RESPONSE OF LOWLAND RICE (*Oryza sativa L.*) VARIETIES TO NITROGEN, PHOSPHORUS, POTASSIUM AND ZINC IN TWO SOIL TYPES IN KIBAHA DISTRICT

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CROP
SCIENCE OF SOKOINE UNIVERSITY OF AGRICULTURE.
MOROGORO, TANZANIA.

2015

ABSTRACT

A study was conducted during 2011/2012 growing season at Mlandizi and Kitomondo villages in Kibaha District, to determine the response of lowland rice varieties to N, P, K and Zn in two soil types. The nutrient treatment levels were as follow; $N_{150} + P_{40} + K_{100} + Zn_{10}$, $N_{150} + P_{40} + K_{100} + Zn_{0}$, $N_{150} + P_{40} + K_{0} + Zn_{0}$, $N_{100} + P_{0} + K_{0} + Zn_{0}$, $N_{75} + P_{20} + K_{0} + Zn_{0}$, $N_{0} + P_{30} + K_{0} + Zn_{0}$ and $N_{0} + P_{0} + K_{0} + Zn_{0}$ as a control. Rice varieties used were SARO5, NERICA and SUPA. The fertility status of the soils for rice production at two experimental sites was evaluated. Generally, based on soil texture, the two sites are suitable for lowland rice production but deficiencies of N, P, K and Zn were identified. Prior to seeding, a basal application of P at the rates of 0, 20, 30, and 40 kg P/ha was applied. The amount of K applied was 100 kg K/ha whereas, 10g of Zinc Sulphate (ZnS04) was used. Nitrogen in the form of Urea (46% N) at rates of 0, 75, 100 and 150 kg N/ha was applied into two splits as follows: one split applied 21 days after sowing , and the second split was applied at panicle initiation stage (42 – 45 days after sowing). Field experiments indicated that the application of N, P, K and Zn increased rice yield from 2.05 (in control) to 6.863 t ha^{-1} ($N_{150} + P_{40} + K_{100} + Zn_{10}$) in Mlandizi and 2.00 (in control) to 7.20 t ha^{-1} ($N_{150} + P_{40} + K_{100} + Zn_{10}$) in Kitomondo site. The yield increases were due to increased availability and uptake of plant nutrients particularly N, P, K and Zn. Based on the generalized yield data it was thus recommended that fertilizer level of N150P40K100Zn10 in Kibaha District should be adopted to achieve high rice yield. Further the results indicated that moisture was another limiting factor to rice yield, hence short to medium maturing varieties (SARO5 and NERICA) were recommended.

DECLARATION

I, Happiness Phillo Mbelle do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation has not been submitted and will not be submitted to any other university for similar or any degree award.

HMbelle

10TH AUGUST, 2016

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(Msc Crop Science Candidate)

Date

The above declaration is confirmed by,

Semoka

10/08/2016

Prof J. M. R Semoka

(Supervisor)

Date

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ACKNOWLEDGMENTS

I would like to thank God Almighty for blessing the year 2014/2015 at Sokoine University of Agriculture [SUA], which stands out as one of my best years in my academic life. I am very grateful to the Belgian Technical Co-operative (BTC), for the financial support throughout the two years of the Master of Science degree study.

Special thanks are due to my supervisor Prof J.M.R Semoka, of the Department of Soil Science, SUA for supervising this study for his guidance, support and kindness. Thank you Prof Semoka for believing in me, and for your invaluable advice and making the dissertation easy and enjoyable. Thanks are also due to the Head of Crop Science and Production, Prof C.L Rweyemamu for valuable advice throughout the study period.

I am grateful for the technical assistance I received from the Soil Science Department laboratory staff, Balton and all non-academic staff who in one way or another assisted me. Also my sincere expressed to the farmers in Kitomondo and Mlandizi villages in Kibaha District- Coast Region.

Special thanks are due to my husband Zakaria Swedi who has been a very special person to me through encouragement and prayers. My parents Phillo Vincent Mbelle and Late Marietha Castor Ndunguru are greatly acknowledged for their tireless help and prayers. Lastly but not least, I would to thank my children (NajmaSarah, Mariam-Lulu, Ibrahim, Daudi and Doreen) for their tolerance when they missed motherly love and company during my long stay away from them.

DEDICATION

This dissertation is dedicated to my twins, Daudi and Doreen (double D) who's missed unreturnable motherly love during accomplishment of this work and their passionate. I real love them.

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LIST OF ABBREVIATIONS

Av	Average
Ca	Calcium
cm	Centimeter
cmol	Centimole
CV	Coefficient of variation
Cu	Copper
°C	Degree Celsius
DAP	Days after planting
DTPA	Diethylene Triamine Pentaacetic Acid
Fer	Fertilizer
Fe	Iron
g	Gramme
ha	hectare
HI	Harvest index
H_2SO_4	Sulphuric acid
IRRI	International Rice Research Institute
K	Potassium
KATC	Kilimanjaro Agriculture Training Centre
KCL	Potassium chloride
kg	Kilogramme
Loc	Location
Mn	Manganese

Mg	Magnesium
mg	Milligramme
ml	Millilitre
N	Nitrogen
Na	Sodium
NERICA	New Rice for Africa
ns	Not significant
P	Phosphorous
t	Tonnes
TDM	Total Dry Matter
t/ha	Tonnes per hectare
TSP	Triple Super Phosphate
USDA	United States Department of Agriculture
Var	Variety
$ZnSO_4$	Zinc Sulphate

Mg	Magnesium
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CHAPTER ONE

1.0 INTRODUCTION

1.1 Importance of Rice in Tanzania

Rice (Oryza sativa L.) is one of the most important crops in Africa as evident from its highest consumption growth rate in the world. In Sub Sahara Africa (SSA), rice is ranked as the fourth most important in terms of production after sorghum, maize and millet (Dibba*et al.*, 2012).

Since 2000, consumption has increased in Africa by more than 34% compared with 8% in Asia and 10% as the world average (WRS/USDA, 2009). Higher demand is increasing the import burden of many countries. In 2009, world rice production was about 680 million tons with a projected record harvest of 710 million tons in 2010 (FAO, 2010), alongside an increase in consumption of about 8 million tons.

Rice is the second widely cultivated cereal food crop in Tanzania after maize. The crop is grown in three agro-ecosystems namely:-rainfed lowland (74%), rainfed upland (20%) and irrigated lowland (6%) (Kanyeka, 1994). Drastic shift of consumers' preference both in urban and rural areas from conventional foods to rice coupled with rapid urbanization has resulted into a simultaneous increase in annual per capita consumption of rice in Tanzania to about 25 - 30 kg/ head/year (Kibanda, 2008). The leading regions in rice production are Shinyanga, Tabora, Mwanza, Mbeya, Rukwa and Morogoro. Others include Kilimanjaro, Arusha, Manyara, Iringa , Coast region, Tangaect. The average yield is very low, 1- 1.5 t/ha (Jerry *et al.*, 2007), while the optimum yield is high compared with that amount and also depend on variety e.g. SARO 5 produce 4.5-5.5 t/ha.

In Tanzania the low rice yields in small scale farms (about 1 t ha^{-1}) is due to soil moisture stress, low soil fertility and improper nutrient management practices (Mghase*et al.*, 2010), resulting into food insecurity and low income generation by the small- scale rice farmers in Tanzania.

There are many problems facing rice growing areas in Tanzania. Such factors include use of traditional varieties, these varieties have long maturity and yield is affected with irregular rainfall pattern, occurrence of pests which contribute to the yield decline, poor crop husbandry, minimum use of fertilizer, inadequate water supply and water management (URT, 2009). Apart from those constraints, soil infertility is among the major constraints to crop production and productivity in most of the tropical regions of the world (Batiano *et al.*, 2008).

Phosphorus (P) deficiency is identified as a constraint to crop production on acid tropical, low-activity clay Ultisols and Oxisols (Sahrawat *et al.*, 2008). Shekifu (1999) reported that Phosphorus application is required in order to obtain optimum rice yield at Ruvu site but the optimum P rate was found to be dependent on the N rate used. Mgata (1996) observed that the lowland rice soils have low amounts of available P ranging from less than 1-3mg P/ha which would limit rice yield.

It is estimated that for every one tone of rice grain harvested, about 15-20 kg N, 2-3kg P and 15-20kg K removed from the soil (Buri *et al.*,1999). The productivity of lowland rice soils is heavily dependent on soil fertility or the chemical nature of the soil. Soil fertility depends on the status of soil nutrients such as total amount of N, P, Kand their capacity to produce easily available forms that can be taken up by the crops (Hao *et al.*, 1998).

Nitrogen (N) is the input required in the largest quantities in lowland rice production. Fertilizer application is thus necessary to meet the crop's demands (Choudhury and Khanif, 2004). To attain optimum level of production, it is necessary to improve soil fertility in areas under rice production by the use of proper amount of fertilizer. The overall objective of this study was to evaluate the response of lowland rice varieties to Nitrogen, Phosphorus, Potassium and Zinc in two soil types in Kibaha District.

1.2 Problem Statement and Justification

The decline in rice production has been experienced in Coast region especially Kibaha district. The average rice production has progressively declined over the past 10 years (2000/2001 – 2010/2011) to 1.09t/ha (DALDO, 2012). There are major factors facing rice production in Kibaha district namely: unreliable and improper distribution of rainfall. For instannce, previously Kibaha experienced bimodal rainfall patterns starting in the early September ending in late December while another season started in early February ending in late May. Currently, however the district experiences a short period of rainfall which start in mid-October ending in late December while another season starts in late March ending in late May. Other factors are poor crop husbandry, decline in soil fertility due to soil erosion caused by flood and continuous removal of nutrients from the soils without replenishment. It is estimated that for every tone of grain rice harvested about 15-20kgN, 2-3kgP, 15-20kgK is removed from the soil (Buri *et al.*, 1999).

Declining of the soil nutrients is among the factor leading to relatively low rice yield.Few studies have been done on evaluating soil fertility status for rice growing areas in Kibaha district. For instance Shekifu and Semoka, (1999) reported P fertilizers should be applied at Ruvu rice farms in order to optimize yield as identified that the area has limited nutrient elements especially N and P. But no further research have been done to evaluate other nutrients e.g. N, K and micronutrients. Apart from this area in Kibaha district where a study has been done, there are other relatively potential rice growing areas Minazimikinda, Kikongo and Kwala soils yet, no studies have been done to assess the soil fertility status in those potential rice growing areas.

To attain optimum level of production and sustain it, it is necessary to solve the above mentioned problems. One of the ways is to improve soil fertility in all areas under production. This requires proper assessment of nutrient status of these soils, developing fertilizer recommendations followed by their adoption by farmers.

1.3 Objectives

1.3.1 Main objective

To evaluate the response of lowland rice varieties to N, P, K and Zinc in two soil types in Kibaha District Council.

1.3.2 Specific objectives

i. To determine the soil fertility status of soils in rice growing areas in Kibaha district in Coast region

ii. To determine the response of rice to N, P, K and Zn application

iii. To assess the performance of NERICA, SARO 5 and SUPA lowland rice varieties

iv. To find out the relationship between yield and yield components of studied rice varieties.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Rice Production in Tanzania

In Eastern and Southern Africa, Tanzania is the leading country where rice ranks the second most popular staple food and cash crop after maize *(Zea mays L.)*. Rice is among the major sources of employment, income and food security for Tanzania farming households. The cultivated area is 681,000 ha; this represents 18 % of Tanzania's cultivated land. About 71 % of the rice grown in Tanzania is produced under rain fed conditions, irrigated land represents 29 % of the total with most of it in small village level traditional irrigations (IRRI, 2007). The average yield is very low (1-1.5 t/ ha).

Farmers grow a number of traditional varieties. These varieties have long maturity and yield is affected by irregular rainfall pattern and occurrence of pests which contribute to the yield decline. In the Central Corridor, rice is extensively produced in three regions namely; Tabora, Shinyanga and Morogoro where there are more favorable growing conditions. Manyara, Singida and Dodoma have some supplementary production in their low lands. Forty eight percent of rice cultivated land in Tanzania is found in the central corridor that involves approximately 230,000 small holder households (RLDC, 2009).

2.2 Roles of Nitrogen, Phosphorus and Potassium in Rice production

The growth of the rice plant in any medium (soil, sand, water) depends on the availability of sunlight, water, and various chemical elements. Sixteen elements are recognized as essential in rice nutrition: carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, manganese, copper, boron, zinc, molybdenum, chloride. Among these, carbon, hydrogen, and oxygen are absorbed directly out of the air and water; the rest must be present in the soil.

The chemical form in which a nutrient element is present in the soil is also important, since the availability of a nutrient to the plant varies with the roots ability to extract the nutrient element from the chemical compound in which it occurs. Major nutrients required for the growth of rice plant are Nitrogen (N), Phosphorus (P) and Potassium (K) but in addition to these major elements some micro-nutrient such as manganese, zinc, sulphur, iron etc are required. If only one of these elements is deficient, the rice plant cannot grow well even though all the other nutrients are abundantly available. Fertilizer application is thus necessary to meet the crop demand. The common fertilizers used in rice production are urea, triple super phosphate, murate of potash etc (Choudhury and Khanif, 2004).

2.2.1 Nitrogen

Rice crop requires nitrogen for growth, development and yield. The rice crop responds positively to N fertilizers applied to N deficient soils. The amount of N uptake and N use efficiency of crops rice inclusive depend on yield levels and environmental conditions (Ceesay, 2004). Under good environmental conditions such as good moisture supply, application of N fertilizers increases number of tillers, leaf area index, harvest index and grain yield of upland rice (Fageria, 2010).

Rice grown under high management requires large amounts of nitrogen (N).One crop consumes approximately 20-25 kg of nitrogen for every ton of yield, making nitrogen the single most important rice nutrient (Baker *etal.*, 2007).Nitrogen is an integral component of many essential plant compound such as amino acids, which are building block of all proteins including enzymes, nucleic acid and chlorophyll (Brandy and Well, 2002; Multers *et al.*, 2006).

