK) + organic fertilizer ($^1/_2$ rate – 2t/ha).

The time of milking treatment (factor B) consisted of three levels namely;

M1 = First Milking at 20 weeks after planting (WAP)

M2 = Second Milking at 24 weeks after planting (WAP)

M3 = Zero milking or harvesting at senescence/physiological maturity.

3.3 Management/Cultural Practices

3.3.1 Land Preparation

The experimental field which had previously been planted to sweet potato, was ploughed with a tractor drawn disc plough. The weed residues were then removed manually to clear the field. The field was pegged out into replications and plots and the mounds raised 1m x 1m apart using hoes.

3.3.2 Planting

Setts was planted on the 30th April, 2010 using an early maturing white yam (*Dioscorea* spp.) cultivar "pona" or " puna" at 1 x 1m spacing to obtain a population density of 10,000 plants per ha^{-1}. Average seed yam or sett size was 260g. Seed yams were obtained from contact farmers of the Savanna Agricultural Research Institute (SARI) from the northern region. Seed yams were treated with Topsin M (a.i. thiophanate-methyl) (70%WP) 20g and Pyrinex (a.i. chlorpyrifos) at 50-70mls to 15litres of water and air-dried for two hours before planting. This was done to protect the yams from fungi infestations.

3.3.3 Mulching

The mounds were mulched after planting using dry grasses and leaves to reduce the impact of intense radiation from the sun.

3.3.4 Staking

Yams were staked with bamboo (2 meters) after sprouting and vines routinely trained to the stakes for effective solar radiation interception for photosynthesis.

3.3.5 Fertilizer application

Fertilizer was applied to the plots on the 15th June 2010 (3 weeks after sprouting or 7 weeks after planting (7WAP) as per the treatments imposed. Fertilizers applied were organic (poultry manure) at the recommended rate of 4 tons/ha and inorganic fertilizer NPK (15:15:15) at the recommended rate of 300kg/ha i.e. 45.00kg N, 19.80kg P and 37.35kg K ha^{-1}. Plots with full inorganic fertilizer application received 0.126kg, 0.055kg and 0.105kg of N, P and K respectively each whereas those with half dose application received 0.063kg, 0.028kg and 0.053kg of N, P and K respectively plus 5.6kg poultry manure. Fertilizers were applied in furrows or grooves created about 3-5cm deep and approximately 10cm from stems on the crest of the mound and covered with soil. Treatments that received recommended dose of inorganic NPK 15:15:15 and organic (poultry manure) fertilizer were given 30g and 400g per plant respectively and 15 and 200g for half dosage treatments. Application rate in terms of quantity was thus 30g NPK and 400g poultry manure for full dose and 15g and 200g NPK and poultry manure respectively for half dose.

3.3.6 Weed control and replacement of fallen stakes

A total of four weedings was done to control weeds. First weeding was by hand pulling at 6WAP. The rest were done at 11, 17, and 24 WAP. At the 17 WAP mound repair or earthen-up was done. Replacement of fallen stakes was done during plant growth and development

3.4 Data Collected

3.4.1 Soil sampling and analysis

Soil samples were randomly taken before planting from five (5) different spots across each block from a depth of 0-15cm and 15-30cm. Representative samples were bulked, air-dried and sieved to pass through a 2-mm mesh. Each composite sample was analyzed separately for soil pH, total nitrogen (N), organic carbon, available P, and exchangeable K.

Soil pH. Soil pH was determined using glass electrode pH meter in a 1:2.5 soil water ratio (Rhodes, 1982).

Total nitrogen (N) of soil. Total nitrogen was determined using the micro-Kjeldahl method which consists of;

(i) Digestion: 10g of soil was weighed and digested with concentrated sulphuric acid using selenium mixture as catalyst. (ii) Distillation: the mixture was made up to 100mls and an aliquot of 10mls was steam distilled by adding 40% sodium hydroxide (NaOH) and collected in boric acid/indicator solution (iii) volumetric analysis: the collected mixture was titrated with known concentration of 0.1M HCl and percentage nitrogen calculated.

Organic carbon (OC). The OC was determined using the Walkley and Black (1934) method. 1.0M potassium dichromate (acidified) was used to oxidize the carbon in the soil. The unreduced dichromate was then titrated with 1.0M ferrous sulphate (acidified solution). The percentage organic matter content was then calculated by multiplying the percentage organic carbon by the conventional "Van Bemmelen factor" of 1.724.

Available phosphorus. This was extracted with Bray-1 solution (Anderson and Ingram., 1989). Colour developed with a mixture of molybdenum and a reducing agent to a blue phospho- molybdonate complex was measured by spectronic 20 at 520nm wavelength.

Exchangeable potassium (K): Soil was extracted with neutral (pH 7.0) ammonium acetate and K was measured in a flame photometer.

3.4.2 Analysis of Poultry Manure

Poultry manure was ashed before chemical analysis to determine the concentration of the major nutrient elements of nitrogen (N), phosphorus (P) and potassium (K).

Ashing: About 5.0g of manure was weighed into a crucible with lid and placed into a muffle furnace. The sample was ignited slowly and the temperature of furnace increased vigorously from 150^{o}C by 50^{o}C each time till it reached 450^{o}C. The sample was allowed at this temperature to ash properly for 4 hours and furnace was switched off. The ash sample was allowed to cool to 110^{o}C. The crucible with sample was placed in an air-tight desiccator and cooled for 20 minutes and then weighed. Percentage ash was determined using the formula:

$$\%Ash = \frac{\text{change in weight}}{\text{Dry weight of sample taken}} \times 100$$

Total nitrogen (N) of poultry manure: This was determined using the micro-Kjeldhal method which consists of i) digestion, ii) distillation and iii) titration. The process was same as described above for soil total nitrogen.

Determination of potassium (K): 10mls aliquots of standard samples, digested and blank were measured into test tubes. The K-emission was measured in an air acetylene flame. The amount of K was determined using the formula below:

$$\%K = \frac{a - b}{\text{Factor}} \times M$$

a = measured µgK/ml in sample

b =measured µgK in blank

M = moisture correction factor

Determination of phosphorus (P): 5ml of digest was measured into a flask and 10ml of vanadomolybdate reagent added and made up with distilled water in a 50-ml volumetric flask. It was then shaken vigorously and kept for 30 minutes. A yellow colour developed and was read at 430nm on a spectrophotometer. The absorbance and P content were determined from the standard curve. A blank determination was done alongside the sample.

$$\% P = \frac{C}{10}$$

Where C= concentration of P (µg/ ml) as read from the standard curve.

3.4.3 Growth measurements

Crops growth was measured at first and second months after planting using the two middle rows per plot. The mean vine length was determined using a tape measure whilst vine number, number of branches and leaves per plant were determined by count.

3.4.4 Disease assessment

Some major field diseases, yam mosaic virus (YMV) and leaf spot disease (Frances, 1989) were assessed at 4 and 5 MAP. Number of plants that were affected per 2 middle rows of pots was counted and expressed in percentage as the proportion of infected plants to the total number of plants in the harvest area.

3.4.5 Tuber Yield

Three harvesting regimes were imposed. Two milking treatments were conducted at 20 and 24 WAP when the tubers were still at economic maturity stage (when tubers were well developed for consumption) and at physiological maturity (32 WAP) when almost all the yam plants had completely senescenced. Two middle rows were harvested from each plot for yield determination. The treatments that were milked were harvested twice and these amounted to the total yield for those plots. The tuber fresh weight per plot was measured

The yam yield was determined per plot for all treatments at each harvest. This was extrapolated to kilogram per hectare. The total yield per plot for the treatments that were harvested twice was determined by summing the yield at milking and that at final harvest. The yield of the "unmilked" plots was determined at senescing of the yam vines. The mean number of tubers per stand and average tuber weight per treatment were determined at each harvest. At each harvest, yield realized was valued using the prevailing market price for yam in the Kumasi metropolis.

Yield was then extrapolated to kilogram (kg) per hectare basis for each treatment. Five average tubers per treatment were used to determine mean diameters of tubers using venier calipers while their lengths and circumference were measured with a tape measure.

3.4.6 Determination of Shelf life

Storage trial was conducted in the yam barn of the CSIR-Crop Research Institute (CRI) to determine the shelf life of yam tubers per the treatments. A total of five healthy tubers were randomly selected from each treatment and fresh weight taken at every 2 weeks. The weight loss, presence and level of rot, storage pests and diseases were also scored. Weight loss was determined as:

$$\text{Percentage weight loss} = \frac{\text{initial weight} - \text{current weight}}{\text{Initial weight}} \times 100$$

Rotting was determined using the formula below:

$$\text{Percentage rot} = \frac{\text{Number of tubers that rotted}}{\text{Total number of tubers stored}} \times 100$$

Rate of rotting was expressed as a percentage of surface area over time

3.4.7 Economic Analysis

Economic analysis of tubers was determined at harvest for all treatments. The price per kilogram value of marketable tuber and seed yam was used for this analysis. A partial budget analysis was used to calculate the net benefits derived from the different treatments. Yields from all the treatments were adjusted downwards by 10% to reflect what farmers would obtain due to inaccuracies that would occur in terms of fertilization and plot size (CIMMYT, 1988). Total variable costs such as cost and transportation of fertilizer, cost of fertilizer application were subtracted from the treatment plots where they were applied to find the net benefit (not profits).

Net benefits = Gross field benefits – Variable costs

The difference between the extra costs associated with applying the treatments and the gain in net benefits were then used to determine the marginal rate of return. Thus:

$$\text{Marginal rate of return (\%)} = \frac{\text{Difference in net benefits}}{\text{Difference in variable costs}}$$

This ratio is usually expressed as a percentage.

3.4.8 Sensory analysis

3.4.8.1 Preparation of boiled yam

The yam tubers were washed, peeled and middle portion (since the proximal and the distal portions vary much in their composition) was cut into smaller uniform cubes of about 30g. These were boiled with 500ml of water for about 20 minutes. A fork was used to test when yam was well cooked. The cooked slices were taken and wrapped with cling film to keep warm. These were then stored in ice chest until panel was ready for sensory evaluation

3.4.8.2 Panel composition

A team of panelist mainly students of the Department of Food Science, KNUST, was used for the test in the sensory laboratory of the Department. Panelists were given short training to have a good understanding of the attributes being rated to enable them provide valid and reliable data.

3.4.8.3 Sensory test

The multiple comparison test was adopted in this study. Culinary qualities as influenced by the various treatments on the eating qualities of yam were assessed. Each panelist was served with the control treatment sample 'C' and the test treatments T4 (884), T6 (381), and T8 (692) simultaneously. Test samples were labeled with three digit codes derived from a standard random table. With each attribute, the control was tested and used as a reference for assessing the test sample by way of comparison A 7 point hedonic scale was used to score for taste; (sweetness), texture (mealiness, sogginess, hardiness and moistness), aroma (how nice) and colour (creaminess). Test samples were thus scored as being same, better than or worse than control. A 0-6 range codes was used where; 0 = much worse 1 = moderately worse, 2 = slightly worse, 3 = no difference, 4 = slightly better, 5 = moderately better, 6 = much better. Each panelist was served with all treatments in the sensory laboratory. Treatment 2 (no fertilizer) was labeled 'C' (control) and the test samples labelled random numbers. Panelists tasted the control treatment first, and then washed their mouth with water before tasting the other treatments.

3.4.9 Proximate Analysis

3.4.9.1 Preparation of yam flour;

Yam tuber was washed and cut into four longitudinal slices. Two opposing slices were peeled and chopped into very smaller pieces and thoroughly mixed. This was oven-dried at 60 ^{0}C for 72 hours (Lape and Treche, 1994). The dried chips were milled into fine flour, stored in deep freezer and used for the food value analysis.

3.4.9.2 Determination of moisture content;

Moisture content for each treatment was determined using the AOAC (1997) method. Yam tuber was washed and cut longitudinally into four equal long slices. Two opposing slices were chopped into smaller pieces. Five grams was weighed using a petri dish that was already oven-dried and cooled in a desiccator, and dried in a thermostatically controlled oven for 5 hrs at 105^{o}C and weighed. Samples were removed and cooled in a desiccator and weighed. This procedure was repeated for 30 minutes until a constant weight was obtained. The moisture content was determined by difference and expressed as percentage using the formula below:

$$\%Moisture = \frac{(\text{wt of petri dish + fresh sample}) - (\text{wt of petri dish + dry sample})}{\text{Wt of fresh sample}} \times 100$$

Percentage dry matter = 100 – Moisture content

3.4.9.3 Determination of ash

The ash content was determined using the Official Methods of Analysis (AOAC, 1997). Two grams of yam flour was transferred into a dried and pre-weighed porcelain crucible. This was then placed in a muffle furnace preheated to 600^{o}C for 2 hours. The crucible was removed and cooled in a desiccator. The crucible and its contents were weighed. Total ash content was calculated and expressed as a percentage.

$$\%\ Ash = \frac{(\text{Weight of crucible} + \text{ash}) - \text{Weight of empty crucible}}{\text{Weight of sample}} \times 100$$

3.4.9.4 Determination of crude fat

A previously oven-dried 250 ml round bottom flask was accurately weighed and asbestos added to it. Two grams of the dried yam flour was transferred to a 22x80 mm paper. Glass wool was placed into the thimble to prevent loss of flour. One hundred and fifty milliliters of petroleum ether was added to the round bottom flask and the apparatus was assembled. A Quickfit condenser was connected to Soxhlet extractor and refluxed for 2 hours on high heat using a heating mantle. The flask was then removed and evaporated on a steam bath. The flask and its content were then heated in an oven for 30 minutes at 103^{o}C and cooled to room temperature in a desiccator and weighed. The fat content was expressed as percentage by weight as follows:

$$\% \text{ Crude fat} = \frac{\text{Weight of extracted matter}}{\text{Weight of sample}} \times 100$$

3.4.9.5 Determination of crude fibre

Residue from the crude fat determination was transferred into a 750 ml Erlenmeyer flask and approximately 0.5 g of asbestos was added. Two hundred milliliters of boiling 1.25% H_2SO_4 was added and the flask was immediately set on a hot plate with condenser fitted. The flask and its content were heated for 30 minutes. The flask was then removed and immediately filtered through linen cloth in a funnel and washed with a large volume of boiling water until washings were no longer acidic.

