© Emmanuel Odoom

University of Cape Coast

UNIVERSITY OF CAPE COAST

THE POTASSIUM STATUS OF SOILS AND ITS ABSORPTION BY CASSAVA IN SELECTED FARMS IN THE CENTRAL REGION

BY

EMMANUEL ODOOM

Thesis submitted to the Department of Soil Science, School of Agriculture, College of Agriculture and Natural Sciences, University of Cape Coast, in partial fulfilment of the requirements for the award of Master of Philosophy degree in Land Use and Environmental Science.

JULY 2017

DECLARATION

Candidate’s Declaration

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

Candidate’s Signature: ……….…………. Date…………

Name: Emmanuel Odoom

Supervisor’s Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor’s Signature: ………………………. . Date………. .

Name: Dr David Oscar Yawson

Co-Supervisor’s Signature: ……………………………… Date………….

Name: Prof. Daniel Okae-Anti

ABSTRACT

Potassium (K) plays an outstanding role in plants and animals. Cassava, a widely grown staple in Ghana is noted for extracting large amounts of K from the soil. Cassava's ability to absorb K from the soil is worth studying as it is vital for sustainable production and biofortification. The study was conducted to assess cassava's ability to absorb K under fertilized and unfertilized systems. Two cassava genotypes, Cape Vars and Botan were grown under different fertilizer treatments; a control, NPK and NPK + KCl in a randomized complete block design. A survey was also undertaken to assess the K status of some cassava farms and cassava tuber produced on such soils in the Central region of Ghana. Composite soil samples were taken at a depth of 0 – 30 cm and analysed for exchangeable and non-exchangeable K. Aside these, the study also compared the extractability of exchangeable K by Nitric Acid, Ammonium Acetate and Calcium Chloride in soils cultivated to cassava. The outcomes of the study revealed that most cassava farms have low levels of exchangeable K (0.76 – 0.06 $\text{cmol}_c\ \text{kg}^{-1}$) likewise the K content of cassava tuber produced from them (0.84% - 0.61%). A significant increase in K content of tubers was however observed in cassava that was treated with NPK + KCl fertilizer (1.13% - 0.86%). Cassava tuber yield also saw a significant increase with the highest yield (20.5 t ha^{-1}) produced from NPK + KCl plots. The study also revealed that Cape Vars variety has a greater ability to absorb K in both fertilized and unfertilized soils. NH_4OAc, HNO_3 and $CaCl_2$ extracted 0.21, 0.64 and 0.23 $\text{cmol}_c\ \text{kg}^{-1}$ exchangeable K respectively. However, $CaCl_2$ – K was found to be more predictive of the K status of cassava soils. The study recommends the sensitization of cassava farmers on fertilizer application as well as a further research into cassava's ability to absorb K in marginal soils.

ACKNOWLEDGEMENTS

I thank the Lord Almighty for His mercies and kindness and for how far He has brought me. My profound gratitude also goes to my supervisors, Dr.David Oscar Yawson and Professor Daniel Okae-Anti for their assistance and professional guidance.

I am also grateful to all Agric Extension Officers of KEEA, Cape Coast North and Twifo- Hemang – Lower - Denkyira districts for their assistance.

Finally, I am thankful to my family and friends for their support especially Mr. William O Kwafo, Mr. Vincent Sarkodie, Miss Dorcas Blankson and Mr. Justice Ankomah-Baffoe and all Agricultural students of Jukwa SHS (2017) who contributed in one way or the other towards the success of this work.

DEDICATION

To my parents, Mr.and Mrs.Odoom

TABLE OF CONTENTS

CHAPTER ONE: INTRODUCTION

CHAPTER THREE: MATERIALS AND METHODS

LIST OF TABLES

LIST OF FIGURES

ABREVIATIONS

COCOBOD	Ghana Cocoa Board
CN	Cape Coast North
CV	Coefficient of Variation
FAO	Food and Agriculture Organization
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
K	Potassium
KEEA	Kommenda Edina Eguafo Abriem
LSD	Least Significant Difference
MAP	Months After Planting
MOFA	Ministry of Food and Agriculture
SD	Standard Deviation
TOPP	Twifo Oil Palm Plantation
HLD	Heman Lower Denkyira

CHAPTER ONE

INTRODUCTION

Background of the Study

Potassium is one of the key elements for life and its abundance in the Earth's crust lends credence to its importance. Among the major soil nutrients, potassium is the most abundant in soils (Elbaalawy, Benbi, & Benipal, 2016) and the second most abundant mineral found in plants (Towett et al., 2015). Potassium is very important for both biophysical and biochemical processes in plants. Some of these processes include the preservation of cell turgor, maintenance of charge balance as well as vacuole and cell expansion (Benito, Haro, Amtmann, Cuin, & Dreyer, 2014). Potassium is of a unique significance to the carbohydrate producers as it plays a significant role towards the translocation of assimilates in the phloem (Patrick, Zhang, Tyerman, Offler, & Walker, 2001). Potassium also plays a vital role in the translocation of photosynthates in root growth (Römheld & Kirkby, 2010) which results in an increase and swelling of tuberous crops such as cassava. Given the role of potassium in plant growth and development, it is obvious that it is needed in massive quantities by plants. Soils have a huge potassium reserves, especially in soils developed from igneous rocks (Mouhamad, Alsaede, & Iqbal, 2016). However not all is available to support plant growth at a time.

In humans, K is vital for the maintenance of important physiochemical processes which are crucial for the wellbeing and survival of the human body (Soetan, Olaiya, & Oyewole, 2010). Potassium serves as an all-important electrolyte that is needed to counteract the effect of sodium consumption contributing to the maintenance of a healthy blood pressure (Whelton et al.,1997). The importance of potassium to human health has been well recognised and studies continue to emphasise its positive effects. Increased dietary intake of K improves the functioning of the cardiovascular system and reduces the risk of cardiovascular diseases and increased mortality from heart diseases (Soetan et al., 2010).

Diets are the main sources of potassium in humans. Potassium dietary sources include vegetables, fruits and nuts (Soetan, Olaiya, & Oyewole, 2010). The bulk of most Ghanaian diets is starchy foods such as cassava, yam and rice. Amongst these, cassava has the highest per capita consumption (Sayre, 2011). Yawson et al. (2016) ranked cassava as the first among yams, plantain, roots (other than cassava) and rice as the top five food items consumed in enormous quantities in Ghana. Cassava also serve as an important staple for half a billion people in Africa and Asia (Cuvaca et al., 2015).

Potassium is very abundant in soil-plant systems in various forms, some of which is considered plant available and others unavailable (Lalitha & Dhakshinamoorthy, 2014). Intensified crop production systems require an efficient soil management towards a sustainable crop production. Potassium content of crops is influenced to a substantial extent by the K content of soils on which such crops are grown. This common knowledge has been tapped to increase bioavailable concentrations of essential elements in edible portions of crops, otherwise known as biofortification (Garcia-Casal, Peña-Rosas, Giyose, 2016). Globally, biofortification of cassava has received due attention but for other equally important nutrients such as protein, minerals, starch, and vitamins (Montagnac, Davis, & Tanumihardjo, 2009). Cassava has a wide geographical distribution (Montagnac et al., 2009). In Ghana, it is grown in all the six agroecological zones (Adowa, 2009). This makes cassava an important crop for reaching parts of the world with mineral deficiencies through biofortification. As cassava provides food for over 500 million people in Africa on daily basis (Montagnac et al., 2009) serving as a dominant staple in areas where mineral deficiency is widespread, especially in Africa, it remains a perfect crop for targeting mineral deficiency in Africa and other parts of the world where mineral deficiency and associated non-communicable diseases constitutes a major health challenge.

Statement of the Problem

Root tubers such as cassava are noted for removing substantial amounts of nutrients from the soil, especially K during their growth period (John & Imas, 2013). However, its ability to thrive and produce reasonable yields on infertile and marginal soils remains a mystery. These foods constitute the bulk and form a major part of the diet of many Ghanaians. Regardless of cassava’s big K budget on the soils, it is grown mostly on marginal soils and fertilization is not a customary practice among cassava farmers.

Cassava, an important staple for Ghanaians and Africans at large is mostly produced by small-holder subsistent farmers who use little or no fertilizer at all (Fermont, Tittonell, & Giller, 2010). Fertilizer application in cassava production is not common in Ghana as farmers attribute several reasons such as high prices of chemical fertilizers and reduction in quality of cassava tuber’s cooking quality and storage. (Yawson, Armah, Afrifa, & Dadzie, 2010)

As the nutrient concentrations in the plant are influenced to a large extent by soil fertility and the fertilisation practices that are undertaken by farmers (CIAT, 2011), the observed high concentrations of K in cassava roots grown on even marginal soils might be due to a special ability of the crop to mobilize K from soils. It is not yet clear why this happens but there is also little information on the relationships between soil K content before and after harvest of cassava and K content of harvested cassava roots from farmers' fields. Hence, this study aims to analyse the K content of soils of selected cassava farms in relation to K content of harvested cassava roots in the Central Region of Ghana.

Justification

There exists a direct relationship between soil potassium and potassium content of crops. According to CIAT (2011), the nutrient status of the soil is proportional to the concentration of nutrients in all tissues of plants that grow on it. Welch & Graham (2004) also established that edible parts of most crops grown on soils lacking mineral elements have low concentrations of such minerals in them. This relationship between soil-plant K can be exploited as a tool to effectively manage the K content of soils and increase the potassium content of food crops such as cassava which has been tagged for its low nutritional value (Fermont et al., 2010) through better soil management practices such as fertilizer application.

Farmers are usually reluctant to apply soil management interventions in cassava production. They stick to a common assertion that the soil had adequate amounts of nutrients, especially K even when the soil is perceived to be marginal (Yawson et al., 2016; White & Broadley, 2005).

This warrants an investigation into the fertility status and more particularly the K status of soils under cassava production to measure cassava's ability to accumulate K on such soils in relation to those grown under fertilized systems. It is also prudent to investigate farmer's reluctance to apply fertilizer in cassava cultivation as this is vital towards improving the nutritional value of cassava with respect to K.

It is very important to study the relationships between soil potassium forms and their levels under various cassava production systems and how the application of fertilizer can improve the K content of important staples like cassava. Again the perception of farmers towards the fertility management of cassava farms and the need to apply fertilizer now or in the near future is very critical towards a sustainable production of cassava which has been identified as a food security crop for the ever increasing population of the world (Adenle, Aworh, Akromah, & Parayil, 2012).

Objectives

The main objective of this work was to assess K uptake by cassava on different soils or production systems.

The specific objectives were:

i. To assess the K absorption in cassava genotypes under fertilized conditions.

ii. To assess the K status of soils and cassava on unfertilized farmer's fields.

iii. To compare the extractability of K by three extraction methods and their relationships with cassava yields.

CHAPTER TWO

LITERATURE REVIEW

Forms of Soil Potassium

Potassium is one of the key elements for life on earth and its abundance lends credence to its importance. Potassium is the fourth most abundant element on earth (Ashley, Grant, & Grabov, 2006) and constitutes 2.6 % of the weight of the earth crust (Sardans & Peñuelas, 2015). Amongst the major nutrient elements potassium is the most abundant in soils (Elbaalawy et al., 2016; Mouhamad et al., 2016) and are found in higher quantities in soils that develops from igneous rocks (Mouhamad et al., 2016) as well as soils from parent materials rich in K – bearing minerals (Havlin, Beaton, Nelson, & Tisdale, 2005). Among the igneous rocks, granite and syenites contains the highest amount of K (46-54K kg^{-1}) however in sedimentary rocks, clayey shales contain 30 K kg^{-1}, and whereas limestone contains 6g kg $^{-1}$ $^{.}$Soils from igneous rocks such as in forest soils would have a higher amount of potassium than ones formed from sedimentary rocks. The upper 0.2 m of the soil profile is known to be very rich in K with their total K content ranging from 3000 – 100000 kg ha^{-1} , however out of this, 98 % is bound in mineral form and only 2 % is in soil solution and exchangeable phases (Mouhamad et al., 2016). This confirms the accession that even though the soil originally has a higher K content, only a small amount is available for plant uptake. The amount of potassium is not the same for all soils but varies greatly depending on factors such as parent material, degree of weathering, gains and losses through fertilizer application and crop removal, erosion and leaching (Elbaalawy et al., 2016).

In Ghana, K levels in forest soils are low as compared to savannah soils, however savannah soils can maintain K supply for a longer time. The low K content of forest soils can be attributed to rapid leaching due to extreme climatic conditions (Yawson, Kwakye, Armah, & Frimpong, 2011). Soil Potassium exists in different fractions in the soil. Per Havlin et al., (2005) and Zorb et al. (2016); soil potassium exists in four forms and these forms are in dynamic equilibrium. This implies that a depletion in one form will result in a shift of the equilibrium in that direction to replenish it (Elbaalawy et al., 2016).

The first form of soil potassium is the soil solution K, which is considered the primary source of potassium for plant uptake. Water soluble K is the fraction of soil K that exists as a soluble cation in soil solution and remains relatively unbound by cation exchange forces, however usually leached (Lalitha & Dhakshinamoorthy, 2014) This form according to Elbaalawy et al., (2016) is the most labile though prone to leaching. Soluble K is about 0.12% is relatively small and almost negligible (Lalitha & Dhakshinamoorthy, 2014). The amount of water soluble potassium is not evenly distributed in the soil profile. According to (Zorb, Senbayram, & Peiter, 2014) top soils have a relatively high water-soluble K than the sub soil. He attributed this to a possible upward translocation of K through capillarity and possibly through the release of K from plant residue and addition of manure from animals. The concentration of solution K depends on important factors such as weathering, past cropping and K fertilization practices (Yawson et al., 2011). The levels of soil solution K are generally low and vary from 2 – 5 mg kl^{-1} for normal agricultural soils in the humid regions.

However, soil solution K, can be adjusted through proper soil amendments (Mouhamad et al., 2016).

The second form of soil K is the exchangeable K. Lalitha & Dhakshinamoorthy (2014) defines exchangeable K as the form of K present in the soil matrix and can be replaced by cations of neutral salts present in the soil solution. It constitutes approximately 90 % of the available K. The type of clay mineral that exists in a particular soil has a strong bearing on the amount of exchangeable K in a given soil. Jeyaraj & Mosi (1973) found the highest exchangeable K in clay and silt fraction of most soils.

The third form of soil potassium is the non-exchangeable K which also ranges from 50-70 mg kg^{-1}. This form of K is considered fixed and is held as fixed ion in the lattice structure of clay minerals and as part of structural forms of minerals (Hamdana & Osumanu, 2013). According to Sparks & Huang (1985) potassium becomes fixed due to the fact that the binding forces between K and clay surfaces are greater than the hydration forces between individual K ions. There is, therefore, a partial collapse of the crystal structure and the K ions are physically trapped to varying degrees leading to a slow K release which is diffusion controlled. Non-exchangeable K is only released when levels of exchangeable and solution K are decreased through crop removal and leaching.

The last form of soil K, which is the mineral K (5000-2500 mg), is found in K bearing minerals in soils depending primarily on the source of the parent material. Mineral K constitutes the greatest part of the total soil K (92 % - 97%) (Elbaalawy et al., 2016). It exists mainly as K – bearing primary mineral such as Muscovite, biotite and feldspars. (Wakeel, Farooq, Qadir, & Schubert, 2011). Non - exchangeable K is very important as it constitutes the major source of K supply to plants (Pasricha, 2002).

According to Sparks and Huang (1985) the forms of K in order of their availability to plants and microbes are; solution > exchangeable > non-exchangeable > mineral. The first two forms are considered to be labile, that is, they meet the immediate requirements of the growing plant, however the last two which are non- labile are vital for the long term supply of K to plants (Askegaard, Eriksen, & Olesen, 2003). With the various forms of K in the soil as discussed earlier, it is clear that most soils are rich in potassium. However, availability is one thing and uptake is also another as K uptake is dependent on several factors. According to Askegaard et al., (2003), K uptake by plants is affected by soil moisture, soil aeration, oxygen levels, soil temperature, tillage and exchangeable K dynamics. Potassium becomes readily available with high soil moisture as it increases the movement of K to plant roots. Soil aeration and oxygen level are also important factors affecting K uptake. Air is necessary for root respiration and potassium uptake.

Aside the already mentioned factors influencing K uptake, soil – solution exchangeable K dynamics is also a very important factor in K uptake. Reaction rates and direction of reactions involving soil solution and exchangeable forms of K need to be considered before soil K amendments can be applied to the soil. This will indicate the fate of K added through fertilizer application as to whether it will be leached, taken up by plants, converted into unavailable forms or released into available forms (Wakeel et al., 2011).

According to (Tripler, Kaushal, Likens, & Todd Walter, 2006) potassium dynamics is driven by two key forces; gravitational force and diffusion. These two forces largely control the movement of water and nutrients in the soil system. Gravitational force controls the movement of water, solutes and particles in and on the soil, whereas diffusion controls movement under concentration gradient. Plant nutrients are normally absorbed by plants against concentration gradients. In the case of K^+ in soil solution – plant systems, two situations create a concentration gradient. The first two happens when the concentration of solution K decreases due to plant uptake, a positive gradient is created between the fertilizer molecules and plant root through the soil solution. Knowledge about the various fractions of soil K and their interaction in the soil is very crucial towards effective potassium management of soils. Effective K management requires an understanding of the various forms of soil potassium and their interactions in the soil.

Methods of Soil K Assessment

An assessment of soil K through laboratory methods is a key tool for understanding soil potassium levels and for accurate K fertilization regimes. The exchangeable K is the widely used approach for evaluating K status (Askegaard et al., 2003; Samadi, 2006). This method relies upon a displacing solution also known as an extractant. An extractant is a chemical solution that is added to a soil sample to dissolve, desorb or exchange a portion of the total amount of a given nutrient(s) in a soil sample (Poon, 2010). The effectiveness and suitability of an extractant for predicting K supply depends on how close the extracted K predicts the actual uptake of plants (Darunsontaya, Suddhiprakarn, Kheoruenromne, & Gilkes, 2010). Laboratory procedure for K determination varies greatly from place to place. Amongst the lot, the commonest includes; Ammonium acetate (1.0 M NH4OAc; pH=7), Hot nitric acid, unbuffered salts such as $CaCl_2$, $BaCl_2$ and Melich 3 solution. The ability to select methods that will allow joint extraction of several nutrients so as to make a good use of multi-element analysers constitutes an important challenge of soil tests (Peck & Soltanpour, 1990). Most of the methods of soil testing used today are old and could date back several years. Such methods were developed in times where there was intensive use of commercial fertilizers, when the sensitivity of analytical methods was lower (Matula, 2009). There is the need to evaluate the efficiency of such methods in present times to form a solid foundation for prudent soil fertility management methods and fertilizer rates.

According to Matula, (2009) a modern-day soil test should satisfy the following requirements;

a. Simultaneous extraction of all important nutrients from the soil.
b. Functionality in all kinds and types of soils, that is, the existence of the best possible compliance of extracted nutrient from heterogeneous soils with their bioavailability requirement of universality.
c. Accuracy and reproducibility
d. Simplicity
e. Reasonable price in agreement with the utility value information.
f. Expeditious detection
g. Reflection of mechanism influencing the availability of a nutrient to plants from the soil in each site.

Most of the soil tests methods do not satisfy such ideal parameters, but the suitability of a particular method can be measured by considering how close they are to such criteria (Matula, 2009). The different forms of potassium in the soil require extractants for their extraction and determination. However, all of the methods extract exchangeable and solution K as well as varying amounts of the fixed K (Rowell, 2014). Ammonium acetate is normally prescribed for extracting available K from the soil and is predominantly used to determine exchangeable cations in agricultural soils. An advantage of the ammonium acetate method is the inclusion of the CEC value (Matula, 2009). This value is an important parameter in soil – plant systems that influences the calibration and interpretation of soil tests for accurate fertilizer recommendations. The CEC value also extents information about capacity character of the soil. Ammonium acetate extracts mainly the exchangeable fraction of soil K. The non - exchangeable K fraction is also extracted by the hot Nitric acid method. This method involves boiling 2g of soil in 20ml of 1M HNO_3 and made to the final volume with deionized water (Darunsontaya et al., 2010). The HNO_3 extracted K comprised exchangeable K and water-soluble K.

