RESPONSE OF SWEET POTATO *(Ipomoea batatas* LAM) TO ORGANIC AND INORGANIC FERTILIZERS IN LOAMY SAND SOIL AT TUMBI, TABORA, TANZANIA

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ABSTRACT

A field experiment was conducted during 2014/15 growing season at Tumbi, Tabora to study response of sweet potato to organic and inorganic fertilizers. The experiment was split plot laid in a Randomized Complete Block Design with four fertilizer types and different rates; 0, 50, 100, 150 (DAP), 100, 200, 300 kg ha^{-1} (Minjingu Mazao), 150, 250, 350 kg ha^{-1} (NPK) and 2.5,5.0,7.5 ton ha^{-1} (FYM) as main plots and three varieties (Kasinia, Simama and Ukerewe) as subplot in three replications. Data on tuber numbers, total tuber weight, marketable tubers weight, marketable tubers diameter, vine length, branch numbers and above ground dry biomass were measured while, agronomic efficiency, net revenue and Value Cost Ratio were calculated then analyzed using Genstat Statistical Software and Tukey's test for mean separation at 5% significance level. Overall yield and yield components increased with increase in fertilizer rates. Highest total tuber weight (13.21 tons ha^{-1}) and tuber numbers (54321) were recorded with FYM (7.5 tons ha $^{-1}$) while, highest marketable tubers weight of 12.47 tons ha^{-1} and marketable tubers diameter (8.88 cm) was recorded in Kasinia with NPK fertilizer (Yara Mila Winner) at 350 kg ha^{-1}. NPK (350 kg ha^{-1}) and FYM (7.5 tons ha^{-1}) gave highest above ground dry biomass weight at 5.70 and 5.62 ton ha^{-1} respectively, while NPK (350 kg ha^{-1}) recorded longest vine (235.3 cm) and number of branches (8.89) than the control. Higher agronomic efficiency of 228.46 was recorded in variety Kasinia with FYM (7.5 ton ha^{-1}) and net revenue of TShs 5172160/- was obtained from variety Simama, which was similar to Kasinia. Kasinia and Simama were more responsive to NPK (350 kg ha^{-1}) and FYM (7.5 tons ha^{-1}) than Ukerewe as they gave highest yields and net revenue.

DECLARATION

I, KASSIM COSTANTINE MASIBUKA do hereby declare to the Senate of the 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.

________________________________ ____________________

Kassim Costantine Masibuka **Date**

(MSc. Crop Science Candidate)

The above declaration is confirmed

________________________________ ____________________

Prof. A.J.P Tarimo **Date**

(Supervisor)

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DEDICATION

This work is dedicated to my wife Joyce William Masolwa, without whom this stage wouldn't have been reached. I also dedicate this work to my children Mahushi, Masanja, Farida, Hollo, N'gwashi and Budoto for the father loneliness they experienced during my absence.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURE

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND ACRONYMS

AE	Agronomic efficiency
Al	Aluminium
ARI	Agricultural Research Institute
C	Carbon
C/N	Carbon / nitrogen ratio
Ca	Calcium
CEC	Cation exchangeable capacity
Cmol	Centimole
CIP	International Potato Centre
Cl	Chlorine
Cm	Centimeter
COSTECH	Commission for Science and Technology
DAP	Di Ammonium Phosphate
et al	and others
FAOSTAT	FAO Statistics
Fe	Iron
FYM	Farm Yard Manure
g	Gram
ha	Hectare
IFA	International Fertilizer industry association
K	Potassium
Kg	Kilogramme
M	Meter
m.a.s.l	Meter above sea level

Meq	Milliequivalent
Mg	Magnesium
mm	Millimeter
Mn	Manganese
N	Nitrogen
NGO’s	Non-Governmental Organizations
O	Oxygen
P	Probability
P	Phosphorus
SUA	Sokoine University of Agriculture
Tshs	Tanzanian Shillings
URT	United Republic of Tanzania
VCR	Value Cost Ratio
W H foods	World’s healthiest and food programme
LSD	Least Significant Different
CV	Coefficient of Variations

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Sweet potato (*Ipomoea batatas* Lam.) is one of the World's most important food crops in terms of human consumption, particularly in Sub-Saharan Africa, parts of Asia and the Pacific Islands. It is grown in more developing countries than any other tuber crop. It is a tuber, not a root, and belongs to the morning-glory family. Many parts of the plant are edible, including leaves, tubers, and vines, and varieties exist with a wide range of skin and flesh colour, from white to yellow to orange and deep purple (CIP, 1999). Sweet potato currently ranks as the Worlds' seventh most important food crop and the fifth most important food crop on a fresh weight basis in developing countries after rice, wheat, maize and sorghum (FAO, 2004).

Tanzania is the second largest producer of sweet potato in East Africa (after Uganda) with an annual production of just under one million tons (URT, 2011a). The crop is grown almost in all agro-ecological zones in marginal soils. It is regarded as an important food security crop and is capable of adapting to climate change challenges. Several improved sweet potato varieties have been developed, which gain their importance through the provision of carbohydrates, protein and vitamins (Gibson, 2006).

Recently, the crop has gained its potential through commercialization both in rural and urban markets. The crop plays an important role in household food security and income generation among farmers and supplies nutritional diets that can greatly reduce the risk of heart disease, stroke and even cancer (Carey *et al.,* 1999; Helen Keller International Tanzania, 2012).

Despite its importance, sweet potato yields are low due to many factors including biotic, abiotic and social economic factors. Among the factors, includes low soil fertility, pests and diseases, drought, low yielding genotypes, poor adaptability to environmental conditions, low prices, poor processing techniques and poor accessibility to markets (Kapinga *et al.,* 1995; Ndunguru *et al.,* 2009).

Although research has been done in many areas in the World and in many African countries, including Tanzania, there is little information on integrated soil fertility management and agronomic recommendations for sweet potato production at farm level particularly in Tabora region (Kapinga *et al.,* 1995; Ndunguru and Rajabu, 2000). This could be a reason for the low yield obtained per unit area of cultivated land as compared with other countries such as China.

1.2 Justification

Sweet potato is one among the important food crops grown in Tabora, but yields are low (1.4 ton ha^{-1}) compared to other parts of the country and elsewhere in the World. The average sweet potato yield in Tanzania is 2.9 ton ha^{-1} (FAOSTAT, 2010) while, in other countries like China it is 21.5 ton ha^{-1}, Indonesia 11.2 ton ha^{-1}, Uganda 4.5 ton ha^{-1}, Nigeria 2.9 ton ha^{-1} (FAOSTAT, 2012). Low soil fertility and poor genotypes could be among the major production constraints for potato crop (Ndunguru *et al.,* 2009). Low soil fertility is the major production constraint in Tabora region. Soils are 80-90% sand with low fertility (Nyadzi *et al*., 2003b). They are low in organic carbon, phosphorus, total nitrogen and cation exchange capacity (CEC) and with pH 4-6 (Nyadzi *et al*., 2003b; Majule *et al*., 2011).

Low yield of sweet potato is caused by many factors, including the use of local varieties, which are susceptible to diseases and are of poor genetic traits. Efforts to introduce genotypes with high yield potential and tolerant to biotic and abiotic stresses have been done, resulting in the cultivation of many improved genotypes. However, farmers are yet to benefit from these outcomes (Ndunguru *et al.,* 2009). This may be due to the fact that, the performance of such improved genotypes has not been tested for different fertilizer recommendations in different agro-ecologies. Sweet potato production depends much on genetic and environmental factors. However, there is a lack of information on the magnitude of effects of fertilizers on yield and yield components of local and improved sweet potato genotypes in soils of Tabora.

Most of the communities in Tabora depend on sweet potato crop as a source of food and income generation which requires attention of researchers and policy makers. For example, Agricultural Research Institutes identified, developed and released many varieties, but no fertilizer recommendations have been provided. This problem has been amplified by continuous crop removal and nutrient leaching (Kwesiga *et al.,* 2003). It is estimated that sweet potato production biomass removes nutrients at a rate of 51.6 kg N ha^{-1}, 7.5 kg P ha^{-1}, and 59 kg K ha^{-1} (IFA, 1992). In addition, the economic revenue of sweet potato to farmers in Tabora is low due to poor soil fertility and crop performance (1.4 ton ha^{-1}). Therefore, the aim of this study was to develop an appropriate integrated soil fertility management options in order to increase sweet potato production in the region.

1.3 Objectives of the Study

1.3.1 Overall objective

To develop fertilizer recommendation to enhance productivity and profitability of sweet potato production in Tabora region

1.3.2 Specific objectives

i. To determine the yield response of sweet potatoes to organic and inorganic fertilizers;
ii. To evaluate the agronomic efficiency of using organic and inorganic fertilizers; and,
iii. To determine the economic benefits of using fertilizers in sweet potato production.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Historical Background of Sweet Potatoes

Sweet potato originated from Central America and is one of the oldest vegetables known to man. The crop has been consumed since prehistoric times and was discovered in Peruvian caves (WH Foods, 2012). Christopher Columbus brought sweet potatoes to Europe after his first visit to the New World in 1492. The Spanish brought the crop to the Philippines and the Portuguese brought it to Africa, India, Indonesia and Southern Asia (WH Foods, 2012).

2.2 Sweet Potato Production and Consumption in Tanzania

Sweet potato is a food crop grown in almost all agro-ecological zones of Tanzania. It occupies approximately 14% of total arable land and mostly cultivated by smallholder farmers (Kapinga *et al.,* 1995). Sweet potato consumption in most families involves boiling, roasting and deep-frying of the tubers and the leaves are eaten as a green or dried vegetable depending on the season. The dried vegetables are packed for consumption during the dry season. In most parts of Tanzania, sweet potato has gained importance due to its adaptability to marginal conditions such as drought, wet conditions, low soil fertility and is ranked high as food security crop when local staple crops like maize and rice are scarce or fail (Ewell and Mutuura, 1991).

Table 1: Trend of sweet potato production area, total production and yield per hectare in Tanzania

Year	Production area(ha)	Total production ('000 metric ton)	Yield per hectare (tons ha^{-1})
2003	135470	207830	1.5
2004	517530	1501620	2.9
2005	469110	1414820	3.0
2006	480000	1396400	2.9
2007	450000	1322000	2.9
2008	460000	1379000	2.9
2009	465000	1381120	2.9
2010	480000	1392000	2.9

Source: FAOSTAT, 2010

2.3 Major Sweet Potatoes Production Constraints

Sweet potato productivity in Tanzania is very low compared to international standards despite its potential. Low yields are caused by use of local varieties that are low yielding and susceptible to diseases and insect pests (Kapinga *et al*., 1995 and Mukasa *et al*., 2003).

According to Ndunguru *et al*. (2009), sweet potato production is constrained by the lack of clean planting materials, lack of high yielding cultivars, low soil fertility and lack of disease and insect pests resistant cultivars. Similarly, the unavailability of high quality planting material of improved varieties is another major limitation in increasing sweet potato production. The situation has been aggravated by the lack of an organized seed system of clonally propagated crops in the seed sector in Tanzania. The need for fast tracking the evaluation of advanced breeding lines through participatory variety selection and release of superior clones cannot be overemphasized.

Drought and low soil fertility in many parts of the country affect crop productivity. Genetic erosion accelerated by the climate change has been another major problem in the country limiting the genetic diversity of sweet potato crop improvement (Kapinga *et al.,* 1995; Bashaasha *et al.,* 1995). Therefore, rapid breeding of new varieties that are high yielding, resistant to diseases and insect pests, and drought tolerant with high dry matter content, good texture and high in beta-carotene are proposed.

According to Carey *et al*. (1999), who reported that the major limiting factor for increased sweet potato production are shortage of clean planting materials of superior varieties. Most farmers in sub Sahara countries are mainly depend on large numbers of landraces where farmers have to source planting material from neighbouring farms.

2.4 Sweet Potato Marketing and Value Chain

Sweet potato marketing is practiced by a small number of small-scale traders, operating privately on an individual basis. Usually, farmers sell sweet potatoes directly to consumers within the villages whenever there is a need. On commercial basis, the marketing chain of sweet potato distribution involves farmers, traders, transporters, commission agents, and final consumers (Bashaasha *et al.,* 1995).

