RESPONSE OF THREE GROUNDNUT (*Arachis Hypogaea* L.) GENOTYPES TO CALCIUM AND PHOSPHATIC FERTILIZERS

HENRY TAMBA NYUMA

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CROP SCIENCE SOKOINE UNIVERSITY OF AGRICULTURE.

MOROGORO, TANZANIA.

2016

ABSTRACT

Soil fertility constraints are among major limitations for optimum groundnut production among small holder farmers in Africa due to little or no external input to replenish nutrients lost at harvest. Unsustainable cultivation of soils without appropriate measures to maintain balance in nutrient trade, (input: export) exposes soil resources to gradual degradation thereby, making soils non-responsive to nutrient uptake in worst cases. In an attempt to investigate the response of groundnut to calcium and phosphorus, an experiment was conducted in a split- plot assigned in a randomized complete block design with four replications at Crop museum, Sokoine University of Agriculture, Morogoro in 2015. Two factors, including three groundnut genotypes (Mangaka, Masasi and Pendo) as main plot and phosphorus and calcium at 0, 55 kg P/ha and 125 kg Ca/ha from diammonium phosphate (DAP) and Minjingu mazao, respectively, were used as sub plot factors. Results from the study showed that application of DAP had significant ($P \leq 0.05$) effect on number of nodules, net assimilation rate, pod harvest index (HI %), shelling percent, 100- kernel weight and kernel yields. Minjingu mazao had significant ($P \leq 0.05$) effect on leaf area index, crop biomass, crop growth rate, biological yield and protein content. Fertilizer application had no significant effect oil content of groundnut. Application of DAP significantly increased kernel yields from 1505 - 1760 kg/ha while significant increase (2 676 – 3 025 kg/ha) was observed in pod yield. A value cost ratio (VCR) of 2.2 was obtained with application of 55 kg P/ha whereas application of Minjingu mazao resulted into a VCR of 0.3. A net income of $ 1 968.90 was accumulated with application of P compared to $ 550.05 under calcium application. A VCR of > 2 as indicated from the current study revealed that farmers can increase kernel and grain yields hence profitability through the application of DAP.

Key words: Soil fertility, Soil resources, Groundnut, Genotypes, Calcium, Phosphorus, VCR

DECLARATION

I, HENRY TAMBA NYUMA, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

Henry Tamba Nyuma Date

(MSc. Crop Science Candidate)

The above declaration is confirmed;

Prof. C. L. Rweyemamu Date

(Supervisor)

COPY RIGHT

ACKNOWLEDGEMENTS

All thanks and appreciation to the most high God who stood firm to his promise that he would never leave me nor abandon in whatever circumstances I had to face along the way (Hebrews 13:5).

My gratitude goes to the International Institute of Tropical Agriculture (IITA) for financial support which empowered me to undertake and complete this study successfully. I owe gratitude to Dr. Amare Tegbaru who was very instrumental in making this study possible. Special thanks go to Ken Giller and Greta Van den Brand who were instrumental in helping me get along with literature aspect of my studies.

I wish to extend special appreciation to the University of Liberia (UL) family, especially the college of Agriculture and Forestry for granting me the permission to pursue higher education. My thanks and appreciation goes to Dr. Roland C. Massaquoi, Dean of College of Agriculture and Forestry and my immediate boss, Professor James Kiazolu, head of Soil test, plant and water analysis laboratory at the University of Liberia as well as Faculty and staff for their moral support.

I am also proud to express my utmost gratitude to my supervisor Professor Cornel L. Rweyemamu, whose mentorship and selfless effort through constructive criticism, encouragement, and academic advice has shifted my perspective about agricultural sciences. Sincere thanks to professors and staff at the Department of Crop Science and Horticulture for their guidance in ensuring that I achieved my study objectives.

I wish to extend thanks to my colleague, Mr. Paul Saidia of Department of Crop Science and Mr. Kisetu of Department of Soil Science for their kind assistance during data analysis. Special gratitude goes to Ms. Judith Kahamba of Institute of Developmental studies institute for motivation and kind assistance during the writing of dissertation.

Acknowledgement goes to the leadership of the Wesleyan Church of Liberia for their Spiritual and moral support which kept served as motivation in difficult time during my studies. I wish to appreciate District Director, Rev. Peter Kollie, Rev. James Duo, Rev. Gordan Pollay and members of Praise Wesleyan Church for their numerous prayers and best wishes for me.

I also wish to use this opportunity to acknowledge the moral and spiritual support of my family while I was away from home, my beloved mother Mrs. Esther K. Nyuma, Sahr Joseph Nyuma, Maima Fahnbulleh, Retired Major Sahr Roberts and family, Mr. and Mrs. James Kolleh and the rest of my family members in and out of the country. My appreciation goes to the Mhana family for their role as my adopted family during my time of studies. Especially, to Ms. Favour Happiness Mhana for her assistance in helping me get along with day-to-day activities at Sokoine University of Agriculture (SUA).

DEDICATION

This dissertation is dedicated to my parents, the late Professor Sahr Joseph Nyuma, Mama Esther Krubo Nyuma for providing an enabling environment that encouraged me to embark upon my academic sojourn. Most importantly to the people of Liberia who stood the test of time and were able to defeat the deadly Ebola Virus disease that took away the lives of thousands of our loved ones during a crucial period of my studies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION AND SYMBOLS

%	Percent
<	Less than
>	Greater than
±	Plus or minus
≤	Less or equal to
$	Dollar
AAS	Atomic Absorption Spectrophotometer
AE	Agronomic efficiency
ANOVA	Analysis of variance
ANR	Average nutrient retention rate
Ave	Average
BM	Biomass
C:N	Carbon Nitrogen ratio
Ca	Calcium
CaO	Calcium oxide
cm	Centimeter
$cmol_c$	Centimole
CO_2	Carbon dioxide
CP	Crude protein
Cu	Copper
CV	Coefficient of variation
DAP	Di–ammonium phosphate
FAO	Food and Agriculture Organization
FAOSTAT	Food Agricultural Organization Statistics data

Fe	Iron
g	Gram
ha	Hectare
HI	Harvest index
IITA	International Institute of Tropical Agriculture
K	Potassium
K^+	Potasium ion
K_2O	Potassium oxide
kg	Kilogram
LAI	Leaf area index
M J	Mega joule
m^2	Meter square
Max	Maximum
m.a.s.l	Meters above sea level
Mg	Magnesium
mg	Milligram
MgO	Magnesium Oxide
Min	Minimum
Mn	Manganese
N	Nitrogen
n.s.	not significant
Na	Sodium
NAR	Net assimilation rate
NUE	Nutrient use efficiency
O_2	Oxygen

^{o}C	Degree Celsius
OC	Organic Carbon
OFC	Overseas Food Corporation
OM	Organic Matter
P	Phosphorus
P_2O_5	Phosphorus penta- oxide
R	correlation coefficient
RCBD	Randomized Complete Block Design
RH	Relative humidity
SE	standard error
SSP	Single super phosphate
SUA	Sokoine University of Agriculture
t	Tonne
TDM	Total dry matter
TMA	Tanzania Meteorology Agency
Tsh	Tanzania shilling
UL	University of Liberia
URT	United Republic of Tanzania
USD	United States dollar
USDA	United States Department of Agriculture
USDA-FAS	United States Department of Agriculture – Foreign Agricultural Service
VCR	Value cost ratio
WAP	Week after planting
Zn	Zinc

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Groundnut (*Arachis hypogaea* L.), also known as peanut, earthnut, monkey-nut or goober, is a self-pollinating, indeterminate, annual herbaceous legume crop (Adinya *et al.,* 2010). Groundnut is the thirteenth most important food crop of the world; fourth most important source of edible oil and the third most important source of vegetable protein (Sorrensen *et al.*, 2004; Taru *et al.,* 2008). Groundnut has the potential to fix atmospheric nitrogen at the rate of 21 to 206 kg/ha annually in soils through root nodule bacterium belonging to the genus *Rhizobium*, thus improves soil fertility (Giller, 2001; Yakubu *et al*., 2010). Nutrient deficiency, especially calcium (Ca) and phosphorus (P) have been reported as major abiotic factors limiting groundnut production especially in Africa where production is characterized by low fertilizer inputs (Bationo *et al.*, 2006; Vara Prasad *et al*., 2009).

In Tanzania, groundnut is the third most import source of edible oil. The crop is grown mainly by small-scale farmers mainly with local tools and little or no fertilizer input (Taru *et al.,* 2010). Adoption of quality seed, cost effective technologies and good agronomic practices especially, appropriate use of fertilizer resources are major steps in enhancing groundnut production among smallholder farmers.

1.2 Problem Statement and Justification

Despite being an important oil crop in Tanzania, groundnut yield is still low, around 0.96 t/ha, compared to its yield potential of 2 t/ha (FAOSTAT, 2013). Such low yield has been attributed to abiotic and socio- economic factors (Pande and Narayana, 2002;

Caliskan *et al.*, 2008) including low fertility status of soils, poor agronomic practices irregular rainfall patterns as well as availability and access to fertilizer resources.

Inappropriate management of soil resources compromises soil fertility and contributes to declining nutrient deficiency especially, Ca and P which have been identified as limiting factors for groundnut production (Msolla *et al.*, 2005; Compaore *et al.*, 2011). Unsustainable agronomic practices such as little or no fertilizer use in the absence of standard soil test is a major abiotic factor affecting soil productivity, crop yield and subsequently farmers' income at household level (Semoka, 2002).

As a crop of nutritious and economic importance, groundnut seeds contain 40 - 50% fat, 20 - 50% protein and 10 - 20% carbohydrate depending on the variety (Okello *et al.*, 2010). Groundnut thrives under low rainfall and has the ability to fix atmospheric nitrogen thus, leaving positive residual effects which could therefore be grown with limited capital investment.

In Tanzania, groundnut is grown in areas below 1500 meters above sea level (m.a.s.l), where reasonable rainfall is received most by small scale farmers (with plot sizes of less than 0.5 ha). Some harvested groundnut kernels are sold to local mills for cooking oil and margarine processing. The remaining is either sold or used locally for confectionery purposes. Besides, groundnut is also an inexpensive source of human nutritious minerals; vitamins, edible oil, as well as other manufactured products and animal feeds (Sorrensen *et al.*, 2004). Therefore, the multiple uses of groundnut crop make it important as food, feed, fuel and cash-crop for the available domestic market given the fact that most of its produce is locally consumed.

Calcium is the first and most critical element in growth and development of groundnut seeds and is the main limiting element of the groundnut production (Ntare *et al*., 2008). Shortage of calcium and low soil pH are important limiting factors in groundnut growth and production (Gashti *et al.*, 2012).

In many parts of the Tropics where groundnut is grown, it is evident that soils with low Ca levels result into pod rot and poorly filled pods ("pops") (Ntare *et al*., 2008; Kamara *et al*., 2011). These are mainly due to effects of varying soil Ca concentrations, with large – seeded types requiring higher levels of Ca as reported by Walker *et al*. (1978). Low content of calcium leads to several serious problems for groundnut including the production of immature pods, black embryo in seed, weak germination of seeds and increases production potential of aflatoxin, especially in soils which are suitable for growth and activity of (*Aspergillus flavus*) fungus and thus, decays peanut pod (Murata, 2003).

Phosphorus is the second major essential nutrient element for crop growth and quality yield. The most obvious effect of P is on the plant root system. There is higher requirement for P in nodulating legumes compared to non-nodulating crops as it plays a significant role in nodule formation and fixation of atmospheric nitrogen (Brady and Weil, 2002). Due to the important role played by P in the physiological processes of plants, adequate supply of P to soil deficient in this nutrient enhances groundnut yield and farmers income.

There is not much documented evidence on specific fertilizer recommended rate (especially, for Ca and P) for groundnut in Tanzania despite the economic potential of groundnut as an important oil crop. Given the economic potential of groundnut, optimal fertilizer use, appropriate crop and soil fertility management practices could enhance productivity, hence, food security and income of smallholder farmers. The aim of this study is to investigate growth and yield response of groundnut genotypes as influenced by fertilizer sources of calcium and phosphorus.

1.3 Objectives

1.3.1 Overall objective

To identify appropriate fertilizer rates for Ca and P from inorganic sources for groundnut production.

1.3.2 Specific objectives

(i) To evaluate the effect of calcium and phosphatic fertilizers on growth and yield of groundnut

(ii) To assess the influence of calcium and phosphatic fertilizers on groundnut seed quality

(iii) To determine the profitability of calcium and phosphorus fertilizer application on groundnut production.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and Distribution

The cultivated groundnut (*Arachis hypogaea L.)* is an ancient crop of the New World, which originated in South America (southern Bolivia/North West Argentina region) where it was cultivated as early as 1000 B.C. (Weiss *et al.*,2000). Groundnut originated in Latin America and was introduced to the African continent from Brazil by the Portuguese in the 1600's (Adinya *et al.*, 2010).

Globally, groundnut is grown on approximately 42 million hectares with a total production of over 35 million tons (Rao *et al.,* 2013). More than half of the production area is in arid and semi-arid regions (Reddy *et al.,* 2003). Tanzania accounts for 2.9% of the global area for groundnut cultivation and 1.7% of global production (FAOSTAT, 2013). Major groundnut growing countries include China, India, the United States and Nigeria (Nautiyal, 2002; USDA-FAS, 2010).

2.1.1 Botany and morphology

Groundnut is a self-pollinating, indeterminate, annual herbaceous legume crop belonging to the legume family *Fabaceae*, tribe *Aeschymanomeneae*, subtribe *Stylosanthineae*. The genus and species names *Arachis hypogaea* are derived from Greek words arachos, meaning weed, and hypogea, meaning underground chamber (Adinya *et al.,* 2010). Groundnut is a geocarpic crop which produces fruits (pods) below ground. Groundnut pods are usually located to a depth of 7 - 10 cm referred to as pod zone (Ademiluyi *et al.*, 2011). Several studies have shown that there is a large agro-morphological diversity in groundnut. This large diversity has led to the distinction of two sub-species: *Arachis hypogaea* subsp. *hypogaea* and *Arachis hypogaea* subsp. *fastigiata*.

These subspecies are distinguished primarily by their port, usually crawling in *hypogaea* and erected in *fastigiata,* the absence of flowers on the main axis in *hypogaea* and the difference in leaf color: dark green in *hypogaea* and light green in *fastigiata* (Fonceka, 2010). Both subspecies were themselves divided into several botanical groups including several commercial types. Table1 shows the botanical groups of *arachis* subspecies.