Aside the use of acids in extracting K as discussed earlier, the unbuffered salts such as $CaCl_2$, $BaCl_2$, $SrCl_2$ has been used as extractants for evaluating the availability of soil nutrients (Bibiso, 2012). For increased laboratory productivity and decreased cost of analysis, multi nutrient extraction is much preferred. Common multi nutrient extractants includes Mehlich 3 (Mehlich, 1984), Morgan extraction (Morgan, 1941) and Oslen extractant (Olsen, 1954). Amongst these multi nutrient extractants, Mehlich 3 is popular and widely used. Mehlich 3 is capable of extracting a number of nutrients at the same time, however it works best for neutral to acid soils (Haney, Haney, Hossner, & Arnold, 2006; Mehlich, 1984).

The efficiency of soil tests for K has been studied over the years by many researchers across the world and the correlation between these extractants and with soil properties has been examined. Bibiso (2012) evaluated three universal extractants for the determination of P, $NO_{3,}$ and K in some soils in Ethiopia and concluded that unbuffered salts may not be effective extractant as compared to the conventional ones when single nutrient extraction is considered. In the same study, He found a very close relationship between conventional soil testing methods and universal extractants for K determination. He also found that the amount of K extracted by the universal extractants is much lower than the conventional soil testing methods. This was attributed to the fact that the Ammonium cation and the potassium ion are almost the same. Darunsontaya et al. (2010) also identified NH_4OAc-K as a highly predictive indicator for available K to plants.

The Role of Potassium in Plants

The abundance of potassium in living organisms gives an indication of its vital role in the survival of plants and animals. Potassium is amongst the top ten elements found in the earth crust (Wedepohl, 1995) and the second most abundant mineral in plants (Towett et al., 2015). In plants, potassium plays a role of enhancing both biophysical and biochemical processes. Some of these processes includes maintaining charge balance, preservation of cell turgor, vacuole and cell expansion (Benito et al., 2014). Aside the aforementioned importance of potassium to plants, potassium is significant for stress response in plants (Min Wang, Zheng, Shen, & Guo, 2013). Potassium plays an outstanding role in shielding the plant against biotic and abiotic stress such as diseases, pests, drought, salinity, cold, frost and water logging.

The role of potassium in plant biotic stress resistance has been well recognized. The significant role of potassium in abiotic stress resistance is the reduction in drought stress in plants. Abiotic stress constitutes the major factors that affect metabolism, growth and yield of crops (Zörb, Senbayram, & Peiter, 2014). According to Zorb et al. (2014), abiotic stress such as bacterial and fungal diseases, insects and pest infestation reduces crop yield. Incidence and duration of drought and heat stress, storms and periodic flooding is likely to increase as predicted by some climate models (Brouder & Volenec, 2008). In the face of such events a fall in crop production is much expected.

The role of potassium in drought stress resistance is worth mentioning. Potassium is the most important osmoticum in plants and the main determinant of cell turgor (White, 2013) which is an important factor in growing plants. Potassium is also essential in the regulation of stomatal aperture. This is very important in limiting water loss. Potassium provides the osmotic driving force for water influx into the guard cell vacuole (Peiter, 2011) which decreases stomatal resistance. Stomatal closure has also been identified in potassium deficient plants (Brag, 1972). In the field there is the need for osmotic adjustment and the need to sustain cell expansion at low soil water levels and the plant to this through ample K supply (Grzebisz, Gransee, Szczepaniak, & Diatta, 2013). Regardless of the role of potassium in drought stress resistance, the low potassium supply on dry soils renders the crop less drought resistant and leads to a slow growth rate in plants. To increase the resistance of plants to drought stress, Römheld & Kirkby (2010) proposed potassium fertilization above the levels required for optimum yield under non-stress conditions. Potassium fertilization regimes can therefore be used as an effective tool in combating crop loss through biotic stress. Potassium has been identified as a limiting nutrient several years back (Goulding & Loveland, 1986). Possible reasons that can be attributed to this includes unbalanced fertilizer regimes and lower Potassium fertilization which has led to the depletion of available K reserves. Optimized potassium fertilizer application in K limited soils is crucial to enhance plant response to abiotic stress. Potassium fertilization is imminent and should be looked at especially with regards to the enormous benefits of potassium to plants.

The availability of K in the soil also affects the uptake of other essential nutrients such as Nitrogen. According to Römheld & Kirkby (2010), an increased nitrogen fertilizer requires further increase in potassium availability to maintain the plants water status especially in dry conditions. In plant disease control and prevention, it has been reported that potassium deficient plants tends to be more susceptible to infection than those with adequate supply (Wang et al., 2013). Sarwar (2012) also reported a surge in rice borer infestation when there was no K supply, but adequate potassium supply corresponded with a fall in rice borer infestation. The role of potassium in plant health is clearly evidential as adequate K levels can be said to have increased the ability of the crops to resist the rice borer attack (Sarwar, 2012).

Potassium plays a key role in translocation of assimilates in the phloem (Patrick et al., 2001) as well as in mass flow driven solute transport in the sieve tubes of the phloem (Zörb et al., 2014). Potassium accumulation has been found to be very important to maintain and establish high osmotic pressure in the sieve tubes to enhance high transport rates (Marschner, 2012). Potassium is also key in the translocation of photosynthates in root growth

(Römheld & Kirkby, 2010) resulting in an increase and swelling of tuberous crops such as cassava. Potassium fertilization in cassava is therefore very necessary in intensified cassava cultivation, as Cassava is noted for a huge K budget on the soil (John & Imas, 2013). Cassava growers therefore need to see K fertilization as a priority for intensified and sustainable production of the crop.

The Role of Potassium in Humans and Animals

Mineral elements play a significant role in the heart and wellbeing of human. Humans need more than 22 elements and this can be supplied by a good diet (White & Broadley, 2005). The presence of minerals in the body is vital for the maintenance of certain important physiochemical processes which are important for the survival of the human body (Soetan & Olaiya, 2010). According to White (2010) people who live in places with soil imbalances can suffer deficiency of certain important minerals. And sub-Saharan Africa is no exception as farming is usually characterized by continuous intensified farming usually under no fertilizer application. These important minerals are needed in the body in different amounts depending on its role in the body. One of such important mineral element is potassium. The role of potassium on human health cannot be overemphasized. An all-important electrolyte that is needed to counteract the effect of sodium consumption contributing to the maintenance of a healthy blood pressure (Megan Ware RDN, 2017). Potassium is also needed for maintenance of total body fluid volume, acid and electrolyte balance and the normal cell functioning (Aburto, Hanson, & Gutierrez, 2013).

In humans and animals, K is important in maintaining water balance and activation of enzymes. Potassium is also essential for osmotic pressure regulation and mediation of carbon and protein metabolism (Saltzman, Birol, Bouis, Boy, & Moura, 2013). Adequate intake of K into the body usually through dietary sources prevents non communicable diseases (Yawson et al., 2016). People die a lot each year due to Non communicable disease than due to all the other causes combined (Aburto et al., 2013). Cardio vascular diseases such as stroke, heart failure and renal failure are usually the key NCD responsible for the death of many in our society. This has become a major health problem in Ghana and has been identified as the leading cause of hospital admissions and deaths (Yawson et al., 2016). Due to the role of potassium in reducing morbidity and mortality from non-communicable diseases, increased potassium intake is considered as the most potential and cost effective intervention (Aburto et al., 2013). However, the potassium intake levels of modern day societies reduced drastically largely due to food processing, and intake of diets high in processed foods and low in vegetables and fruits. According to (Amine et al., 2002), world potassium consumption is below 70 – 80 mmol day^{-1}, and many in Africa and parts of the world are living on diets below this level.

The human body, according to W.H.O., (2012) requires about 100 mg of K daily to support key bodily processes. High potassium consumption has several benefits, the intake is associated with 20 % decrease of dying from all causes, reduced stroke, lower blood pressure, and prevents the formation of kidney stones. Potassium is needed to keep the heart running as it controls the electrical activity of the heart and other muscles. Aside the numerous benefits of potassium on the heart, it is also vital for bone and muscle maintenance. Potassium is one of the naturally abundant minerals and perhaps justifies its importance to the human body. Potassium abounds in a variety of unrefined foods, especially fruits and vegetables. Since the chief source of K to the body is diet, the type of foods that constitute the main diet of people will indicate the amount of potassium the body will benefit from. A diet dominated by processed foods and low in fresh fruits and vegetables is often deficient in potassium.

In Ghana, the top five food items consumed in enormous quantities in their other of importance includes; Cassava and products, yams, plantain, roots (other), and rice. These food items supply the following amount of K per person per day; 264, 278, 189, 32, and 2 mg respectively. Maize and tomatoes also supplies appreciable amounts of K (3 mg and 38 mg K per person per day) (Yawson et al., 2016). These values give an indication that most Ghanaian diets have low quantities of potassium. The bulk of K supply in Ghanaian diets according to Yawson et al. (2016) comes from yam, cassava and plantain as depicted by Figure 1. The aforementioned foods that form the bulk of Ghanaian diets have relatively moderate to low levels of K and even that, some fraction is lost through processing. Ensuring adequate K supply and achieving recommended levels would imply that the potassium levels of these staples must be looked at.

Attempts to minimize morbidity and mortality from non-communicable diseases must be centred on increasing the K content of these important staples through necessary but sustainable means such as management of potassium levels in soil systems. Potassium is of much importance to animals just as in humans and is recognized as an essential nutrient in animal nutrition. In the animal's body, potassium is the third most abundant mineral element, exceeding sodium concentration by 20 – 30 times (Preston & Linsner, 1998). Potassium is crucial for the life of farm animals as extreme deficiency in young animals is known to cause death in few days (Preston & Linsner, 1998).

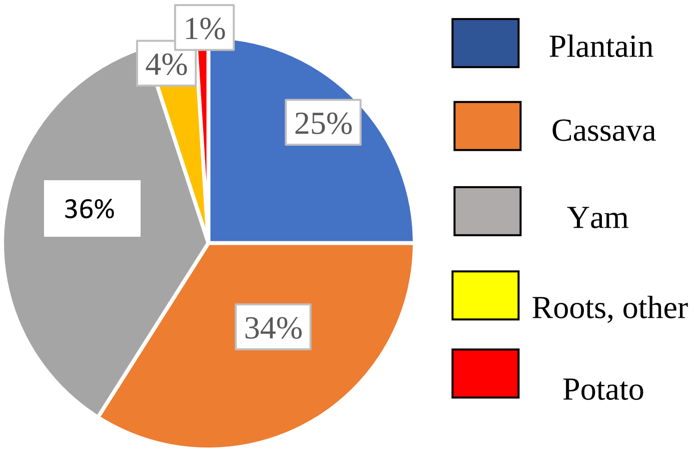

Figure 1: Contribution of root tubers to dietary K requirement of Ghanaians

Source: Yawson et al. (2016)

Mineral elements are very important for the metabolic processes of animals. Potassium is especially important in the diet of chicken and turkey during the first 8 weeks. Adequate K levels in diets of chicken is essential for good egg production, egg white and shell thickness (Preston & Linsner, 1998). There is therefore the need for adequate K supply in the feed of farm animals as potassium deficiency diseases can affect the performance of farm animals and decrease production. In dairy cattle, it has been found that milk production severely falls due to hypokalaemia (Soetan & Olaiya, 2010). The recommended potassium levels in the ration of some farm animals per (Preston & Linsner, 1998) is depicted in Table 1. Dairy cattle have the highest

K requirement due to the role of potassium in milk production as mentioned earlier. There is the need to ensure that farm animals obtain their recommended potassium requirements through feed rich in dietary potassium. Despite the numerous significance of K in farm animals, excessive intake can cause complications. It is therefore essential in animal production to carefully manage the amounts of these essential minerals in the diet of farm animals.

Table 1*: Recommended K levels of some farm animals*

Animal	Recommended level % K in dry ration
Beef cattle	0. 6-0.7
Dairy cattle	0. 65 – 1.0
Sheep	0.5
Pig	0.19- 0.33
Horses	0.25 – 0.45
Poultry-	
Chicks	0.30
Breeding hen	0.40
Turkey	0.6 – 0.8

Source:Soetan & Olaiya (2010)

Cassava:An Important Staple

Cassava has been over the years and still remains an all-important staple that serves as food for many globally, most especially in Africa where it remains the most important source of calorie and a diet for over 250 million people (Siriwat et al., 2012). Cassava is the sixth most important crop after sugarcane, maize, rice, wheat and potato in terms of global annual production

(Burns, Gleadow, Cliff, Zacarias, & Cavagnaro, 2010). Globally, about 750 million people depend on cassava as a staple (Burns et al., 2010; Gbadegesin, Olaiya, & Beeching, 2013). Cassava is cultivated principally for food, consumed in many forms such as sliced and cooked or processed into flour or granular product such as tapioca or gari (Balagopalan, 2002; A. Burns et al., 2010; Gbadegesin et al., 2013). Over the years cassava has been a good source of food and feed for both man and animals, ranging from the fresh roots, peels and leaves (Boateng, 2015). About 200 million tonnes of the harvested roots are currently produced globally, of which 50%, 34% and 15% are produced by Africa, Asia and Latin America respectively (Adenle et al., 2012; FAO & IFAD, 2005).

Cassava provides food for many Africans directly or indirectly as a major part of the main diet and it is considered as a food security crop for the people of Africa (Adenle et al., 2012). Cassava food products are the most important staples of rural and urban households in southern Nigeria where the current dietary calorie equivalent of per capita consumption of cassava amounts to about 238 kcal (Cock & Reyes, 1985). A research conducted by FAO and IFAD revealed cassava as the cheapest source of calories amongst all food crops in Ghana and Nigeria where people grow cassava exclusively for food (FAO & IFAD, 2005). The FAO estimated cassava utilisation as food at 102million tonnes in 2000. The level of utilisation will continue to rise due to rapid population growth coupled with high cost of living. Cassava becomes an important food for many poor communities of the world especially in sub – Saharan Africa where the greatest per capita consumption (800g per person per day) is found (IFAD, 2000).

Cassava’s importance as a staple crop is not limited to Africa, but to other parts of the world as well. In South America and parts of the south Pacific, consumption is relatively high (Burns et al., 2010). They again predicted an increase in utilisation of cassava in the coming years due to global climate change. This lays emphasis on the role of cassava as a food security crop mostly for the people of Africa, a continent racked with hunger, poverty and HIV AIDS pandemic (FAO & IFAD, 2005). The crops ability to adapt to wide agroecological zones and produce good yields in areas where many crops cannot thrive makes it the most important food security crops at the household level (Prakash, 2013). Cassava’s unique importance as a staple in difficult times has earned it the title “the drought, war and famine crop” (Burns et al., 2010).

Cassava as an Industrial Crop

Cassava (*Manihot esculenta Crantz*) is a staple crop with great economic importance as a chief source of food for many people in the world. Cassava serves as a daily source of food for over 600 million people (Jansson, 2010). Almost all of the cassava that is produced (more than two-thirds) is consumed by humans (Prakash, 2013). In West Africa, cassava serves as the principal food for many, consumed as cassava flour and gari in large quantities (Tonukari, 2004). The second most important use of cassava globally is feed. According to Prakash (2013), about a quarter of global cassava production is used as feed for pork, poultry, cattle and fish directly or indirectly through incorporation into the compound feed. Despite being an important food crop, especially for the poor, cassava has evolved into a multipurpose crop serving the priorities of developing countries worldwide (FAO, 2013). One of such important priorities is the use of cassava for producing industrial starch. Starch serves as a raw material for a variety of food products and industrial goods, including paper, cardboard, textile, plywood glue and alcohol (Mejía-Agüero, Galeno, Hernández-Hernández, Matehus, & Tovar, 2012).

In the food industry, starch serves many purposes. Cassava starch is employed in extruded snacks for improved expansion. It is also used as a thicker in foods that are not rigorously processed. Cassava starch is also an ingredient in baby foods and is used as filler and bonding agent in confectionary and biscuit industries (Tonukari, 2004). Cassava starch has a remarkable industrial usage as well. In the textile industry, starch is used in sizing and dying to increase brightness and weight of the cloth. Again, cassava starch is also of much importance in the pharmaceutical industry. The starch is used as a filler material and as a bonding agent for making tablets. Starch is also used in the pharmaceutical companies to control characteristics such as texture, moisture, consistency and shelf stability (Akpan, Uraih, Obuekwe, & Ikenebomeh, 1988). Cassava starch can be converted into glucose as well as other modified sugars and organic acids (Tan, Ferguson, & Carlton, 1983) Starch may also be converted into fructose syrup and for gelatine capsules (Vuilleumier, 1993).

Practically every industry uses starch or its derivative in one form or another (Akpan et al., 1988). Aside from the already discussed industrial uses, cassava starch has other important uses as well. In cement manufacturing, it is used as an additive to improve the setting time and even in oil industry, it is important for improving the viscosity of drilling muds in oil wells. Paper manufacturers also fall on cassava starch as glue for binding sheets together and achieve brightness and strength. The importance of cassava starch is numerous but not limited to the rubber and foam industries and detergent soap manufacturers. In the latex industry, starch is employed for enhancing better foaming and colour.

Aside from the industrial use of cassava as starch, it also provides a reliable source of ethanol. The use of cassava ethanol for biofuel has been widely exploited and continue to receive attention due to the numerous advantages of the use of biofuels over fossil fuels especially in sustainability and environmentally friendly terms (Chan, Rudravaram, Narasu, Rao, & Ravindra, 2007). Biofuels have received due attention these days as a renewable energy source (Faaij & Londo, 2010) Ethanol, the product of carbohydrate hydrolysis and fermentation may be used directly or in a mixture with fossil fuels(Nuwamanya, Chiwona-karltun, Kawuki, & Baguma, 2012). According to Nuwamanya et al. (2012) crops normally grown for energy production includes sugar cane, cassava, corn and sweet potato. Among these crops cassava is mostly preferred for bio ethanol production due to many favourable characteristics of the crop such as high drought resistance, low requirement for fertilizers and high starch content (Jansson, 2010). Again, cassava has a better bio fuel conversion than the other crops mentioned earlier. Wang, (2005) compared bio fuel conversion of five bio fuel crop as presented in Table 2.

Table 2:*Bio-ethanol yield of some crops*

CROP	YIELD Tonne ha^{-1} yr^{-1}	Conversion rate To bio ethanol L $tonne^{-1}$	Bio ethanol yield L $ha^{-1}yr^{-1}$
Sugarcane	70	70	49000
Cassava	40	150	6000
Sweet sorghum	35	80	2800
Maize	5	410	2050
Wheat	4	390	1560
Rice	5	450	2250

Source: Wang (2005)

From Table 2 cassava produces the highest ethanol per hectare per year. Cassava is thus a very important emerging industrial crop.

Ethanol from cassava has several uses. It serve as fuel for many cars in countries like the United States of America and Brazil where it offers a cheap alternative source of fuel for automobiles (Goldemberg, 2008). Ethanol has become a preferred alternative for fossil fuels since its basal resources are renewable and combustion produces reduced particulate emissions. This offers a fantastic opportunity for reducing air pollution which is characteristic of fossil engines. Goldemberg (2008) estimated that ethanol is used as a replacement for approximately 3% of fossil based gasoline used worldwide. Generally, cassava utilization for ethanol production will largely depend on the availability and relative price of close substitutes such as maize (Prakash, 2013).

Cassava as an Animal Feed

Cassava in various forms offers a source of feed for most animals and the use of cassava as animal feed is expected to grow at 1.6 % per year by 2020 in developing countries (Tonukari, 2004). In Africa, cassava utilisation as animal feed has gained much recognition over the years and this can be attributed partly to the cost of alternatives such as maize in the livestock industry (Tewe & Lutaladio, 2004). Africa’s share of cassava production used as livestock feed is relatively low and is estimated at 6 % of the total production. This value, According to Tewe & Lutaladio., (2004) is an underestimation as cassava roots, peel, and leaves are also fed to sheep and goats. However, in Latin America, Asia and Europe cassava utilisation as livestock feed is well exploited and enjoys a bigger share of the total output. In Latin America, 32.4 % of cassava that is produced goes into livestock feeding whilst Asia exports 40% of its cassava to support the livestock industry in Europe (IFAD, 2000).

