IMPROVING UPLAND RICE (*Oryza sativa* L.) PERFOMANCE THROUGH ENHANCED SOIL FERTILITY AND WATER CONSERVATION METHODS AT UKIRIGURU MWANZA, TANZANIA

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ABSTRACT

The experiment was conducted at Agricultural Research Institute (ARI)–Ukiriguru Mwanza, Tanzania from November 2011 to May 2012, aiming at improving upland rice performance through enhanced soil fertility and water conservation methods. A split–split plot experiment in randomized complete block design with three replications and three factors that were (a) upland rice cultivars (WAB 450, NERICA1 and NERICA4) (b) fertilizer types, (urea 80kg N/ha, farm yard manure 5 t/ha and control) (c) three water conservation methods (flat cultivation, open ridge and tie ridge were applied). Rice was sown in seven rows at 30cm inter–and intra–row spacing. Data on soil, weather, crop growth, yield components and grain yield were collected. Rainfall was 651.2mm during the cropping season which was poorly distributed. Average temperature was 24^{o}C with mean relative humidity of 75%. Soil analysis results showed that total nitrogen was 0.08%, phosphorus 2.09 mgP/kg and organic carbon 0.58%. The soil calcium was 3.38cmol$_{c}$/kg, potassium was 0.36cmol$_{c}$/kg, while zinc was 0.39 mg/kg. Cultivars had significant effect on yields which were 2 856, 2 507 and 2 140kg/ha for WAB 450, NERICA4 and NERICA1 respectively. Fertilizer types also significantly affected grain yield in the order of urea (3 368kg/ha) > FYM (2 723kg/ha) and > control (1 421kg/ha). Further, moisture conservation methods significantly affected yield in the order of tie ridges (2 710kg/ha), open ridge (2 398kg/ha) and flat cultivation (2 394kg/ha). Overall the study results indicated low soil fertility, although it was found to be suitable for upland rice production with further improvement. It is concluded that rice cultivar, WAB 450 had the highest yield potential, while application of urea at 80kg N/ha gave high grain yield, and tie ridges were the best in soil moisture conservation.

DECLARATION

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

Mohamed Ibrahim Shemahonge — Date

(MSc. Crop Science Candidate)

The above declaration is confirmed by;

Prof. C.L. Rweyemamu — Date

Supervisor

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LIST OF ABBREVIATION AND SYMBOLS

%	percent
<	Less than
>	Greater than
≤	Less or equal to
±	Plus or minus
AAS	Atomic absorption spectrophotometer
ACT	Agricultural Council of Tanzania
Al	Aluminum
Al^{3+}	Aluminum ion
ANOVA	Analysis of variance
ARC	Africa Rice Centre
ARI	Agricultural Research Institute
ASA	America Society of Agronomy
^{o}C	Degree Celsius
Ca	Calcium
Ca^{+2}	Calcium ion
CAN	Calcium ammonium nitrate
CAO	Calcium oxide
CBO’s	Community Based Organizations
CEC	Cation exchange capacity
cm	Centimeter
$cmol_c$	Centimole
CO_2	Carbon dioxide
Cu	Copper

CV	Coefficient of variation
DAP	Di–ammonium phosphate
EC	Electrical conductivity
e.g.	for example
FAO	Food Agricultural Organization
FAOSTAT	Food Agricultural organization Statistics data
Fe	Iron
FSR	Farming system research
FYM	Farm yard manure
g	Gram
ha	Hectare
H_2S	Hydrogen sulphide
HI	Harvest index
hrs	Hours
i.e.	that is
IRI	International Research Institute
IRRI	International Rice Research Institute
K	Potasium
K^+	Potasium ion
KATRIN	Kilombero Agriculture Training and Research Institute
kg	Kilogram
LAI	Leaf area index
l	Litre
m^2	Meter square
MACZ	Ministry of Agriculture and Cooperative in Zambia
MAFSC	Ministry of Agriculture Food Security and Cooperatives

Max	Maximum
Min	Minimum
Mg	Magnesium
Mg^{+2}	Magnesium ion
mg	Milligram
M J	Mega joule
Mn	Manganese
Mn^{+2}	Manganese ion
N	Nitrogen
Na	Sodium
Na^{+}	Sodium ion
N P K	Nitrogen phosphorous potasium
NERICA	New Rice for Africa
NGO's	Non government organizations
n.s.	no significant difference
O_2	Oxygen
OC	Organic carbon
OM	Organic matter
P	Phosphorus
P_2O_5	Phosphate
pH	Hydrogen ion concentration
p.p.m	parts per million
R	correlation coefficient
RCBD	Randomized complete block design
RH	Relative humidity
RLDC	Rural Livelihood Development Company

RRP	Rice research program
RYMV	Rice yellow mottle virus
SA	Ammonium sulphate
s.d.	standard deviation
s.e	standard error
SUA	Sokoine University of Agriculture
t	Tonne
TARO	Tanzania Agricultural Research Organization
TDM	Total dry matter
TMA	Tanzania Meteorology Agency
TSP	Triple supper phosphate
USDA	United States Department of Agriculture
WAB	West Africa Bouke
WARDA	West Africa Rice Development Association
WCGA	Western Cotton Growing Area
Zn	Zinc

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Rice (*Oryza sativa* L.) ranks second after wheat in the world cereals grain production. More than half of the world's population depends on rice as food. The utilization of rice is increasing and the inequity between domestic productions has been increasing in sub–Saharan Africa (Oikeh *et al*., 2008). About 80% of rice in Africa is produced by small–scale farmers for their own utilization and local market (WARDA, 2007).

Population increase, rising of incomes and change in consumer desire in favour of rice particularly in urban areas has comparatively increased rice demand in Sub–Sahara Africa than in any other place in the world (Somado *et al*., 2008). Africa became a big competitor in the international rice markets collecting up 32% of the world imports in 2006 with record of 9 million tonne in that particular year (WARDA, 2007). In Tanzania, rice is among the mostly grown crops and is the second among most essential food crop. Apart from meeting local utilization needs, rice also is used for income generation and as a source of employment for the people in rural areas (MAFSC, 2009).

According to African Rice Centre (ARC) (2011), Lake zone of Tanzania accounts for about 60% of the rice cultivated in the country. The inland valley systems offer an important portion of the rice production area in the Lake zone. Kanyeka *et al*. (1994) reported that, in Tanzania rice is grown in three agro–ecosystems which are; rain fed lowland, which covers 74%, rain fed upland, 20% and irrigated lowland, 6% of the country production.

In the effort to increase rice production and productivity in the country, the Rice Research Program (RRP) made many efforts such as, conducting farmers training, introducing improved varieties and carryout different research aimed at improving rice production to meet local demand, increase householder's income and to create employment (MAFSC, 2009).

Other effort done by the RRP is engagement in introduction of New Rice for Africa (NERICA) since 2002. The new varieties were not common in the country because most people who engage in upland rice production used local cultivars, which are susceptible to diseases and have low yield potential, but have acceptable, palatable, aroma and cook ability to the consumers. The NERICA varieties were developed purposely for low resource farmers in Africa (Somado *et al*., 2008).

Upland rice is usually produced under aerobic conditions without irrigation or paddling. The crop can be found in a range of environments from low–lying valley bottom to steep sloping land with high runoff, where land preparation and sowing is done under dry conditions as direct sowing. This rice is also grown either as a mono–crop or as mixture with other food crops normally without any fertilizer use (FAO, 2009; IRRI, 2009). This type of rice can be grown on wide range of soils varying from moderately–drained to well–drained soils such as sandy loam to sandy clay, respectively with soil pH range from 4.7 to 6.8.

Major difference between upland rice and low land rice soil is that upland rice is grown on un flooded land for a long time during the growing season whereby, rice plant has to regulate to dry aerobic soil conditions, whilst lowland rainfed rice grows under flooded land under anaerobic condition and normally in water saturated soils (Gupta and O'Toole, 1986).

1.2 Problem Statement and Justification

Several factors are generally known as the major constraints in upland rice production. However, unreliable and poor rainfall distribution, low soil fertility, soil erosion, weed competition, insect pests and diseases have been noted to have more critical limitations (Wade *et al*., 1999). In the Lake Zone areas of Tanzania, particularly in Shinyanga and Mwanza regions, unreliable and unevenly distribution rainfall and low soil fertility are regarded as the most important upland rice production constraints (Meertens, 2003; Kajiru, 2006). These factors contribute to low yields of both upland and lowland rice currently averaging 0.5t/ha for upland rice, while lowland system average is 1.0 t/ha (MAFSC, 2009).

Rain water management is one of the most useful measures on soil conservation (Hatibu, 2000). The tie ridging system is used to capture rainwater in the relatively drier areas which are flat to gently sloping. Results from tie ridges research conducted on upland alfisols shows lower runoff collection of 0 – 15% of the seasonal rainfall, while 20 – 45% of the seasonal rainfall was collected on open ridges (Meertens, 2003). Yield of several cereal crops like sorghum and maize planted on tie ridges showed significant increases as compared to those grown on flat surface in Western Cotton Growing Areas of Tanzania (Kajiru, 2010). The increase of population in Tanzania and changing dietary habits in many regions such that from traditional foods like cassava, sorghum, sweet potato, banana and maize, has resulted into rice consumption increase for the people of both rural and urban areas (Kibanda, 2008).

Many studies have been done on lowland rainfed rice, such as the use of organic and inorganic fertilizers and water management. However, little is documented on response of upland rice varieties to moisture conservation methods, organic and inorganic fertilizer uses in Tanzania. Therefore this study aims at determining the effectiveness of enhanced methods of soil fertility and moisture conservation for upland rice production in Mwanza, which is part of the Lake zone of Tanzania.

1.3 Objectives

1.3.1 Overall objective

To improve skills and knowledge in soil fertility enrichment and water conservation methods that will increase and sustain upland rice productivity in the Lake zone of Tanzania.

1.3.2 Specific objectives

i. To evaluate the fertility status of the soil and its suitability for upland rice production;
ii. To evaluate the effect of nitrogen from organic and inorganic sources on upland rice cultivars in terms of yield and yield components and

iii. To assess the performance of upland rice cultivars grown under different water conservation methods in terms of growth characteristics and grain yield.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin of Rice

Rice (*Oryza sativa* L.) which is the seed grain of the monocot plants (Asian rice) or *Oryza glaberrima* (African rice). Rice is the most important staple food for the large areas of the world population, and is the second highest in production and consumption in the global (FAO, 2009). Rice has been cultivated in China since ancient times and was introduced to India before the time of the Greeks. Chinese records of rice cultivation go back 4 000 years. In classical Chinese literature the words for agriculture and for rice culture are synonymous, signifying that it was already a staple crop at the time the language was taking form. In several Asian languages, the words for rice and food are identical. Many ceremonies have arisen in connection with planting and harvesting rice, and the grain and the plant are traditional motifs in Oriental art. Thousands of rice strains are now known, both cultivated and escaped, and the original form is unknown (Yoshida, 1981). Rice grown in Asia is classified into three sub species known as Indica, Joponica and Javanica (Gupta and O'Toole, 1986).

Cultivation of crop has been carried into all regions having the necessary warmth and abundant moisture favorable to its growth, mainly subtropical rather than hot or cold. The crop was common in West Africa by the end of the 17th century. It is thought that slaves from that area were transported to the Carolinas in the mid–18th century (FAO, 2009).

2.2 Botany of Rice

Rice belongs to the family Poaceae that is an annual grass. It is a self–pollinated, short day crop and also is a semi–aquatic plant which consist arenchymatic tissues. Arechymatic cells on leaf culm and root give out oxygen from aerial parts downward the roots. A rice plant possesses a fibrous root system which consists of, rootlets and root hairs; and seminal roots developing from the seed. The plant has adventitious roots which are real functional roots develop from the lower nodes of the culm (Yoshida, 1981).

Plant height can be 1 – 1.8 m, rarely more or less of this depend on the cultivated variety and fertility status of the given soil. Leaves are slender 50 to 100 cm long while width is 2 – 2.5 cm. Rice produce tillers and flowers in branched arching to inflorescence, 30 – 50 cm long with the grain length ranging from 5 – 12 mm (FAO, 2009).

2.3 Climatic Conditions and Soil Requirements for Rice Production

Rice is primarily a tropical and subtropical crop. However, some temperate regions in the world like Japan, Korea and Italy produce good grain yield of the crop. The climatic conditions like temperature, rainfall, relative humidity, solar radiation; soil types and nutrient status may affect the crop development and performance (De Datta, 1981; FAO, 2009).

2.3.1 Temperature

Temperature is considered to be one of the main factors that affect the growth and yield of rice. Temperature requirement in rice differs from one growth stage to another as indicated in Table 1. Low temperature in early growth stages retards the development of seedling and dry matter production (Yoshida, 1976). The effect of rising temperature on rice potential production is generally negative. It decreases photosynthesis, increases respiration, shortens the vegetative and grain filling period.

Table 1: Response of the rice plant to varying temperature at different growth stages

Growth stage	Critical Low	Temperature High	(^{o}C) Optimal
Germination*	10	45	20–35
Seed germination, emergence and establishment*	12–13	35	25–30
Rooting*	16	35	25–28
Leaf elongation**	7–12	45	31
Tillering**	9–16	33	25–31
Initial of panicle primordial**	15	–	–
Panicle differentiation**	15–20	38	–
Anthesis**	22	35	30–33
Ripening**	12–18	30	20–25

(Source Yoshida, 1981): * = Soil temperature and ** air temperature.

2.3.2 Radiation and relative humidity

Solar radiation is the most important energy source for crop growth and extremely affects temperature and evaporation. However, reliable information on radiation in upland rice regions is seldom available (Gupta and O'Toole, 1986). Nevertheless, Amgain *et al*. (2006) reported on decreasing of both maximum and minimum temperature by 4^{o}C and increasing solar radiation by 1MJ/m^{2}/day, increased the rice grain yield by 18% and growth duration by 24 days showing the interactive effect of temperature and solar radiation. They further reported that temperature, solar radiation and water directly affect the physiological processes involved in grain development and indirectly affect grain yield through influencing the incidence of diseases and insects. According to Tunde *et al*. (2011) yield of rice is directly related to the solar radiation at reproductive and ripening phase.