Table 1: Subspecies of Arachis hypogaea

Subspecies	**Site of flower and pod**	**Growth habit**	**Botanical variety and market type**	**Seed dormancy**	**Maturation time(days)**
Hypogaea	Lateral branches	Spreading	Hypogaea Runner	Present	Long 145 – 165
		Bunching	Hypogaea Virginia Hirstua	Present	Short 90 – 100
Fastigiata	Main stem	Erect	Fastigiata Valencia Vulgaris Spanish	Low/ absent Absent Low/ absent Low/ absent	

Source: Madhan and Nigam (2013)

Groundnut emergence is intermediate between the epigeal (hypocotyl elongates and cotyledons emerge above ground as in soybean) and hypogeal (cotyledons remain below ground as in field pea). The hypocotyl elongates but usually stops before cotyledons emerge. Leaves are alternate and pinnate with four leaflets (tetra foliate). Groundnut plant can be erect or prostrate (15 - 61 cm) with a well-developed taproot and many lateral roots and nodules. Groundnut plants develop three major stems, i.e. two stems from the cotyledonary axillary buds equal in size to the central stem during early growth. Bright yellow flowers with both male and female parts are located on inflorescences resembling spikes in the axils of leaves.

One to several flowers may be present at each node and are usually more abundant at lower nodes. The first flowers appear at 4 to 6 weeks and may continue through the various growth stages after planting with maximum flower production occuring 6 to 10 weeks after planting (Table 2). The groundnut crop matures after 7 to 9 weeks in the soil, which is indicated by maximum levels of protein, oil, dry matter, and presence of darkened veining and brown splotching inside the pod. Groundnut is harvested when most of the leaves turned yellow and pods become hard (Arakama, 2013); usually 120 – 150 days after planting depending on the variety (Oyelade *et al.,* 2011).

2.1.2 Utilization

Groundnut is thirteenth most important food crop and the third major oilseed of the world next to soybean and cotton (Taru *et al.,* 2010; USDA-FAS, 2010; Nautiyal *et al*., 2011). The crop is mainly grown for its oil, protein and carbohydrates (Abdzad *et al.*, 2010). The multiple uses of the groundnut plant make it an important food and cash crop for domestic consumption and export. Globally, 50% of total groundnut production is used for oil extraction, 37% for confectionery use and 12% for seed (Taru *et al.,* 2010).

In Tanzania, the crop is ranked third after cotton seeds and sunflower as a source of edible oil. Though grown mainly for confectionery purposes, groundnut is a food crop which is consumed within the household though it can be sold to earn income

(Mangasini *et al.*, 2013). The crop can also be used as fodder for farm animals while the residue is returned to the soil as organic matter. However, in West Africa, groundnut is crucial for economic prosperity and nutritional welfare of smallholder farmers (Kamara *et al.*, 2011). Groundnut is the principal source of dietary protein, oil/fat, and vitamins such as thiamine, riboflavin and niacin. Groundnut paste is an important source of calories for small children, particularly those being weaned (Kamara *et al.*, 2011). Though average national yield of 0.6 t/ha is lower than other African countries (FAOSTAT, 2013), groundnut is a major part of household diets and also an important source of income of smallholder farmers especially in Loaf County. Improvements in groundnut productivity and output will improve the sustainability of farming systems, impact on rural employment, trade and purchasing power for resource-poor smallholder families, strengthen the economic position of women and improve household nutrition (Kamara *et al*., 2011).

2.1.3 Climatic and soil requirements

As an essential tropical plant, groundnut requires a long and warm growing season (Weiss *et al*., 2000). The favourable climate for groundnut is a well-distributed rainfall of at least 500mm during the growing season, and with abundance of sunshine and relatively warm temperature. Weiss *et al.* (2000) reported that temperature in the range of 25 to 30°C is optimum for plant development. Heat and/or drought induced stresses are the major environmental factors limiting pod yields in the Semi- Arid tropics. Craufurd *et al.* (2002) observed that high day/night temperature (38/22°C) from 21 to 90 days after planting reduced total dry weight by 20 to 35%, seed harvest index by 0 to 65% and seed dry weight by 23 to 78%.

Table 2: Groundnut growth stages description*

Growth stage Codes	Description
Vegetative	
VE	50% of plants with some parts visible at soil surface
V1	50% of plant with 1 developed node on the main axis
V2	50% of plants with 2 developed node on the main axis
V3	50% of plants with 3 developed nodes on the main axis
V4[b]	50% of plants with 4 developed nodes on the main axis
V(n)	50% of plants with n developed nodes on the main axis
Reproductive	
R1	50% of plants beginning bloom. 50% with at least 1 or open flower at any node
R2	50% of plants beginning peg. 50% of plant with 1 elongated peg (gynophore)
R3	50% of plants beginning pod. 50% of plants with 1 peg in soil with turned swollen ovary at least twice the width of the peg
R4[b]	Full pod. 50% of plants with 1 fully – expanded pod, to dimensions characteristics of the cultivar
R5	Beginning seed. 50% of plants with 1 fully – expanded pod with cotyledon growth visible when pod cut in cross section with razor blade(past liquid endosperm phase)
R6	Full seed. 50% of plants with 1 pod with seed seeds filling cavity of pod when fresh
R7	Beginning maturity. 50% of plants with 1 pod showing visible natural coloration or blotching of inner pericarp coloration
R8	Harvest maturity. 50% of plants with 2/3 to ¾ of all developed pods having testa or pericarp coloration
R9	Over –matured. 50% of plants with 1 undamaged pod showing orange –tan coloration of the testa and/ natural peg detioration

* According to Boote (1982)

The optimum day and night temperature for vegetative and reproductive growth and development in groundnut ranges from 25/25 to 30/26˚C and from 25/25 to 26/22˚ C, respectively (Kakani *et al.*, 2002). Groundnut productivity is low in the semi-arid tropics mainly due to drought caused by low and erratic rainfall (Nigam *et al.,* 2001).

Groundnut thrives best in light textured, well-drained sandy loam, loamy or organic soils with pH of 5.3- 6.5 (Farm Management Handbook, 2010) which allow easy penetration and development of pegs. Generally, 600 – 650 mm water is sufficient to raise a full groundnut crop however, irrigation is necessary under prolonged moisture stress especially, during flowering and pegging and pod formation as moisture stress has adverse effects on Ca uptake which is essential for proper pod formation, seed development, seed quality and germination in the next season (Madhan and Nigam, 2013). Soil temperatures lower than 18°C reduce germination and crop growth and temperatures higher than 37°C during pod development restrict pod and kernel growth resulting in lower pod yields (Vara Prasad *et al*., 2000; Ghosh *et al*., 2006).

2.1.4 Rainfall and soil moisture

Rainfall is the most significant climatic factor affecting groundnut production, as 70% of the crop area under semi-arid tropics is characterized by low and erratic rainfall. Low rainfall and prolonged dry spells during crop growth period were reported to be main reasons for low yields in most of the regions of Asia and Africa (Reddy *et al.,* 2003). Badiane (2001) reported that persistent droughts and insufficient rainfall represent one of the greatest constraints on groundnut crop. Dulvenbooden *et al.* (2002) reported that groundnut production is significantly determined by rainfall.

Appropriate soil moisture management is crucial to achieve early germination, uniform plant establishment and high productivity in the crop. Yakubu *et al.* (2010) reported that nodulation and nitrogen fixation show rapid decline under drought conditions and maintained that prolonged desiccation could lead to nodule loss with partial inability to further form nodules. At harvest, traits such as seed weight are the sum of development and responses to stresses over the growing season and particularly during the reproductive phase of growth (Teng *et al.,* 2008).

Boote *et al*. (1982) reported that optimum water management involves scheduling irrigation to maintain less than 50% soil water deficit in the top 30cm during early growth and irrigating at 25% soil water deficit during pod formation and seed growth. Some authors suggested that if the soil water potential is measured in the top 15–30 cm of soil, irrigation should be scheduled to maintain soil water potential above −0.6 bar (−60 kPa) on sandy or sandy loam soils, although irrigating to maintain soil water potential above −0.25 to −0.50 bar (−25 to −50 kPa) may be desirable during long, dry, hot periods occurring during the sensitive growth stages of pegging, pod formation and early pod fill (Vara Prasad *et al*., 2000).

2.2 Nutrient Requirements

Although groundnut has the ability to fix atmospheric nitrogen, balanced nutrition can enhance crop development and further increase yield. To achieve optimum yield and sustained production, attention should be given to the rate of nutrient removal based on soil analytical data. Optimum production of groundnut production requires balanced nutrition as nutrient deficiencies can have adverse effects on crop growth development and yield. Panda (2010) suggested 10 -20 kg N/ha, 18 kg P/ha and 33 kg K/ha under rainfed condition and 20 kg N/ha, 18 - 40 kg P/ha and 17 - 33 kg K/ha under irrigated condition. Rezaul *et al.* (2013) recommended 50 and 110 kg/ha P and Ca, respectively for optimum groundnut production. Yakubu *et al.* (2010) observed poor nodule formation in soils deficient in N and P. Compaore *et al.* (2011) reported that Ca and P are also important nutrients in groundnut production whose deficiency cause reduction in crop yield.

2.2.1 Effect of phosphorus on growth and yield of groundnut

Phosphorus is an essential constituent of nucleic acids and stimulates root growth as well as increase nodule activity in plant. Phosphorus is essentially required for healthy growth with efficient root system and profuse nodulation which, in turn can affect the N_2-fixation potential (Kwari, 2005). Deficiency of P due to inavailability of soluble phosphate in soil solution is considered as a limiting factor in plant nutrition (Uma and Sathiyavani, 2012). Tarawali and Quee (2014) reported that application of P as single super phosphate (SSP) enhanced crop performance and increased nodule formation from 1 878 – 2 403 kg/ha as well as biomass production from 2 324 – 2 479 kg/ha. Kamara *et al.* (2011) also reported increase in groundnut biomass due to the application of P, given that phosphorus is known to enhance the development of more extensive root system.

2.2.2 Effect of calcium on growth and yield of groundnut

Calcium is a critical and limiting element for groundnut production the Tropics where the crop is widely grown (Ntare *et al*., 2008). Calcium deficiency leads to high percentage of aborted seeds (empty pods), improperly filled pods aborted or shriveled fruit, including darkened plumules and production of pods without seed (Ntare *et al.,* 2008). Among the secondary macro nutrients, calcium deficiency causes groundnut pegs and pods to abort hence, reduced yield (Meena *et al*., 2007). Rahman (2006) observed that Ca significantly influenced plant height with the longest plants resulting from plots treated with 150 kg

Ca/ha, whilst the shortest plants were recorded in the control plot. Rahman (2006) further reported that Ca significantly affected all the yield attributes and qualitative characteristics such as protein and oil contents with the increasing level of Ca from 0 – 100 kg/ha. Murata (2003) reported that increasing Ca application rates increased the pH of the soil thereby eliciting positive effects on the growth and productivity of groundnut. Gashti *et al*. (2012) recommended that groundnut pegging zone be kept moist as it facilitates the uptake of Ca by pods and is essential for seed development.

2.2.3 Effects of phosphorus and calcium on groundnut quality

Groundnut quality is affected by availability of essential plant nutrients, either from organic or inorganic sources based on soil analysis. Rezaul *et al.* (2013) reported positive effects of Ca and P on growth parameters, yield and yield contributing characters of groundnut. Tarawali and Quee (2014) reported enhanced crop performance, increased nodule formation from 1878 – 2403 kg/ha due to application of P as single super sulphate (SSP). Alireza *et al.* (2012) reported that 100- kernel weight was affected by increasing rate of Ca, thus resulting into bigger kernel size and hence, higher kernel weight.

Rezaul *et al.* (2013) recommended that 50 and 110 kg/ha P and Ca, respectively had significant effect on crop quality and yield, increasing yield from 1000 to 3000 kg/ha. Kamara *et al.* (2011) reported that application of Ca and P fertilizers increased nutrients availability to groundnut crop and subsequently led to greater utilization of assimilates into the pods and ultimately increased number of filled pods and shelling percent.

2.3 Groundnut Production in Tanzania

Commercial groundnut production in Tanzania started around 1946 – 1951 (URT, 2012) under an ambitious British colonial plan to grow 1 284 000 ha in East Africa to meet the high demand of fat in Europe at the time. The aim was to produce 800 000 tons per annum under the Overseas Food Corporation (OFC) which developed projects in Kongwa, Dodoma investing USD 8.3 million and Urambo (Tabora) some USD 120 million. Irregular rainfall and crop diseases rendered the project not viable (URT, 2012) .

Important growing regions include Mtwara, Tabora, Shinyanga, Kigoma, Dodoma and Mwanza. These regions receive annual rainfall varying between 500 and 1200 mm (Mangasini *et al.,* 2013). Despite been the third source of edible oil after cotton seed and sunflower in Tanzania, average groundnut yield is less than 1 t/ha compared with Nigeria (1.5 t/ha) and Sudan (0.85 t/ha) (USDA-FAS, 2010).

2.3.1 Groundnut varieties commonly grown in Tanzania

Cultivated varieties of preference grown in include Nyota, Johari, Pendo, ICGV, 99555, SM99557 and Sawia. While Virginia type varieties are Mangiwae, Kanyomwa and Chimbuvila. Kanyomwa is characterized by having 2-3 kernels per pod while Manguru and Chimbuvila have predominantly 2 big kernels per pod. Improved varieties include Mangaka, Masasi, Pendo, and Nyota. Pendo and Nyota are both Spanish types whereas Johari and Sawia belong to the Virginia type. Pendo is most preferred by farmers due to its early maturity, high yield performances, ease to harvest and plucking, marketability and seed size.

However, on-farm experiments conducted by Bucheyeki *et al.* (2008) for adaptation and adoption of promising groundnut varieties in Tanzania revealed that farmers and researchers ranked Pendo and Johari as the most preferred genotypes. The study also revealed that Pendo (1 444 kg/ha) and Johari (1 163 kg/ha) out yielded other varieties.

2.3.2 Agronomic practices of groundnut crop in Tanzania

Currently, groundnut production in Tanzania is mostly done through smallholder farming. Groundnut in the country is grown entirely under rain-fed conditions. It is usually intercropped with cereals or cassava. Normally, the crop is grown without application of fertilizers. Groundnut farmers in Tanzania often use wide spacing, (50 cm rows, 10 cm within rows for Spanish varieties, 20 000 plant/ha and 50 cm rows, 15 cm within rows for Virginia varieties, (13 333 plant/ha) (Ronner *et al.*, 2012). However, Ronner *et al*. (2012) recommended a closer spacing for optimum benefits. Groundnut varieties of preference include Pendo and Johari though other varieties are grown across the country (Bucheyeki *et al.,* 2008). Farmers grow groundnut on flat seedbeds, on the tops of ridges, or just on the lower sides of these ridges. Earthing is an agronomic practice that is carried out by piling up soil to the base of the crop at pegging to ensure proper burial of gynophores to enhance optimum pod formation as groundnut is a geocarpic crop (Barker, 2005).

Hoe and hand weeding are common practices where hoe weeding is mainly practiced at pegging so as to avoid damage to forming pods. Irrigation in part, adverse weather conditions particularly unreliable rainfall have been recognized as one of the factors responsible for low yields (Bucheyeki *et al.,* 2010).

Harvesting of groundnut is usually done manually with hoe when 50% of the plants have developed pods having testa or pericarp discoloration.