Over the world, there has been an increased pressure on energy sources such as maize by humans and livestock feed formulators leading to scarcity or high prices. This has stimulated the use of close substitutes of energy sources that are locally available (Apata & Babalola, 2012) The root tubers such as cassava offer the greatest alternative especially in the rural tropics where it abounds. The root tubers, however, remain under-utilized due to certain anti-nutritional factors such as the presence of cyanogenic glucosides and other unfavourable properties such as mouldiness during processing, dustiness of dried products and high fibre content of the peel (Agwunobi, Angwukam, Cora, & Isika, 2002).

Aside these factors, there are other important limitations of the use of root and tubers as animal feed. Apata & Babalola, (2012) listed the following important limitations.

- All root tubers are succulent materials with low dry matter (25%-32 %) making their preservation, transport and handling more difficult.
- Most root tubers have poor nutritional content with starch being the major component with low protein content. (2.7% - 7.1%) and thus needs adequate protein supplementation.
- Some of them contain anti-nutritional factors such as cyanogenic glucosides in cassava that make the root bitter and affect the palatability.
- Microbial contamination due to high moisture content.

Regardless of these limitations, root tubers such as cassava are used in diets for a wide range of animals such as poultry, fish, and pigs. Some studies have even predicted a possible substitution of conventional energy feed ingredients such as maize, rice and sorghum as conventional energy sources in diets in most parts of Africa (Akinfala & Tewe, 2001) Cassava can be fed to pigs either in the fresh state or boiled or included in the diet as dried meal best served in the form of pellets. Powdery forms are known to cause complications in some animals (Apata & Babalola, 2012). The use of cassava as feed for pigs is widely accepted and research has indicated acceptable performance and carcas quality in pigs raised on cassava diets.

In poultry enterprise, cassava offers a means of cutting down feed cost and the overall cost of production (Olorede, Sadu, Abdurahim, Ajagbonna, & Akinloye, 2002). However, to realise the full potential of such cassava diets, rations must be nutritionally balanced with a good protein source (Tewe & Lutaladio, 2004). Again, cassava is very important in diets for fish where it serves as a source of energy in the meal of the fishes.

Cassava utilisation as livestock feed per Tewe is the most promising among other utilisation types due to the following;

- It's standard required for feed grade cassava products aren’t stinging as far as other products.
- As animal protein combustion is projected to increase on the continent, there is tremendous potential for growth and expansion of the animal feed industry which is the main component of cost in livestock production.
- The availability of maize, the main energy source in compounded feed is being threatened due to constraints in the importation and increased in cost of fertilizers and unfavourable weather conditions. In view of this, the role of cassava in achieving food security is worth reviewing and research attention. Cassava is a food security crop that has the capacity to sustain both human and livestock populations. As humans largely depend on the tuber for food, the surplus can go into making feed for livestock. This can result in an expansion of cassava market which according to Tewe (1992) is key to maintaining the socioeconomic status of cassava farmers and achieving food security.

Growth Requirement

Cassava is a tropical crop grown mostly in the regions that fall between latitude 30 ^{0}N and 30 ^{0}S (Nassar & Ortiz, 2009). It thrives favourably under humid – warm climates at temperatures between 25 ^{0}C – 29 ^{0}C and rainfall between 1000 mm – 1500 mm which is evenly distributed. Cassava has the ability to adapt to different climatic conditions and it is well known for its capacity to withstand extended periods of water stress but with an associated reduction in yield (Burns et al., 2010). Cassava's ability to withstand extended periods of water stress can be attributed to a number of physiological adaptations such as a high degree of control over the stomata aperture, leaf movement and stimulation of root growth (Augusto & Alves, 2002). The crop prefers light to medium well-drained soils with a pH range of 4.5 – 7.5. Nevertheless, the crop has inherent physiological makeup that enables it to thrive even in acidic and calcareous soils (John & Imas, 2013).

Production levels

Cassava's major role in employment and income creation as well as a food security crop in most parts of the humid tropics of Africa is worth mentioning (Ugwu & Ukpabi, 2002). The crop is however produced under conditions of little or no fertilizer application which eventually results in a reduction in yield and soil fertility (Cadavid, 1988). In Nigeria, the crop has been identified as an important food security crop and a major contributor to the rural economy of Nigerians (Salami & Sangoyomi, 2013).

Cassava is grown globally serving as a basic staple for many tropical and sub-tropical inhabitants (Ayoola & Makinde, 2007). Africa contributes to a greater percentage (57%) of the global production area which stood at 18 million in 2000(Ayoola & Makinde, 2007) with a corresponding 118. 5 million tonnes production level. Africa is ahead of Asia, Latin America and the Carribean which contributed 18% and 16% respectively Cassava production levels continues to soar in response to increasing demand due to population growth. Per FAO/IFAD two important forces explain this dramatic increase in production levels. These includes the increasing demand of cassava due to rapid population growth coupled with increasing poverty and secondly as a result of genetic research which has led to the use of sound agronomic practices and the cultivation of high yielding cassava varieties (FAO & IFAD, 2005).

In 2012, FAO reported a 60% increase in production levels and estimated that more than 280 million tonnes of cassava were produced. This surge in production level was attributed to expansion of area under cultivation rather than sustainable methods as world area under cultivation also increased from 13.6 million to 19.6 million. In sub-Saharan Africa, increase in production which was estimated at 140.9m tonnes which was more than halve of the global production was recorded in 2010 (FAO, 2013). Africa contributes to a greater proportion of cassava production mostly through increase in area under cultivation which is rather unsustainable. In 1997, IITA reported Nigeria as the leading producer of cassava in Africa with 35 % of all the cassava produced in Africa. Other countries such as the Democratic Republic of Congo, Ghana and Mozambique contributed 19.6%, 8%, 7% and 6% respectively of the total cassava produced in Africa (ITTA, 1990).

Ghana was ranked 6th on the world cassava production ranking in 2005 (Angelucci, 2012). Recently Ghana has a world share of 6.2% of total cassava produced globally and is ranked 5th among the top 10 cassava producing countries in the world (Factfish, 2017). Ghanaians produce quite substantial amount of cassava annually, with production over the last decade reaching 10million metric tonnes (Angelucci, 2012). Cassava contributes 22% of

Ghana's GDP and remains the second largest crop after maize in terms of area under cultivation (MOFA, 2016). Cassava remains the most important crop in Ghana in terms of production levels with production levels peaked at 13, 504, 00 metric tonnes.

Cassava production in Ghana is on both subsistence and commercial levels. However it has been dominated by smallholders in Ghana (FAO & IFAD, 2005). Recently there has been a shift from production for home consumption to commercial production under which cassava is produced for urban consumers, livestock feed and for industrial uses. This according to FAO & IFAD (2005) can be described as the cassava transformation. Under such transformation, methods which aim at increasing yield such as the cultivation of high yielding varieties and the use of improved processing technology is employed. However, in all of these intensification and transformation, little or nothing at all is done in terms of soil fertility management. Increase in yield will correspond to increase in depletion of soil nutrients which if not replaced can have adverse consequences on the sustainability of cassava production.

The Effect of Soil Fertility On the Nutritional Value Of Cassava

Cassava is usually regarded as a low – nutrient crop as it usually serves as food for the poor (FAO, 2013). The crop provides food for the low-income households in various forms which are relatively cheaper than most grains (Nweke, 2004). Cassava has been tagged as a low nutrient crop probably due to the low protein content in the storage root, the chief edible product. (Talsma et al., 2016). Most at times, the crop is valued nutritionally only for its high-energy source. However, cassava has a considerable number of important nutrients and minerals one can think of. Cassava is rich in minerals like calcium, phosphorus, potassium, sodium and magnesium (Montagnac et al., 2009). The crop is also a good source of vitamin C (Ascorbic acid) ranging between 15 – 45 mg/100g of the edible part.

The nutritional value of cassava depends on specific plant part (root or leaf) under consideration. While cassava tubers have low protein content (100 g – 1. 36 g in raw cassava tuber). (Montagnac et al., 2009; Elise F Talsma et al., 2016). It has been reported that the leaves are a rich source of protein (Aregheore, 2012).

Aside these, other factors such as variety, the age of the plant at harvest, and environmental condition also plays a significant role affecting the nutritional value of cassava (Montagnac et al., 2009). Nutrient concentrations in the plant are also influenced to a large extent by soil fertility and the fertilisation practices that are undertaken by farmers (CIAT, 2011) This is of much significance to this study as it tries to understudy the effect of fertilizer treatment on nutrient absorption, specifical, potassium in cassava and compare the levels of potassium and other important minerals in cassava grown under no or limited soil management.

Soil fertility or nutritional status of soils is very important and influence the levels of a nutrient in a crop. According to CIAT (2011), the nutrient status of the soil is proportional to the concentration of nutrients in all tissues of plants that grow on it. This makes the fertility status of soils so important and a factor that cannot be overlooked in dealing with the nutritional value of food crops. It also presents an avenue for modifying the nutritional value of certain important staples like cassava in a more convenient, simple and sustainable manner.

Again this perhaps can explain the reason why cassava (tuber) is usually of a low nutritional value, as the crop is mostly grown on marginalised soils (Adenle et al., 2012) and under poor soil management. Cassava production is dominated by poor farm households (Adenle et al., 2012; FAO & IFAD, 2005). These farmers cannot afford the cost of inorganic fertilizers and other soil amendments to increase or maintain the nutritional status of their soils. The nutritional value of such crops, therefore, depends solely on the inherent fertility status of the soils on which it is grown. The worse of it all is that, even though cassava is a heavy feeder mostly of potassium, and grown under no soil management, it is continually cropped for many years leading to depletion or reduction in the fertility of the soil. The loss in fertility status is easily determined as yield drops considerably, however, reduction in nutritional value of the crop remains unnoticed. Soil fertility management and fertilizer application in cassava cultivation are very important if not for the sake of yield, but for a higher nutritional value of the crop.

Cassava Nutrition

Cassava is one of the important staples grown mostly in the humid tropics. The crop does well on a wide range of soils ranging from poor to acidic soils and thus, farmers usually pay less attention to proper soil management. Cassava production in Africa is by smallholder subsistence farmers who use little or no fertilizer at all (Fermont et al., 2010). The crop's ability to thrive in poor and acidic soils has even given rise to the misconception that the plant does not respond to fertilisation and hence does not need fertilizer at all (Howeler, Lutaladio, & Thomas, 2013). In parts of Africa, like the East, cassava is even thought of as a crop with the ability to restore soil fertility (Fermont et al., 2010).

Cassava production in Ghana is done in similar conditions under no proper soil management and good fertilizer regimes. Farmers threat fertilizer application in cassava as a *taboo* and attribute several reasons such as high prices of chemical fertilizer and a reduction in tuber quality and storage (Boateng, 2015). However, the crop is very responsive to fertilisation and this is of much importance to this study. Several fertilizer trials have shown that cassava responds highly to fertilisation even though the crop can do well under poor soil management systems. FAO trials in 1999 indicated cassava responds highly to fertilizer application which commensurates with a yield increase of 49% in West Africa and up to 110% in Latin America. Later in 2006, (Vanlauwe & Giller, 2006) reported a yield increase of 12 to 25t ha^{-1}with an application of a moderate amount of NPK and a yield increase of 40t ha^{-1} with an application of a higher rate of NPK. In both cases, cassava's responsiveness to fertilizer application was largely measured in terms of its yield, as what most fertilizer trials seek to achieve ignoring the effects of such treatments on the nutritional status of the harvested roots.

Cassava's response to fertilizer application as indicated by many trials is also coupled with a high nutrient requirement usually under intensive systems. Among tropical crops, it is a common knowledge that cassava has a higher demand for essential nutrients such as Nitrogen, Phosphorus and Potassium, the largest being Potassium (Howeler, 1981). Cassava is a heavy K feeder, and per Howeler et al. (2013), a root yield of 15t ha^{-1} removes about 30 kg N, 20 kg K and 3.5 kg P. The crop, therefore, requires a balanced fertilisation of NPK to produce high yields. Given the crops nutrient requirement and its ability to remove large volumes of nutrients from the soil, intensive cultivation without good soil fertility management is a threat to sustainable agriculture. Surprisingly this is what goes on in Ghana and Africa at large as farmers don't accept fertilizer application in cassava production.

Extensive fertilizer trials have led to many fertilizer recommendations to maximise yield. FAO (2013) recommended an initial application of equal amounts of N, P_2O_5 and K_2O at a rate of 500 kg $ha^{-1}$to 800 kg ha^{-1}in the form of a compound fertilizer (15:15:15). However, fertilizer application should not only seek to increase yield but should also maintain soil fertility for a sustainable production of crops. In line with this, Howeler et al., (2013) prescribed an annual per hectare application estimated at 50 kg – 100 kg N, 65 kg – 80 kg K and 10 kg – 25 kg P. This fertilizer recommendation has two cornerstones that must be considered; the soils native fertility and desired yield levels. For a good response to fertilizer application, the soils inherent fertility is of much importance and must be looked at. Soils in the humid tropics of Africa have low fertility and have a shortfall in macro nutrients such as N, P and K (Yawson et al., 2011). Yawson et al. (2011) reported a low K status of tropical soils and attributed this to the origin of the soil, high rainfall and elevated temperatures. This possibly explains accelerated weathering which releases nutrients from rocks which are eventually leached out of the soil system. (Yost, 2006). Tropical soils, therefore, tend to have high Al and Ca content but have low K concentrations (Towett et al., 2015).

In Ghana, application of K fertilizers is of utmost importance. A significant number of Ghanaian farmers are into root and tuber production which are noted for depleting the soil of its K content (Yawson et al., 2011). Potassium fertilizer requirement, however,differs with the soil type. Per Yawson et al. (2011) forest soils will require frequent and split application since they have a lower capacity to maintain long term supply of Potassium. On the contrary, savanna soils need less frequent but higher doses of K fertilizer to maintain its nutrient pool and provide plants with their needed nutritional requirement.

Cassava Biofortification

Morbidity and mortality because of non-communicable diseases has been a global challenge. Research has established that, the human body requires a lot of minerals (22) for proper functioning (White & Broadley, 2005). Deficiency in such minerals, otherwise known as hidden hunger, predisposes the body to non- communicable diseases. As the bulk of these minerals have dietary sources, a prudent solution to such nutrient deficiency has been attempts to increase the mineral concentration in the edible portions of the crop. Many traditional interventions to end mineral malnutrition such as supplementation, food fortification and dietary variation has been unsuccessful (He & MacGregor, 2008). However, one method that seems to be a valuable tool for reducing mineral malnutrition is biofortification. Lots of research have been committed to this and far advances have been made.

White (2005) defines biofortification as the process of increasing bioavailable concentration of essential elements in edible portions of the crop through agronomic interventions or genetic selection. Biofortification is also defined as the indirect increase in the content of an essential vitamin, mineral or other substance in crops to support nutritional health goals (Garcia-Casal, Peña-Rosas, Giyose, 2016). The two definitions are similar and present the sole aim of biofortification which is raising the levels of essential nutrients in crops. Garcia et al. (2016) enlists three agronomic methods of biofortification which includes the application of fertilizer to the soil or the leaves of crops, conventional or traditional plant breeding and genetic engineering. Amongst the methods of biofortification mentioned earlier, fertilizer application seems to be the simplest and faster method of biofortification that can be practised by farmers. It is valid to argue that the soil has adequate amounts of nutrients, especially K, and even when the soil is perceived to be marginal, has sufficient concentrations of minerals. However, not all is available to support the heavy demand of crops that grows on it (White & Broadley, 2005). Soil fertility management is very crucial and an important tool for biofortification of crops especially in Africa where most of the soils have been rendered infertile. Welch and Graham (2002) found a relationship between nutrient levels of crops and fertility status of soils they grow upon. They indicated that, edible parts of most crops grow on soil lacking mineral elements have low mineral concentrations of minerals in them. Improving the fertility status of such soils would increase nutritional value of crops grown on them, most especially in the case of some essential mineral elements such as K and Na which occurs solely as inorganic ions in plant – soil systems.

Fertilization becomes the most readily available method of fortifying crops with mineral elements such as potassium and sodium. However, biofortification through agronomic method is faced with several challenges, the heart of this is the cost of fertilizer in both economic and environmental terms (Welch & Graham, 2004). Other limitations of fertilizer application as method of biofortification as proposed by Garcia et al (2016) includes the need for a continual application of fertilizer and its adverse effect on soil health as well as the physiological differences between plants that could affect effective absorption and the geographic variation of soil micro nutrient deficiencies. Again, fertilizer application could be greatly affected by certain uncontrollable factors such as weather conditions. Several challenges and shortfalls of the agronomic method of biofortification as mentioned earlier and others have made biofortification through breeding of crops with superior ability such as high yielding and the ability to accumulate minerals from poor soils gain considerable recognition (White & Broadley, 2005). Biofortification has gained recognition recently because its present an avenue to reach populations where supply of mineral supplements and other fortification activities becomes impossible (WHO, 2016). Several biofortification research studies are currently being undertaken, but the ones of much interest to WHO includes

- Iron biofortification of rice, beans, sweet potato and maize.
- Pro- vitamin A carotenoid – biofortification of sweet potato maize and cassava.
- Amino acid and protein biofortification of sorghum and cassava.

Lots of research has gone into addressing the nutritional constraints of important crops such as cassava. One of such is the Bio Cassava plus program which is the largest coordinated research development and deployment program funded for cassava (Sayre, 2011). Bio cassava plus, is an integrated team of scientists from Africa and North America with an objective to reduce malnutrition among two 250 million people in sub-Saharan Africa who rely on cassava as a stable food and more nutrition (danforthcenter. org). The program focused on the important nutrients such as pro-vitamin A, iron and zinc. Biofortified yellow cassava per Talsma, has an enormous potential to alleviate vitamin A deficiency. He recorded an increase in serum retinol concentration and a large increase in B – carotene concentration in Kenyan children fed to the pro-vitamin A cassava (Elise F Talsma et al., 2016). Zhang et al. (2003) were also successful in increasing amino acid composition in cassava tubers. The story of cassava biofortification isn't a new one. Over the years several researches have been dedicated to this and most of them has been successful. Bio fortified crops such as pro- vitamin A rich orange and sweet potato, yellow cassava and orange maize as well as iron rich beans, pearl millet, and zinc rich rice and wheat were officially released for production in over 30 countries in 2015 and currently tested in more than 50 countries (Birol, Meenakshi, Oparinde, Perez, & Tomlins, 2015). However little or no effort at all is seen in fortifying cassava with Potassium. In view of the immense role of potassium in the diet of humans and animals, it should be given the due attention by plant breeders and researchers.

Cassava has become a target crop for biofortification in most of the projects mentioned earlier and that can be attributed to cassava's wide geographic distribution (Burns et al., 2010). This presents an opportunity to reach remote populations where supplying mineral supplements becomes impossible (WHO, 2016). Serving as food for over 500 million people in Africa on daily basis (Montagnac et al., 2009) and as a dominant staple in arrears where mineral deficiency is widespread, especially in Africa, cassava remains a perfect crop for targeting mineral deficiency in Africa and other parts of the world where mineral deficiency and associated non-communicable diseases constitutes a major health challenge. However, most efforts in increasing the nutritional value of cassava reviewed earlier has been geared towards equally important nutrients such pro- vitamin A, Iron and amino acid ignoring important minerals like potassium. This Could possibly be attributed to the fact that potassium is very abundant in soils(Mouhamad et al., 2016) has several dietary sources.

Most soils truly have a large potassium reserves, but this becomes gradually depleted largely due to crop removal and leaching (Elbaalawy et al., 2016; Zörb et al., 2014). Even though potassium is relatively abundant, crops grown on poor soils could be deficient in K. As cassava is mostly grown on poor soils (Salami & Sangoyomi, 2013) which are mostly depleted due to continuous and intensified cropping, efficient soil management and fertilizer application is key in increasing the levels of K in the crop.