2.5 Status of Sweet Potato Production in Tanzania

Sweet potato currently ranks the seventh as world's most important food crop and the fifth most important food crop on a fresh weight basis in developing countries, after rice, wheat, maize and sorghum (FAO, 2004). Major staple foods in Tanzania include maize, paddy rice and cassava while sorghum, wheat, millet and sweet potatoes are categorized as other staples. Tanzania is the second largest producer of sweet potato (*Ipomoea batatas* Lam.) in East Africa (after Uganda) with an annual production of just under one million tons (URT, 2011a). In Tanzania, sweet potato is the third most important tuber and tuber crop after cassava and Irish potato. The crop is grown almost in all agro-ecological zones (Lake Zone, Western Zone, Southern Highlands Zone, Eastern Zone and Northern Zone) because of its hardy nature and broad adaptability, hence providing a sustainable food supply when other crops fail (Jana, 1982; Kapinga *et al.,* 1995; Ndunguru and Rajabu, 2000). Sweet potato is produced in large quantities in the Lake Zone (330,600 tons year^{-1}) followed by Southern Highlands Zone (271 000 tons year^{-1}), Eastern Zone (107 400 tons year^{-1}) and lowest in the Southern Zone (37,400 tons year^{-1}) (Helen Keller International Tanzania, 2012).

2.6 Importance of Sweet Potatoes

Sweet potatoes use low amount of water, hence suitable for semi-arid areas, their potential provide guarantee on ensuring food security to people (Bashaasha *et al*., 1995). It provides good ground cover, grows on soils with limited fertility, low available moisture and has a short growth period with high yields. The tuberous roots is high in food value, fibre and energy, it is rich in sugar and vitamin C. It also contains good quantities of vitamin A, vitamin B, calcium and iron (Helen Keller International Tanzania, 2012).

2.7 Soil and Climatic Requirements

Soils required for sweet potato production are generally sandy to loamy sand in texture, leveled or slightly sloped, moderately fertile and well drained (Hartemink *et al.,* 2000), which are typical soil conditions of the western zone, particularly Tabora region.

Poorly drained heavy soils with clay result in irregularly sized and shaped fleshy tubers. Sweet potatoes are fairly tolerant to variations in soil pH of 5.2 and 6.7. However, the optimum soil pH for high yields of quality sweet potatoes is 5.8 to 6.0 (Kapinga *et al.,* 1995). Sweet potato is a warm season crop that produces best in temperatures varying from 29^{o} to 35^{o}C. Temperatures above 37.9^{o}C slow down growth of sweet potatoes (Hartemink *et al*., 2000).

2.8 Plant Nutrients

Essential elements of plants are those elements or nutrients required to complete its life cycle. These nutrients could be those supplied by soil or provided to plants as a supplement through fertilizers. Plant nutrients can be subdivided into macro and micro nutrients. Macronutrients are Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg) and Sulfur (S) these are required relatively in large quantities while micronutrients are those elements required in relatively small quantities. These include Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), Boron (B), Molybdenum (Mo) and Chlorine (Cl). Carbon (C), Oxygen (O) and Hydrogen (H), are supplied by the atmosphere and are considered non-limiting (IFA, 1992).

2.8.1 Nutrient requirements

The estimated nutrient removal by a sweet potato crop producing 14 tons of biomass per hectare (10 tons of tubers and 4 tons of leaves) has been found to be (in kilograms per hectare); N (51.6), P_2O_5 (17.2), K_2O (71.0), MgO (6.1), CaO (6.3) and Fe (0.8) (IFA, 1992).

2.8.2 Macronutrients

For most soils, nitrogen application increases tuber yield. However, excess nitrogen can stimulate foliage production at the expense of tubers and may also lead to tuber cracking. The full benefit from nitrogen application is only obtained where there is also sufficient potassium. It is usual recommended to apply 50 kg of potassium per hectare, but less on soils well supplied with nitrogen (IFA, 1992). The crop removes more potassium than phosphorus, which has a larger effect on yield than phosphorous. Under normal conditions, about 22 kg P ha^{-1} should be applied, but this needs to be increased to 30–40 kg P ha^{-1} on soils with a low phosphorus status. The crop needs a good supply of K and N: K_2O ratio of from 1:1.5 to 1:2. A blanket recommendation is to apply 66–100 kg K ha^{-1}. Potassium chloride depresses tuber dry matter content. Where this is the case, the use of potassium sulphate or a mixture of both sources is recommended. Sweet potatoes can suffer from Mg and S deficiencies; hence, their inclusion in the fertilizer recommendations may be necessary (IFA, 1992).

2.8.3 Micronutrients

Sweet potatoes can also suffer from B deficiency, hence corrective control measures may be necessary. Soil application rates ranging from 9 to 26 kg borax ha^{-1} may be necessary. For foliar application, the suggested rate is 5–15 kg Solubor ha^{-1} at a maximum concentration of 2.5–5.0 percent (Shorrocks, 1984).

2.8.4 Organic fertilizers

Application of organic fertilizers such as Farm Yard Manure and compost play an important role in the improvement of soil structure and cation Exchange Capacity (CEC), especially in many highly weathered tropical soils where the inherent CEC is often low (Onwudike, 2010) . Soil organic matter plays a key role in enhancing soil buffer capacity, moisture retention and nutrient availability. It is often a good source of the secondary elements and micronutrients necessary for plant growth and contributes a modest quantity of the primary nutrients (N, P and K) requirements (Onunka *et al*., 2012).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the Study Area

A field experiment was conducted in Tabora Municipality at Tumbi Agricultural Research Institute during the 2014/2015 growing season. Tumbi is located at S $05^{O}04'08.0''$ E $032^{O}41'15.3''$ and an elevation of 1190 meters above sea level (m.a.s.l) in western part of Tanzania, within the Miombo woodland ecosystem. The region receives a unimodal type of rainfall at an average of 880 mm per year. The region has a long dry season of about 5 - 6 months. Temperatures range from a mean minimum of $14.6^{O}C$ in June to a mean maximum of $32.5^{O}C$ in October. Major economic activity in the region includes cultivation of maize, rice, tobacco, groundnuts, beans, sweet potato, cassava, cotton and fruits such as mangoes and oranges. The area is mainly characterized by warm conditions with varied soil types.

3.2 Determination of Soil Physical and Chemical Properties

3.2.1 Soil sampling

Before planting, composite soil samples were collected from the experimental site. Three composite soils were dug from 20 points identified in a random manner at a depth of 0-20, 21-30 and 31- 45cm to form three groups of composite samples. The soil depth was based on plant tuber depth and capability of nutrient extraction. The soil samples from each depth were reduced by quartering to one kilogram, then air dried, ground and sieved through a 2-mm sieve for laboratory analysis.

3.2.2 Soil analysis

The soil characteristics were determined in order to know nutrients status of the experimental site before application of organic or inorganic fertilizers. Three composite soil samples were taken to Mlingano National Soil Service Centre for determination of physical and chemical properties. The parameters analyzed were soil pH in 1:2.5 water suspension, total nitrogen (%) was determined using semi-micro Kjeldahl digestion followed by distillation. Available phosphorus (mg/kg) was determined by spectrophotometry technique at 884 -890 nm wavelength according to Bray-1-Kurtz method (Bray and Kurtz, 1945). Exchangeable bases were extracted by 1M CH_3COONH_4 at pH 7.0 (Rhoades, 1982) and cations exchangeable capacity (CEC) in Cmol (+)/kg was determined by atomic absorption spectrophotometry, while Organic carbon (%) was analyzed according to Nelson and Sommers, (1982).

3.2.3 Farm yard manure analysis

Composite Farm Yard Manure samples were collected from decomposed pit, mixed well, ground and sieved in 2 mm sieve then analyzed for chemical properties including pH in 1:2.5 water suspension, organic matter (%) and organic carbon in (%) was determined by the dichromate wet oxidation method (Walkley and Black, 1934), total nitrogen in (%) was determined using semi-micro Kjeldahl digestion followed by distillation, carbon/nitrogen ratio, available phosphorus was determined by spectrophotometry technique at 884 -890 nm wavelength according to Olsen method (mg/kg), exchangeable bases (Cmol (+)/kg) were determined by the IN NH_4OAC extraction procedure and Na and K were read up by flame photometry.

3.3 Materials

Sweet potato varieties namely Ukerewe, Simama and Kasinia were used as planting materials. Farm Yard Manure, Minjingu Mazao, DAP and NPK (Yara Mila Winner) compound fertilizer were used as sources of nutrients supply.

3.4 Experimental Design and Crop Establishment

The experiment was arranged in a split plot laid out in a Randomized Complete Block Design (RCBD) with three replications. Fertilizer types served as main plots and sweet potato varieties as subplots.

The experiment had a total of 13 fertilizers treatments as main plots T1 = control, T2 = DAP (50 kg ha^{-1}), T3 = DAP (100 kg ha^{-1}), T4 = DAP (150 kg ha^{-1}), T5=NPK Yara Mila Winner (150 kg ha^{-1}), T=6 NPK (250 kg ha^{-1}), T7= NPK (350 kg ha^{-1}), T8= Minjingu Mazao (100 kg ha^{-1}), T9 = Minjingu Mazao (200 kg ha^{-1}), T10 = Minjingu Mazao (300 kg ha^{-1}), T11 = Farm Yard Manure (2.5 ton ha^{-1}), T12 = Farm Yard Manure (5.0 ton ha^{-1}), T13 = Farm Yard Manure (7.5 ton ha^{-1}) and three sweet potato varieties as subplots, namely Simama, Ukerewe (improved varieties) and Kasinia as control. Actual fertilizers and nutrients rates applied per plot are presented below (Table 2; Appendix 3)

3.5 Land Preparation

Land preparation was done in mid-January 2015. Ridges of 0.9 m apart were constructed in each subplot, a tie ridge across the ridge was made for water conservation and reduces nutrient movement from one experimental unit to another. Planting of sweet potato vines was done on 30th January 2015.Sweet potatoes vines of Ukerewe and Simama were collected from Ukiriguru Agriculture Research Institute while, Kasinia vines were collected from local farmers in Tabora. These were established in nurseries for two months and used as planting materials.

Table 2: Fertilizers sources, rates and nutrient elements applied in each plot.

Treat. Code	Fertilizer sources	Fertilizer applied (kg ha^{-1})	Nutrients rates applied (kg ha^{-1})							
			N	P	K	Ca	Mg	S	Zn	B
T1	Control.	0	0	0	0	-		-	-	-
T2	NPK Yara Mila	150	22.5	5.94	24.9	-	1.63	1.9	0.03	0.023
T3	NPK Yara Mila	250	37.5	9.9	41.5		2.72	3.7	0.05	0.038
T4	NPK Yara Mila	350	52.5	13.86	58.1		3.81	4.43	0.07	0.054
T5	DAP	50	9.0	10	-	-	-	-	-	-
T6	DAP	100	18	20	-	-	-	-	-	-
T7	DAP	150	27	30	-	-	-	-	-	-
T8	Minjingu Mazao	100	10	8.8	-	17.88	-	5	0.5	0.1
T9	Minjingu Mazao	200	20	17.6	-	35.75	-	10	1.0	0.2
T10	Minjingu Mazao	300	30	26.4	-	53.63	-	15	1.5	0.3
T11	FYM	2500	13	12.25	0.11	-	-	-	-	-
T12	FYM	5000	26	24.5	0.22	-	-	-	-	-
T13	FYM	7500	39	36.75	0.33	-	-	-	-	-

3.5.1 Plot size

The main plot size was 11.8 x 1.5 m, the subplots were 3.6 x 1.5m. Each plot size consisted of six ridges and a path of 0.5 m separating the main plots, subplots and replications. The total experimental area was 994 m^2. Net plot area was1.8 x 0.9 m for yield and growth data sampling and six plants were sampled per net area.

3.5.2 Spacing

The plant spacing used was 0. 9 x 0.3 m. with 4 rows and 5 plants per row. Each subplot had 20 plants, making a total of 60 plants in the main plot.

3.5.3 The size of cuttings and planting parts

The middle part of the vine was used as planting materials. Two ends from both sides were discarded for uniform maturation of the crop. Vine cutting lengths of 25 cm from actively growing sections were used for planting. Two-thirds of each vine with 4 to 6 nodes was buried into the soil at about 15 to 20 cm depth, and leaving 2-3 nodes above the ground.

3.6 Field Management

3.6.1 Fertilizer application

Well decomposed Farm Yard Manure (FYM) was incorporated into the ridges two weeks before planting of vines to allow further decomposition. Diammonium Phosphate, NPK Yara Mila Winner and Minjingu Mazao were applied two weeks after planting in two splits as basal and as top dressing at 5 weeks after transplanting, respectively. A furrow of 5cm depth and 10 cm wide was opened for fertilizer application and covered by soil.

3.6.2 Weeding

Weeding was done to eliminate other plants that could utilize nutrients, moisture and harbor pests that would compete with sweet potato growth. Two hoe weedings were done at 3 and 5 weeks after planting to control weeds. Earthing up was done to establish a desirable soil bulk for tuber expansion and moisture conservation.