Nitrogen accumulates first in the leaves during vegetative phase, and migrates to the panicles and grain. At maturity 75% of the nitrogen is present in the grains (Woperes *et al.*, 2009). Nitrogen's fundamental importance as a primary nutrient element is augmented by the fact that many improved rice varieties cultivated around the world have been bred to show a marked response to the application of nitrogenous fertilizers. Nitrogen increases the vigor and enhances the growth of the rice plant. When absorbed during the vegetative phase, nitrogen: - helps synthesize the chlorophyll necessary for photosynthesis (as evidenced by a marked "greening" of the leaves) - promotes rapid leaf, stem, and root growth (as evidenced by an increase in the height, size, and number of tillers, as well as an increase in the size of leaves) - speeds growth, thus enabling seedlings to grow fast enough to avoid many seedling blights (Baker *et al.*, 2007).

When absorbed during the reproductive and ripening phases, nitrogen: - promotes development of the panicle (as evidenced by an increase in the number of spikelets) - stimulates nutrient absorption and assimilation (as evidenced by an increase in size and number of filled grains - increases the protein content of the grains, thus improving the quality of the crop (Baker *et al.*, 2007). Nitrogen deficiency in rice can be recognized by: - yellowish, color of the leaves, particularly of younger leaves - small size of plants - low number of tillers - straightness, stiffness or upper leaves. Further, nitrogen increases plant height, number of tillers, leaf size, number of spikelets per panicle, percentage filled spikelets and grains (Fageria, 2010).

2.2.2 Phosphorus

Phosphorous is an essential constituent of Adenosine Triphosphate (ATP), nucleotides, nucleic acids and phospholipids. Its major functions are energy storage and transfer within the plant (Dick, 2011). Phosphorus is a major of ATP, the molecule that provides "energy" to the plant for such processes as photosynthesis, protein synthesis, nutrient translocation, nutrient uptake and respiration. Phosphorus is also a component of other compounds necessary for protein synthesis and transfer of genetic material (DNA, RNA) (Zhang and Rau, 2006). Phosphorus promotes root development, early flowering and ripening. It is particularly important in early growing stages (Dobermann and Fairhurst, 2000).

Phosphorus increases the protein content of the grains thus improving the food value of the crop. Phosphorus not only enhances the yields but also reduces spikelet sterility (Alam, 2009). Phosphorus (P) deficiency is one of the major limiting factors of crop productivity in most soils throughout the world (Pierrou, 1976; Li *et al.*, 2006). Phosphorus deficiency can arise in soils where P is strongly bound to soil particles (Wissuwa, 2005). Plants suffers from P deficiencies exhibit retard growth (Marschner 1993, Mutters *et al.*, 2006),with greatly reduced tillering (Mutters *et al.*, 2006) . Application of phosphorus fertilizers is one of the most important for higher crop yield (Bunemann *et al.*, 2011). Although in general response to phosphorous in irrigated rice is less marked than response to nitrogen, phosphorus is none the less a very important nutrient, one crop consumes approximately 15 kg of phosphorous for every ton of yield (Carkmark, 2005).

2.2.3 Potassium

Potassium plays a particular role in contributing to the survival of crop plants under environmental stress conditions. Potassium is essential for many physiological processes, such as photosynthesis, translocation of photosynthates into sink organs, maintenance of turgidity, activation of enzymes, and reducing excess uptake of ions such as Na and Fe in saline and flooded soils (Carkmak, 2005).

The response of rice to potassium is often not as marked as the responses to nitrogen and or phosphorus, except in unusual situations. Nevertheless, potassium should not be overlooked as an important nutrient element, since each crop requires approximately 15 kg of potassium for every -ton of yield. When absorbed during the vegetative phase, potassium strengthens cell walls, thus making the plant physically stronger and enabling it to withstand the adverse effects of bad weather, increases the plant's resistance to penetration by disease organisms. When absorbed during the reproductive and ripening phases, potassium increases the plant's resistance to diseases affecting the panicle and grains, increases the protein content of the grains, thus improving the quality of the crop, and increases the size and weight of the grains (Baker *et al.*, 2007).

Potassium deficiency in rice can be recognized by deep, dark color of the leaves (spreading from the tips), irregular dead spots on the leaves and panicles, droopiness of leaves, resulting in reduced photosynthesis and consequent slower growth and unusual susceptibility to disease and pest attack.

2.2.4 Zinc

Zinc is essential element for crop production and optimal size of fruit, also it required in the carbonic enzyme which present in photosynthetic tissues, and required for chlorophyll biosynthesis (Graham *et al.*, 2010; Ali *et al.*, 2008; Mousavi, 2011; Xi – Wen, 2011). Crop yield significantly increases with the use of micronutrients such as zinc, iron, boron, copper, manganese ect.

Zinc deficiency causes multiple symptoms which usually appear 2 to 3 weeks after transplanting of rice seedlings, with leaves developing brown blotches and streaks that may fuse to entire by older leaves, and plants remain stunted, where as in severe cases, the plants may die, while those which recover will show substantial delay in maturity and reduction in yield (Alam *et al.*, 2010; Abdou et al., 2011, Mousavi, 2011).

2.3 Status of Nitrogen, Phosphorus, Potassium and Zinc in Rice Growing Areas of Tanzania

2.3.1 Status of nitrogen

Nitrogen deficiency is the most commonly detected nutrient deficient symptoms in rice. Significant yield responses to applied n are obtained in nearly all lowland rice soils where irrigation and other nutrients and pests are not limiting (Dobermann and Fairhurst, 2000). "Paddy soils" denote soils in irrigated and rainfed lowland rice production systems with a prolonged period of submergence (Buresh and Haefele, 2010). Severe nitrogen losses occur in soils subjected to alternate draining (aerobic) and flooding (anaerobic) (Mutters *et al.*, 2006).Studies have examined the kinetics of gross nitrogen, mineralization, immobilization and nitrification rates in soil at temperatures above 15^{0}C (ie under tropical condition) (Holyle *et al.*, 2006). The total N content for most soils ranges from less than 0.02% in sub soil to more than 2.5% in peats. Plow layers of most cultivated soils contain between 0.08% and 0.4% N (Robert, 1998). Previous studies shown that proper use of fertilizer can increase yield and improve the quality of rice significantly (Awan *et al.*, 2003; Ahmed, 2005; Oikeh *et al.*, 2008). Several studies have shown that application of N fertilizer to rice, leads to increase in plant height, panicle number, leaf size, spikelet number and grain yield (Balasubramaniam, 2002; Walker *et al.*, 2008). Kamara *et al.* (2011) conducted that nitrogen application increased rice grain yield and yield components with the highest grain yield obtained at 100kg Nha^{-1}. Nitrogen application even lower rates significantly increased grain yield of the rice varieties suggesting that N is a major limiting nutrient in rice production.

2.3.2 Status of phosphorus

Phosphorus (P) availability in soil is closely related not only to soil P content but also to soil physical, chemical and biological properties, which are closely associated with P sorption and biochemical transformation (Guo *et al.*, 2009). Flooded soils exhibit a greater capacity to supply plant available phosphorus than non-flooded soils (Dobermann and Fairhurst, 2000). Yosefi *et al.* (2011) reveals that P fertilizer significantly influenced grain number per panicles. In addition, Panhawar *et al.* (2011) reported information of p fertilizer found to increase upland rice yield. Li *et al.* (2010) argued that application of P fertilizer is most important practices for rice crop yield. P deficiency is widespread in rain –fed rice soils and its particularly prominent in drought prone environments because the nutrient mobility decreases sharply as soil dries. In additional, the soil infertility problem is mostly under intensified agricultural production systems. For this reason, the application of inorganic P fertilizers is a major requirement for sustained crop production in rice as well as for enhancing soil fertility (Sahrawat *et al.*, 2008).

2.3.3 Status of Potassium

Potassium (K) is a macronutrient taken up by plants in large quantities with total above ground uptake in mature crops approaching or exceeding the equivalent of 200lbk$_2$0/acre (Slaton*et al.*, 2009). Potassium performs important roles in enzymes activation photosynthesis, photorynthate, translocation, protein synthesis (ienitrogenuse) and plant water relations and is known to play an important role in the plants ability to resist disease (Maschmann *et al.*, 2010). Use of insufficient K fertilizer rates on silt and sandy loam soils for seven years will lead to K deficient and yield loss. Rice and soybeans are more susceptible to many plant diseases when K nutrition is low or deficient, which can cause yield and / or quality losses beyond that caused from the physiological effects of insufficient K nutrition (Slaton *et al.*, 2009). High incidence of brown leaf spot (Bipolarisoryzae, stem rot (Sclerotiumoryzae) and other opportunities diseases are important signs of potential K deficiency in rice. The amount of K removed by harvested grain typically accounts for < 20% of total above ground K uptake by rice. Research in the Sacramento Valley of California shows that potassium (K) fertilization of soils deficient in available K will not only increase rice yields, but also reduce pressure from such diseases as stem rot and aggregate sheath spot. (Jack *et al.*, 2001).

2.4 Constrains to Rice Production in Tanzania

Several challenges exists in rice development such as development and availability of improved seeds resistant or tolerant to major biotic (includes weeds, insects and diseases)and abiotic (drought/flooding, low soil fertility, iron toxicity etc.) stress, development of availability of improved post-harvest processing technologies and value addition (grading and packaging) process (URT, 2009).

Poor soil nutrients, degraded, and often acidic soils limit crop production in many tropical regions. When coupled with the high cost of inorganic fertilizer, especially in Africa, much small-scale agriculture occurs under conditions of nutrient deprivation (Delmer, 2005). Limiting amounts of phosphorous and excessive levels of aluminum are characteristic problems of acidic soils. Soil problem in other rain fed areas includes salinity, alkalinity and or zinc deficiency that could efficiently be solved with affordable soil amendments and use of tolerant high yielding rice varieties.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location

The study was conducted at Mlandizi village Longitude 6° 42' 56.11" S, Latitude 38° 45' 01.57" E and altitude 38.70 m above sea level with GPS reading E 470357 N9261993 in Mlandizi ward and Kitomondo village Longitude 6° 44' 35.54" S, Latitude 38° 43' 12.59" E, and altitude 69.18 m above sea level with GPS reading E455025 N9238572 in Ruvu ward, Kibaha District Council, Coastal region. The study sites experience bimodal rainfall pattern with average rainfall of 650 to 1000 mm per annum and an average temperature of 18 to 30°C; the long rain season (*masika*) being from early February to mid-May while the short rainfall season (Vuli) is from early October to late December.

3.2 Materials

Three rice varieties namely TXD 306 (SARO 5), NERICA from Agricultural Seed Agency (ASA) in Morogoro and SUPA local variety collected from farmers were used. Also, fertilizers such as Triple supper phosphate (TSP 46% P_20_5), Urea (46%N), Muriate of potash (60%K_2O) and Zinc Sulphate (10% ZnSO4 .7H_2O) from agro-shops were used.

3.3 Soil Characterization

Characterization of soils was done in selected eighteen villages in rice fields for determination of physical and chemical properties. A composite representative soil sample per village in rice farms was obtained by sampling ten different positions selected randomly at a depth of 0- 20 cm. Then, ten spot soil samples were mixed together, quartering method was used to get one composite soil sample which was prepared for analysis (Motsara and Roy, 2008).

Soil analysis was done in the Department of Soil Science Laboratory, Sokoine University of Agriculture (SUA) Morogoro, Tanzania. The soil properties determined include particle size distribution (soil texture), soil pH, organic carbon, , total N, extractable P, cation exchange capacity (CEC), exchangeable bases (Ca, Mg and K), Sulfate – S and exchangeable Zn.

Particle size distribution was determined by hydrometer method after dispersing the soil sample with sodium hexametaphosphate solution. The texture class was determined using USDA textural triangle (FAO, 1984). Soil pH was determined in water at a soil ratio 1:2.5 using a pH meter as described by Motsara and Roy (2008). Organic carbon content in the soil was determined by the wet oxidation method of Walkley and Black as described by Nelson and Sommers (1982). Total N was determined by micro – Kjeldahl digestion followed by the distillation and titration as described by Bremmer and Mulvaney (1982). P was extracted by Bray – I method, and P concentration in the soil was determined using the method described Motsara and Roy (2008). Cation exchange capacity (CEC) was determined by the ammonium acetate saturation method. After extracting Ca, Mg and K with 1M ammonium acetate (pH7), exchangeable bases Ca and Mg were determined from ammonium acetate leachate by atomic absorption spectrophotometer while exchangeable K was determined by using flame spectrophotometer. The sulfur content in soil was determined by colorimetric method and the quantity determined using spectrophotometer at 535nm as described by Motsara and Roy (2008). Exchangeable Zn was determined by extraction with 0.005M DTPA (diethylene triamine penta-acetic acid) and quantified using atomic absorption spectrophotometer as described by Motsara and Roy (2008).

3.4 Field Experiments

Field experiments were conducted at Mlandizi and Kitomondo villages to study the response of lowland rice varieties to nitrogen, phosphorus, potassium and zinc in two soil types in Kibaha. The experiments were set up as split-plot design. The main plot factor was three rice varieties namely SARO5, NERICA and SUPA while the sub-plots were four nutrient treatments namely N, P, K and Zn. Nitrogen and P were tested at four levels namely 0, 75, 100 and 150 kg N/ha and 0, 20, 30, and 40 kgP/ha, respectively; two levels for potassium (0 and 100 kg K/ha) and zinc (0 and10 kg Zn/ha), giving a combination of nutrients and levels as shown in Table 1.