Again, potassium dietary sources are truly numerous. Potassium abounds in vegetables and most fruits (World Health Organization, 2012) and is also common in unrefined foods. This amount of K in such foods is reduced through processing and a diet that constitutes the bulk of such foods and low in fruits and vegetables is often low in potassium (Webster, Dunford, & Neal, 2010). Such fruits and vegetables are scarcely found in Ghanaian diets. On the contrary, most African and Ghanaian diets are high in roots and tubers, mostly cassava and yam (Yawson et al., 2016a). It is therefore likely that the K requirements of most Ghanaians are not met. An effort to fortify cassava tubers with K through fertilization is a step in the right direction especially in these times where coronary and cardiovascular diseases constitutes the major health challenge of most countries and has become a leading cause of death globally (Aburto et al., 2013).

The prevalence of non-communicable diseases is high in the sub-Sahara Africa and this per Adenle (2012), is an indication that people are living on diets deficient in micro elements. Because of poverty, people cannot afford a balance diet and lives entirely on staples of which root tubers constitute the greater percentage. Adenle et al., (2012) then proposed that people in the sub-Saharan Africa need fortified staples at low cost. Their idea was perfect as such staples are less expensive and can be afforded by the poor who mostly cannot afford a balanced diet all the time. The needed K levels required by the body can be obtained from dietary sources without the need for supplementation or from formulated product (Soetan & Olaiya, 2010). Therefore, increasing potassium levels in staples like cassava can help elevate non-communicable diseases such as hypertension which has become a global health problem. Recent data from around the world indicates potassium consumption below WHO recommended levels (70 - 80 mmol day^{-1}). There is therefore the need for proper sensitization to encourage people to increase their intake of foods rich in potassium. Again current studies confirms that reduced potassium intake has been associated with hypertension and cardiovascular diseases but has found appropriate consumption levels to be protective against these conditions (Amine et al., 2002). Potassium levels in staples need to be modified through appropriate means possible, most especially through biofortification.

Potassium Dynamics in Relation to Sustainable Cassava Production

Global population increases exponentially and has been predicted to hit 9.6 billion by 2050 (United Nations, 2015). With such a sharp increase in population growth, global food security remains under a great threat, as farmers need to produce more and more food to feed the ever-increasing populations. Population growth will result in an increased pressure on agricultural sustainability and food security (Fan, 2010). There is the need for a sustainable crop production technique such as proper soil fertility management all over the world, especially in the African continent which per Fan (2010) has a fragile food security and agro ecosystems. As Africa is known as a major contributor to the rapid global population growth (United Nations, 2015) with the region's population projected to increase from 746 million in 2005 to 1.8 million in 2050.

Sub Saharan farmers need to produce more food, feed and fibre to support its growing populations (Benard & Giller, 2006). This puts a lot of stress on small holder farmers who are already faced with challenges such as limited resources, credit shortage, lack of economies of scale and high price volatility (United Nations, 2002). Such pressure is likely to push small holder farmers into the use of unsustainable farming methods and agricultural practices such as intensified production under no proper fertility management. Achieving sustainable food security in sub-Saharan Africa would need special attention (Fan, 2010). However, the plight of sub Saharan Africa is worsened by climate change which puts additional pressure on food security.

The role of cassava in achieving food security in the event of rapid population growth is worth mentioning as the crop is a calorie provider for more than 200 million sub- Saharan Africans (Manyong, 2000). Cassava has been identified as a food security crop several years back and remains an important staple in recent times. Cassava production has seen an upward adjustment in recent times. Such an increase in production has been attributed to intensified production and expansion of the area under cultivation. However, posterity reasons demand that intensification needs to be sustainable. Sustainable intensification implies producing more food from the same area under cultivation while reducing the environmental impacts (Godfray et al., 2012).

Sustainable cassava production, which is at the heart of this discussion will thereby imply producing cassava continuously without depleting the soil of its nutrient reserves, especially K. Cassava relies largely on potassium to produce calories. Sustainable production would hereby depend on the ability of cassava soils to supply K for over a long period. The soils ability to supply potassium for a long time is referred to as the Potential Buffering Capacity of potassium, (PBCK) otherwise referred to as the soils supplying power of Potassium (Yawson et al., 2011). For a sustainable production of cassava, potassium dynamics is very important as it can influence certain fertility management decisions.

The knowledge of the interaction of the various fractions of soil potassium is key towards soil management and for sustainable production of crops such as cassava (Uddin, Abedin Mian, Islam, Saleque, & Islam, 2012). This depicts the mechanism of potassium release in the soil which is defined as the replenishment of the readily available K removed either by crops or by chemical extraction (Uddin et al., 2012). As cassava extracts huge volumes of

K from the soil the interaction of the various K forms is a key factor for proper soil management of K under intensive cultivation.

CHAPTER THREE

MATERIALS AND METHODS

Experimental Site

The experimental site was the University of Cape Coast Teaching and Research farm at Cape Coast, (lat:5^{o} 7’55. 24’N and longitude 1^{o} 17’30’00W). Cape Coast is a humid area with a mean monthly relative humidity varying between 85% and 99%. The area has a double maximum rainfall between 750 mm – 1000 mm. The vegetation consists of shrubs and grasses with scattered trees.

Experimental Design and Treatments

The experimental design was a randomized complete block design (RCBD). It involved two treatments: fertilizer and genotype. Blocking was necessary to minimize the variability within the treatments and maximize the variability among the blocks to help assess the effect of different levels of fertilizer treatment on factors of interest and minimize the differences in fertility status of the field which could serve as a source of variability.

There were three fertilizer rates and two genotypes. Each replication had six plots measuring 3 m x 5 m. Plots were separated by a distance of 2 m. The fertilizer rates were T1 or no fertilizer, T_2 which consisted of N. P. K (15:15:15) applied at the balanced rate of 68 kg ha^{-1} N, 68 kg ha^{-1} P and 68 kg ha^{-1} K and T_3 which consisted of NPK applied at the same rate as in T2 plus KCl applied at a rate of 68 kg ha^{-1} K. This was done in an attempt to double the K supplied by T2 to measure how increased K application will affect K absorption in cassava and its concentrations in cassava tuber.

Land Preparation

The field was ploughed prior to planting. It was then lined and pegged to help lay out the experiment.

Experimental layout

The experiment was laid out using the Randomized Complete Block Design. There were four blocks per the entire field. Each block had six plots measuring 3 m x 5 m.

Planting

Cassava stems were cut at a length of 25 cm long with about 5 nodes available. This was planted at a spacing of 1m x 1m resulting in a plant population of 15 plants per plot and 360 plants per the entire field. The stem cuttings were planted at 45^0 to the soil surface with two thirds of the cuttings buried in the soil. Planting was done on 23rdJune 2016. Refilling was done four weeks after planting to maintain the plant population. Two varieties that were planted include the Cape Vars variety and the Botan variety, high yielding varieties developed at the University of Cape Coast.

Fertilizer Application

Fertilizer treatments were applied sixty (60) days after planting. NPK (15:15:15) and KCl were applied at a recommended rate of 68 kg ha^{-1} N, 68 kg ha^{-1} P and 68 kg ha^{-1} K. Fertilizer treatments applied were T1= no fertilizer (control), T2= NP.K (15:15:15) and T3 = NPK + KCl . The fertilizer was applied using the band placement method. It was applied in short bands 20 cm long, dug with a hoe to a depth of 4 cm deep and 5 cm away from the cassava plants. After application, the fertilizer was covered with soil to prevent volatilization and nutrient loss due to run-off. The soil was watered to help dissolve the fertilizer.

Weed Control

Weeding was done at regular intervals with a hoe and cutlass to minimize the competition of weeds for resources.

Field Survey

Ninety cassava farms were selected from three cassava growing districts, namely, Cape Coast north (CN), Hemang - Lower - Denkyira (HLD), and Komenda Edina Eguaafo Abrem districts (KEEA). These districts span across the coastal savanna and deciduous forest agroecological zones of Ghana (Ministry of Environment, 2011). Farms were selected purposively in consultation with the agricultural extension agents in whose respective operational areas farmers were located. Thirty farms were selected from each district. The criteria for selection included farm size of at least 0.5 acre and cassava which is under mono cropping systems. Basic information about the soil fertility management method employed by cassava farmers in the study area was accessed through direct interviews. 80 farmers were interviewed for the study. Some information elicited by the interviews include farmers' knowledge of the nutrient status of their soils and the kind of soil management practices employed by farmers. Responses were subjected to statistical analysis using the Statistical Package for Social Sciences (SPSS) version 20. Output was presented as frequencies and means. Composite soil samples were taken from the selected farms prior or at the initial stages of planting of cassava for analysis. Geographic locations of the farms were recorded using a GPS. Cassava tuber samples where later collected from selected farms at harvest for K analysis to determine the amount of potassium in cassava roots and peels.

Laboratory Analysis of Soils

Collection and analysis of Soil Samples

For the experimental site, soil samples were taken randomly at a depth of 0 – 15 and 15 – 30 cm at different spots across the field prior to planting. Similarly, soil sampling was done at harvest to determine the K content of the soils. Again, composite soil samples taken at a depth of 0 – 30 cm from the selected farms were sent to the laboratory for analysis of soil properties. Samples were air dried, crushed and sieved through a 2 mm mesh to obtain the fine earth fraction. Soil samples were analysed for pH, organic carbon, exchangeable K, Ca, Mg and Efective Cation Exchange Capacity (ECEC).

Determination of pH

The soil samples were air dried, grinded and sieved through a 2 mm sieve. Ten (10 g) of the air-dried soil samples were weighed into plastic bottles with screw cap. Twenty-five (25 ml) of distilled water was added and agitated on a mechanical shaker for 15mins. The pH meter was calibrated using a buffer solution of pH = 7. The meter was then adjusted with buffer solutions of known pH (4.0 – 9.2). The Electrode of the pH meter was then inserted into the soil-water suspension and the pH readings recorded (Rowel, 1994).

Determination of Organic Carbon

Total organic carbon in soil sample from the experimental field was determined by the (Walkley & Black, 1934) method. The carbon in the soil was oxidized with 1.0 M potassium dichromate. An acidified 1.0 M ferrous ammonium sulphate was then titrated with unreduced dichromate. The percentage organic carbon was then multiplied by 1. 724 (Van Bemmelen factor).

Determination of Exchangeable K (NH_4OAc-extraction)

Two grams (2 g) of the prepared soil sample is weighed into an extraction flask. 20 ml of extracting solution (1M NH_4OAc at pH = 7) was added to the soil in the extraction flask. The mixture is shaken for 5 minutes in a horizontal shaker at 200 revolutions per minute. The suspension was then filtered through a Whatman no. 2 filter paper. The working standards and the filtrates were aspirated in a flame photometer. The concentrations of the sample solutions were extrapolated from the standard curve using their emissions (Warncke & Brown, 1988).

Determination of Non-Exchangeable K

Two grams (2 g) of the prepared soil sample was weighed into a 100-ml volumetric flask. About 20 ml of the extracting solution (1M HNO_3) was added and boiled at 113 ^{o}C on a hot plate for 25 minutes. The solution was allowed to cool and then filtered through a Whatman filter paper. The soil was then leached with 20 ml of 0.1 M HNO_3 and made up to the mark. The potassium content of filtrate was determined by flame photometry.

Data Collection (Experimental Field)

Parameters that were measured at harvest include data on the tuberous roots and the K content of the cassava tuber.

Number of storage root

The number of storage roots per each of the plants harvested was countered. The number of storage root was given by:

Average number of roots per plant = number of roots harvested ÷ number of plants harvested.

Weight of fresh tuber

Fresh weight of tubers from four randomly selected plants was measured with a top pan balance for each plot. Fresh weight per area harvested was extrapolated to yield in tons per hectare as;

$$t/ha = \frac{10000\ m2\ x\ wt\ of\ root\ harvested(kg)}{area\ harvested\ (m2)}$$

Analysis of Cassava Root Samples

Preparation of food samples for analysis

Four cassava plants were randomly selected from the farmer’s field. Two kilograms (2 kg) of fresh tuber was taken from each farm and were sent to the laboratory for analysis. Tubers were washed and sliced into smaller units for drying at 80 ^{0}C in an oven. Cassava peels of the samples were also washed cut into convenient sizes and dried alongside the food samples. The dried samples were then homogenized into powdery form and stored in a refrigerator prior to analysis.

Determination of potassium in food sample

The oven dried food samples were digested with a digestion mixture comprising of 350 mL of hydrogen peroxide, 0.42 g of selenium powder, 14 g Lithium Sulphate and 420 mL sulphuric acid 0.2 g of the prepared food sample was weighed into a 100 mL Kjeldahl flask and 4.4 mL of the mixed digestion reagent was added and the samples digested at 360 ^{o}C for two hours. Blank digestions (digestion of the digestion mixture without sample) were carried out in the same way. After the digestion, the digests were transferred quantitatively into 100 mL volumetric flasks and made up to volume.

Potassium concentrations were determined by flame photometry (Allen, Grimshaw, Parkinson, & Quarmby, 1974).

Statistical analysis

Data were analysed with GenStat statistical package (version 12) using analysis of variance (ANOVA). Treatment means were compared with the LSD method at 5 % probability.

CHAPTER FOUR

RESULTS

Physical and chemical properties of soil at experimental site

The physical and chemical properties of the experimental field are presented in Table 3. Soil parameters were measured in the surface (0-15 cm) and sub-surface (15-30 cm) soil. The soil at the experimental site was loamy sand, slightly acidic with a pH of 6.4. Again, the soil had low levels of total nitrogen and basic cations. The Soil had an organic carbon content of 2.77% and an ECEC of 3.51 cmol$_c$ kg^{-1}.

Table 3:*Physical and chemical properties of soil (experimental field)*

Soil parameters	**0 – 15 cm**	**15 – 30 cm**
% clay	10.321	-
% sand	80.344	-
% silt	9.343	-
Texture	Loamy sand	
Bulk density (g cm^{-1})	1.46	
% Organic carbon	0.69	0.37
Total Nitrogen	0.07	0.04
Exchangeable K(cmol$_c$ kg^{-1})	0.26	0.39
pH	6.47	-
Ca (cmol$_c$ kg^{-1})	1.89	2.72
Mg (cmol$_c$ kg^{-1})	0.63	0.64
Na (cmol$_c$ kg^{-1})	0.73	0.55
CEC (cmol$_c$ kg^{-1})	3.51	4.32
Bulk density (g cm^{-3})	1.46	-

The bulk density of the soil was 1.46 g cm^{-3} which is satisfactory for sandy soils. The soil had adequate levels of bases but saturated with Ca (1.89 $cmol_c$ kg^{-1}). The Soil properties are relatively better at 0 - 15 cm than at 15 – 30 cm.

K absorption and yield of cassava under fertilized conditions

Effect of cassava genotype on K concentration in cassava tuber.

Summary statistics of varietal ability to accumulate K is presented in Table 4. The mean K content of Cassava tuber because of varietal effect was higher in the tuber than in the peel for all cassava varieties or genotypes. There was a minimal variability in %K content of Cape Vars as compared to Botan.

Table 4: *Summary Statistics for Cassava Varieties and the %K in tuber*

	Tuber		**Peel**	
	Cape Vars	**Botan**	**Cape Vars**	**Botan**
Mean	1.059	0.974	1.015	0.918
Min	0.687	0.728	0.801	0.832
Max	1.259	1.282	1.245	1.076
SD	0.167	0.141	0.111	0.075
CV (%)	15.77	14.5	10.90	8.24

Source: field data

SD = Standard Deviation CV= Coefficient of variation

An analysis of variance (ANOVA) was further conducted to determine if there existed differences in the mean %K content of tuber and peel as affected by the respective genotypes. The result has been presented in Table 5. Potassium content of tuber did not differ significantly ($P > 0.005$) among the two varieties. Variety 1 (Cape Vars) however accumulated a lot of K (1.059%) than variety 2 (Botan) which accumulated (0.974 %). Differences between K content of cassava peels for the two varieties were however significant ($P \leq 0.05$). Variety 1(Cape Vars) had more K in the peel (1.01 %) than variety 2 (Botan) which had 0.92% K in the peels.

Table 5: Effect of variety on mean K content of cassava tuber and peel

Treatments **Variety** **(n = 24)**	**% K content of tuber**	**% K content of peel**
(Cape Vars)	1.059	1.015
(Botan)	0.974	0.918
P (0. 05)	0.053	0.028
LSD (0. 05)	0.0858	0.095

Source: field data

Effect of fertilizer treatment on K concentration in cassava tuber.

Cassava's ability to accumulate K in the root tuber was observed in two cassava genotypes under different fertilizer treatments. Aside this the yield and yield components of cassava were also evaluated.

The mean %K of cassava tuber is high under a recommended NPK levels and increases on additional KCl application. In all cases of fertilizer treatments, the mean %K content is higher in the tuber than in the peel (Table 6)

Table 6: *Summary Statistics for Effect of fertilizer treatment on %K levels in cassava tuber and peel*

	Tuber			Peel		
%K	**Control**	**NPK**	**NPK + KCl**	**Control**	**NPK**	**NPK + KCl**
Mean	0.863	1.058	1.129	0.931	0.975	0.994
Min	0.687	0.859	1.002	0.801	0.846	0.843
Max	1.042	1.259	1.282	1.071	1.245	1.076
SD	0.113	0.119	0.105	0.099	0.135	0.076
CV (%)	13.12	11.21	9.306	10.67	13.84	7.72

Source: field data

Min: minimum CV: coefficient of variation

Max: maximum SD: standard deviation

Analysis of Variance for the Means of % K in Tuber and Peels

The mean K values of cassava tuber and peel as affected by fertilizer treatments are presented in Table 7. Potassium content of cassava tuber was greatly affected by fertilizer treatments as differences were highly significant ($P \leq 0.05$). Plants that received additional K in the form of KCl accumulated more potassium (1.129 %) than T2 and the control. Fertilizer treatments did not influence K content of cassava peels that much as differences were not significant. ($P > 0.05$). Plants grown under T3 accumulated more K in the peels (0.99 %) than the others.

Table 7*: Table of means for effect of fertilizer treatment on K content of cassava tuber and peel*

Treatments	% K content of tuber	% K content of peel
(control)	0.863	0.931
(NPK)	1.058	0.975
(NPK + KCl)	1.129	0.994
LSD (0. 05)	0.1051	0.104

Source: field data

K content of cassava under variety*fertilizer combinations

Mean K values due to variety and fertilizer interaction is presented in Table 8. Potassium content of cassava tuber was not much affected by fertilizer-variety combinations as differences were not significant ($P > 0.05$). However, the V1T3 was the best combination as it recorded the highest K content (1.15%) in the cassava tuber. Fertilizer variety combinations did not affect Peel K content so much. Differences were not significant at ($P > 0.05$). V1T2 was the best combination as it resulted in the highest K content (1.05%) in the peels.

Table 8*: Effect of Variety-Fertilizer interaction on K content of cassava tuber and peel*

Treatments Variety – fertilizer (n = 24)	% K content of tuber	% K content of peel
Cape Vars (control)	0.881	0.960
Cape Vars (NPK)	1.137	1.052
Cape Vars (NPK+KCl)	1.158	1.034
Botan (control)	0.844	0.903
Botan (NPK)	0.979	0.897
Botan (NPK+KCl)	1.099	0.954
P	0.438	0.590
LSD (0. 05)	0.148	0.147

Source: field data

Post Analysis of soil of experimental field for exchangeable K

Soil samples from the experimental field were analysed for exchangeable K after crops were harvested from the field. Composite samples were picked from all plots (24) and analysed for exchangeable K. The mean K content of the soils was grouped according to the fertilizer treatments applied. (Table 9). Differences were observed in the exchangeable K content of the field after the experiment. K content of the soil was variable among the plots, especially in the control plots and can be attributed to site heterogeneity. Exchangeable K increased in all plots where fertilizer treatment was applied except in the control.