The filtrate and asbestos were washed back into a flask with 200 ml boiling 1.25% NaOH solution. The flask was then connected to the condenser and boiled for exactly 30 minutes. At the end of 30 minutes, the content in the flask was filtered through linen cloth in a funnel and washed with large volumes of boiling water.

The residue was transferred into a Gooch crucible with water from the wash bottle. This was then washed with 15 ml alcohol. The crucible and its contents were dried for 1 hour at 100^{o}C. The crucible was cooled in a desiccator and weighed. The crucible was then ignited in a muffle furnace for 30 minutes, cooled in a desiccator and re-weighed.

$$\% \text{ Crude fibre} = \frac{\text{Weight of dried sample - Weight of ash}}{\text{Weight of fat residue}} \text{ X } 100$$

3.4.9.6 Determination of crude protein

1 Digestion: Two grams of yam flour was transferred into a digestion flask. Half of selenium based catalyst tablet and a few anti-bumping agents were added to the flask. Thirty millilitres of concentrated sulphuric acid (H_2SO_4) was added and the flask shaken to ensure that the yam flour was thoroughly wet. The flask was then placed on a digestion burner and heated slowly until the resulting solution became clear. The flask and its

content were cooled to room temperature. The digested flour solution was transferred into a 100 ml volumetric flask and distilled water added to the mark.

2 Distillation: To flush out the apparatus before use, distilled water was boiled in a steam generator of the distillation apparatus, with the connections arranged to circulate through the condenser, for at least 10 minutes. Twenty millilitres of 4% boric acid was pipetted into a 250 ml conical flask and 2 drops of mixed indicator added. Liquid from the steam trap was drained. The conical flask and its contents were placed under the condenser in such a position that the tip of the condenser was completely immersed in solution. Ten milliliters of the digested solution sample was measured into the distillation flask. Excess of 40% NaOH was added to the distillation flask and the funnel stopcock closed. The stopcock on the steam trap outlet was shut to force steam through the distillation chamber in order to drive the liberated ammonia into the collection flask.

3 Titration: The distillate was titrated with 0.1M HCl solution. The acid was added until the solution was pink. The same procedure was followed for the blank.

3.4.9.7 Determination of total carbohydrate

Total carbohydrate was calculated by the difference between 100 and the sum of moisture, ash, crude fat, crude protein and crude fibre (Pellet and Young, 1980).

3.5 Data Analysis

The data (except sensory evaluation data) were analyzed with analysis of variance (ANOVA) technique using Genstat statistical package (discovery edition 3). Differences between treatment means were determined using Least Significant Difference (LSD) at 5% level of probability. Sensory evaluation data was analysed using SPSS statistical software (version 17). One sample t-test and mean scores were determined using the p-value at 95%.

CHAPTER FOUR

4.0 RESULTS

4.1 Soil Physical and Chemical Properties

The results of the physical and chemical properties of the soil (0-30cm) of the experimental site are presented in Table 4.1. The texture of the experimental site was sandy loam and well drained. Available phosphorus of 4.84mg/kg and soil total nitrogen of 0.12% were low (Bray and Kurtz, 1945). Exchangeable potassium was 0.19cmol/kg and was classified as moderate (Anderson and Ingram, 1993). Soil pH was strongly acidic (4.72). The value of organic carbon percentage was low (1.03%) across the field.

Table 4.1: Soil physical and chemical properties (0-30cm) of the experimental site

Soil properties	**0-15cm**	**15-30cm**
Organic carbon (%)	1.19	0.87
Organic matter (%)	2.06	1.49
Total Nitrogen (%)	0.13	0.11
Potassium (K) (cmol kg-1)	0.23	0.15
Available P(mg/kg)	8.44	1.24
pH (H_2O)	4.84	4.6
Sand (%)	84.3	80.97
Silt (%)	3.9	4
Clay (%)	11.77	15.1
Textural class:	Sandy loam	

The nutrient content of the manure on a dry matter basis was relatively low; in the range of 4.06%, 1.65% and 3.01% for N, P, and K respectively. Poultry manure according to Leonard (1995) has about 11%N, 11%P and 5%K.

Table 4.2: The chemical composition of organic fertilizer (poultry manure) applied to yam

Nutrient element	Nitrogen (N)	Phosphorus (P)	Potassium (K)	Organic carbon	Organic matter
Percentage (%)	4.06	1.65	3.01	9.67	16.67

4.2 Milked tuber yield, Seed yam and Total tuber yields of yam (t/ha).

Total tuber yield was statistically different ($p<0.01$) among the fertilizer treatments (Table 4.3). Application of half rates (i.e. 2t/ha + 150 hg/ha) of PM+ NPK recorded the highest yield of 38.97t/ha, which was significantly higher than the control treatment effect value. All other treatment means were statistically similar. Time of harvest did not affect milked tuber yield.

Seed yam yield was significantly ($p<0.05$) affected by fertilizer application (Table 4.3). The effects of the half organic and inorganic fertilizer treatments and NPK treatment only were not significantly different from one another, but either effect was significantly higher than the control treatment effect. Seed yam yield from the poultry manure only treatment was significantly lower than that of the half rates of the organic and inorganic fertilizer treatment. Seed yam yield was significantly ($p<0.05$) affected by time of milking. Milking at 20 WAP produced seed yam that was significantly higher than milking at 24 WAP (Table 4.3).

Table 4.3: Effect of fertilizer and milking time on milked tuber yield, seed yam and total tuber yield of *D. rotundata* (t/ha).

Treatment	Yield of milked yam) (t/ha) *	Yield of seed yam (t/ha)	Total tuber yield (t/ha)
Fertilization (A)			
No fertilizer	18.57	9.91	27.42
Poultry manure (PM)(4t/ha)	23.86	10.65	33.70
NPK 15:15:15 (300kg/ha)	23.26	11.87	33.22
NPK + PM (half rates)	27.86	14.44	38.97
Lsd (0.05)	7.29	3.23	5.03
Milking (B)			
20 WAP	21.60	16.66	38.28
24 WAP	25.22	6.77	31.93
32 WAP (no milking)	-	-	29.77
Lsd (0.05)	Ns	2.28	4.36
CV (%)	30	26.5	18.2

***significant in**teraction effects of treatment values at p<0.05

4.3 Number of tubers per stand, Tuber length and Tuber girth

Fertilizer application and time of harvesting did not significantly (p>0.05) affect tuber length and tuber girth (Table 4.4). The effect of the half organic and inorganic fertilizer treatment on number of tubers per stand was however, significantly higher (p<0.05) than the control treatment effect. There was however significant interaction effects of treatment values on tuber length.

Table 4.4: Effect of fertilizer and time of harvest on yield components of yam.

Treatment	Number of tubers	Tuber length (cm)*	Tuber girth (cm)
Fertilization (A)			
No fertilizer	1.68	33.3	22.4
Poultry manure (4t/ha)	1.89	35.2	23.4
NPK15:15:15 (300kg/ha)	1.92	33.1	23.2
PM + NPK (half rates)	2.12	32.9	22.1
Lsd (0.05)	0.43	Ns	Ns
Milking (B)			
20 WAP	2.05	32.2	22.7
24 WAP	1.81	34.9	23.3
32 WAP	1.85	33.8	22.3
Lsd (0.05)	Ns	Ns	Ns
CV (%)	23	10.4	10.6

*** significant interaction effects of treatment values at $p<0.05$**

4. 4 Correlation of yield and yield components

The correlation between yield and all the yield components considered showed negative correlations (Table 4.5). The result showed positive correlation between tuber diameter and tuber weight (r = 0.24) and tuber number (r = 0.001). Tuber girth also correlated positively with tuber number (r = 0.012) and tuber length (r = 0.19) but correlated negatively with tuber weight (r = - 0.09). There was positive correlation between tuber number and tuber weight (r = 0.34) during the study.

Table 4.5: Correlation co-efficients (r) between yield and yield components of white yam.

Component	correlations 1	2	3	4	5	6
Yield	1.00					
Mean Tuber Diameter	-0.07	1.00				
Mean Tuber girth	-0.35	-0.77	1.00			
Mean Tuber number	-0.39	0.00	0.01	1.00		
Mean Tuber Length	-0.33	-0.42	0.19	-0.09	1.00	
Mean Tuber weight	-0.43	0.24	-0.09	0.34	-0.18	1.00

4.5 Yam Mosaic Virus (YMV) and leaf spot infections at 4 and 5 MAP

There was a higher level of Yam Mosaic Virus infection (42.6%) in the sole NPK treatment and this was significantly higher ($p<0.05$) than all other treatment effects (Fig. 4.1) at 4 MAP. There were reduced levels of YMV infection in all the treatments at 5MAP, and treatment differences were not significantly different

Leaf spot infection at 5 MAP was highest in the PM+NPK treatment (20.10%) and this was significantly higher ($p<0.05$) than all other treatment effects. All other treatment effects were statistically similar.

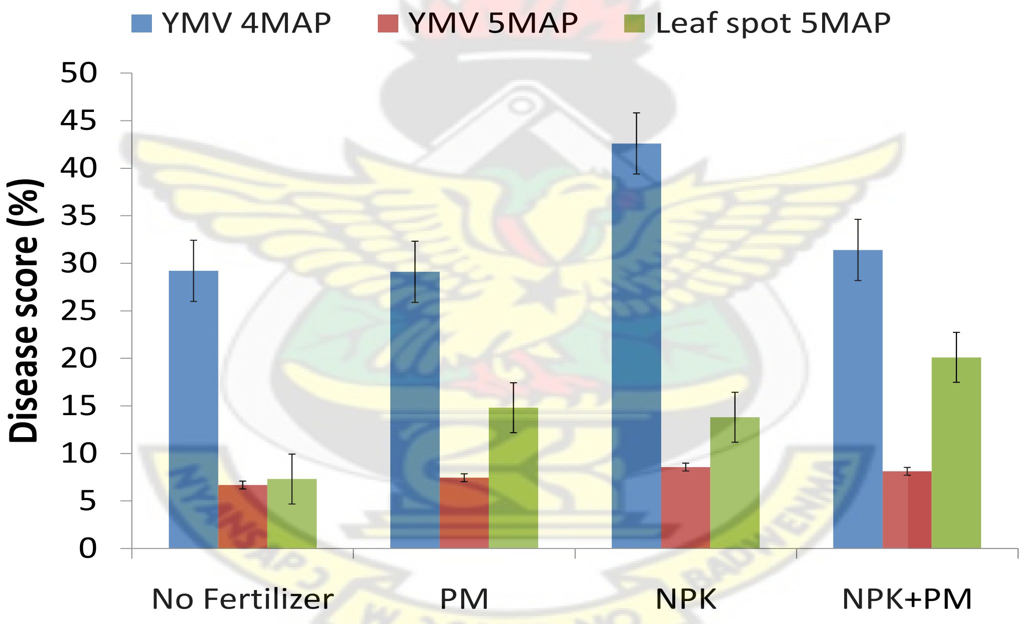


Fig. 4.1: Yam Mosaic Virus (YMV) and leaf spot disease incidence (%) at 4 and 5 MAP

4.6 Tuber weight loss and rot score at storage.

The application of fertilizer on white yam significantly ($p<0.05$) influenced tuber weight loss during storage (Table 4.6). Application of poultry manure led to significant weight loss (23.79%) during storage compared to the no fertilization (16.74%) and combined application of PM and NPK (18.97%). Weight loss of poultry manure treated yam during storage was however not different from that treated with sole NPK fertilization. All other treatment means were not significantly different from one another. Time of harvesting significantly influenced mean tuber weight loss over the 3-month storage period (Table 4.6). Weight loss under storage was significantly higher (p<0.01) when yam was harvested at 20 WAP compared to 24 and 32 WAP. The difference between the latter two treatments was not significant.

Tuber rot score at storage was greatest in the combined organic and inorganic fertilizer treatment, which was significantly higher than all other treatment effects. All other treatment differences were statistically similar (Table 4.6). Harvesting at 24 WAP resulted in the greatest tuber rot score which was significantly higher than the other treatment effects.