Table 1: Type of different nutrient elements applied to the experimental plots

S/N°	Treatment	Treatment description
1	T1	Control
2	T2	$N_{100} + P_0 + K_0 + Zn_0$
3	T3	$N_0 + P_{30} + K_0 + Zn_0$
4	T4	$N_{75} + P_{20} + K_0 + Zn_0$
5	T5	$N_{100} + P_{40} + K_0 + Zn_0$
6	T6	$N_{150} + P_{40} + K_{100} + Zn_0$
7	T7	$N_{150} + P_{40} + K_{100} + Zn_{10}$

NB: Subscript numbers on nutrient symbols represent the amount of nutrient applied in kilogram per hector.

The subplot area was 3m x 5m = $15m^2$ while the main plot area was 24m x 18m = $432m^2$, with inter – block and inter – plot spacing of 1 and 0.5m, respectively. This formed a total experimental area of $1,302m^2$.

3.5 Crop Husbandry Practices

3.5.1 Land preparation

Ploughing and harrowing was done manually by a hand hoe and the leveling was done manually using hand hoes. Then plots were demarcated according to the experimental design described above.

3.5.2 Sowing

Direct seeding of lowland rice was done at a spacing of 20 cm by 20 cm, three seeds were sown per hill on 20th February 2012 and thinning was done two weeks after emergence in order to keep two seedlings per hill.

3.5.3 Fertilizer application

Prior to seeding, basal application of 0, 20,30, and 40 kg P/ha as Triple super phosphate (TSP) equivalent to 0 g, 30g, 45g, and 60g phosphate plot^{-1} applied by broadcasting uniformly to the plots while same plots received amount of100 kg K/ha equivalent to 0.15g potassium plot^{-1} and 10g of Zinc sulphate ($ZnS0_4$) equivalent to 66g Zinc plot-$_1$. Nitrogen in the form of Urea (46% N) at a rate of 0, 75, 100 and 150kgN/ha equivalent to 0g, 245g, 330g and 489g urea plot^{-1} respectively was measured using electronic measuring balance and applied into two splits as follows:- one split applied 21 days after sowing ie (0g, 122.5g, 165g and 244.5gN plot^{-1}) and the second split (0g, 122.5g, 165gp and 244.5gN plot^{-1}) was applied at panicle initiation stage (42 – 45 days after sowing).

3.5.4 Cultural practices

Bird and weed damage to seedlings and established crop were kept to minimum throughout the growing season. Frequent weeding was done to keep the experimental plots weed free during the entire cropping period. All weeding regimes were done by hand. First weeding was done on 9th March 2012 while the second weeding was done on 1st May 2012. The common weeds were wild rice (Oryza spp) and Cyperus spp.

3.6 Data Collection

3.6.1 Weather conditions

Rainfall data were collected from the nearby station at Kibaha Agrovet during the research period from Sept 2011 to July 2012 as shown in appendix 1. The meteorological data were recorded on a daily basis then averaged on monthly basis. The minimum and maximum temperature were also recorded in each site respectively.

3.6.2 Growth parameters

3.6.2.1 Plant height

At physiological maturity, ten randomly selected plants from each plot were measured from the ground surface to the tip of longest panicle by using measuring ruler and the mean plant height computed and recorded in centimeters (cm).

3.6.2.2 Days to 50% heading

Days to 50% heading were recorded by counting the number of days from sowing to when 50% of the plants in each plot had flowered. Average was computed for three replicates

3.6.2.3 Harvest index (HI)

The harvest index in percentage was determined by dividing the grain yield (Economic yield) over Total dry mass (TDM) yield (Biomass yield) multiplied by one hundred for each plot to obtain harvest index in percentage.

HI (%) = (Grain yield per meter square/Total dry mass yield per meter square) x 100.

3.6.3 Yield parameters

3.6.3.1 Number of panicles per meter square

Number of panicles per square meter was counted after harvesting the one meter quadrant from each plot and the total number of panicles for each subplot recorded.

3.6.3.2 Panicle length

Ten panicles were randomly selected to measure panicle length. The panicle lengths were measured using measuring ruler from the panicle neck to the tip and the mean computed and recorded in (cm).

3.6.3.3 Total dry matter

At harvest time, ten plants were randomly selected from inner plots and the above ground biomass was determined. Total dry matter (TDM) was determined as described by Roy *et al.* (2006). Plants after sampling were sun - dried. The total plant dry weight was taken using an electronic balance. The total weight was divided by the number of 10 plants to obtain dry weight per plant.

3.6.3.4 Grain yield

This was determined for grains from one square meter harvested area of each plot excluded border rows, which was threshed, winnowed, and sun dried to 14% moisture content and weighed in grams. Moisture meter device was used to determine grain moisture content by squeezing grain after drying to constant moisture and then the yield obtained was converted to t/ha.

3.7 Data analysis

The data collected were subjected to analysis of variance (ANOVA) using GenStat (14th Edition) computer program. Mean separation was performed using LSD and Tukey's test at 95% confidence interval. The statistical model for split-plot design is as follows:

$$Y_{ijk} = \mu + \beta_i + A_j + \delta_{ij} + B_k + AB_{ik} + \varepsilon_{ijk} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where: Y_{ijk}= Response level, μ = General effect or general error mean, β_i = Block effect, A_j = Main plot effect, δ_{ij} = The main plot random error (Error a), B_k = Sub-plot effect, AB_{ik}= Interaction effect between the main plot and the subplot and ε_{ijk}= random error effect (Error c).

The comparison of means for the significant treatments were subjected to Turkey's (HSD) test for comparison at $P \leq 0.05$. Relationship between yield and yield components were determined by calculating partial correlation coefficients.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 General Observations

During the growing season weeds (wild rice and cyperus) and birds were recorded at both sites. The weeding regimes were done by hands while the birds were controlled by bird scaring using toys. At both sites birds affected SUPA variety more severely than the other two rice varieties (SARO5 and NERICA4).

4.2 Weather Characteristics during Growing Season

The weather characteristics recorded during season was 687.9 mm rainfall for Mlandizi and Kitomondo sites respectively as shown in Appendix 1. The minimum (min) temperature ranged from 15.0 to 18.6^{0}C for Mlandizi and Kitomondo while the maximum (max) ranged from 21.4 to 26.2^{0}C Mlandizi and Kitomondo sites respectively. The mean temperatures during growing season were 18.3 and 23.6^{0}C for Mlandizi and Kitomondo sites respectively. The average rainfall and temperature recorded were satisfactory for rice production because the optimum rice yield in the study areas requires an average rainfall ranging from 600 – 1,000mm and the temperature ranging from 18–30^{0}C (Kibaha Agrovet, 2012).

4.3 Physical and chemical Properties of Selected Soils in Rice Growing Areas

The physical and chemical properties of soils in selected rice growing areas of Kibaha District are presented in Table 2.

Table 2: Physical and chemical properties of soils in the rice growing areas of Kibaha District

VILLAGE	PSD (%)			Texture	pH	Total N (%)	Ext P (mg/kg)	Exchangeable bases (cmol (+)/ kg soil)			SO4 (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
	Clay	Silt	Sand					Mg^{2+}	K^+	Na^+			
KITOMONDO	73	11	16	C	6.14	0.15	1.67	13.2	0.66	1.1	13.14	2.61	0.46
MINAZI MIKINDA 'A'	55	19	26	C	6.0	0.15	18.26	9.33	0.61	0.62	8.76	4.86	1.77
MINAZI MIKINDA 'B'	55	13	32	C	5.91	0.17	34.99	9.38	0.84	0.47	15.5	5.32	2.88
MWANABWITO	53	7	40	C	6.03	0.20	29.54	10.68	0.71	1.07	4.38	3.45	3.5
KIDAI-1	41	7	52	SC	5.49	0.21	43.06	7.84	0.43	0.81	19.21	2.99	2.32
KIDAI-2	23	7	70	SCL	5.97	0.16	7.38	3.32	0.14	0.89	7.75	1.11	0.46
MLANDIZI'B'	43	9	48	SC	6.06	0.16	22.99	7.58	0.55	0.69	16.85	3.31	3.28
MLANDIZI B-2	23	7	70	SCL	6.18	0.16	0.7	4.01	0.22	0.49	4.72	1.11	0.59
MLANDIZI B-3	23	1	76	SCL	7.62	0.11	5.57	0.13	0.14	0.2	10.11	0.04	0.17
MLANDIZI B-4	41	7	52	SC	7.7	0.12	2.09	6.79	0.2	0.68	19.55	0.79	0.08
MLANDIZI B-5	35	3	62	SC	6.49	0.11	0.84	3.48	0.22	0.69	16.85	0.65	0.15
MLANDIZI B-6	25	5	70	SCL	5.25	0.12	0.7	2.48	0.15	0.35	33.7	1.25	0.61
VIKURUTI	73	13	14	C	5.31	0.21	9.76	13.6	0.58	1.1	13.82	3.64	1.83
MLANDIZI	23	3	74	SCL	5.13	0.11	0.56	1.72	0.23	0.64	11.46	0.65	0.10
MADEGE A	57	15	28	C	5.78	0.14	12.12	10.11	0.77	1.43	9.1	3.08	0.75
MADEGE B	31	7	62	SCL	5.93	0.11	40.69	4.82	0.31	0.53	10.78	2.19	1.01
DUTUMI	73	9	18	C	5.61	0.21	36.51	9.43	0.82	0.42	12.47	5.28	2.17
MWEMBENGOZI	53	23	24	C	5.85	0.14	11.15	14.99	0.68	1.29	11.8	2.89	0.41

4.3.1 Soil texture

The textural class of soils in rice growing areas of Kibaha District vary from clay soils, sand clay soils and sand clay loamy soils (Table 2). The data on Table 1 show that eight out of the eighteen tested soils were heavy Clay soil. Four tested soils were Sandy Clay while the remaining six soils were medium textured soil (Sandy Clay Loam). Optimum rice production requires soils of medium to heavy texture. Clay soils have high moisture and ion retention capacity. These soils are suitable for lowland rice ecosystem and are good for making bands like structure for water storage used when rice is growing in flooding conditions.

4.3.2 Soil pH

The soil pH of rice growing areas in Kibaha District is in the range of 5.1 to 7.7. Soils with pH ranges 5.1 – 5.5 are strongly acid, 5.6 – 6.0 medium acid, 6.1 – 6.5 slightly acid, 6.6 – 7.3 neutral and 7.4 – 7.8 mildly alkaline according to Landon (1991). Therefore, soil reactions in rice growing areas of Kibaha District are ranging from acidic to alkalinity soils. Sixteen soils out of eighteen soils were of low to medium pH range (< 7.0), while two soils had high pH range (>7.0). Landon (1991) suggests that the pH for rice production to be 5.5 and 6.5 when dry and that this may rise to 7.0 to 7.2 when flooded. However it was reported that for those soils which have low soil pH (< 5.5) phosphate ions compounds are not readily available to plant. At high pH levels (7.0 – 8.5) P availability is also reduced because P tends to be converted to Calcium phosphate (Landon, 1991).

4.3.3 Total nitrogen in the soil

Total nitrogen is between 0.11 and 0.21%. Soils with total nitrogen 0.10- 0.20% have low N content while 0.21 – 0.50% have medium N content (Landon, 1991). Hence, most of soils in Kibaha rice growing areas have low N content while very few areas have low to medium nitrogen. Therefore, nitrogen fertilizer applications are very important in these areas in order to increase lowland rice productivity.

4.3.4 Extractable phosphorus

Extractable phosphorus is between 0.56 to 43 mg/kg. According to the ratings by Landon (1991), soils vary in phosphorus content, some rice growing areas have very low P, some have medium and few have high P content in the soils. Depending on soil type and varieties, medium to high P content in the soil is important for rice production (Yoshida, 1981). Therefore, application of phosphate fertilizers would increase lowland rice production in areas with very low, low and medium soil P content with the following percentages:- 44% for very low, 17% for low and 11% for medium respectively.

4.3.5 Exchangeable bases

Exchangeable bases included potassium (K), magnesium (Mg) and sodium (Na). Exchangeable K in rice growing soils at Kibaha District differed from one lowland rice growing area to another. Basing on Landon (1991) ratings, some few rice soils have very low exchangeable K, while some other have low to medium exchangeable K content. Hence, in all rice growing soils with very low to low exchangeable K it is necessary to apply potassium fertilizers to increase rice productivity. Exchangeable Mg also varied from one rice growing area to another. According to Landon (1991), rice-growing areas in Kibaha District ranged from very low to very high exchangeable Mg. Most areas have soils rich in magnesium content. Exchangeable Na in Kibaha rice growing soils was varying from one growing area to another. According to Landon (1991), few areas have soils with low Na while most of soils are rich in Na content. Therefore, rice growing areas in Kibaha District have soils which are good in cation exchange capacity.

4.3.6 Sulphur content in the soil

Sulphur levels in soils range between 4.38 to 33.7 mg/kg. Atlas Interlates (1989) rates Sulphur> 10mg/kg high, 6.1 – 10mg/kg moderate, 3.1 – 6.0mg/kg low while < 3.0mg/kg very low. Hence thirteen soils showed high rate of Sulphur, three soils showed moderate rate of sulphur while two soils showed low rate of sulphur. Therefore, the soils with low sulphur content would respond well to addition of S fertilizers and improve rice productivity.

4.3.7 Micronutrients in the soil

The micronutrients in rice growing areas of Kibaha District vary from one place to another as shown in Table 2. According to Lindsay and Norvell (1978) rated zinc levels < 0.8 low, 0.8-2.0 medium and > 2.0 high while copper levels< 0.2 = low, 0.2 – 1.0= medium and > 1.0 = high. Zinc in almost all lowland rice growing areas in Kibaha is low while copper is high. This implies that application of Zn in these areas is very important in order to improve rice production.