3.7 Data Collected

3.7.1 Determining the yield response of sweet potatoes to organic and inorganic fertilizers

Growth and yield performance data were collected in order to determine the crop response to organic and inorganic fertilizers. The following data was collected: total tuber yields on fresh weight basis, tuber market size, vines length, number of primary branches (sprouts) and total above ground dry biomass. The marketable and unmarketable tubers were determined by measuring middle tuber diameter using vernier calipers. Tubers with diameter less than 3 cm were considered unmarketable, while those with tuber diameter of 3 cm or above were considered of marketable size.

3.7.2 Evaluation of the agronomic efficiency of sweet potatoes under organic and inorganic fertilizers

Data collected on crop yield performances as affected by Nitrogen, Phosphorus and Potassium levels and combinations of levels of fertilizer rates were used for calculating the agronomic efficiency (AE). Agronomic efficiency (AE) measures the amount of additional yield obtained per kg of nutrient applied. Agronomic efficiency is defined as the incremental return of output to applied inputs (kg kg^{-1}). Agronomy efficiency = Yield in fertilized plot –Yield in control plot divided by input applied, where: yield of fertilized plots and yield of control or unfertilized plots expressed in kg ha^{-1} and the fertilizer treatments or input applied per hectare expressed as kg nutrient ha^{-1}.

3.7.3 Determination of economic benefits of fertilizer use in sweet potato production

The Value Cost Ratio (VCR) was calculated to compare the changes in costs and income gains when a farmer moves from current production practices to a new set of practices. It incorporates both agronomic (yield) and economic (price/cost) information. The VCR was calculated to estimate the values of additional production resulting from a change in practices (i.e. incremental output x market price) divided by the supplementary costs of moving to the new practice (costs of purchased inputs, additional labour use). The Value Cost Ratio assesses the economic benefits of using fertilizer by comparing it with the value of additional yield and input costs:

$$VCR = \frac{\text{Extra yield produced (kg) x Value of produced kg ha}^{-1}}{\text{Inputs applied (kg) x Cost of inputs kg ha}^{-1}}$$

i. The Value Cost Ratio is interpreted as follows:

ii. Value Cost Ratio = 1: Breakeven point, where yield increase does not justify financial incentive to new practices, VCR= 1 and 2: Farmers earn some little profit and VCR >2: Maximum acceptable level for new practices.

iii. Data collected were tuber yield, cost of fertilizer from agro-dealers, and survey of sweet potato market price from three local and three urban markets was carried out.

iv. Economic analysis -tuber yield obtained from each fertilizer treatment with respect to varieties were used in economic analysis of Value Cost Ratio and net revenue (CIMMTY, 1988). The field price of 1 kg of sweet potato tuber that farmers receive from sale was taken as 500 Tshs. Fertilizers applied were Minjingu Mazao, DAP, NPK Yara Mila Winner and Farm Yard Manure and their prices were collected from three different agro stockiest, which differed in prices. The prices in Tshs per kg were 800, 1500, 1500 and 200, for fertilizers and manure, respectively. Net revenue was calculated by subtracting the total variable cost from the gross benefit.

3.8 Data Analysis

Collected data on total tubers weight, marketable size, vine length, number of primary branches (sprouts) and total above ground dry biomass were organized using Microsoft excel and subjected to analysis of variance (ANOVA) using GENSTAT (14th Edition) at a significance level of 5%. Mean separation was done using turkeys Multiple Range Test. Correlation of total tuber weight, above ground dry biomass, vine length, number of branches, diameter of marketable tubers, Value Cost Ratio, agronomic efficiency and net revenue were determined according to Gomez and Gomez (1984).

CHAPTER FOUR

4.0 RESULTS

This chapter provides results obtained from a field experiment which examined soil characteristics of the experimental area, effects of inorganic and organic fertilizers on sweet potato growth and yield. The study also focused on tuber yield and yield components, which included number of tuber, total tuber weight and marketable size of tubers. Growth data included vine length, number of primary branches (sprouts), total above ground dry biomass and economic data, were agronomic efficiency, Value Cost Ratio and net revenue.

4.1 Rainfall Distribution during the Cropping Season

Rainfall data were collected from the Tanzania Meteorological Agency (TMA) station at ARI- Tumbi, Tabora. Weather elements that were collected during the cropping season are shown in Figure. 1. Total Monthly rainfall (mm) and number of rainy days in the month were collected daily from September 2014 to June 2015. Methods for measuring weather elements were as described by TMA (2010). The rainfall data were then summarized in terms of monthly values. December 2014 received the highest rainfall (262.2 mm) and more rainy days than the other months. A small amount of rainfall of 35.1 mm and 3 rainy days was received in May 2015. A total of 521.6mm was received during the entire growing season.

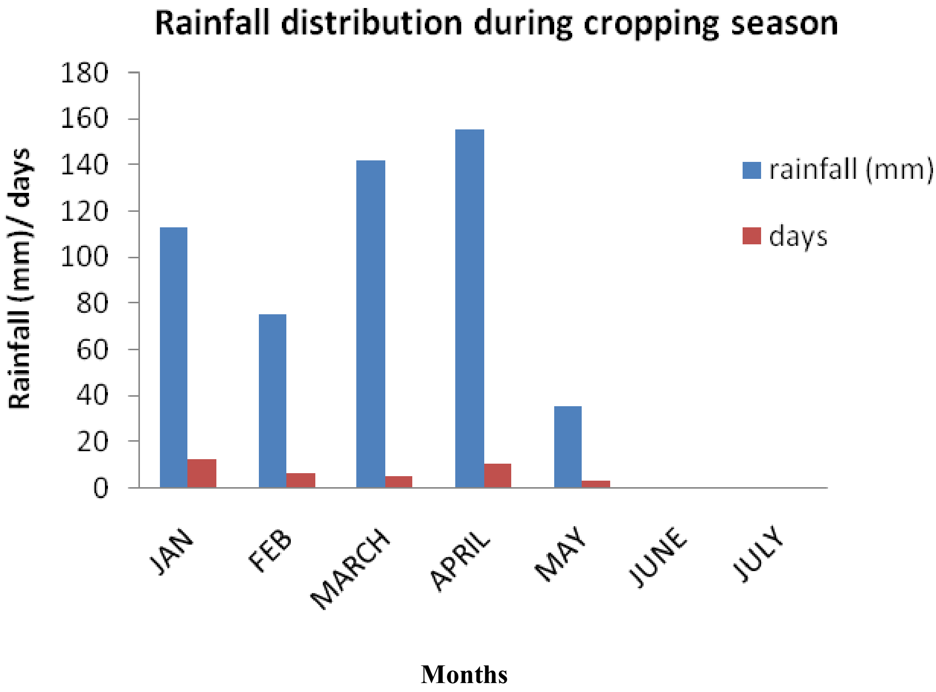

Figure 1: Rainfall distribution during the cropping season

4.2 Soil Physical and Chemical Characteristics

4.2.1 Physical characteristics

The physical and chemical properties of the studied soils are presented in Table 3. General soil fertility was evaluated based on the standards set by Landon (1991). The textural class from all soil profile depths showed that, particle size distribution was composed of 80 - 86% sand (Table 3). Thus, the soil was considered to be loamy sand according to USDA textural class triangle classification (USDA, 1975).

4.2.2 Chemical characteristics

The results on soil chemical characteristics of the experimental site were interpreted based on the critical values established by Landon (1991). The soil pH were 4.8 -5.0, implying that it was strongly acidic (Table 4). The Organic carbon (%) was 0.14-0.4%. This soil was considered to be low in organic carbon. Total nitrogen varied from 0.01 - 0.03%. This soil was considered to be very low in total nitrogen (Table 3; Appendix 1, 3 and 7).

Table 3: Physical and chemical characteristics of soils in experimental site

			Depth (cm)			Rating
Determinations	Measurements	Units	0-20	20- 30	30-45	
Physical properties	Sand	%	84	80	86	
	Coarse silt	%	6	6	4	
	Fine silt	%	2	4	4	
	Clay	%	8	10	6	
Textural classes			Loamy sand	Loamy sand	Loamy sand	
Chemical properties	pH		5	5	4.8	Strongly acidic
	Org. carbon	%	0.4	0.23	0.14	Low
	Total nitrogen	%	0.03	0.03	0.01	Low
	Available-P	mg P/kg	0.61	0.61	0.49	Low
Exchangeable bases	Calcium	Cmol (+)/kg	1.09	0.79	0.89	Low
	Magnesium	Cmol (+)/kg	3.49	2	2.66	Low
	potassium	Cmol (+)/kg	0.22	0.16	0.13	Low
	sodium	Cmol (+)/kg	0.01	0.01	0.01	Low
	CEC	Cmol (+)/kg	4.81	2.96	3.69	Low

The results on available P levels, exchangeable potassium, exchangeable calcium and exchangeable sodium of this soil were all low (Table 3). Exchangeable magnesium was high on the top soil to medium below plough layer (Table 3; Appendices 1, 3 and 7). The results indicate that the soil in the experimental area were of low fertility.

4.2.3 Chemical characteristics of Farm Yard Manure

The results showed that total nitrogen, organic matter, organic carbon and available phosphorus were found to be high while exchangeable cations K and Na were low in availability to plants, respectively (Table 4; Landon, 1991; EUROCONSULT 1989).

4.3 Vegetative Growth Response to Different Fertilizer Types and Rates

4.3.1 Vine length

The results on vine length revealed very highly significant differences ($P<0.001$) among varieties, fertilizers and their interactions (Table 5). Among varieties, the longest vines (173.7 cm) were recorded from Kasinia while the shortest ones (107.7 cm) were recorded from variety Ukerewe. Ukerewe and Simama gave statistically similar vine lengths (Table 5).

Table 4: Chemical characteristics of Farm Yard Manure used in the study

Chemical characteristics	Units	Magnitude	Rating
pH	-	9.3	Alkaline
Organic C	%	3.7	High
Organic matter	%	6.3	High
Total N	%	0.52	High
Carbon/Nitrogen		7	High
Available Phosphorus	mg/kg	49.0	High
Potassium	Cmol (+)/kg	0.001	Low
Sodium	Cmol (+)/kg	0.171	Low

Among fertilizer types and rates, the longest vine of 185.3cm were recorded with 350 kg ha^{-1} NPK Yara Mila Winner mineral fertilizers while, the shortest ones (87.6 cm) were recorded from the control (Table 5). Statistically similar results on vine length were recorded from treatments applied with FYM (5.0 and 7.5 ton ha^{-1}), Minjingu Mazao

(100 to 300 kg ha^{-1}) and NPK Yara Mila Winner mineral fertilizer (150 kg ha^{-1}) (Table 5).

The interaction of variety and fertilizers showed longest vines (235.3 cm) in Kasinia applied with NPK Yara Mila Winner mineral fertilizer (350 kg ha^{-1}) and shortest vines mean (63.9 cm) were recorded from variety Ukerewe in the control. A gradual increase in vine length with increasing fertilizer rates was observed among fertilizer types (Table 5). Vine length usually depends on number of primary branches and the phenotypic characteristics of varieties.

Table 5: Response of vine length to different fertilizer types and rates

		Average vine length (cm)			
Treatments	**Rate (kg ha^{-1})**	**Kasinia**	**Simama**	**Ukerewe**	**Mean (A)**
Control	0	123.5 c-h	75.3 ab	63.9 a	87.6 a
DAP	50	125.1 d-i	77.9 a-c	75.6 ab	92.9 ab
DAP	100	159.9 g-m	87.7 a-d	89.1 a-d	112.2 bc
DAP	150	173.2j-n	128.4 d-j	103.0 a-f	134.9 d
NPK Yara Mila Winer	150	209.8no	115.0 b-g	114.0 b-g	146.3 de
NPK Yara Mila Winner	250	209.6o	144.7 f-l	119.3 b-g	157.9 e
NPK Yara Mila Winner	350	235.3o	188.0 l-n	132.7 d-k	185.3 f
Minjingu Mazao	100	169.6 i-n	93.8 a-e	108.9 a-f	124.1 cd
Minjingu Mazao	200	175. K-n	98.6 a-f	139.3 e-k	137.9 de
Minjingu Mazao	300	185.5l-n	109.7 a-f	143.7 f-l	146.3 de
FYM	2500	131.3 d-k	93.1 a-d	94.4 a-e	106.3 a-c
FYM	5000	168.3 h-n	106.1 a-f	103.0 a-f	125.8 cd
FYM	7500	191.7 m-o	110.7 b-f	113.7 b-f	138.7 de
Mean (B)		**173.7 b**	**109.9 a**	**107.7 a**	**130.5**
LSD		**22.75**	**6.31**		**13.14**
CV%		**4.9**	**10.7**		**7.0**
F prob		**<.001**	**<.001**		**<.001**

Means followed by the same letter(s) in the same or across columns are not significantly different according to Tukey's test.