2.3.3 Fertilizer use on groundnut production in Tanzania

The use of fertilizers in crop production in Tanzania is still below minimum recommended rate of 50 kg/ha set by Abuja Declaration. In Tanzania, crop research does not indicate fertilizer recommendation for oil crops including groundnut (Kamhabwa, 2014). Like most crops cultivated by smallholder farmers, groundnut production is characterized by fluctuating yields as cultivation is not usually done in irrigated land characterized by erratic rainfall and low application of fertilizers due to high input prices (Kamhabwa, 2014). However, several reports, (Bucheyeki *et al.,* 2008; Bucheyeki *et al.*, 2010; Mangasini *et al.*, 2013) highlight production and agronomic limitations affecting groundnut production in the country.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of Study Area

Field experiment was laid out at Sokoine University of Agriculture (SUA), Crop Museum situated at latitude 6° 45'' South and longitude 37° 40" East at 525 m.a.s.l in Morogoro municipality. The area is situated at the foot of Uluguru Mountain in Morogoro and has a bi-modal rainfall pattern, with short rains from November to December and long rains from March to May/June. Rainfall is predominantly sub- humid and its distribution is irregular and unreliable (Mahoo *et al*., 1999). The experimental area is characterized by kaolinitic clay soils, which are well drained and mostly clay (Semoka, 2003). The area was under sweet potatoes *(Ipomea batatas L.)* during the previous cropping season of 2013/ 2014.

3.2 Experimental Materials

Three groundnut varieties, Pendo, Masasi and Mangaka obtained from Naliedendele Agricultural Research Institute (ARI), in Mtwara, Tanzania were used in the experiment. Fertilizer materials used included Minjingu Mazao which contained N (10%), 20% P_2O_5, 25 % CaO, 5% S, 0.5% Zn, 1.5% MgO and 0.1% Boron (Minjingu Mines and Fertilizer Ltd, 2014), and Diammonium Phosphate (DAP) $(NH_4)_2$ (HPO_4) contains 18% N and 46%P_2O_5.

3.3 Soil Sampling and Analysis

Soil samples were collected as recommended by Landon (1991) at the depth of 0 – 20cm. Composite samples were prepared and taken to the Soil Science laboratory at SUA for Physicochemical analyses. Analyses conducted included particle size (%), soil pH (1:2.5), organic carbon (%), total nitrogen (%), available phosphorus (mg/kg), exchangeable bases ($cmol_c^{(+)}$/kg), and micronutrients (mg/kg). Soil particle size distribution was determined by Bouyoucos Hydrometer method (Gee and Bauder, 1996) and textural classes were determined by using USDA textural triangle. Soil pH was determined electrometrically in 1:2.5 soil–water suspensions as described by Thomas (1996). Available P was analyzed using Bray –1 (Olsen and Sommers, 1982). Organic carbon determination was done by wet digestion method of Walkley and Black (Nelson and Sommers, 1982). Total N was determined by the micro – Kjeldahl digestion–distillation method (Bremner and Mulvaney, 1982). Exchangeable bases, K and Na were analyzed by flame photometer whereas Ca and Mg were determined by Atomic Absorption Spectrophotometer (AAS) as described by Petersen (1996). Available Cu, Zn, Fe, and Mn were extracted by DTPA as described by Lindsay *et al*. (1978). And soil biological characteristics were not determined during the time of the study. Detailed soil analysis procedures are shown in Table 3.

Table 3: Methods for determinationation and characterization of soil at the experimental site

Properties	Unit	Method	Reference
A. Physical			
Texture		Bouyoucos hydrometer	Gee and Bauder (1996)
Sand	%		
Clay	%		
Silt	%		
B. Chemical			
pH		1:2.5 soil: water Suspensions	Thomas (1996)
Organic Carbon	%	Walkley Black	Nelson and Sommers (1982).
Total Nitrogen	%		Bremner and Mulvaney (1982)
Organic Matter	%		
C : N ratio			
Extractable P	mg/kg	Bray -1	Olsen and Sommers (1982).
Exchangeable Cations		Ammonium acetate saturation	Petersen (1996)
Calcium	$cmol_c^{(+)}/kg$		
Magnesium	$cmol_c^{(+)}/kg$		
Potassium	$cmol_c^{(+)}/kg$		
Sodium	$cmol_c^{(+)}/kg$		
Micronutrients (mg/kg)		DPTA extraction	Lindsay *et al.* (1978)
Iron	mg/kg		
Manganese	mg/kg		
Cooper	mg/kg		
Zinc	mg/kg		

3.4 Land Preparation

Land clearing was done manually while ploughing and harrowing were done by tractor and leveling was carried out by hoe. Ploughing was done at 20 cm depth and field lay out of plots as described by Kanyeka *et al.* (2007).

3.5 Experimental Lay Out and Agronomic practices

A split plot experiment was laid out in Randomized Complete Block Design (RCBD) with four replications and three groundnut genotypes (Mangaka, Masasi and Pendo) as main plot factor (factor A) whereas fertilizer types (control, DAP and Minjingu mazao) were applied as sub –plot factor (factor B).

Fertilizer types were applied as follows: 0 kg ha, 55 kg P/ha as DAP and 125 kg Ca/ha as Minjingu mazao. Minjingu mazao contained 20% P_2O_5; (9% P) which was computed by multiplying % P_2O_5 by 0.43. Phosphorus was applied as diammonium phosphate supplying 91% P (54.6 kg P/ha). Minjingu mazao used as ource was applied at pegging. Spacing of 0.45m by 0.1m (between rows and between hills respectively) was used with 4 rows and 10 plants per row with a plant population of 222 222 /ha. A main plot size of $5.4m^2$ and sub- plot size of $1.8m^2$ was used giving a total experimental area of 22.7 by 9 ($204.3m^2$). Sowing was done on 22 January 2015 with single seed per hill.

Agronomic practices including weeding, irrigation, fertilizer applications and earthing, were carried out. Basal application of P as DAP, (accounting for 91% P) was done at sowing whereas Ca was applied as Minjingu mazao, at peg formation,6 weeks after planting (WAP). Weeding was done at 4, 6, 8 and 10 (WAP). Hoe weeding was done prior to flowering (4 WAP) whereas hand weeding was done thereafter throughout the growing season so as to avoid interference with flowering, peg and pod formations. Irrigation was carried out based on available soil moisture content. Earthing was done at the onset of peg formation which was at 6 WAP.

Boring pests were observed at vegetative stage and were controlled by spraying with Cypermathin 25 EC at 1ml/liter of water. Soil rot (*Rhizoctonia solani*) was observed at physiology maturity and controlled as described by Turner and Backman (1988).

Harvesting was done manually when 50% of the plants have developed pods having testa or pericarp discoloration.

3.6 Data Collection

3.6.1 Weather data

Weather data was collected from Tanzania Meteorological Agency (TMA), SUA station. Daily maximum and minimum temperature ($^{\circ}C$), relative humidity (%), evapotranspiration (PAN) (mm), radiation (MJ m^{-2} d^{-1}) and rain fall (mm) were collected and means were recorded.

3.6.2 Crop data

Crop growth and phenological variables were assessed as described by Boote (1982). These included:

(a) **Days to 50% crop emergence**: assessing the number of plants visually by stands, 2 weeks after planting from the middle rows.

(b) **Days to 50% flowering**: determined visually by counting the number of days when 50% of the plants from the experimental units had at least one or two open flowers.

(c) **Numbers of nodules per plant**: Determination of number of nodules per plant was done by counting the number of nodes visible on the roots of three plants per plot at 4, 6 and 8 WAP and average was calculated as follows :

$$\text{Number of nodules per plant} = \frac{\text{Total number of nodules from three plants}}{\text{Number of plants}}$$

(d) Days to maturity: Days to crop maturity were assessed as described by Arakama (2013).Three plants were uprooted and the number of mature pods indicated by the blackening of the internal shell wall with brownish yellow kernel was recorded.

(e) Biomass per plant (g/plant): was determined from three plants including roots were harvested from the penultimate rows of the plot for destructive sampling at 4, 6, 8 and 10 WAP. Plants were oven dried at 70 °C for 48 hours and the dry weights were recorded using (Doran 7000, Doran Inc.) electronic weighing scale. Calculations were done as follows:

$$\text{Biomass per plant} = \frac{\text{Biomass of three plants}}{\text{Number of plants}}$$

(f) Leaf area index: Leaf area index (L.A.I) was determined at growth stages as follows: V4, R1, R2 and R3 by use of destructive method. Leaf area index was calculated as described by Brown (1984) as indicated below:

$$\textbf{LAI} = \frac{\text{Leaf area of three plants (cm}^2)}{\text{Ground area of three plants (cm}^2)} \times 0.9$$

(g) Crop growth rate (g.m^2/day): CGR was determined by assessing the ratio of crop biomass including roots to time interval of sampling from three plants per plot. Therefore, CGR was computed as recommended by Brown (1984).

$$\textbf{CG R} = \frac{W_2 - W_1}{SA\,(t_2 - t_1)} = g\ m^2\ /\text{day}$$

Where, SA= Ground area occupied by the plants at each sampling. W_1 and W_2 are the total dry matter production in grams at different growth stages t_1 and t_2, i.e. at V_4, R_1, R_2 and $R_{3,}$respectively.

(h) **Net assimilation rate (g m^2 /day):** NAR was determined by assessing the ratio of CGR and LAI at various growth stages. Net assimilation rate was calculated as described by Brown (1984).

NAR = (1/LAI) (dw/dt) = g m^2/ day

Where;

NAR = net assimilation rate

dw/dt = the change in plant dry matter per unit time

LAI = leaf area index

3.6.3 Yield components and yield

Yield components: Yield components in groundnut that composed of pod and kernel yield per unit area according to Fageria *et al.* (1997) was collected for data analysis.

Number of pods per plant: Number of filled pods per plant was determined by counting the number of filled pods from the five plants harvested from the two middle rows and the mean calculated as follows:

$$\text{Number of pods per plant} = \frac{\text{Total number of pod/plant}}{\text{Number of plant /plot}}$$

Number of kernels per pod: Number of kernels per pod was assessed from randomly selected pod from harvested plants and the number of kernels was calculated as follows:

$$\text{Number of pods per kernel} = \frac{\text{Number of kernel}}{\text{Number of pod}}$$

100 kernel weight (g): A random 100 air dried kernels at 15% moisture content were taken from the harvested plants and weight calculated, thereafter; seed size was determined as described by (Acland, 1971).

Number of empty pods: The number of empty pods was assessed from five harvested plants from the two middle rows. The pods were plucked and pressed with the fore-finger and the thumb. Those that produced a pop sound were counted as empty (unfilled) or pods without seeds.

Shelling percentage (%): Shelling percentage was determined by computing percentage of kernel weight from pod weight of five harvested plants and expressed the ratio of kernel weight to pod weight as percent.

Shelling percentage = kernel weight (kg) / pod weight (kg) x 100

Harvest index (%): Harvest index (HI), was calculated as percentage based on the ratio of biological and economic yields from five harvests as described by Rezaul *et al.* (2013). Harvest index was determined by using the following formula:

$$\text{Harvest index (HI)} = \frac{\text{Economical yield (kg)}}{\text{Biological yield (kg)}} \times 100$$

3.7 Yield

Biological yield (kg/ha): was calculated as the total mass (above ground) at harvest and dried to 15% moisture content after sun drying.

Pod yield (kg /ha) : Pods from the two middle rows were separated from plants and sun-dried for seven days at an average temperature of 23°C, at 15% moisture and weighed to record pod yield per plot and then converted into pod yield (kg/ha) by using the formula:

$$\textbf{Pod yield (kg/ha)} = \frac{\text{pod yield (kg) x 1 0000 (m}^2\text{)}}{\text{Harvested area (m}^2\text{)}}$$

Kernel yield (kg/ha): Kernel yield was determined at 15% moisture content (Fageria *et al.,* 1997).

Kernel yield = pod yield x shelling percentage

3.8 Crop Quality

Crude protein: protein content (%CP) was determined by Kjeldahl method (Bremner and Mulvaney, 1982) at the Department of Food Science and Technology at SUA.

Oil content: oil content (%fat) was determined by standard Soxhlet extraction procedure (AOAC, 1990) at the Department of Food Science and Technology at SUA.

Marketable-quality

Visual assessment of kernels was done and kernel grade for marketable quality based on kernel size, shape and color as described by Acland (1971). Kernels weighing 10 -35 g were considered to be small; 35 – 70 g medium and > 70 g were considered to be large.

3.9 Crop Profitability

Cost of inputs, including seeds, fertilizers, labour and price of groundnut for revenue were assessed. Value -Cost Ratio (VCR) was used to determine the ratio between the value of the additional crop yield and the cost of inputs as described by Bhatti (2006).

$$\mathbf{VCR} = \frac{\Sigma y_i \times p_1}{\Sigma x_i p_2}$$

Where: y_i = extra yield produced due to input (kg/ha)

p_1= value of extra yield produced ($/kg)

x_i = input applied (kg/ha)

p_2= cost of input ($/kg)

Value cost ratio was further rated as follows:

VCR = 1: yield may be increased but no financial incentive to adopt new practice

VCR = 1 and 2: farmers earn profits

VCR = >2: Minimum acceptable level for adoption of new practice by farmers

3.10 Data Analysis

Data collected were subjected to analysis of variance (ANOVA) using GENSTAT released version 14th edition and declared significant at $P < 0.05$ using the following statistical model as described by Gomez and Gomez (1984).

$$y_{ijk} = \mu + \alpha_i + c_{ik} + \beta_j + (\alpha\beta)_{ij} + e_{ijk}$$

Where;

yijk = general performance

μ = a population mean

αi = main effect of factor A (groundnut genotype)

βj= main effect of factor B (Fertilizer type)

(αβ) ij = interaction effect of factors A and B

cik = main plot error distribution

eijk = subplot error

The mean separation test was done using Duncan Multiple Range Test (DMRT) at $P \leq 0.05$. All computations were done using the GenStat statistical software version 14. Soil and crop phenological data were interpreted according to Landon (1991) and Boote (1982), respectively, and weather data were interpreted as described by TMA (2016).

CHAPTER FOUR

4.0 RESULTS

4.1 Soil Characteristics

4.1.1 Physical characteristics

Detailed soil analysis results of experimental site are shown in Table 4. Soil analysis results indicated that the soil was sandy clay loam with 49.2% sand, 42.72% clay and 8.08% silt with a bulk density of 1.2 g/cm^3 considered optimum in relation to plant root growth (Lal and Shukla, 2004).

4.1.2 Chemical characteristics

Results of the chemical characteristics of soils in the interpretation were based on classification by Landon (1991). A moderately acidic soil pH of 5.9 was recorded whereas soil organic carbon, organic matter and total nitrogen were characterized as very low 0.07, 0.12 and 0.18%, respectively, while carbon Nitrogen (C:N) was rated as narrow.

4.1.3 Available phosphorus

The available phosphorus level at the experimental site was found to be 0.048 mg/kg which was low (Landon, 1991).

4.1.4 Exchangeable bases (Ca, Mg, Na and K)

Calcium

Soil analysis results from this study found exchangeable calcium as 27.3 $cmol_c^{(+)}$ /kg, Mg 186.6 $cmol_c^{(+)}$ /kg and Na 5.4 $cmol_c^{(+)}$ /kg as very high whereas exchangeable K $cmol_c$ $2.16^{(+)}$ /kg which was rated high (Landon, 1991).