Tuber weight at harvest among all fertilizer treatments were not significantly different (p>0.05) from one another (Table 4.6). Harvesting at 32 WAP produced the greatest tuber weight, which was significantly higher than the other treatment effects, which were similar.

Table 4.6: Tuber weight loss and rot score at storage.

Treatment	Weight loss of tuber (%) (3 mths)**	Mean tuber wt at harvest (kg)	Rot score of tubers in storage (%)*
Fertilization (A)			
No fertilizer	16.7	1.35	8.0
Poultry manure	23.8	1.37	16.0
NPK 15:15:15 (300kg/ha)	19.8	1.22	16.8
PM + NPK (half rates)	19.0	1.24	35.3
Lsd (0.05)	4.5	0.3	12.0
Milking (B)			
20 WAP	23.5	1.03	14.9
24 WAP	19.5	1.11	30.1
32 WAP	16.4	1.75	12.1
Lsd (0.05)	4.0	0.26	10.4
CV (%)	23.2	23.9	64.4

*** significant interaction effects of treatments values at $p<0.05$**

4.7. Proximate analysis

4.7.1 Chemical composition of yam at 20 WAP

Proximate analysis (Table 4.7) at 20 WAP indicates that none of the fertilizer treatments improved the ash levels of tuber. Only the sole NPK fertilizer treatment performed equal to the no fertilization. It was, however, revealed that there was better improvement in carbohydrate content for all fertilizer treatments compared to no fertilization. The sole PM treatment had the highest carbohydrate content of 20.34±0.95%. There was significant difference ($p<0.05$) in the crude fibre content for PM and sole NPK compared to PM+NPK and no fertilization. There was significant difference among the fertilizer treatments in crude protein, nitrogen, fat and potassium contents of the tuber at 20 WAP (Table 4.7). Sole NPK and PM treatments had low moisture content of 65.48±0.83% and 66.73±0.08% respectively while the no fertilization had the highest percentage of 70.56±0.23.

Table 4.7: Effect of fertilizer on the chemical composition of yam (% fresh tuber) at 20 WAP

Treatment	Ash	Carbohydrate	Crude fibre	Crude protein	Fat	Moisture	Nitrogen	Potassium
Control	2.15±0.07	13.35±0.40	1.28±0.04	12.15±0.14	0.51±0.01	70.56±0.23	1.95±0.02	1.46±0.08
P. manure	1.55±0.07	20.34±0.95	1.98±0.07	9.67±0.05	0.98±0.03	65.48±0.83	1.55±0.01	1.10±0.03
NPK only	2.11±0.13	16.55±0.70	2.01±0.04	12.13±0.18	0.48±0.04	66.73±0.08	1.94±0.03	1.62±0.17
PM+NPK	1.74±0.08	16.95±0.54	1.03±0.01	11.66±0.22	0.98±0.04	67.65±0.21	1.87±0.04	1.33±0.11
Lsd (0.05)	0.22	1.88	0.12	0.44	0.08	1.94	0.07	0.30
Mean	1.89	16.8	1.57	11.4	0.74	67.61	1.82	1.38
CV(%)	5	4	2.8	1.4	4	1	1.4	7.9

Values with common letters along columns are not significantly different at $p>0.05$

4.7.2 Chemical composition of yam at 24 WAP.

The application of NPK fertilizer showed significant effect in the ash content of yam at 24 WAP. Significant difference ($p<0.05$) also existed among treatment means for carbohydrate (Table 4.8) with PM treatment mean being the highest. With crude protein, all the fertilizer treatments recorded higher values than the control. All fertilizer treatments gave higher crude protein and nitrogen levels than the control. The mean fat and potassium contents for sole NPK fertilizer showed significant difference ($p<0.05$) in relation to the other treatments. Fertilizer application also caused significant difference in moisture content of tuber harvested at 24 WAP. PM+NPK fertilizer treatment had the lowest moisture content of 60.28±0.04% (Table 4.8).

Table 4.8: Effect of fertilizer on the chemical composition of yam (% fresh tuber) at 24 WAP.

Treatment	Ash	Carbohydrate	Crude fibre	Crude protein	Fat	Moisture	Nitrogen	Potassium
Control	1.41±0.01	24.44±0.32	0.53±0.02	11.35±0.04	0.99±0.02	61.30±0.28	1.82±0.01	1.55±0.18
P. manure	1.39±0.01	25.91±0.36	0.52±0.01	11.72±0.13	1.46±0.06	59.02±0.16	1.88±0.02	1.23±0.04
NPK only	2.33±0.10	17.38±0.47	0.51±0.01	11.76±0.08	1.96±0.06	66.06±0.23	1.88±0.01	2.13±0.14
PM+NPK	1.53±0.11	24.51±0.57	0.48±0.01	12.23±0.04	0.97±0.04	60.28±0.40	1.96±0.01	1.43±0.18
Lsd (0.05)	0.20	1.23	0.04	0.23	0.13	0.79	0.04	0.41
Mean	1.66	23.06	0.51	11.76	1.34	61.67	1.88	1.58
CV (%)	4.4	1.9	2.7	0.7	3.5	0.5	0.7	9.3

Values with common letters along columns are not significantly different at p>0.05

4.7.3 Chemical composition of yam at 32 WAP

The effect of fertilizer application on mean ash content was not significant (($p>0.05$) at 32 WAP (Table 4.9). Sole PM and PM+NPK treatments however exhibited significant difference in their carbohydrate levels in relation to the sole NPK and the control. Sole NPK treatment was also significantly higher ($p<0.05$) in crude fibre compared to the other fertilizer and control treatments. There were variations in treatment means for crude protein, fat, moisture, nitrogen and potassium among the fertilizer treatments but none of them differed significantly from the control treatment (Table 4.9).

Table 4.9: Effect of fertilizer on the chemical composition of yam (% fresh tuber) at 32 WAP.

Treatment	Ash	Carbohydrate	Crude fibre	Crude protein	Fat	Moisture	Nitrogen	Potassium
Control	1.36±0.02	21.77±1.06	1.41±0.06	14.00±0.73	1.96±0.08a	59.50±0.16	2.24±0.11	1.23±0.21
P. manure	1.42±0.02	28.45±1.06	1.08±0.06	7.51±0.73	1.56±0.08b	59.98±0.16	1.20±0.11	1.55±0.21
NPK only	1.36±0.06	26.66±3.58	2.00±0.01	7.43±0.61	1.41±0.13b	61.13±4.01	1.19±0.10	1.55±0.08
PM+NPK	1.51±0.13	27.75±1.62	1.48±0.06	11.70±0.45	0.51±0.01c	57.05±0.07	1.87±0.07	1.45±0.08
Lsd (0.05)	0.21	5.21	0.17	1.46	0.23	5.57	0.23	0.34
Mean	1.41	26.16	1.49	10.16	1.36	59.42	1.63	1.44
CV (%)	5.4	7.2	4	5.2	6	3.4	5.1	8.5

Values with common letters along columns are not significantly different at p>0.05

4.8 Sensory Analysis

The results (Tables 4.10, 4.11, and 4.12) showed that the taste/sweetness of yam under PM + NPK application was similar to the control at 20 and 24 WAP and better than the control at 32 WAP. Mealiness improved with time amongst the treatments and were rated similar to the control at 24 WAP, but PM + NPK was better than the control at 32 WAP. The PM treatment and the control were not different in hardness at 20, 24 and 32 WAP. The PM + NPK treatment was rated harder (3.55) than the control at 24 WAP but similar at 20 and 32 WAP in hardness. Both NPK and PM + NPK treatments had higher moisture levels (4.06 and 3.94 respectively) than the control (3.00) at 32 WAP. Even though the colour of yam under PM treatment was better (3.81) than the control at 20 WAP, it was similar to the control (2.69) at 32 WAP. The PM + NPK and the control did not differ in aroma at 20 and 24 WAP but the former was better (4.13) than the control at 32 WAP.

Table 4.10: Sensory evaluation of boiled yam at 20 WAP harvest

Treatment	Sweetness	Mealiness	Moistness	Sogginess	Hardness	Aroma	Colour
PM	2.24	2.00	2.43	3.00	2.90	2.43	3.81
NPK	1.52	2.19	2.19	2.67	2.14	1.81	1.95
PM+NPK	3.24	2.62	2.52	2.52	3.00	3.00	1.71
p-value	***	***	***	***	***	***	***

Means for 21 respondents.
Scale; 0-6 where, 0 = much worse, 1 = moderately worse, 2 = slightly worse, 3 = no difference, 4 = slightly better, 5 = moderately better, 6 = much better

Table 4.11: Sensory evaluation of boiled yam at 24 WAP harvest

Treatment	Sweetness	Mealiness	Moistness	Sogginess	Hardness	Aroma	Colour
PM	2.59	2.86	2.91	3.41	3.05	2.27	2.95
NPK	2.23	2.59	2.27	2.41	3.00	2.14	1.82
PM+NPK	2.68	2.64	3.32	3.91	3.55	2.68	4.68
p-value	***	***	***	***	***	***	***

Means for 22 respondents.
Scale; 0-6 where, 0 = much worse, 1 = moderately worse, 2 = slightly worse, 3 = no difference, 4 = slightly better, 5 = moderately better, 6 = much better

Table 4.12: Sensory evaluation of boiled yam at 32 WAP harvest

Treatment	Sweetness	Mealiness	Moistness	Sogginess	Hardness	Aroma	Colour
PM	2.75	3.44	2.31	3.50	3.31	3.44	2.69
NPK	2.50	3.38	4.06	3.69	2.81	3.50	3.06
PM+NPK	3.50	3.88	3.94	2.38	3.13	4.13	2.75
p-value	***	***	***	***	***	***	***

Means for 16 respondents.
Scale; 0-6 where, 0 = much worse, 1 = moderately worse, 2 = slightly worse, 3 = no difference, 4 = slightly better, 5 = moderately better, 6 = much better

4.9 Economic analysis

The economic analysis revealed that the application of PM + NPK gave the highest extra/gain in net benefits of Gh¢ 5595.03, Gh¢ 4152.83 and Gh¢ 3027.43 when yam was harvested at 20 WAP, 24 WAP and 32 WAP respectively (Table 4.13). The least extra benefit of Gh¢ 1274.57 was realized under sole NPK application when harvested at 24 WAP while the most profitable (Gh¢ 5595.03) was under application of PM + NPK at 20 WAP. The application of PM gave its highest extra benefit of Gh¢ 2920.62 at physiological maturity (32 WAP).

CHAPTER FIVE

5.0 DISCUSSION

5.1 Tuber yield of yam (t/ha)

The fertilizer treatments had significantly higher tuber yields than the control (no fertilizer) treatments. The difference observed in the tuber yield (t/ha) due to fertilizer treatment was not significant between sole PM and sole NPK. Yield from PM +NPK treatment was significantly higher (p=<0.001) than the PM, NPK and no fertilizer treatment effects. This could be due to the synergy of early nutrients by the NPK and the gradual release of nutrients by the poultry manure (Orkwor and Asadu, 1998). The highest yield (38.97 t/ha) was obtained from the PM+NPK treatment while the lowest (27.42 t/ha) was from the control treatment. This is contrary to earlier report by Iguilo (1989) that fertilization had no significant effect on yield of *D. rotundata* that were staked. However, the results corroborates the observation by Kayode (1985) that application of fertilizer increases the yield of white yam (*D. rotundata*) as application of 35 kg N/ha gave yield increase of 10.7% and 15.6% in 1980 and 1981 respectively. Similar results were obtained when 300 kg of NPK (15:15:15) was applied in fertilizer studies in white yam (Law-Ogbomo and Emokaro, 2009 and Law-Ogbomo and Remison, 2008). The yield of fertilized treatments ranged from 33.22 to 38.97 t/ha (Table 4.3). This was within the average reported potential yield of 20-50t/ha (FAO, 1985). FAOSTAT (2005) reported 7.9 t/ha for Africa and 13.8 t/ha for Asia. Fertilization of yam was reported to give highest yield in yam when it was followed by a dry period i.e. reducing leaching (O'Sullivan, 2010). Timely application of fertilizer at early vegetative stage and four (4) times weeding as well as staking could have led to efficient utilisation of fertiliser by yam (Unamma, 1981; Ndegwe, 1990). The results also indicated that the time of harvest treatment made significant difference in yield of white yam ("pona"). Harvesting at 20 WAP (Table 4.3) gave the highest yield of 38.28 t/ha. This was found to be significantly higher ($p<0.001$) than harvesting at 32 WAP (29.77 t/ha) and a better option since this would generate more seed yam. The yams harvested at 32 WAP were basically ware tubers which are not very good for seed yam. The higher total yield for the 20 WAP harvest treatment could be attributed to the milking. Milking might result in physiological stimulation that encourages production and transport of more photosynthate to the sink. This can be seen from the positive relation of harvest times and total yields (Table 4.3). There was no significant difference ($p>0.05$) in the total yield (t/ha) between 24 WAP and 32 WAP harvest times. The rate of photosynthate preparation and transport from the source to the sink might have slowed down due to vine senescence.