Table 9: *Post-harvest Soil exchangeable K content of the experimental field*

Plot	K (cmol$_c$ kg^{-1}) Pre- experiment	K (cmol$_c$ kg^{-1}) Post experiment	SD	CV (%)
Control	0. 261	0. 196	0. 112	50. 0
NPK plots	0. 261	0. 287	0. 140	48. 8
NPK + KCl	0. 261	0. 331	0. 106	32. 1

Source: field data

It is therefore necessary to determine the relationships between treatments on the K content of the soil after the experiment. An analysis of variance (ANOVA) was conducted on the mean K contents of the plots determined after the experiment. This is shown in Table 10.

Table 10*: Table of means for K (exchangeable) content of soil after experiment*

Treatment		Mean K-levels of plots cmol$_c$ kg^{-1}
Fertilizer		
Control	(n = 8)	0. 196
NPK	(n = 8)	0.287
NPK + KCl	(n = 8)	0.331
P		0.02*
LSD (0. 05)		0.09

Source: field data * denotes significance at 0.05

Significant differences ($p \leq 0.05$) were observed in the K content of plots that received NPK & KCl and the control. However, differences between the K content of plots that received NPK+KCL and NPK only was insignificant. ($p > 0.05$).

Genotype and yield component

The performance of Cape Vars and Botan with respect to yield and other yield components are presented in Table 11. All the yield components were not significantly different between the two genotypes.

Number of storage roots (tubers) was the same between the two varieties. Both Cape Vars and Botan developed 9 tubers respectively.

The length of storage roots were almost the same with Botan developing slightly longer storage roots (26.6 cm) than Cape Vars (25.7cm) The diameter of storage root did not differ much between the two varieties as differences were highly insignificant ($P > 0.05$). Cape Vars however developed much bigger tubers(50.8 mm) than Botan (44.9 mm).

Differences in yield between the two varieties were very minimal and not significant at ($P > 0.05$). Botan produced a yield of 16.3 t ha^{-1} which was higher than Cape Vars (14.5 t ha^{-1}).

Table 11*: Table of means for effect of genotype on yield components*

Treatments	Yield components				
Variety	Average number of storage roots	Length of storage root (cm)	Diameter of storage root (mm)	Fresh tuber (kg)	Yield (t ha^{-1})
Cape Vars	9	25. 73	50. 8	21. 8	14.5
Botan	9	26. 60	44. 9	24. 8	16.3
LSD (0. 05)	1. 698	2. 754	7. 77	7. 74	4.27

Source: field data

The effect of fertilizer treatment on yield components

The effect of fertilizer treatment on yield parameters is presented in Table 12. Fertilizer treatments insignificantly ($P > 0.05$) affected the development of storage roots. Plants grown under T2 developed the greatest number of tuberous roots (10) which was higher than that developed by plants grown under the control treatment and T3. Fertilizer treatment did not show much effect on the diameter of storage roots of cassava varieties. T3 (NPK + KCl) produced plants with the biggest root diameter of 51. 5mm. T1 and T2 plants produced plants with almost the same root diameter.

Fertilizer treatment on yield was significant ($P = 0.05$) with T3 recording the highest yield of (20.5 tha^{-1}), T2 (NPK) produced a higher yield than T1 (control).

Table 12*: Table of means for effect of fertilizer alone on yield parameters*

Treatment	**Yield components**				
Fertilizer	Number of storage roots	Length of storage root (cm)	Diameter of storage root (mm)	Fresh wt-tuber (kg)	Yield (t ha^{-1})
Control	8	25.14	45.5	23.1	10.4
NPK	10	26.13	46.6	18.2	15.2
NPK+ KCl	8	27.23	51.5	28.5	20.5
P	0. 092	0.87	0.381	0.103	0.003
LSD (0. 05)	2. 080	3.374	9.52	9.48	1.654

Source: field data

LSD: Least Significant difference

Effect of variety*fertilizer interactions on yield components

The effect of variety-fertilizer interactions on yield and its components are presented in Table 13. Variety-fertilizer interaction was also insignificant ($P > 0.05$) in the development of storage roots by cassava. But here plants grown under T2 developed more tuberous roots (10) than the rest. Fertilizer-variety interaction did not affect root diameter that much, as differences were highly insignificant. ($P > 0.05$). However, V1T3 (Cape Vars and treatment 3) developed the biggest root tuber. (54.2 mm). Yield was not much affected by fertilizer and variety combinations as differences were smaller and insignificant ($P > 0.05$).

Table 13*: Table of means for variety- fertilizer interactions on yield*

Treatment	Yield components				
Variety*fertilizer	Number of storage roots	Length of storage root (cm)	Diameter of storage root (mm)	Fresh wt-tuber (kg)	Yield (t ha^{-1})
V1T1	8	25.23	46.4	21.8	11.5
V1T2	10	24.43	51.8	21.5	14.4
V1T3	8	27.55	54.2	22.3	17.5
V2T1	8	25.06	44.7	24.5	9.4
V2T2	10	27.83	41.3	15.0	16.0
V2T3	8	26.90	48.8	34.8	23.5
P	0. 959	0.98	0.62	0.14	0.29
LSD	2. 941	4.771	13.46	13.41	7.39

Source: field data

T1 = Control T2 = NPK T3 = NPK+ KCl

V1= Cape Vars V2= Botan

Soil Chemical Properties of Farmers Field

Chemical properties observed in the soils of farmers' fields are presented in Table 14 Soil chemical properties of much relevance to the study included the soil exchangeable K, pH, exchangeable bases and ECEC. The pH of the soils ranged from 4.2 to 7.5. This implies that most soils were slightly acidic with few of them in the neutral range.

From Table 14 ECEC of soils investigated ranged from 9.7 – 1.18 cmol kg^{-1} with a mean CEC of 4.7 cmol kg^{-1}. Soils also had appreciable amounts of Ca, Mg, Na and K with a mean of 3.2, 0.85, 0.43, and 0.22 cmol kg^{-1} respectively. It's obvious that soils have a high Ca content relative to the other bases however low in exchangeable K. Sodium (Na) and K content of the soils also differed significantly ($P \leq 0.05$) among the three districts.

Table 14*: Chemical properties of soils in farmers' fields*

District	**pH**	**Ca** **cmol kg^{-1}**	**Mg** **cmol kg^{-1}**	**Na** **cmol kg^{-1}**	**K** **cmol kg^{-1}**	**ECEC cmol kg^{-1}**
CN	5.7	3.06	0.85	0. 32	0.21	4.43
HLD	5.8	3.72	0.84	0. 46	0.17	4.13
KEEA	6.0	2.62	0.91	0. 53	0.30	4.4
Mean	5.8	3.2	0.86	0. 43	0.22	4.7
Range	7.5-4.2	7.4 – 1.11	2.38 - 0.15	0.95 - 0.17	0.83 - 0.06	9.7-1.18
LSD	0.31	1.40	0.29	0. 09	0.07	1.5
P(0. 05)	0.11	0.29	0.88	<. 0001*	0.003*	0.47
Cv (%)	9.7	80.2	62.8	39. 8	61.2	59

Source: field Survey * denotes significance at 0.05

CN : Cape Coast North

HLD : Heman – lower – Denkyira

KEEA : Komenda – Edina – Eguafo - Abriem

Evaluation of K- status of Soils across three Districts

For a better understanding of the potassium status of soils investigated, the soils were tested for exchangeable and non-exchangeable forms. This is presented in Figure 2. Figure 2 depicts that most soils studied had low levels of exchangeable K relative to the non-exchangeable K. Soil non-exchangeable K peaked at 3.05 $\text{cmol}_c\ \text{kg}^{-1}$.

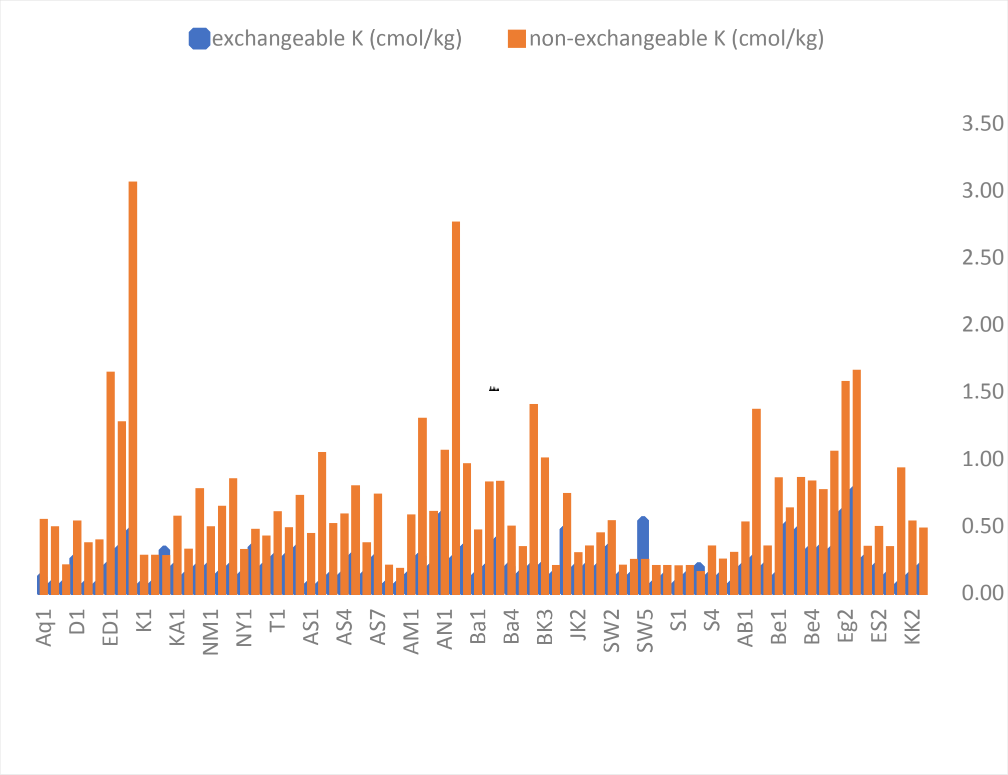

Figure 2: Potassium status of soils in the study area

Source: Field data

Table 15 presents the summary statistics for exchangeable and non-exchangeable K status of unfertilized farmer’s fields. It is evident that soils investigated were low in exchangeable K compared to the non-exchangeable K with a mean of 0.28 cmol (+) kg^{-1} and a range of 0.83 – 0.063 cmol kg^{-1}. Non-exchangeable K on the other hand is relatively higher with a mean K value of 0.56 cmol kg^{-1} K and a range of 3.05 – 0.06 cmol kg^{-1}

Table 15: summary statistics for exchangeable and non-exchangeable K content of farmers fields

Form of soil K	Exchangeable K (cmol kg^{-1})	Non exchangeable K (cmol kg^{-1})
Maximum	0.835	3.0
Minimum	0.063	0.064
Mean	0.288	0.566
Range	0.84 – 0.06	3.0 – 0.06

Source: field Survey

Yield and K Content of Cassava from unfertilized farmers' fields

Descriptive statistics of yield and %K content of cassava tuber in from all farms surveyed are presented in Table 16. Yield ranged from 2.4 t ha^{-1} to 28. 8 ha^{-1}. However, there was a wide variation in yield across the study area. Mean %K of tuber also ranged from 0.40% to 0.89% but values were more consistent.

Table 16*: Descriptive statistics of % K content and yield of cassava from selected unfertilized farms.*

	%K-Tuber	**Yield (t ha^{-1})**
Mean	0. 69	10. 89
Minimum	0. 40	2. 4
Maximum	0. 89	28. 83
SD	0. 10	5. 94
CV (%)	14. 4	54. 6

Source: field Survey

SD: Standard Deviation CV: Coefficient of Variation

Analysis of variance of the mean yield and K content of tuber was conducted to help identify the variation that exists among the three districts. This is presented in Table 17. Mean tuber yield did not differ much ($P > 0.05$) among the three districts studied. The district that recorded the highest tuber yield was the Cape North district with 12.827 t ha^{-1} which was marginally higher than KEEA (11.174 t ha^{-1}) and the HLD district which recorded the lowest yield (10.366 t ha^{-1}). Again, no significant difference ($p > 0.05$) was observed in the mean %K content of cassava tubers from the three districts. However, cassava tubers from the KEEA tend to have more K in the tuber than cassava from the Cape North District. Cassava from KEEA had the least %K in the tuber. No relationship was observed between yield and K content of cassava.

Table 17 *Yield and %K content of cassava from three districts*

DISTRICT	Yield (t ha^{-1})	K-tuber (%)
KEEA	11.174	0.661
HLD	10.366	0.844
CAPE NORTH	12.827	0.701
Mean	11.365	0.740
P	0.452	0.215
LSD (0. 05)	3.891	0.224

Source: field Survey

Extractability of K by three extraction method

As a means of assessing the efficiency of Calcium Chloride ($CaCl_2$), Nitric Acid (HNO_3), and Ammonium Acetate (NH_4OAc) as extraction reagents commonly used in the extraction of soil K, an analysis of varianace

(ANOVA) was performed on the mean K values obtained in the three named districts (Table 18). A significant difference ($p \leq 0.05$) was observed in NH4OAc-K values for all districts However, the mean K for the HNO_3 and NH_4OAc were insignificant ($P > 0.05$).

Table 18*: The Mean-K Values for Extraction Methods in Three Districts*

DISTRICT	**EXTRACTION METHODS**		
	NH_4OAc-K_{ex} ($cmol_c\ kg^{-1}$)	**HNO_3-K_{ex} ($cmol_c\ kg^{-1}$)**	**$CaCl_2$-K_{ex} ($cmol_c\ kg^{-1}$)**
KEEA (n = 30)	0.289	0.739	0.245
HLDD (n = 30)	0.173	0.536	0.231
CN (n=30)	0.196	0.654	0.230
Mean	0.210	0.640	0.235
LSD	0.074	0.279	0.072
P (0. 05)	0 005*	0.333	0.889

Source: field Survey * denotes significance at 0.05

NH_4OAc-K_{ex}**:** Ammonium Acetate exchangeable K

HNO_3-K_{ex}: Nitric acid exchangeable K

$CaCl_2$-K_{ex}: Calcium Chloride exchangeable K

Again, the quantity of exchangeable K extracted by each of the named extractants was correlated with the yield of cassava to find out which amongst them will have the best relationship. The results are presented in Table 19. A positive and significant correlation ($p \leq 0.05$) was observed between $CaCl_2$ – K and Yield (Table 19). However, a negative correlation existed between HNO_3 K and NH_4OAc-K.

Table 19*: A cross correlation of extraction methods and yield*

	CaCl KK_{ex}	**HNO_3 KK_{ex}**	**NH_4OAc-KK_{ex}**
CaCl K_{ex}	-		
HNO_3K_{ex}	0. 4637	-	
NH_4OAc- K_{ex}	0. 3058	0. 3348	-
YIELD (t ha^{-1})	0. 0452*	-0. 0185*	-0. 0203*

Source: field Survey * denotes significance at 0. 05

Production level and fertility management of cassava farmers

Scale of Cassava Production

Table 20 depicts the level of production of cassava in the study area. It is evident that cassava is evolving into a cash crop. About (65%) grows cassava to supplement family calorie source and as an income source. Currently, few people grow cassava on commercial basis. On Table 20, this is represented by only 5% of total responses.

Table 20*: Production level of cassava farmers*

	Frequency	Percent
Purely Commercial	4	5
Subsistence	24	30
Commercial & Subsistence	52	65
Total	80	100

Source: field Survey

Soil Fertility Management among Cassava Farmers

Soil management methods employed by farmers in the study area are presented in Table 21. Most farmers (55%) indicated they don’t put in any soil management intervention as they responded “no” to soil management as any intervention applied to the soil to maintain soil fertility. However, quite a few farmers (45%) also claimed they manage their soils.

Table 21*: Soil Management of Cassava Farms*

	Frequency	Percent
YES	36	45
NO	44	55
TOTAL	80	100

Source: field Survey

Application of Chemical Fertilizer on Cassava Farms

Figure 3 shows the reason behind farmer's reluctance to apply fertilizer in cassava production. Prominent among these reasons is that farmers presume fertilizer application will cause tuber rot in cassava as this accounts for 25% of total responses. Farmers also have a strong believe that fertilizer application in cassava can lead to health problems. This represents 23% of the total responses.

Interestingly, an appreciable number of farmers (18%) are also of the view that cassava does not need to be fertilized. The few farmers who would want to apply fertilizer are prevented by the cost of inorganic fertilizers as they claim fertilizers are expensive. This accounts for 20% of total responses. A section of farmers was of the view that fertilizer application will destroy the soil. This represented 11.5 % of the total responses.

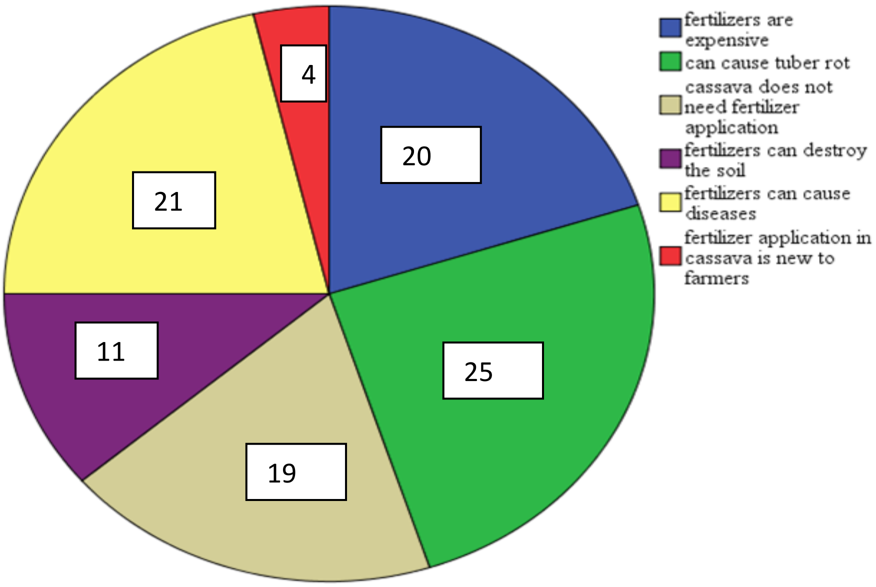

Figure 3*: Why cassava farmers don't apply chemical fertilizer*

Source: field Survey

Farmers Knowledge about nutrient Status of Soil on their farms

Soil tests are very important and presents the only way by which the soil can be accessed and the basis of recommending soil amendments to remedy fertility issues. All respondents indicated they don't have knowledge of the nutrient composition or fertility status of their soils. This is presented in Table 22.

Table 22*: Farmers Knowledge About Fertility Status of Soil*

	Frequency	Percent	Valid Percent
No	80	100	100

Source: field Survey

Why Farmers Don’t Test Their Soils

Soil tests are vital as they give a reflection of the nutrient status of such soils which will warrant any possible soil management intervention. Farmers attributed several reasons to why they don’t test their soils. This is represented in Table 23. Majority of farmers (36%) claimed soil tests are expensive and thus cannot afford it. Farmers also don’t see the need for soil tests as this constituted 35% of total responses.

Table 23*: Why farmers don’t test their soils*

Reason	**Frequency**	**Percent**
it’s expensive	29	36
Don’t have knowledge about soil test	23	29
feels it’s unnecessary	28	35
Total	80	100

Source: field Survey, (2017)

Fertilizer Application Training

Training and sensitization of fertilizer application is very important towards sustainable production of the various crops. Figure 4 presents the stakeholders who provide some form of training on fertilizer for farmers in the study area. Farmers in the catchment areas of Twifo Oil Palm plantations indicated they receive some form of training on fertilizers from them and they constitute 3.4 %. The Ministry of Food and Agriculture also plays a significant role through agricultural extension agents. This constituted the largest of the total responses, (68%). Ghana COCOBOD also contributes significantly (27 %) towards education of farmers on fertilizer usage in the study area.