4.4 Response of Rice Varieties and Nutrient Treatments on Yield and Various Growth Stages

4.4.1 Plant Height

Analysis of variance showed no significant difference ($P \leq 0.001$) for plant height among the tested rice varieties at Mlandizi and Kitomondo as shown in Table 3 and 4. The plant height at Mlandizi had a range of 86.2 cm (NERICA) to 125.2 cm (SUPA) with mean of 101.7 cm while at Kitomondo ranged from 86.5 cm (NERICA) to 124.7 cm (SUPA) with mean of 101.7 cm. In all the two sites the highest plant height was observed from SUPA followed by SARO5 and NERICA as the variety having the shortest plant height.

No significant difference ($P \leq 0.05$) in plant height among the tested fertilizer rates was observed at Mlandizi and Kitomondo. This explains that the addition of fertilizer to the soils of these areas has no effect on rice height. The plant height mean at Mlandizi and Kitomondo did not differ both had a plant height mean of 101.7 cm. The highest plant heights were found in N150P40K100 followed by N150P40 and the lowest plant height was found in the control at both sites. Several studies have shown that application of fertilizers to rice leads to increase in plant height; (Balasubramaniam, 2002; Walter *et al*., 2008).

4.4.2 Tiller Number

Analysis of variance showed no significant difference ($P \leq 0.05$) for rice tiller number among the tested rice varieties at Mlandizi and Kitomondo as shown in Table 3 and 4. Rice tiller number at Mlandizi had a range of 10.1 (SARO5) to 11.1 (SUPA) with mean of 10.7 while at Kitomondo ranged from 10.5 (SARO) to 11.9 (SUPA) with mean of 11.1. In all the two sites the longest panicle was observed from SUPA followed by NERICA and SARO5 as the variety having the shortest panicle in both sites.

Analysis of variance showed highly significance ($P \leq 0.001$) increase in number of tillers followed the application of nutrient elements N, P, K and Zn. At Mlandizi and Kitomondo the application of N150P40K100 demonstrated high number of tillers while the lowest number of tillers was observed from the control in both sites. Therefore the application of nutrient elements particularly N150P40K100 is useful in rice as it increases the number of tillers almost twice the control. Number of tillers is direct proportion to rice yield, therefore the higher the number of tillers the higher the rice yield. This result is in agreement with results reported by Baker *et al.* (2007).

Table 3: Effect of varieties on performance of rice grown in Mlandizi Village.

Variety	Response variables							
	Plant height	Tiller Number	Panicle Number	Panicle length	50% flowering	TDM	Yield (t/ha)	HI
SARO5	93.6a	10.1a	10.9a	20.17a	99a	11.81c	5.7b	0.48a
NERICA	86.2a	10.9a	9.9a	22.48b	100a	6.60b	2.7a	0.43a
SUPA	125.2a	11.1a	9.8a	24.59c	124b	4.66a	1.9a	0.42b
GM	101.67	10.7	10.2	22.41	107.67	7.69	3.43	0.44
CV (%)	8.4	25.2	21	9.9	1.9	28.7	29.6	16.2
$N_{150}P_{40}K_{100}Zn_{10}$	96.0a	9.3ab	8.3a	21.74a	107a	8.1a	3.4a	0.43a
N_{100}	100.2a	11.3bc	10.1ab	21.93a	108a	7.1a	3.3a	0.47a
$N_{75}P_{20}$	103.7a	10.2abc	9.5a	21.72a	108a	8.6a	3.9a	0.44a
$N_0P_0K_0Zn_0$	99.9a	7.4a	9.5a	22.14a	107a	6.9a	3.1a	0.41a
$N_{150}P_{40}$	104.8a	11.0bc	10.4ab	22.70a	106a	7.1a	3.3a	0.44a
P_{30}	101.6a	12.7c	12.2c	23.69a	108a	7.4a	3.6a	0.45a
$N_{150}P_{40}K_{100}$	105.8a	12.8c	12.6c	22.97a	108a	8.5a	3.7a	0.46a
GM	102.67	10.9	10.37	22.40	107	7.6	3.5	0.44
CV (%)	19.7	19.9	16.6	13.0	11.7	51.0	59.5	17.4

Key: TDM= total dry matter; HI= Harvest index. *Means in the same column bearing different letter(s) differ significantly at 5% level of probability based on Tukey's $P< 0.05$ confidence intervals.*

4.4.3 Panicle Number

Analysis of variance showed that there was no significance variance ($P \leq 0.001$) in panicle number among rice varieties at Mlandizi (Table 3). Panicle number at Mlandizi ranged from 9.8 (SUPA) to 10.9 (SARO) with the mean of 10.2, while at Kitomondo no significance variance ($P \leq 0.05$) on panicle number was observed and the panicle number ranged from 9.3 (SUPA) to 11.3 (SARO) with the mean of 10.1 (Table 4). SARO5 demonstrated the highest number of panicles at both sites followed by NERICA and SUPA having fewer numbers of panicles.

Analysis of variance showed highly significance ($P \leq 0.001$) increase in number of panicles followed the application of nutrient elements N, P, K and Zn. At Mlandizi the application of N150P40K100 demonstrated high number of panicles while the lowest number of panicles was observed from the control. At Kitomondo the application of N150P40K100 demonstrated high number of panicles while the lowest number of panicles was observed from the control. Therefore the application of nutrient treatments particularly N150P40K100 is useful in rice as it increases the number of panicles almost twice the control. In this study a variety with the highest number of panicles also had higher yield compared to a variety with low panicle number. Therefore panicle number can be used to select varieties with high yield. This study supported the previous study on number of rice panicle increase as a result of fertilizer application (Baker *et al.*, 2007).

Table 4: Effect of varieties on mean performance of rice grown in Kitomondo Village.

Variety	Response variables							
	Plant height	Tiller Number	Panicle Number	Panicle length	50% flowering	TDM	Yield (t/ha)	HI
SARO5	93.9b	10.5a	11.3a	20.23a	99a	11.8a	5.7b	0.48a
NERICA	86.5a	10.9a	9.8a	22.50b	100a	6.6a	2.7a	0.43a
SUPA	124.7c	11.9a	9.3a	24.58c	124b	4.7a	1.9a	0.42a
GM	101.7	11.1	10.1	22.43	107	9.5	3.4	0.44
CV (%)	9.1	25.3	23.0	10.0	2.2	28.7	3.6	20.0
$N_{150}P_{40}K_{100}Zn_{10}$	100.5a	13.6gh	12.3h	24.72a	109.1a	7.9a	4.05a	0.52e
N_{100}	100.2a	10.78bd	9.6de	21.28a	109.6a	8.4a	4.21a	0.49e
$N_{75}P_{20}$	98.0a	9.4b	8.3ac	21.00a	107.4a	6.5a	3.00a	0.47cd
$N_0P_0K_0Zn_0$	96.3a	6.7a	6.8a	22.76a	104.2a	6.4a	2.05a	0.32a
$N_{150}P_{40}$	101.1a	12.2efh	11.1fg	21.30a	108.0a	9.6a	3.83a	0.39ab
P_{30}	100.2a	11.4bdf	10.3deg	22.06a	108.3a	6.8a	3.07a	0.45cd
$N_{150}P_{40}K_{100}$	115.6a	13.9h	12.5h	23.93a	107.2a	8.a	3.93a	0.46cd
GM	101.7	11.1	10.1	22.43	107.7	7.6	3.4	0.44
CV (%)	18.9	14.6	15.6	11.8	11.7	9.4	7.4	15.6

Key: TDM= total dry matter; HI= Harvest index. *The means along the same column bearing different letter(s) differ significantly at 5% level of probability based on Tukey's P< 0.05 confidence intervals*

4.4.4 Panicle length

Analysis of variance showed significant difference ($P \leq 0.001$) for rice panicle length among the tested rice varieties at Mlandizi and Kitomondo as shown in Table 3 and 4 . The rice panicle length at Mlandizi had a range of 20.17 cm (SARO5) to 24.59 cm (SUPA) with mean of 22.41 cm while at Kitomondo ranged from 20.23 cm (SARO5) to 24.58 cm (SUPA) with mean of 22.43 cm. In all the two sites the longest panicle was observed from SUPA followed by NERICA and SARO5 as the variety having the shortest panicle.

No significant difference ($P \leq 0.05$) in panicle length among the tested fertilizer rates was observed at Mlandizi and Kitomondo. This explains that the addition of fertilizer has no effect on the panicle length.

4.4.5 Days to 50% Flowering

Analysis of variance showed significant difference ($P \leq 0.001$) in Days to 50% flowering in both locations among rice varieties with a range of 99 to 124 with a mean of 108. The shortest days to 50% flowering among the three tested varieties in both locations was observed to be 99 days in SARO5 followed by NERICA which reached 50% flowering at 100 days after planting while SUPA took 124 days to attain 50 % flowering and scored as the latest variety to reach 50 % flowering among the tested varieties.

No significant difference in fertilizer effect ($P \leq 0.05$) in 50 % flowering of rice was observed in this study among the tested fertilizer rates at Mlandizi and Kitomondo (Table 3 and 4). This explains that flowering in rice does not depend on the amount of fertilizer applied but it mostly dependent on the rice variety used.

4.4.6 Total Dry Matter (TDM)

Analysis of variance showed highly significant difference ($P \leq 0.001$) in TDM in both locations among rice varieties with a range of 4.66 to 11.81 with a mean of 7.69. There was no mean different in TDM between the two sites. The highest TDM in both sites was observed in SARO5 followed by NERICA and SUPA had the smallest TDM.

No significant difference in fertilizer effect ($P \leq 0.05$) in TDM in both locations. Total dry matter is much influenced by the variety of rice used. Results from this study are in contrast with previous studies which showed significant increase in TDM as a result of fertilizer application (Li et al., 2010)

4.4.7 Grain Yield

Analysis of variance showed very highly significant difference ($P \leq 0.001$) for rice yield/hectare among the tested rice varieties at Mlandizi and Kitomondo. The average total yields ranged from 1.9 (SUPA) to 5.7 (SARO5) for Mlandizi and Kitomondo sites respectively as indicated in Table 3 and Table 4. In both sites the highest yielding variety was SARO5 followed by NERICA and SUPA as the least performing variety. SARO5 demonstrated almost twice the yield of NERICA and three times the yield of SUPA in both sites. This shows that the variety has the best performance and will give high returns to farmers as compared to NERICA and SUPA. Similar results were reported by Kamara et al. (2011) that increased in fertilizer rates increased in rice yield.

No significant fertilizer effect ($P \leq 0.05$) on yield of rice was observed in this study among the tested nutrients at Mlandizi and Kitomondo as shown in Tables 3 and 4. These results were not expected since the soil deficiency was corrected by applying nutrient elements. Probably some other factor might have affected the grain yield, hence the interaction of variety and nutrient levels should be examined further to identify if there was another limiting factor.

4.4.8 Harvest Index (HI)

Analysis of variance showed that there was significant difference ($P \leq 0.05$) in harvest index among genotypes at Mlandizi and Kitomondo as shown in Table 3. The HI was not significant at Kitomondo (Table 4). The harvest index at Mlandizi and Kitomondo ranged from 0.42 (SUPA) to 0.48 (SARO5) with the mean of 0.44. Among the tested varieties SARO5 had the highest HI Harvest index implies the relative distribution of photosynthesis products between economical sinks and other existing sinks in the plant. Therefore the higher the HI the more the variety distribution of photosynthesis products to economical sinks and hence more yield.

There is highly significance different ($P \leq 0.001$) in HI among the tested rates of fertilizers at Mlandizi and Kitomondo (Table3 & 4). The mean HI at Mlandizi and Kitomondo were the same, which is 0.44. The highest HI at Mlandizi was observed from N100 which had 0.47 followed by N150P40K100 which had 0.46 while at Kitomondo was observed from N150P40K100Zn10 which had 0.52 followed by N100 which had 0.49 and the control was observed to have the lowest. The results reported in this study are in agreement to those reported by Fageria (2010) that increase in fertilizers increase the harvest index in rice.

Table 5: Effects of interaction of nutrients and Varieties on performance of rice grown in Mlandizi Village.

Varieties	Fertilizers	Response variables							
		Plant height	Tiller Number	Panicle Number	Panicle length	50% flowering	TDM	Yield (t/ha)	HI
SARO5	N150P40K100Zn10	82.5a	6.67ab	7.8ab	18.8a	100.0a	11.2abdf	4.8abdf	0.44a
	N100	94.1ab	9.6abd	9.6abd	20.3abdf	100.3a	11.6cdfef	5.5cf	0.47a
	N75P20	93.8a	9.0abd	8.9abd	20.1abd	100.0a	13.4ab	6.9g	0.52a
	N0P0K0Zn0	92.0ab	9.0abd	8.9abd	19.4ab	98.3a	10.8abdf	5.1cdf	0.45a
	N150P40	97.1abd	10.7abd	10.1abdf	20.5abdf	99.0a	11.0abdf	5.5cf	0.48a
	P30	98.5ab	13.0cd	13.3cf	21.3abdfhj	98.3a	14.0g	6.2g	0.45a
	N150P40K100	97.5abd	12.3abd	12.6cf	20.9abdfhjln	99.0a	10.8abdf	6.2g	0.55a
NERICA	N150P40K100Zn10	83.1a	6.0a	7.0a	19.6ab	99.3a	8.7abdf	3.6abdf	0.43a
	N100	85.5a	12.0abd	10.7abdf	22.5abdfhjl	100.7a	5.6ab	2.6abd	0.46a
	N75P20	83.9a	10.0abd	9.3abd	20.7abdfh	98.7a	7.6abdf	2.6abd	0.37a
	N0P0K0Zn0	84.8a	9.0abd	10.0abdf	21.1abdfhj	100.3a	5.8ab	2.3abd	0.41a
	N150P40	86.1a	11.7abd	12.0cdf	22.0abdfhjl	98.3a	5.6ab	2.3abd	0.41a
	P30	90.6ab	14.0e	14.3g	26.2kl	101.7a	6.7abdf	2.7abd	0.44a
	N150P40K100	89.3a	13.3c	13.3cf	25.2cfhjl	99.7a	6.3abd	2.5abd	0.42a
SUPA	N150P40K100Zn10	122.3cf	9.7abd	10.0abdf	26.80m	125.0b	4.9ab	1.7a	0.35a
	N100	120.9cf	12.3abd	10.0abdf	23.0abdfhjl	126.3b	4.2a	2.0ab	0.48a
	N75P20	133.3g	11.7abd	10.3abdf	24.3cdfhjl	123.33b	4.9ab	2.1ab	0.43a
	N0P0K0Zn0	122.8cf	10.0abd	9.7abd	25.97ijl	122.0b	4.2ab	1.7ab	0.43a
	N150P40	131.1g	10.7abd	9.0abd	25.6ghjl	124.0b	4.79ab	1.99ab	0.4a
	P30	115.6c	11.3abd	10.0abdf	23.6abdfhjl	125.3b	4.8ab	2.2abd	0.5a
	N150P40K100	130.6g	12.3abd	10.7abdf	22.8abdfhjl	122.0b	4.83ab	2.0ab	0.42a
CV (5%)		8.2	19.8	13.9	7.8	1.9	30.9	31.4	17
	Var. (V)	5.2	1.3	7.8	1.1	1.3	1.5	0.7	0.05
	V× F	13.82	3.5	1.37	2.89	3.36	3.92	1.79	0.124

Key: TDM= total dry matter; HI= Harvest index. *The means along the same column bearing different letter(s) differ significantly at 5% level of probability based on Tukey's 95% confidence intervals.*

Table 6: Effect of Fertilizers and Varieties interaction on mean performance of rice grown in Kitomondo Village.