The interaction of fertilizer application and time of harvesting did not cause significant difference in the tuber yields. During milking (early harvest), only PM+NPK fertilizer treatment gave significant yield difference compared to the no fertilizer treatment (Table 4.3). Yield of early harvesting (milking) at 20 WAP and 24 WAP were not significantly different ($p>0.05$). In tuber formation, there is initial rapid increase in size and weight, but relatively low dry matter content (Okoli, 1980; Melteras *et al*., 2008 and O'Sullivan, 2010). The interaction of the time of harvest and the fertilizer treatments did not result in significant yield difference. During the second (final harvest), PM+MPK treatment yielded significantly higher ($p<0.05$) seed yam (14.44 t/ha) than sole PM (10.65t/ha) and the control (9.91 t/ha) due to fertilizer application. The sole PM yielded the least seed yam per hectare among the fertilizer treatments probably because a large amount of it had not yet mineralized. Leonard (1995) reported that only an average of 30% of the N and P_2O_5 and 50% of K_2O in poultry manure are available to crops during the first season of application. It can be observed that harvesting at 20 WAP gave seed yam yield of 16.66t/ha. This was 60% higher than seed yam yield at 24 WAP milking (6.77 t/ha). This observation was similar to findings made by Bencini (1991) that milking was good at 5-6 months after planting to regenerate seed yam. The results of second harvest indicate that the difference in yields was significant ($p<0.001$) among the times of harvest. Much more seed yam was generated by harvesting pona at 20 WAP than when delayed for another month (24 WAP). The yield results suggest that yam's general growth activities reduce after 5 months as vine growth ceases and tips become inactive (Melteras *et al*, 2008). The interaction effects of fertilizer application and time of harvesting on yield of seed yam was not significant ($p>0.05$).

5.2 Yield components of yam

The results (Table 4.4) indicated that the application of fertilizer on yam did gave significantly higher number of tubers (2.12) per stand ($p<0.05$). The number of tubers ranged from 1.68 (control) to 2.12 (PM+NPK) per stand. This observation contrasts the findings of Murwira and Kurchman (1993) where fertilization did not influence the number of tubers per stand. This was however, not significantly different from the other fertilizer treatment effects. This can be attributed to the fertilizer since the control was relatively lower. Fertilizer application could thus be good for seed yam (especially for minisett) production. Time of harvesting treatments did not make significant difference in the mean number of tubers per stand. This result was expected as tuber initiation and development precede harvesting. No significant interaction was observed with respect to the number of tubers per stand.

No significant ($p>0.05$) effect on tuber length of yam was observed. The interaction effect of sole organic fertilizer (PM) application on tuber length (37.93cm) was significantly higher than the PM + NPK (29.23cm) when both were harvested at 20 WAP. Interaction effects of time of harvesting at 24 WAP with PM+NPK treatment was also found to influence tuber length (38.33cm) significantly compared to 32.20cm of the control at the same harvest time. These two observations suggest that poultry manure has the potential for improving yam production for early harvesting. This will reduce the high cost of managing soil fertility where mineral fertilizer is costly. Contrary, Akanbi *et al*. (2007) reported longer tubers under yam without fetilizer than fertilizer treatments.

The mean tuber girth (cm) was not significantly influenced by fertilizer application (Table 4.4). The results again showed that there was no significant difference in mean tuber girth (cm) amongst the harvest time treatments. The period between the first and final harvest (20-32 WAP) recorded insignificant changes in tuber girth between the various harvest times. This is probably because tuber growth had reached the gradual phase but continues to accept dry matter accumulation (Melteras *et al*, 2008). This was contrary to observation by Akanbi *et al*. (2007) that application of cassava peel compost produced tubers with larger girths. There was no significant interaction effect on tuber girth ($p>0.05$).

The results obtained with respect to tuber girth (Table 4.5), indicate that there was no significant difference in diameter too as a result of fertilizer or time of harvest treatments and their interactions. This finding was, however, different from the earlier report by Murwira and Kirchman (1993) that combined application of organic and inorganic fertilizer had best influence on tuber characteristics of yams.

5.3 Yam Mosaic Virus (YMV) and leaf spot diseases of yam

Yam Mosaic Virus (YMV) was assessed at 4 MAP and the sole NPK (15:15:15, 300 kg/ha) treatment had significantly higher YMV infection (42.6%) compared to the other treatments (Fig. 4.1). Sole PM (4 t/ha) and PM + NPK treatment were not significantly different in mean YMV infection compared to each other and the control. There was a sharp reduction in YMV infection at 5 MAP (one month later) ranging from 8.56% for the sole NPK treatment to a low of 6.67 % for the no fertilizer treatment. This could be due to good nutrition as a result of the NPK application and the higher rainfall. Staking is also reported to have reduced diseases in yam (Hahn *et al*., 1987). The time of harvest had no effect on the incidence of YMV when means were compared ($p>0.05$). Results of leaf spot disease (a fungal disease caused by *Cercospora spp.*) (Fig. 4.1) showed that fertilizer treatments had significant effect on the disease prevalence. The application of PM + NPK significantly increased leaf spot disease incidence to 20.1% compared to 7.3% of the no fertilizer treatment. There was, however, no significant difference in leaf spot disease incidence among all fertilizer treatments. The trend in Fig. 4.1 indicates that poultry manure might predispose white yam to leaf spot disease infection. Further research work might support or disprove this claim or assumption. There was no observed significant difference in leaf spot disease infection at different harvesting times ($p>0.05$). This means that the harvest time of yam can be dissociated from leaf spot disease infection. Interaction of fertilizer application and time of harvest showed no significant effect on leaf spot disease rate at 5 MAP.

5.4 The storability of white yam tubers grown with different fertilizers.

Results from Table 4.6, indicated that the application of fertilizer had significant ($p<0.05$) effect on the percentage weight loss of white yam during the storage period. Application of PM led to 23.8% tuber weight loss during the 3 month storage. This was significant ($p<0.05$) compared to 16.7% of the no fertilizer treatment and 19.0% of PM+NPK. It was however, not significantly different from sole NPK treatment ($p>0.05$). The PM treatment tubers might have lost water rapidly during storage. Optimum fertilizer combination would reduce weight loss of yam under storage (Kpeglo *et al*., 1981). In this study, there was no significant difference between the weight loss due to sole application of NPK and all the treatments. Tuber weight losses are basically due to rotting and physiological activities of the tubers (Passan *et al.*, 1978). Time of harvest (Table 4.6) significantly influenced tuber weight loss over the 3 month storage period. There was significant difference ($p<0.01$) in weight loss of yam when it was harvested at 20 WAP (23.5%) compared to 24 (19.5%) and 32 WAP (16.45). There was highly significant ($p<0.001$).interaction effect of fertilization and time of harvest on tuber weight loss. Weight losses of up to 25% of initial weight of tuber during the first 5 months of storage have been reported by Osagie (1992). Tuber weight at 32 WAP (1.75 kg) was significantly higher than 20 WAP (1.03 kg) and 24 WAP (1.11 kg) ($p<0.5$). There was significant tuber weight loss due to interaction of PM and harvesting at 24 WAP ($p<0.05$). Weight loss of tubers of control treatment harvested at 20 WAP was however significantly higher than PM+NPK treatment harvested at 24 WAP.

It was observed from the results (Table 4.6) that fertilizer application did not cause significant difference in tuber weight of yam ($p>0.05$). Difference in yield was therefore due to high number of tubers in the fertilizer treatments. Tuber weights of 0.52kg and 3.51kg under no fertilizer and 600kg NPK/ha, respectively, were reported by Akanbi *et al*. (2007) at physiological maturity; while application of cassava peel compost (2.5 t/ha) plus NPK (450 kg/ha) produced very large tubers.

The influence of harvest time on tuber weight (kg) of yam was, however, significant at $p<0.01$. Tuber weight of harvest at 32 WAP was 36% and 41% higher than harvesting at 24 and 20 WAP respectively. This means that yam tuber undergoes dry matter accumulation during the later stages of development resulting in reduced moisture content. This observation is similar to report that yam tubers normally have initial rapid growth in size and weight but with low dry matter content and gain maximum dry matter yield when vine senescence is almost complete (Melteras *et al*., 2008; O'Sullivan 2010). The results also show that there was no significant interaction effect for all the treatments. This implies that harvesting at 32 WAP could be recommended when the objective is to produce large tuber.

There was high significant difference ($p<0.001$) in percentage rot of yam as a result of fertilizer application (Table 4.6). Chukwu *et al*. (2000) reported that some yam farmers would not use inorganic fertilizer in the production of seed yams meant to be stored beyond six months after harvest. Combination of PM and NPK had significantly higher percentage (35.3%) rot compared to 8% for the control (i.e.77.3% higher) and the sole applications of poultry manure and NPK (both about 16%). Percentage rot difference was not significant amongst sole PM, NPK and the control ($p>0.05$). However, Asadu (1995) reported that tubers grown with organic manure stored longer than those treated with chemical fertilizer in the field. High rotting rate could also be due to the type of cultivar. Gray (1996) observed "pona" to be more perishable and susceptible to rotting under storage compared to other varieties of *D. rotundata* species. It could be that the synergic effect of the fertilizer combination (i.e. PM+NPK) hindered the storability of the tubers. From Table 4.6, there was highly significant difference ($p<0.01$) in rot (%) of tubers when yam was harvested at 24 WAP compared to harvesting at 20 and 32 WAP. The fertilizer affected significantly the percentage rot of tubers at 24 WAP. This could be attributed to high humidity and temperatures at that time which could be predisposing factors. However, no significant difference in rot was realized at 20 and 32 WAP ($p>0.05$) harvesting periods. Harvesting at 32 WAP and PM+NPK recorded significant interaction effect ($p<0.05$). The interaction of percentage rot of tubers at 24 WAP and sole PM and PM+NPK were significantly higher compared to the control ($p<0.05$).

5.5 Proximate analysis of white yam

The results of the proximate analysis (Table 4.7) indicated that at 20 WAP, no fertilizer treatment gave significantly higher ($p<0.05$) ash content compared to the PM and PM+NPK treatments. The highest and lowest ash contents of 2.3 and 1.4% were recorded under sole NPK treatment at 24 and 32 WAP (Tables 4.8 and 4.9) respectively. This suggests that application of poultry manure on yam may not improve on tuber ash (mineral) level during the first 24 WAP compared to NPK fertilizer since manure releases nutrients slowly (Yayock *et al.*, 1988). The observed ash contents of 1.4% to 1.7% for PM+NPK and PM treatments, however, fall within the reported range of 0.68-2.56% under no fertilization Coursey (1967). The apparent ability of NPK in maintaining significant levels of ash in yam decreased as yam stayed longer on field. Meanwhile ask content continued to decline from 2.2% (20 WAP) to 1.4% (32 WAP) in the no fertilizer treatment.

The carbohydrate percentage was, however, significantly higher ($p<0.05$) when sole PM was applied on yam relative to all the other fertilizer treatments when yam was harvested at 20 WAP. There were continued increases in carbohydrate content in all fertilizer treatments from 20 WAP to 32 WAP except the control treatment where it was highest at 24 WAP. The PM treatment also had the highest carbohydrate value of 28.5% at 32 WAP confirming the slow rate of nutrient release by PM (Yayock *et al.*, 1988). The application of PM on yam would increase the amount of energy (kcal) that can be derived from it. Generally, the PM treatments have consistently proven to be superior in improving the carbohydrate content of white yam over the three harvest times. All fertilizer treatments recorded higher carbohydrate contents ranging between 26.66-28.45%. These were above the earlier reported range of 15-23% by Coursey (1967). At 20 WAP, control treatment had carbohydrate level of 13.35% which is lower than the reported range of 15-23% by Coursey (1967). The results showed that the highest moisture content of 70.6% was realized with the no fertilizer treatment at 20 WAP while the lowest (57.1%) was PM+NPK treatment at 32 WAP. However, Coursey (1967) reported moisture range of 58-80% for white yam. This implies that the application of the fertilizers enhanced the accumulation of dry matter.

There was significant increase in the crude fibre (%) ($p<0.05$) with the application of sole PM and sole NPK compared to the control and the PM+NPK combination at the 20 WAP harvest (Table 4.7). Sufficient amounts of crude fibre in white yam ("pona") could be good for enhancing digestion. While crude fibre was lowest (0.5%) at 24 WAP under PM+NPK treatment, NPK treatment recorded the highest (2.01%) at 20 WAP probably due to the quick release of nutrients by the NPK. Generally, the crude fibre content under each of the treatments was lowest at 24 WAP (Table 4.8). Crude fibre levels were significantly higher in the control than the PM+NPK treatment but did not vary when compared to the other fertilizer treatments ($p>0.05$) at 24 WAP. The fertilizer treatments had relatively higher crude fibre content ranging from 1.03% for PM+NPK to 2.01% for NPK treatment at 20 WAP harvesting.