2.3.3 Relative humidity

Relative humidity (RH) directly influences the water relations of rice plant and indirectly affects leaf growth, photosynthesis, pollination, occurrence of fungal diseases such as rice blast and leaf blast and finally economic yield. The dryness of the atmosphere as represented by saturation deficit (100 – RH) reduces dry matter production in rice plant through stomatal control and leaf water potential. Reduced transpiration influences translocation of food materials and nutrients, moderately high RH of 60 – 70% is beneficial to rice crop development and performance (FAO, 2002).

2.3.4 Soil and nutrient requirements

Rice is cultivated on a wide range of soils from sandy loam to heavy clay soils. It is well recognized that heavy soils with characteristics of river valley are more preferred than lighter soils in rice cultivation. The best soil for rice should have fine fractions of silt and clay, while a difference in yield from one place to another may be due to greater variation in soil conditions and extension of rice cultivation to unsuitable soils. The optimum soil pH for rice growth in dry conditions is 5.5 – 6.5. It may rise from 7.0 to 7.2 under flooded conditions (Somado *et al.*, 2008).

In upland rice, soil structure and fertility are major yield determinants because the amount of mineral fertilizer used is often small while in irrigated rice, soil structure is deliberately destroyed during land preparation. The effect of flooding generally improves nutrient availability and reduces the effects of very alkaline or acid soil conditions on plant growth that occurs under aerobic conditions (Nwilene *et al.*, 2008). In high rice yielding environments where improved varieties are used, the difference between the soil's indigenous nutrient supply and crop nutrient demand must be provided in the form of mineral fertilizer. Results on soil analysis for selected upland rice growing areas in three regions, Mbeya, Morogoro and Tanga, in a study conducted in 2010 showed that total nitrogen (N) range from 0.1 to1.2 % was low to support the growth of rice, available phosphorous (P) was also low < 7 to medium 7–20 mg/kg P, while organic carbon was medium, range was 1.26 – 2.50% (Landon, 1991). According to these results, the areas that were under study experience low N and P values, the elements that limiting rice production, also the use of fertilizer among farmers was very low, about 15 – 20% farmers use fertilizer in their field (Mghase *et al.*, 2010).

Most smallholder upland rice farmers do rarely use inorganic fertilizers and/or manure. This situation is attributed by financial constraints, availability of fertilizer, high price of fertilizers, availability of inadequate manure, transportation problems due to bulkiness of FYM required per unit area and in some areas ignorance among farmers on an importance of FYM is also another factor. Organic fertilizers are mostly in form of compost, crop residues or farm yard manure (Kajiru, 2006).

Inorganic fertilizer such as Triple super phosphate (TSP– 46% P_20_5), Ammonium sulphate (SA–21% N), Urea (46% N) and Calcium ammonium nitrate (CAN–26% N) are straight (single) fertilizer that supply only one primary nutrient, and are widely used in Tanzania and other areas in north and west Africa. Other types commonly used are compound fertilizers such that NPK (20 – 10 – 10), Minjingu mazao (N 10%, P_2O_5 20 %, Cao 30%, S 5%) and Minjingu grain (P_2O_5 27 – 40%, Cao 36–38%), Minjingu nongrain (P_2O_5 28–40%, CaO 38–40%) (Nwilene *et al*., 2008; RLDC, 2011). Nitrogen fertilizer recommendation are 100–120 kg N /ha if soil has low N i.e. < 1.0g total N/kg of soil), then 60 – 80kg N /ha is recommended (when is medium i.e. 1.0 – 2.0 g total N /kg of soil) and while < 40kg N / ha, (high N content), soil has (> 2.0 g total N/ kg of soil). Phosphorous application 30 – 60 P for low P content soils, 15 – 30kg P for medium and 15 kg P for high P contents soil (Nwilene *et al*., 2008).

Recommendation for potassium is 30 – 60kg K for low, 15 – 30 K for medium and 0 – 15 K for high K in the soil (Oikeh *et al*., 2008). Application of phosphorous and potassium should be done one week before transplanting while topdressing can be applied in three equal splits at transplanting/ sowing, mid–tillering and during panicle initiation (Somado *et al.*, 2008; FAO, 2009). In Tanzania the rate of 60 – 80 N kg/ ha and 30kg P /ha give optimal grain yield (Kanyeka *et al*., 2007). However, there is no fertilizer recommendation drawn for upland rice in Tanzania (Kajiru, G. J. personal communication, 2011).

2.3.5 Soil water

Retention of rain water is among the most common and important soil management method. When rainfall water infiltrates and retained in the soil, it increases the rate of available soil moisture for crops growth and development (Kajiru, 2006). Saito e*t al*. (2005) revealed that there is a yield increase of upland rice improved varieties when water stress does not exist during the growth stage.

Several technologies are used in water conservation, although, tie ridges and stored bunds are among the most common technologies used for retaining water in the soil (Sanginga and Woomer, 2009). Tie ridges technology may create small structure like dams which collect the rain water hence reduce their movement. Tie - ridges can be used in both conditions i.e. in dry condition, because they conserve moisture which can be available for crop when rain stops, while during the rainfall (wet) season crops do not suffer from water logging since planting is done on the edges of the ridges (Odunze *et al*., 2010).

Tie–ridges were found as the most effective method in conserving soil water and raising the level of production for most field crop (Mutune *et al.,* 2011). They are very effective in soil with low organic matter, fine texture, compacted surface with high runoff and low infiltration rate. Several studies have shown that when tie ridges and fertilizer are used in combination have resulted in crop yield increase than when used alone in Semi–arid areas. The advantages of ridging systems are known but the acceptance of the technology for boosting agriculture productivity is still very low in Tanzania (Kajiru, 2010; Mutune *et al*., 2011). This situation could have been attributed to the fact that the technology is labor demanding and time consuming.

The amount of rainfall and its distribution, fertility status of the soil and soil type are among the important areas of consideration for effective use of tie ridges, (Junge *et al.*, 2008). Open ridges are very common in many areas especial in the Lake zone; however, the technology is not effective in moisture conservation rather than water drainage system. The nature of the ridges allow movement of water through furrow between ridges out the field, while flat cultivation expose the field to the risk of soil erosion especially when the field located on a slope (Kajiru, 2006).

2.4 Rice Growth and Development

2.4.1 Seed germination

In rice germination is mostly affected by the temperature. The temperature has a profound influence on germination by affecting the activation stage and post germination growth. The effects of temperature on germination can be examined in three aspects: temperature, time, and germination percentage. Moisture is also important for imbibitions to allow the first internode elongation and emerging through the soil surface, moreover, emerged plant need moisture for nutrients and water supply to the plants (Yoshida, 1981).

2.4.2 Varietal effect on rice growth

The varieties have an effect on rice growth due to genetic characteristics. Some varieties have high nutrient use efficiency due to nature of their roots system whereby some have long roots or many roots; others have many tillers or small number of tillers. Further, local varieties of upland rice are known for the characteristics of having low number of tillers ranging from 2 – 4 while improved varieties go up to 14 tillers depending on the soil moisture and nutrients (WARDA, 2007). Also this is in agreement with Fageria *et al.* (1997) who stated that tillering characteristics among other factors is very much influenced by the genetic characteristics of the cultivars grown.

The NERICA rice is the result of extended family of several 3 000 siblings. They are outcome of crosses between two most commonly cultivated rice species, African rice (*Oryza glaberrima steud*) which has the ability of surviving in cruel environment, and Asian rice (*Oryza sativa L.*) with high yield potential (WARDA, 2008). NERICA varieties have improved African rice production in many countries, Tanzania being among them (FAO, 2007). These varieties have potential of producing many tillers more than the traditional upland rice varieties with an average of 17 tillers (in long rainfall areas) and 10 tillers (short rainfall areas). Most of the local upland varieties produce an average of 4 tillers per plant. The NERICA rice varieties were bred intentionally for resource limited smallholder upland rice production systems in Africa (WARDA, 2008).

2.4.3 Effect of aeration on rice growth and development

The direction in which roots grow is important to the plant. It determines the extent and distribution of the root system and hence the efficiency with which water and nutrient content of the soil is exploited. The aerenchyma may provide a photosynthetic benefit by concentrating CO_2 from root respiration and transporting it to the leaf intercellular spaces in some wetland plant species (Konings, 1995). The principal cause of damage to plants grown in waterlogged soil is inadequate supply of oxygen to the submerged tissues as a result of slow diffusion of gases in water and rapid consumption of O_2 by soil microorganisms. In addition to the O_2 deficiency, production of toxic substances such as Mn^{2+}, and H_2S by reduction of redox potential causes severe damage to plants under waterlogged conditions. Unlike other crop plants, rice has some adaptive traits for tolerance of submergence. One of the traits is formation of the longitudinal interconnection of gas spaces, called aerenchyma that enables internal aeration between shoot and roots (Setter *et al.*, 2009).

2.4.4 Influence of leaf area index on rice growth

Leaf area index (LAI) is the area of the leaf surface per unit area of land surface. A LAI is necessary to intercept incident solar radiation. However, the dimension of LAI needed to give maximum crop photosynthesis it depends on the leaf orientation of the canopy. According to Yoshida (1981), 95% of sunlight is absorbed by the leaves in an erect–leaves canopy and 5% reaches the soil surface when LAI is 7.5. In droopy leaved canopy of rice plant, LAI of 3.7 is sufficient to intercept 95% of the sunlight. This means erect leaves allow the sunlight to penetrate deeper into the canopy because they are oriented with the incident sun beams when the sun is high.

An increase in LAI in rice plants is associated with high tillering capacity and shorter plant height. An increase in LAI contributes more to increased grain yield and nitrogen response than a smaller foliar absorption coefficient (De Datta, 1981).

2.4.5 Influence of leaves and stems on total dry matter

The total dry matter of a plant refers to total biological yield which may involve leaves, stalks, straws, and other plant parts that may not be used commercially as economically used parts such as grains. This refers to above ground grown parts however, may involve below ground plant parts for some crops. Grain yield are related to total biomass yield as well as other yield component traits. Grain yield in rice, maize and wheat is correlated positively with biological yield (Fageria, 1997).

2.5 Tillering Characteristics as Affected by Various Factors

The tillering stage starts with appearance of the first tiller from axil of the second leaf of the main culm. The coleoptile and first leaf nodes do not bear tillers. In each tiller, development of prophyll, which corresponds to the coleoptile of main culm, precedes emergence of the first leaf. Primary tillers develop from the main culm in an alternate order. Primary tillers produce secondary tillers in the same order, secondary tillers bear a third group of tillers; the tertiary tillers. The production of tertiary tillers begins at the end of secondary tiller production (Konings, 1995).

There is wide evidence indicating that increased light intensity on canopies leads to higher tillering on rice and other grasses. This effect is more important than that of light on leaf appearance rate. Light intensities lead to highest site filling values. This increase carbon availability usually leads to enhanced root growth and proliferation, tillering might be promoted because of more cytokinins transported from roots (Nishiuchi *et al*., 2012).

Evidence indicate that low temperature promote tillering when plants are compared at a given development stage. But it normally affects on site filling and not on number of tillers per plant at a given time, which may be reduced by low temperature due to slow leaf development on the main axis. Low temperature might exert its effect by changing many physiological variables that are in turn, expected to have an effect on tillering (Gupta and O'Toole, 1986). Tillering is severely affected by low water availability. Leaf elongation is the first and most sensitive process altered by water deficit. Soil water deficits decrease the rate of appearance of mainstem tillers and also severely reduce development of tillers at the coleoptilar node (Konings, 1995).

Rice variety has influence on tiller development and other characteristics. Some varieties produce low number of tillers per plant while others produce many tillers per plant (Te–Tzu and Bardenas 1965). Fageria *et al.* (1997) stated that tillering characteristics is influenced by the genetic characteristics of the variety.

The application of different types and levels of fertilizers may have effect on number of tillers (Fairhurst *et al*. (2007). Application of nitrogen and phosphorous mineral nutrients resulted into increased number of tillers and panicle, panicle length (cm), number of spikelets which consequently increased grain yield (kg/ha). Further, Fageria and Baligar (2001) reported that increase in number of tillers resulted from the increased levels of nitrogen applied.

2.6 Rice Varieties Grown

In Tanzania rice is grown using improved as well as local varieties. Some of the most common improved lowland rice varieties are TXD 306 (SARO 5), TXD 85, Katrin, IR 54, Dakawa, Mwangaza and Kalalu; while upland rice varieties are BKN/RAT 3036A which mature in 125 – 130 days, Salam, Mulmani (130 – 140 days). The local varieties include Supa, Rangimbili, Kahogo, Tulenabwana, Shingoyamwali, Afaa mwanza, and Moshi wakoroboi as described by Ngwediagi *et al.* (2009) and shown in Appendix 2. The attributes that make the varieties to be grown are aroma, palatability, cook ability and milling ability.

2.7 Cultural Practices of Rice Crop in Tanzania

Production of rice in Tanzania is carried out mainly by small–scale farmers. More than 90% of rice in the country is produced by small–scale farmers mostly using conventional agricultural systems on small scale fields ranging between 0.25 and 2 ha, under cultural practices involving hand hoe ploughing and paddling, dry nursery establishment, transplanting, fertilization, hand weeding, harvesting and winnowing (Kanyeka *et al*., 1994; Kajiru, 2006). Small–scale paddy farming practiced in lowlands through traditional or improved small scale irrigation facilities which are completely depend on rainfall (Kashenge *et al*., 2012). Normally, upland rice in Tanzania is grown under intercropping systems such as maize, sorghum or cassava intercrops (FAO, 2002).

2.8 Upland Rice Cultivation

This is the rice produced on flat fields without bunds, where land preparation and seeding are done in dry and in aerobic conditions. Upland rice growing areas of Tanzania normally receive bimodal rainfall with short, low intensity rains commonly known as "*vuli". These rains start in mid of October to December while long heavy rains known as (*masika*) start from March to May. Short rains are utilized for production of short duration crops includes rice. Normally these areas experience high temperature 28^{o}C or more from July to September while October to June is a moderate to cool period varying from 18 to 22^{o}C (Mghase *et al*., 2010).

2.8.1 Site selection and land preparation under upland rice

Soils for upland rice normally are well drainage, fertile with good capacity to retain moisture such that contains some organic matter and or clay. In Tanzania, most of the areas producing upland rice have soil ranging from sandy loam to clay soil with soil pH range of 4.7 to 6.5, these areas experience rainfall ranging between 1 062 and 2 925 mm annually (Mghase *et al.,* 2010).