Varieties	Fertilizers	Response variables							
		Plant height	Tiller Number	Panicle Number	Panicle Length	50% flowering	TDM	Yield (t/ha)	HI
SARO5	N150P40K100Zn10	99.0L	12.67hikm	10.81degik	21.18aceg	99.00ace	14.03jk	7.197k	0.513fgi
	N100	94.4hik	10.33acegikl	8.87aceg	20.53ac	103.67h	11.55fgik	6.700ij	0.5800j
	N75P20	91.8fgi	8.67aceg	7.31ac	19.06a	98.00ace	9.40degik	4.390ef	0.466acegi
	N0P0K0Zn0	83.3a	7.00ace	6.14a	19.05a	95.67a	8.18aceg	2.633ab	0.3233ac
	N150P40	97.0jk	11.33fgikm	10.33degi	19.58ac	99.00ace	14.55L	6.833ij	0.4800acegi
	P30	93.4hik	10.00acegik	8.60aceg	20.32ac	101.33fg	11.42fgik	5.267gh	0.4633acegi
	N150P40K100	98.5L	13.67Lm	12.75jk	20.88 ace	98.33ace	13.53hik	7.163k	0.5333hi
NERICA	N150P40K100Zn10	90.0deg	14.67n	14.00L	26.08lmp	103.33h	5.25ac	2.887abd	0.5533hi
	N100	85.7ace	11.00degikl	11.00 fgik	22.28degi	101.67fg	9.06acegi	3.833cdf	0.4400acegi
	N75P20	84.6ac	9.00acegi	10.33 degi	20.19ac	99.67aceg	5.45ac	2.513ab	0.4667acegi
	N0P0K0Zn0	83.0a	6.67ac	8.33ace	20.28ac	97.00ac	5.53ac	1.840a	0.3333ace
	N150P40	86.1ace	11.67hikm	11.67fgik	22.01degi	100.00deg	8.80acegi	2.597ab	0.3067a
	P30	85.7ace	10.00acegik	10.33 degi	21.76aceg	98.67ace	5.24ac	2.270ab	0.4467acegi
	N150P40K100	90.4deg	13.67Lm	13.67 jk	24.87 jkm	98.33ace	6.90ace	2.680ab	0.3933aceg
SUPA	N150P40K100Zn10	112.5n	13.33jkm	12.00hik	26.90no	125.00L	4.23ac	2.063a	0.4933deik
	N100	120.4p	11.00 degikl	9.00aceg	21.02ace	123.33jk	4.66ac	2.087a	0.4600acegi
	N75P20	117.6no	10.67acegikl	7.33ac	23.74fgik	124.67L	4.54ac	2.103a	0.4633acegi
	N0P0K0Zn0	122.4p	6.33a	6.00a	28.96p	120.00j	5.45ac	1.687a	0.3100ac
	N150P40	120.2p	13.67Lm	11.33 fgik	21.29aceg	125.00L	5.46ac	2.050a	0.3767aceg
	P30	121.4p	14.33 Lm	12.00hik	24.10hikm	125.00L	3.75a	1.663a	0.4467acegi
	N150P40K100	158.0p	14.33 Lm	11.00 fgik	26.03Lm	125.00L	4.51ac	1.960a	0.4400acegi
CV (5%)		2.1	12.8	11.2	4.2	1.2	22.6	15.8	13.4
	Var. (V)	1.315	0.886	0.709	0.585	0.837	1.086	0.3409	0.03691
	V× F	3.479	2.345	1.876	1.547	2.213	2.872	0.9019	0.09767

Key: TDM= total dry matter; HI= Harvest index. *The means along the same column bearing different letter(s) differ significantly at 5% level of probability based on Tukey's 95% confidence intervals.*

Significant rice variety by fertilizer interaction at Mlandizi was observed from panicle number and panicle length while no significant variety by fertilizer rates interaction ($P \leq 0.05$) was obtained from the other parameters (Table 5).

Significant rice variety by fertilizer rates interaction ($P \leq 0.05$) at Kitomondo was observed from plant height, panicle number, panicle length, 50% flowering, TDM and yield while no significance variety by fertilizer rates interaction ($P \leq 0.05$) was obtained from number of tillers and HI (Table 6). Due to variety by fertilizer interaction the performance of varieties in terms of yield were increased differently, that is the rate of fertilizer which resulted to high yield in SARO5 could not necessarily be the same for NERICA and SUPA. The highest yield in SARO5 was recorded from N150P40K100Zn10 (7.20 t/ha) followed by N150P40K100 (7.16 t/ha) and N150P40 (6.833 t/ha), for NERICA the highest yield was recorded from N100 (3.83 t/ha) followed by N150P40K100Zn10 (2.89 t/ha) and N150P40K100 (2.68 t/ha). For SUPA the highest yield was observed from N75P20 (2.10 t/ha) followed by N100 (2.09 t/ha) and N150P40K100Zn10 (2.06 t/ha). Generally the application of N150P40K100Zn10 in all the varieties used demonstrated high yield, therefore for high yield in Kibaha district it is better to apply N150P40K100Zn10. The observation showed that there was a high performance of yield in SARO5, limited in NERICA and poor performance in SUPA variety. This trend is thought to be due to moisture stress. SARO5 reached 50% flowering earlier followed by NERICA and SUPA variety flowered late when moisture stress had already set in (Appendix 1) hence grains were not well filled which resulted to low yield. Rainfall distribution showed that the rain stopped by end of May (Appendix 1), hence SUPA variety performed poorly because it took 124days to reach 50% flowering. The results indicate that moisture stress was the limiting factor for yield to SUPA and less in NERICA. Therefore, it can be concluded that moisture condition is very important for rice production.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The results of the experiment revealed that soils in rice growing areas of Kibaha district are characterized by clay, sandy clay and sandy clay loam. Soil pH ranged from acidic to mild alkaline. Optimum rice production requires soils of medium to heavy texture.

Therefore, it is concluded that clay soils are suitable for lowland rice ecosystem because they have high moisture and ion retention capacity.

Soil analysis revealed that nitrogen, phosphorus and zinc were the major soil fertility constraints in rice growing areas in Kibaha district.

Application of N, P, K and Zn ($N_{150}P_{40}K_{100}Zn_{10}$) was necessary in order to achieve high yields of rice.

Of the varieties tested SARO5 was the best performer. Therefore farmers should be advised to plant SARO5 for high yield

5.2 Recommendations

From the findings the following are recommended

i. Fertilizer level of $N_{150}P_{40}K_{100}Zn_{10}$ in Kibaha District should be adopted to achieve high rice yield

ii Short to medium maturing varieties are recommended in lowland rice ecosystem in all areas experiencing short rains. Therefore SARO5 and NEREICA are highly recommended currently due to climate changes.

iii Fertilizer manufacturers should be advised to include Zinc in rice fertilizers.

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APPENDICES

Appendix 1: Monthly weather data for 2011 and 2012 growing season

Year	**Month**		**Weather characteristics**					
			Mlandizi			**Kitomondo**		
		Rainfall (mm)	Temp. (°C) Min	Temp. (°C)Max	Average Temp (°C)	Temp. (°C) Min	Temp. (°C) Max	Average Temp(°C)
2011	September	NIL	15	20.2	17.60	18.6	24	21.30
	October	NIL	15.5	20.4	17.95	19	25.1	22.05
	November	NIL	15.7	20.3	18.00	19.5	25	22.25
	December	107	15.2	20.6	17.90	19.3	25.4	22.35
	Sub total (mm)	**113**						
2012	January	18	16.4	20.3	18.35	20.2	25	22.60
	February	25.6	16.9	21.4	19.15	23.6	26.2	24.90
	March	187.7	16.5	21.2	18.85	23	26	24.50
	April	235.8	16	20.9	18.45	22.4	25	23.70
	May	100.4	16.2	20.5	18.35	22.8	25.2	24.00
	June	7.4	16	20.1	18.05	22.6	25.2	23.90
	July	0	15.8	20.7	18.25	22.9	25	23.95
	Sub total (mm)	**574.9**						
	Grand total (mm)	**687.9**						

Source: Kibaha Agrovet, 2012

Appendix 2: Guide to general evaluation of some soil chemical and physical properties

(Source: Baize (1993), ILACO (1991), Hazelton and Murphy (2007) and Landon (1991)

1 Organic matter and total nitrogen

	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 carbon %	<0.60	0.60-1.25	1.26-2.50	2.51-3.50	>3.50
Total nitrogen %	<0.10	0.10-0.20	0.21-0.50	>0.50	

C/N ratios give an indication of the quality of the organic matter:

C/N ratio 8-13: good quality

C/N ratio 14-20: moderate quality

C/N ratio >20: poor quality

2 Soil reaction

Soil reaction (pH H_2O) is classified as follows

Extremely acid	pH < 4.5	Neutral	pH 6.6-7.3
Very strongly acid	pH 4.5-5.0	Mildly alkaline	ph 7.4-7.8
Strongly acid	pH 5.1-5.5	Moderately alkaline	pH 7.9-8.4
Medium acid	pH 5.6-6.0	Strongly alkaline	pH 8.5-9.0
Slightly acid	pH 6.1-6.5	Very strongly alkaline	pH> 9.0

3 Available phosphorus

mgP/Kg soil	Low	Medium	High
Available P (Bray-Kurtz 1)	< 7	7-20	> 20
Available P (Olsen)	< 5	5-10	> 10

Available P is determined by the Bray-Kurtz 1 method if the pH H_2O of the soil is less than 7.0. In soils with a pH H_2O more than 7.0 the Olsen method is used.

4 Cation exchange capacity (CEC)

cmol(+)/Kg soil	Very low	Low	Medium	High	Very high
CEC	< 6.0	6.0-12.0	12.1-25.0	25.0-40.0	>40.0

CEC is determined using 1M ammonium acetate in soils with pH less than 7.5. In soils with pH greater than 7.5 CEC is determined using 1M sodium acetate.

5 Exchangeable calcium

cmol(+)/Kg soil	Very low	Low	Medium	High	Very high
Ca (clay soils rich in 2:1 clays)	< 2.0	2.0-5.0	5.1-10.0	10.1-20.0	> 20.0
Ca (loamy soils)	< 0.5	0.5-2.0	2.1-4.0	4.1-6.0	> 6.0
Ca (kaolenitic and sandy soils)	< 0.2	0.2-0.5	0.6-2.5	2.6-5.0	> 5.0

6 Exchangeable magnesium

cmol(+)/Kg soil	Very low	Low	Medium	High	Very high
Mg (clay 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	2.1-4.0	> 4.0
Mg (sandy soils)	< 0.2	0.2-0.5	0.5-1.0	1.1-2.0	> 2.0

The desirable saturation level of exchangeable Mg is 10-15% for sandy, and kaolenitic soils 6-8% Mg is still sufficient. Ca/Mg ratios of 2 to 4 are favourable.

7 Exchangeable potassium

cmol(+)/Kg soil	Very low	Low	Medium	High	Very high
K (clay soils)	< 0.20	0.20-0.40	0.41-1.20	1.21-2.0	> 2.0
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	0.11-0.40	0.41-0.70	> 0.70

The desirable saturation level of exchangeable K is 2-7%. Favourable Mg/ K ratio for most crops are in the range of 1 to 4.

8 Exchangeable sodium

cmol(+)/Kg soil	Very low	Low	Medium	High	Very high
Na	< 0.10	0.10-0.30	0.31-0.70	0.71-2.00	> 2.00

More important than the absolute level of exchangeable Na is the exchangeable sodium percentage (ESP), it is calculated by diving exchangeable Na by CEC (*100). ESP values are a measure of the sodicity of the soil.

9 Soil sodicity

Non sodic	Slightly sodic	Moderately sodic	Strongly sodic	Very strong sodic	Extremely sodic
ESP % < 6	6-10	11-15	16-25	26-35	> 35

ESP < 15%, up to 50% yield reduction of a sensitive crops (maize, beans)

ESP 16-25%, up to 50% yields reduction of semi-tolerant crops (rice, wheat, sorghum and sugarcane).