The no fertilizer treatment and sole NPK application had significantly ($p<0.05$) higher crude protein levels of 12.15% and 12.13% respectively compared to the sole PM and PM+NPK treatments at 20 WAP (Table 4.7). This observation could be due to the slow release nutrients by PM (Yayock *et al*., 1988). The application of PM+NPK also gave significantly higher crude protein level of 11.66% than the 9.67% for the PM treatment. According to Trech and Agbor-Egbe (1995), the crude protein content of *D. alata* ranges from 4.7 to 15.6 g/100g. The highest crude protein value was recorded at 32 WAP with the no fertilizer treatment. The crude protein levels for all the fertilizer treatments were better than the control at 24 WAP and could be recommended for children having protein deficiencies.

The fat content was significantly higher under sole NPK (2.0%) than the other treatments at 24 WAP harvest ($p<0.05$) (Table 4.8). Higher fat levels in yam could supplement the carbohydrate and protein in its energy providing capability (Eka, 1985). Tubers from sole NPK treated plot at 24 WAP will supply much more energy (kcal) when eaten.

Meanwhile, both highest and lowest fat contents of 2.0% (24 WAP) and 0.5% (20 WAP) were reported from the sole NPK and control (2.0% at 32 WAP) treatments. The application of sole NPK might be able to improve the fat level of white yam. The no fertilizer treatment and PM+NPK treatments had the lowest fat values.

There was no significant difference in potassium contents amongst all treatments ($p>0.05$) at the 20 WAP harvest time. It was observed that at 24 WAP the application of sole NPK had significant influence on potassium levels of white yam than the rest of the treatments. Potassium is reported to be good in helping the kidneys to function well. Such high values could make it recommendable for people with high blood pressure (Osagie, 1992) but may not be good for those with renal failure. Mean potassium levels of the other fertilizer treatments did not differ from each other and from the control ($p>0.05$).

5.6 Sensory evaluation

Taste/sweetness of the cooked yam differed significantly ($p<0.01$) among treatments. There was low preference for yam treated with sole NPK and PM fertilisers compared to the PM+NPK treated yam which was similar to the no fertilizer treatment in many attributes after boiling at 20 WAP (Table 4.10). In the southern part of Ghana where the main consumption pattern of yam is boiling and eating, the culinary characteristics of the tuber is more important than yield in selecting genotypes by farmers (Otoo *et al*., 2001). The least preferred in terms of taste was NPK treated yam (1.52). The PM+NPK fertilizer treatment was rated similar (3.0) to the control in all the quality attributes assessed except in colour where it was slightly worse (1.7) (colour of pona is white to light cream). The sensory attributes of taste, appearance, colour and texture are key determinants of food acceptability (Lawless and Heymann, 1998; FAO, 2000). Sole PM and NPK treatments were said to be slightly worse (2.0) than the control in terms of taste, mealiness, moistness and aroma but sole PM treatment was slightly better (4.0) than the no fertilizer treatment in colour. Sole NPK treated yam was rated worse than the control in all aspect except sogginess where there was no difference. PM+NPK treated yam had hardness and aroma levels same as the control when yam was boiled (Table 4.10). According to Otegbayo *et al*. (2005) mealiness, hardness, sogginess, waxiness and stickiness are important textural classes in boiled yam.

When yam was harvested at 24 WAP, PM and PM+NPK treated yam had taste /sweetness comparable to that of the no fertilizer treatment (Table 4.11) and sole NPK treated yam was rated slightly worse in taste (2.23). The no fertilizer treatment was poor in mealiness after cooking. The PM+NPK treatment was moderately better than the control treatment in colour, hardness and sogginess after boiling. Colour, mealiness and taste/flavor are reported to be key quality parameters for boiled yam (Abass *et al*., 2003; Egesi *et al*., 2003). However, the no fertilizer treatment was better than PM and NPK treatments in aroma but same in hardness. Sole PM was same as no fertilizer treatment in colour. It is evident from this result that PM manure application helps to improve the cooking qualities of white yam.

At physiological maturity (32 WAP), high preference was given to PM+NPK boiled yam for taste/sweetness, mealiness, moistness and aroma. In terms of sogginess, hardness and colour, PM+NPK treatment and no fertilizer treatment yams did not differ from each other. Sole PM and NPK treated yams were rated similar to no fertilizer treatment in taste, colour and hardness. Sole PM treated yam and no fertilizer treatments recorded was similar values (3.0) in mealiness and aroma but slightly worse than control in moistness at 32 WAP (Table 4.12). Otegbayo *et al*. (2001) reported that boiled yam from "pona" (a cultivar from *D. rotundata*) was rated superior to other cultivars in cooking quality attributes due to its sweet taste, softness and mealy texture after cooking. Generally, in this study sole NPK treated yam was rated to be similar to the sole PM in the quality attributes assessed, at 32 WAP. Sole NPK treated yam was thus rated as being same or better than the control in all the attributes tested (Table 4.12).

5.7 Profitability assessment of fertilizer treatments in yam production

Economic analysis was done using the partial budget to assess the costs and benefits of the various treatments. The average yield (t/ha) obtained in the research work was used for this analysis. The yield was adjusted lower by 10% for all treatments including the control (considered here as the farmer practice). It is has been suggested by researchers that farmers would obtain yields 10% lower than researchers when they use or practice the same technologies (CIMMYT, 1988). The field price of yam in the Kumasi metropolis (PPMED, MOFA, 2010) was used to calculate the gross field benefits (value in Ghana cedis) of the adjusted yield for each treatment. The total variable costs for the treatments were deducted from the gross benefits to determine the net benefits (not profit). The variable costs included fertilizers (poultry manure/ or NPK 15:15:15), cost of transporting fertilizer to the farm and the cost of applying fertilizer.

The control treatment's net benefit was deducted from each fertilizer treatment net benefit to find their respective extra benefits or gain in net benefits. This is the additional extra cash resulting from the application of the treatment. However, the marginal analysis would determine which treatment is the most economically acceptable.

The results (Table 4.13) showed that all the fertilizer treatments were practicable economic-wise as they all gave marginal benefits greater that one (1). Investing 1 cedi per hectare extra on fertilizer would thus recover the Gh ¢1 plus a profit equivalent to the corresponding extra benefits (Gh¢).

The most economical treatment (Table 4.13) for all the three (3) times of harvest was PM+NPK. It gave the highest extra benefit of Gh¢ 5595.03 and marginal benefits of Gh¢

8.31 (831%). The most profitable harvest time for sole manure (PM) where it gave extra benefit of Gh¢ 2920.62 and marginal benefit of Gh¢5.14 was when yam was at physiological maturity (32 WAP) while that of sole NPK was at 20 WAP with extra benefit of Gh¢ 2734.97and Gh¢4.05 marginal returns. At 32 WAP harvest, sole NPK was the worst performer giving the lowest marginal returns of Gh ¢2.32. The least economical (Table 4.10) of all the treatments was the sole application of NPK at 24 WAP as it accrued the lowest extra benefit of Gh¢ 1274.57 and Gh¢ 1.98 as marginal returns.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSION

In order to keep the soil productive it is imperative to improve soil condition and fertility management practices like the application of organic and or inorganic fertilizers. Recommended fertilizer requirement in yam production is still appears a dearth in research and the effects of fertilizer on yam is a concern to consumers and producers.

This research has shown that fertilizer application has the potential of improving yields in yam production. The application of PM+NPK (2t/ha +150kg/ha) proved to be the best as it recorded the highest yield of 38.97t/ha. Milking yam at 20 WAP also gave the highest yield of 38.28t/ha. Sole PM application resulted in tuber weight loss of 23.8% under storage while PM+NPK fertilizer application recorded high tuber rot of 35.3% under storage. The sole application of fertilizer NPK is recommended for ware yam production at physiological maturity (32 WAP). Since organic manure has the added advantage of improving the soil physical properties, the combination of NPK and PM is therefore recommended for production of yam that is not for storage. Harvesting *D. rotundata* at 20 weeks after planting is the best time to obtain the highest quantity of seed yam for the next season.

The quality of yam was enhanced in terms of carbohydrate by PM at 20 WAP. The application of PM or PM+NPK to white yam have the potential of impacting positively on its carbohydrate level at physiological maturity (32 WAP). The sole application of NPK fertilizer improved the potassium and ash contents of white yam at 24 WAP. High potassium content in the yam could be recommended for people who suffer from high blood pressure.

Contrary to general assertion, fertilizer application (relatively lower rates) in yam production was found to improve many organoleptic properties of yam. The taste of yam treated with PM+NPK was more acceptable by consumers when harvested at 24 and 32 WAP. Moistness level of boiled yam treated with PM+NPK was best at 32 WAP.

It has been confirmed that the PM+NPK treatment will give the most economic returns in yam production in all three times of harvest.

6.2 Recommendations

i). The combined application of PM and NPK on yam at 2t/ha and 150kg/ ha respectively is recommended for yam production.

ii). Harvesting yam at 20 WAP is recommended to obtain higher seed yam and overall yield.

iii) Poultry manure could be applied earlier (at mounding) to enhance its mineralization.

6.3 Recommendations for future research

i). Further studies should be conducted using straight fertilizers to ascertain their effects on yield and quality of yam, especially its general acceptability by consumers, in other yam growing areas in Ghana.

ii). More studies needed in improving the storage of fertilizer treated yams

iii). The use of cover crops and green manure with mineral or organic manure should be researched into as this could improve the yield and probably consumer acceptability of yam.

REFERENCES:

Abass, A. B., Olorunda, A. O., Asiedu, R. and Bokanga, M. 2003. Effect of age of yam tuber at harvest on the qualities of yam foods. In Root Crops: The Small Processor and Development of Local Food Industries for Market Economy. Proceedings of the 8th Triennial Symposium of the International Society for Tropical Root Crops-Africa Branch (ISTRC-AB), Ibadan, Akoroda, M.O. (ed) pp.131-138.

Adeniji, M.O. 1998. Effects of different fertilizer combinations on tuber yield, storage and food qualities of 2 yams (*Dioscorea*) species. MSc. report, University of Ibadan, 85 p.

Adesiyan S.O. and Adeniji M.O. 1976. Studies on some aspects of yam Nematode (*Scutellonema bradys*). *Ghana Journal of Agricultural Science* 9: 131-136.

Adu, S. V. and Asiamah, R. D. 1992. Soils of the Ayensu-Densu Basin, Central, Eastern and Greater Accra Regions of Ghana. Council for Scientific and Industrial Research (CSIR) - *Soil Research Institute Memoir* No. 9. 117 pp.

Aduayi, E.A. and Okpon, S.N. 1980. Role of continuous nitrogen fertilization on nutrient composition of leaves sampled at various stages of growth and on yield of yam (*Dioscorea rotundata*). Commun in soil science and plant analysis. 11 (3): 267-282.

Agboola, A. A. 1981. The Effect of different soil tillage and management practices on the physical and chemical properties of soil and maize yield in a rainforest zone of western Nigeria. *Agronomy Journal*. 73 (2): 247 – 251.

Akanbi, W.B., Olaniran, O. A, and Olaniyan A. B. 2007. Effects of integrated use of organic and inorganic nutrient sources on growth and tuber characteristics of white yam (*Dioscorea rotundata*) cv ehuru. African Crop Science Conference Proceedings. 8: 359-363.

Alexandra, B. and Jose, B. 2005. The importance of soil organic matter: key to drought-resistant soil and sustained food production. FAO, Rome.

Alhassan, A.Y. 1994. Manipulation of BAP and agar concentrations for rapid clonal propagation of *Dioscorea alata* shoot cultures. Proc. 5th triennial symposium ISTRC – Africa branch,Kampala, Uganda, 22-28 Nov. 1992. ISTRC-AB, CTA, IITA, Ibadan, Nigeria, p. 157-160.

Anchirinah, V., Ojha, D., Owusu-Sekyere, R., Raminanan, N., and Zhou Shengkun.1996. Production and marketing of yam in the forest/savanna transition zone of Ghana *and Crop Management Monograph* No. 21, Ibadan, Nigeria: IITA.

Anderson, J.M. and Ingram, J.S.I. 1993. Tropical Soil Biology and Fertility: A handbook of Methods. Second edition. CAB International. Wallingford, UK. p. 37.

Andreas, B.T. 2003. Controlling Post-Harvest Losses of Yam (*Dioscorea* spp.) by Application of Gibberellic Acid. PhD dissertation submitted to the Swiss Federal Institute of Technology, Zurich.

Antwi, A., Adu-Mensah, J. and Asiedu, R. 2000. The status of yam industry in Ghana: Research and development needs. Report, Kumasi, Ghana: Crop Research Institute (CRI).

AOAC. (1997). Official Methods of Analysis of the Association of Official Analytical Chemists, 15th edition. The Association: Arlington, VA. USA.

Asadu, C. L. A. 1990. Soil resources management, a critical factor in national development In : the Challenges of Agriculture in National Development. A. I. Ikeme (ed). Optimal Computer solutionsLtd ; Enuge Nigeria, 142pp.

Asadu, C..L.A., Nweke, F.I. and Akamigbo F.O.R. 1998. The performances of six yam cultivars of white yam derived from three sources and evaluated across six zones in southeastern Nigeria. Cropping Sys. Res. 1: 215-224.