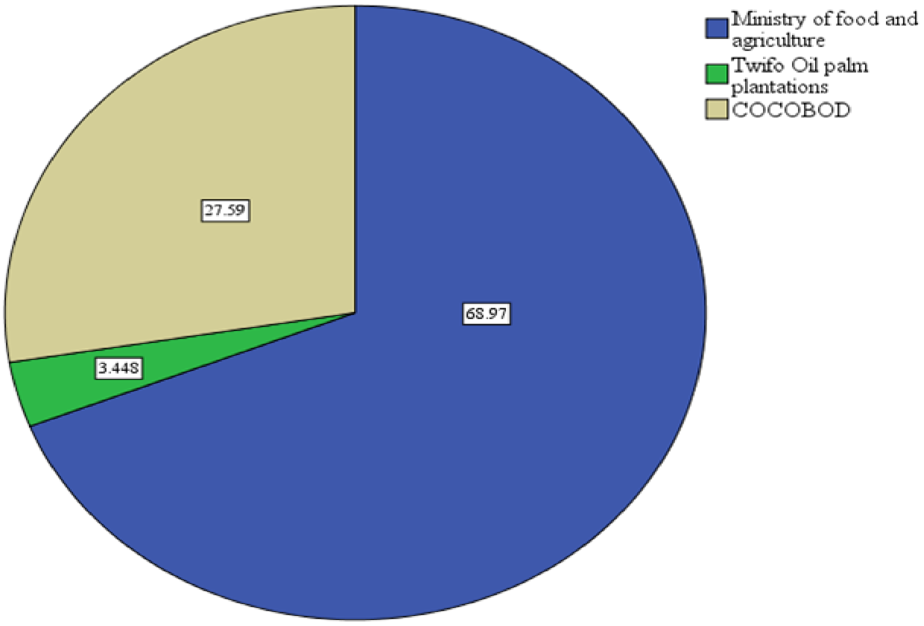

Figure 4:Organizers of fertilizer application training in KEEA, CN and HLD districts.

Source: field Survey

CHAPTER FIVE

DISCUSSION

Physical and chemical properties of soil at experimental site

The soil at the experimental site was a loamy sand, slightly acidic with a pH of 6. 4 far above the critical value of pH (< 5.0) at which the availability of potassium and other important nutrients may be reduced (Pan & Murphy, 2007). However, even at low pH where many crops will fail, cassava's growth and yield is less affected. A pH of 6.4 is therefore good for optimal performance of the crop.

A low organic carbon level of the soil of the experimental field suggests poor fertility. The bulk density of the soil was also ideal for root penetration. According to Pan & Murphy, (2007) the critical bulk density at which root penetration is likely to be severely restricted is 1.8 g cm^{-3}. Bulk density of 1.2 – 1.8 g cm^{-3} indicates a very open soil condition in sandy soils. Generally, a bulk density < 1.0 g cm^{-3} is considered to be low whilst densities greater than 1.9 g cm^{-3} is high (Pan & Murphy, 2007). The bulk density of the experimental field (1.46 g cm^{-3}) can be said to be satisfactory for sandy soils and generally moderate. It also implies the soil is very open and can promote tuberous root development.

Again, the soil had low levels of total nitrogen and basic cations. The low levels of bases might be accountable for its low ECEC which suggests that the soil has poor nutrient holding capacity (Ketterings, Reid, & Rao, 2007). Low ECEC could also indicate a decline in soil organic matter possibly due to erosion. Soil properties were better in the surface soils (0-15) except K which might be because of depletion of exchangeable K by plant uptake and leaching.

K- absorption by cassava genotypes

Varietal ability to absorb more K was evident between Cape Vars variety and Botan. Cape Vars variety showed superior ability in K absorption than Botan (Table 4).Treatments (T2 and T3) accumulated more K than those grown in the control plots. Post analysis of soil of the experimental field indicated an increase of exchangeable K of plots that were treated with K fertilizer . K content was relatively higher in plots that received both NPK and KCl which indicates a possible increase in the exchangeable K concentration of the soil directly because of the fertilizer treatment. This is in line with Mouhamad et al. (2016) which stated that the exchangeable K content of the soil can be affected by the kind of soil amendments and fertility management method that is applied to the soil. A significant increase in K content of cassava tuber by increased K application could be as a result of the saturation of the exchangeable pool of the soil.

Cassava is known to remove substantial amounts of nutrients from the soil, the largest being potassium (Kamaraj, Jagadeeswaran, Murugappan, & Rao, 2008). However, it has relatively low levels of K in the tuber. Per Montagnac et al., (2009) cassava tuber contains 0.72% K. However, the%K content for Cape Vars and Botan were 1.05% and 0. 97% , respectively, which is higher than the established K content for cassava. This could be attributed to an enhanced ability of the two genotypes to absorb K from the soil.

As the nutritional value of a crop is related to the fertility status of the soil on which it grows(Welch & Graham, 2004) it can be said that K content of the soil is proportional to K content of cassava tuber produced on it. Potassium accumulation was very responsive to fertilizer application, especially in plants that received additional potassium in the form of KCl. According to a general guide developed for interpretation of plant tissue analysis (Howeler, 2002), fertilized and unfertilized cassava can accumulate %K content of 1.05 and 0.71 in the tuber respectively. However, this is subject to variation due to varietal differences as well as edaphic and climatic conditions (Howeler, 2002). The mean %K for Cape Vars and Botan under a recommended NPK application was 1.058%, 0.994 % respectively which compares very well with the established K content in fertilized cassava tuber mentioned earlier. However, it was observed that under a balanced fertilization the K content of cassava tuber (1.058 %) and peel (0.994 %) were almost the same. However more K is stored in the tuber (1.129%) than in the peel (0.975 %) under increased application of K fertilizer. This depicts a kind of K partitioning that can be very useful for moderating K content of cassava tubers.

Effect of fertilizer on yield and yield components

Cassava exhibits positive response to fertilization. Uwah et al., (2013) observed superior growth attributes in cassava plants supplied with high rates of N and K. This has been attributed to enhanced physiological activities such as cell multiplication and photosynthesis (Uwah, Effa, Ekpenyong, & Akpan, 2013).

Yield and yield components of cassava are known to be very responsive to fertilizer application. Fermont et al., (2010) observed strong increases in cassava yield with NPK application but with variety choice.

Cassava yield and yield components show a strong response to application of K and a moderate response to N and P (Howeler,1991). However, an important factor affecting crop response to fertilizer treatment is the variation in soil conditions present in an area (Burns et al., 2012). This could account for reasons why certain yield parameters did not show significant differences with the application of fertilizer treatments.

Even though most yield components such as diameter of storage root and number of storage roots did not show a significant response, fertilized plants performed better than control plants.

Physical and Chemical Characteristics of soils – farmers' fields

Soils investigated fall within the coastal savannah and the moist semi deciduous forest ecological zones of Ghana where Acrisols dominate as the major soil type (FAO, 2005). Soil parameters such as pH is of much importance and worth looking at in dealing with soil fertility status of soils (Kundu et al., 2017). It is one soil property that has great bearing on mobility and bioavailability of nutrients (Du Laing, Rinklebe, Vandecasteele, Meers, & Tack, 2009). Plant growth is usually the best in slightly acidic soils of pH 6. 0-7. 0(Hazelton & Murphy, 2016). Cassava can do well in a wide range of soil pH, from acidic to very strongly alkaline soils with a pH of 4 - 9(ITTA, 2015). Most of the soils investigated had pH between 4.2 - 7.5 and can therefore be considered as suitable for cassava production in terms of pH. Most farms had adequate ECEC value which according to soil testing guide of MOFA is 5-20 and thus puts them in an advantageous position to retain good amount of soil nutrients for plant use. Several farms also had low ECEC values of 1-5cmol kg^{-1}which suggests that such soils might have low fertility status and thus require immediate intervention for a sustainable cassava production. A low ECEC also indicates thst soil had low organic matter contents possibly due to leaching.

Nutrient availability is much influenced by the cation exchange capacity of soils. Soils that have a low CEC are likely to be low in the basic cations such as Ca^{2+}, Mg^{2+}, Na^{2+} and K^{+}. However high CEC soils can retain such cations for long (Ketterings et al., 2007). The soils can therefore be said to have a poor nutrient holding ability.

Potassium Status of Cassava Farms in Three Districts

From the results of the study, it is evident that soils investigated had moderate exchangeable K, with a mean of 0.28 cmol kg^{-1} K which according to Pan & Murphy., (2007) is low when it falls within a range of 0.2 – 0.3$cmol_c$ kg^{-1}.

There were substantial variations in the observed exchangeable K contents from farmers' fields across the three districts that were studied. Such a variability is likely due to the fact that the soils developed from different parent materials and hence might differ in chemical properties (Elbaalawy et al., 2016; Mouhamad et al., 2016). Soil exchangeable K is found in higher quantities in soils that develop from igneous rocks (Mouhamad et al., 2016) as well as soils from parent materials rich in K – bearing minerals (Havlin et al., 2005). Among the igneous rocks, granite and syenites contain the highest amount of K (46-54K kg^{-1}) however in sedimentary rocks, clayey shales contain 30 K kg^{-1}, whereas limestone contains 6gkg $^{-1}$ soils from igneous rocks such as forest soils would have a higher amount of potassium than ones formed from sedimentary rocks.

This variation in K content across the districts could be attributed to the different parent materials of the soils. Cape Coast and KEEA districts have ferric Acrisols whilst HLD has Orphic Acrisols (Cottenie, 1980).Again according to Yawson et al.(2011), K levels of forest soils are low as compared to that of savanna soils. This could be the reason behind the low exchangeable K content of the HLD soils, as this district is found in the deciduous forest agro-ecological zone of Ghana. Leaching due to high rainfall could explain its low K content.

Even though exchangeable K levels are low (0.83 – 0.063), most soils had values above the critical value (< 0.15) established by Howeler & Cadavid, (1990) and Kang,(1984). However, quite a few soils (34 farms) across the study area had exchangeable K levels below the critical level and needs attention for sustainable cassava production.

Exchangeable K which constitutes the water soluble K represents 90 % of the K available to crops (Lalitha & Dhakshinamoorthy, 2014). The amount of exchangeable K present in the soil could be influenced by soil management employed by farmers such as addition of organic matter to the soil and application of fertilizers to the soil. (Claassen, Dessougi, & Trehan, 2001).

Non-exchangeable K on the other hand is relatively higher with a mean K value of 0.56 cmol kg^{-1} K. According to Lalitha & Dhakshinamoorthy, (2014), non-exchangeable K is not readily available to crops, however remains in a dynamic equilibrium with the available forms of K acting as a reservoir. Inherent K status and long term K supply depends largely upon the amount of non-exchangeable K present in the soil (Lalitha & Dhakshinamoorthy, 2014).

Low levels of exchangeable K might imply that soils have been continuously cropped and exchangeable K in surface soils has been depleted. Again, this is possible as a review of soil management practices by farmers indicated that a greater proportion of farmers (55%) did not apply any soil management intervention (Table 20).Under a system of intensification without adequate fertility management the soil will be depleted of its essential nutrients especially K.

Extractability of K by different extraction methods

For better understanding of the fertility status of cassava farms with respect to K, it is important to look at the various methods of available K extraction. The choice of a extractant according to Affinnih, Salawu, and Isah., (2014) is determined by the correlation between amount extracted and crop growth or yield. A significant correlation found between exchangeable K extracted with $CaCl_2$ and cassava tuber yield suggests that exchangeable K has a better extractability with Calcium Chloride than with Ammonium Acetate and Nitric Acid. However, among the extraction methods compared in the study, the Ammonium Acetate method produced significant values among the three districts studied. Bibiso (2012) studied the effectiveness of three unbuffered salts; $CaCl_2$, $BaCl_2$ and $SrCl_2$ for extraction of P, NO_3 and K in Ethiopian soils and established that extraction of nutrients by unbuffered salts such as $CaCl_2$ is rapid and a simple way to evaluate soil nutrient status. However, for the amount of K extracted, the conventional soil testing method which usually refers to ammonium acetate extraction method performed better as K values for extraction with unbuffered salts were relatively lower. Results of the study, however, revealed that Nitric acid extractable K had higher values with a mean of 0.64 cmol kg^{-1}relative to ammonium acetate and calcium chloride extractable K. This could be attributed to the fact that Nitric Acid K is comprised of some amount of the non-exchangeable K and thus is always higher. Again a high Nitric Acid extractable K is also indicative of the fact that methods usually used for exchangeable K extraction underestimate the available K content of soils (Madaras & Koubová, 2015).

Between ammonium acetate and calcium chloride as extractants, exchangeable K was more extractable by Calcium Chloride as K values were higher than that extracted by Ammonium Acetate. But among the common extraction methods, ammonium acetate is normally prescribed for extracting available K from the soil and is predominantly used to determine exchangeable cations in agricultural soils (Barbagelata & Mallarino, 2013). This could be attributed to an advantage of ammonium acetate method over the other methods which is an inclusion of the CEC value (Matula, 2009) and the fact that the Ammonium cation (NH_4^+)and the Potassium ion (K^+) are almost the same (Bibiso, 2012).

Ammonium Acetate has been found as very predictive for available K to plants (Darunsontaya, Suddhiprakarn, Kheoruenromne, Prakongkep, & Gilkes, 2012) and the findings of this study agree to that but found that $CaCl_2$ – K haves a better relationship with tuber yield of cassava and could predict K levels better in cassava producing soils.

Soil Management Practices Employed by Cassava Farmers

A greater proportion of cassava farmers studied scarcely manage their soils as most farmers (55%) indicated they did not put in any effort to maintain the fertility status of their soils (Table 21). As cassava is being grown extensively, there is the need for effective soil management for a more sustainable cassava production enterprise. Cassava is noted for removing substantial amounts of nutrients especially K mostly with the harvested roots (Ayoola & Makinde, 2007). Farmers however seem unconcerned about fertility status of the soils on which they farm as results from the field survey indicated that all respondents have never tested their soils before and thus have no knowledge of the fertility status of their soils (Table 21). Cassava's ability to thrive on marginal soils and produce reasonable yields(John & Imas, 2013) could be accountable for the reason why farmers don't see soil fertility management in cassava production as a necessity.

Effective soil fertility management would require a good soil monitoring system. Soil test is a key tool for monitoring nutrient levels which will inform farmers on the need for an intervention for sustainable production of food crops. All respondents were of diverse views about why they would not test their soils. Key among their responses was the fact that soil tests are expensive.

Application of Chemical Fertilizer on Cassava Farms

In the face of increasing population pressure and scarcity of land, farmers in many parts of Africa have resorted to intensification which is rather unsustainable. (Fermont et al., 2010). The soil is likely to be depleted especially in its available K as root and tubers like cassava are heavy K feeders (Yawson et al., 2016). Nevertheless, farmers are reluctant to apply chemical fertilizer on cassava farms.

Cassava farmers have a wide range of perceptions about fertilizer application in cassava production. Out of their many reasons, the most important is that, farmers are of the view that application of chemical fertilizers can lead to tuber rot. This accounted for 25% of total responses (Figure 3). Aside this, farmers also had the belief that fertilizer application can cause diseases in human beings.

Quite number farmers also had the strong belief that cassava does not need fertilizer at all. Cassava's ability to thrive in poor and acidic soils has given rise to the misconception that it does not need fertilizer at all (Howeler et al., 2013). Aside the prohibitive cost of inorganic fertilizers which deters the few farmers who might want to apply chemical fertilizers, farmers also indicated they don't apply chemical fertilizers because it can destroy the soil. This assertion holds to some extent as some chemical fertilizers have the potential of rendering the soil acidic. Reasons behind farmer's unwillingness to apply chemical fertilizer is similar to that of Boateng (2015) who itemised high prices of chemical fertilizers and reduced tuber quality and storage as the reasons why cassava farmers in Ghana don't apply chemical fertilizer on cassava farms. Boateng (2015) itemized unaffordable prices of chemical fertilizer, as well as reduced tuber quality and storage as the reasons why farmers are reluctant to the application of chemical fertilizers in cassava production.

It' obvious that sensitization and training of farmers on fertilizer usage is necessary. sThe study revealed the operation of three stake-holders in the operational area. They included MOFA, TOPP and COCOBOD. The Ministry of Food and Agriculture (MOFA) was found to be very active in educating and sensitizing farmers as most respondents indicated they have attained some level of education on fertilizer usage from MOFA Agric Extension Agents

(Figure 4, page 73). TOPP and COCOBOD also contributed significantly to education and training of farmers as they represented 3% and 27%, respectively. However, their effort is mostly geared towards the cultivation and undertaking of sound agronomic practices in the cultivation of their target crop.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

Conclusion

The following conclusions could be made from the results obtained. Yield parameters of cassava showed a positive response to fertilizer application. The results of the study revealed that Cape Vars variety has a better K accumulation capacity than the Botan variety.

Potassium absorption increased significantly in cassava grown under fertilized conditions, however, cassava tends to accumulate more K in the peels than in the fleshy part of the tuber when grown under unfertilized conditions.

Soils investigated in the field survey had low levels of exchangeable K, but good amounts of non-exchangeable K. Soil also had low ECEC and this indicates soils were of low fertility. Potassium content of cassava tubers and yield from the field survey was quite good. It can be said that cassava has an increased ability to absorb K even in unfertilized soils.

Extractability of exchangeable K among the three extractancts were found to be in a decreasing order of $HNO_3K_{ex} > NH_4OAcK_{ex} > CaCl_2\ K_{ex}$. However $CaCl_2$ was found to be more predictive for exchangeable K in soils for cassava production as it has a positive and significant relationship with cassava tuber yield.

Cassava production can also be said to be unsustainable as farmers just produce continuously without any proper fertility management. All evidence points to the fact that K content of cassava tubers can be increased by raising the levels of exchangeable K in the soil which is possible through fertilizer application.

Recommendations

Major stakeholders of cassava production should endeavour to educate cassava farmers to clear their misconceptions on fertilizer application in cassava production. Sensitization on the need for soil fertility management by cassava farmers towards a more sustainable production of cassava is crucial towards food security and public health in Ghana and Africa at large.

Cassava farmers should consider the application of potassium fertilizers to increase the K content of cassava to help reduce K deficiency diseases among Ghanaians.

Further research into cassava’s ability to absorb K in unfertilized soils and the effect of potassium fertilizers on anti-nutritional factors in cassava is recommended.

REFERENCES

Aburto, N. J., Hanson, S., & Gutierrez, H. (2013). Effect of increased potassium intake on cardiovascular risk factors and disease : systematic review and meta-analyses, *1378*(April), 1–19.https://doi.org/10.113 6/bmj.f13 78

Adenle, A. A., Aworh, O. C., Akromah, R., & Parayil, G. (2012). Developing GM super cassava for improved health and food security: future challenges in Africa. *Agriculture & Food Security*, *1*(1), 11. https://doi.org/10.1186/2048-7010-1-11

Adowa, H. M. (2009). *Growth, Yield And Quality of Cassava as influenced by Terramend 21, Poultry and Inorganic fertilizer*. Kwame Nkrumah University of Science and Technology.

Affinnih, K.O., Salawu, I.S. Isah, A. . (2014). Methods of Available Potassium Assessment. *Agrosearch*, *14*, 76–87.

Agwunobi, L. N., Angwukam, P. O., Cora, O. O., & Isika, M. A. (2002). Studies on the use of Colocasia esculenta (taro cocoyam) in the diets of weaned pigs. *Tropical Animal Health and Production*, *34*(3), 241–247.

Akinfala, E. O., & Tewe, O. O. (2001). Utilisation of whole cassava plant in the diets of growing pigs in the tropics. *Livestock Research for Rural Development*, *13*(5), 13–21.

Akpan, I., Uraih, N., Obuekwe, C. O., & Ikenebomeh, M. J. (1988). Production of ethanol from cassava whey. *Engineering in Life Sciences*, *8*(1), 39–45.

Allen, S. E., Grimshaw, H. M., Parkinson, J. A., & Quarmby, C. (1974). *Chemical analysis of ecological materials.* Blackwell Scientific Publications.