ESP 35%, up to 50% yield reduction of tolerant crops (barley, cotton)

11 Aluminium saturation

	Very low	Low	Medium	High	Very high
Al saturation%	< 10	10-30	31-50	51-80	> 81

12 Extractable sulphur

Category	Low	Medium	High
mg/kg	<5	5 – 10	> 10

13 Micronutrients

Compiled by Esu (1991), Lindsay and Norvell (1978)

Parameter	Rating		
	Low	Medium	High
Fe (mg/Kg soil)	< 4.5	4.5-10.0	> 10.0
Cu (mg/Kg soil)	< 0.2	0.2-1.0	> 1.0
Zn (mg/Kg soil)	< 0.8	0.8-2.0	> 2.0
Mn (mg/Kg soil)	< 5	5-10	> 10.0

Appendix 3: Description of the sites where soil samples were collected in Kibaha district – Coast Region

Site Name/Village (Ward)	GPS reading	Duration of Cultivation	Fertilizer used	Av. Yield (t/ha)
Kitomondo(Ruvu)	E45502 N9238572	More than 20years	Nil	2.5t/ha
Minazimikinda'B'(Ruvu)	E460836 N9247625	More than 20years	Nil	2.5t/ha
Minazimikinda'A'(Ruvu)	E460598 N9247785	More than 20years	Nil	2.5t/ha
Mwanabwito(Kikongo)	E463986 N9249878	More than 20years	Nil	2.5t/ha
Kidai (Kikongo)	E465614 N9252487	More than 20years	Nil	2.5t/ha
Kidai 2 (Kikongo)	E465751 N9253491	More than 20years	Nil	2.5t/ha
Mlandizi'B' (Mlandizi)	E466410 N9260547	More than 20years	Nil	2.5t/ha
Mlandizi B-2(Mlandizi)	E468534 N9256275	More than 20years	Nil	2.5t/ha
Mlandizi B-3 (Mlandizi)	E468837 N9259140	More than 20years	Nil	2.5t/ha
Mlandizi B-4(Mlandizi)	E469160 N9258937	More than 20years	Nil	2.5t/ha
Mlandizi B-5(Mlandizi)	E469641 N9258627	More than 20years	Nil	2.5t/ha
MlandiziB-6(Mlandizi)	E 4696340 N 92585118	More than 20years	Nil	2.5t/ha
Mlandizi 'A' (Mlandizi)	E 470357 N9261993	More than 20years	Nil	2.5t/ha
Vikuruti (Mlandizi)	E 470257 N 9261797	More than 20years	Nil	2.5t/ha
Madege'A' (Dutumi)	E450490 N9236512	More than 20years	Nil	2.5t/ha
Maadege 'B'(Dutumi)	E 451658 N 9238655	More than 20years	Nil	2.4t/ha
Dutumi (Dutumi)	E 453054 N9240348	More than 20years	Nil	2.3t/ha
Mwembengozi (Dutumi)	E 456814 N9246915	More than 20years	Nil	2.5t/ha

Appendix 4: Individual nutrients used and their rates

Nutrients	N	P	K	Zn	
Treatments					
	1	0	0	0	0
	2	100	0	0	0
	3	0	30	0	0
	4	75	20	0	0
	5	150	40	0	0
	6	150	40	100	0
	7	150	40	100	10

Appendix 5: Analysis of variance (ANOVA) for the effect of different nutrients omissions on mean performance of rice grown in Mlandizi Village.

Source of variation	**DF**	**Response variables and their mean sum square (m.s.)**							
		Plant height	Tiller Number	Panicle Number	Panicle length	50% flowering	TDM	Yield	HI
Replication	2	245.2	20.1	16.3	1.2	43.3	3.6	7.01	0.078
Fertilizers	6	103.0ns	32.1***	21.0***	4.9ns	5.4ns	4.5ns	0.70ns	0.004ns
Residual	12	401.2	4.5	3	8.5	159.2	15.4	4.21	0.006
Total	20								
P Value		0.95	<.001	<.001	0.75	1	0.94	0.95	0.67

Key: ns = Not significant ($P>0.05$); ***= highly significant ($P<0.001$).

Appendix 6: Analysis of variance (ANOVA) for the effect of Varieties on mean performance of rice grown in Mlandizi Village.

Source of Variation	**DF**	**Response variables and their mean sum square (m.s.)**							
		Plant height	Tiller number	Panicle Number	Panicle length	50% flowering	TDM	Yield	HI
Replication	2	245.2	20.1	16.3	1.2	43.3	3.6	7.01	0.08
Varieties	1	9020.8***	6.8ns	5.8ns	102.4***	4186.9***	287.2***	85.4***	0.023*
Residual	2	73.1	7.3	4.7	4.9	4.4	4.9	1.04	0.005
Total	5								
P Value		<.001	0.400	0.298	<.001	<.001	<.001	<.001	0.017

Key: ns = Not significant (P>0.05); * = significant (0.05≥P≥0.01);***= highly significant (P<0.001).

Appendix 7: Analysis of variance (ANOVA) for the effect of different nutrients omissions on mean performance of rice grown in Kitomondo Village.

Source of Variation	**DF**	**Response variables and their mean sum square (m.s.)**							
		Plant height	Tiller Number	Panicle Number	Panicle length	50% flowering	TDM	Yield	HI
Replication	2	4	0.62	0.403	1.81	2.7	3.52	0.57	0.0007
Nutrients	6	366.8ns	56.51***	38.24***	18.61*	27.5ns	12.89ns	5.41ns	0.04***
Residual	12	368.9	2.66	2.51	6.98	158.2	14.45	3.92	0.005
Total	20								
P Value		0.44	<.001	<.001	0.024	0.98	0.51	0.24	<.001

Key: ns = Not significant (P>0.05); * = significant (0.05≥P≥0.01); ***= highly significant (P<0.001).

Appendix 8: Analysis of variance (ANOVA) for the effect of Varieties on mean performance of rice grown in Kitomondo Village.

Source of Variation	**DF**	**Response variables and their mean sum square (m.s.)**							
		Plant height	Tiller Number	Panicle Number	Panicle Length	50% flowering	TDM	Yield	HI
Replication	2	4	0.62	0.4	1.81	2.68	3.52	0.57	0.0007
Varieties	1	8596.2***	11.29ns	24.26*	99.32***	4186.9***	287.21***	85.43***	0.023ns
Residual	2	85.02	7.93	5.46	5	5.76	4.88	1.26	0.008
Total	5								
P Value		<.001	0.25	0.02	<.001	<.001	<.001	<.001	0.06

Key: ns = Not significant (P>0.05); * = significant (0.05≥P≥0.01); ***= highly significant (P<0.001).

Appendix 9: Mean Plant height as affected by the interaction of Location by Varieties by Fertilizers treatments

Varieties	Fertilizers	Plant Height (cm) Mlandizi		Kitomondo	
SARO5	N150P40K100Zn66	98.45	G	98.99	g
	N100	94.11	Hijk	94.37	hij
	N75P20	92.03	jklm	91.76	jklm
	N0P0K0Zn0	82.50	O	83.31	o
	N150P40	97.07	ghi	97.03	ghi
	P30	93.79	hijkl	93.38	ijkl
	N150P40K100	97.46	gh	98.47	g
NERICA4	N150P40K100Zn66	90.63	jklm	90.04	lm
	N100	85.52	no	85.70	no
	N75P20	84.77	o	84.58	o
	N0P0K0Zn0	83.12	o	83.02	o
	N150P40	86.14	no	86.07	no
	P30	83.88	o	85.74	no
	N150P40K100	89.28	mn	90.42	klm
SUPA	N150P40K100Zn66	117.60	de	112.50	f
	N100	119.80	bcde	120.40	bcde
	N75P20	117.50	e	117.60	e
	N0P0K0Zn0	120.70	bcde	122.40	b
	N150P40	121.20	bcde	120.20	bcde
	P30	121.50	bc	121.40	bcd
	N150P40K100	118.40	cde	158.00	a
	Mean	**99.78**		**101.68**	
	STDev	**15.05**		**19.11**	
	STDErr	**3.28**		**4.17**	

The means followed by the same letters are not significantly different at $P < 0.05$ by Tukey Honestly Significance Difference

Appendix 10: Mean 80% phy mat. as affected by the interaction of Location by Varieties by Fertilizers treatments

Varieties	Fertilizers	Days 80% Phys Mat. Mlandizi		Kitomondo	
SARO5	N150P40K100Zn66	120.00	n	128.30	ij
	N100	123.80	l	128.30	ij
	N75P20	122.90	lm	129.00	i
	N0P0K0Zn0	127.00	jk	125.70	k
	N150P40	123.40	lm	128.00	ij
	P30	126.10	k	128.70	i
	N150P40K100	122.00	m	128.70	i
NERICA4	N150P40K100Zn66	93.50	w	95.33	uv
	N100	97.00	st	98.67	opqr
	N75P20	94.03	vw	96.00	tu
	N0P0K0Zn0	98.80	opq	100.00	o
	N150P40	97.47	qrst	98.33	pqrs
	P30	97.20	rst	99.00	op
	N150P40K100	93.60	w	95.00	uvw
SUPA	N150P40K100Zn66	141.40	gh	151.30	a
	N100	146.10	d	148.00	c
	N75P20	145.20	de	149.70	b
	N0P0K0Zn0	151.90	a	143.70	Ef
	N150P40	142.70	fg	152.00	a
	P30	145.10	de	148.00	c
	N150P40K100	140.70	h	152.30	A
	Mean	121.42		124.95	
	STDev	20.65		21.89	
	STDErr	4.51		4.78	

The means followed by the same letters are not significantly different at $P < 0.05$ by Tukey Honestly Significance Difference

Appendix 11:Mean Tiller number as affected by the interaction of Location by Varieties by Fertilizers treatments

		Tiller Number			
Varieties	**Fertilizers**	**Mlandizi**		**Kitomondo**	
SARO5	N150P40K100Zn66	13.33	abcd	12.67	bcde
	N100	10.00	hijk	10.33	ghijk
	N75P20	9.33	ijkl	8.67	klm
	N0P0K0Zn0	8.00	lmn	7.00	mn
	N150P40	10.67	fghij	11.33	efgh
	P30	9.00	jkl	10.00	hijk
	N150P40K100	12.67	bcde	13.67	abc
NERICA4	N150P40K100Zn66	14.67	a	14.67	a
	N100	12.00	cdefg	11.00	efghi
	N75P20	10.00	hijk	9.00	jkl
	N0P0K0Zn0	7.00	mn	6.67	n
	N150P40	12.33	cdef	11.67	defgh
	P30	10.00	hijk	10.00	hijk
	N150P40K100	13.67	abc	13.67	abc
SUPA	N150P40K100Zn66	8.67	klm	13.33	abcd
	N100	10.33	ghijk	11.00	efghi
	N75P20	10.00	hijk	10.67	fghij
	N0P0K0Zn0	9.00	jkl	6.33	n
	N150P40	10.00	hijk	13.67	abc
	P30	9.33	ijkl	14.33	ab
	N150P40K100	9.33	ijkl	14.33	ab
	Mean	**10.44**		**11.14**	
	STDev	**1.97**		**2.59**	
	STDErr	**0.43**		**0.56**	

The means followed by the same letters are not significantly different at $P < 0.05$ by Tukey Honestly Significance Difference

Appendix 12: Mean Panicle length as affected by the interaction of Location by Varieties by Fertilizers treatments