Asadu, C.L.A. 1995. Traditional/field storage practices intended to promote shelf life of yam in southeastern Nigeria. A paper presented on pests and pathogens of yam in storage at the International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria, May 25, 1995b

Asadu, C.L.A. and Akamigbo, F.O.R. 1990. Relative contribution of organic matter and clay fractions to cation exchange capacity of soils in southeastern Nigeria. Samaru. *J. agri. Res,* 7:17-23

Asiedu, J.J. (1986). Processing and Physical/Chemical Properties of Tropical Products Pfaffenhofen.

Attaie H., Zakhia N. and Bricas N., 1998. Etat des connaissances et de la recherche sur la transformation et les utilisations alimentaires de l'igname. *In* Berthaud J., Bricas N., Marchand J.L. (ed.). L'igname, plante séculaire et culture d'avenir. Actes du séminaire international Cirad-Inra-Orstom-Coraf, 3-6 juin 1997, Montpellier, France, p 275-284

Ayensu, E. S. 1972. VI. *Dioscoreales*. In: Anatomy of the monocotyledons. Metcalfe, C. R. (ed.). Clarendon press, Oxford, UK.

Azih, V.A. 1987. Effects of different rates of N, P and K fertilizers on the yield and storage quality of yellow yam (*D. cayenensis*). *Journal of Root Crops*; 2: pp1-6.

Babaleye, T. 2003. West Africa; Improving yam production technology, ANA-BIA supplement issue/edition No. 463.

Baudoin, W.O. and Lutaladio, N.B. 1998. Yam cultivation and utilization for improved food security. FAOs position paper, Rome, Italy: FAO. 40p..

Bell, A. 1983. Mineral content of yam tubers: Raw, boiled and as flour. In: Tropical Root Crops. Production and uses in Africa. Proceedings of the Second Triennial

Sympossium of the International Society for Tropical Root Crops, Africa Branch, Douala, Cameroon, 14-19 August, 1983. pp.157-160..

Bell, A. and Favier, J.C. 1981. Effects of traditional food processing methods on the nutritional valu of yams in Cameroon. In, 1981, Proc. 11th Triennial Root Crops Sympossium of the International Society for Tropical Root Crops (ISTRC-AB), IDRC Otawa, Canada, p 214-224.

Bencini, M.C. 1991. Post-harvest and processing technologies of African staple foods: a technical compendium. Agriculture Services bulletin No. 89, FAO, Rome.

Bray, R.H. and Kurtz, L.T. 1945. Determination of total organic and available forms of phosphorus in soils. Soil Science 59: 39-45.

Burkill, I. H. 1960. The organography and the evolution of Dioscoreaceae, the family of the yams. *The Journal of the Linnean Society of London, Botany* 56:319-412.

Chukwu, G. O., Orkwor, G. C., Ikwelle, M. C. and Ohiri, A. C. 2000. Famers' practice and evaluation of fertilizer use on the quality of yam tuber in Nigeria. Paper to be Presenter at International Symposium on Balanced Nutrient Management systems for the Moist Savanna and Humid Forest Zones of Africa, Cotonou Republic of Benin Oct ; 9-12th 2000.

CIMMYT. 1988. Economics Program. From Agronomic Data to Farmer Recommendations: An Economics Training Manual.

Coursey, D.G. 1967. Yams: An account of the nature, origins, cultivation and utilization of the useful members of the *Dioscoreaceae*. Tropical Agriculture Series. Longmans: London.

Coursey, D.G. 1969. Ascorbic Acid in Ghana Yams, *Journal of Food Science and Agriculture*, 17: 446– 449.

Coursey, D.G.1976. The origins and domestication of yams in Africa. In: Origins of African Plant Domestication, J.R. Harlan, J.M.J de Wet and A.B.L. Stemler, eds. Mouton, The Hague. pp. 383-403.

De Pedro, L.B., Bastasa, G.N., and De Pedro, R.C.J.R. 1989. Bioassay of farmer-formulated botanical pesticides: its implication to integrated pest management program in Eastern Visayas (Philippines). Pest Control Council of the Philippines, 20 (5): 9-12.

Degras L. 1993. The Yam. A tropical root crop. The yam tuber; Its structure, use and storage. Macmillan press, London and Basingstoke, UK. pp. 32.

Degras L., 1986. L'igname: plante à tubercule tropicale.. Ed. Maisonneuve et Larose, Techniques Agricoles et Productions tropicale, Paris, France 1986 - (36): 408.

Degras, L. 1987. Post harvest studies and quality of yams. Antilles: – a review INRA, centre des Antilles Guyana, 1988 In: CFLS, 23rd Annual meeting Antigua, 1987.

Diehl, L. 1981. Smallholder Farming Systems with Yam in the Southern Guinea Savannah of Nigeria. Eschborn, GTZ (Gesellschaft für Technische Zusammenarbeit).

Dumont, R. and Jeanteur, P. 1988. Bilan de cinq années de production, en grande culture, sur la variété Florido (*D.alata*), dans la région centre de la Côte d'Ivoire. In *VIIth Symposium of the International Society for Tropical Root Crops, Gosier (Guadeloupe), 1-6 July1985* (ed. by INRA), pp.179-194. Paris.

Dumont, R. Letourmy, P. and Kouakou, A.M. 1997. Effect of chemical fertilization on yam preservation in Côte d'Ivoire. *Cahiersd'Etudeset de RecherchesFrancophonesAgricultures (France)* 6(France), 107-114.

Egesi, C. N., Asiedu, R., Egunjobi, J. K. and Bokanga, M. 2003. Genetic diversity of organoleptic properties in water yam. *Journal of the Science of Food and Agriculture* 83: 858-865.

Eka, O.U. 1985. The Chemical Composition of Yam Tubers. In: Advances in Yam Research. G. Osuji ed. Anambra State University of Technology, Enugu, Nigeria. P 49-75

Ekanayake, I.J. and Asiedu, R. 2003. Problems and Prospects of Yam-Based Cropping Systems in Africa. 540-543

Eze, S.C. and Orkwor, G.C. 2010. Studies on effects of mineral fertilizer, organic manure and cultivar on the yield and storability of yam (*Dioscorea rotundata* Poir). *African Journal of Food, Agriculture, Nutrition and Development.* NRCRI. Umudike, Nigeria.

Ezumah, H.C. 1986. Import root Crops production systems in southern Nigeria. Paper presented at a seminar at the Institute of African studies, University of Ibadan, Ibadan, Nigeria.

Ezumah, S.K. and Akodundu, I.O. 1991. The response of yam (*Dioscorea rotundata* Poir.) to various periods of weed interference in an intercropping with maize (*Zea mays* L.), Okra (*Abelmoshus esculentus* L. Moench) and sweetpotato (*Ipomoea batatas* I. Lam) – Tropical Root Crops in a Developing Economy: Proceedings of the Ninth Symposium of the International Society for Tropical Roots Crops. 349-354.

FAO 1999. Food and Agriculture Organization of the United Nations: Rome (15th June 1999).

FAO. 2000. Enzymatic Browning in Fruits, Vegetables and Seafoods. Eds. M.R. Marshall, J. Kim and C-I Wei. (http://www.fao.org/ag/ags/agsi/ENZYMEFINAL/Enzymatic, accessed on 30th October 2011).

FAO. STAT 2005. FAO ststistical yearbook 2005. Rome. Food and Agricultural Organisation of the United Nations.

FOASTAT 2006. FAO Statistics Division 2006

FAO. 1985. Marketing, processing and prices of tubers and plantains in humid tropical Africa. FAO Commodities and Trade Division. Workshop, Kinshasa, 30th Sept. 1985.

Food and Agricultural Organisation (FAO). 1998. Production Year Book. FAO Rome.

Ferguson, T.U. and Hayness, R. 1970. The response of yams (*Dioscorea* spp) to NPK and Organic manure fertilizers. In: Proceeding of second International Symposium of Tropical Root and Tuber Crops. D.C Plaknet eds: 23-30 August, 1970. University of Hawaii Honolulu. pp 93-96.

Food and Agriculture Organisation FAO. 2006. FOASTAT. FAO Statistics Division. Rome.

Frances, L.C. 1989. Guide to maintaining a good quality yam crop. CARDI Factsheet.

GERDAT - IRAT, Réunion d'Agronomie de l'IRAT, Bouake

Ghana Export Promotion Council (GEPC). 2009. Global Demand for Ghana Yam (www.mcc.gov/documents/investmentopps/bom-ghana-eng-yams, accessed on 14/08/2010)

Girardin, O. 1996. Etude de l"amelioration du stockage traditionnel. Sempervira (Abidjan) No. 5, Ministere de l"Enseignement Supereur, de la Recherche et de l"Innovation Technologique Republique de Côte d"Ivoire, CSRS ISSN 1025-8167.

Goudou-Urbino, C., Konate, G., Quiot, J.B. and Dubern, J. 1996. Aetiology and ecology of a yam mosaic disease in Burkina Faso. Trop. Sci. 36: 34-40.

Gray, A. 1996. Report on yam marketing in Ghana. Project A0497; R6505. Chantham: natural Resource Institute, 13/03 – 06/03/1996.

Hahn, S.K., Osiru, D.S.O., Akoroda, M.O. and Otoo, J.A. 1987. Yam production and its future prospects. Outlook on Agriculture; 16: 105-110.

Iguilo, N.O. 1989. Response of white yam cultivars to staking and fertilizer application. Trop. Agric., 66:38-42.

Ikotun,T., 1989. Diseases of yam tubers. International Journal of Tropical Plant Diseases 7: 1- 21

Kayode, G. O. 1985. Effect of NPK application on tuber yield, starch content and dry matter accumulation of white yam (*Dioscorea rotundata*) in a forest alfisol of southwestern Nigeria. Experimental Agriculture, Great Britain 21: 389-393.

Kleih, U; Crentsil D; Gallat, S; Gogoe, S F; Nettey, D A S; and Yeboah, D. 1994. Assessment of post-harvest needs in non-grain starch staple food crops systems in Ghana. NRI Report.

Kochlar, S.L. 1981. Tropical Crops: A textbook of economic botany. Macmillan Publishers, New Delhi. pp. 230-232

Kone, D. 1987. Influence of climatic factors on the field behavior of two yam cultivars *Dioscorea cayenensis-rotundata* Krengle and *Dioscorea alata* Florida. University of Montpellier 2. Montpellier (France). p. 31.

Kpeglo K.D., Obigbesan G.O. and Wilson J.E. 1981. Yield and shelf life of white yam (*Dioscorea rotundata* Poir) as influenced by fertilizer nutrients. Beiträge zur tropischen Landwirtschaft und verterinärmedizin 19 (3): 301-308.

Lagemann, J. 1977. Traditional African farming systems in Eastern Nigeria, Muenchen, Weltforum, Verlag. pp. 269.

Lal, R. 1978. Influence of within- and between-row mulching on soil temperature, soil moisture, root development and yield of maize (*Zea mays* L.) in a tropical soil. *Field Crops Res.*, 1: 127–139

Lape, M. I. and Treche, S. 1994. Nutritional Quality of Yam (*Dioscorea dumentorum* and *D. rotundata*) Flours for Growing Rats. *J. Sci. Food Agric*. 66: 447-455.

Lawless, H.T., and Heymann, H. 1998. Sensory Evaluation of Food-Principles and practices. Chapman and Hall, New York (1998).

Law-Ogbomo K. E. and Remison S.U. 2008. Growth and yield of white guinea yam (*Dioscorea rotundata* Poir) influenced by NPK fertilization on a forest site in Nigeria. *Journal of Tropical Agriculture* 46 (1-2): 21-24.

Law-Ogbomo K.E. and Emokoro C.O. 2009. Economic analysis of the Effect of Fertilizer Application on the Performance of White Guinea Yam in Different Ecological Zones of Edo State, Nigeria. World Journal of Agricultural Sciences 5 (1): 121-125.

Le Buanec B. 1972. "Absorption et exportation des éléments majeurs par l'igname. GERDAT IRAT, Rénion d'Agronomie de l'IRAT, Bouake.

Leonard, D. 1995. Crops and Fertilizer use. Proceedings of Serminar of Organic and Sedentry

Agriculture. 1-3 Nov. 1995. Edited by Akita, V., Shroder, P. and Bemile, S.K. p. 16.

Lyonga, S. N. 1983. Studies on fertilization of yam (*Dioscorea* spp) and yam tuber storage. Proceedings of Sympossium of the International Society for Tropical roots. 6: 1983/02/21-26.

Maduakor, H. O., Lal, R., and Opara Nadi, O. A. 1984. Effects of methods of seedbed preparation and mulching on the growth and yield of white yam (*Dioscorea rotundata*) on an ultisol in southeastern Nigeria. Field Crops Res. 9: 119-130.

Manyong, V. M., Smith, J., Weber, G. K., Jagtap, S. S. and Oyewole, B. 1996. Macro-characterization of agricultural systems in West Africa: An overview. *Resource and Crop Management Monograph* No. 21, Ibadan, Nigeria: IITA.