Amine, E., Baba, N., Belhadj, M., Deurenbery-Yap, M., Djazayery, A., Forrester, T., … MBuyamba, J. (2002). *Diet, nutrition and the prevention of chronic diseases: report of a Joint WHO/FAO Expert Consultation*. World Health Organization.

Angelucci, F. (2012). Analysis of incentives and disincentives for maize in Ghana. *Technical Notes Series, MAFAP, FAO, Rome*.

Apata, D. F., & Babalola, T. O. (2012). The use of cassava, sweet potato and cocoyam, and their by-products by non–ruminants. *International Journal of Food Science and Nutrition Engineering, 2*(4), 54–62.

Aregheore, E. M. (2012). Nutritive value and inherent anti-nutritive factors in four indigenous edible leafy vegetables in human nutrition in Nigeria. *Journal of Food Resourse Science*. https://doi.org/10.3923/jfrs.2012.1.14

Ashley, M. K., Grant, M., & Grabov, A. (2006). Plant responses to potassium deficiencies: A role for potassium transport proteins. In *Journal of Experimental Botany* (Vol. 57, pp. 425–436). https://doi.org/10.1093/jxb/erj034

Askegaard, M., Eriksen, J., & Olesen, J. E. (2003). Exchangeable potassium and potassium balances in organic crop rotations on a coarse sand. *Soil Use and Management, 19*(2), 96–103.

Augusto, A., & Alves, C. (2002). *Cassava Botany and Physiology*.

Ayoola, O. T., & Makinde, E. A. (2007). Fertilizer Treatment Effects on Performance of Cassava under Two Planting Patterns in a Cassava - based Cropping System in South West Nigeria. *Research Journal of Agriculture and Biological Sciences*, *3*(1), 13–20.

Balagopalan, C. (2002). Cassava utilization in food, feed and industry. *Cassava: Biology, Production and Utilization*, 301–318.

Barbagelata, P. A., & Mallarino, A. P. (2013). Field Correlation of Potassium Soil Test Methods Based on Dried and Field-Moist Soil Samples for Corn and Soybean. *Soil Science Society of America Journal*, *77*, 318–327. https://doi.org/10.2136/sssaj2012.0253

Benard, V., & Giller, K. E. (2006). Popular myths around soil fertility management in sub-Saharan Africa. *Agriculture, Ecosystems & Environment*, *116*, 34–46. https://doi.org/10.1016/j.agee.2006.03.016

Benito, B., Haro, R., Amtmann, A., Cuin, T. A., & Dreyer, I. (2014). The twins K+ and Na+ in plants. *Journal of Plant Physiology*, *171*(9), 723–731. https://doi.org/10.1016/j.jplph.2013.10.014

Bibiso, M. (2012). Evaluation of Three Universal Extractants for the Determination of P , NO 3- and K in Some Soils of Ethiopia. *Advances in Life Science and Technology*, *6*(3), 16–25.

Birol, E., Meenakshi, J. V, Oparinde, A., Perez, S., & Tomlins, K. (2015). Developing country consumers’ acceptance of biofortified foods: a synthesis. *Food Security*, *7*(3), 555–568.

Boateng, B. A. (2015). *Influence of rates and time of npk fertilizer application on cassava (Manihot esculenta Crantz)*. Kwame Nkrumah University of Science And Technology.

Brag, H. (1972). The Influence of Potassium on the Transpiration Rate and Stomatal Opening in Triticum aestivum andPisum sativum. *Physiologia Plantarum*, *26*(2), 250–257.

Brouder, S. M., & Volenec, J. J. (2008). Impact of climate change on crop nutrient and water use efficiencies. *Physiologia Plantarum*, *133*(4), 705–724.

Burns, A. E., Gleadow, R. M., Zacarias, A. M., Cuambe, C. E., Miller, R. E., & Cavagnaro, T. R. (2012). Variations in the chemical composition of cassava (Manihot esculenta Crantz) leaves and roots as affected by genotypic and environmental variation. *Journal of Agricultural and Food Chemistry*, *60*(19), 4946–4956.

Burns, A., Gleadow, R., Cliff, J., Zacarias, A., & Cavagnaro, T. (2010). Cassava: The drought, war and famine crop in a changing world. *Sustainability*, *2*(11), 3572–3607. https://doi.org/10.3390/su2113572

Cadavid, L. F. (1988). Respuesta de la yuca (Manihot esculenta Crantz) a la aplicacion de NPK en suelos con diferentes características. *Trabajo Especial. Univ Nacional de Colombia, Palmira, Colombia*, *185*.

Chan, E. S., Rudravaram, R., Narasu, M. L., Rao, L. V., & Ravindra, P. (2007). Economics and environmental impact of bioethanol production technologies: an appraisal. *Biotechnology and Molecular Biology Reviews*, *2*(1), 14–32.

CIAT. (2011). *The Cassava Handbook*. (R. . Howeler, Ed.) (1st ed.). Bankok.

Claassen, N., Dessougi, H. E., & Trehan, S. P. (2001). Crop growth and potassium uptake as related to plant and soil properties. In *International Symposium on importance of potassium in nutrient management on sustainable crop production in India* (pp. 102–123).

Cock, J., & Reyes, J. A. (1985). Cassava: research, production and utilization.

Cottenie, A. (1980). Soil and plant testing and analysis as a basis of fertilizer recommendations. FAO Soils Bulletin No. 38/2. *Fao Soils Buletin*.

Cuvaca, I. B., Eash, N. S., Zivanovic, S., Lambert, D. M., Walker, F., & Rustrick, B. (2015). Cassava (Manihot esculenta Crantz) Tuber Quality as Measured by Starch and Cyanide (HCN) Affected by Nitrogen , Phosphorus , and Potassium Fertilizer Rates, *7*(6), 36–49. https://doi.org/10.5539/jas.v7n6p36

Darunsontaya, T., Suddhiprakarn, A., Kheoruenromne, I., & Gilkes, R. J. (2010). A comparison of extraction methods to assess potassium availability for Thai upland soils. *19th World Congress of Soil Science, Soil Solutions for a Changing World*, (August), 1–4.

Darunsontaya, T., Suddhiprakarn, A., Kheoruenromne, I., Prakongkep, N., & Gilkes, R. J. (2012). The forms and availability to plants of soil potassium as related to mineralogy for upland Oxisols and Ultisols from Thailand. *Geoderma, 170,* 11–24. https://doi.org/10.1016/j.geoderma.2011.10.002

Du Laing, G., Rinklebe, J., Vandecasteele, B., Meers, E., & Tack, F. M. G. (2009). Trace metal behaviour in estuarine and riverine floodplain soils and sediments: a review. *Science of the Total Environment*, *407*(13), 3972–3985.

Elbaalawy, A. M., Benbi, D. K., & Benipal, D. S. (2016). *Potassium forms in relation to clay mineralogy and other soil properties in different agro-ecological sub-regions of*, *53*(10), 200–206.

F. Apata, D., & O. Babalola, T. (2012). The Use of Cassava, Sweet Potato and Cocoyam, and Their By-Products by Non – Ruminants. *International Journal of Food Science and Nutrition Engineering*, *2*(4), 54–62. https://doi.org/10.5923/j.food.20120204.02

Faaij, A., & Londo, M. (2010). A roadmap for biofuels…. Pergamon.

Factfish. (2017). Factfish (2014) Ghana cassava. Retrieved July 23, 2017, from http//:www.factfish.com/statistic-country/Ghana/cassava

Fan, S. (2010). Achieving Sustainable Food Security: New Trends and Emerging Agenda. *Multistakeholder Dialogue on Implementing Sustainable Development, United Nations Headquarters, New York*, 1–9.

FAO. (2005). Fertilizer use by crop in Ghana. *Tropical Agriculture*.

FAO. (2013). *Save and Grow: Cassava. A Guide to Sustainable Production Intensification*. Retrieved from http://www.fao.org/3/a-i3278e.pdf

FAO, & IFAD. (2005). A review of cassava in Africa with country case studies on Nigeria , Ghana , the United. *A Review of Cassava in Africa with Country Case Studies on Nigeria , Ghana , the United Republic of Tanzania, Uganda and Benin. Proceedings of the validation forum on the global cassava development strategy Volume 2*, 357.

Fermont, A. M., Tittonell, Æ. P. A., & Giller, K. E. (2010). Towards understanding factors that govern fertilizer response in cassava : lessons from East Africa, 133–151. https://doi.org/10.1007/s10705-009-9278-3

Garcia-Casal, M. N., Peña-Rosas, J. P., Giyose, B., & consultation working groups. (2016). Staple crops biofortified with increased vitamins and minerals: considerations for a public health strategy. *Annals of the New York Academy of Sciences*, *1*(1), 3–13. https://doi.org/10.1111/nyas. 13293

Gbadegesin, M. A., Olaiya, C. O., & Beeching, J. R. (2013). African Cassava : Biotechnology and Molecular Breeding to the Rescue, *3*(3), 305–317. https://doi.org/10.9734/BBJ/2013/3449

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., … Toulmin, C. (2012). The Challenge of Food Security. *Science*, *327*(February), 812. https://doi.org/10.4337/9780857939388

Goldemberg, J. (2008). The Brazilian biofuels industry. *Biotechnology for Biofuels*, *1*(1), 6. https://doi.org/10.1186/1754-6834-1-6

Goulding, K. W. T., & Loveland, P. J. (1986). The classification and mapping of potassium reserves in soils of England and Wales. *European Journal of Soil Science*, *37*(4), 555–565.

Grzebisz, W., Gransee, A., Szczepaniak, W., & Diatta, J. (2013). The effects of potassium fertilization on water-use efficiency in crop plants. *Journal of Plant Nutrition and Soil Science*, *176*(3), 355–374. https://doi.org/10.1002/jpln.201200287

Hamdana Jol, & Osumanu, H. A. (2013). Potassium dynamics of a forest soil developed on a weathered schist regolith. *Archives of Agronomy and Soil Science*, *59*(4), 593–602. https://doi.org/10.1080/03650340.2012.663489

Haney, R., Haney, E., Hossner, L., & Arnold, J. (2006). Development of a new soil extractant for simultaneous phosphorus, ammonium, and nitrate analysis. *Communications in Soil Science and Plant Analysis*, *37*(11–12), 1511–1523. https://doi.org/10.1080/00103620600709977

Havlin, J. L., Beaton, J. D., Nelson, W. L., & Tisdale, S. L. (2005). *Soil fertility and fertilizers: An introduction to nutrient management* (Vol. 515). Pearson Prentice Hall Upper Saddle River, NJ.

Hazelton, P., & Murphy, B. (2016). *Interpreting soil test results: what do all the numbers mean?* CSIRO publishing.

He, F. J., & MacGregor, G. A. (2008). Beneficial effects of potassium on human health. *Physiologia Plantarum*, *133*(4), 725–735.

Howeler, R. (1981). Mineral nutrition and Fertilization of cassava. In *Mineral nutrition and Fertilization of cassava* (p. 52). Cali: Centro Internacional de Agricultura Tropical.

Howeler, R. H. (1991). Long-term effect of cassava cultivation on soil productivity. *Field Crops Research*, *26*(1), 1–18.

Howeler, R. H. (2001). Cassava mineral nutrition and fertilization. *Cassava: Biology, Production and Utilization*, 115–147. https://doi.org/10.1079/9780851995243.0115

Howeler, R. H., & Cadavid, L. F. (1990). Short-and long-term fertility trials in Colombia to determine the nutrient requirements of cassava. *Nutrient Cycling in Agroecosystems*, *26*(1), 61–80.

Howeler, R., Lutaladio, N., & Thomas, G. (2013). Save and grow: cassava. In *A guide to sustainable production intensification* (Vol. 1, pp. 87–97). Retrieved from https://scholar.google.com/scholar?hl=en&as_sdt= 0,5& qsp=1&q=save+and+grow+cassava

IFAD, F. A. O. (2000). The world cassava economy. Facts, trends and outlook. *Rome, IFAD, FAO*.

ITTA. (1990). *Cassava in Tropical Africa: A Reference Manual*. IITA.

ITTA. (2015). *Guide to Cassava Cultivation Frequently Asked Questions*. Ibadan: ITTA. Retrieved from http://oldlrinternet.iita.org/c/document _library/get_file?uuid=a66f2cb5-cf02-48db-af76-4e88e9c469d3&groupId=25357

Jansson, C. (2010). Lawrence Berkeley National Laboratory Lawrence Berkeley National Laboratory. *Office*.

Jeyaraj, G., & Mosi, A. D. (1973). Studies on different forms of potassium in the mechanical fr actions of typical soils of Tamil Nadu. *Madras Agricultural Journal*.

John, K. S., & Imas, P. (2013). Potassium Nutrition of Cassava. *Electronic International Fertiliser Correspondent*, (34), 13–18.

Kamaraj, S., Jagadeeswaran, R., Murugappan, V., & Rao, T. N. (2008). Balanced Fertilisation for Cassava. *Better Crops*, 8–9.

Kang, B. T. (1984). Potassium and magnesium responses of cassava grown in ultisol in southern Nigeria. *Nutrient Cycling in Agroecosystems*, *5*(4), 403–410.

Ketterings, Q. M., Reid, S., & Rao, R. (2007). Cation Exchange Capacity (CEC). *Cornell University Cooperative Extension*, 1–2. https://doi.org/10.1080/01431160305010

Kundu, C. A., Ishii, M., Sato, K., Wanjogu, R. K., Makihara, D., Yamauchi, A., & Masunaga, T. (2017). An Assessement of Paddy Production System in Central Kenya with Special Reference to Micronutrients. *Journal of Agricultural Science*, *9*(6), 49. https://doi.org/10.5539/jas.v9n6p49

Lalitha, M., & Dhakshinamoorthy, M. (2014). Forms of Soil Potassium-a Review, *35*(1), 64–68. https://doi.org/10.5958/j.0976-0741.35.1.008

Madaras, M., & Koubová, M. (2015). Potassium availability and soil extraction tests in agricultural soils with low exchangeable potassium content. *Plant, Soil and Environment*, *61*(5), 234–239. https://doi.org/10.17221/171/2015-PSE

Manyong, V. M. (2000). *Impact: The Contribution of IITA-improved Cassava to Food Security in Sub-Saharan Africa*. IITA.

Marschner, H. (2012). Marschner's mineral nutrition of higher plants, vol. 89. Academic press.

Matula, J. (2009). A relationship between multi-nutrient soil tests (Mehlich 3, ammonium acetate, and water extraction) and bioavailability of nutrients from soils for barley. *Plant, Soil and Environment*, *55*(4), 173–180.

Megan Ware RDN, L. (2017). Potassium: Health Benefits, Recommended Intake. Retrieved April 5, 2017, from http://www.medicalnewstoday.com/articles/287212.php

Mehlich, A. (1984). Mehlich 3 soil test extractant: A modification of Mehlich 2 extractant. *Communications in Soil Science & Plant Analysis*, *15*(12), 1409–1416.

Mejía-Agüero, L. E., Galeno, F., Hernández-Hernández, O., Matehus, J., & Tovar, J. (2012). Starch determination, amylose content and susceptibility to in vitro amylolysis in flours from the roots of 25 cassava varieties. *Journal of the Science of Food and Agriculture*, *92*(3), 673–678.

Ministry of Environment, S. and T. G. (2011). Republic of Ghana Ministry of Environment , Science and Technology Ghana Strategic Investment Framework (Gsif) for Sustainable Land Management (SLM), (June), 2011–2025.

MOFA. (2016). Agriculture in Ghana.Facts and Figures. Retrieved from https://www.insurethebox.com/insurethebox-in-numbers

Montagnac, J. A., Davis, C. R., & Tanumihardjo, S. A. (2009). Nutritional value of cassava for use as a staple food and recent advances for improvement. *Comprehensive Reviews in Food Science and Food Safety*, *8*(3), 181–194. https://doi.org/10.1111/j.1541-4337.2009.00077.x

Morgan, M. F. (1941). Chemical Diagnosis by the Universal Soil Testing System. Conn. Agr. Exp. *Sta (New Haven) Bull, 450*.

Mouhamad, R., Alsaede, A., & Iqbal, M. (2016). Behavior of Potassium in Soil : A mini review, 58–69.

Nassar, N. M. A., & Ortiz, R. (2009). *Cassava Genetic Resources: Manipulation for Crop Improvement*. *Plant Breeding Reviews* (Vol. 31). https://doi.org/10.1002/9780470593783.ch5

Nuwamanya, E., Chiwona-karltun, L., Kawuki, R. S., & Baguma, Y. (2012). Bio-Ethanol Production from Non-Food Parts of Cassava (Manihot esculenta Crantz), 262–270. https://doi.org/10.1007/s13280-011-0183-z

Nweke, F. I. (2004). *New challenges in the cassava transformation in Nigeria and Ghana* (Vol. 118). Intl Food Policy Res Inst.

Olorede, B. R., Sadu, Y., Abdurahim, I., Ajagbonna, O. P., & Akinloye, O. A. (2002). Blood chemistry and histopathology of cockerel fed cassava flour. *ASAN Proceedings*, 38–40.

Olsen, S. R. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *US Dep. Agric. Circ.*, *939*, 1–19.

Organization, W. H. (2012). *Guideline: potassium intake for adults and children*. World Health Organization.

Pan, H., & Murphy, B. (2007). *INTERPRETING SOIL TEST RESULTS WHAT DO ALL THE NUMBERS MEAN ?* (2nd ed.). Collingwood: CSIRO.

Pasricha, N. S. (2002). Potassium dynamics in soils in relation to crop nutrition. *Journal of the Indian Society of Soil Science*, *50*(4), 333–344.

Patrick, J. W., Zhang, W., Tyerman, S. D., Offler, C. E., & Walker, N. A. (2001). Role of membrane transport in phloem translocation of assimilates and water. *Functional Plant Biology*, *28*(7), 697–709.

Peck, T. R., & Soltanpour, P. N. (1990). The principles of soil testing. *The Principles of Soil Testing.*, (Third Edition), 1–9.

Peiter, E. (2011). The plant vacuole: emitter and receiver of calcium signals. *Cell Calcium*, *50*(2), 120–128.

Poon, D. (2010). Understanding Different Soil Test Methods. *Nutrient Managament Factsheet*, (3), 1–5.

Prakash, A. (2013). Cassava: International Market Profile, 2–11. Retrieved from http://go.worldbank.org/XSRUM2ZXM0

Preston, R. L., & Linsner, J. R. (1998). Potassium in Animal Nutrition. *Better Crops*, *82*(3), 32–36.

Römheld, V., & Kirkby, E. A. (2010). Research on potassium in agriculture: needs and prospects. *Plant and Soil*, *335*(1–2), 155–180.

Rowell, D. L. (2014). *Soil science: Methods & applications*. Routledge.

Salami, B. T., & Sangoyomi, T. E. (2013). Soil Fertility Status of Cassava Fields in South Western Nigeria, *3*(1), 152–164.

Saltzman, A., Birol, E., Bouis, H., Boy, E., & Moura, F. De. (2013). Biofortification: progress toward a more nourishing future. *Global Food*. Retrieved from http://www.sciencedirect.com/science/article/pii /S22119 12412000466

Samadi, A. (2006). Potassium exchange isotherms as a plant availability index in selected calcareous soils of western Azarbaijan Province, Iran. *Turkish Journal of Agriculture and Forestry*, *30*(3), 213–222.

Sardans, J., & Peñuelas, J. (2015). Potassium: a neglected nutrient in global change Introduction: potassium in thE, 261–275. https://doi.org/10.1111/geb.12259

Sarwar, M. (2012). Effects of potassium fertilization on population build up of rice stem borers (lepidopteron pests) and rice (Oryza sativa L.) yield. *Journal of Cereals and Oilseeds*, *3*(1), 6–9.

Sayre, R. T. (2011a). Biofortification of cassava for Africa : the BioCassava Plus program, 113–120.

Sayre, R. T. (2011b). Biofortification of cassava for Africa : the BioCassava Plus program. In *Access not Excess* (pp. 113–120).