Land preparation for new farm should start before the rains by uprooting stumps, roots and trees before ploughing. Plough should be done once using tractor, animal traction hand hoe or by new introduced technology of power tiller, this should be followed by fine two harrows. Harrowing should be done two weeks after plough (Oikeh *et al*., 2008). In Tanzania about 95% of rice produced by small–scale farmers whose use hand hoe in land preparation (MAFCS, 2009).

2.8.2 Sowing methods under upland rice

Direct sowing is the most common practice in upland rice. Sowing can be by dibble method whereby 4 to 6 seeds per hill dropped in the depth of 2 – 3cm, planting space of 30 x 30cm. Other method is seed drilling, seeds are drilled sparsely in the small furrow in the interval of 25 – 30 x 5cm and then covered with a soil. Broadcasting is another method of direct sowing whereby seeds are broadcasted in the prepared seedbed. The estimated seed rate for these methods are dibble 50 – 60kg, drill 75 – 80kg and 80 –100kg/ ha for broadcast.

Thinning can be done 2 – 3 weeks after sowing; 2 – 4 seedlings per hill should be maintained to give 22 – 44 plants per m^2 for 30 x 30cm spacing and 50 – 100 plants per m^2 for 25 – 30 x 5cm (Somado *et al*., 2008). In Tanzania the most common used methods are dibbling and broadcasting methods; sowing is done between November and March. In the Lake Zone, planting of both low and upland rice is done between December and January (Kajiru, 2006).

2.8.3 Lowland rain fed

Most of the rice produced in Tanzania fall under this agro–ecosystem. It has a large share in terms of area under cultivation and also rice production. Rice grown under this ecosystem depends on rainfall and normally produced in bunded fields. Most of the growing cycle plants are in watered fields, under anaerobic environment. Most of the crop is transplanted using seedling raised from the nursery; however, in other areas seeds are sown direct under moist condition (Oikeh *et al.*, 2008).

2.9 Important Rice Agronomic Practices

2.9.1 Nursery preparation

The production of lowland rice starts with nursery establishment. Select a good site with well – drained fertile soil exposed to full sunlight. The area should be conveniently located close to the main field to facilities efficient watering when needed. Prepare seed bed at least 7 days but preferably 14 days before sowing, seed bed should be 1 to 1.5m wide, 10 m long, 4 to 6cm above the ground surface, well leveled. Soak the seeds in water for 24 hours spread seeds on the floor, incubate seeds by covering with polyethylene bags for 48 hours for seeds to sprout. Spread the sprouted seed uniformly on a puddle nursery (wet bed nursery) or on a leveled surface for a dry bed nursery (Aucland, 1971). Use seed rate of 80–100kg/ha depending on percentage seed viability and grain filling percentage for the actual requirement. Drain the excess water from the nursery bed for about a week, then flood to 2–3cm depth if using wet bed nursery. 1 000m^2 is required to transplant 1 hectare field i.e. 1:10 ratio.

The nursery should be water regularly to keep the soil moist but not puddle. Seedling are ready for transplanting 3 – 4 weeks after sowing when they have 4 – 5 leaves (FAOSTAT, 2002; Nwilene *et al.*, 2008).

2.9.2 Land preparation under lowland rice system

In Tanzania smallholder farmers have considerable contribution to the whole rice production even though 95% of the field operations are practiced manually (RLDC, 2011). Preparation of the main field starts one to two month before transplanting.

Ploughing (breaking and turning over of the soil) can be done by tractor, animal traction, power tillers or by using hand hoe. The next activity is construction of the bunds around the field for the purpose of retaining water. Then proper levelling by breaking the soil clods is performed to create conducive environment for transplanting, reducing soil permeability and percolation losses (Nwilene *et al.*, 2008).

2.9.3 Transplanting of the seedlings

Seedlings are ready for transplanting when they have four to five leaves, three to four weeks after sowing. Transplant 2 – 3 seedlings per hill to a depth of 3 – 4cm, at the spacing of 30cm x 30cm for late maturity or 20cm x 20cm if there is sufficient soil fertility. Transplanting should be done in the evening to avoid exposing new established seedling from sun. Weeding is a routine activity that should be done immediately when weeds infestation occur (Somado *et al*., 2008).

2.9.4 Cropping sequences

The arrangement of the crops in the successive order is the cropping sequences. Cropping sequence is essential to consider for sustainable production. The sequence not only aim at crop yield but on other hand contributing to sustainable production. Therefore, apart from crops being sown for yield, some are deliberately sown for other functions like soil fertility improvement although; this is very rare due to limited land. Leguminous crops can improve soil fertility through nitrogen fixation. Among cropping sequences tested in India, rice–potato–cowpea was found to have a better productive efficiency than other field crops tested. But vegetable based sequences in rice have also promising production efficiency. Various cropping systems have shown good impact is soil nutrients amendment like improving level of N, P and K (Prasad *et al*., 2011).

2.9.5 Crop protection measures

In rice production, various pests and diseases affect the crop in the field. Some of the most important ones are rice blast (*Magnaporthe grisea*) and rice yellow mottle virus (RYMV). Insects are other threats to rice production. These include stem borers (*Chillo zacconius*) African rice gall midge and birds especial quelea quelea. Some of the measures taken to address insect pests and diseases are breeding for resistant and tolerant varieties, development of integrated pest and diseases management packages and seed treatment by insecticides and fungicides such as Apron Star^{TM} 42 Ws, PROCOT 40 WS and CALTHIO C50 WS (Nwilene *at al*., 2008; RLDC, 2011;). Most commonly used herbicide are Gramoxone (Pre– emergence, Delmin Forte (2, 4 –D amine salt) or Amine Force (2, 4 – D amine). Other enemies like vermin such as Rats (*Rattus rattus)* are controlled by using poison (bait) mixed with maize, sorghum or rice bran; however, local metal traps are also used. Scaring, mechanical kill and aerial sprays are used to control birds (Oikeh *et al.,* 2008).

2.9.6 Rice harvest and utilization

Agricultural Council of Tanzania (ACT) (2007) found that most of the produced rice in Tanzania is by smallholder farmers who have minimum use of mechanized equipments for harvesting and post– harvest operations like threshing and winnowing The current impressions are that post– production is labour intensive, as the operations involve harvesting using sickles and knives, hand– reaping, field sun– drying before threshing by trampling and wind winnowing. These result in poor quality rice since may contain sand, stones and many other contaminants (MAFSC, 2009).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 General Description of Study Area

This study was conducted at Agricultural Research Institute (ARI) Ukiriguru at Machafu block in Misungwi district, Mwanza region, Tanzania. According to Nyambo (1983) the Institute lies between latitude $2^{0}42$ S and longitude $33^{0}.1$ E at an elevation of 1 236 m above sea level. The Institute is located south east of the Mwanza city and east of the Lake Victoria shore. The area experiences short and long rainfall whereby short rains start during the second week of October to the end of December while long rains start during the second week of March to the end of May. Ukiriguru experience a mean annual rainfall ranging between 800 and 1 200 mm and temperature ranges from 18 to 31.5^{o}C.

The ARI–Ukiriguru lies within dry savannas' area and its soils range from granitic hillsands to heavy clays in the valley bottoms, such that all major cotton soils in Western Cotton Growing Areas (WCGA) are represented. Cropping history of the site shows that the land previously used for growing different upland rice varieties during the 2007/2008 and 2010/2011 cropping seasons.

3.2 Experimental Materials

Planting materials used during the experiment were upland rice varieties that were NERICA 1, NERICA 4 and WAB 450. Rice varieties were collected from the Department of Crop Science and Production at Sokoine University of Agriculture

(SUA) includes NERICA 1 and NERICA 4 and from Kilombero Agricultural Training and Research Institute (KATRIN) Ifakara that include WAB 450 both institutions are in Morogoro region. These are short duration rice varieties which were found to adapt well in Lake Zone environmental. Inorganic fertilizers used were urea (46% N) and, triple super phosphate (46% P_20_5) which was bought from Agrochemical supplier (MUKPAR Tanzania, Ltd) based in Mwanza. Cattle manure was collected from farmers' boma's at ARI–Ukiriguru.

3.3 Methods

3.3.1 Soil sampling and analysis

Soil sampling was done as recommended by Okalebo *et al*. (1993) at a depth of 0–30 cm and one composite soil was prepared and taken to SUA at the laboratory of the Department of Soil Science for physical and chemical analysis. The composite soil sample was analyzed for soil pH, particle size distribution, organic carbon, cation exchange capacity (CEC), total N, available P, exchangeable bases namely K, Ca, Na, and Mg and for Micro nutrients Cu, Zn, and Mn.

The soil pH was determined electrometrically in 1:2.5 soil–water suspension as described by McLean (1982). The available P was analyzed using Bray –1 method since a pH of the soil was below 7 (Oisen and Sommers, 1982). Organic carbon was established by wet digestion method of Walkley and Black (Nelson and Sommers, 1982). The total N was determined by the micro – Kjeldahl digestion–distillation method (Bremner and Mulvaney, 1982). The CEC was determined by the buffered ammonium acetate saturation method (Chapman,1965).The quantity of exchangeable bases K^+ and Na^+ determined by Flame photometer while Ca^{2+} and Mg^{2+} by atomic absorption spectrophotometer (AAS) as described by Thomas (1982).

Particle size distribution was determined by the hydrometer method (Juo, 1979) and textural classes by using the USDA textural triangle. Available Cu, Zn, Fe, and Mn measured by AAS (Baker and Amacher, 1982). However, bulk density (g/cm^{-3}) was determined at ARI–Ukiruguru, (due to its characteristics) in the Department of Natural Resource Management by using core method as described by Okelebo *et al*. (1993). Details on soil physical and chemical characteristics determined are shown in Table 2. Farm yard manure was dried at 70^oC to constant weight and grounded to 0.5 mm sieve. The composite sample was analyzed for pH in water at manure solution of 1:2.5, total nitrogen (Bremner and Malvaney, 1982) P, K and total carbon (Andeson and Ingram, 1993).

3.3.2 Land preparation, experimental layout and treatment application

3.3.2.1 Land preparation

Land preparation was done as described by Kanyeka *et al.* (2007) that included ploughing and harrowing using an oxen drawn implement. Construction of ridges was done by using hand hoes at interval of 0.3 m apart which is the recommended inter- rows spacing for upland rice.

3.3.2.2 Experimental layout and treatment application

A split–split plot experiment in a randomized complete block design (RCBD) as described by Kuelh (2000) was applied. The main plot size was $85.05m^2$, sub–plot size was $28.35m^2$ and sub–subplots size was $9.45m^2$. Main treatments (factor A) were three upland rice varieties that included (i) NERICA 1 (ii) NERICA 4 and (iii) WAB 450. Direct seeding was done on 3 December 2011. Seeding was done by the dibbling method whereby 5 – 8 seeds per hill were sown as describe by Kanyeka *et al*. (2007). The sub treatments (factor B) were different fertilizer types. (i) Farm yard manure (FYM) at the rate of 5t/ ha, (ii) urea 46% N at a rate of 80 kg N/ha and (iii) no fertilizer application (control). Farm yard manure was applied by broadcasting and incorporated in the soil before sowing, while urea was applied as top dressing in two splits; first at tillering initiation [i.e.30 Days after planting (DAP)] and second application was done at panicle initiation i.e. 65 DAP as describe by Kanyeka *et al*. (2007).

3.3.3 Other agronomic practices

Other agronomic management practices as described by Kanyeka *et al*. (2007) were applied including application of triple super phosphate (TSP) by broadcasting at a rate of 20 kg P/ha at sowing. Thinning was done to two plants per hill at 14 days after planting to retain two plants per hill. Weeding was done four times at 21, 35, 54 and 70 DAP. Supplementary irrigation was applied once at 68 DAP i.e. at heading stage to rescue crop from drought. There were no incidences of diseases or insects; a small threat from birds was controlled manually by scarring– off the birds.

3.4 Data Collection

3.4.1 Weather data

Daily rainfall (mm), minimum and maximum temperature (^{o}C) and percentage relative humidity (RH%) were recorded from the Tanzania Meteorology Agency (TMA) situated at ARI–Ukiriguru on daily basis. Data on solar radiation were not recorded because there was no equipment for determining this parameter at the ARI–Ukiriguru TMA station. The nearby station, Mwanza airport is 40 km from the ARI Ukiriguru which is too far to give reliable data at the experimental station.

3.4.2 Crop vegetative growth phase

Crop vegetative growth and development stages from emergency to panicle initiation were recorded as described by Wopereis *et al*. (2009). These included days to 50% emergence, plant population at thinning, days to first tiller, number of leaves and total number of tillers.

i. Days to 50% emergence were determined by observing and counting plants when 50% of them had emerged from sowing to 15 DAP (at two leaves).

ii. Plant population was determined by observing and counting plants that had emerged in each plot at 21 DAP (at two to four leaves).

iii. Days to first tillering were obtained by determining a number of days from sowing to when 50% of plants tillering.

iv. Number of leaves per plant determined by counting a number of leaves per plant at the flowering stage.

v. Number of tiller was determined by observing, counting and recording all emerging shoots in the hill from the time of planting to when 50% of plants reached flowering stage.

3.4.3 Reproduction phase

Data pertaining to reproductive phase were recorded as described by Gomez (1972); Wopereis (2009) as shown below.

i. Days to 50% plants heading were determined by counting the number of days from planting to 50% of plants reach heading stage.

ii. Days to 50% flowering were determined by counting number of days from planting to day when 50% of the plants in the plot had flowed.

iii. Days to initial panicle formation were determined by counting number of days from planting to panicle initiation.

iv. Leaf area index (LAI) was determined by taking randomly 10 plants from the middle of plot and determining the variable as follows.

Leaf area was determined as length of the leaf (cm) x width of the leaf (cm) x 0.75 as recommended by Gomez (1972). Leaf area from each leaf was multiplied by the number of leaves per plant and per sampled area cm^2. Leaf area index (LAI) was then calculated using the following ratio;

Total leaf area (cm^2)/ Total ground area (cm^2) from where the plants were sampled.