Martin, F.W. 1979. Composition, nutritional value and toxic substances of the tropical yams. In: Tropical foods: chemistry and nutrition, Inglett, G.E. Charalambous, G., Academic Press, New-York, USA. pp. 249-263.

Melteras M. –V., Lebot V., Asher C.J. and O'Sullivan J.N. 2008. Crop development and root distribution in lesser yam (*Dioscorea esculenta*): Implications for fertilization. Experimental Agriculture 44(2): 209-221.

MiDA, 2009. Yam production in Ghana. (www.mcc.gov/documents/investmentopps/bom-ghana-eng-yams, accessed on 14/08/2010)

MoFA, 2010. Ministry of Food and Agriculture: Policy Planning Monitoring and Evaluation Department (PPMED). Market Report, Kumasi.

Morse, S. Acholo, M. McNamara, N. and Oliver, R. 2000. Control of storage insects as a means of limiting yam tuber fungal rots**.** *J. Stored Products Res. 36*: 37-45

Murwira, H.K., and Kurchmann H. 1993. Carbon and Nitrogen Mineralisation of cattle manures subjected to different treatments in Zimbabwean and Swedish soils. In: Mulongy, K.R, Merckx (eds). Soil organic matter dynamics and sustainability of tropical agriculture. pp 189-198.

Nambiar, K.K.M., Soni, P.N.., Vats, M.R., Sahgal, D.K. and Mehta, D.K. 1989. Annual Reports of All India Coordinated Research Project on Long Term Fertilizer Experiments (ICAR), Indian Agric. Research Institute, New Delhi.

Ndegwe, N.A., Ikpe, F.N., Gbosi, S.D. and Jaja, E.T. 1990. Effect of staking method on yield and its components in sole-cropped white Guinea yam (*Disocorea rotundata* Poir) in a high rainfall area of Nigeria. Tropical Agriculture (Trinidad) 67(1): 29-32.

Njoku, E. 1963. The propagation of yams *Dioscorea* spp. by vine cutting. *Journal of West African Science Association.* 8: 22-29.

Njoku, E., Nwoke, F.I.O., Okonkwo, S.N.C. and Oyolu, C. 1994. Pattern of growth and development in *Dioscorea rotundata* Poir. Tropical Agriculture 61: 17-20.

NRCRI (National Root Crops Research Institute). 1986. *Annual Report NRCRI 1985*, Umudike, Nigeria: NRCRI.

NRCRI. 1985. Yam: Science and technology briefing. 20–22 February, National Root

nutritional value of yams in Cameroun. In "Tropical root crops: research strategies for the

Nwakiti, A.O. 1988. Sprout removal in storage and seed yam production in Nigeria. Tropical Agriculture..65 (4): 367-369

Nweke, F.I.O., Ugwu, B.O., Asadu, C.L.A. and Ay, P. 1991. Production costs in the Yam-based Cropping Systems of Southwestern Nigeria. Resource and Crop Management Programme. Research Monograph (6): 29. International Institute of Tropical Agriculture

Nwinyi, S.C.O. (1981) Preliminary evaluation of soils of the major yam-growing areas in Nigeria In : 1981 Annual Report. NRCRI, Umudike, Umuahia, Nigeria.

Nwoke, F.I.O., Njoku, E. and Okonkwo, S.N.C. 1983. Effect of sett size on yield of individual plants of *Dioscorea rotundata* Poir.Tropical Agriculture (Trinidad). 61 (2): 99-101.

Nwosu, N.A. 1975. Recent development in vegetative propagation of edible yams (*Dioscorea* species). In: Proc. Agric. Society, (Nigeria). 12: 15-16

Obigbesan, G.O. 1993. Soil nutrient factors for yam production. In: Advances in Yam Research Production and Post-haverst. Technology of the Yam Tuber. G.O. Osuji (ed) Cooperative Agric. Centre Prairie A&M Univ. Texas USA. (2): 17-24

Obigbesan, G.O. and Adesiyan, S.O. 1981. The influence of fertiliser nutrients on population levels of *Scutellonema bradys* in three yam species; *Dioscorea* *rotundata, Dioscorea alata and Dioscorea cayanensis.* Nematologia Mediterranea 9 (1): 21-28.

Obigbessan, G.O. and Agboola, A.A. 1978. Uptake and distribution of nutrients by yams (*Dioscorea* spp.) in western Nigeria. Experimental Agriculture (14): 349-355.

Ohiri, A.C. 1995. Soil physical and chemical conditions favourable for yam (*Dioscorea* spp.) growth and tuber development in Nigeria, African Soils 28: 231-242.

Ohiri, A.C. 1990. Fertilizer practices on root and tuber crops in Nigeria. In: Proc. Of 2nd National Fertilizer Workshop, Abuja, Boma Entreprises (Nig) Ltd, Ibadan pp 50-57

Ohiri, A.C. and Chukwu, G. 1991. Evaluation of optimum levels of organic (cow dung) manure with or without mineral fertilizers for yam (*Dioscorea rotundata*) production. In: Annual Report of the National Root Crops Research Institute, Umudike, Nigeria. pp 18-23.

Ohiri, A.C., Igbokwe, M.C. and Lekwa G. 1985. Physico-chemical characterization, classification and management of selected soils of Northern Nigeria in relation to yam production. Proc. International Society of Soil Science Commissions IVRVI pp 68-81.

Ohiri, A.C., Nwokocha, H. N., Okwuowulu, P.A. and Chuhwu, G.O. 1996. Literature review and survey of farms on the effects of inorganic fertilizers on quality (taste and shelf-life) of root and tuber crop. Final Report Submitted to NAFCON, (Nig.) Ltd, NRCRI Umudike 53pp.

Ojating, I. 1997. The role of forestry, folklore, traditional/customary institutions, beliefs and taboos in management and utilization of marginal lands in Nigeria. Proc. SSN Conf. Sokoto, Nigeria. pp 23-26

Okigbo, B. N. 1980. A review of cropping systems in relation to residue management in the humid tropics of Africa. In: Organic Recycling in Africa. Rome, Italy: FAO pp.13-37

Okoh, R.N. 1996. Economic validation of Losses in Yams (*Dioscorea* spp.) stored in Traditional Yam Barns. Tropical Science in press.

Okoli O.O. 1980. Dry matter accumulation and tuber sprouting in yams (*Dioscorea* spp.). Experimental Agriculture 16, 161-167.

Okoli, O. O. and Akoroda, M. O. 1995. Providing Seed Tubers for the Production of Food Yams. African Journal of Root and Tuber Crops (1): 1-6.

Okonkwo, S.N.C. 1985. The botany of the plant and its exploitation in enhanced production of the crop. Advances in research (1) 1-29

Okpon, S.N. and Aduayi, E.A. 1988. Effect of nitrogen fertilizer sources on the quality and nutrient composition of yam Ife journal of Agriculture 10 (1& 2) : 20-28

Okwuowulu, P. A. 1995. Yield Response of edible yam (*Dioscorea* ssp) to time of fertilizer application and age at harvest in an ultisol in the humid zone of southeastern Nigeria. National Roots Crops Research Institute. 1 (1): 6-10

Onayemi, O., Idowu A., 1988. Physical and chemical changes in traditionally stored yam tubers (*Dioscorea rotundata Poir and Dioscorea cayenensis Lam*). Department of Food Science and Technology, University of Ile-Ife (NGA). Journal of Agricultural and Food Chemistry (USA). 36 (3): 588-591

Onochie, B.E. 1974. Critical period of weed competition in yam plots. *Nigeria Agriculture Journal*, 11 (3): 13-16.

Onwueme, I. and Sinha, C. 1991. Field crop production in tropical Africa. The Netherlands, p. 480.

Onwueme, I. C. 1978. The Tropical Tuber Crops. Chichester.

Onwueme, I.C. 1975. Tuber formation in yam (*Dioscorea spp*.): Effect of moisture stress; contribution of the parent sett. *Journal of Agricultural Sciences*. 85 (2): 267-269.

Opara, L.U. 1999. Yam storage. In: Bakker-Arkema et al. (eds). CIGR Handbook of Agricultural Engineering Volume IV Agro Processing. pp. 182-214. The American Society of Agricultural Engineers, St. Joseph, MI.

Opara-Nadi, O. A. and Lal, R. 1987. Effects of no till and disc ploughing with and without residue mulch on tropical root crops in southern Nigeria. Soil Tillage Res. 9: 231-240.

Orkwor, G.C. and Asadu, C.L.A. 1997. Agronomy. In: Food Yams: Advances in Research, Orkwor, G.C., Asiedu, R. and Ekanayake, I.J. (Eds). NRCRI/IITA, Ibadan, Nigeria, pp.105-141.

Orkwor, G.C. 1998. Importance of yam. In: Food Yams. Advances in Research. G.C. Orkwor, R. Asiedu and I.J. Ekanayake, eds. National Root Crops Research Institute, Umudike and International Institute of Tropical Agriculture, Ibadan Nigreia. pp. 1-12.

Orkwor G.C. and Asadu, C.L.A. 1998. Agronomy. In: Food yams. Advances in research. G.C. Orkwor, R. Asiedu and I.J. Ekanayake, IITA, Ibadan Nigeria. pp. 105-141.

Orkwor, G. C. 1990. Studies on the critical period of weed interference in yam (*Dioscorea rotundata* Poir) intercropped with maize (*Zea mays* L.), okra (*Abelmoschus esculentus* L. Moench), sweet potato and the biology of associated weeds. Ph. D. Thesis, Nsukka, Nigeria: University of Nigeria. 262 pp.

Orkwor, G. C. Asiedu, R. and Ekanayake, I. J. 1998. Food Yams. Advances in research. Ibadan. IITA/NRCRI, Nigeria. 249 p.

Orkwor, G.C. and Ekanayake, I.J. 1998. Growth and Development. In: Food Yams. Advances in research. G.C. Orkwor, R.A. Asiedu and I.J. Ekanayake, eds. National Root Crops Research Institute, Umudike and International Institute of Tropical Agriculture, Ibadan Nigreia. Pp. 39-63.

Orkwor, G. C., Okereke, O. U., Ezedi, F.O.C., Hahn, S. K. Ezumah, H. C. and Akobundu, I. O. 1994. The response of yam (Dioscorea rotundata Poir) to various periods of weed interference in an intercrop with maize (Zea mays), okra (Abelmoschus esculentus (L.) Moench) and sweet potato (Ipomea batatas). In F. Ofori and S. K. Hahn, eds. Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, Accra, Ghana: International Society for Tropical Root Crops. Pp. 349-354.

Osagie, A. U. and Eka, O. U. 1998. Chemical Composition of Root and Tuber crops. In: Nutritional quality of plant foods. Department of biochemistry, University of Benin, Benin City Nigeria.

Osagie, A.U., 1992. The yam tuber in storage. Benin City. (NIG): Postharvest Research Unit. Department of Biochemistry, University of Benin, 1992. 247p

Osiru, D. S. O. and S. K. Hahn. (1994). Effects of mulching materials on the growth, development and yield of white yam. *African Crop Science Journal* 2:153-160.

Otegbayo, B., Aina, J., Asiedu, R., and Bokanga, M. 2005. Microstructure of boiled yam (*Dioscorea* spp.) and its implication for assessment for textural quality. J. Texture Stud. 36. 324-332.

O'sullivan, J. N. 2010. Yam nutrition: nutrient disorders and fertility management. ACIAR Monograph No. 144.

Otegbayo, B.O., Achidi, A. U., Asiedu, R. and Bokanga, M. 2001. Food Quality attributes of *Pona* yam. Paper presented at 8th Triennial Symposium of the International

Society for Root and Tuber Crops-Africa Branch (ISTRC-AB) held at International Institute of Tropical Agriculture (IITA), Ibadan, 12-16 November, 2001.

Otoo, E., Moses, E., Lamptey J.N.L., and Adu-Mensah, J. 2001. *Farmer participatory evaluation of Dioscorea* spp in Ghana. In. Proceeding of Participatory Plant Breeding and Participatory Plant Genetic Resource Enhancement- An Africa-wide Exchange of Experiences, Warda, M'be, Ivory Coast. May 7-10, 2001. pp. 245-251.

Passam, H.C., Read S.J, and Richard J.E. 1978. Respiration of yam tubers and its contribution to storage loss; *Tropical Agric* 55: 207-214.

Pellet, L.P. and Young, V.R.1980. Nutritional Evolution of Protein Foods. UN Univ. Publ.

Purseglove, J.W. 1972. Tropical crops. Monocotyledons. Longman Group Ltd., London, pp 97-117.

Rasmussen P.E. and Collins, H.P. 1991. Long-term impacts of tillage, fertilizer, and crop residue on soil organic matter in temperate semiarid regions. Adv Agron. 45: 93-134.

Robin, G., Clarke, B., Adams, H., Bellon, S. and Genthon, M.1984. Introduction of clean *Dioscorea alata* planting material into small farm systems of Domonica. In: 20th Annual Meeting of the Caribbean Food Crops Society: St. Croix, US Virgin Islands; October 21-26 1984.

Rhodes, J.D. 1982. In Methods f Soil Analysis, Part 2. Second Edition (A.L. Page, R.H. Miller and D.R. Keeney, Eds.). American Society of Agronomy, Inc., Madison.