4.3.2 Total above ground dry biomass

Total above ground dry biomass was significantly different (P<0.05) among varieties, fertilizers and their interactions (Table 6). Among varieties, the highest total above ground dry biomass of 3.83 tons ha^{-1} was recorded from Kasinia and the lowest of 3.5 tons ha^{-1} was from Ukerewe. The differences were statistically significant among varieties (Table 6).

Among fertilizer types and rates, the highest total above ground dry biomass of 5.45 tons ha^{-1} was recorded with NPK Yara Mila Winner fertilizer (350 kg ha^{-1}) and the lowest 2.09 tons ha^{-1} was from the control. The results indicate increases in the total above-ground dry biomass with each additional fertilizer inputs among all sweet potato varieties despites the significant differences observed (Table 6).

The interaction of variety and fertilizers gave highest total above ground dry biomass (5.70 tons ha^{-1}) in variety Kasinia with 350 kg ha^{-1} NPK Yara Mila Winner and the lowest (1.82 tons ha^{-1}) was recorded from Simama in the control. Statistically,Kasinia and Simama produced similar above ground dry biomass with 350 kg ha^{-1} NPK Yara Mila Winner mineral fertilizer. Similar observation was recorded also from FYM (7.5 ton ha^{-1}) with Kasinia. The higher rates of all fertilizer type; DAP, FYM, Minjingu Mazao and NPK resulted in increases of above ground dry biomass (Table 6; Appendix 6). The above ground dry biomass usually depends on vine lengths and number of branches per plant and other phenotypic characteristics of plants.

4.3.3 Number of primary branches

The results on number of primary branches per plant revealed very highly significant differences (P<0.001) among varieties, fertilizer rates and their interactions (Table 7).

The highest number of primary branches (6.94) was recorded from variety Ukerewe, which was statistically similar to that of Kasinia; while smaller mean number (5.61) was from Simama.

Among fertilizer types and rates, the highest mean number of primary branches per plant of 8.29 was recorded with 350 kg ha^{-1} NPK Yara Mila Winner while the control treatment produced smaller mean number of primary branches per plant (4.48). There were slightly increases in the number of primary branches per plant with each additional fertilizer type applied (Table 7).

Table 6: Response of total above ground dry biomass to different fertilizer types and rates

		Above ground dry biomass (tons ha^{-1})			
Treatments	**Rate (kg ha^{-1})**	**Kasinia**	**Simama**	**Ukerewe**	**Mean (A)**
Control	0	2.06ab	1.82a	2.42a-c	2.09a
DAP	50	2.59a-f	2.25a-c	2.54a-e	2.46ab
DAP	100	2.98a-h	2.47a-d	3.07a-h	2.84a-c
DAP	150	3.08a-h	2.58a-f	3.28a-j	2.99bc
NPK Yara Mila Winner	150	3.67b-k	4.29e-l	3.86c-k	3.94de
NPK Yara Mila Winner	200	4.69 h-l	5.05kl	4.84i-l	4.86fg
NPK Yara Mila Winner	350	5.70 l	5.65 l	4.98 j-l	5.45 g
Minjingu Mazao	100	2.98a-h	2.55a-e	3.03a-h	2.85 a-c
Minjingu Mazao	200	4.20d-l	3.56a-k	3.17a-i	3.64cd
Minjingu Mazao	300	4.48g-l	4.35g-l	3.52a-k	4.12def
FYM	2500	3.27a-j	3.99c-l	2.80a-g	3.35cd
FYM	5000	4.42g-l	3.52 a-k	3.78 b-k	3.90d
FYM	7500	5.62 l	4.43 g-l	4.32f-l	4.79 efg
Mean (B)		**3.83b**	**3.58ab**	**3.5 a**	**3.6**
LSD		**0.86**	**0.24**		**0.5**
CV%		**4.4**	**13.3**		**9.9**
F-prob.		**0.032**	**0.024**		**<.001**

Means followed by the same letter(s) in the same or across columns are not significantly different according to Tukey's test.

The interaction of variety and fertilizers showed that the highest number of primary branches per plant (8.89) was recorded in Kasinia with 350 kg ha^{-1} NPK Yara Mila Winner mineral fertilizer while the control plots produced the lowest (3.0) in variety Simama. There were significant increases in the number of branches per plant with each additional fertilizer inputs, although DAP (150 kg ha^{-1}) and Minjingu Mazao (200 kg ha^{-1}) gave similar results in variety Kasinia (Table 7).

Table 7: Response of mean primary branches number per plant on different fertilizer types and rates

		Number of primary branches per plants			
Treatments	**Rate (kg ha^{-1})**	**Kasinia**	**Simama**	**Ukerewe**	**Mean (A)**
Control	0	4.44a-d	3.0a	6.00 b-k	4.48a
DAP	50	5.33a-i	4.67a-e	6.33 c-l	5.44ab
DAP	100	6.33 c-l	4.67a-e	6.53c-m	5.84bc
DAP	150	7.67i-m	6.00 b-k	6.67 c-m	6.78c-f
NPK Yara Mila Winner	150	6.89d-m	5.11a-h	6.50c-m	6.17b-d
NPK Yara Mila Winner	250	7.44 g-m	7.56h-m	7.22 f-m	7.41 e-g
NPK Yara Mila Winner	350	8.89m	8.33k-m	7.67i-m	8.29g
Minjingu Mazao	100	6.44c-m	3.57ab	6.54c-m	5.52ab
Minjingu Mazao	200	7.78i-m	4.33a-c	7.00e-m	6.37b-e
Minjingu Mazao	300	8.00j-m	6.22c-l	7.67i-m	7.29d-g
FYM	2500	4.99 a-g	4.89a-f	6.40 c-m	5.42ab
FYM	5000	5.55 b-j	6.56 c-m	7.00e-m	6.37b-e
FYM	7500	7.00 e-m	8.00j-m	8.67lm	7.89fg
Mean (B)		**6.67b**	**5.61a**	**6.94b**	**6.4**
Lsd		**1.23**	**0.34**		**0.71**
CV%		**2.5**	**10.5**		**8.3**
Fprob.		**<.001**	**<.001**		**<.001**

Means followed by the same letter(s) in the same or across columns are not significantly different according to Tukey's test.

4.4 Yield and Yield Components Response to Different Fertilizer Types and Rates

4.4 .1 Total tuber weight

The results on total tubers weight revealed very highly significant differences (P<0.001) among varieties, fertilizers and their interactions (Table 8). Among varieties, the highest mean total tuber weight (7.84 tons ha^{-1}) was recorded in variety Kasinia, which was similar to that of Simama while the minimum mean total tuber weight (5.35 tons ha^{-1}) was from variety Ukerewe (Table 8).

Among fertilizer types and rates, NPK Yara Mila Winner mineral fertilizer (350kg ha^{-1}) produced the highest mean total tuber weight (11.19 ton ha^{-1}) while, the smallest mean weight (2.72 tons ha^{-1}) was recorded from the control. The fertilizers, Di-ammonium Phosphate (150 kg ha^{-1}), NPK Yara Mila Winner (150 kg ha^{-1}) and Minjingu Mazao (200 kg ha^{-1}) produced statistically similar total tuber weight (Table 8).

The interaction of varieties and fertilizers showed that FYM (7.5 tons ha^{-1}) gave the highest mean total tuber weight (13.21 tons ha^{-1}) with variety Kasinia, while the control gave the lowest total tuber weight (2.16 tons ha^{-1}) in variety Ukerewe. However, NPK Yara Mila Winner mineral fertilizer (350 kg ha^{-1}) produced similar total tuber weight in varieties Kasinia and Simama. Apart from high total tuber weight recorded, each fertilizer type and rates gave significant yield increases as compared to control (Appendix 5). Total tuber weight is usually dependent on number of tubers per hectare.

4.4.2 Tuber number per hectare

The results on number of tubers per hectare revealed very highly significant differences (P<0.001) among fertilizers and variety x fertilizer interactions (Table 9). Among varieities, the highest tuber number (37702 ha^{-1}) was recorded in variety Simama and

Kasinia,while fewer tuber numbers (31727 ha^{-1}) was recorded from variety Ukerewe. However, no significant differences were recorded between Kasinia and Simama varieties (Table 9).

Table 8: Response of total tuber weight to different fertilizer types and rates

		Total tuber weight (tons ha^{-1})			
Treatments	**Rate (kg ha^{-1})**	**Kasinia**	**Simama**	**Ukerewe**	**Mean (A)**
Control	0	3.457a-d	2.531ab	2.160a	2.716a
DAP	50	3.981a-f	3.889a-e	3.580a-e	3.817ab
DAP	100	5.833a-h	6.049b-h	5.679a-h	5.854cd
DAP	150	6.914d-i	6.543c-i	6.420c-i	6.626c-e
NPK Yara Mila Winner	150	7.284e-i	6.790d-i	5.185a-g	6.420c-e
NPK Yara Mila Winner	250	11.111j-m	9.012h-l	6.294b-i	8.806f
NPK Yara Mila Winner	350	12.593lm	12.654lm	8.333g-k	11.193g
Minjingu Mazao	100	6.543c-i	5.802a-h	2.963a-c	5.103bc
Minjingu Mazao	200	7.778f-j	7.222d-i	4.444a-f	6.481c-e
Minjingu Mazao	300	8.272g-k	8.519g-k	5.917a-h	7.569d-f
FYM	2500	5.062a-g	5.432a-h	4.938a-g	5.144bc
FYM	5000	9.877i-m	8.272g-k	6.481c-i	8.210ef
FYM	7500	13.210m	11.975k-m	7.160d-i	10.782g
Mean (B)		**7.840b**	**7.284b**	**5.351a**	**6.824.7**
LSD		**0.559**		**2.017**	**1.164**
CV%		**6.1**		**16.9**	**12.2**
F prob		**<.001**		**0.014**	**<.001**

Means followed by the same letter(s) in the same or across columns are not significantly different according to Tukey's test.

Among fertilizer types and rates, the highest number of tubers per hectare (50206 ha^{-1}) was recorded with 350 kg ha^{-1} NPK Yara Mila Winner mineral fertilizer while Di-ammonium Phosphate (50kg ha^{-1}) gave lowest number of tubers per hectare (23868 ha^{-1}). The interaction of variety and fertilizers showed that the highest number of tubers (54321 ha^{-1}) was recorded from variety Kasinia with 350 kg ha^{-1} NPK Yara Mila Winner mineral fertilizer while, Di-ammonium Phosphate (50 kg ha^{-1}) produced the lowest number of tubers (22222 ha^{-1}) in variety Ukerewe. There were significant increases in number of tubers per plant with each additional fertilizer applied (Table 9). Total tuber weight (ton ha^{-1}) and number of tubers per hectare usually determine marketable tuber weight at harvest.

Table 9: Tuber numbers per hectare to different fertilizer types and rates

Treatments	Rate (kg ha^{-1})	Tuber numbers ha^{-1} Kasinia	Simama	Ukerewe	Mean (A)
Control	0	29630a-f	28395a-e	23457ab	27160ab
DAP	50	24691abc	24691abc	22222a	23868a
DAP	100	28395a-e	30864a-g	30864a-g	30041abc
DAP	150	33333a-h	35802a-h	28395a-e	32510bc
NPK Yara Mila Winner	150	32099a-h	37037b-h	25926a-d	31687bc
NPK Yara Mila Winner	250	45679hij	44444g-j	35686a-h	41936de
NPK Yara Mila Winner	350	54321j	51852ij	44444g-j	50206f
Minjingu Mazao	100	30864a-g	30864a-g	22222a	27984ab
Minjingu Mazao	200	37037b-h	39506d-i	33333a-h	36626cd
Minjingu Mazao	300	43210f-j	45679hij	38073c-i	42321de
FYM	2500	30864a-g	32099a-h	29630a-f	30864bc
FYM	5000	44444g-j	43210f-j	36221a-h	41292de
FYM	7500	45679hij	45679hij	41975e-j	44444ef
Mean (B)		**36942b**	**37702b**	**31727a**	**35457**
LSD		**1931.6**		**6964.3**	**4020.9**
CV%		**4.8**		**12.1**	**8.4**
F prob		**<.001**		**0.799**	**<.001**

Means followed by the same letter(s) in the same or across columns are not significantly different according to Tukey's test.