4.1.5 Micronutrient

Micronutrients level (Table 4), including Iron (Fe), Manganese (Mn), Copper (Cu) and Zinc (Zn) were found to be 3.17 mg/kg, 92.0 mg/ kg,13.0 mg/kg and 26.4 mg/kg ,respectively and was rated as very high (Landon, 1991).

Table 4: Soil physio-chemical characteristics at experimental site

Properties	**Result**	**unit**	**Remarks***
A. Physical			
Texture			Sandy Clay Loam
Sand	49.2	%	
Clay	42.72	%	
Silt	8.08	%	
B. Chemical			
pH	5.9		Moderately acid
Organic Carbon	0.07	%	Very low
Total Nitrogen	0.18	%	Very low
Organic Matter	0.12	%	Very low
C : N ratio	1:2.5		Narrow
Extractable P	0.048	mg/kg	Low
Exchangeable Cations			
Calcium	27.3	$cmol_c^{(+)}/kg$	Very high
Magnesium	186.6	$cmol_c^{(+)}/kg$	Very high
Potassium	2.16	$cmol_c^{(+)}/kg$	High
Sodium	5.4	$cmol_c^{(+)}/kg$	Very high
Micronutrients (mg/kg)			
Iron	31.7	mg/kg	Very high
Manganese	92.0	mg/kg	Very high
Cooper	13.0	mg/kg	Very high
Zinc	24.6	mg/kg	Very high

*According to Landon (1991)

4.2 Weather Data

Weather data collected during the study period is shown in Table 5.

4.2.1 Rainfall (mm)

Rainfall pattern during the duration of the experiment is indicated in Table 5. Total monthly rainfall ranged from 4.6 mm to 27.28 mm with highest monthly total recorded during March (27.8 mm) whereas the lowest was recorded in February (4.6 mm). The average monthly rainfall also ranged from 1.1 mm to 5.46 mm.

4.2.2 Temperature (°C) and relative humidity (%)

Mean temperature recorded during the growing season ranged from 21.23 – 26.5 °C. The highest mean temperature was recorded in February whereas was recorded in May. Mean relative humidity (RH %) ranged from 76% to 90.3% with highest recorded in May while the lowest was in February.

4.2.3 Radiation (MJ/m^2)

Weather data collected during the study period showed that the highest solar radiation was recorded in February (88.4 MJ/m^2) while the lowest was recorded in May (68.48 MJ/m^2). Overall, average radiation recorded during the experimental period was 72 MJ/m^2.

4.2.4 Evapo-transpiration (mm)

Mean evapotranspiration ranged from 3.2 – 7.35 mm and was in February while the lowest was in May.

Table 5: Weather data collected during the experiment period

Month/ year 2015	Rainfall (mm)	Temp.(°C) Max	Min	RAD (MJ/m^2)	RH (%)	PAN Evaporation (mm)
January						
Week 1	1.1	25.4	23.2	17.85	82.42	4.72
Week 2	9.85	24.0	22.5	19.38	88.28	5.18
Week 3	1.15	24.2	22.0	13.34	90.0	3.21
Week 4	0.00	24.0	23.0	23.13	79.42	7.35
Week 5*	0.00	25.5	24.0	22.91	78.66	6.66
Total	**12.1**	**N/A**	**N/A**	**96.61**	**N/A**	**27.12**
Mean	**2.24**	**24.62**	**22.94**	**19.32**	**83.75**	**5.42**
February						
Week 1	0.0	26.3	24.5	23.65	73	8.6
Week 2	0.0	27.0	24.6	23.93	75	8.6
Week 3	3.24	26.0	24.0	19.06	80	5.5
Week 4	1.42	26.7	24.42	21.78	72.14	6.71
Week 5	N/A	N/A	N/A	N/A	N/A	N/A
Total	**4.66**	**N/A**	**N/A**	**88.4**	**N/A**	**29.4**
Mean	**1.16**	**26.5**	**24.32**	**22.10**	**76**	**7.35**
March						
Week 1	5.5	28.0	22.2	19.58	82.42	5.88
Week 2	0.0	26.6	24.5	23.6	75.57	8.21
Week 3	4.1	24.9	23.1	17.15	85.71	5.81
Week 4	6.08	24.8	23.1	14.53	88.42	3.15
Week 5	11.6	25	24.0	17.14	87.66	4.4
Total	**27.28**	**N/A**	**N/A**	**92**	**N/A**	**27.45**
Mean	**5.46**	**25.86**	**23.38**	**18.4**	**83.95**	**5.49**
April						
Week 1	3.32	25.8	23.0	16.01	86.86	4.54
Week 2	3.65	25.0	24.0	17.82	86.71	3.37
Week 3	1.92	25.7	23.0	19.58	85.71	4.35
Week 4	9.0	24.5	21.1	14.53	93.85	3.4
Week 5	3.0	24.0	23.5	12.92	89.5	2.5
Total	**20.89**	**N/A**	**N/A**	**80.86**	**N/A**	**18.16**
Mean	**4.17**	**25.0**	**22.92**	**16.17**	**88.52**	**3.63**
May						
Week 1	7.78	26.8	22.2	12.70	93.0	3.4
Week 2	1.67	23.8	22.0	13.35	91.0	2.42
Week 3	0.08	23.0	20.0	16.87	89.71	4.01
Week 4	0.0	23.0	20.2	12.57	88.28	7.71
Week 5	1.86	22.6	22.2	12.97	89.66	4.1
Total	**11.39**	**N/A**	**N/A**	**68.46**	**N/A**	**21.64**
Mean	**2.27**	**23.84**	**21.32**	**13.69**	**90.33**	**4.32**

Source: Tanzania Meteorological Agency (TMA), SUA station

*The fifth week refers to the extra number of days the month had after the 28th day or the 4th week of the month.

4.2.5 Growth pattern of groundnut genotype as influenced by phosphorus application

Results from the current study revealed that application of phosphorus influenced growth pattern of groundnut genotype. Mangaka was the earliest to flower within 15 DAP while Masasi was the latest of the three genotypes to flower taking 27 DAP. Groundnut growth patterns as affected by genotypes and phosphorus are shown in Table 6.

Table 6: Growth pattern as affected by groundnut genotype and phosphorus

	Days to specific growth stage (DAP)								
	Mangaka			Masasi			Pendo		
	0kg	55 kg	Ave	0kg	55 kg	Ave	0kg	55 kg	Ave
Growth stage*									
Planting	0	0	0	0	0	0	0	0	0
50% emergence	6	4	5	9	5	7	7	3	5
50% flowering	16	14	15	30	24	27	15	7	22
50% peg formation	40	30	35	48	42	45	55	25	40
50% pod formation	56	40	48	70	50	60	65	39	52
Physiological maturity	95	65	80	100	90	95	100	74	87
Harvest maturity	115	85	100	130	100	115	110	100	105

*According to Boote, 1982; DAP refers to days after planting
Data not subjected to statistical analysis

4.3 Groundnut Growth Variables as Affected by Genotype and Fertilizer Type

All variables statistically analyzed as described in subsection 3.10 are summarized in Appendix 1. Results on effects of genotype and fertilizer type on growth variables of groundnut are shown in Tables 7.

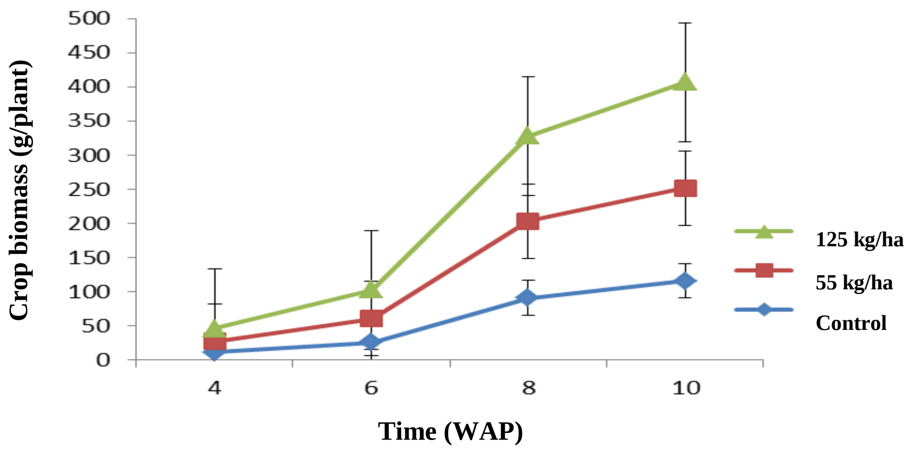
Table 7: Effect of genotype and fertilizer type on growth variables of groundnut

Treatment effect	BM (g/plant)	LAI	CGR ($g\ m^2$/day)	NAR ($g\ m^2$/day)	Number of Nodules
Genotype Factor(A)					
Mangaka	75.00a[*]	3.71b	11.18a	8.53a	42.14a
Masasi	79.25a	3.95b	13.04c	12.36c	64.93b
Pendo	75.01a	2.86a	12.88b	10.56b	63.25b
Mean	76.4	1.14	12.36	9.68	56.8
SE $\pm$	3.33	0.14	1.67	0.16	3.24
CV (a)	4.4	4.60	5.3	3.1	5.7
P value	0.01	0.01	0.032	0.001	0.001
Fertilizer types Factor (B)					
Control	63.62a	3.51a	8.48a	7.79a	57.08b
DAP	76.85b	3.52a	13.55b	10.84b	47.01a
Minjingu mazao	88.79c	4.03b	15.05c	10.81b	66.22c
Mean	76.4	1.14	12.36	9.68	56.8
SE +	3.17	0.02	3.35	0.076	2.76
CV (b)	4.1	1.8	4.9	3.0	4.9
P value	0.001	0.001	0.001	0.076	0.001

[*]Means in the same column and factor followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan Multiple Range Test. Note: BM = plant biomass (g/ plant), LAI = Leaf area index; CGR: Crop growth rate ($g\ m^2$/d,) and NAR: Net assimilation rate ($g\ m^{-2}$/d).

4.3.1 Biomass and LAI

Biomass for groundnut genotype ranged from 75.0 to 79.25 g/ plant with no significant influence of genotype on biomass which was recorded in the order of Masasi (79.25 g/plant), Pendo (75.01 g/ plant) and Mangaka (75.0 g/ plant). However; fertilizer had significant (P=0.001) influence on biomass. The highest biomass (88.79 g /plant) was recorded with application of Minjingu mazao. Exponential increase in biomass was observed from 8 to 10 WAP Figure 1.



Key: WAP = Week After Planting

Figure 1: Effect of fertilizer type on groundnut biomass production at various growth stages

The study also revealed significant (P=0.01) effect of genotypes on LAI. Mangaka recorded the highest LAI, (3.71) while the lowest was observed in Pendo (2.86). Application of fertilizer resulted into increased LAI. Leaf area index was recorded in the order of Minjingu mazao > DAP > control. The influence of fertilizer type on LAI and biomass are shown in Figure 2.

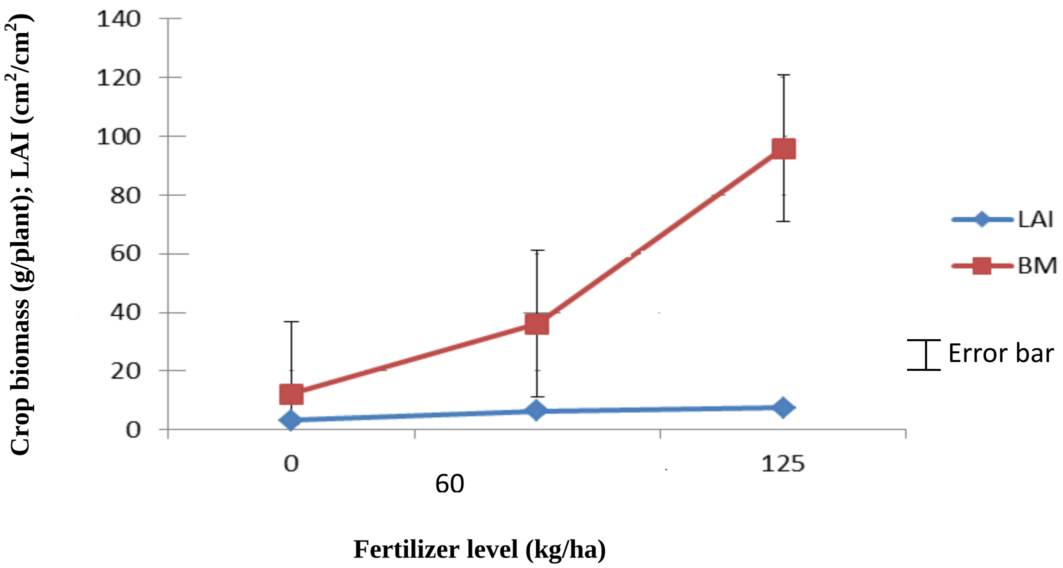


Figure 2: Effect of fertilizer type on LAI and crop biomass

4.3.2 Crop growth rate and net assimilation rate

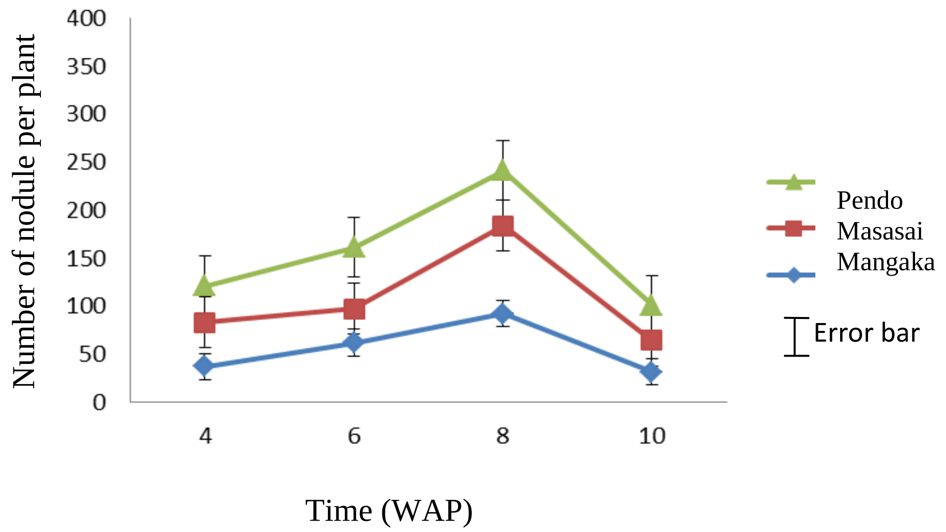
Groundnut genotype had significant (P= 0.032) influence on CGR as the lowest CGR was observed in Mangaka (11.18 g m^2/day) whereas the highest was observed in Masasi (12.88 g m^2/day). Significant (P=0.001) influence of fertilizer type on CGR was observed and recorded in the order of Minjingu mazao > DAP > control.