3.4.4 Ripening phase

Data for ripening phase were collected from flowering stage to maturity stage as described by Gomez (1972) as indicated below:

i. Panicle number was obtained by counting all developed panicles from randomly selected 10 hills from the centre of each plot. The average number of panicle was computed.

ii. Panicle length (cm) was measured from the middle panicle using a meter rule

iii. Total number of spikelets was determined from randomly selected middle panicle and the average was computed.

iv. The 1 000 seeds were weighed using electric balance (Model RB 153–A4ZA10a. 1 500g) and weight recorded.

v. Percent (%) unfilled grains were obtained by threshing middle panicles, counting filled and unfilled grains. Then percentage of unfilled grains was obtained through the relationship between the number of unfilled and total number of grains.

vi. Grain yield weight obtained by harvesting rice from one meter square area in the middle of each plot and threshed accordingly. The paddy were then adjusted at 14% moisture content using the formula that follows, and then the grain weights for each plot were recorded and converted in to kg/ha as described by Gomez (1972).

$$\text{Adjusted grain weight} = (A \times W) \quad \text{.....(1)}$$

$$\text{Adjustment coefficient computed by } A = \frac{100 - M}{86} \quad \text{.....(2)}$$

Where A is adjustment coefficient, M is the moisture content (%) of the harvested grains and W is the weight of the harvested grains.

vii. Total dry matter accumulation was determined using the method described by (Gomez, 1972). At physiological maturity, plants from 1 m^2 area in each plot were harvested at ground level, oven dried at 70^oC for 72 hours and then weighed to get dry matter accumulation per plot. Harvest index computed as described by (Fageria, 2001) as follows below:

viii. Harvest index = $$\frac{\text{Grain yield (g)}}{\text{Total biomass } (m^{-2})} \quad \text{.....(3)}$$

3.5 Data Analysis

Data collected were subjected to analysis of variance (ANOVA) using the following statistical model version:

$Yijk = \mu + R_i + Vj + (Ea)_{ij} + (F)k + (VF)_{jk} + (Eb)_{ik} + (W)_l + (VW)_{jl} + (FW)_{kl} + (VFW)_{jkl} + (Ec)_{ijkl}$

Where;

Y_{ijkl} = Response,

μ = General mean,

R_i = Replication effect (ith)

$(V)_j$ = jth effect of varieties,

$(Ea)_{ij}$ = Main plot error (error a),

$(F)_k$ = ith effect of fertilizer,

(VF)jk = Interaction of varieties and fertilizer,

$(Eb)_{ik}$ = sub–plot error (error b)

(W)l = Water conservation method effect,

$(VW)_{jl}$ = interaction of varieties and water conservation method

$(FW)_{kl}$ = Interaction of fertilizer and water conservation method,

$(VFW)_{jkl}$ = Interaction of varieties, Fertilizers and Water conservation method,

$Ec)_{ijkl}$ = Experimental error.(error c)

The mean separation test was done using Student Newmans Kuels (S–N–K) at $P \leq 0.05$. All computations were done using the Genstat statistical software version 14. Simple correlations were calculated and analyzed at $P \leq 0.05$ where the numbers of observations were 81 while the degrees of freedom used were n–2 (Gomez and Gomez, 1984).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Soil Characteristics

4.1.1 Physical characteristics

The physical analysis results of the composite soil sample collected from the experimental area is presented in Table 2. The soil composition was found to be 71% sand, 23% clay and 6% silt. According to Gerakis and Baer (1999), this soil can be classified as Sand clay loam. The soil had bulk density 0.934 g/cm^3, buck density is an indication of a soil compaction USDA (2008). The low bulk density reported in this study indicates that the soil has high soil porosity and low soil compaction.

4.1.2 Soil chemical properties

4.1.2.1 Soil pH

The soil pH was found to be 6.07 which can be classified as medium. The optimum soil pH for upland rice is 4.7 – 7.0 (Somado *et al.*, 2008). Based on these findings, soils at Ukiriguru were found to be suitable for upland rice cultivation.

4.1.2.2 Total nitrogen

The percentage of total nitrogen recorded was 0.08% which is very low according to Landon (1991). Nwilene *et al*. (2008) revealed that N < 1.0 g of total N/kg was rated as low. Low amount of total nitrogen reported in this study may be associated with continuous cultivation without addition of any soil amendments such as use of organic or inorganic fertilizers. From this result the amendments of the soil suggested for optimal upland rice production.

4.1.2.3 Available phosphorus

The available phosphorus in the soils at the site was 2.09 mg/kg which is rated as low (Landon, 1991). Wopereis *et al*. (2009) rated P as low when it was 3 – 6mg/kg. Although rice is a low P demanding crop, current results indicate that soils used would not satisfy the phosphate requirement for the crop. Therefore, it is important for rice growers in the area to abide by P recommendation given by researcher such as Kanyeka *et al.* (1997).

4.1.2.4 Potassium (K)

The exchangeable K in the soil was found to be 0.36 $cmol_c^{(+)}$ /kg of soil, which is rated as medium (Landon, 1991). Pillai (2005) reported the minimum absolute level of exchangeable K in soils to range between 0.07 and 0.2$cmol_c$ K/kg soil. Thus the soil K value of 0.36 $cmol_c^{(+)}$/ kg soil at the site used was above the minimum levels of 0.07 and 0.2$cmol_c$ K/kg soil. Basing on these results, the area does not need application of K. These results have also been reported by Kanyeka *et al*. (2007) for rice growing areas in Tanzania.

4.1.2.5 Organic carbon

The organic carbon content in the soil was 0.58%. The value rated as being very low Landon (1991) for rice production as is less than 2%. For improvement of the soil condition for upland rice production amendment of the soils should be done through incorporating manure and plant residues in the soils. According to Nwilene *et al*. (2008) N is rated as low when in < 1.0 g total N/kg, medium when 1.0 – 2.0 g total N/kg and high when >2.0 g total N/kg.

4.1.2.6 Cation exchange capacity

The cation exchange capacity (CEC) of the area was 9.6$cml_c{}^{(+)}$ /kg, which is rated as low (Landon, 1991). The low to medium CEC of the soils could be attributed to the low organic matter content in the soils as well as the nature of the parent materials from which the soils were developed and the type of the layer silicate clay minerals in the soils. The physical and chemical characteristics of the soils showed low percentage of clay and very low organic matter. Since the CEC value was low, the results also show low nutrients content and low capacity of soils to hold moisture, which are important for upland rice production. To improve the soil CEC, amendment of soil is suggested such that application of organic fertilizers in the soil. Heilligmann (1994) reported that, organic matter and clay mineral of the soil have negative charged sites on their surfaces which adsorb and hold positive charged ions (cations) by electrostatic force. This electrical charge is critical to the supply of nutrients to plants because many nutrients exist as cations dissolved in the soil water and adsorbed on the surface of the soil colloids. The CEC might be viewed as reservoir of plant nutrients i.e. the higher the CEC, the larger the reservoir (Koelling, 1995).

4.1.2.7 Exchangeable bases (Ca, Mg and Na)

Calcium availability at the experimental site was 3.38 $cmol_c{}^{(+)}$ /kg, which rated as high >2 $cmol_c$Ca /kg soil (Landon, 1991). From these results the soils in the study area have sufficient Ca for the production of rice. According to WARDA (2007) adequate supply of Ca increase resistance to disease such as bacteria leaf blight or leaf spot. Deficient of Ca results in chlorotic – necrotic and impaired root function which may predispose the rice plant to Fe toxicity. The exchangeable Mg in the soil (Table 2) was 0.85cmol$_c$ $^{(+)}$ /kg. The value rated as high (>0.5 cmol$_c^{(+)}$ /kg soil), according to Landon (1991). Following the results the soil in the study area had enough amount of exchangeable Mg for rice production. Magnesium activates several enzymes. It is a constituent of chlorophyll and thus is involved in CO_2 assimilation and protein synthesis, it also activator of several enzymes and is a constituent of chlorophyll. Magnesium also regulate cellular pH and cation – anion balance, Mg is retranslocated easily from old leaves to young leaves (WARDA, 2007). The exchangeable Na in the soils was 0.4cmol$_c$ Na /kg soil, this value was rated as low (Landon, 1991). Based on the results the level of sodium in the experimental area is not sufficient for the production of rice, therefore amendments of the soil is suggested.

4.1.2.8 Micronutrient

The available Zn in the soil was 0.39mg/kg (Table 2) which is rated as low, Landon (1991). Zinc rated as low when it is 0.5 to 1.0 (De Datta, 1989). Similar values were reported for upland crops by Gupta and O'Toole (1986). The availability of both resident soil zinc and applied zinc is much higher in upland soils than in submerged soils. Soil submergence causes a substantial decrease in the zinc concentration in the soil solution; however, some rice varieties differ in their ability to grow on zinc–deficient soils (Gupta and O'Toole, 1986).

Table 2: Some of the physical and chemical properties of the soils at 0 – 30 cm depth at Machafu block, Ukiriguru

Soil characteristic	Method	Value	Remarks
Physical characteristics			
Soil particle analysis	Hydrometer		
Sand		71 %	Textural class
Silt		6 %	Sand clay loam
Clay		23 %	
Bulk density	Core Method	0.938g/cm^3	Low
Chemical characteristics			
Soil pH	Electrometrical in 1:2:5 soil H_2o	6.07 (H_2O)	Medium
Total Nitrogen	Micro Kjeldhl	0.08 %	Very Low
Available Phosphate	Bray 1	2.09 mgP /kg	Low
Potassium (K^+)	Flame photometer	0.36 $cmol_c^{(+)}$ /kg	Medium
Organic carbon	Walkley and Black	0.58 %	Very low
CE C	Buffer ammonium acetate	9.6 $cmol_c^{(+)}$ kg	Low
Exchangeable Bases			
Calcium (Ca^{2+})	Atomic absorption spectrophotometer	3.38 $cmol_є^{(+)}$/kg	High
Magnesium (Mg^{2+})	Atomic Absorption spectropotometer	0.85 $cmol_c^{(+)}$ /kg	High
Sodium (Na^+)	Flame photometer	0.14 $cmolc^{(+)}$ /kg	Low
Micro nutrients			
Copper ($Cu^{2+)}$	DTPA extract measured by ASS	0.35 mg/ kg	Low
Zinc ($Zn^{2+)}$	DTPA extract measured by ASS	0.39 mg/ kg	Low
Manganese ($Mn^{2+)}$	DTPA extract measured by ASS	56.34 mg/ kg	Very high

According to Landon, (1991)

4.1.2.9 Chemical properties of the FYM

Some of the chemical properties of FYM used in this study are presented in Appendix 3. The results showed nitrogen content of 0.95% and organic carbon of 6.89% which were low according to Locomte (1980). The low values of these nutrients could be attributed to the types of feeds given to the animals, digestion efficiency of the animals and FYM handling. Available phosphorus was high as its value was 1.48mgP/kg, while potassium was 1.38$cmol_c$ $^{(+)}$/kg was also high. With respect of Zn, and Mg the values were found to be 165.5 and 0.75$cmol_c$ $^{(+)}$ /kg. These values of Zn and Mg were high according to Weller and Willetts (1977). This could probably be associated with the types of feed supplements given to the animals. The pH 8.4 of FYM was within the range from 6.5 to 8.5 accepted as reported by Locomte (1980).

4.2 Weather Data During Growing Season

4.2.1 Rainfall (mm)

Primary weather data on rainfall, temperature and relative humidity were collected from the Tanzania Meteorology Agency (TMA) at Ukiriguru Research Institute. The rainfall amount during the growing seasons is as indicated in Table 3. The rice test crop was planted 03 December 2011, the time when rainfall amount and distribution were good. Total monthly rainfall amount were 125 and 173.3mm during the month of November and December 2011, respectively. The rainfall distribution had good impact in crop growth and establishment on all treatments. However, the situation was worse in January 2012 when total monthly rainfall received was 11.4 mm. Upland rice grows and develops well to give the optimal yield when 1 000 mm well distributed rainfall is obtained during the growing season (Somado *et al*., 2008). During the growing season, amount of rainfall received and its distribution were not adequate in some of the months (Fig. 1) as some week had 0 or less than 5.0 mm especially during the months of January, February and March 2012.

4.2.2 Temperature (^oC) and relative humidity (%)

The atmospheric temperature has considerable effect on growth and development of rice. The recorded mean maximum temperature during growing season was 29.3 while the mean minimum temperature during the period was 18.6^{o}C, respectively. This recorded temperature was optimum for rice growth and development (Yoshida and Parao, 1976). According to the author for higher rice grain yield, a day temperature of 25 to 32^{o}C and night temperature range from 15 to 20^{o}C are preferred.

Relative humidity (RH) at experimental site ranged from 60.8 to 89.4% in December 2011 to March 2012 as shown in (Table 3, Fig. 1). The recorded RH was 89.4 in December 2011 was received at the time of planting and 67.4% in May 2012 at the time of harvest. The mean RH during the growing season was 75%. According to Oikech *et al.* (2008) optimum RH range from 60 to 70% are beneficial for crop development. The observed RH was above the preferred value required for rice production.