4.4.3 Marketable tubers weight

The results showed highly significant differences in marketable tuber weight (P<0.001) among fertilizers and their interactions with varieties. However, there were no significant differences among varieties (Table 10). Among varieties, the highest marketable tuber weight (7.42 tons ha^{-1}) was observed from Kasinia, that was statistically similar to that observed from variety Simama while, the lowest (4.94 tons ha^{-1}) was observed from the variety Ukerewe.

Among fertilizer types and rates, NPK Yara Mila Winner mineral fertilizer (350 kg ha^{-1}) produced the highest marketable tuber weight (10.62 tons ha^{-1}) while the lowest (2.51 tons ha^{-1}) was recorded from the control (Table 10).

The interaction of varieties and fertilizers showed that NPK Yara Mila Winner mineral fertilizer (350 kg ha^{-1}) gave the highest marketable tuber weight (12.47 tons ha^{-1}) in variety Simama while the control gave the lowest marketable tuber weight (1.98 ton ha^{-1}) in variety Ukerewe. Similarly significant results on marketable tuber weight were recorded in NPK at a rate of 350 kg ha^{-1} and FYM (7.5 ton ha^{-1}) in the variety Simama (Table 10).

4.4.4 Diameter of marketable tubers

The results on marketable tuber diameter showed highly significant differences ($P<0.001$) among varieties, fertilizers and their interactions (Table 11). Among varieties, the highest marketable tuber diameter (6.85 cm) was from Kasinia while the smallest (5.69 cm) was from Ukerewe (Table11).

Among fertilizers types and rates, NPK Yara Mila Winner mineral fertilizer (350 kg ha^{-1}) and FYM at 7.5 tons ha^{-1} gave the highest marketable tuber diameter (8.06 cm) while the smallest marketable tuber diameters (4.41 cm) was recorded from the control. (Table11).
The interaction of variety and fertilizers showed that NPK Yara Mila Winner mineral fertilizer at 350 kg ha^{-1} gave the largest marketable tuber diameters (8.88 cm), which was

observed from variety Kasinia while the smallest (3.37 cm) was recorded from the control (Table 11).

Table 10: Response of marketable tubers weight to different fertilizer types and rates

Treatments	Rate (kg ha^{-1})	Kasinia	Marketable tubers (tons ha^{-1}) Simama	Ukerewe	Mean (A)
Control	0	3.08a-c	2.46ab	1.98a	2.51 a
DAP	50	5.31 a-f	4.44a-e	3.15a-c	4.3ab
DAP	100	5.56 a-f	5.802 a-f	4.94 a-e	5.43 b-d
DAP	150	6.67b-g	6.17 a-g	5.74 a-f	6.19b-e
NPK Yara Mila Winner	150	8.39e-i	6.91c-g	5.18 a-f	6.83de
NPK Yara Mila Winner	250	10.25 g-i	8.395e-i	6.05a-g	8.23e
NPK Yara Mila Winner	350	11.61 hi	12.47i	7.7 8d-h	10.62f
Minjingu Mazao	100	5.68 a-f	5.19 a-f	2.84a-c	4.57a-c
Minjingu Mazao	200	6.91 c-g	6.05a-g	3.70a-d	5.56b-d
Minjingu Mazao	300	7.04 c-g	6.91c-g	5.995a-g	6.65c-e
FYM	2500	4.57a-e	5.19 a-f	4.32a-e	4.69bc
FYM	5000	9.38f-i	8.15 e-i	5.63a-f	7.72e
FYM	7500	11.98 hi	12.47i	6.91c-g	10.45 f
Mean (B)		**7.42 b**	**6.97 b**	**4.94a**	**6.44**
LSD		**2.133**		**0.592**	**1.232**
CV%		**5.55.5**		**20.3**	16.2
F prob		**0.058**		**<.001**	**<.001**

Means followed by the same letter(s) in the same or across columns are not significantly different according to Tukey's test.

Table 11: Response of marketable tuber diameters to different fertilizer types and rates

		Diameter of marketable tubers (cm)			
Treatments	**Rate (kg ha^{-1})**	**Kasinia**	**Simama**	**Ukerewe**	**Mean(A)**
Control	0	5.46 b-f	4.41 ab	3.37 a	4.41a
DAP	50	6.03 b-g	5.2 a-d	4.87 a-c	5.36b
DAP	100	6.3 b-h	5.63 b-f	5.21 a-d	5.71bc
DAP	150	6.79 c-h	6.33 b-h	5.5 b-f	6.21bc
NPK yara winer	150	6.7 c-h	5.84 b-f	5.06 a-d	5.87bc
NPK yara winer	250	6.92 d-h	6.26b-h	5.48 b-f	6.22bc
NPK yara winer	350	8.88 i	7.38 f-i	7.92 g-i	8.06d
Minjingu Mazao	100	6.1 b-g	5.36 b-e	4.9 a-c	5.45bc
Minjingu Mazao	200	6.67 c-h	6 b-g	5.1 a-d	5.93bc
Minjingu Mazao	300	7.93 g-i	7.23 e-i	7.15 e-i	7.43d
FYM	2500	6.53 c-h	5.77 b-f	5.2 –d	5.83bc
FYM	5000	6.85 d-h	6.05 b-g	6.1 b-g	6.33c
FYM	7500	7.91 g-i	8.1 hi	8.167 hi	8.06d
Mean (B)		**6.85c**	**6.12b**	**5.69a**	**6.2**
LSD		**0.95**		**0.26**	**0.55**
CV%		**2.4**		**9.4**	5.1
F prob		**<.001**		**<.001**	**<.001**

Means followed by the same letter(s) in the same or across columns are not significantly different according to Tukey's test.

4.5 Agronomic Efficiency of Sweet Potato under Different Fertilizer Types and Rates

The results on agronomic efficiency revealed very highly significant differences ($P < 0.001$) among varieties, fertilizers and their interactions (Table 12). Among varieties, the highest agronomic efficiency of 110.68 was recorded from variety Simama. However, there was no statistically significant differences with Kasinia while, the lowest (66.42) was recorded from variety Ukerewe (Table 12). Among fertilizer types, the highest agronomic efficiency of 171.81 were recorded from Farm Yard Manure (7500 kg ha^{-1}) while the lowest (47.28) was observed from Di-ammonium Phosphate (50 kg ha^{-1}) (Table 12).

The interaction of variety and fertilizer indicated that the highest agronomic efficiency of 228.46 was observed from the variety Kasinia applied with Farm Yard Manure (7500 kg ha^{-1}) which was statistically similar to that of Farm Yard Manure (5000 kg ha^{-1}) while the lowest (25.08) was recorded from Kasinia applied with Di-ammonium Phosphate (50 kg ha^{-1}) (Table 12). The highest agronomic efficiency observed from fertilizers and varieties revealed high production of above ground dry biomass, tuber numbers, total tuber weight, marketable tuber weight and large marketable tuber diameter Table 6; 8; 9; 10 and 11).

4.6 Value Cost Ratio of Sweet Potato under Different Fertilizer Types and Rate

Results on Value Cost Ratio showed highly significant differences ($P<0.05$) among varieties, fertilizers and their interactions (Table 13). Among varieties, the highest Value Cost Ratio of 2.91 was recorded from variety Kasinia, which was similar to that of Simama while, the lowest value (1.73) was observed from variety Ukerewe (Table 13).

Table 12: Agronomic Efficiency response to different fertilizer types and rates

Fertilizer	Rates (kg ha^{-1})	N, P and K ratio applied	Agronomic efficiency kg kg-^{1}			
			Kasinia	Simama	Ukerewe	Mean (A)
Control	0					
DAP	50	1:1:0	25.08a	54.39ab	62.38ab	47.28ab
DAP	100	1:1:0	62.54ab	92.59a-d	90.84a-d	81.99bc
DAP	150	1:1:0	60.65ab	70.39ab	74.72abc	68.59b
NPK yara mila winer	150	4:1:5	71.80abc	79.91abc	56.75ab	69.49b
NPK yara mila winer	250	4:1:5	86.10abc	72.91abc	42.90ab	67.30b
NPK yara mila winer	350	4:1:5	73.32abc	81.25abc	49.54ab	68.04b
Minjingu Mazao	100	1:1:0	164.17b-e	174.02b-e	82.45abc	140.22cde
Minjingu Mazao	200	1:1:0	113.71a-e	123.46a-e	72.39abc	103.18bcd
Minjingu Mazao	300	1:1:0	85.98abc	106.92a-e	71.08ab	87.99bc
Farm Yard Manure	2500	1:1:0	102.02a-e	203.88cde	109.53a-e	138.48cde
Farm Yard Manure	5000	1:1:0	225.57e	157.86b-e	85.19abc	156.21de
Farm Yard Manure	7500	1:1:0	228.46e	221.23de	65.72ab	171.81e
Mean (B)			**99.95b**	**110.68b**	**66.42a**	**92.4**
LSD			**18.14**	**65.39**		**37.75**
CV%			**11.7**	**11.7**		**30.2**
F prob			**<.001**	**0.003**		**<.001**

Means followed by the same letter(s) in the same or across columns are not significantly different according to Tukey's test.

Among fertilizer a type, the highest Value Cost Ratio of 3.85 was observed with 350 kg ha^{-1} NPK Yara Mila Winner mineral fertilizer while, the lowest of 1.16 was recorded from the control (Table 13). The interaction of variety and fertilizer showed that the highest Value Cost Ratio of 4.53 was recorded from the variety Kasinia applied with 250 kg ha^{-1} NPK Yara Mila Winner mineral fertilizer while, the lowest of 0.68 was recorded from variety Ukerewe applied with the FYM (7.5 tons ha^{-1}) (Table13).

Table 13: Value cost ratio of sweet potato response to different fertilizer types and rates

		Value cost ratio			
Treatments	**Rate (kg ha^{-1})**	**Kasinia**	**Simama**	**Ukerewe**	**Mean (A)**
Control	0	1.743a-i	1.009a-d	0.715ab	1.156a
DAP	50	1.824a-k	1.758c-j	1.539a-h	1.707ab
DAP	100	2.524b-n	2.878e-p	2.638c-o	2.680c
DAP	150	2.891e-p	2.826e- p	2.802e-p	2.840c
NPK yara winer	150	3.260h-p	2.971f-p	2.032a-l	2.754c
NPK yara winer	250	4.528p	3.484i-p	2.149a-n	3.387cd
NPK yara winer	350	4.451op	4.478p	2.608c-n	3.846d
Minjingu Mazao	100	3.608k-p	3.086g-p	1.087a-e	2.594bc
Minjingu Mazao	200	3.923n-p	3.571j-p	1.813b-k	3.102cd
Minjingu Mazao	300	3.754l-p	3.896m-p	2.411a-n	3.354cd
FYM	2500	12.240a-f	1.404a-g	1.185a-f	1.276a
FYM	5000	2.030a-l	1.537a-h	0.887a-c	1.485a
FYM	7500	2.101a-m	1.811a-k	0.68 a	1.53a
Mean (B)		**2.914b**	**2.670b**	**1.734a**	**2.4**
LSD		**0.89**	**0.25**		**0.52**
CV%		**8.7**	**22.5**		**16.2**
F prob		**<.001**	**0.002**		**<.001**

Means followed by the same letter(s) in the same or across columns are not significantly different according to Tukey's test.

4.7 Net Revenue from Yield Responses to Different Fertilizer Types and Rates

Results on net revenue showed highly significant differences (P<0.05) among varieties, fertilizers and their interactions (Table 14). Among varieties, the highest net revenue of Tshs 2878828/- was observed from variety Kasinia that was similar to that of Simama (2623129/-) while the lowest net revenue of Tshs 1650463/- was observed from variety Ukerewe (Table 14). Among fertilizer types, the highest net revenue of Tshs 4441708/- was observed with 350 kg ha^{-1} NPK Yara Mila Winner mineral fertilizer while the lowest (Tshs 728025/-) was recorded from the control (Table14).

The interactions of variety and fertilizers indicated that, the highest net revenue of Tshs 5172160/- was recorded from variety Simama applied with 350 kg ha^{-1} NPK Yara Mila Winner mineral fertilizer, which was statistically similar to that recorded from Kasinia while, the lowest revenue of Tshs 450247/- was recorded from the control (Table 14). The interaction effects showed significant increases in percent revenue due to fertilizer applications.

4.8 Correlation Analysis of Yield and Yield Components of Sweet Potatoes

Correlation analysis on yield and yield components of sweet potato revealed both positive and negative correlations. Correlation matrix of dependent variables showed that total tuber yield was highly significant and positively correlated with, marketable tubers weight (r = 0.98), marketable tuber diameter, (r = 0.38), primary branches (r = 0.41), vine length (r = 0.55), above ground dry biomass (r = 0.69) and number of tubers per hectare (r = 0.90) (Table 15). The result further indicated that as the levels of fertilizers increased, the yield and yield component parameters increased linearly indicating that 7.5tons ha^{-1} of Farm Yard Manure and 350 kg of NPK Yara Mila Winner mineral fertilizer are not the optimum levels for sweet potato production.