Siriwat, W., Kalapanulak, S., Suksangpanomrung, M., Netrphan, S., Meechai, A., & Saithong, T. (2012). Transcriptomic data integration inferring the dominance of starch biosynthesis in carbon utilization of developing cassava roots. *Procedia Computer Science*, *11*, 96–106.

Soetan, K. O., Olaiya, C. O., & Oyewole, O. E. (2010a). The importance of mineral elements for humans , domestic animals and plants. *African Journal of Food Science*, *4*(5), 200–222.

Soetan, K. O., Olaiya, C. O., & Oyewole, O. E. (2010b). The importance of mineral elements for humans , domestic animals and plants : A review. *African Journal of Food Science*, *4*(May), 200–222.

Soetan, K., & Olaiya, C. (2010). The importance of mineral elements for humans, domestic animals and plants-A review. *African Journal of Food*. Retrieved from http://www.academicjournals.org/journal/AJFS/article-abstract/045441523024

Sparks, D. L., & Huang, P. M. (1985). Physical chemistry of soil potassium. *Potassium in Agriculture*, (potassiuminagri), 201–276.

Talsma, E. F., Brouwer, I. D., Verhoef, H., Mbera, G. N. K., Mwangi, A. M., Maziya-dixon, B., … Melse-boonstra, A. (2016). Biofortified yellow cassava and vitamin A status of Kenyan children : a randomized controlled trial 1 , 2, 258–267. https://doi.org/10.3945/ajcn.114.100164.1

Talsma, E. F., Brouwer, I. D., Verhoef, H., Mbera, G. N., Mwangi, A. M., Demir, A. Y., … Melse-Boonstra, A. (2016). Biofortified yellow cassava and vitamin A status of Kenyan children: a randomized controlled trial. *American Journal of Clinical Nutrition*, *103*(1), 258–267. https://doi.org/10.3945/ajcn.114.100164

Tan, K. H., Ferguson, L. B., & Carlton, C. (1983). Conversion of cassava starch to biomass, carbohydrates, and acids by Aspergillus niger. *Journal of Applied Biochemistry*, *6*(1–2), 80–90.

Tewe, O., & Lutaladio, N. (2004). Cassava for livestock feed in sub-Saharan Africa. *Rome: FAO*, 28–31. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Cassava+for+livestock+feed+in+sub-Saharan+Africa#1

Tewe, O. O. (1992). Detoxification of cassava products and effects of residual toxins on consuming animals. *Roots, Tubers, Plantains and Bananas in Animal Feeding (Editors: D Machin and AW Speedy). FAO Animal Production and Health. Paper*, (95), 85–91.

Tonukari, N. J. (2004). Cassava and the future of starch. *Electronic Journal of Biotechnology*, *7*(1), 12–15. https://doi.org/10.2225/vol7-issue1-fulltext-i02

Towett, E. K., Shepherd, K. D., Tondoh, J. E., Winowiecki, L. A., Lulseged, T., Nyambura, M., … Cadisch, G. (2015). Total elemental composition of soils in Sub-Saharan Africa and relationship with soil forming factors. *Geoderma Regional*, *5*, 157–168. https://doi.org/http://dx.doi.org/10.1016/j.geodrs.2015.06.002

Tripler, C. E., Kaushal, S. S., Likens, G. E., & Todd Walter, M. (2006). Patterns in potassium dynamics in forest ecosystems. *Ecology Letters*, *9*(4), 451–466. https://doi.org/10.1111/j.1461-0248.2006.00891.x

Uddin, M. S., Abedin Mian, M. J., Islam, M. R., Saleque, M. a, & Islam, M. (2012). Potassium Status of Four Rice Growing Soils of Bangladesh. *Bangladesh Journal of Agricultural Research*, *36*(4), 633–646. https://doi.org/10.3329/bjar.v36i4.11750

Ugwu, B. O., & Ukpabi, U. J. (2002). Potential of soy-cassava flour processing to sustain increasing cassava production in Nigeria. *Outlook on Agriculture*, *31*(2), 129–133.

United Nations. (2002). World population prospects-the 2004 revision population database. *New York, United Nations Population Division*.

United Nations. (2015). *World Population Prospect: The 2015 Revision World Population 2015 Wallchart. World Population Prospect: The 2015 Revision,World Population 2015 Wallchart. ST/ESA/SER.A/378*. https://doi.org/ST/ESA/SER.A/378

Uwah, D. F., Effa, E. B., Ekpenyong, L. E., & Akpan, I. E. (2013). CASSAVA (Manihot esculenta Crantz) Performance as influenced by nitrogen and potassium fertilizers in uyo , Nigeria, *23*(2), 550–555.

Vanlauwe, B., & Giller, K. E. (2006). Popular myths around soil fertility management in sub-Saharan Africa. *Agriculture, Ecosystems & Environment*, *116*(1–2), 34–46.

Vuilleumier, S. (1993). Worldwide production of high-fructose syrup and crystalline fructose. *The American Journal of Clinical Nutrition*, *58*(5), 733S–736S.

Wakeel, A., Farooq, M., Qadir, M., & Schubert, S. (2011). Potassium Substitution by Sodium in Plants, 401–413. https://doi.org/10.1080/07352689.2011.587728

Walkley, A., & Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science*, *37*(1), 29–38.

Wang, M. (2005). Updated energy and greenhouse gas emissions results of fuel ethanol.

Wang, M., Zheng, Q., Shen, Q., & Guo, S. (2013). The critical role of potassium in plant stress response. *International Journal of Molecular Sciences*, *14*(4), 7370–7390. https://doi.org/10.3390/ijms14047370

Warncke, D., & Brown, J. (1988). Potassium and Other Basic Cations. In: Recommended Chemical Soil Test Procedures for the North Central Region. *North Central Regional Publication No. 221*, *221*(NDSU Bull. No. 499), 31–33.

Webster, J. L., Dunford, E. K., & Neal, B. C. (2010). A systematic survey of the sodium contents of processed foods. *The American Journal of Clinical Nutrition*, *91*(2), 413–420.

Wedepohl, K. H. (1995). The composition of the continental crust. *Geochimica et Cosmochimica Acta*, *59*(7), 1217–1232.

Welch, R. M., & Graham, R. D. (2004). Breeding for micronutrients in staple food crops from a human nutrition perspective. *Journal of Experimental Botany*, *55*(396), 353–364.

Whelton, P. K., He, J., Cutler, J. A., Brancati, F. L., Appel, L. J., Follmann, D., & Klag, M. J. (1997). Effects of oral potassium on blood pressure: meta-analysis of randomized controlled clinical trials. *Jama*, *277*(20), 1624–1632.

White, P. J. (2013). Improving potassium acquisition and utilisation by crop plants. *Journal of Plant Nutrition and Soil Science*, *176*(3), 305–316.

White, P. J., & Broadley, M. R. (2005). Biofortifying crops with essential mineral elements. *Trends in Plant Science*, *10*(12), 586–593. https://doi.org/10.1016/j.tplants.2005.10.001

WHO. (2016). Biofortification of staple crops. Retrieved August 12, 2017, from http://www.who.int/elena/titles/biofortification/en/

World Health Organization. (2012). Guideline: Potassium intake for adults and children, 52.

Yawson, D. O., Adu, M. O., Ason, B., Armah, F. A., Boateng, E., & Quansah, R. (2016). Ghanaians Might Be at Risk of Inadequate Dietary Intake of Potassium. *Journal of Nutrition and Metabolism*, *2016*, 8. https://doi.org/10.1155/2016/3150498

Yawson, D. O., Armah, F. A., Afrifa, E. K. A., & Dadzie, S. K. N. (2010). Ghana's Fertilizer Subsidy Policy: Early Field Lessons From Farmers in the Central Region. *Journal Sustainable Development in Africa*, *12*(3), 191–203.

Yawson, D. O., Kwakye, P. K., Armah, F. A., & Frimpong, K. A. (2011). THE DYNAMICS OF POTASSIUM (K) IN REPRESENTATIVE SOIL, *6*(1), 48–55.

Yost RS, A. T. (2006). Predicting and testing site-specific potassium fertilizer of maize in soils of the tropics - an example from thailand. *Soil Science*.

Zorb, C., Senbayram, M., & Peiter, E. (2014). Potassium in agriculture - Status and perspectives. *Journal of Plant Physiology*, *171*(9), 656–669. https://doi.org/10.1016/j.jplph.2013.08.008

Zörb, C., Senbayram, M., & Peiter, E. (2014). Potassium in agriculture – Status and perspectives ଓ organis ms effec t K releas e. *Journal of Plant Physiology*, *171*(9), 656–669. https://doi.org/10.1016/j.jplph.2013.08.008

APPENDICES

APPENDIX A

UNIVERSITY OF CAPE COAST

COLLEGE OF AGRICULTURE AND NATURAL SCIENCES

DEPARTMENT OF SOIL SCIENCE *case no.* ☐

Interview guide for assessing soil management practices employed by cassava farmers

sex ……………………. age …………………………

1. Farm size ………………… fresh root yield (kg/ha) ☐
2. Scale of production

   Purely commercial ☐ subsistence ☐ commercial and subsistence ☐

3. Have you heard of soil analysis before?

   YES ☐ NO ☐

4. Have you analysed your soil before?

   YES ☐ NO ☐

5. If No give reasons

   It's expensive ☐

   Have not heard of it before ☐

   It's unnecessary ☐

   Other(s) specify

……………………………………………………………………………

6. Do you undertake soil management?

   YES ☐ NO ☐

7. If yes, what management practice you undertake

Manuring ☐

Liming ☐

Fertilizer application ☐

8. Do you apply chemical fertilizer to your soil?

YES ☐ NO ☐

9. If no give reasons

…………………………………………………………………………

…………………………………………………………………………

Have you participated in any training on fertilizer application before?

YES ☐ NO ☐

10. If yes who were the organizers?

…………………………………………………………………………

APPENDIX B

Chemical Properties of the farmers field

FARM	pH	Ca (cmol/kg)	Mg (cmol/kg)	Na (cmol/kg)	CEC (cmol/kg)	K (cmol/kg)
Aq1	5. 08	0. 59	0. 07	0. 17	0. 95	0. 12
Aq2	5. 25	2. 31	0. 33	0. 57	3. 28	0. 07
Aq3	5. 62	1. 59	0. 32	0. 37	2. 35	0. 07
D1	6. 11	6. 94	0. 63	0. 18	8. 01	0. 26
D2	5. 94	1. 79	0. 16	0. 19	2. 21	0. 07
D3	5. 74	1. 68	0. 61	0. 18	2. 54	0. 06
ED1	5. 73	3. 00	1. 00	0. 39	4. 59	0. 21
ED2	5. 81	3. 82	0. 80	0. 37	5. 32	0. 33
ED3	5. 64	4. 30	2. 39	0. 37	7. 51	0. 46
K1	5. 75	1. 26	0. 31	0. 18	1. 82	0. 06
K2	5. 93	1. 44	0. 64	0. 19	2. 34	0. 07
K3	5. 6	4. 48	2. 34	0. 45	7. 60	0. 32
KA1	5. 4	3. 82	2. 23	0. 18	6. 43	0. 20
KA2	5. 68	2. 72	0. 16	0. 19	3. 20	0. 13
KA3	5. 97	2. 17	0. 31	0. 18	2. 85	0. 19
NM1	6. 07	4. 38	1. 46	0. 19	6. 22	0. 20
NM2	5. 9	4. 94	0. 85	0. 20	6. 13	0. 14
NM3	5. 28	3. 96	1. 43	0. 37	5. 95	0. 20
NY1	5. 61	2. 47	0. 82	0. 19	3. 61	0. 14
NY2	5. 34	2. 17	0. 33	0. 39	3. 23	0. 34
NY3	5. 34	2. 11	0. 81	0. 38	3. 50	0. 20

T1	5. 77	4. 12	1. 15	0. 38	5. 93	0. 27
T2	5. 73	2. 77	0. 33	0. 38	3. 74	0. 27
T3	5. 81	3. 39	1. 29	0. 37	5. 39	0. 33
AS1	6. 42	2. 78	0. 00	0. 18	3. 02	0. 06
AS2	6. 25	5. 19	1. 10	0. 55	6. 90	0. 06
AS3	6. 11	4. 06	1. 62	0. 38	6. 19	0. 13
AS4	6. 35	3. 23	0. 81	0. 19	4. 36	0. 13
AS5	5. 74	7. 43	1. 69	0. 39	9. 79	0. 28
AS6	6. 24	1. 49	0. 50	0. 19	2. 31	0. 14
AS7	6. 32	3. 80	0. 79	0. 37	5. 22	0. 26
AMP1	5. 61	2. 26	0. 32	0. 19	2. 83	0. 07
AMP2	6. 07	1. 46	0. 16	0. 38	2. 06	0. 07
AM1	5. 85	5. 11	0. 99	0. 38	6. 62	0. 14
AM2	6. 09	3. 51	0. 33	0. 39	4. 51	0. 28
AM3	5. 28	4. 56	0. 94	0. 36	6. 06	0. 19
AN1	5. 87	3. 30	1. 41	0. 55	5. 84	0. 58
AN2	6. 08	3. 09	1. 24	0. 54	5. 12	0. 26
AN3	5. 74	2. 81	0. 99	0. 57	4. 72	0. 34
Ba1	6	4. 33	1. 39	0. 72	6. 56	0. 13
Ba2	5. 1	2. 05	0. 79	0. 55	3. 59	0. 20
Ba3	5. 83	4. 34	1. 77	0. 56	7. 06	0. 40
Ba4	5. 77	4. 17	1. 60	0. 93	6. 90	0. 20
BK1	4. 22	1. 82	1. 32	0. 96	4. 24	0. 14
BK2	7. 5	2. 84	0. 63	0. 37	4. 03	0. 20
BK3	5. 47	22. 59	0. 50	0. 77	2. 06	0. 21

BK5	5. 34	1. 50	1. 50	0. 58	3. 71	0. 14
JK1	5. 4	3. 64	1. 65	0. 57	6. 34	0. 48
JK2	6. 52	2. 31	0. 15	0. 53	3. 19	0. 19
JK3	5. 59	4. 54	0. 32	0. 56	5. 63	0. 20
SW1	5. 87	2. 84	0. 32	0. 37	3. 72	0. 20
SW2	7. 58	3. 31	1. 16	0. 38	5. 19	0. 34
SW3	5. 78	7. 00	0. 98	0. 38	8. 48	0. 13
SW4	5. 92	2. 54	0. 64	0. 37	3. 68	0. 13
SW5	5. 5	2. 62	0. 65	0. 38	4. 19	0. 54
SW6	5. 45	3. 15	0. 33	0. 38	3. 93	0. 07
SW7	5. 74	1. 69	0. 46	0. 71	2. 99	0. 13
S1	5. 65	1. 65	0. 66	0. 38	2. 75	0. 07
S2	4. 78	2. 26	0. 32	0. 37	3. 09	0. 13
S3	5	1. 12	0. 16	0. 37	1. 85	0. 20
S4	6. 13	2. 06	1. 11	0. 37	3. 67	0. 13
S5	7. 55	3. 90	1. 25	0. 54	5. 81	0. 13
S6	5. 32	2. 30	0. 66	0. 57	3. 59	0. 07
AB1	6. 05	3. 29	-0. 16	0. 36	3. 69	0. 19
AB2	4. 84	2. 03	1. 88	0. 54	4. 71	0. 26
AB3	6. 64	2. 41	1. 13	0. 37	4. 11	0. 20
Be1	5. 9	2. 16	0. 77	0. 54	3. 59	0. 13
Be2	6. 19	2. 47	1. 08	0. 71	4. 77	0. 51
Be3	5. 92	2. 44	0. 81	0. 38	4. 10	0. 47
Be4	5. 25	1. 89	0. 94	0. 73	3. 89	0. 32
Be5	6. 57	2. 11	0. 65	0. 19	3. 28	0. 33

Eg1	7. 16	2. 19	0. 78	0. 36	3. 66	0. 32
Eg2	5. 88	2. 61	0. 82	0. 57	4. 60	0. 61
Eg3	5. 74	1. 71	1. 09	0. 54	4. 10	0. 77
ES1	5. 45	2. 51	0. 94	0. 36	4. 08	0. 26
ES2	6. 24	2. 41	0. 97	0. 75	4. 33	0. 20
ES3	6. 03	2. 24	0. 80	0. 74	3. 92	0. 13
KK1	6. 42	1. 73	1. 10	0. 73	3. 63	0. 06
KK2	6. 87	1. 88	0. 78	0. 73	3. 52	0. 13
KK3	6. 47	1. 93	0. 64	0. 75	3. 52	0. 20

APPENDIX C

Yield and Tuber K content offarmers field

FARM	YIELD t/ha	K-TUBER	FARM	YIELD t/ha	K-TUBER
Aq1	9. 04	0. 73	Ba2	6. 74	0. 55
Aq2	5. 12	0. 60	Ba3	6. 08	0. 75
Aq3	14. 41	0. 74	Ba4	10. 28	0. 84
D1	12. 9	0. 69	BK1	4. 34	0. 41
D2	13. 28	0. 79	BK2	11. 54	0. 63
D3	8. 18	0. 73	BK3	5. 11	0. 57
ED1	7. 43	0. 60	BK5	10. 98	0. 82
ED2	14. 1	0. 62	JK1	46. 43	0. 76
ED3	14. 64	0. 60	JK2	13. 3	0. 47
K1	6. 04	0. 70	JK3	17. 04	0. 80
K2	28. 83	0. 64	SW1	14. 54	0. 75
K3	5. 86	0. 67	SW2	7. 67	0. 73
KA1	11. 98	0. 76	SW3	7. 58	0. 72
KA2	3. 19	0. 63	SW4	15. 84	0. 74
KA3	5. 34	0. 69	SW5	12. 48	4. 31
NM1	4. 65	0. 61	SW6	7. 56	0. 53
NM2	4. 92	0. 63	SW7	2. 4	0. 57
NM3	6. 2	0. 54	S1	2. 57	0. 81
NY1	16. 5	0. 75	S2	6. 6	0. 50
NY2	27. 63	0. 40	S3	20. 16	0. 64
NY3	6. 55	0. 73	S4	9. 03	0. 68

T1	4. 93	0. 58	S5	6. 67	0. 69
T2	12. 58	0. 79	S6	6. 71	0. 74
T3	18. 37	0. 74	AB1	16. 09	0. 83
AS1	3. 06	0. 89	AB2	21. 78	0. 85
AS2	13. 8	0. 78	AB3	8. 52	0. 68
AS3	10. 52	0. 65	Be1	12. 5	0. 83
AS4	28. 5	0. 65	Be2	18. 98	0. 69
AS5	5. 4	0. 76	Be3	10. 48	0. 81
AS6	7. 56	0. 72	Be4	3. 68	0. 81
AS7	8. 2	0. 87	Be5	3. 24	0. 76
AMP1	14. 91	0. 71	Eg1	5. 85	0. 73
AMP2	15. 14	0. 69	Eg2	10. 08	0. 80
AM1	19. 64	0. 56	Eg3	4. 63	0. 66
AM2	14. 62	0. 66	ES1	11. 16	0. 72
AM3	10. 13	0. 75	ES2	17. 52	0. 71
AN1	17. 24	0. 83	ES3	10. 84	0. 68
AN2	8. 62	0. 77	KK1	6. 33	0. 81
AN3	5. 99	0. 75	KK2	9. 6	0. 78
Ba1	13. 98	0. 77	KK3	12. 1	0. 76

APPENDIX-D

TOWNS SURVEYED UNDER THE STUDY

CAPE NORTH	**ID**	**KEEA**	**ID**	**THLD**	
KROBO	K	ABII	AB	AMPENKRO	AMP
DEHIA	D	AMISAANO	AM	SHED	S
AQUAKROM	AQ	EGUASE	EG	SEWI	SW
NYINASIN	NY	BESEASE	BA	BAAKONDIDI	BK
NYAMEBEKYERE	NM	ESSIAM	ES	JUKWA	JK
TAIDO	T	ANTADO	AN	KAYEFI	KY
EDUKROM	ED	KWAHINKROM	KK		
		BERASI	BE		