Table 3: Weather data for 2011/2012 growing season at Ukiriguru

Month/Year		**Temperature (^oC)**		
Nov 2011	**Rainfall (mm)**	**Max**	**(Min)**	**RH (%)**
Week 1	6.2	27.9	19.0	83.0
Week 2	16.1	27.4	18.4	90.4
Week 3	60.4	26.4	18.6	90.8
Week 4	42.3	25.3	18.5	90.3
Total	**125**	**–**	**–**	**–**
Mean	**31.3**	**26.8**	**18.6**	**88.6**
Dec 2011				
Week 1	38.1	26.6	18.2	92
Week 2	6.6	27.5	18.9	87.4
Week 3	82.5	27.3	18.5	88.4
Week 4	46.1	28.4	18.8	89.6
Total	**173.3**	**–**	**–**	**–**
Mean	**43.3**	**27.5**	**18.6**	**89.4**
Jan 2012				
Week 1	1.8	29.2	17.5	88.6
Week 2	1.8	29.5	19.2	84.6
Week 3	6.7	28.5	18.4	87.6
Week 4.	1.1	31.1	18.9	77.4
Total	**11.4**	**–**	**–**	**–**
Mean	**8.9**	**29.6**	**18.5**	**84.6**
Feb 2012				
Week 1	0.0	32.5	18.8	53.9
Week 2	5.3	32.1	20.4	51.3
Week 3	27.6	34.9	18.2	71.2
Week 4	24.1	30.5	18.6	71.7
Total	**57**	**–**	**–**	**–**
Mean	**14.3**	**32.5**	**19.0**	**62.0**

Table 3 Continued

Month/Year		**Temperature °C**		
March 2012	**Rainfall (mm)**	**Max**	**Min**	**RH (%)**
Week 1	29.5	26.4	17.7	66.9
Week 2	0.4	30.5	18.5	64.9
Week 3	3.8	31.1	18.5	56.6
Week 4	2.8	34.9	19.8	55.0
Total	**36.5**	**–**	**–**	**–**
Mean	**9.13**	**30.7**	**18.8**	**60.8**
April 2012				
Week 1	32.6	28.7	18.6	75.5
Week 2	29.7	32.7	18.7	68.1
Week 3	16.5	28.1	18.4	74.9
Week 4	113.6	27.6	17.9	71.5
Total	**192.4**	**–**	**–**	**–**
Mean	**48.1**	**29.3**	**18.4**	**72.5**
May 2012				
Week 1	22.8	28.2	18.7	71.4
Week 2	16.5	28.6	18.4	68.4
Week 3	13.6	28.7	18.9	70.2
Week 4	2.7	29.9	18.3	59.4
Total	**55.6**	**–**	**–**	**–**
Mean	**13.7**	**28.8**	**18.6**	**67.4**
Annual total	**651.2**	–	–	**–**
Annual mean	**93.03**	**29.3**	**18.6**	**75**

Source: Tanzania Meteorological Agency; Ukiriguru station 2011/2012

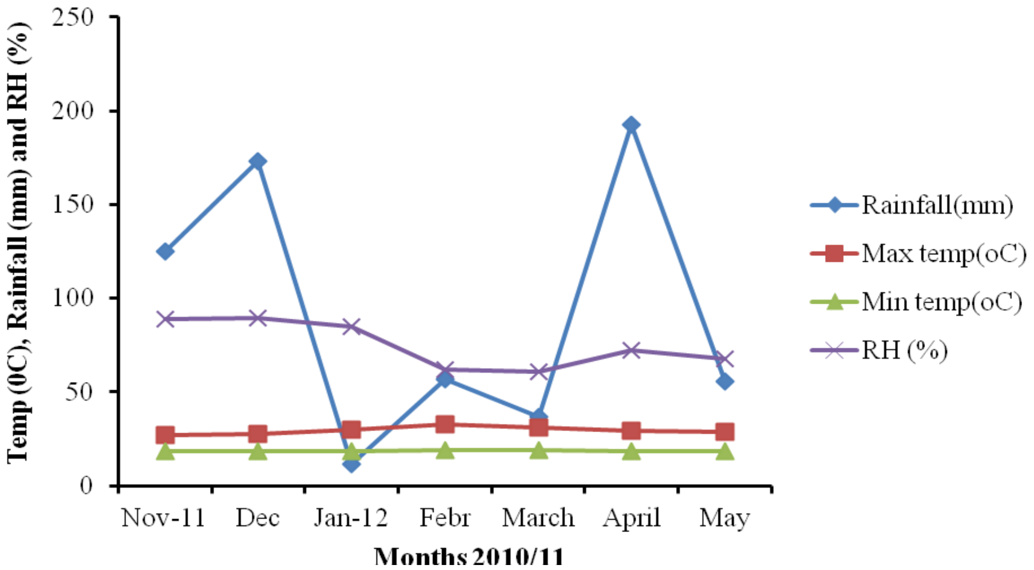

Figure 1: Weather condition during cropping season (Nov 2011 – May 2012)

4.3 Upland Rice Growth Pattern of Selected Cultivars

The crop growth patterns observed during the cropping season are as shown in Table 4. Days from sowing to 50% emergence ranged between 6 and 7 Days after planting (DAP). First tillering among the cultivars used was between 30 and 35 DAP, while days to 50% heading ranged between 75 - 83 DAP. Finally DAP to 50% physiolo gical maturity was between 110 – 119 with a range of 9 days between cultivars.

Cultivar WAB 450 was the earliest to flower taking 79 DAP while cultivar NERICA 1 was the latest taking 86 DAP. The same pattern was observed for number of days taken to mature. Although radiation data could not be collected as stated in subsection 3.4.1, the characteristics may have been influenced by both the cultivars genetic characteristics expression and environmental condition. According to Atera *et al.* (2011) day to maturity for NERICA 1 and NERICA 4 in Kenya were reported to be 102 and 105 DAP respectively. The NERICA varieties in Kenya were planted in western Kenya at 0^{o} 29′N latitude and 34^{o}.07′E longitude, at 1 189 m above sea level. The area experience annual rainfall ranging from 653.5 to 848 mm, while it has been reported by the Ministry of Agriculture and Co operatives Zambia (MACZ) (2010) that days to maturity for NERICA 1 ranged between 105 and 115 while NERICA 4 was 110 – 120 days after planting, under low lying area at 1 700 m above sea level, the area received annual rainfall ranging from 450 to 500 mm under crop rotation cultural.

Table 4: Crop growth pattern as affected by cultivars used

Growth stages	NERICA 1	NERICA 4	WAB 450	Range	Average
Days at planting	0	0	0	0	0
Days to 50 % Emergence	7	7	6	1	6
To first tiller initiation	35	33	30	5	32
Days to 50 % heading	83	77	75	8	78
Days to 50 % flowering	86	81	79	7	82
Days to 50 % Physiological maturity	119	114	110	9	114

Inferential statistical analysis not done for these data

4.3.1 Effects of varieties, fertilizer and water conservation methods on growth characteristics

4.3.1.1 Effect of treatments on plant height and leaf area index (LAI)

The results in this study showed that among three cultivars used, cultivar WAB 450 had significant effect ($P \leq 0.05$) in plant height. The plant height was in this order WAB 450 had 73.04 cm, NERICA 4 had 64.48 and NERICA 1 had 64.18 cm (Table 5). Furthermore, the results indicated that there was no significant effect in leaf area index among the three cultivars. However, differences among the cultivars existed such that NERICA 4 had 1.48, WAB 450 had 1.45 and NERICA1 had 1.31. The different in plant height could be attributed to genotypic differences.

The effect on application of different fertilizer types on plant height and Leaf Area Index (LAI) showed that application of urea at a rate of 80 kg N/ha resulted into the highest plant height of 68.27 cm while the shortest plant height of 65.82cm was observed from control plots. Moreover, the same trend was observed in the LAI such that urea resulted into 1.93, FYM had 1.59 and control had the value of 0.70. The increase in plant height with urea application compared to FYM and control could have been associated with the fact that nitrogen from inorganic sources have ammonium and nitrate which was available to plant use instantly after being applied compared to FYM which had to be decomposed and converted to ammonium and nitrate before being used by plant, this was also reported by Mattson *et al*. (2009). The use of different water conservation methods indicated that there was no significant effect ($P \leq 0.05$) on LAI such that tie ridges had 1.49, flat cultivation had 1.46 and open ridges had 1.28, respectively. The effects on plant height were significant ($P \leq 0.05$) among the conservation methods. Tie ridges had the highest plant height of 68.20cm, flat cultivation had 66.85cm while open ridges had 66.66 cm. These differences in plant height could be attributed to the ability of tie ridges in conserving moisture which was utilized by plants in drought condition. The present results are also supported by Allahyar (2011) who reported that moisture and nitrogen fertilizer had significant influences on plant height, total dry matter, a number of tillers, days to flowering and days to physiological maturity.

4.3.1.2 Effects of treatments on total dry matter and harvest index

Total dry matter was significantly affected ($P \leq 0.05$) by the cultivars used in this study as indicated in Table 5. Cultivar WAB 450 had highest total dry matter (TDM) production of 488.42g/m^2 while NERICA 4 had the lowest TDM production of 437 g/m^2 at 115 DAP. The effect of cultivars on harvest index indicated that cultivar WAB 450 had the highest harvest index of 0.58 followed by NERICA 4 with 0.57 which statistically was not significantly different from that of WAB 450, while NERICA1 had lowest harvest index of 0.54 at 115 DAP. The results could have been attributed to cultivar growth characteristic as results of cultivars genotypic difference.

The application of urea at 80 kg N/ha had significant effect ($P \leq 0.05$) on TDM with the value of 569.30g/m^2, while as expected the lowest amount was found in the control plots that was 349.25g/m^2. The effect of application of different fertilizer types on harvest index indicated that application of FYM had highest HI value of 0.61, followed by application of urea at 80kg N/ha 0.58 and the lowest value of HI observed in control plots that was 0.50. The results could have been attributed to the fact that inorganic fertilizers are readily available to plant after being applied. The effect of the use of different water conservation methods on TDM production and HI resulted on significant effect ($P \leq 0.05$) on total dry matter production such that; tie ridges had the highest TDM of 498.69g/m^2 followed by open ridges 468.89 g/m^2 and lowest was flat cultivation 415.6g/m^2. While tie ridges again had significant effect ($P \leq 0.05$) on HI such that had 0.60 compared to the use of open ridge had 0.56 and flat cultivation 0.54. These results are supported by Rahma *et al*. (2007) who reported that plant height, number tiller, number panicle, panicle length, number of filled grains per panicle, 1 000–grain weight, harvest index (HI), total dry matter (TMD) and yield were decreased with increasing moisture deficient. On the other hand, Sarvestani *et al*. (2008) reported that plant height was significantly affected by water stress at booting, flowering and grain filling stages over the control. Information with regards to agronomical and socio economic factors influencing upland rice productivity and NERICA adaptation in Tanzania is inadequate (Mghase. 2010). This means few research on upland rice particularly on NERICA have been conducted and results reported in Tanzania.

Table 5: Effects of cultivar, fertilizer and water conservation method on rice growth characteristics

Treatment effect	LAI	PH(cm)	TDM(g/m^2)	HI(115 DAP)
Varieties (A)				
NERICA 1	1.31a*	64.18a	457.42a	0.54a
NERICA 4	1.48a	64.48a	437.41a	0.57b
WAB 450	145.a	73.04b	488. 42b	0.58b
Mean	**1.41**	**67.23**	**436.6**	**0.56**
SE±	**0.35**	**0.46**	**15.32**	**0.02**
CV (%)	**24.6**	**1.0**	**3.5**	**4.1**
Fertilizer (B)				
Control	0.70b	65.82 a	349.25a	0.50a
Urea	1.93c	68.27 **c**	569.30c	0.58b
FYM	1.59a	67.62 **b**	464.70b	0.61c
Mean	**1.41**	**67.23**	**436.6**	**0.56**
SE±	**0.09**	**0.45**	**18.32**	**0.03**
CV(%)	**6.5**	**0.7**	**4.2**	**4.8**
W CM				
Flat	1.46a	66.85a	415.68a	0.54a
Open ridge	1.28a	66.66a	468.89b	0.5.6c
Tie ridge	1.49a	68.20b	498.69c	0.60b
Grand Mean	**1.41**	**67.23**	**436.6**	**0.56**
SE±	**0.14**	**0.44**	**17.84**	**0.01**
CV (%)	**10.1**	**0.7**	**4.1**	**1.7**

*Means in the same column followed by the same letter are not significantly different at P≤ according to Student New Keul test (P ≤ 0.05)

Note LAI = Leaf area index, PH=Plant height(cm), TDM= Total dry matter(gm^{-2}) and HI= Harvest index

4.4 Effects of Cultivars, Fertilizer Types and Water Conservation Methods on Rice Yield Components and Yields (kg/ha)

4.4.1 Effect of treatments in number of tillers and number of panicles per plant

The values recorded in this study on number of tillers (NT) and numbers of panicles (NP) at flowering were the same within the treatments applied. Among the rice cultivars used in the study, cultivar WAB 450 had significant effect ($P \leq 0.05$) on number of tillers (Table 6). The average highest number of tillers per plant on WAB 450 recorded was 10.37 while cultivar NERICA1 had the lowest number of tillers 8.56 at flowering. This is in agreement with Fageria *et al.* (1997) who stated that tillering characteristics among other factors is very much influenced by the genetic characteristics of the cultivars grown.

Under application of different fertilizer type, urea (46%N) at 80kg N/ha produced the highest number of tillers per plant (10.68); followed by FYM (9.25) and lastly control plots (7.89). These results are similar to those by Fairhurst *et al.* (2007) in which application of N and P nutrients resulted into increase in numbers of tillers and panicle, panicle length (cm), number of spikelets and consequently increase in grain yield. Fageria and Baligar (2001) also reported that increase in number of tillers resulted from the increased levels of nitrogen applied. This could be the reason for getting the lowest number of tillers in plots where fertilizer was not applied in this study. According to various literatures, including that of Califonia Fertilizer Foundation (2011), FYM (cow manure) is reported to supply nutrients around 1.91% and also improves soil structure leading to improvement of soil water holding capacity. Therefore these two factors inorganic and organic fertilizers have influence on tillering ability of rice crop.

The use of tie ridges resulted into the highest number of tillers per plant (10.34) followed by flat cultivation with (8.97) and lastly open ridges (8.50). The highest number of tillers under tie ridging may have influenced by moisture conserved by the ties. Similar trend of results was observed from the numbers of panicle per plant and panicle length (cm) reported in this study. The influence of soil moisture management also resulted into similar results on number of tillers and panicle as each developed tiller produced a panicle.

4.4.2 Effect of treatments on panicle length (cm)

The effect of treatments on panicle length showed that cultivar WAB 450 had significant effect ($P \leq 0.05$) on panicle length (cm), cultivar had the longest panicle length with 19.29cm, while cultivar NERICA 4 had the shortest panicle length with 17.79cm. This could have been influenced by both environmental factors and genetic characteristic of the cultivar. On the other hand, application of urea fertilizer 80 kg N/ha resulted into longest panicles with 19.73cm while control had the shortest panicles of 17.54cm, and FYM had average panicle length of 18.24cm (Table 6).

The use of different moisture conservation methods indicated that the use of tie ridges gave the longest panicle length (19.33cm) followed by flat cultivation (18.22 cm) and lastly open ridges (17. 96cm). These results might have been influenced by the ability of tie ridges to conserve moisture which was made available for plant use. Sikuku *et al*. (2010) reported increases in panicle length with increase of soil moisture availability, the condition that may have influenced the results reported in this study.