Romain, H.R. 2001. Crop production in tropical Africa, Macmillan London, p. 244.

Sauphanor B., Bordat, D, Delvare, G and Ratnadass, A. 1987. Les insectes des ignames stockées en Côte d'Ivoire. Inventaire faunistique et éléments biologiques. IDESSA, Bouaké (CIV). Agronomie Tropicale (FRA). 42 (4): 305-312.

Scott, G. J., Rosegrant, M. and Ringler, C. 2000. Roots and Tubers for the 21st Century: Trends, projections and policy options. Food Agriculture and the Environment Discussion 31. International Food Policy Research Institute (IFPRI) and international Potato Centre (CIP). Washington, D.C, U. S. A.

Sobulo, R. A. 1972. Studies on white yam (*Dioscorea rotundata*) I, Growth analysis. *Exptl. Agric*. (8):99-106

Society for Tropical Root Crops–Africa Branch (ISTRC-AB), October 1998, Cotonou, Republic of Benin. pp. 759-773. (In French)

Swannell, M. C., Wheeler, T. R., Asiedu, R. and Craufurd, P. Q. 2003. Effect of harvest date on the dormancy period of yam (*Dioscorea rotundata*). *Trop. Sci*., (43): 103-107

Tetteh, J.P. and Saakwa, C. 1994. Prospects and constraints to yam production in Ghana. In: Tropical root crops in a developing economy. Ofori, F. and Hahn S.K.(eds). Proceedings of the 9th Symposium of the International Society for Tropical Root Crops, 20-26 Oct., Accra, Ghana.

Tetteh, J.P. and Saakwa, C.1991. Prospects and Constraints of Yam Production in Ghana. In: Proceedings of Ninth Symposium of the International Society of Tropical Crops. Ofori, F. and S. K. Hahn. Accra, Ghana. 20-26 October, 355-356

Toure, G. 1986. Study of the nutritional value of yam peels in sheep. Universite, des nantes, loire- Atlanque (france) Nantes (Fra): Envin, 1986, 94 p. :27 ref., 25 table., 7 graph. – these (Thesis) (Doctorat verterinaire).

Toyohara, H., H. Kikuno, K. Irie, and F. Kikuchi. 1997. Effects of mulching on the growth of yam (*Dioscorea alata* L.) varieties introduced from tropical region. *Japanese Journal of Tropical Agriculture* 41:74-80.

Trèche, S. 1979. Evolution au cours de la conservation des potentialités nutritionnelles de quelques espèces d'ignames cultivées au Cameroun. ORSTOM. Paris (FRA). Colloque International de Technologie. Yaoundé, 1979/11/05-10. In: AUPELF. La conservation des denrées alimentaires cultivées en climat chaud et humide. 1980, p. 247-273.

Trèche, S and Agbor-Egbe, T. 1995. Evaluation of the chemical composition of Cameroonian yam germplasm. *Journal of Food Composition Analysis* 8(3): 274–283.

Trenbath B.R. 1976. Plant interaction in mixed crop communities. Multiple cropping. American Society of Agronomy (ASA). Special publications 27: 129-169

Tschannen, A. T., Girardin, O., Nindjin, C., Dao, D., Farah, Z., Stamp, P. and Escher, F. 2003. Improving the application of gibberellic acid to prolong dormancy of yam tubers (*Dioscorea* spp.). *Journal of the Science of Food and Agriculture* (83):787-796. Uganda.

Unamma, R.P.A. 1981. Investigations on weed interference in white yam (*Discorea* sp)

Unamma, R.P.A. and Malifonwu, A.A. 1986. Herbicides for seed yam production from minisetts in the rainforest zone of Nigeria. Weed research, 26 (2): 115-120.

Vasquez, E.A. and Platino, M.A.G. 1995. *Dioscorea hispida*: potential botanical for the control of cassava scale insect. Philippine Journal of Crop Science, Philippine.

Vernier, P., K. E. N'kpenu, and G. C. Orkwor. (2001). Analyse comparée de la production d'igname pour la transformation en cossette au Bénin, Nigéria, et Togo: un exemple de sédentarisation de la culture de l'igname. In Root Crops in 21st Century, ed., M. O. Akoroda and J. M. Ngeve, proceedings of the 7th Symposium, International Society for Tropical Root Crops–Africa Branch (ISTRC-AB), October 1998, Cotonou, Republic of Benin. pp. 759-773. (In French)

Waitt, A.W. 1961. Yams. Rep. Dept. Agric. Res., Nigeria, p. 16-19.

Walkley, A. and Black, I.A. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed chromic acid titration method. Soil Sci. 37: 29-38.

Wanyera, N. M. W., R. Asiedu, R. Kapinga, and P. R. Speijer. (1996). Yams (Dioscorea spp.) in Tanzania and Uganda. A survey report. IITA, Ibadan, Nigeria and IITA ESARC, Uganda.

Watt, J. N. and Breyer-Brandwijk, M.G.1976. The medical and poisonous plants of southern and eastern Africa. Livingstone, London and Edinburgh.

Yayock, J. Y., Lombion, G., Owonubi, J. J. and Onazi, O. C. 1988. Crop Science and Production in warm climates. Macmillan Publisher Ltd, London. p. 215.

Young, A. 1976. Tropical soils and Soil Surveys. Cambridge University Press, Cambridge, UK.

APPENDICES

APPENDIX A:Multiple comparison sensory evaluation questionnaire used for evaluating boiled yam.

MULTIPLE COMPARISON TEST

Yam Sensory Evaluation

Name…………………………………. Sex……….

Date………………..

You are to assess each of the coded samples of **boiled yam** in comparison with the reference sample labeled CONTROL.

Taste sample labeled **control** first. Then, take water.

Taste test sample and score the range of difference using the codes below.

SCORING CODES: 0 = much worse, 1 = moderately worse, 2 = slightly worse, 3 = no difference, 4 = slightly better, 5 = moderately better, 6 = much better.

TASTE/FLAVOUR	SCORE CODES						
Sample	0	1	2	3	4	5	6
884							
381							
692							

Scoring codes: 0 = much worse, 1 = moderately worse, 2 = slightly worse, 3 = no difference, 4 = slightly better, 5 = moderately better, 6 = much better.

MEALINESS	SCORE CODES						
Sample	0	1	2	3	4	5	6
884							
381							
692							

Scoring codes: 0 = much worse, 1 = moderately worse, 2 = slightly worse, 3 = no difference, 4 = slightly better, 5 = moderately better, 6 = much better.

MOISTNESS	SCORE CODES						
Sample	0	1	2	3	4	5	6
884							
381							
692							

Scoring codes: 0 = much worse, 1 = moderately worse, 2 = slightly worse, 3 = no difference, 4 = slightly better, 5 = moderately better, 6 = much better.

SOGGINESS	SCORE CODES						
Sample	0	1	2	3	4	5	6
884							
381							
692							

Scoring codes: 0 = much worse, 1 = moderately worse, 2 = slightly worse, 3 = no difference, 4 = slightly better, 5 = moderately better, 6 = much better.

HARDNESS	SCORE CODES						
Sample	0	1	2	3	4	5	6
884							
381							
692							

Scoring codes: 0 = much worse, 1 = moderately worse, 2 = slightly worse, 3 = no difference, 4 = slightly better, 5 = moderately better, 6 = much better.

AROMA	SCORE CODES						
Sample	0	1	2	3	4	5	6
884							
381							
692							

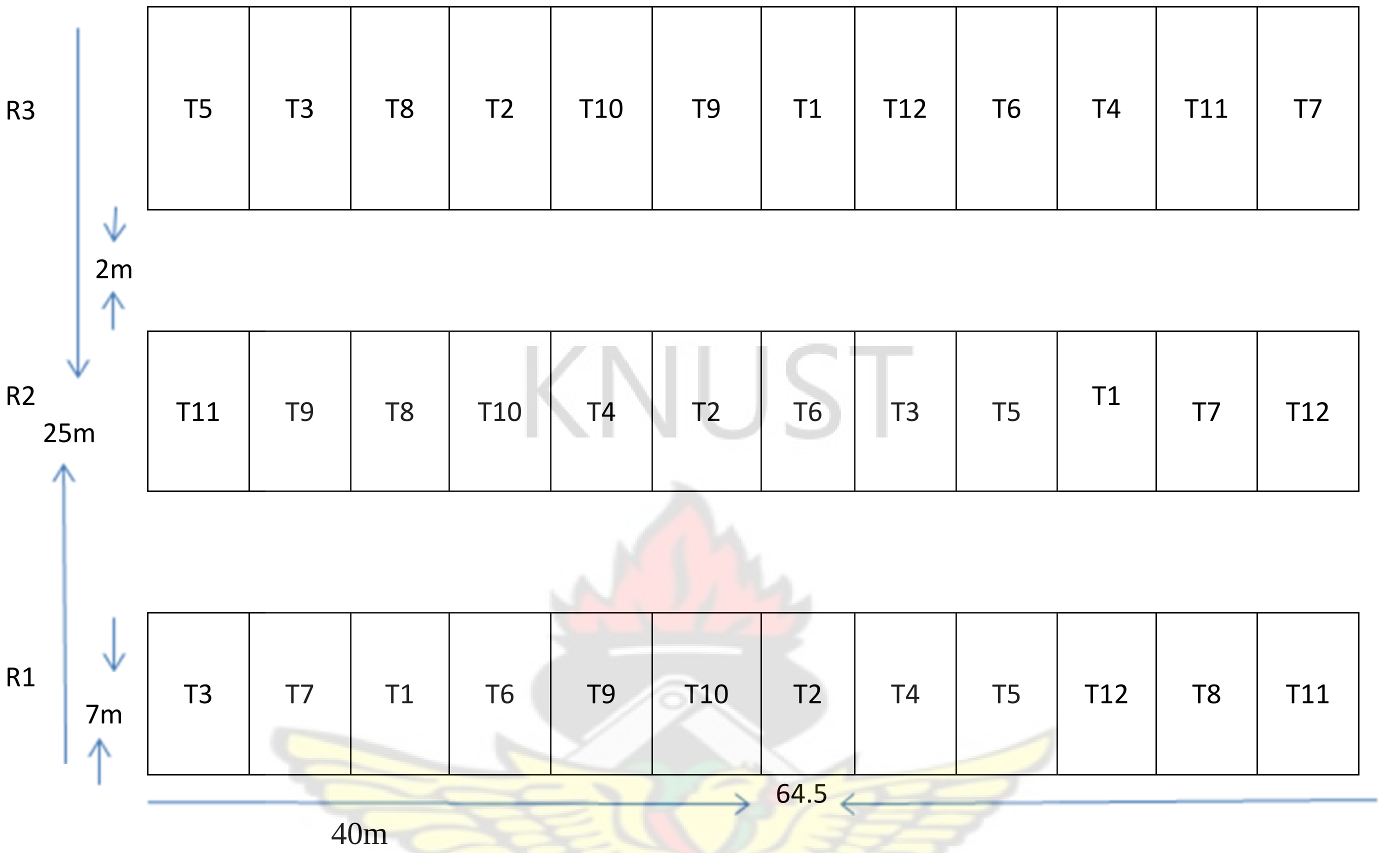
Scoring codes: 0 = much worse, 1 = moderately worse, 2 = slightly worse, 3 = no difference, 4 = slightly better, 5 = moderately better, 6 = much better.

COLOUR	SCORE CODES						
Sample	0	1	2	3	4	5	6
884							
381							
692							


APPENDIX B: Regenerated sett of pona after milking


Appendix C: A section of the sensory panel evaluating boiled yam.

Appendix D: Field Plan:



Appendix E: Economic analysis of different fertilizer treatments.

Harvest time	20WAP				24WAP				32WAP			
Fertiliser level	Control	PM only	NPK only	PM+NPK	Control	PM only	NPK only	PM+NPK	Control	PM only	NPK only	PM+NPK
Average yield (t/ha)	30.54	37.58	38.97	46.02	26.44	31.43	31.29	38.56	25.28	32.08	29.40	32.34
Adjusted yield (t/ha)	27.49	33.82	35.07	41.42	23.8	28.29	28.16	34.7	22.75	28.87	26.46	29.11
Gross benefit (Gh¢/ha)	12370.50	15219.00	15781.50	18639.00	10472.00	12447.60	12390.40	15268.00	12967.50	16455.90	15082.20	16592.70
Total variable cost (Ghc/ha)	374.9	944.78	1050.93	1048.37	338	889.48	981.83	981.17	327.5	895.28	964.83	925.27
Net benefits (Ghc/ha)	11995.6	14274.22	14730.57	17590.63	10134	11558.12	11408.57	14286.83	12640	15560.62	14117.37	15667.43
Extra(gain in net) benefits	—	2278.62	2734.97	5595.03	—	1424.12	1274.57	4152.83	—	2920.62	1477.37	3027.43
Marginal analysis	—	4.00	4.05	8.31	—	2.58	1.98	6.46	—	5.14	2.32	5.06
Percentage	—	400%	405%	831%	—	258%	198%	646%	—	514%	232%	506%