Table 14: Net Revenue of sweet potato response to different fertilizer types and rates

		Net revenue (tshs ha^{-1})			
Treatments	**Rate (kg ha^{-1})**	**Kasinia**	**Simama**	**Ukerewe**	**Mean (A)**
Control	0	1098395a-c	635432ab	450247a	728025a
DAP	50	1285741a-e	1239444a-d	1085123a-c	1203436ab
DAP	100	1973866a-i	2244691a-i	2039607a-i	2086055b-e
DAP	150	2477570b-i	2416605a-i	2388145a-i	2427440d-f
NPK Yara Mila Winner	150	2786975c-k	2540062b-j	1737593a-h	2354877c-f
NPK Yara Mila Winner	250	4550556kl	3501173h-l	2148379a-i	3400036g
NPK Yara Mila Winner	350	5141296l	5172160l	3011667c-k	4441708h
Minjingu Mazao	100	2561605b-j	2191235a-i	771481ab	1841440b-d
Minjingu Mazao	200	3098889d-k	2821111c-k	1432222a-g	2450741d-g
Minjingu Mazao	300	3265802e-l	3389259g-l	2088496a-i	2914519e-g
FYM	2500	1400864a-f	1586049a-h	1339136a-f	1442016a-c
FYM	5000	3308272f-l	2505802b-j	1513681a-g	2442585d-g
FYM	7500	4474938j-l	3857654i-l	1450247b-g	3260947fg
Mean (B)		**2878828b**	**2623129b**	**1650463a**	**2384140**
LSD		**974655.6**		**270320.8**	**562717.7**
CV%		**8.4**		**25.1**	**16.3**
F prob.		**<.001**		**0.002**	**<.001**

Means followed by the same letter(s) in the same or across columns are not significantly different according to Tukey's test.

Table 15: Correlation coefficient (r) between yield and yield components of sweet potatoes

Total tuber weight	1	-						
Marketable tuber weight	2	0.98***	-					
Diameter of marketable tuber	3	0.41**	0.42***	-				
Primary branches	4	0.38**	0.39**	0.63***	-			
Vine length	5	0.55***	0.57***	0.64***	0.60***	-		
Above ground biomass	6	0.69***	0.66***	0.38**	0.44***	0.45***	-	
Number of tuber per hectare	7	0.90***	0.89***	0.48***	0.49***	0.57***	0.74***	-
		1	2	3	4	5	6	7

significant * highly significant

1= Total tuber weight, 2= Marketable tuber weight 3 = Diameter of marketable tuber, 4 = Primary branches, 5=Vine length, 6= Above ground dry biomass weight and 7= Number of tuber per hectare.

CHAPTER FIVE

5.0 DISCUSSIONS

This chapter discusses the results obtained from a field experiment in which soil characteristics and Farm Yard Manure were analyzed and sweet potato responses to inorganic and organic fertilizers were studied.

5.1 Physicochemical Properties of the Soils at Experimental Site

The results of soil analysis before planting (Table 3) show that the soil at the site was loamy sand in texture (84 % sand) according to soil textural classification (USDA 1975). The soil pH was strongly acidic (pH 5.0). Bouwkamp (1985) reported that sweet potato could grow below pH 5.0 and give appreciable yields.

The data further showed that total nitrogen ranged from 0.01-0.03%. This value is rated as very low according to Landon, (1991). Exchangeable cations (Mg, Ca, K and Na) were low in terms of availability to plants. The available phosphorus was low (0.61 and 0.49 mg P/kg soil) according to Landon (1991) (Table 3). Organic carbon content of the soil was low, indicating that the soil in the experimental area was low in fertility; this is a typical phenomenon of sandy soil as exchange sites are very few. These findings complied with those of Nyadzi *et al*. (2003b) who observed that the soils of Tabora were 80-90% sand with low fertility and low levels of organic carbon, phosphorus, total nitrogen and cation exchange capacity (CEC) and soil pH range of 4-6. This problem of low soil fertility could have been amplified by continuous cultivation of the land with inadequate or non-use of fertilizers and these caused insufficient levels of the major nutrients in the soil. The sweet potatoes were expected to benefit from the treatments applied. These results further suggest that the soil required external application of nutrients as manures or chemical fertilizers for good growth and yield responses of sweet potato.

5.2 Vegetative Growth Responses to Fertilizer

Differences in sweet potato response to fertilizer application during vegetative growth were significant among above-ground dry biomass, vine length and number of primary branches per plant. The highest above ground biomass was due to high number of branches per plant and long vines observed in variety Kasinia. The variations observed among fertilizer treatments and varieties could result from genotype and or phenotypic characteristics of varieties as they adapted to the environmental conditions and sufficiency of nutrients for plant growth and development. Positive responses of growth characteristics resulted from the applied Farm Yard Manure and NPK Yara Mila Winner mineral fertilizers. These responses are attributed to the role of fertilizers in supplying essential plant nutrients for plant growth and yield responses while, organic manure have an added advantage of improving soil structure, moisture retention and multiple nutrients supplies, which gave rise to greater length of vines, number of primary branches per plant and heavier above ground dry biomass.

Crop establishment, coupled with early canopy cover, increases size of the assimilatory surface area and consequently greater of interception solar radiation and hence, greater biomass production. Peter and Hruska (1988) reported that among the three major yield determining factors of sweet potato, number of branches, number of tubers per plant and average tuber weight were important. However, number of branches depended more on the intrinsic potential of the cultivar than on addition of fertilizers. Thus, branch number may be influenced by other factors, such as genetic potential of the cultivar, the number of viable sprouts at planting, sprout damage before and after planting (Zelalem *et al.*, 2009). To the contrary, Najim *et al*. (2010) showed that rates of nitrogen fertilizer led to highly significant differences in shoot dry matter, leaf area and plant height. The better performance of variety Kasinia could be attributed with adequate supply of the nitrogen containing fertilizers which encouraged formation of branches, vine elongation and subsequently, greater above ground dry biomass.

The vigorous growth of vines in length was influenced by the supply of adequate nutrients, particularly nitrogen, phosphorus and potassium since these nutrients play major role in cell division, elongation and metabolic processes that enhanced development of long vines. This observation complies well with the findings of Trehan *et al.* (2009) who reported that potassium increased vine length, crop vigor and leaf expansion, particularly at early stages of growth and extended leaf area duration. Gardner *et al*. (1985), Naidu *et al.* (2000) and Singh *et al.* (2000) reported that increased supply of phosphorus resulted in increases in shoot dry weight due to photosynthetic products being transferred to the aerial parts and its beneficial effects on activation of photosynthesis and metabolic processes of organic compounds in plants, thus, encouraging plant growth.
Positive response of growth characters to applied Farm Yard Manure (7.5 ton $^{-1}$) and NPK Yara Mila Winner mineral fertilizer (350 kg ha^{-1}) could be attributed with adequacy of nutrients supplied particularly nitrogen, phosphorus and potassium from fertilizer sources as these nutrients have a role in vegetative growth and development in accelerating formation of more branches. This observation complies well with El-Glamry (2011) who reported that vegetative growth parameters such as branching tended to increase with increasing rates of mineral fertilizers and organic manures while, Njoku *et al.* (2001) observed that nitrogen and potassium were critical to sweet potato production. The variations recorded between fertilizer and variety interactions could be also influenced by

genotype or phenotypic expression of varieties towards growth and development like cell division, cell elongation and metabolic process of the plant.

5.3 Yield and Yield Components

High total tubers yield obtained from varieties Kasinia and Simama, were a responsiviness to Farm Yard Manure (7.5 ton ha^{-1}) and NPK Yara Mila Winner mineral fertilizer (350 kg ha^{-1}) application. The better performances of varieties in terms of yield was directly linked with adequacy of nutrients from those fertilizers, which facilitated well-developed assimilatory surface area and increased physiological activities, which led to greater assimilate production and partitioning for rapid tuber development (sink) and hence greater production.

Increased total tuber yields with Farm Yard Manure application (7.5 tons ha^{-1}) and NPK (350 kg ha^{-1}) could be attributed to increased tuber numbers per hectare. A variation in tuber yield among varieties and fertilizers rates could be due to genotypic and improved soil fertility conditions during crop growth. This observation indicates that each variety had a different response to the fertilizer applied in terms of increasing tuber yield. Kasinia and Simama gave greater tuber yield increases than Ukerewe. Greater yields in Kasinia and Simama could be attributed to longer vines, high number of primary branches and high above ground dry biomass. This observation complies with the findings of Kareem (2013) who reported that the yield of sweet potato is significantly depressed if potassium is missing. However, eliminating phosphorus does not significantly affect the yield, but high potassium level increases leaf area duration and suppresses excessive leaf growth, resulting in higher tuber yield (Kareem, 2013). Furthermore, key factors for increasing sweet potato yield are the careful regulation of N levels and liberal supply of K to increase sink capacity and photosynthesis.

Responses of sweet potato in terms of tuber number following application of 350 kg ha^{-1} NPK Yara Mila Winner mineral fertilizer were remarkable. It increased the number of tubers from 22222 to 54321ha^{-1}. The increased number of tubers in response to increased levels of NPK Yara Mila Winner mineral fertilizer and other fertilizers could be attributed to availability of balanced nutrients in the soil (for uptake) that encouraged tuber formation. Such increases could be associated with multiple supply of mineral nutrient elements, particularly N, P and K that played roles in plant growth and development, which had profound effects on tuber formation, enhanced physiological activity and translocation of assimilates to tubers over the control. This observation complies with the finding of Struik *et al*. (1990) who reported that nitrogen least affects the number of tubers, but mainly influenced tuber size and tuber weight. In the contrary, Kleinhenz and Bennet (1992) reported that application of nitrogen at higher than normal rates; both tuber weight and number are decreased. Similarly, the average tuber number is highly dependent upon genotype rather than fertilizer application.

Greater marketable tuber yield could be a result of adequate supply of nutrients particularly nitrogen, phosphorus and potassium. Potassium stimulates vigorous growth of vegetative parts for solar radiation interception and photosynthesis and play a role in catalyzing metabolic process and translocation to underground tubers of sweet potato, round potato and cassava. These crops have high demand for K because leaves, vines, stems, tuber and tubers usually remove substantial quantity of K from the soil. These results agree well with those of Jenkins and Nelson (1992) who reported that nitrogen increased the numbers and size of tubers per plant and hence, increasing economic yield. In the contrary, Zrust and Juzl (1996) reported that the number and size of tuber per unit ground area depended on variety, soil texture and temperature for tuber expansion.

The highest marketable tuber diameters (8.06 cm) recorded with NPK Yara Mila Winner (350 kg ha^{-1}) and FYM (7.5 ton ha^{-1}) resulted in significant increases in total marketable tuber yields. With these treatments, fractional nutrient content, particularly potassium, accelerated translocation of photosynthates from leaves to tubers through increased photosynthetic efficiency. Potassium is the most important nutrient in the production of sweet potato as it increases yield by formation of larger sized tubers. This observation complies with the findings of Degras (2003) who reported that Potassium affects the number, size, and quality and unit weight of tuberous roots. The responses to applied fertilizers in this study were most probably due to potassium, which was present in NPK Yara Mila Winner as well as in FYM. Zrust and Juzl (1996) reported that the number of large sized tubers not only depended on cultivar and physiological characteristics of the mother plant but also on soil texture and temperature for tuber expansion. Hence, better performance of Kasinia and Simama over Ukerewe in tuber yield could be attributed to the longer vines and higher leaf biomass which facilitated greater solar radiation interception.

5.4 Agronomic Efficiency of Using Fertilizer

The findings indicated high agronomic efficiency with Farm Yard Manure (7500 kg ha^{-1}) application on variety Kasinia and low values with DAP (150 kg ha^{-1}) on Kasinia (Table 14). Farm Yard Manure (7500 kg ha^{-1}) caused greater responses in growth and yields with high efficiency and more effective than the other treatments. Adequate and balanced application of multiple nutrients improved the efficiency and effectiveness in terms of growth and yield performances. This study has clearly demonstrated that higher agronomic efficiency was observed with high fertilizer application rates than low rates.