Net assimilation rate was significantly (P=0.001) influenced by genotype. Mangaka recorded the lowest NAR (8.53 g m^2/day) whereas Masasi recorded the highest NAR (10.56 g m^2/day). Fertilizer type had significant (P=0.076) effect on NAR.

Net assimilation rate ranged from 7.79 to 10.84 g m^2/day. The highest NAR was observed with application of 55 kg P/ha whereas the lowest was observed in control plots.

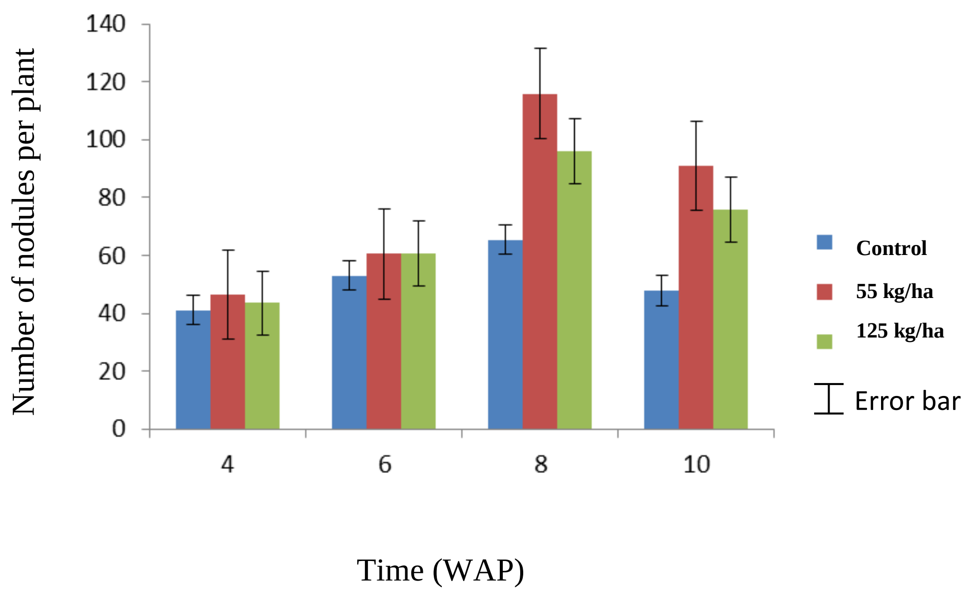
4.3.3 Number of nodules per plant

Groundnut genotype and fertilizer type had significant (P=0.001) influence on the number of nodules. Masasi had the highest number of nodules (64.93) while the lowest were observed in Mangaka (42.14). Increase in number of nodules was recorded for all genotypes with the peak observed in Masasi and Pendo between 6-8 WAP (Figure 3). Number of nodules was significantly (P=0.001) influenced by fertilizer type. Number of nodules ranged from 47.01- 66.22, whereas the highest number of nodules was observed with application of DAP. Numbers of nodules increased by 29% with the application of DAP compared to the control (Figure 4).



Key: WAP = Week After Planting

Figure 3: Number of nodules as affected by groundnut genotype



Key: WAP = Week After Planting

Figure 4: Effect of fertilizer type on number of nodules at various growth stages

4.4 Effect of Groundnut Genotype and Fertilizer type on Yield Components

4.4.1 Effect of genotype and fertilizer type on number of pod per plant

Results on the influence of groundnut genotypes and fertilizer types on yield and yield components are shown in Table 8. Number of pod was significantly (P=0.001) influenced by groundnut genotype as the highest was observed in pendo (38.25), whereas the lowest was observed in Masasi (29.65). Application of fertilizer significantly (P=0.004) influenced number of pods as the highest was observed with application of Minjingu mazao as shown in Table 8.

4.4.2 Effect of genotype and fertilizer type on number of kernel per pod, 100- kernel weight

Groundnut genotype had no significant influence on the number of kernel per pod however, lowest number of kernel per pod was observed in pendo (1.96). Masasi significantly (P=0.001) influenced 100- kernel weight whereas the lowest was observed in Pendo. Application of DAP had significant (P=0.001) influence on 100- kernel weight whereas Minjingu mazao significantly (P=0.004) influenced number of kernel (Table 8).

Table 8: The effect of groundnut genotype and fertilizer type on groundnut yield components

Treatment effect	No. of pods^/ plant	Kernels/ Pod	100-kernel wt.(g)
Variety factor (A)			
Mangaka	28.25b*	1.98a	47.23b
Masasi	16.38a	2.13a	76.60c
Pendo	38.25c	1.96a	44.17a
Mean	27.63	2.02	56.00
SE +	1.91	0.13	1.05
CV (a)	6.9	6.5	1.9
P-value(a)	0.001	0.22	0.001
Fertilizers Factor (B)			
Control	28.78a	1.84a	56.09b
DAP	26.35a	1.96a	63.11c
Minjingu mazao	30.01b	2.27b	48.81a
Mean	27.63	2.02	56.00
SE +	0.91	0.11	0.66
CV (b)	3.3	5.6	1.2
P -value(b)	0.004	0.004	0.001

*Means in the same column and factor followed by the same letter are not significantly different at P< 0.05 according to Duncan Multiple Range Test.
^ Pod refers to part of the peg that develops into a fruit of groundnut.

4.5 Effect of Genotype and Fertilizer Type on Biological Yield (TDM), HI, Shelling Percent, Pod and Kernel Yields

Results for TDM, harvest index, shelling percent, pod and kernel yields are shown in Table 9.

4.5.1 Effect of genotype and fertilizer type on biological yield (kg/ha)

Groundnut genotypes had significant (P= 0.018) effect on biological yield. The highest biological yield was observed in Mangaka (7 626 kg/ha), whereas the lowest was recorded in Masasi (7 096 kg/ha) though not significantly different from Pendo.

Minjingu mazao had significant (P= 0.001) effect on biological yield compared to control plots which recorded the lowest (Table 9).

4.5.2 Effect of genotype and fertilizer type on harvest index and shelling percent

Significant (P= 0.001) difference existed among groundnut genotypes and fertilizer types for harvest index (HI). No Significant difference was observed among groundnut genotypes on shelling percent. The highest HI was observed in Masasi (46.7%) which differed significantly from Pendo (31.75%) and Mangaka (32.11%). Shelling percent was lowest in Mangaka (66.75%) which was not significantly different from Masasi (68.8%) and Pendo (66.9). Application of DAP had significant effect on HI (40.78%) compared with the control (34.9%). However, the application of Minjingu mazao had no significant effect on HI. There was significant (P= 0.08) effect of fertilizer types on shelling percent with (4%) increase in shelling percent compared with the control plots which recorded the lowest.

4.5.3 Effect of genotype and fertilizer type on pod and kernel yield (kg/ha)

Results for pod and kernel yields from the study are shown in Table 9.

4.5.4 Pod yield (kg/ha)

Results from the current study revealed significant (P=0.001) effect of groundnut genotypes on pod yield. Pod yield ranged from 2 267 to 3 341 kg/ha. The highest pod yield was observed in Masasi, whereas the lowest was observed in Pendo. Fertilizer types also had significant (P=0.001) effect on pod yield. The highest pod yield was observed with DAP (3 025 kg/ha). The lowest yield was observed in plots treated with Minjingu mazao (2 338kg/ha) which differed significantly (P= 0.001) from those treated with DAP.

4.5.5 Effect of groundnut genotype and fertilizer type on kernel yield

Groundnut genotype significantly (P= 0.002) influenced kernel yield. Masasi recorded the highest kernel yield (1 901 kg/ha), whereas the lowest yield was recorded in Mangaka (1 310 kg/ha). Application of DAP gave the highest kernel yield whereas the lowest was observed in plots treat with Minjingu mazao (Table 9).

4.5.6 Effect of fertilizer type on number of pods and unfilled pods (Pops)

Results on the influence of groundnut genotypes and fertilizer types on number of pods, and unfilled pods (pops) are shown in Table 10. Groundnut genotype had significant effect on number of pods and filled pods whereas no significant effect on number of pops was observed. Number of pods among groundnut genotypes ranged from 364.1 to 850 pods m^{-2}. The highest number of pods was recorded in pendo whereas the lowest were recorded in Masasi. The highest number of filled pods was also observed in Pendo while Masasi recorded the lowest number of pops. Number of pops ranged from 46.3- 50.0 pops m^{-2}.

Table 9: The effect of groundnut genotype and fertilizer type on total dry matter, HI, Shelling percentage, pod and kernel yields

Treatment effect	Biological yield (kg/ha)	HI (%)	Shelling (%)	Pod yield (kg/ha)	Kernel yield (kg/ha)
Variety factor (A)					
Mangaka	7 626b*	32.11a	66.75a	2 433b	1 380a
Masasi	7 096a	46.70b	66.97a	3 341 c	1 901b
Pendo	7 209a	31.75a	67.46a	2 286a	1 310a
Mean	7 310	36.84	67.06	2 687	1 530
SE +	190.9	0.59	1.99	84.5	175.5
CV (a)	2.6	3.2	3.0	3.1	11.9
P-value(a)	0.018	0.001	0.87	0.001	0.002
Fertilizers Factor (B)					
Control	6 717a	34.82a	65.81a	2 697b	1 505ab
DAP	7 432b	40.94b	68.61b	3 025c	1 760b
Minjingu mazao	7 782c	34.82a	66.77ab	2 338a	1 327a
Mean	7 310	36.82	67.06	2 687	1 530
SE +	122.7	0.85	1.43	84.1	15.70
CV (b)	1.7	2.3	2.1	3.0	10.6
P -value(b)	0.001	0.04	0.08	0.001	0.05

*Means in the same column and factor followed by the same letter are not significantly different $P< 0.05$ according to Duncan Multiple Range Test

Though not significantly different, the highest number of pops was recorded in Mangaka and Masasi while the lowest was recorded in Pendo. Application of fertilizer had significant (P= 0.004) effect on number of pods. No significant influence of genotype was observed on number of pops however, application of fertilizer had significant (P=0.001), effect on the number of pops as the lowest number of pops were observed with Minjingu mazao (46.3%) decrease in number of pops compared with the control plots (Table10).

Table 10: Effect of fertilizer type on number of pods and pops (m^2)

Treatment effect	No. of pod* (m^2)	Number of filled pods	Unfilled Pod (m^{-2})	% filled pods
Variety factor (A)				
Mangaka	627.7 b	577.7b	50.0a	91.71b
Masasi	364.0a	314.0 a	50.0a	86.86a
Pendo	849.9c	803.6 c	46.3a	94.48b
Mean	**614.0**	**565.1**	**48.8**	**91.02**
SE +	**42.5**	**38.48**	**8.55**	**1.75**
CV (a)	**6.9**	**6.8**	**17.5**	**1.9**
p-value (a)	**0.001**	**0.001**	**0.907**	**0.002**
Fertilizers Factor (B				
Control	585.5 a	550a	75.93b	85.58a
DAP	661.8 b	518.5a	35.19	93.51 b
Minjingu mazao	594.4 a	626.6b	35.193a	93.95b
Mean	**614.0**	**565.1**	**48.8**	**91.02**
SE +	**0.91**	**2.93**	**0.69**	**0.34**
CV (b)	**3.3**	**11.01**	**12.9**	**6.8**
p-value (b)	**0.004**	**0.058**	**0.001**	**0.001**

*Means in the same column and factor followed by the same letter are not significantly different according to Duncan Multiple Range Test P< 0.05

4.6 Effect of Genotype and Fertilizer Type on Groundnut Seed Quality

Results for groundnut quality as influenced by genotype and fertilizer type are shown in Table 11.

4.6.1 Crude protein (%CP)

Results from the study revealed that groundnut genotypes had significant (P=0.001) effect on crude protein content. Pendo had the highest crude protein content (32.42%) whereas the lowest was observed in Mangaka (28.50%) which differed significantly (Table 11). However, there was no significant influence in protein content due to the application of fertilizers.

4.6.2 Oil content (% Fat)

Groundnut oil content was significantly (P=0.001) influenced by genotype and was recorded in the order of Pendo (44.24%), Masasi (43.38%) and Mangaka (41.42%). Application of Minjingu mazao increased fat content by 1.58% which differed significantly (P=0.001) from DAP.

Table 11: Influence of groundnut genotype and fertilizer type on protein and oil content

Genotype Factor (A)	Kernel size (g)	CP (%)	Fat (%)
Mangaka	47.23b*	28.50a	41.42a
Masasi	76.60c	30.99b	43.38b
Pendo	44.17a	32.42b	44.24c
Mean	56.00	30.64	43.06
SE±	1.05	0.77	0.10
CV(a)	1.9	22.4	11.6
P value (a)	0.001	0.001	0.001
Fertilizer Types Factor (B)			
Control	56.09b	30.55a	42.79a
DAP	63.11c	30.47a	42.77a
Minjingu Mazao	48.81a	30.90a	43.48b
	56.00	30.64	43.06
Mean			
SE±	0.66	0.77	0.10
CV(b)	1.2	6.1	3.25
P value (b)	0.001	0.835	0.001

*Means in the same column and factor followed by the same letter are not significantly different according to Duncan Multiple Range P< 0.05

4.7 Effect of Fertilizer Application on Groundnut Yield and Profitability

Results from the current study revealed that application of Ca from minjingu mazao had no significant influence on groundnut profitability (Table 12). However, significant gain on yield was observed with application of DAP (14.4 and 24.6%) more than the control and Minjingu mazao, respectively.

4.8 Interaction Effects of Groundnut Genotypes and Fertilizer Types

4.8.1 Growth parameters

Significant (P=0.2) interaction effect for Pendo x DAP was observed on plant biomass There was also significant (P=0.09) interaction effect of Pendo x Minjingu mazao on LAI (Table 13). Significant (P= 0.04) and (P= 0.003) interaction effect for CGR and NAR was observed with Masasi x Minjingu mazao and Masasi x Minjingu mazao, respectively. Number of nodules was significantly (P=0.001) influenced by genotype x fertilizer interaction with Pendo x Minjingu mazao interaction showing positive response.

4.8.2 Yield components and yield

Genotype x fertilizer interaction had significant influence on number of kernel per pod, shelling percent, HI, pod yield and kernel yield. However, no significant interaction effect was observed on 100- kernel weight and biological yield (Table 14).

4.8.3 Protein and oil content

Significant interaction effects were observed for protein and oil contents in Mangaka x Minjingu mazao and Pendo x Minjingu mazao, respectively (Table 15).

Table 12: Relative contribution of fertilizer type to groundnut kernel yield kg/ha net return and VCR

Treatment (Fertilizer type)[1]	Kernel yield (kg/ha)	Average yield (kg/ha)	Market price ($/kg)[2]	Gross income ($/kg)	Fertilizer required (kg/ha)	Fertilizer cost ($/kg)[3]	Total fertilizer cost ($/kg)[4]	Net income ($/ha)	VCR
Control	1 505	0	1.63	2 453.2	0	0	0.00	2 453.2	0.00
DAP	1 760	225	1.63	2 868.9	55	16.36	900	1 968.9	2.2
Minjingu mazao	1 327	-178	1.63	2 163.0	125	12.9	1 612.5	550.5	0.3

VCR= Value cost ratio, Tsh = Tanzanian shillings

[1]Fertilizer type, based on available sources of P and Ca

[2]Price based on the observed market price in the study area in USD ($)

3 Retail cost price charged for DAP and Minjingu mazao at local agricultural stores in 2015.

[4]Currency conversion was based on the banking exchange rate of US$1: 2000 Tanzanian Shillings.