Table 6: Effects of cultivar, fertilizer and water conservation methods on grain yield components and yield

Treatment effect	NT Plant^{-1}	NP Plant^{-1}	PL(cm)	NS Panicles^{-1}	UG (%)	GY (gm^{-2})	GY Kg/ha
Variety							
NERICA 1	8.56a*	8.56a	18.24a	25.75b	21.70c	0.2140a	2140a
NERICA 4	8.88b	8.88b	17.97a	25.23a	18.26a	0.2506b	2507b
WAB 450	10.37c	10.37c	19.29b	35.66c	19.15b	0.2855c	2856c
Mean	**9.27**	**9.27**	**18.50**	**28.88**	**19.70**	**0.2500**	**2500**
SE±	**0.33**	**0.33**	**0.55**	**0.61**	**3.26**	**0.01**	**58.3**
CV (a)%	**3.5**	**3.5**	**2.9**	**2.1**	**16.5**	**2.3**	**2.3**
Fertilizer							
Control	7.89a	7.89a	17.54a	26.92a.	24.33c	0.1411a	1412a
Urea	10.68c	10.68c	19.73b	31.89b	16.37a	0.3367c	3368c
FYM	9.25b	9.25b	18.24a	27.84a	18.41b	0.2722b	2723b
Mean	**9.27**	**9.27**	**18.50**	**28.88**	**19.70**	**0.2500**	**2500**
SE±	**0.08**	**0.08**	**0.45**	**0.29**	**2.75**	**0.01**	**62.8**
CV (b)%	**0.9**	**0.9**	**2.4**	**1.0**	**14.0**	**2.5**	**2.5**
WCM							
Flat cultiv	8.97b	8.97b	18.22b	28.03a	22.30b	0.2394a	2394a
Open ridge	8.50a	8.50a	17.96a	27.47a	22.52b	0.2397a	2398a
Tie ridge	10.34c	10.34c	19.33c	31.15b	14.30a	0.2710b	2710b
G/mean	**9.27**	**9.27**	**18.50**	**28.88**	**19.70**	**0.2500**	**2500**
SE±	**0.23**	**0.23**	**0.18**	**0.39**	**1.97**	**0.004**	**42.3**
CV (c)%	**2.5**	**2.5**	**1.0**	**1.4**	**10.0**	**1.7**	**1.7**

*Means in the same column followed by the same letter are not significantly different according to Student New Keul test ($P \leq 0.05$)

Note: NT=Number of tillers, NP= Number of panicle plant^{-1}, PL=panicle length, NS =number of spikelets^{-1}, UG= unfilled grain(%), GY= grain yield Kgha^{-1}, WCM = water conservation method, FYM= farm yard manure.

4.4.3 Effects of treatments on number of spikelets and unfilled grains (%)

The effect of treatment on number of spikelet showed that WAB 450 had significant effect ($P \leq 0.05$) on spikelets with mean of 35.66 spikelets per panicle. NERICA 4 had the lowest number of spikelets, averaging 25.23 per panicle, while NERICA 1 was in the middle with average spikelets number of 25.75. On the other hand NERICA 1 had significant effect ($P \leq 0.05$) on percentage unfilled grains with the highest percentage (21.70%) followed by WAB 450 (19.15%), while NERICA 4 had lowest percentage unfilled grains of (18.26%). These results could have been influenced by both environmental and genetically characteristics of cultivars as stated in sub sections 4.4.1 and 4.4.2, such that some cultivars have high nutrient use efficiency due to nature of their roots system, some have long or many roots. However, some cultivars have either many or few numbers of tillers these factors may contribute in nutrients, water and light competition which may have an impact on grain filling and yield.

On the other hand the application of urea had highest number of spikelets per panicle (31.89) while control plots had the lowest (26.92) and FYM had average of (27.84) spikelets per panicle. These results may have been influenced by the application of inorganic fertilizer as described by Mattson *et al.* (2009) reported on the presence of ammonium and nitrate in inorganic fertilizer which can be available for plant use immediately after being applied compare to FYM which needs to decompose before be available for plant uptake. Chaturvedi (2005) reported the increase of yield components in rice with the use of urea.

The use of tie ridges as water conservation measure showed promising results on number of spikelets per panicle with average of (31.15) spikelets per panicle while open ridge had the least number (27.47) and flat cultivation ranked the second after tie ridge with 28.03 spikelets per panicle. These results could have been associated with low ability of open ridges and flat cultivation to retain or conserve water in the soil, while the capacity of tie ridges to hold water and let it infiltrate hence increasing soil moisture availability. Mutune *et al*, (2011) also reported on the efficiency of tie–ridges in conserving soil water and raising the level rice of production. Furthermore, NERICA1 had the highest (%) of unfilled grain 21.70 followed by WAB 450 with 19.15% while NERICA 4 had the lowest 18.26%. These results could have been contributed by environmental and genetic characteristic of the cultivars. With regard to fertilizer application urea had the lowest percentage unfilled grains (16.37) followed by FYM (18.4) and control (24.33). These results also supported by Califonia fertilizer foundation (2011) reported that cow manure is reported to supply nutrients around 1.91% and also improves soil structure leading to improvement of soil water holding capacity. Therefore these two fertilizers; inorganic and organic have influence on grain filling of rice crop.

With regard to different water conservation methods, tie ridges had lowest percentage unfilled grains (14.30) followed by flat cultivation (22.30) and open ridges (22.52). These results contributed by the moisture stress which had impact on plant chemical and physiological processes, like photosynthesis, transpiration and nutrient uptake which are important in sink production and partition in the plant. The importance of tie ridges was described in sub section 4.4.2.

4.4.4 The effects of treatments on rice grain yield

Rice cultivars differed significantly in grain yield. Cultivar WAB 450 giving the highest grain yield of 2 856kg/ha followed by NERICA 4 which had 2 507kg/ha and lastly NERICA 1 with 2 140 kg/ha (Table 6). The present results could have been influenced by cultivar genetic characteristics since WAB 450 had the highest number of tillers, panicles per plant, spikeletes per panicle and panicle length (cm). These yield components had high significant ($P \leq 0.05$) correlation with r = 0.823*** to grain yield (Appendix 4). Other two rice cultivars, i.e. NERICA 1 and NERICA 4 had the lowest values in the number and size of the yield components. Fageria *et al*. (2011) found that yield components, like number of panicle, numbers of tiller, number of spikelets and panicle length (cm) were significantly and positively associated with grain yield in upland rice.

The increase of number and size of yield components is attributed to grain yield as they have significant correlation of r = 0.823*** for the number of tiller, r = 0.535 *** for the number of spikelets and r = 0.8238*** for number of panicle in grain yield (Appendix 4).

Application of urea gave significantly different on grain yield of 3 368kg/ha, followed by FYM (2 723kg/ha) and lastly the control (1 412kg/ha). The significant effect of urea application could be associated with the ability of ammonium to be readily available immediately after application. Elsewhere, Saidu *et al.* (2012) reported that nitrogenous fertilizers in the form of ammonium are known to have the peculiarity of fast release of their nutrient contents compared to FYM which release nutrients gradually as they need to be converted to ammonium before being released for plant. Similar results were reported by Fageria *et al.* (2011) in which use of urea resulted into the highest grain yield of 4.49kg/ha. The use of tie ridges resulted into highest grain yield. The grain yields were in the following order 2 710 >2 398 >2 39

4kg/ha for the tie ridges, open ridges and flat cultivation, respectively. According to the results (Table 6) the use of tie – ridges, application of urea and sowing cultivar WAB 450 gave high grain yield as to compare with other treatments such that use open or flat cultivation, FYM or control and use of Cultivars NERICA 1 or NERICA 4. The results indicated the ability of tie ridges in water conservation by the increase number and size of yield components and grain yield. This is supported by observed greater number of tillers per hill, number of panicle per plant, panicle length and number of spikelets per panicle in plots where tie–ridge practiced.

The results are supported by Mutune *et al. (*2011) who revealed that tie–ridges were found as the most effective method in conserving soil water and raising the level of production for mainly field crop in most part of Sub–Sahara areas. The efficiency of ties was also reported by Odunze *et al.* (2010) who found that significantly rice grain yield was obtained under contoured + cross banded ridges (1.68t/ha) where contoured ridge produced 1.64t/ha and flat planting 1.36t/ha. The results suggested that contoured + cross banded ridges would result in 50% higher grain yield up – down in slope ridging whereas contoured ridging alone had 46% more grain yield than up–down slope ridging. The results in these study also indicated the increase number and size of yield components and grain yield where tie – ridge, urea and cultivar WAB 450 interacted compared to other interactions; such that use of open or flat cultivation and FYM or no fertilizer in combination with cultivar NERICA 1 or NERICA 4.

4.5 Interaction Effects of Varieties, Fertilizer Types and Moisture Conservation Methods

According to the results on interaction of three factors that is Upland rice cultivars, (NERICA 1, NERICA 4 and WAB 450), different fertilizer types (FYM, urea and control) and different moisture conservation methods (flat cultivation, open ridges and tie ridges), there were significant effect ($P \leq 0.05$) in three variable that is 1 000 grain weight, number of spikeletes per panicle and leaf area index (Appendex 1). Although there were difference in results between treatment in other variables but statistically are not significant (Appendix 5).

However, according to various statistical literatures, interaction is generally defined as "the effect of one independent variable may depend on the level of the other independent variable". While interaction effect defined as "effect of one independent variable on the dependent variable, depending on the particular level of another independent variable" (Bernstein and Ruth, 1999). From the summary of Analysis of Variance (ANOVA), (Appendix 1), various inferences can be drawn. Much as the ANOVA table indicates the varieties, fertilizer types and moisture conservation methods act differently; the interaction terms are also significant at $P \leq 0.05$. Since the interaction effects within study are significant in some variables it may not be important to discuss difference between various treatments (Kothari, 2011). It is suggested, therefore, to conduct an experiment that will include different levels of treatments and use the graphic method in order to study the interaction effects of factors involved. When the connecting the graphic lines that do cross over each other as recommended by Kothari, (2011); Gomez and Gomez, (1984).

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDETIONS

5.1 Conclusions

Regarding the soil suitability for the upland rainfed rice production, the soil used was found to be moderately suitable for upland rice production due to its soil texture of sand clay loam and its low bulk density of 0.94g/cm^{-3} which plays essential role in increasing the capacity of the soil to hold water for plant use. The soil chemical characteristics of the site was low in total nitrogen (0.08%), organic carbon (0.58%) and available phosphorous (2.08mgp/kg) and cation exchange capacity (9.6cmol$^{(+)}$/kg were found to be low. The soil pH is in the range of 6–8 which is suitable for upland rice production.

Results observed from application of different types of fertilizers showed that the application of urea in a rate of 80kg N/ha had an increase in number of tiller per plant, panicle per plant, panicle length and number of spikelets which contributed on higher grain yield of 3.4t/ha in comparison to application of farm yard manure at a rate of 5t/ha and control that gave 2.7 and 1.4 t/ ha respectively.

Based on the use of different moisture conservation methods on upland rice production particularly in areas with unreliable and poor rainfall distribution, the use of tie–ridges resulted on improved crop growth characteristics that were plant height (cm), leaf area index, harvest index and total dry matter (g/m^{-2}). The increase of number of tiller and panicle per plant, panicle length (cm) and number of spikelets per panicle attributed an increase of grain yield in (g/m^{-2}) compared to those obtained from open ridges and flat cultivation practices.

Among three upland rice varieties used in this study that were NERICA 1, NERICA 4 and WAB 450, rice variety WAB 450 out yielded two NERICAs in both yield components and grain yield in kg/ha, from applied treatments, that were fertilizer types and water conservation methods. This should be based on the interaction results noted in the analysis results.

Based on interaction among treatments the interaction of WAB 450, tie – ridge and use of urea fertilizer out yielded other interaction on number of tillers, plant height, panicle length, number of spikeletes, and grain yield 4 179kg/ha.

5.2 Recommendations

Based on the results it advised that farmers around Ukiriguru should use variety WAB 450 for upland rice production by applying inorganic fertilizer urea at (80kg N/ ha) under tie– ridge as soil moisture conservation method.

Farmers should however be trained through demonstration, farmer field schools and also be encourage to practice the technology that is being recommended.

Also recommend that further studies on socio–economic component of recommended practices i.e. the use of inorganic (urea), organic fertilizer and use of tie–ridges as methods in order to come up with a firm and acceptable recommendation by the upland rice farmers.

Also participatory varieties assessment to observe others attributes farmer consider in choosing variety to adopt (e.g. aroma, grain quality, palatability, etc) should be considered.

REFERENCES

Agricultural Council of Tanzania (2007). *Report on Output Market Support*. Centre for Sustainable Development Initiatives, Dar es Salaam. 82pp.

Allahyar, F. (2011). Interactive effects of nitrogen and irrigation methods on growth and yield of rice in Amol area. *International Journal of Agriculture and Crop Science* 3(4): 111–113.

Amgain, L. P., Devkotal, N. R., Timsina, J. and Singh, B. (2006). Effect of climate change and Co2 concentration on growth and yield of Rice and wheat in Punjab: Simulations using csm–ceres–rice and csm–ceres–wheat wodels. *Journal of Institute of Agriculture and Animal Science* 27: 103 – 110.

Anderson, J. M. and Ingram, J. S. I. (1993). *Tropical Soil Biology and Fertility*. *A hand book of methods*. CAB International, UK. 221pp.

African Rice Centre (2011). *Sustainable Intensification and Diversification of Rice–Based Inland Valley Systems in the National Rice Basket of Tanzania*. Draft concept note Morogoro. 9 pp.

Atera, E. A., Onyango, J. C., Azumal, T., Asanuma, S. and Itoh, K. (2011). Field evaluation of selected NERICA rice cultivars in Western Kenya. *African Journal of Agricultural Research* 6(1): 60 – 66.

Aucland, J. D. (1971). *East African Crops*. *An introduction to the production of field and plantation crops in Tanzania, Kenya and Uganda*. Longman Publisher, London. 252 pp.

Baker, D. E. and Amacher, M. C. (1982). Nickel copper and cadimium. In: *Hand book of Methods of Soil Analysis*. (Edited by Page, A. L., Miller, R. M. and Keeney, D. R.). American Society of Agronomy, Madson, Winscosin. 336 pp.