The poor responses in growth and development observed could be attributed to poor inherent fertility of the soil and inadequately or imbalanced nutrients supplies especially in terms of potassium that likely to occur on sandy soil while, only N and P were contained in DAP, this could be a reasons of low agronomic efficient observed on DAP fertilizer as also affect overall sweet potato production and economic returns as compared to other fertilized plots. Fertilizer efficiency and effectiveness is likely to occur to soil supplied with balanced nutrient and improvement on soil moisture and nutrient supplies at the crucial time of plant growth and development. Hence, high tuber yields could be due to the fact that the Farm Yard Manure was capable of providing nutrients as well as supplying organic matter, which improved soil physical and chemical properties. This resulted in greater tuberous roots expansion. However, all fertilizer treatments showed increases in yield compared to the control. The current results agree with the findings of Degras (2003) who reported that yields of sweet potato are reduced if severe water stress occurs at the time of tuber formation. Singer and Munns (1987) reported that moisture status of the soil affects plant growth and yield.

The relationship between efficiency and effectiveness was further explained when Fixen *et al*. (2005) suggested that the value of improving nutrient use efficiency is dependent upon the effectiveness in meeting the objectives of nutrient use such as providing economically optimum nourishment to the crop, minimizing nutrient losses from the field, and contributions to system sustainability through soil fertility or other soil quality components.

Hence, agronomic efficiency is the product of the efficiency of N recovery from applied N sources. Physiological efficiency is the efficiency in which the plant uses each unit of N acquired from applied fertilizer. Yadav (2003) reported that Agronomic efficiency is a useful measure of nutrient use efficiency as it provides an integrative index that quantifies total economic output relative to the utilization of all nutrient resources in the system.

According to Cassman *et al.*(1996), Nitrogen improves biomass production because it promotes faster photosynthetic rates by increasing crop radiation interception and conversion efficiency into biomass.

5.5 Profitability of Using Fertilizer on Sweet Potato

The profitability of fertilizer use on sweet potato production depends on the cost of fertilizer and the market price of produce. Furthermore, results indicated that each additional units of fertilizer contributed more to output than the low level applied and thus farmers could benefit by using more fertilizers. The yields (output) can highly influence the economic returns achieved in an enterprise. Thus, the net revenue of sweet potato varieties was highly significantly affected by fertilizer application rate. The net revenue was observed to have increased with increasing application rates in all the sweet potatoes varieties (Table 16). The price relationship between fertilizers applied and market value of this crop, largely determines the profitability and incentive for using fertilizers. Even though, the relative importance of these factors varies depending on weather conditions. Farmers can pursue higher revenue through higher balanced soil fertility in terms of nutrient supplies and also farmers can apply plant nutrients where their beneficial effects on crop yields are profitable. The decision to apply external plant nutrients will generally be based on price and affordability, availability of resources and the production risks involved. A farmer with a little or no purchasing power can try to produce sufficient food for family needs at the lowest risk. Such farmers are forced to operate at a subsistence level of farming. In these situations, farmer can choose the amount of fertilizer to apply depending on affordability and needs. On the other hand, farmers with access to good market prices of produce and fertilizer can produce with assurance to maximize returns on money invested. The response function to fertilizer use is a basic tool that relates the amount of crop that can be produced to the amount of fertilizer and other farm inputs applied.

Farm Yard Manure (7.5ton ha^{-1}) and 350 kg ha^{-1} NPK Yara Mila Winner mineral fertilizer gave greater net revenue in variety Simama, and increased consistently with increasing fertilizer rates. This observation complies with that of Cisse and Amar (2000) who explained that application of essential plant nutrients in optimum amounts, right proportions, correct method and time of application, is the key to increased and sustained crop production. Randall and Schmitt (1993) also suggests that fertilizer application on crops for optimum yield generally is an economically and environmentally acceptable practice while, over application of nitrogen causes nitrate leaching from the tuber zone and under application limits yields. The results of this study show the importance of farmers doing some economic analysis so as to know the direction taken by their farming enterprises.

5.6 Incentives of Using Fertilizers on Sweet Potato Production (Value Cost Ratio)

The Value Cost Ratio in all treatments that were more than 2.0 showed satisfactory risk coverage against investment in fertilizer use. With VCR of 1.0, fertilizer application at these levels is uneconomical; farmers can increase incomes by increasing fertilizer application rates (Table 15). Farmers can operate over a wide range of fertilizer application rates and benefit from them to the optimal levels. In this respect, farmers with sufficient resources can use fertilizer rates that are at or near the optimum in terms of economic returns. On the other hand, small-scale farmers with limited resources can invest on fertilizer rate that would give them economic return on the money they spend on investment; such farmers will be sacrificing a considerable portion of the achievable yields and profits by operating below the optimal level. Hence, Farmers should aim to maximize net revenue from fertilizer use as indicated by the Value Cost Ratio. The decision of farmers to use fertilizer type and rates based on the VCR level will depend on scale of production and profitability. However, the absolute net revenue should also be considered because, at low application rates of fertilizers, the VCR may be very high owing to the small cost of the treatment and the associated high rate of response. However, at low application rates, the net return would also be small and unattractive to farmers. In addition, other factors should be taken into consideration, such as expected yield, price of market produce and fertilizers. Farmers will apply plant nutrients only where the beneficial effects on crop yields are profitable. The decision to apply external plant nutrients to a particular crop will mainly be based on price and affordability.

Generally, among the other, Farm Yard Manure (7.5 tons ha^{-1}) gave the highest net revenue when compared to the other treatments. This could be influenced by more additional organic matter by improving soil physical properties and nutrients that increased chemical properties, which enhanced and supported moisture and nutrients retention for good crop growth and development.

According to Saleem *et al.* (1986) Value Cost Ratio of 2.0 is recommended for farmers because it represents 100% profit on the money invested in fertilizer and VCR greater than 2.0 is recommended for yield and profit maximization, while a VCR of 1.0 indicates that production under this management is not profitable. It is within a break-even point where production costs are equal to economic returns.

5.7 Correlation Analysis of Yield and Yield Components of Sweet Potato

The positive response of sweet potatoes in terms of tuber yield and its yield components could be directly linked to effects of fertilizer on tuber formation, tuber expansion, well-developed photosynthetic surfaces (vine length, number of leaves and branches) and increased physiological activities leading to more assimilates being produced and subsequently translocated and utilized for rapid tuber development and hence, production (Table 15).

The application of NPK Yara Mila Winner fertilizer at higher rates (350 kg ha^{-1}), significantly increased vine length, number of branches and dry weight of above ground biomass. The positive correlation coefficient (r) between total tubers yield and other plant characters of sweet potato varieties indicated that the those fertilizer applied influenced the performance of the plant characters, which led to high tuber yield of the sweet potato varieties. Njoku *et al.* (2001) reported that nitrogen and potassium were critical to sweet potato production while Trehan *et al.* (2009) observed that potassium increased vine length, crop vigour and leaf expansion particularly at early stages of growth and extended leaf area duration.

This positive response of growth characters to applied Farm Yard Manure, NPK Yara Mila Winner and other compound fertilizers in this study can be attributed to its role in the improvement of soil structure, soil nutrients and water retention as in the case of FYM. Application of nitrogen gave rise to increased length of vines, number of leaves and branches and consequently heavier above ground dry biomass. This facilitated cell multiplication chlorophyll formation for solar radiation capture and photosynthesis, which are essential for growth and development of yield components as more assimilates being produced, translocated and utilized in rapid tuber development and production.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The present study has revealed that Farm Yard Manure at 7.5 ton $^{-1}$ and NPK Yara Mila Winner at 350 kg ha^{-1} improved sweet potato growth, yield and net revenue obtained under these management practices.

Varieties, Kasinia and Simama were more responsive to fertilizer application in terms of growth, yield and economic benefit than variety Ukerewe.

The agronomic efficiency observed in this study was high and efficient with high fertilizer application rates particularly Farm Yard Manure.

Value Cost Ratio greater than 2.0 was associated with good crop growth, high yield and greater net revenue obtained from fertilizer management practices as these showed satisfactory risk coverage against investment in fertilizer use.

6.2 Recommendations

Based on soil analysis, application of Farm Yard Manure, inorganic fertilizers and economic analysis, the following recommendations were made:

i. Soils should be applied with Farm Yard Manure at the rate of 7.5 tons ha^{-1} so as to revamp sweet potato production in Tabora region.
ii. Varieties, Kasinia and Simama, are recommended for use by farmer.

iii. Farmers could use the inorganic fertilizer at the rate of 350 kg ha^{-1} NPK Yara Mila Winner for maximum yield and economic returns.

iv. More studies on integrated soil fertility management are needed to develop sustainable soil nutrients replenishment programme for the sandy soils of Tabora because a single study is not enough to answer all questions and problems related to the production areas.

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APPENDICES

Appendix 1: Soil Parameter Units, Methods and Particle Distribution

Soil parameter	Units	Method used
pH (water)	pH	1:1(soil:H_2O)
pH (KCl)	pH	1:1 (soil:1 M KCl)
Organic C	%	Wet oxidation (Walkley and Black
Total N	%	Kjeldahl method
Available P	mg/kg	Bray ll or Olsen method spectrophotometer
Exch. K	Cmol(+)/kg	1 M NH_4Cl, flame photometer
Exch. Na	Cmol(+)/kg	1 M NH_4Cl, flame photometer
Exch. Ca	Cmol(+)/kg	1 M NH_4Cl, atomic absorption spectrophotometer
Exch. Mg	Cmol(+)/kg	1MNH_4Cl, atomic absorption spectrophotometer
Exchangeable Al	Cmol /kg	1 M KCl titration method
Exchangeable H	Cmol /kg	1 M KCl titration method
Eff. cation exch. capacity (ECEC)	Cmo/kg	Exchangeable K+ Na+ Ca+ Mg+ Al+ H
Al saturation	%	(Exchangeable Al/ECEC) x 100
Sand	%	Pipette method
Silt	%	Pipette method
Clay	%	Pipette method

Sources, Africa Soil Health Consortium

Appendix 2: Critical values for some physical and chemical properties of soils.

Property	SI units	Value	Comments
Sand	%	>50	Leaching losses are likely to be large. Important to return crop residues to replenish soil organic matter, improve nutrient retention and soil moisture availability
Clay	%	>45	Drainage problems likely, large cation exchange capacity if clay is made up of 2:1 clay minerals
Clay	%	<30	Poor nutrient content; poor soil moisture retention; difficult to increase soil organic matter.
pH (H_2O, 1:2.5 or 1.5)	pH	<4.5	Liming may be required
	pH	> 5.5	No advantage from liming

Source; Africa Soil Health Consortium

Appendix 3: Soil mate changes reporting units for cations

In keeping Soil Mate aligned with scientific and industry standards, it has been decided to align the reporting units for the major cations (calcium, magnesium, potassium, sodium, and aluminum) and effective cation exchange capacity (eCEC) with the standard units used by the research community for a number of years. This will see the universally used milliequivalent/100 g (meq/100g) replaced by the cmol(+)/kg. Fortunately, this replacement is in name only and the critical levels that you may remember will remain unchanged as 1 meq/100g = 1 cmol(+)/kg as will the calculation of exchangeable cation percentages.