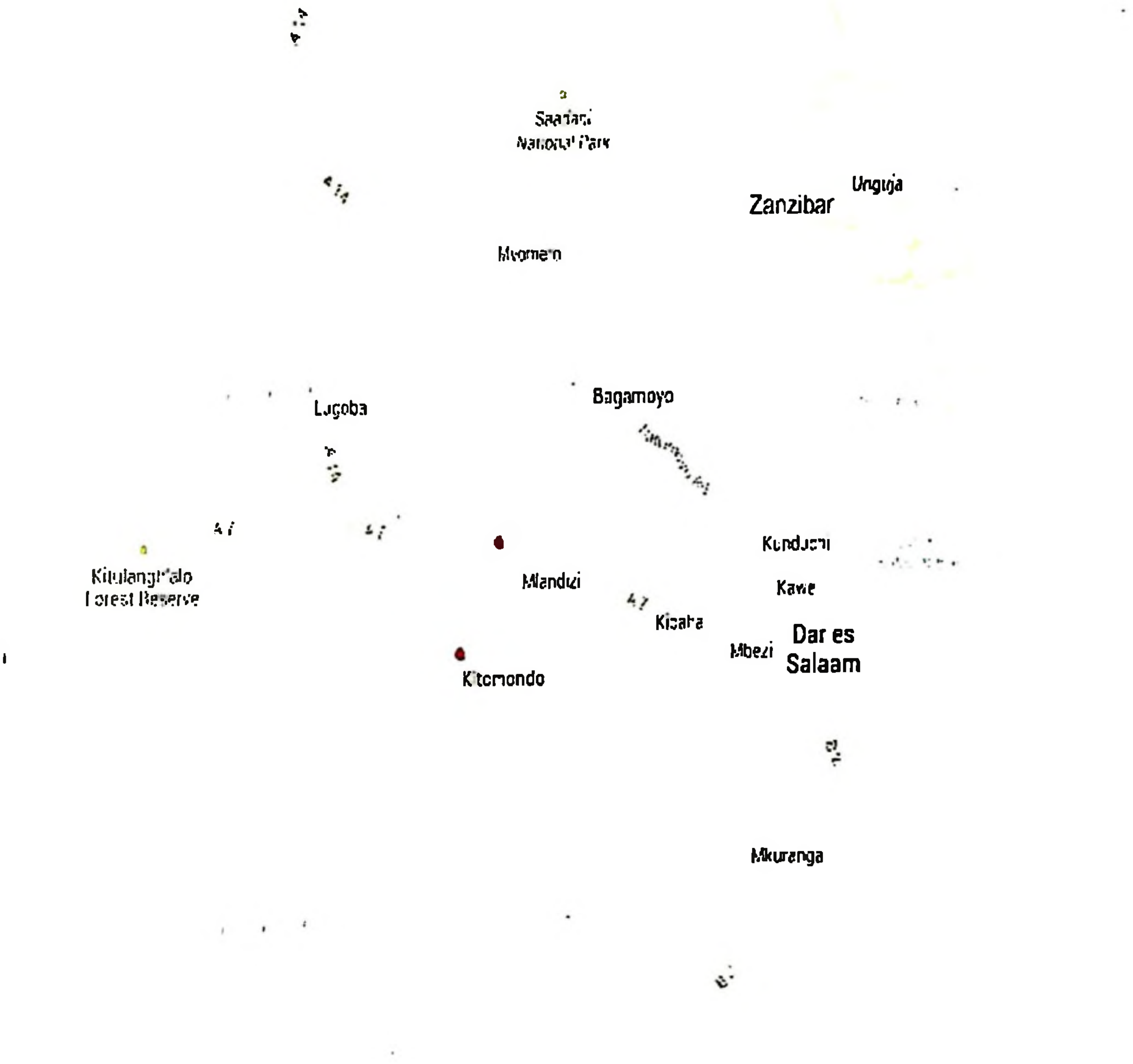
		Panicle Length (cm)			
Varieties	Fertilizers	Mlandizi		Kitomondo	
SARO5	N150P40K100Zn66	21.25	HIJKL	21.18	HIJKLM
	N100	20.28	JKLMNO	20.53	IJKLMNO
	N75P20	19.38	MNO	19.06	NO
	N0P0K0Zn0	18.80	O	19.05	NO
	N150P40	20.49	IJKLMNO	20.58	IJKLMNO
	P30	20.12	KLMNO	20.32	JKLMNO
	N150P40K100	20.89	HIJKLMN	20.88	HIJKLMN
NERICA4	N150P40K100Zn66	26.21	BC	26.08	BC
	N100	22.51	FGH	22.28	FGHI
	N75P20	21.09	HIJKLM	20.19	JKLMNO
	N0P0K0Zn0	19.62	LMNO	20.28	JKLMNO
	N150P40	22.01	GHIJ	22.01	GHIJ
	P30	20.73	HIJKLMN	21.76	HIJK
	N150P40K100	25.19	BCDE	24.87	CDE
SUPA	N150P40K100Zn66	24.79	CDE	26.90	B
	N100	24.88	CDE	21.02	HIJKLM
	N75P20	24.39	CDE	23.74	EFG
	N0P0K0Zn0	25.74	BCD	28.96	A
	N150P40	25.93	BCD	21.29	HIJKL
	P30	25.13	BCDE	24.10	DEF
	N150P40K100	26.81	B	26.03	BC
	Mean	**22.68**		**22.43**	
	STDev	**2.63**		**2.75**	
	STDErr	**0.57**		**0.60**	

The means followed by the same letters are not significantly different at P < 0.05 by Tukey Honestly Significance Difference

Appendix 13: Partial Correlation Among yield components

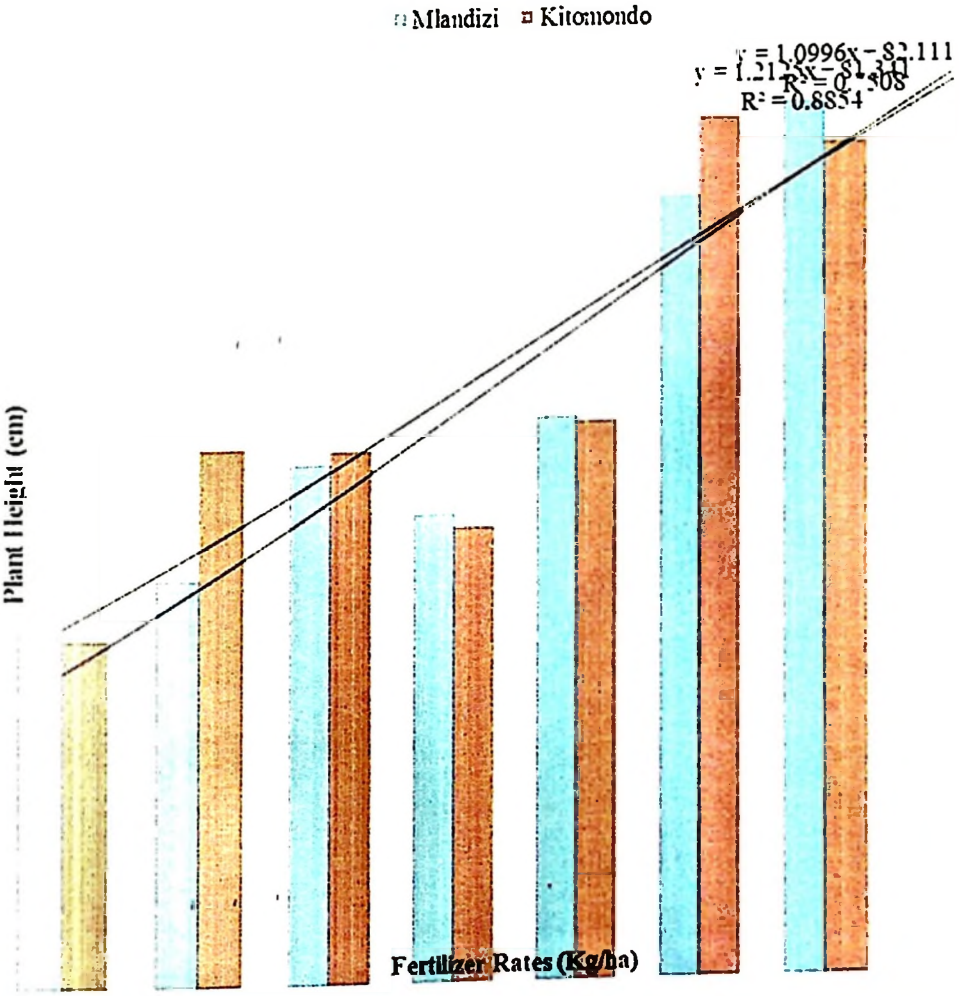
	1	2	3	4	5	6	7	8
Days to 50% Flowering	0							
Harvest Index	0.2116	0						
Plant Height	0.2740	-0.0199	0					
Days to 80% Physiological Maturity	0.9400	-0.1952	0.0262	0				
Panicle Length	0.1921	0.0604	0.3934	-0.2717	0			
Panicle Number	-0.0709	0.1586	0.0412	-0.0053	0.1227	0		
Total Dry Matter (g)	0.3836	-0.2582	-0.0987	-0.3500	0.1285	0.2411	0	
Tiller Number	-0.1186	-0.0174	0.2362	0.0823	0.0400	0.7370	-0.2395	0
Yield Kg/ha	-0.2804	0.4440	-0.1211	0.3269	-0.2959	-0.1213	0.6679	0.2764

Appendix 14: Map of Coast Region showing the Mlandizi and Kitomondo study areas in Kibaha District Council

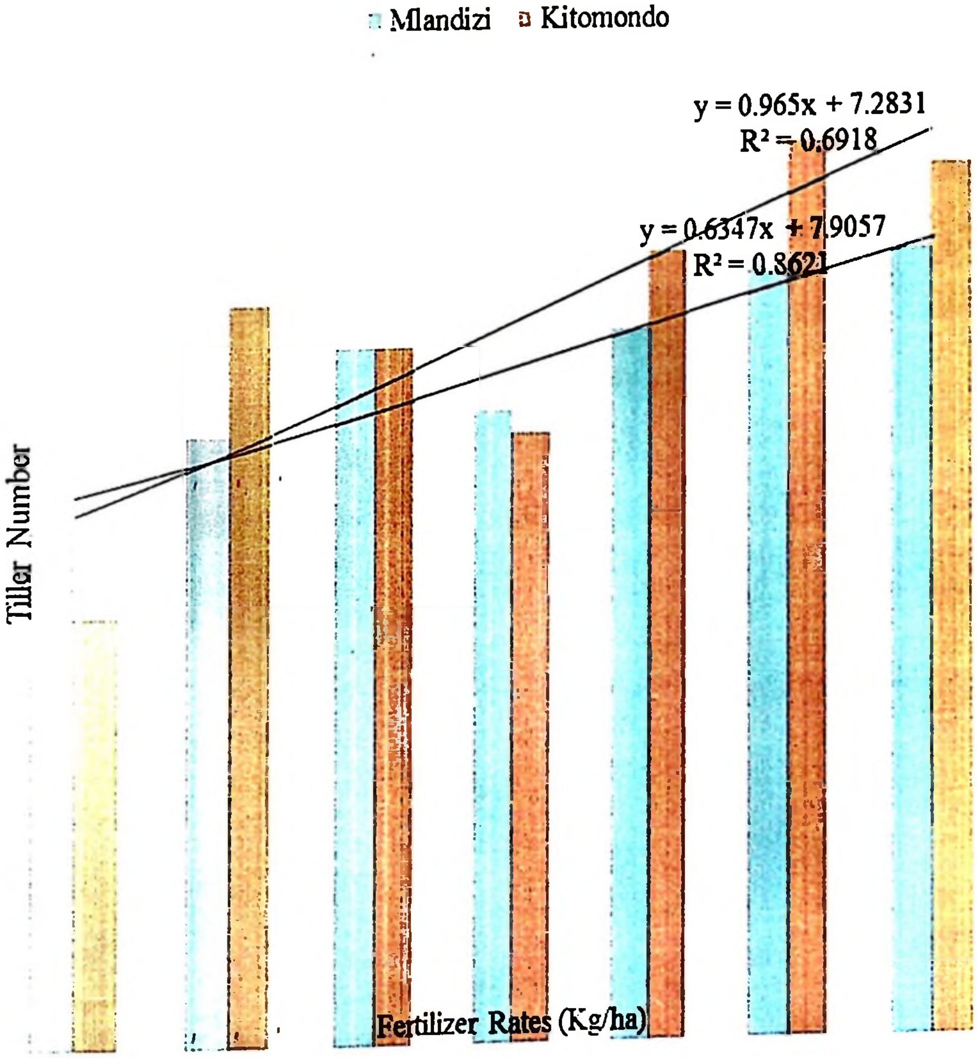


Appendix 15: The plot with the treatment 30Kg/ha P only followed by a plot with 0 Kg/ha of all N, P, K and Zn and the plot with 75Kg/ha N, 20Kg/ha P and 0Kg/ha of both K and Zn at the right.

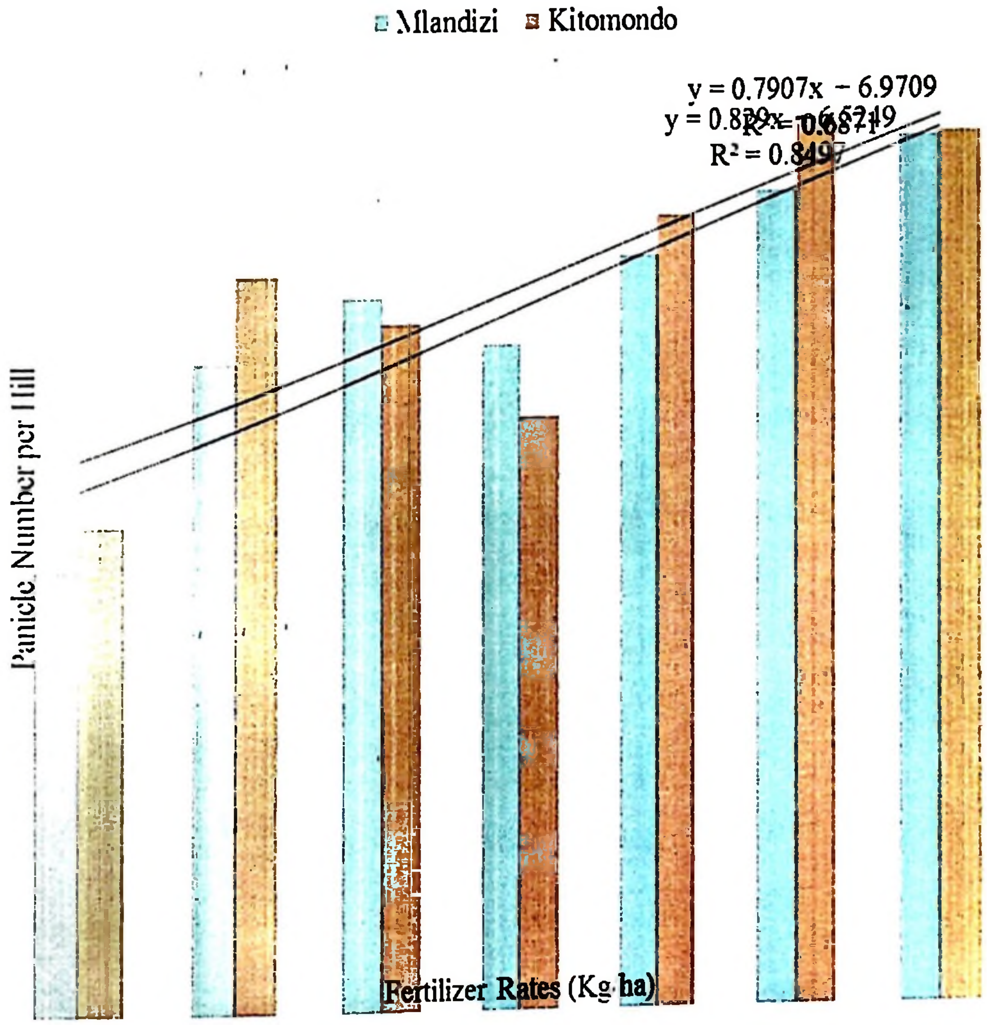
Appendix 16: Effect of Fertilizer and Locations on plant height