Benstein, S. and Ruth, B. (1999). *Theory of Problems of Elementary of Statistics II.* The McGraw-Hill Companies, inc.United State of America.

Bremner, J. M. and Mulvaney, C. S. (1982). Total Nitrogen. In: *Methods of soil analysis*. (*Edited by Page, A. L., Miller, R. M. and Keeney, D. R*.), American Society of Agronomy, Madson, Winscosin. pp.149 – 157.

Califonia Fertilizer Foundation (2011). Natural resource fact sheet. [www.learn.ab outag.org] site visited 20/9/2012.

Chapman, H. D. (1965). Cation exchange capacity. In: *Method of Soil analysis*. (Edited by Black, C. A., Evans, D. D., White, J. L., Ensminger, L. E. and Clark, F. E.), ASA, Madison, Winscosin, USA. pp. 891 – 901.

Chaturvedi, I. (2005). Effect of nitrogen on growth, yield and quality of hybrid rice. *Journal of Central European agriculture* 4: 611–618.

De Datta, S. K. (1981). *Principles and Practices of Rice Production*. IRRI. Los Banos, Philippine. 618pp.

De Datta, S. K. (1989). Diagnosis of nutrients deficiency and toxicity. In: *Detecting Mineral Nutrients Deficiencies in Tropical Temperate Crops.* (*Edited by Donald, L. P. and Haward, B. S.*), West view Press, Corolado, USA. pp. 41–51.

Fageria, N. K., Baligar, V. C. and Jones, C. A. (1997). *Growth and Mineral Nutrition of Field Crop.* .Second Edition revised and expanded, Marcel Dekker, INC. New York. Basel. Hong Kong. 624pp.

Fageria, N. K. and Baligar, V. C. (2001). Lowland rice response to nitrogen fertilization. *Soil Science Plant Analysis* 32: 1405–1429.

Fageria, N. K., Moreira, A. and Coelho, A. M. (2011). Yield and yield components of upland rice as influenced by nitrogen sources. *Journal of Plant Nutrition* 34: 361–370.

Fairhurst, T., Will, C., Buresh, R. and Dobermann, A. (Eds.) (2007). *A practical Guide to Nutrient Management*. International Rice Research Institute, Metro Manila, Philippines. 89pp.

Food Agricultural Organization (2002). FAOSTAT data, 2002. [http//www.apps.fao.org/] site visited on 2/7/2012.

Food Agricultural Organization (2007). Factors affecting wetland rice production and the classification of wetlands for agricultural production. [http://www.fao.org/docrep/html] site visited on 12/08/2012.

Food Agricultural Organization (2007). *Fertilizer and Plant Nutrition Bulletin* No. 16. Rome, Italy. 368pp.

Food Agricultural Organization (2009). Corporate document repository [http://www.fao.org /docrop/003/X6 611/x6611e03c. htm] site visited on 12/08/2012.

Gerakis, A. and Baer, B. (1999). A computer program for soil textural classification. *Soil Science Society of America Journal* 63: 807 – 808.

Gomez, K. (1972). *Techniques for Field Experiments with Rice*. International Rice Research Institute, Los Banos, Laguna, Philippines. 48pp.

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

Gupta, P. C. and O'Toole, J. C. (1986). *Upland Rice: A Global Perspective*. International Rice Research Institute Manila, Philippines. 416pp.

Hatibu, N. (2000). Introduction In: *Rainwater Harvesting for Natural Resource Management: A Planning Guide for Tanzania*. (Edited by Hatibu, N. and Mahoo, H. F). Technical Handbook No. 22 RELMA, Nairobi, Kenya 165pp.

Heiligmann, R. D. (1994). Soil and Christmas tree production soil moisture. *Michigan. Chrisimas. Tree Journal.* 40(4): 34417.

International Rice Research Institute (IRRI) (2009). International maize and wheat improvement center. [riceknowledg ebank.http:/www.knowledgebank.irri.org/submergedsoils/rice–growing–env ironment/lesson–4–htm] sited visited on 29/11/012.

Junge, B., Abaidoo, R., Chikoye, D. and Stahr, K. (2008). Soil conservation in Nigeria. Past and present on–station and on–farm Initiative. [www.swcs.org] site visited on 15/11/2011.

Juo, A. S. R. (1979). *Method of Plant Analysis*. International Institute for Tropical Agriculture, Ibadan, Nigeria. 70pp.

Kajiru, G. J. (2006). Soil fertility status and response of rice to nitrogen, phosphorus and farm yard manure under rainwater harvesting system in semi arid areas of Maswa, Tanzania. Thesis for award of PhD Degree at the Sokoine University of Agriculture, Morogoro, Tanzania, 206pp.

Kajiru, G. J. (2010). Effect of ridging on crop production in Shinyanga, Tanzania. In: *Proceedings of the Agricultural Water Management Interventions Bearing Returns on Investment in Eastern and Southern Africa.* (Edited by Bancy, M.and Mati, A.), March 2010 IMAWESA ICRISAT Nairobi, Kenya. pp. 90 – 100.

Kanyeka, Z. L., Msomba, S. W., Kihupi, A. N. and Penza M. S. F. (1994). Rice ecosystems in Tanzania: Characterization and classification. *Research and Training Newsletter* 9(1–2): 13 – 15.

Kanyeka, E., Kamala, R. and Kasuga, R. (2007). *Improved Agricultural Technologies in Tanzania.* 1st edition. Published by the Department of Research and Training, Ministry of Agriculture Food Security and Cooperatives, Dar es Salaam, Tanzania. 125 pp.

Kashenge, K. S. (2012). Farm characteristics and production constraints in selected salt affected areas of north – eastern Tanzania. *Journal Advanced Developed Research* 3(1): 1 – 14.

Kibanda, N. J. M. (2008). Rice research and production in Tanzania. In: *Paper Presented at the African Japanese Plenary Workshop on Sustainable Rice Production Held in Alexandria,* Egypt, 23 –25 August 2008. pp. 1 – 5.

Koelling, M. R. (1995). Soil and christmas tree production oil pH. *Michigan Christimas. Tree Journal 41(1): 37-41*.

Konings, H. (1995). Gravitropism of roots. An evaluation of progress during the last three decades. *Acta Botanica Neerlandica* 44: 195 – 223.

Kothari, C. R. (2011). *Research Methodology, Methods and Techniques.* (2nd Ed.). New Age International Publisher, New Delhi , Bangalore India. 482pp.

Kuahl, R. O. (2000). *Design of Experiments Statistical Principle of Research Design and Analysis.* (2nd edition). Book Cole, Cengagedleas, Learning. 666pp.

Landon, J. R. (1991). *Booker Tropical Soil Manual*, *A handbook for soil survey and agricultural land evaluation in the tropics and subtropics*. John Wiley and Sons Publisher, New York. 155pp.

Lecomte, R. (1980). The influence of agronomic application of slurry on the yield and composition of erable crops and grassland and changes in the soil properties. In: *Efficient from Livestock.* (Edited by Gasser, J.K.R.). Applied Science Publishers Ltd. London. Pp. 139–180.

Ministry of Agriculture Cooperatives Zambia (MACZ) (2010). *Growing NERICA in Zambia Upland.* Rice Food Crop Diversification Support Project, Zambia. 13pp.

Ministry Agriculture Food Security and Cooperative (MAFSC) (2009*).* National Rice Development Strategy Final Draft. Dar es Salaam, Tanzania. 32 pp. [http://www.kilimo.go.tz] site visited on 5/10/2012.

Mattson, N., Leatherwood, R. and Peter, C. (2009). Nitrogen all forms are not equal comparative extension Edition of GMPro Magazine. 5pp.

McLean, E. O. (1982). Soil pH and lime requirement. In: *Methods of Soil Analysis*, (Edited by Page, A. L., Miller, R. M. and Keeney, D. R.), American Society of Agronomy, Madson, Winscosin. pp. 167 – 224.

Meertens, H. C. C. (2003). The prospects for sustainable nutrient management for sustainable rainfed lowland rice production in Sukumaland, Tanzania. *Nutrient Cycling in Agro Ecosystems* 65: 163 – 171.

Mghase, J. J., Shiwachi, H., Nakasone, K. and Takahashi, H. (2010). Agronomic and socio economic constraints to higher yield of upland rice in Tanzania. *African Journal of Agricultural Research* 5(2): 150 – 158.

Mutune, J., Mburu, J., Nyikal, R. and Kiranchi, G. (2011). Determination of adoption of conservation tillage practice in maize–cowpea cropping system: The case study of Makuen district, Kenya. *Journal of Science and Environmental Management* 2(11): 354 – 361.

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

Ngwediagi, P., Maeda, E., Kimomwe, H., Kamara, R., Massawe, S., Akonaay, H. B. and Mapunda, L. N. D. (2009). *Plant Genetic Resources for Food and Agriculture in Tanzania.* Ministry of Agriculture Food Security and Cooperatives, Dar es Salaam, Tanzania. 72pp.

Nishiuchi, S., Yamauchi, T., Takahashi, H., Kotula, L. and Nakazono, M. (2012). Mechanisms for coping with submergence and waterlogging in rice. [http://www.thericejournal.com/content/5/1/2] site visited on 10/01/2013.

Nwilene, F. C., Oikeh, S. O., Agunbiade, T., Oladimeji, O., Ajayi, O., Sie, M., Gregorio, G. B., Togola, A. and Toure, A. D. (2008). *Growing Lowland Rice*. Production hand book Africa Rice Center. Cotonou, Benin. 40 pp.

Nyambo, B. T. (1983). Historical and background information on the research center and its substations. In: *Ukiriguru 50 years of research 1932 to 1982, the golden jubilee*. Published by Tanzania Agricultural Research Organization, Ukiriguru Research Institute. pp. 11– 13.

Odunze, A. C., Kudi, M. T., Daudu, C., Adeosun, J., AyoolaI. G., Amapu, 1. Y. A., Abu, S.T., Mando, A., Ezui, G. and Costance, D. (2010). Soil moisture stress mitigation for sustainable upland rice production in the Northern Guinea of Nigeria. *Journal of Development and Agricultural Economics.* 2(11):382 – 388.

Oikeh, S. O., Nwilene, F., Diatta, S., Osiname, O., Toure, A. and Okeleye, K. A. (Eds.) (2008). *Respond of Upland NERICA Rice to Nitrogen and Phosphorus in Forest Agro Ecosystem.* Department of Plant Physiology and Crop Production, University of Agriculture, Abeokuta, Ogun, Nigeria. 74pp.

Oikeh, S. O., Nwilene, F. F., Angnbiade, T., Oladimeji, O., Ajai, O., Semon, M., Tsenematsu, H. and Samejima, H. (Eds.) (2008). *Growing Upland* Rice: A production hand book, African Rice Centre, Cotonou, Benin. 44pp.

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

Okalebo, J. R., Gathua, K. W. and Woomer, P. L. (1993). *Laboratory Methods of Soil and Plant Analysis.* A working manual. KARI and Rost. TSBF/UNESCO/EPZ, Nairobi, Kenya. 88pp.

Pillai, K. G. (2005). Rice (Oryza sativa L.). World fertilizer use manual. Rice crop Data. In: [www.fertilizer.org/ifa/bublicat/html/pubman/rice.htm.] site visited on 18/05/2005.

Prasad, D., Urkurkar, J. S., Bhoi, S. K. and Nag, N. (2011). Production potential and analysis of different rice based cropping system in Chhattisgarh plain. *Research Journal of Agriculture Science* 2(1): 36 – 39.

Rahman, M. H., Ali, M. H., Ali, M. M., Khatun, M. M. (2007). Effect of different level of nitrogen on growth and yield of transplanted aman rice. *International Journal Sustainable Crop Production* 2(1): 28 - 34

Rural Livelihood Development Company (RLDC) (2011). *Improving Rice Profitability through Increased Productivity and Better Marketing Focusing on Tanzania Central Corridor.* Rice assessment and Draft sector Strategy. Morogoro, Tanzania 37pp.

Saidu, A., Abayomi, Y., Abiola, A. and Morolake, O. (2012). Evaluation of complementary use of organic and inorganic fertilizers on the performance of Upland rice. *International Journal of Advanced Biological Research* 2(3): 487 – 491.

Saito, K., Linquist, B., Atlin, G. N., Phanthaboon, K., Shiraiwa, T. and Horie, T. (2005). Response of traditional and improved upland rice cultivars to N and P in northern Laos. [www.scincedirect.co] site visited on 22/05/2012.

Sanginga, N. and Woomen, P. L. (Eds.) (2009). *Integrated Soil Fertility Management in Africa*: *Principles, Practices and Developmental process*. Topical Soil Biology and Fertility Institute of International Centre for Tropical Agriculture. Nairobi, Kenya. 263pp.

Sarvestani, Z. T., Pirdashti, H., Sanavy, S. A. M. M. and Balouchi, H. (2008). Study of water stress effect in different growth stages on yield and yield components of different rice. *Pakistan Journal of Biological Science* 11(100): 1303 – 1309.

Setter, T. L., Waters, I., Sharma, S. K., Singh, K. N., Kulshreshtha, N., Yaduvanshi, N.P.S., Ram, P.C., Singh, B. N., Rane, J., McDonald, G., Khabaz–Saveri, H., Biddulph, T.B., Wilson, R., Barclay, I., McLean, R., Cakir, M. (2009) Review of wheat improvement for water logging tolerance in Australia and India: the importance of anaerobiosis and element toxicities associated with different soils. *Annals of Botany Journal* 103: 221–235.

Sikuku, P. A., Netondo, G. W., Musyimi, D. M. and Onyango J. C. (2010). Effects of water deficit on days to maturity and yield of three NERICA rainfed rice varieties. *Journal of Agricultural and Biological Science* 5(3): 1 – 7.

Somado, E. A., Guei, R. G. and Keya, S. O. (Eds.) (2008). African Rice Centre WARDA FAO/SAA. *NERICA the New Rice for Africa* – A Compendium. Cotonou Sasakawa Africa Association. Tokyo, Japan. 210pp.

Te–Tzu, T. and Bardenas, E. M. (1965). *The Morphology and Varietal Characteristics of Rice Plant*. Technical Bulletin No. 4: International Rice research Institute, Los Bonos, Laguna, the Phillipines. 284pp.