Table 13: Interaction effect of groundnut genotype and fertilizer type on growth parameters of groundnut

Treatment Effect	BM (g/plant)	LAI	CGR (g m^2/day)	NAR (g m^2/day)	Number Nodules /plant	Biological Yield (kg/ha)
Mangaka x control	66.12ab*	3.267 c	13.75a	11.74a	63.70d	8 156c
Mangaka x DAP	62.51a	3.15 c	13.77a	11.87 a	54.79c	7 510 b
Mangaka x Minjingu mazao	62.24a	3.10 c	12.00a	11.65a	27.74a	7 211 b
Masasi x control	73.63bc	1.95a	22.72c	16.35b	34.99b	7 550b
Masasi x DAP	82.01cd	1.99a	26.83c	16.35b	54.54c	7 302 b
Masasi x Minjingu mazao	74.92bc	1.88a	24.96c	17.32 c	51.50c	6 436 a
Pendo x control	85.26de	2.31b	13.76b	11.57 a	52.77c	7 640 b
Pendo x DAP	93.24e	2.31b	21.86c	11.41 a	85.46e	7 483b
Pendo x Minjingu mazao	87.87de	2.36b	16.36b	12.52a	85.48e	6 505a
Mean	**76.42**	**2.47**	**69.0**	**15.64**	**56.77**	**2 687**
SE±	**6.13**	**6.06**	**6.13**	**0.30**	**4.46**	**172.1**
Cv(ab) %	**7.8**	**13.3**	**8.9**	**2.3**	**7.9**	**6.4**
P- value	**0.2**	**0.09**	**0.04**	**0.003**	**0.001**	**0.26**

*Means in the same column and factor followed by the same letter are not significantly different at P ≤ 0.05 according to Duncan Multiple Range Test
Note: BM = plant biomass (g/ plant), LAI: Leaf area index; CGR: Crop growth rate (g m^2/d) and NAR: Net assimilation rate (g m^2/day)

Table 14: Interaction effect of groundnut genotype and fertilizer type on yield components and yield of groundnut

Treatment effect	Number of pods/plant	Kernel/ Pod	SP (%)	Kernel weight (g)	HI%	Pod yield (kg/ha)	Kernel yield (kg/ha)
Mangaka x control	32.25c*	2.20cde	66.02a	46.50bcd	26.01a	2 112a	1 120a
Mangaka x DAP	26.00b	2.30de	67.05ab	46.80cd	34.49c	2 606c	1 392a
Mangaka x Minjingu mazao	26.50b	2.32e	67.17 ab	48.40 d	35.84 c	2 582bc	1 351a
Masasi x control	15.85a	1.90bc	66.25 ab	76.47f	47.54d	3 593d	2 068b
Masasi x DAP	16.05a	1.97bcd	68.46 ab	98.45 g	56.32e	4 105e	2 414b
Masasi x Minjingu mazao	17.25a	2.02bcde	67.69 ab	54.87e	36.15c	2 327ab	1 379a
Pendo x control	41.25e	1.85ab	65.16 a	45.30abc	31.25b	2 387bc	1 369a
Pendo x DAP	36.99d	2.12bcde	70.32b	44.07ab	31.54b	2 364abc	1 065a
Pendo x Minjingu mazao	36.50d	1.55a	65.43a	43.15a	32.46b	2106a	1 122a
Mean	**27.63**	**2.02**	**67.06**	**56.0**	**36.84**	**2 687**	**1 476**
SE $\pm$	**2.59**	**0.21**	**2.58**	**1.71**	**2.07**	**172.1**	**269.9**
CV(ab)	**9.4**	**10.5**	**3.8**	**3.1**	**5.6**	**6.4**	**18.3**
P- value	**0.03**	**0.04**	**0.21**	**0.001**	**0.001**	**0.001**	**0.001**

*Means in the same column and factor followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan Multiple Range Test
Note: SP = shelling percentage, HI = harvest index

Table 15: Interaction effects of groundnut genotype and fertilizer type on crude protein and oil contents

Treatment effect*	**%Crude protein**	**% fats**
Mangaka x control	32.32c	43.25cd
Mangaka x DAP	40.50d	43.70d
Mangaka x Minjingu mazao	40.60d	43.18c
Masasi x control	28.80a	41.00 a
Masasi x DAP	28.40a	40.90a
Masasi x Minjingu mazao	28.30 a	42.40 b
Pendo x control	30.55 b	44.15e
Pendo x DAP	30.45 b	43.65d
Pendo x Minjingu mazao	32.00 c	44.90f
Mean	**32.43**	**43.014**
SE±	**0.45**	**0.30**
Cv(ab) %	**1.45**	**0.70**
P- value	**0.001**	**0.001**

*Means in the same column and factor followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan Multiple Range Test

4.9 Correlation Analysis

Correlation analysis showing degree of relationship (P = 0.05) among various growth parameters and yield components is shown in Table 16 revealed that LAI was significant and positively correlated with biomass (r= 0.24), CGR (r = 0.54), number of nodules per plant (r= 0.20), number of pod per plant (r = 0.78), numbers of pop per plant (r = 0.78), protein content (r = 0.59) and oil content (r = 0.76). The study also revealed that LAI was also negatively correlated with NAR (r= -0.99), numbers of kernel per pod (r = -0.08), 100 – kernel weight (r = -055), shelling percentage (r =-0.20), harvest index (r = -0.62) and kernel yield (r = -0.30).

Number of nodules was positively correlated with biomass (r= 0.41), CGR (r= 0.21), number of pods per plant (r= 0.07), number of kernels per plant (0.00), HI (r=0.14), number of pops per plant (r=0.02), protein content (r=0.10), oil content (r= 0.17) and kernel yield (r=0.04). Number of nodules was negatively correlated with NAR (r= -0.21), shelling percentage (r=-0.13), biological yield (r=-0.08) and 100- kernel weight (r=-0.18). Biomass was positively correlated with CGR (r=0.68), number of pod per plant (r= 0.50), shelling percentage (r= 0.11), harvest index (r=0.02), biological yield (r=0.31), 100- biological yield, protein content (r=0.02) and fat content (r=0.19). Biomass was negatively correlated with NAR (r=-0.21), number of pods per plant (r=-0.12), number of kernel per pod (r=-0.35), 100- kernel weight (r=-0.13) and kernel yield (r=-0.11). Crop growth rate showed positive correlation with NAR (r=0.57), shelling percent (r=0.25), 100- kernel weight (r=0.310), HI (r=0.52), biological yield (r=0.17) and kernel yield (r=0.13) but, negatively correlated with number of kernel per plant (r=-0.23), number of pop per plant (r=-0.02), protein content (r= -0.43) and oil content (r=-0.42). Net assimilation rate was positively correlated with number of kernel per plant (r=0.08), number of pop per plant (r=0.09), shelling percentage (r=0.22), 100- kernel weight (r=0.56), HI (r=0.66) and kernel yield (r=0.29). Net assimilation rate was negatively correlated with number of pod (r=-0.76), protein content (r=-0.11) and protein content (r=-0.75). Number of pod was positively correlated with biological yield (r=0.27), protein content (r=0.34) and oil content (r=0.73). Number of pod was negatively correlated with number of kernel per plant (r=-025), number of pop per plant (r=-0.10), shelling percentage (r=-0.12), HI (r=-0.46), 100-kernel weight (r=-0.43) and kernel yield (r=-0.25).

The study findings also revealed that number of kernel per pod was positively correlated with shelling percentage (r=0.10), HI (r=0.01), 100- kernel weight (r= 0.15), protein content (r=0.28) and kernel yield (r=0.20). Whereas, negative correlation was recorded with number of pop per plant (r=-0.22), fat content (r=-011) and biological yield (r=-0.18). Number of pop was positively correlated with 100- kernel weight (r=0.11), HI (r=0.04), protein content (r=0.05) and oil content (r=0.15). Number of pop was negatively correlated with shelling percentage (r=-0.04), biological yield (r=-0.06) and kernel yield (r=-0.21). Shelling percentage was positively correlated with HI (r=0.13), biological yield (r=0.11) and kernel yield (r=0.15), whereas 100- kernel yield (r=-0.17), protein content (r=-0.1) and oil content (r=-0.2) were negatively correlated with shelling percentage. Harvest index (r=0.24) and kernel yield (r=0.08) were positively correlated with 100- kernel weight whereas biological yield (r=-0.02), protein content (r=-0.35) and oil content (r=-0.51) were negatively correlated with 100- kernel weight. Kernel yield was positively correlated with biological yield (r=0.01) and HI (r=0.27) whereas protein content (r=-0.1) and oil content (r=-0.26) were negatively correlated with kernel yield. Biological yield was positively correlated with oil content (r=0.02) whereas HI (r=-0.43) and protein content (r=-0.08) were negatively correlated with biological yield. Harvest index was negatively correlated with protein content (r=-0.44) and oil content (r=-0.56). Protein content was positively correlated with oil content (r=0.52) (Table 16).

Findings from the study revealed that yield and yield components of groundnut were associated with the performance of growth parameters. In order to enhance groundnut crop yield, appropriate agronomic practices that encourages optimum growth and development be put into place.

Table 16: Correlation between crop growth parameters, yield and yield components

Parameters	LAI	Node	BM	CGR	NAR	Peg	Pod/ plant	Kernel/ pod	Pop/ plant	SH (%)	Kernel wt.	Kernel yield	Biological yield	HI (%)	protein	Fats
LAI	1.00															
Nodules	0.20	1.00														
BM	0.24	0.41	1.00													
CGR	0.54	0.21	0.68	1.00												
NAR	-0.99	-0.20	-0.21	0.57	1.00											
Peg/plant	0.73	0.08	0.34	-0.25	-0.71	1.00										
Pod/plant	0.78	0.07	0.50	-0.17	-0.76	0.87	1.00									
Kernel/pod	-0.08	0.00	-0.35	-0.23	0.08	-0.21	-0.25	1.00								
Pop/plant	-0.08	0.02	-0.12	-0.02	0.09	0.11	-0.10	-0.22	1.00							
Shelling%	-0.20	-0.13	0.11	0.25	0.22	-0.30	-0.12	0.10	-0.40	1.00						
100-kernel wt.	-0.55	-0.18	-0.13	0.31	0.56	-0.35	-0.43	0.15	0.11	-0.17	1.00					
Kernel yield(kg/ha)	-0.30	0.04	-0.11	0.13	0.29	-0.21	-0.25	0.20	-0.21	0.15	0.08	1.00				
Biological yield	0.09	-0.08	0.31	0.17	-0.11	0.16	0.27	-0.18	-0.06	0.11	-0.02	0.00	1.00			
HI (%)	-0.62	0.14	0.02	0.52	0.66	-0.41	-0.46	0.00	0.04	0.13	0.24	0.27	-0.43	1.00		
%Protein	0.59	0.10	0.02	-0.43	-0.60	0.33	0.34	0.28	0.05	-0.10	-0.35	-0.10	-0.08	-0.44	1.00	
%Fats	0.76	0.17	0.19	-0.42	-0.75	0.71	0.73	-0.10	0.15	-0.20	-0.51	-0.26	0.02	-0.56	0.52	1.00

LAI = leaf area index, BM = plant biomass, SH% = shelling percentage, HI% = harvest index

CHAPTER FIVE

5.0 DISCUSSION

The objective of this study was to determine the response of three groundnut genotypes to calcium and phosphatic fertilizers during the growing season of 2015.

5.1 Soil Physical and Chemical Properties

Soil analysis report of the study area revealed that the soil was sandy clay loam with a bulk density of 1.2g/cm^3 which is considered an optimum bulk density for most crops (Lal and Shukla, 2004). Soil pH at the experimental site was 5.9, considered favourable for groundnuts (Murata, 2003). Nkot *et al*., 2011 reported poor groundnut nodulation and nitrogen fixation in acid soils of pH 3.6 -6.9. Low soil nitrogen content (0.18% T.N) at the experimental site was an indicator associated with the history of continuous cultivation with little or no addition of organic or inorganic fertilizers. Though not required in large quantities by legumes, soil available nitrogen is essential for vegetative growth as such, addition of nitrogen fertilizers at low rate as a starter dose to leguminous crops such as groundnut is necessary especially where soil nitrogen content is low (Tubbs *et al*., 2012).

A very low status of available P (0.048 mg/kg), at the experimental site was evident that P was a major limiting factor for groundnut production and as such its application to enhance optimum yield was important. Phosphorus deficiency constitutes a serious limitation to crop production in weathered tropical soils containing high Fe and Al oxides that quickly fix added P. Moazed *et al.* (2010) reported that low quantities of soluble P in Oxisols limit crop production and productivity.

Kanyeka *et al.* (2007) recommended the application of 55kg P/ha for optimum groundnut yield. However, calcium is also a very important nutrient for optimum groundnut kernel yield (Brown, 2011). Exchangeable cations i.e.; Ca, Mg and K ranged from high (2.16 $cmol_c^{(+)}$ /kg) to very high (186.6$cmol_c^{(+)}$/kg). Soil calcium level was rated very high according to Landon (1991) but was inadequate to meet crop growth requirement. The level of soil Ca was affected by level of organic matter resulting in the inability of the soil to hold the amount required for crop growth. Calcium availability is crucial for pod formation Calcium application also influences shelling percent, seed and pod yields in groundnut (Murata, 2003). Soil analysis results from the experimental site indicated that soil macronutrients including Mg, K and Na were adequate (Landon, 1991). Results also revealed that macronutrient deficiencies, especially P could be a major constraint to groundnut production because initial soil P was very low for optimum yield (Katsaruware and Mabwe, 2014).

5.2 Growth Pattern of Groundnut Genotypes

Application of P had no significant influence on field emergence as observed during the current study which is in conformity with Katsaruware and Mabwe (2014). This was due to the fact that seed germination is not affected by basal fertilizer application but instead fertilization enhances growth through initiating root development and providing nutrients needed for growth (Tillman *et al.,* 2009). Interaction of variety and phosphorus levels was non- significant ($P \leq 0.05$) contrary to findings by Kamara *et al*. (2011); Tarawali and Quee (2014) who reported significant interaction effect of groundnut varieties and phosphorus. Days to 50% flowering was significantly influenced by genotype and not by application of P which is in agreement with Kamara *et al*. (2011). Number of days to flowering could be influenced by climatic factors including rainfall, temperature and radiation as the lowest mean rainfall (1.16 mm) was experienced during the onset of reproductive stage. Semalulu *et al.* (2014) reported that soil and micro-climatic conditions have effect on the performance of different groundnut genotypes.

5.2.1 Influence of fertilizer types on plant biomass and LAI

Application of fertilizer type had significant effect ($P \leq 0.05$) on plant biomass and LAI. The highest biomass and LAI were observed with application of Minjingu mazao with an observed increase in biomass (28.35%). This result is in conformity with Rezaul *et al.* (2013) who also reported increase in crop biomass with application of Ca.