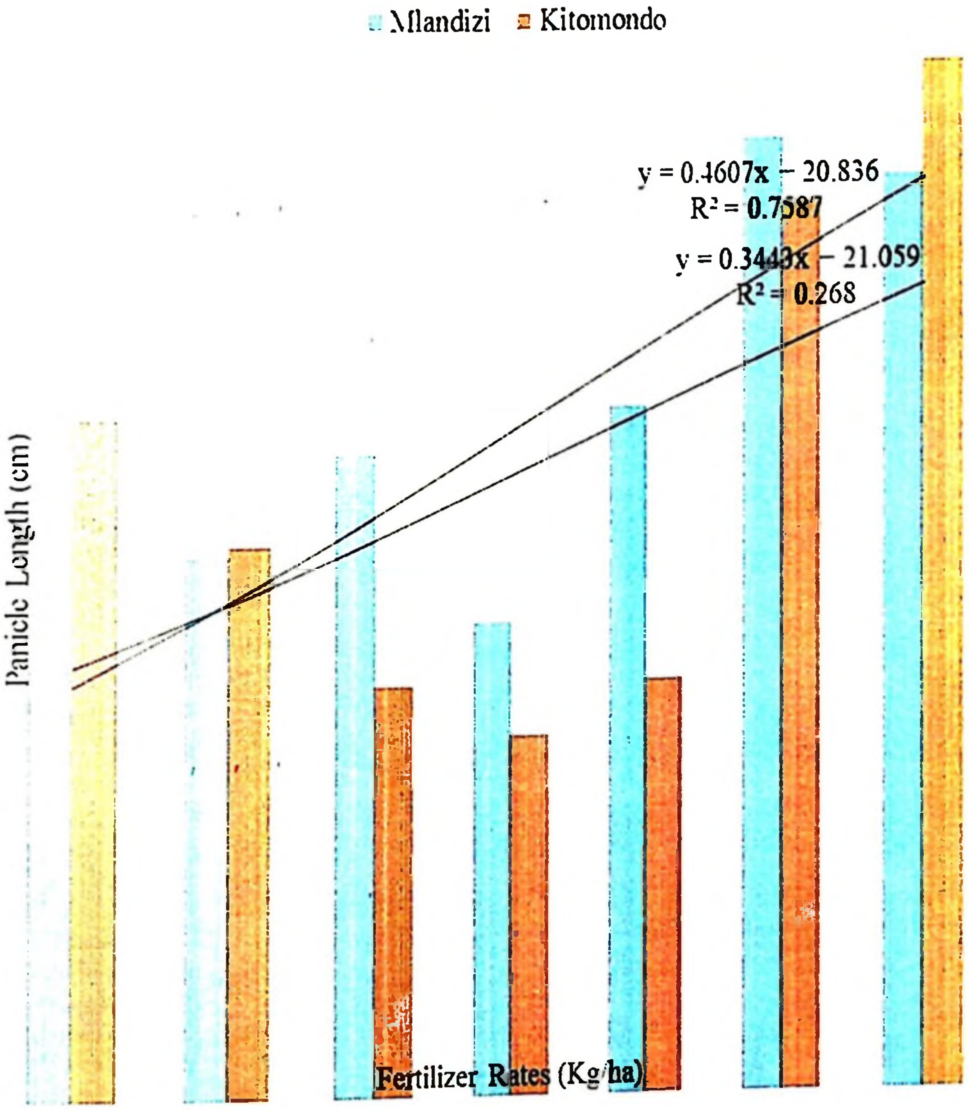
Appendix 17: Effect of Fertilizer and Locations on Tiller Number



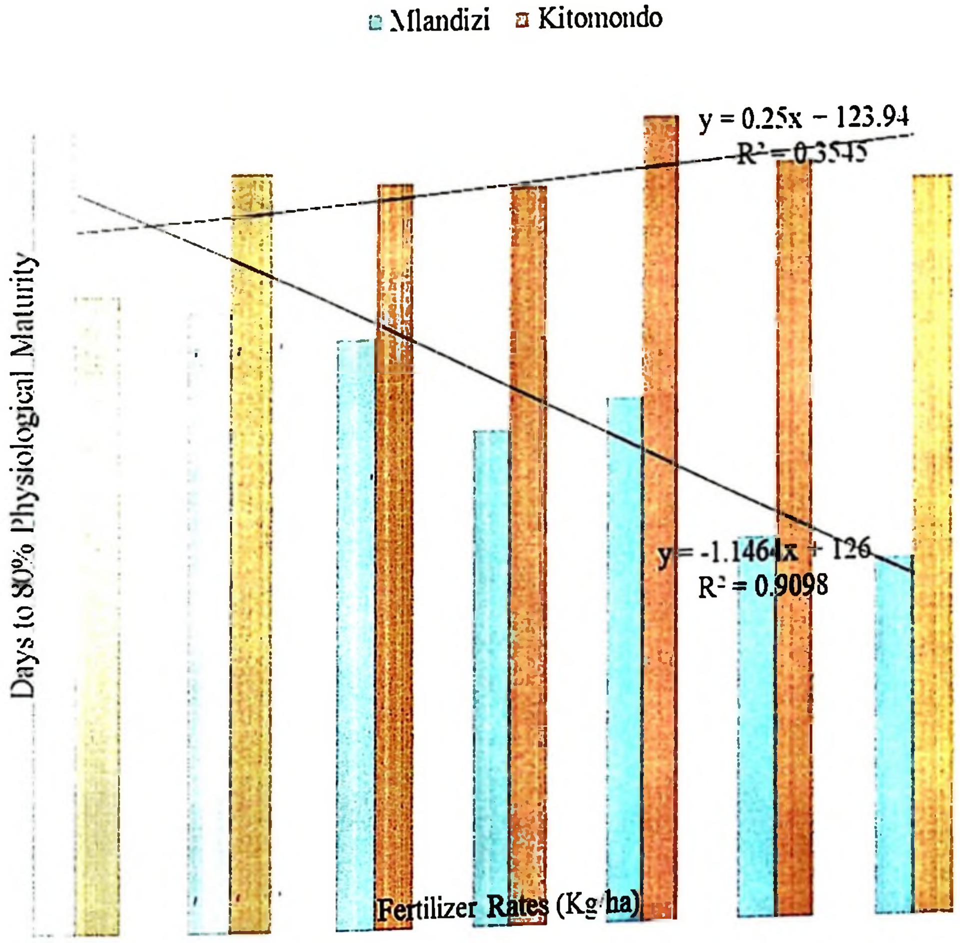
Appendix 18: Effect of Fertilizer and Locations on Panicle Number



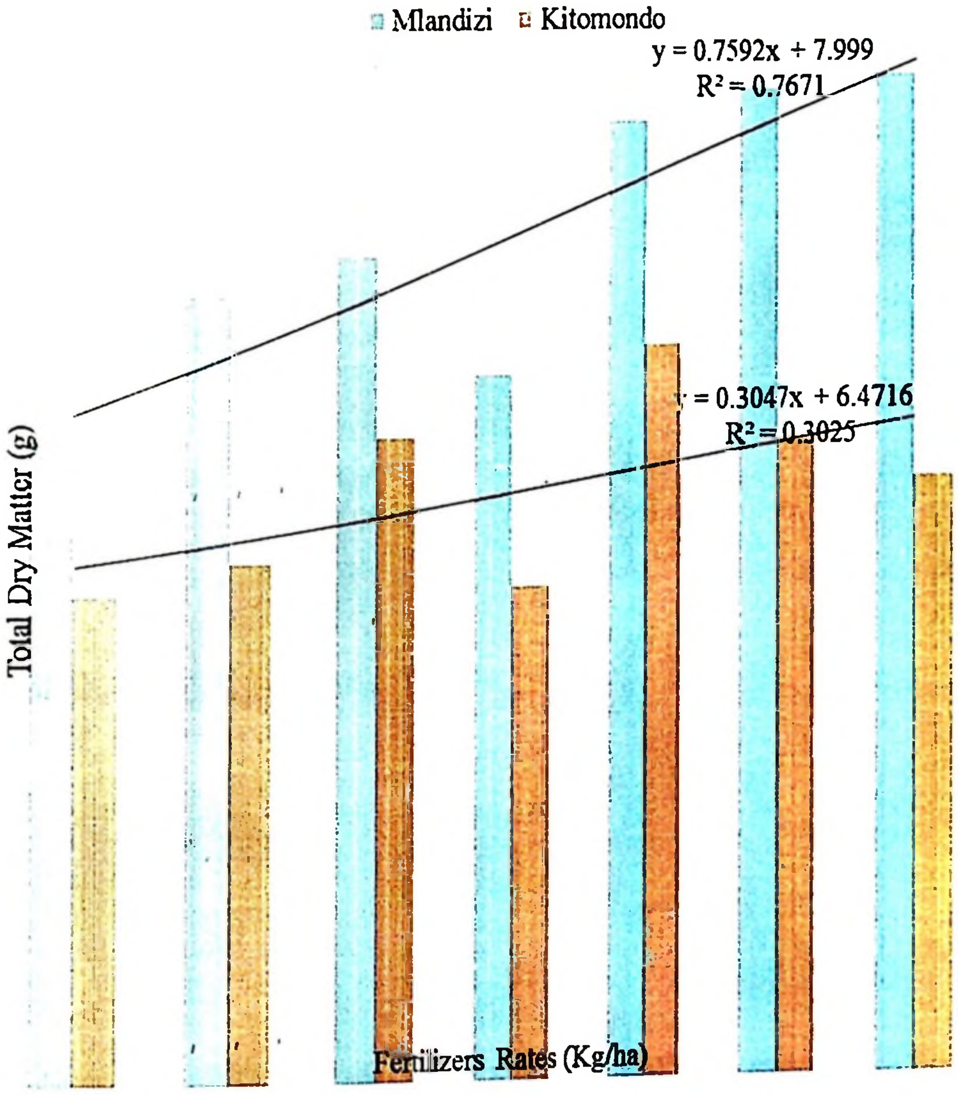
Appendix 19: Effect of Fertilizer and Locations on Panicle Length (cm)



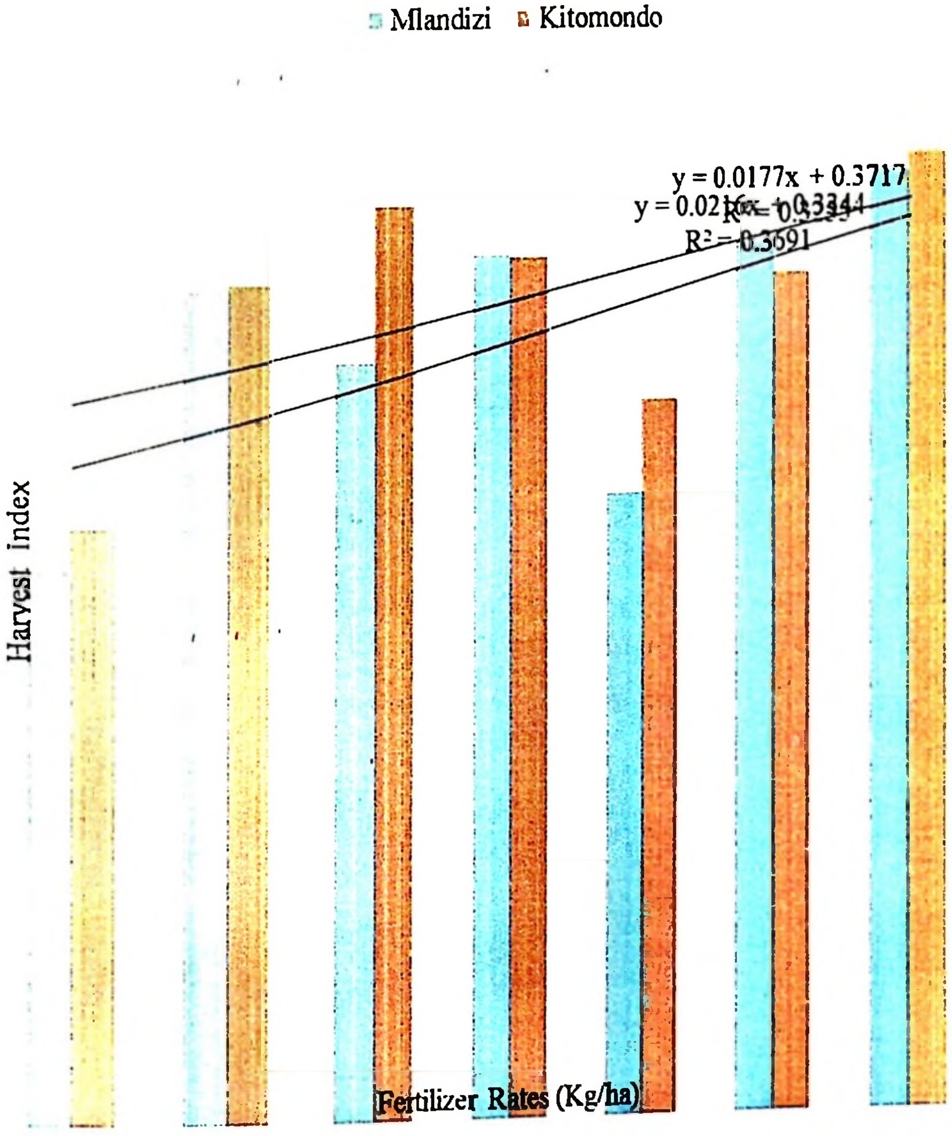
Appendix 20: Effect of fertilizer and locations on days to 80% physiological maturity



Appendix 21: Effect of fertilizer and locations on Total Dry Matter (g)



Appendix 22: Effect of fertilizer and locations on Harvest Index



Appendix 23: SARO 5 and NERICA4 at fertilizer application rates N150P40K100 at the background right and N0P0K0Zn0 at the fore ground in the field at Kitomondo village in Ruvu ward