Thomas, G. W. (1982). Exchangeable cations. In: *Method of soil analysis*. (Edited by Page, A. l., Miller, R. H. and Keeney, D.R.), American Society of Agronomy, Madson, Winscosin. pp.154– 169.

Tunde, A. M., Usman1, B. A. and Olawepo, V. O. (2011). Effect of climatic variables on crop production in Patigi, Kwara state Nigeria. *Journal of Geography and Region Planning* 4(14): 695 – 700.

United States Department of Agriculture (USDA) (2008). Natural Resources conservation service. *Soil quality indicator* [www. natr phys ind Usda.gov] site visited on 15/12/2012.

Wade, L. J., Fukai, S., Samson, B. K., Ali, A. and Mazid, M. A. (1999). Rainfed lowland rice: Physical environment and cultivar requirements. *Journal of Field Crops Research* 64: 3–12.

West Africa Rice Development Association (WARDA) (2007). Report on the Fifth *External Program and Management* Review of the Africa Rice Centre, Cotonou, Benin. 135pp.

West Africa Rice Development Association (WARDA) (2008). NERICA the *New Rice for Africa*. Rice Production Hand book, Cotonou, Benin. 72pp.

Weller, J. B. and Welletts, S. L. (1977). *Farm Waste Management*. Crosby Lockwood staples, London. 235pp.

Wopereis, M. C. S., Defoer, T., Idinoba, P., Diack, S. and Dugue, M. J. (2008). *Participatory Learning and Action Research (PLAR) for Integrated Rice Manangement (IRM) in Inland Valleys of Sub–Saharan Africa*: Technical Manual. WARDA Training Series. Africa Rice Centre, Cotonou, Benin. 128pp.

Wopereis, M. C. S., Defoer, T., Idinoba, P., Diack, S. and Dugue, M. (2009). *Integrated Rice Management in Inland Valleys of Sub–Saharan Africa*, Technical Manual. Africa Rice Center (WARDA), Cotonou, Benin. 120pp.

Yoshida, S. (1976). *Tropical Climate and Its Influence on Rice*. International Rice Research Institute. Research Paper Series No. 20. Los Bonos, Laguna, Manila, Philippines. 125 pp.

Yoshida, S. (1981). *Fundamentals of Rice Crop Science*. International Rice Research Institute, Los Bonos, Laguna, Manila, Philippines. 255pp.

Yoshinda, S. and Parao, F. T. (1976). Climatic influence on yield and yield components of lowland rice in the tropics. In: *Climate and Rice*. (*Edited by International Rice Research Institute*). International Rice Research Institute, Los Banos, Philippines. pp. 471–491.

APPENDICES

Appendix 1: Summary of analysis of variance (ANOVA) of three factors used (Rice varieties, types of fertilizer and water conservation methods)

Source of variation	Varieties (A)	fertilizer types (B)	Variety.X Fertilizer (AB)	Moisture regime (C)	VarietyX.Mcm (AC)	FertilizerX..Moisture Regime (BC)	Variety X.Fertilizer .x MCR(ABC)
Days to 50% booting	***	ns	ns	***	ns	ns	ns
1000 grain weight (g)	***	ns	**	***	ns	ns	***
Days to 50% flowering	***	*	ns	***	ns	ns	ns
Days to 50% Physiological maturity	***	*	ns	***	ns	ns	ns
Plant height (cm)	***	***	**	***	ns	**	ns
Number of tiller at panicle development	***	***	*	***	*	***	ns
Number of panicle /hill	***	***	*	***	ns	***	ns
Panicle length (cm)	***	***	*	***	*	***	ns
Number of spikelet / panicle	***	***	***	***	ns	***	***
Leaf Area Index	ns	***	*	ns	ns	ns	**
Harvest Index	ns	***	ns	***	ns	ns	ns
% unfilled grains	ns	***	ns	***	**	ns	ns
Total dry matter accumulation	ns	**	ns	ns	ns	ns	ns
Grain yield Kg/ha	***	***	***	***	ns	**	ns

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

Appendix 2: Common cultivated rice varieties grown in Tanzania and their characteristics

Variety	Year of Release	Owners/ Maintainer and seed source	Optimal production altitude range	Grain yield (t/Ha)	Distinctive characters	Special attributes
Supa	Before 1950's	ARI KATRIN	0–400	1.5–3.5	–Days to heading: 93–100 –Panicle type:intermediate –Second branching: light –Awn presence:absent –Grain shape:slender –Seed coat colour: white	Moderately resistant to rice yellow mottle virus and shealth rot
IR 54	1980's	ARI KATRIN	400–600	4.0–7.0	Days to heading:93–100 –Panicle type: ntermediate –Grain shape: some white belly –Seed coat colour:white	Moderately resistant to blight and sheath rot
IR 22	1983	ARI KATRIN	400–1000	6.6–8.0	Days to maturity: 120–134	Resistant to bacterial blight
KATRIN	1983	ARI KATRIN	400–1000	6.6–8.0	–Leaf blade pubescence: intermediate –Flage leaf angle:erect –Panicle type: compact –Second branching –Scent (aroma):not scented Plant height: medium statured	Very low panicle shattering
Dakawa	1990	DAKAWA	400–1000	3.5–5.2		None–photoperiod sensitive. Resistant to lodging except under very high N levels. Easy to thresh
TXD 85	2001	DAKAWA	0–400	4.8–7.0		Moderately resistant to sheath rot, rice blast and Rice Yellow Mottle Virus
TXD 88	2001	DAKAWA	0–400	2.8–6.5	–Days to heading:86–95 days –Flage leaf angle:erect –Panicle type: intermediate	Moderately resistant to shealth rot, rice blast and

					–Plant height: semi–dwarf –Awn presence: absent –Grain shape:slender –Scent (aroma):lightly scented	Rice Yellow Mottle Virus
TXD 306 (SARO 5)	2002	DAKAWA	0–600	4.0–6.5	–Days to heading: 100–102 –Flage leaf angle: mixture of different types –Panicle type: intermediate Awn presence:absent Seed coat colour: light brown Scent (aroma): semi–aromatic	Moderated susceptible to Moderated susceptible to Rice Yellow Mottle Virus and sheath rot. Adapted to rain–fed lowlands and irrigated ecosystems
KALULU	2006	SUA	–	2–3	–Leaf blade pubescence: glabrous –Leaf angle: horizontal –Flage leaf angle: horizontal –Panicle type:intermediate –Awn presence: shortly and partly awned –Scent (aroma): –Plant height: 118 cm	Resistant to Rice Yellow Mottle Virus and Rice blast
MWANGAZA	2006	SUA	–	2–3	Leaf blade pubescence: glabrous –Leaf angle:horizontal –Flage leaf angle: horizontal –Panicle type: heavy –Awn presence:shortly and fully awned –Plant height: 118 cm	Resistant to Rice Yellow Mottle Virus and Rice blast

Source:Tanzania report on plant genetic resources for food and agriculture (2009)

Appendix 3: Chemical characteristics of Farm Yard Manure used

Farm yard manure characteristics	**Value**	**Re marks**
Chemical characteristics		
Farm yard manure pH	8.4(H_2O)	Moderately alkaline
Total Nitrogen	0.95 %	Low
Organic carbon	6.89 %	Low
Extractable Phosphate	1.48 mgp Kg^{-1}	High
Calcium	1.07 $cmol_c^{(+)}$ Kg^{-1}	Medium
Magnesium	0.75 $cmol_c^{(+)}$ Kg^{-1}	Low
Potassium	1.38 $cmol_c^{(+)}$ Kg^{-1}	Low
Sodium	8.13 $cmol_c^{(+)}$ Kg^{-1}	High
Copper	8.60 mg Kg^{-1}	High
Zinc	165.50 mg Kg^{-1}	High

Remarks according to Palm *et al*. (1997)

Appendix 4: Correlation coefficient of rice growth characteristics, yield components and grain yield

	GW	%UG	GY	HI	LAI	NP	NS	NT	PL	PH	PP	TDM
GW	1											
%UG	0.2876**	1										
GY	0.3663***	0.6725***	1									
HI	0.3054NS	0.5662***	0.6654***	1								
LAI	0.1013***	0.4349***	0.7146***	0.4506***	1							
NP	0.5131***	0.6741***	0.8233***	0.5359***	0.5741***	1						
NS	0.6878***	0.3082*	0.5354***	0.3075*	0.2233*	0.7341**8	1					
NT	0.5132***	0.6741***	0.8233***	0.5359***	0.5741***	1.0000***	0.7341***	1				
PL	0.3481*	0.5897***	0.7178***	0.3686***	0.4749***	0.8077***	0.6930***	0.8077***	1			
PH	0.8286***	0.2792*	0.5104***	0.36198***	0.2478*	0.6634***	0.8705***	0.6634***	0.5749***	1		
PP	0.0191 NS	0.2853**	0.1693 NS	0.0316 NS	0.1959NS	0.1249NS	0.0294NS	0.1249*	0.1683NS	0.0129NS	1	
TDM	0.2842NS	0.5775***	0.9209***	0.3895***	0.6728***	0.7610***	0.4870**	0.7610***	0.6916***	0.4477***	0.1867NS	1

n= 81, df= n–2

*** significant at 0.001, **significant at 0.01 and * significant at 0.05 and NS refers to non–significant

Note: GW –1000 grain weight, UG– % unfilled grain, GY–grain yield, HI– harvest index, LAI–leaf area index, NP–number of panicle, NS–number spikelet, NT–number of tillers, PL– panicle length, PH– plant height, PP –plant population, TDM – total dry matter

Appendix 5: Interaction effect of variety, fertilizers and water conservation methods in yield and yield components

Treatment	No of tillers[1]	No of panicle	Panicle length(cm	No-Spikelet's	Total dry matter	% Unfillied grain	Grain yied kg/Ha
NERICE1,NF, WC1	6.73a	6.733a	17.911ab	20.97ab	241.3ab	29.00i	1072a
NERICA1,NF, WC2	6.77a	6.77a	17.67ab	19.27a	316.5abcd	28.33hi	1101a
NERICA1,NF,WC 3	7.37abc	7.37abc	18.03ab	23.20bcd	230.4a	19.67abcdefghi	1221a
NERICA1,Urea,WC1	9.43def	9.43def	18.10abc	28.47fghi	501.2ghij	23.67defghi	2741e
NERICA1,Urea,WC2	8.73cde	8.73cde	18.00ab	25.50def	484.7ghi	23.33 def g hi	2718e
NERICA1,Urea,WC3	11.17gh	11.17gh	19.36abc	30.80gj	519.3ghij	20.33bcdefghi	3006ef
NERIA1,Fym,WC1	8.933def	8.93def	17.03abc	23.93cde	425.8cdefg h	23.00cdefghi	2257d
NERICA1,Fym,WC2	8.27bcde	8.27bcde	18.13ab	27.70fg	406.3cdef	23.67defghi	2338d
NERICA1,Fym,WC3	9.67def	9.67def	18.80abc	30.93gij	422.1cdefg	13.67abc	2809e
NERICE 4,NF,WC1	6.97a	6.97a	17.33ab	27.73fgh	271.4ab	26.00fghi	1261a
NERICA.4 ,NF, WC2	7.20ab	7.20ab	17.10a	25.63def	256.0ab	26.00fghi	1265a
NERICA 4,NF,WC 3	8.60cde	8.60cde	18.13abc	27.83fgh	269.3ab	20.33bcdefghi	1415ab
NERICA4, Urea,WC1	9.47def	9.47def	18.03abc	27.83fgh	553.8ij	17.00abcdef	3237f
NERICA 4,Urea,WC2	9.57def	9.57def	18.07abc	26.63ef	549.4hij	16.33abcde	3240f
NERICA4, Urea,WC3	11.70h	11.70h	20.30cd	31.27ij	607.8jk	11.33ab	3687g
NERICA4 ,Fym,WC1	8.70cde	8.70cde	17.60ab	20.83ab	465.6efghi	19.00abcdefgh	3000ef
NERICA4, Fym,WC2	8.20bcd	8.20bcd	17.27ab	20.77ab	443.4efghi	17.67abcdef	2704e
NERICA4, Fym,WC3	9.53def	9.53def	18.13abc	22.53bc	453.8efghi	10.67a	3251f

Appendix 5 continued:

Treatment	No of tillers[1]	No of p anicle	Panicle length(cm	No-Spikelet's	**Total dry matter**	**% Unfillied grain**	Grain yield kg/Ha
WAB 450,NF,WC1	9.03def	9.03def	18.50abc	32.77jk	347.5bcde	25.00efghi	1719bc
WAB 450,NF,WC2	8.40bcde	8.40bcde	18.07abc	33.23jk	315.6abc	27.67ghi	1680c
WAB 450,NF,WC3,	9.90ef	9.90ef	18.67abc	35.27kl	355.3bcdef	17.00abcdef	1970c
WAB 450,Urea,WC1	11.70h	11.70h	19.50bc	37.50l	635.7k	16.00abcde	3737g
WAB 450,Urea,WC2	10.33fg	10.33fg	2020cd	35.40kl	594.3jk	18.33abcdefg	3767g
WAB 450,Urea, WC3	14.00i	14.00i	21.53d	42.57m	660.9k	10.33a	4179h
WAB 450,Fym, WC1	9.80def	9.80def	18.60abc	34.93kl	466.3efghi	22.00cdefghi	2799e
WAB 450,Fym, WC2	9.07def	9.07def	18.43abc	33.33jk	472.2fghi	21.33cdefghi	2827e
WAB 450,Fym,WC3	11.10gh	11.10gh	19.27abc	35.53klj	459.0efghi	14.67abcd	3021ef
Mean	**9.272**	**9.272**	**18.423**	**28.98**	**435.7**	**19.70**	**2501**
SE±	**0.5622**	**0.5622**	**0.4952**	**1.307**	**45.28**	**3.255**	**126.6**
CV(abc) %	**6.1**	**6.1**	**4.2**	**4.5**	**10.40**	**16.5**	**5.1**

*Means in the same column followed by the same letter are not significantly different according to Student New Keul test (P≤ 0.05)

Note: NT=Number of tillers, NP= Number of panicle plant^{-1}, PL=panicle length, NS =number of spikelets^{-1}, UG= unfilled grain(%), GY= grain yield Kgha^{-1}, WCM1 = Flat cultivation,WCM2= Open ridge, WCM3=Tie - ridge FYM= farm yard manure.