Findings from the current study are contrary to reports of Kamara *et al*. (2011) who reported increases in crop biomass due to phosphorus application as phosphorus plays crucial roles in enhancing development of extensive root system thus, resulting into increased nutrient uptake. Leaf area index had significant effect on groundnut genotype and fertilizer type. Application of Minjingu mazao had significant (P=0.001) effect on LAI which is similar to findings by Rezaul *et al.* (2013).

5.2.2 Crop growth rate and Net assimilation rate

Application of fertilizer significantly (P = 0.001) influenced CGR (15.05 g m^2/day) as the highest CGR was observed with application of Ca in the form Minjingu mazao is in conformity with Rezaul *et al.* (2013) who reported increase in CGR with application of P and Ca.

Contrary to the above findings, Hosseinzadeh *et al*. (2012) reported positive influence of Ca on pod grain and biological yield of groundnut and not growth variables. Significant influence of DAP on NAR as observed in the current study and genotype x fertilizer interaction for both CGR and NAR from the current study revealed that Masasi was most responsive to fertilizer application contrary to findings by Bucheyeki *et al.* (2008). The superior performance of Masasi could be due to its late growth pattern which was favoured by weather patterns. Weather pattern can be said to have influenced plant nutrient uptake hence, CGR and NAR in Masasi as optimum temperature and rainfall affect nutrient uptake especially during early critical growth stages such as onset of flowering and peg formation. Similar observations were made by Reddy *et al.* (2003). Teng *et al.* (2008) also reported the impact of climatic stresses on plant nutrient uptake especially during reproductive phase.

5.2.3 Nodulation

Fertilizer type had significant influence on the number of nodules in groundnut. Application of Minjingu mazao significantly increased number of nodules whereas the lowest number of nodules was recorded in plots treated with DAP. Increase in number of nodules with application of 125 kg Ca/ha could be attributed to nutrient composition of Minjingu mazao with 9% P hence, leading to further enhancement of nodule formation, especially when applied at peg formation as reported by Semalulu *et al.* (2014). Influence of Ca on number of nodules is contrary to findings by Taruvinga (2014) who reported increased nodulation in groundnut with application of P. Timing of fertilizer application could have played a major role in nutrient availability as observed from the current study. Nodulation was highest for Ca at 8 WAP while a drastic decline was observed at 6- 8 WAP with the application of 55 kg P/ha as shown in Figure 2. Weisany *et al.* (2013) suggested that high phosphorus supply is needed for nodulation. However, increase in number of nodules due to application of Ca as observed in the current study could be reflective of soil reaction, nodulating bacteria and availability of macronutrients including N and P (Nkot *et al.*, 2011).

5.3 Yield and Yield Components

Application of fertilizer type had influence on some parameters of yield and yield components of groundnut (Table 9). Application of phosphorus influenced 100 kernel weight, harvest index shelling percentage, biological, and pod and kernel yields, of groundnut (Table 9). These results are inconformity with studies carried out in Africa and elsewhere around the world where significance influence of P was observed on yields and other parameters of different grain and non-grain legumes as well as other non-legume crops like maize (Mupangwa and Tagwira, 2005; Naab *et al.,* 2009, Shiyam, 2010; Compaore *et al.,* 2011; Kamara *et al.,* 2011; Veeramani and Subrahmaniyan, 2011; Tran and Tu, 2011; Rezaul *et al*., 2013).

Hosseinzadeh *et al*. (2012) observed a strong positive influence of Ca over control on pod, grain, and biological yield of groundnut, contrary to this study, pod and kernel yields were significantly influenced by P. This could be attributed to the time of fertilizer application as DAP; representing 91% P was applied at sowing and application of Minjingu mazao (containing 9% P) at pegging. The study results also revealed significant (P=0.004) influence of fertilizer on number of pods and number of kernels per plant which is contrary to findings by Taruvinga (2014) and Shiyam (2010).

5.4 Oil and Protein Content

The current study revealed that oil content for all groundnut genotypes ranged from 41.42% - 44.24% similar to observation made by Okello *et al.* (2010) who indicated that groundnut seeds contain 40 - 50% fat and 20 - 50% protein. It was also observed that application of calcium increased groundnut oil content. Protein content of groundnut was enhanced due to application of fertilizer (28.5% -32.40%) in agreement with Madhan and Nigam (2013).

The result also revealed that application of Ca and P increased protein content of Pendo. Studies results by other researchers showed that fertilizer application increased the protein content of groundnut as observed by Kamara *et al.* (2011). Contrary to the findings above, application of Ca and P had no significant effect on oil content of groundnut.

5.5 Effect of Fertilizer Application on Groundnut yield and Profitability

Grain and pod yields responded more positively to application of DAP indicating that P was observed to be the most contributing nutrient element leading to the increase in grain yield over control however, VCR analysis was conducted focusing on the extra benefit derived from application of DAP and Minjingu mazao as sources of P and Ca respectively. Crop requirement for Ca and the cost of meeting crop nutrient demand outweighed the cost of 55 kg P/ha from DAP as the cost of P from DAP almost doubled the cost of Ca from Minjingu mazao (Table 12). Similarly, gross return and VCR increased with application of DAP whereas application of Minjingu mazao resulted into lower gross return and VCR of $2 163 and 0.3, respectively. The highest gross return for fertilizer and VCR resulted from the application of DAP which is similar to findings by (Taruvinga, 2014).

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The current study results showed positive response of groundnut to P application which implied that P was the most limiting element for groundnut production in the study area. Increased yield was attributed to application of DAP which contributed to increased crop growth, yield and yield components, hence profitability. Given the significant influence of P on crop biomass, CGR, NAR, 100- kernel weight, HI, shelling percent, pod and kernel yields at 55 kg P/ha it is appropriate for groundnut production in the study area.

Application of Minjingu mazao had significant influence on growth parameter including plant biomass and LAI, number of pods, number of kernel per pod, number of pops and number of filled pods as well as fats (oil) content which is significant on the basic of groundnut marketable quality; indicating that calcium was also important contributor to growth yield and quality of groundnut. However, it is important that recommendation for Ca application in the study area should be based on standard soil analysis.

Given the increase kernel yield as a result of applying DAP and VCR (< 2) over Minjingu mazao, it can be concluded that the use of DAP as source of P for groundnut production is a worthwhile investment for smallholder farmers as it enhances crop productivity.

6.2 Recommendations

The current study was conducted during one cropping season and at a single location as such the results obtained are not exhaustive enough but can be used as a tool to give insight into happenings as it relates to groundnut productivity and fertilizer use. Given the results from the current study the following are recommended:

i. Application of P fertilizer at 55 kg P/ ha based on appropriate agronomic practices enhances crop growth, pod and kernel yield, hence, profitability of groundnut.

ii. Multi locational trials should be conducted for more than one cropping season in the study area and other groundnut producing regions in Tanzania so as to further validate the current study.

iii. Further research be conducted to determine the response of groundnut to different rates or combinations of calcium and phosphatic fertilizers.

iv. Further studies to assess other attributes such as nutrient use efficiency (NUE), agronomic efficiency (AE), and average nutrient recovery rate (ANR) on groundnut production in the study and other groundnut producing regions in Tanzania.

v. Extension services such as field demonstration on methods of fertilizer application including timing and placement is recommended as means of optimizing fertilizer inputs.

REFERENCES

Abdzad, G., Noorhosseini, A. and Niyaki, S. A. (2010). Effects of iron and nitrogen fertilizers on yield and yield components of peanut (*Arachis hypogaea L.)* in Astaneh Ashrafiyeh, Iran. *American Eurasian Journal of Agricultural and Environmental Science* 9(3): 256 – 262.

Acland, J. D. (1971). *Groundnuts East African Crops*. Food and Agriculture Organization, Rome, Italy. 133pp.

Ademiluyi, Y. S., Oyelade, O. A., Jaes, D. and Ozumba, I. C. (2011). Performance evaluation of a tractor drawn groundnut digger/shaker for agricultural productivity. *Tillage for Agriculture Productivity and Environmental Sustainability Conference*, February 21 – 23 February 2011. Ilorin, Nigeria. pp. 15 – 27.

Adinya, I. B., Enun, E. E. and Ijoma, J. U. (2010). Exploring profitability potentials in groundnut production through agroforestry practices: a case study in Nigeria. *Journal of Animal and Plant Sciences* 20(2): 123 – 131.

Alireza, H. G., Mohammad, N. S. V. and Mohammad, H. H. (2012). Effect of potassium and calcium application on yield, yield components and qualitative characteristics of peanut (*Arachis hypogaea L.). World Applied Sciences Journal* 16(4): 540 – 546.

AOAC (1990). Association of Official Analytical Chemists Inc. *Official Methods of analysis*. (15th Edition). Washington DC. 1298pp.

Arakama, N. K. (2013). Profitability of intercropping corn with mungbean and peanut. *Journal of Peanut* 17(1): 65 – 70.

Badiane, C. (2001). Senegal's Trade in Groundnuts: Economic, Social and Environmental Implications. Senegal. http://www.american.edu/TED/senegalgroundnut.htm] site visited on 1/7/2016.

Barker, N. P. (2005). A review and survey of basicarpy, geocarpy, and amphicarpy in the African and Madagascan flora. *Annals of the Missouri Botanical Garden* 92: 445 – 462.

Bationo, A., Hattemink A., Lungu, O., Naimi, M., Okoth, P., Smaling, E. and Thiombiano, L. (Ed) (2006). *African Soils: Their Productivity and Profitability of Fertilizer Use.* African Fertilizer Submit, Abuja, Nigeria. 39pp.

Bhatti, A. U. (2006). *Statistical Procedures for Analysis of Agriculture Research Experiments.* Department of Soil and Environmental Sciences, University Peshawar, Pakistan. 115pp.

Boote, K. J. (1982). Growth stages of peanut (*Arachis hypogaea L.). Journal of Peanut Science* 9(1): 35 – 40.

Boote, K. J., Stansell, J. R., Schubert, A. M. and Stone, J. F. (1982). Irrigation, water use, and water relations. In: *Peanut Science and Technology*. (Edited by Pattee, H. E. and Young, C. T.), American Peanut Research and Education Society, Yoakum. pp. 164 – 205.

Brady, N. C. and Weil, R .R. (2002). *The Nature and Properties of Soils*. (13th Ed.), Pearson Education Pvt. Ltd., Indian Branch, Singapore. 311pp.

Bremner, J. M. and Mulvaney, C. S. (1982). Total nitrogen. In: *Methods of Soil Analysis Part 2. Chemical and Microbiological Properties.* (Edited by Page, A. L., Miller. R. H. and Keeney, D. R.), American Society of Agronomy and soil Science of America, Madison, Wisconsin. pp. 593 – 624.

Brown, R. H. (1984). *Growth of the green plant, Physiological Basis of Crop Growth and Development*. ASA, CSSA, Madison, Wisconsin, USA. pp. 153 – 173

Brown, S. C. (2011). Crop yield and water infiltration response to gypsum applications. *Journal of the National Association of county Agricultural Agents* 4(2): 1 – 22.

Bucheyeki, T. L., Shenkalwa, M. E., Mapunda, T. and Matata, W. L. (2008). On-farm evaluation of promising groundnuts varieties for adaptation and adoption in Tanzania. *African Journal of Agricultural Research* 3(8): 531 – 536.

Bucheyeki, T. L., Shenkalwa, M. E., Mapunda, T. and Matata, W. L. (2010). The groundnuts client oriented research in Tabora, Tanzania. *African Journal of Agricultural Research* 5(5): 356 – 362.

Caliskan, S., Caliskan, M. E., Arsian, M. and Arioglu, H. (2008). Effects of sowing date and growth duration in Mediterranean type environment in Turkey. *Field Crops Research* 15(2): 131 – 140.

Compaore, E., Catton, P. and Taonda J. B. S. (2011). Effect of continuous mineral and organic fertilizer inputs and plowing on groundnut yield and soil fertility and groundnut sorghum rotation in Central Burkina Faso. In: *Innovation as Key to Green Revolution in Africa*. (Edited by Batiano, A., Hattemink A., Lungu, O., Naimi, M., Okoth, P., Smaling, E. and Thiombiano, L.), Central Burkina, Faso. pp. 22 – 36.

Craufurd, P. Q., Prasad, P. V. V. and Summerfield, R. J. (2002). Dry matter production and rate of change of harvest index at high temperature in peanut. *Crop Science* 42: 146 – 151.

Dulvenbooden, N. V., Abdoussalam, S. and Moamed, A. B. (2002). Impact of climate change on agricultural production in the Sahel-Part 2. Case study for groundnut and Cowpea in Niger. *Climatic Change* 24(3): 349 – 368.

Fageria, N. K., Baligar, V. C. and Charles-Allen, J. (1997). *Growth and Mineral Nutrition of Field Crops*. (Second Edition), Marcel Kekker, Inc., New York. 66pp.

FAOSTAT (2013). Database in crop production.[http:// faostat.fao.org/site/567/ DesktopDefau laspx?PageID=567#ancor] site visited on 5/08/2015.

Farm Management Handbook (2010). *The Farmer's Hand Book.* ZFC Limited, Harare, Zimbabwe. 125pp.

Fonceka, D. (2010). *Elargissement De La Base Génétique De L'arachidecultivée (Arachis Hypogaea): Applications Pour La Construction De Populations.* l'identificationde QTL et l'amélioration de l'espècecultivée. Thèse de doctorat de Montpellier. 162pp.

Gashti, A. H., Vishekaei, M. N. and Hosseinzadeh, M. H. (2012). Effect of potassium and calcium application on yield, yield components and qualitative characteristics of peanut (*Arachis hypogaea L.)* In Guilan Province, Iran. *World Applied Sciences Journal* 16: 540 – 546.

Gee, G. W. and Bauder, J. W. (1996). *Particle Size Analysis In: Methods of Soil Analysis Physical and Mineralogical Methods Soil Science Society of America.* American Society of Agronomy Inc., Madison, Wisconsin. 412pp.

Ghosh, P. K., Dayal, D., Bandyopadhyay, K. K. and Mohanty, M. (2006). Evaluation of straw and polythene mulch for enhancing productivity of irrigated summer groundnut. *Field Crops Research* 99: 76 – 86.

Giller, K. E. (2001). *Nitrogen Fixations in Tropical Cropping Systems*. (2nd Ed.), Commonwealth for Agriculture Bureau International, Wallingford, UK. 323pp.

Gomez, A. K. and Gomez, A. A. (1984). *Statistical Procedure for Agricultural Research.* John Wiley and Sons, Inc., London. 680pp.

Hosseinzadeh, G. A., Vishekaei, M. N. and Hosseinzadeh, M. H. (2012). Effect of potassium and calcium application on yield, yield components and qualitative characteristics of peanut (*Arachis hypogaea L.*) in Guilan Province, Iran. *World Applied Sciences Journal* 16: 540 – 546.