1 cmole(+)/kg potassium = 1 meq/100g potassium = 391 mg/kg potassium

1 cmole(+)/kg calcium = 1 meq/100g calcium = 200 mg/kg calcium

1 cmole(+)/kg magnesium = 1 meq/100g magnesium= 120 mg/kg magnesium

1 cmole(+)/kg sodium = 1 meq/100g sodium = 230 mg/kg sodium

Conversion from non-SI unit to SI units

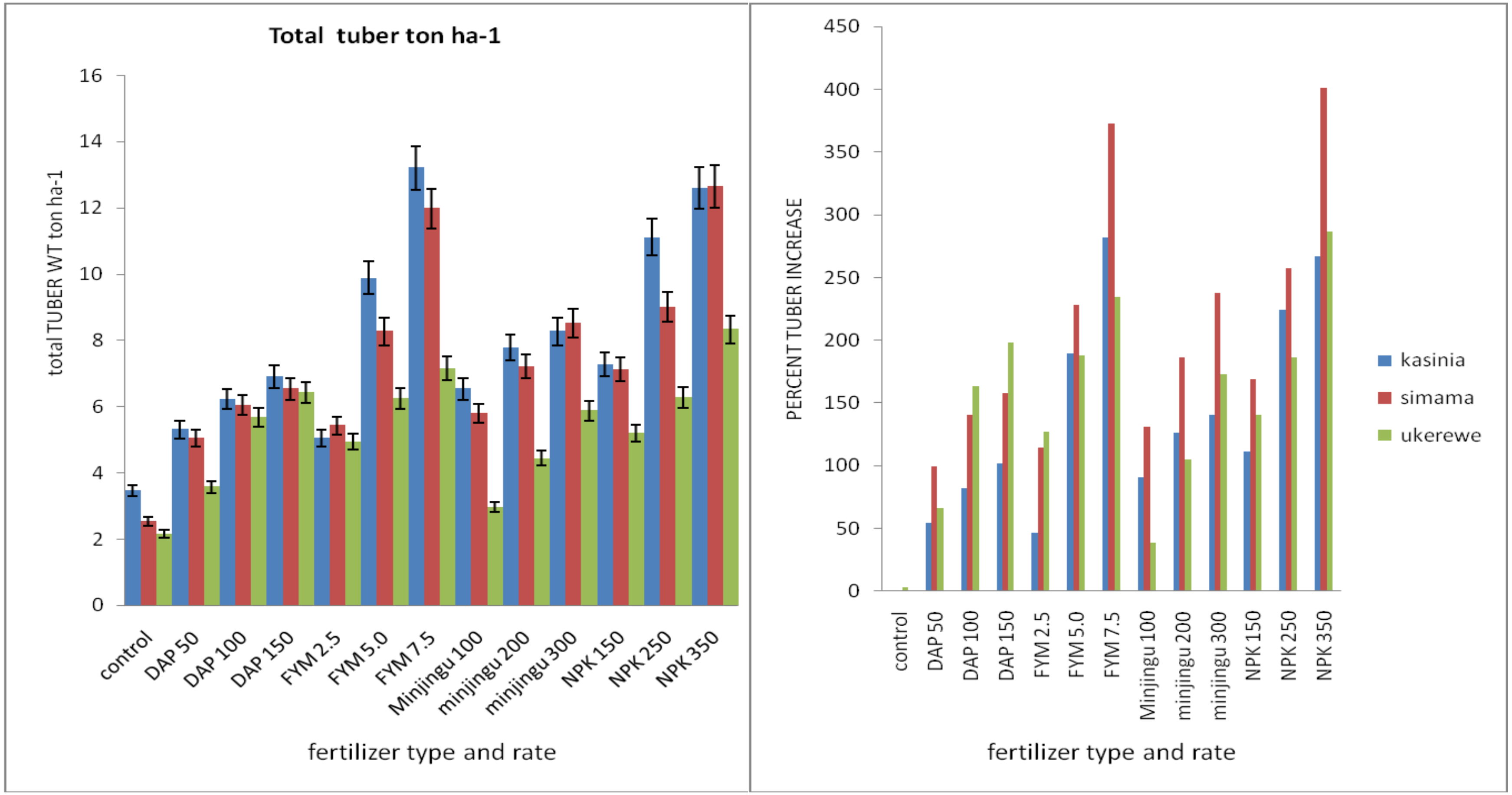
From	To	Multiply by	From	To	Multiply by
N	Protein	6.25			
P	P_2O_5	2.29	P_2O_5	P	0.436
K	K_2O	1.20	K_2O	K	0.83
Ca	CaO	1.40	CaO	Ca	0.715
Mg	MgO	1.66	MgO	Mg	0.603
S	SO_4	3.0	SO_4	S	0.33
S	SO_3	2.5	SO_3	S	0.44

Sources, Africa Soil Health Consortium

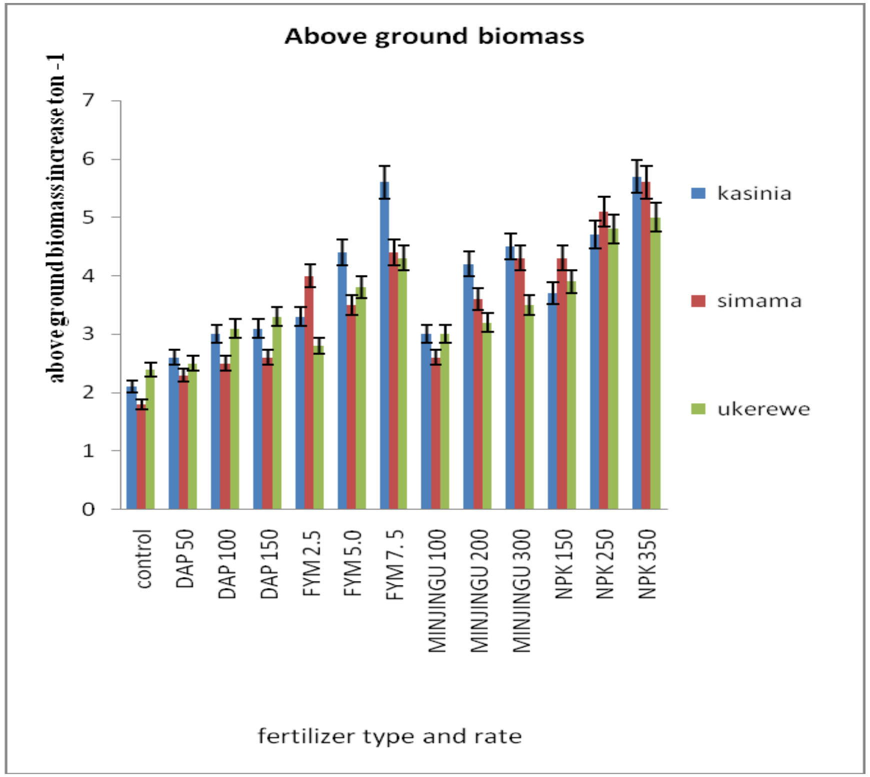
Appendix 4: Different Fertilizers Sources, Rates and Nutrient Elements Applied

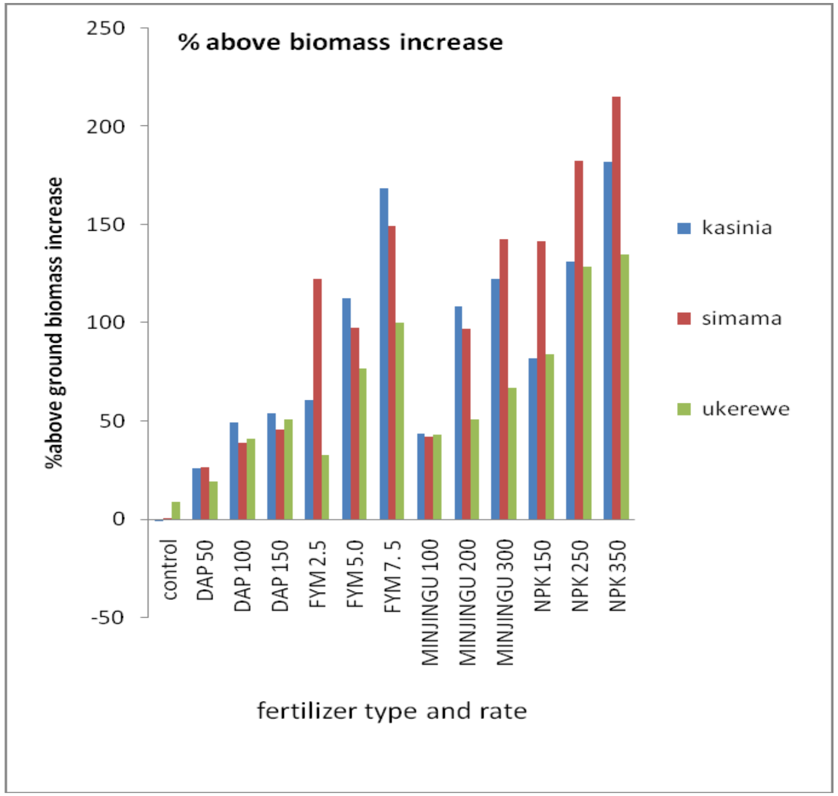
Treatment	Unit area(ha)in m^2	Amount (kg/ha)	Nutrients applied kg/ha			area in m^2	Amount applied in sub plots (gm)	Nutrients supplied per subplot (gm)			Fertilizer applied in main plots (gm)	Fertilizers applied per plants (gm)
			N	P	K			N	P	K		
Control	10,000	0	0	0	0	5.4	0	0	0		0	0
NPK Yara Mila Winner	10,000	150	22.5	5.9	24.9	5.4	18	12.15	3.21	13.5	243	4.05
NPK Yara Mila Winner	10,000	250	37.5	9.9	41.5	5.4	135	20.15	5.35	22.4	405	6.75
NPK Yara Mila Winner	10,000	350	52.5	14	58.1	5.4	189	28.35	7.48	31.4	567	9.45
DAP	10,000	50	9	10	-	5.4	27	4.86	5.4	-	81	1.35
DAP	10,000	100	18	20	-	5.4	54	9.72	10.8	-	162	2.7
DAP	10,000	150	27	30	-	5.4	81	14.58	16.2	-	243	4.05
Minjingu Mazao	10,000	100	10	8.8	-	5.4	54	5.4	4.752	-	162	2.7
Minjingu Mazao	10,000	200	20	18	-	5.4	108	10.8	9.50	-	324	5.4
Minjingu Mazao	10,000	300	30	26	-	5.4	162	16.2	14.26	-	486	8.1
FYM	10,000	2500	13	1.23	0.11	5.4	1350	7.02	0.66	-	4050	67.5
FYM	10,000	5000	26	2.46	0.22	5.4	2700	14.04	1.33	-	8100	135
FYM	10,000	7500	39	3.69	0.33	5.4	4050	21.06	1.99	-	12150	202.5

Appendix 5: Percentage increase in tuber weight



Appendix 6: Percentage increase in above ground dry biomass weight





Appendix 8: Nutrient ratings Landon 1991and EUROCONSULT. (1989).

1. Organic matter and Total nitrogen

Parameters	Very low	Low	medium	High	Very high
Organic matter %	< 1.0	1.0-2.0	2.1-4.2	4.3-6.0	> 6.0
Organic C %	< 0.60	0.60-1.25	1.26-2.5	2.51-3.50	> 3.50
T otal N %	< 0.10	0.10-0.20	0.21-0.50	>0.50	

C/N ratio give an indication of the quality of organic matter; C/N 8-13 good quality, C/N 14-20 moderate quality and >20 poor quality.

2. Soil reaction (pH H_2O) is classified as follows

Extremely acid	< 4.5	Neutral	6.6-7.3
Very strongly acid	4.5-5.0	Mildy alkaline	7.4-7.8
Strongly acid	5.1-5.5	Moderate alkaline	7.9-8.4
medium acid	5.6-6.0	Very strongly alkaline	8.5 -9.0
Slightly acid	6.1-6.5	Strongly alkaline	>9.0

3. Available phosphorus

Mg/kg	Low	medium	high
Available P. (Bray-Kurtz)	<7	7-20	>20
Available P. (Olsen)	<5	5-10	>10

Available phosphorus is determined by Bray and Kurtz method if the pH soil in H_2O is less than 7.0 and in Olsen if more than 7.0.

4. Exchangeable Calcium

Cmol(+)/kg	Very low	Low	medium	High	Very high
Ca (clayey soils)	<2.0	2.0-5.0	5.1-10	10.1-20.0	> 20.0
Ca (loamy soils)	<0.5	5.0-2.0	2.1-4.0	4.1-6.0	> 6.0
Ca (sandy soils)	<0.2	0.2-0.5	0.6-2.5	2.6-5.0	> 5.0

5. Exchangeable Magnesium

Cmol(+)/kg	Very low	Low	medium	High	Very high
Mg (clayey soils)	<0.3	0.3-1.0	1.1-3.0	3.1-6.0	> 6.0
Mg (loamy soils)	<0.25	0.25-0.75	0.75-2.0	2.1-4	> 4.1
Mg(sandy soils)	<0.2	0.2-0.5	0.5-1.0	1.1-2.0	> 2.0

The desired saturation level of exchangeable magnesium is 10 to 15 percent; for sandy and kaolinitic soils 6 t0 8 percent magnesium is still sufficient. Ca and Mg ratios of 2 to 4 are favorable.

6. Exchangeable Potassium

Cmol(+)/kg	Very low	Low	medium	High	Very high
K (clayey soils)	<0.2	0.20 -0.40	0.41-1.20	1.21-2.00	> 2.00
K (loamy soils)	<0.13	0.13-0.25	0.26-0.80	0.81-1.35	> 1.35
K(sandy soils)	<0.05	0.05-0.10	0.11-0.4	0.41-0.70	> 0.70

The desired saturation level of exchangeable magnesium is 2 to 7 percent. Mg: K ratios of 2 to 4 for most crop are in range of 1 to 4.

6.

Exchangeable Sodium

Cmol(+)/kg	Very low	Low	medium	High	Very high
	<0.10	0.10- -0.30	0.31-0.70	0.71-2.00	> 2.00