Kakani, V. G., Prasad, P. V. V., Craufurd, P. Q. and Wheeler, T. R. (2002). Response of in vitro pollen germination and pollen tube growth of groundnut (*Arachis hypogaea L.*) genotypes to temperature. *Plant Cell and Environment* 25: 1651 – 1661.

Kamara, A. Y., Ekeleme, F., Kwari, J. D., Omoigui, L. O. and Chikoye, D. (2011). Phosphorus effect on growth and yield of groundnut varieties in the tropical savanna of North Eastern Nigeria. *Journal of Tropical Africa* 49(2): 24 – 30.

Kamara, E. G., Olympio, N. S and Asibuo, J. Y. (2011). Effect of calcium and phosphorus on the growth and yield of groundnut (*Arachis hypogaea L.*). *International Research Journal of Agricultural Science and Soil Science* 1(8): 326 – 331.

Kamhabwa, F. (2014). *Consumption of Fertilizers and Fertilizer Use by Crop in Tanzania.* Dar es Salaam, Tanzania. 23pp.

Kanyeka, E., Kamala, R. and Kasuga, R. (2007). *Improved Agricultural Technologies in Tanzania.* Ministry of Agriculture Food Security and Cooperatives, Dar es Salaam, Tanzania. 125pp.

Katsaruware, R. D. and Mabwe, C. (2014). Response of groundnut (*arachis hypogea*) to inorganic fertilizer use in smallholder farming of Makonde District, Zimbabwe. *Journal of Biology, Agriculture and Healthcare* 4:7.

Kwari, J. D. (2005). *Soil Fertility Status in Some Communities of Southern Borno*. PROSAB, Nigeria. 21pp.

Lal, R. and Shukla, M. K. (2004). *Principles of Soil Physics*. The Ohio State University Columbus, Ohio, USA. 699pp.

Landon, J. R. (1991). *Booker Tropical Soil Manual. A Hand Book For Soil Survey and Agricultural Land Evaluation In The Tropics And Sub Tropics.* Longman Publishers, New York. 474pp.

Lindsay, W. L. (1978). Development of a DPTA soil test for zinc, iron, manganese and copper. *Journal of American Soil Science Society* 42: 421 – 428.

Madhan, M. M. and Nigam, S. N. (2013). *Principles and Practices for Groundnut Seed Production in India*. Information Bulletin No. 94. International Crops Research Institute for the Semi-Arid Tropics, Andhra Pradesh, India. 64pp.

Mahoo, H. F., Young, M. D. B. and Mziray, O. B. (1999). Rainfall variability and its implication for the transferability of experimental results in semi-arid areas of Tanzania. *Journal of Agricultural Sciences* 2(2): 127 – 140.

Mangasini, A. K., Mwanahawa, L. M., Arbogast, G. and Neema, P. (2013). Socio-economic factors limiting smallholder groundnut production in Tabora Region. [http.//:www.repoa.or.tz] site visited on 20/07/2015.

Meena, S., Malarkodi, M. and Senthilvalavan, P. (2007). Secondary and micronutrients for groundnut. *Agricultural Reviews* 28: 1 – 4.

Minjingu Mines and fertilizer LTD, (2014). *Developing Indigenous Resources for Fertilizer Production in Africa:* Minjingu Mines and Fertilizer Ltd., Mtwara, Tanzania. 20pp.

Moazed, H., Hoseini, Y., Naseri, A. A. and Abbasi, F. (2010). Determining phosphorus adsorption isotherm in soil and its relation to soil characteristics. *International Journal of Soil Science* 5: 131–139.

Msolla, M., Semoka, J. R. M. and Borggaard, O. (2005). Hard Minjingu phosphate rock: An alternative P source for Maize production on acid soils in Tanzania. *Nutrient Cycling in Agroecosystems* 72(3): 299 – 308.

Mupangwa, W. T. and Stagira, F. (2005). Groundnut yield response to single superphosphate, calcitic lime and gypsum on acid granitic sandy soil. International Crop Research Institute for Semi-Arid Tropics, Bulawayo, Zimbabwe. 8pp.

Murata, M. R. (2003). The impact of soil acidity amelioration on groundnut production on sandy soils of Zimbabwe. Thesis for Award of PhD Degree at University of Pretoria, South Africa, 229pp.

Naab, J. B., Seini, S. S., Gyasi, K. O., Mahama, G. Y., Prasad, P. V. V., Boote, K. J. and Jones, J. W. (2009). Groundnut yield response and economic benefits of fungicide and phosphorus application in farmer-managed trials in Northern Ghana. *Expl Agriculture* 45: 385 – 399.

Nautiyal, P. (2002). *Groundnut Post-harvest Operations.* National Research Centre for Groundnut, New Delhi, India. 38pp.

Nautiyal, P. C., Zala, P. V., Tomar, R. S., Sodavadiya, P. and Tavethia, B. (2011). Evaluation of water use efficient newly developed varieties of groundnut in on-farm trials in two different rainfall areas in Gujarat, India. *Journal of Agricultural Research* 9: 44 – 62.

Nelson, D. W. and Sommers, L. E. (1982). Total carbon and organic matter. In: *Methods of Soil Analysis, Chemical and Microbiology Properties.* (Edited by Page, A. L., Miller, R. M. and Keeney, D. R.), American Society of Agronomy, Madson, Winscosin. pp. 539 – 577.

Nigam, S. N., Upadhayaya, H. D., Chandra, S., NageswaraRao, R. C., Wright, G. C. and Reddy, A. G. S. (2001). Gene effects for specific area and harvest index in three crosses of groundnut (*Arachis hypogaea L.*). *Annals of Applied Biology* 39(3): 301 – 306.

Nkot, L., Nwaga, D., Ngakou, A., Fankem, H. and Etoa, F. (2011). Variation in nodulation and growth of groundnut (*Arachis hypogaea L.*) on oxisols from land use systems of the humid forest zone in southern Cameroon. *African Journal of Biotechnology* 10(20): 3996 – 4004.

Ntare, B. R., Diallo, A. T., Ndjeunga, A. T. and Waliyar, F. (2008). *Groundnut Seed Production Manual.* International Crops Research institute for the Semi-Arid Tropics, Andhra Pradesh, India. 20pp.

Olsen, R. S. and Sommers, L. E. (1982). Phoshorus. In: *Methods of Soil Analysis.*(Edited by Page, A. L., Miller, R. M. and Keeney, D. R.), American Society of Agronomy, Madson, Winscosin. pp. 422 – 430.

Okello, D. K., Biruma, M. and Deom, C. M. (2010). Overview of groundnuts research in Uganda: Past, present and future. *African Journal of Biotechnology* 9(39): 6448 – 6459.

Oyelade, O. A., Ademiluyi, Y. S., James, D. Ozumba, I. C. (2011). Performance evaluation of a modified tractor drawn groundnut digger/shaker for agricultural productivity. *Tillage for Agriculture Productivity and Environmental Sustainability Conference.* 21 – 23 February 20111, Ilorin, Nigeria. pp. 7 – 12.

Panda, S. C. (2010). Crop management and Integrated Farming. Agrobios Publisher, Jodhpur, India. 271pp.

Pande, S. and Narayana, R. J. (2002). Effect of plant population densities on the severity of late leaf spot and rust of groundnut. *Journal of Plant Pathology* 18(5): 217 – 278.

Petersen, L. (1996). *Soil Analytical Methods. Soil Testing Management and Development Soil.* Resources Development Institute, Dhaka, Bangladesh. 12pp.

Rahman, M. A. (2006). Effect of Calcium and Bradyrhizobium inoculation of the Growth, Yield and quality of groundnut (*Arachis hypogaea L.*). *Bangladesh Journal of Science Indian Research* 41(4): 181 – 188.

Rao, H. S. B., Venkatesh, B., Rao, T. V. and Reddy, K. H. C. (2013). Experimental investigation on engine performance of diesel engine operating on peanut seed oil biodiesel blends. *International Journal of Current Engineering and Technology* 3(4): 1429 – 1435.

Reddy, T. Y., Reddy, V. R. and Anbumozhi, V. (2003). Physiological responses of groundnut (*Arachis hypogaea L.*) to drought stress and its amelioration: a critical review. *Plant Growth Regulation* 41: 75 – 88.

Rezaul, K., Sabina, Y., Mominul, I. A. K. and MdAbdur R. S. (2013). Effect of Phosphorus, Calcium and Boron on the Growth and Yield of Groundnut (*Arachis hypogaea L.*). *International Journal of Bio-Science and Bio-Technology* 5(3): 1 – 10.

Ronner, E., Baijukya, F. P. and Giller, K. (2012). Opportunities for N2 Africa in Tanzania. [www.N2Africa.org] site visited on 20/12/2015.

Semalulu, B., Mugonola, J., Bonabana-Wabbi, S. T. and Kayangaand, H. M. (2014). Optimizing use of integrated soil fertility management options for profitable groundnut production in Uganda. *Agriculture and Soil Sciences* 1(5): 61 – 69.

Semoka, J. M. R. (2002). *Progress Report for 2001 for the Research on Rock Phosphate Utilization Project. Agricultural Sector Programme Support*. Ministry of Agriculture and Food Security, Dar es Salaam, Tanzania. 22pp.

Semoka, J. R. M. (2003). *Research Report for Progress Rock Phosphate Project.* Sokoine University of Agriculture, Morogoro, Tanzania. 24pp.

Shiyam, J. O. (2010). Growth and yield response of groundnut (*Arachis hypogaea* L.) to plant densities and phosphorus on an ultisol in Southeastern Nigeria. *Libyan Agriculture Research Center Journal International* 1: 211 – 214.

Sorrensen, R., Butts, C., Lamb, M. and Rowland, D. (2004). *Five Years of Subsurface Drip Irrigation on Peanut.* Research and Extension Bulletin No. 2004.

Tarawali, A. and Quee, D. (2014). Performance of groundnut varieties in two agro-ecologies in Sierra Leone. *African Journal of Agricultural Research* 9(19): 1442 – 1448.

Taru, V. B., Khagya, I. Z., Mshelia, S. I. and Adebayo, E. F. (2008). Economic efficiency of resource use in groundnut production in Adamawa State of Nigeria. *World Journal of Agricultural Science* 56: 4896 – 900.

Taru, V. B., Kyagya, I. Z. and Mshelia, S. I. (2010). Profitability of groundnut production in Michika Local Government Area of Adamawa State, Nigeria. *Journal of Agricultural Science* 1(1): 25 – 29.

Taruvinga, B. (2014). Nutritional and soil fertility benefits: influence of fertilizers on groundnuts (*Arachis hypogaea L.*) yield and soil nitrogen contribution for smallholder farmers in Uganda. Dissertation for Award of MSc Degree at Wageningen University, Netherlands, 81pp.

Teng, W., Zhai, Y., Du, Y., Sun, D., Zhang, Z., Qu, L., Sun, G. and Li, W. (2008). QTL analysis of seed weight during the development of soybean (*Glycine max L. Merr.).* [http:// nature.com/hyd/journal/v102/nu/full/hyd2008108a.html] site visited on 29/10/2014.

Thomas, G. W. (1996). Exchangeable cations. In: *Method of Soil Analysis.* (Edited by Page, A. l., Miller, R. H. and Keeney, D. R.), American Society of Agronomy, Madson, Winscosin. pp. 154– 169.

Tran, T. and Tu, H. (2011). Effect of phosphorus fertilizer on groundnut yield in poor alluvial and sandy soils of Thua Thien Hue. *Better Crops International* 17: 16 – 17.

Tubbs, R. S., Harris, G. S., Smith, N. B. (2012). Effect of inoculation and nitrogen application at planting on peanut production in Georgia. [http:/scien cesocieties.org/publications/ cm/abstract] site visited on 4/11/2015.

Turner, J. T. and Backman, P. A. (1988). Severity , distribution, and losses from taproot cankers caused by rhizoctonia solanis in peanut. *Peanut Science* 15: 73 – 75.

United Republic of Tanzania (2012). *Assessment of the Potential of Edible Oilseeds Produced in Tanzania: The Case of Sunflower and Sesame*. National Report 2007/2008. Goverment Printers, Dar es Saalam, Tanzania. 48pp.

Uma, M. N. and Sathiyavani, G. (2012). Solubilization of phosphate by Bacillus Sps., from groundnut rhizosphere (*Arachis hypogaea L.*). *Journal of Chemical and Pharmaceutical Research* 4(8): 4007 – 4011.

USDA-FAS (2010). United States Department of agricultural service peanut area, yield, and production. [http://www.fas.usda.gov/psdonline/psdQuery.aspx]site visited on 2/10/2015.

Vara Prasad, P. V., Craufurd, P. Q. and Summerfield, R. J. (2000). Effect of high air and soil temperature on dry matter production, pod yield and yield components of groundnut. *Plant Soil* 222: 231 – 239.

Vara Prasad, P. V., VijayaGopal , K. and Hari, D. U. (2009). Growth and production of groundnut, in Soils, Plant Growth and Crop Production. In: *Encyclopedia of Life Support Systems*. (Ed. Willy H. V.), United Nations Education Scientific and Cultural Organization, Eolss. pp. 11 – 27.

Veeramani, P. and Subrahmaniyan, K. (2011). Nutrient management for sustainable groundnut productivity in India: A review *International Journal of Engineering Science and Technology* 3: 8138 – 8153.

Walker, M. E., Keisling, T. C. and Drexler, J. S. (1978). Response of three peanut cultivars to gypsum. *Journal of Agronomy* 68: 527 – 528.

Weiss, A., Van Crowder, L. and M. Bernardi, M. (2000). Communicating agrometeorological information to farming communities. *Agricultural Forest Meteorology* 103: 185–196.

Weisany, R. Y. and Allahverdipoor, K. H. (2013). *Role of Some of Mineral Nutrients in Biological Nitrogen Fixation. Bulletin of Environment, Pharmacology and Life Sciences*. Academy for Environment and Life Sciences, India.112pp.

Yakubu, H., Kwari, J. D. and Tekwa, J. A. (2010). Nodulation and N2 – fixation by grainlegumes as affected by Boron Fertilizers in Sudano – Sahelian Zone of North eastern Nigeria. *American Eurasian Journal of Agriculture and Environmental Science* 8(5): 514 – 519.

APPENDICES

Appendix 1: Summary of analysis of variance (ANOVA) for crop growth parameters, yield and yield components (groundnut genotypes, and fertilizer types)

Source of variation	Variety(A)	Fertilizer types(B)	Fertilizer x variety (AxB)
LAI	*	***	**
Biomass	ns	***	*
CGR	**	***	**
NAR	***	**	***
Number of nodules	***	***	****
Number of pegs/plant	**	**	**
Number of pod/plant	***	***	**
Number of kernel/pod	ns	***	**
Number of pop	ns	**	*
Crude protein (%)	***	ns	*
Oil content (%Fats)	***	***	**
Kernel yield	***	**	***
100-kernel weight	***	***	***
Pod yield	***	***	***
Shelling percentage (%)	ns	**	*
Harvest index (%)	***	**	***
Biological yield	**	***	*

***significant at 0.001, significant at ** 0.01 and * significant at 0.05, ns= not significant.