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(RESEARCH ARTICLE)

Improving upland rice (*Oryza sativa* l.) performance through enhanced soil fertility and water conservation methods

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Abstract

The experiment was conducted at Experimental sites of Tanzania Agricultural Research Institute (TARI) – Ukiriguru, Mwanza, Tanzania. The objective was to improve performance of upland rice through enhanced soil fertility and water conservation methods. A split–split plot experiment in a 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 30 cm inter–and intra–row spacing. Data on soil, weather, crop growth, yield components and grain yield were collected. Rainfall was 651.2 mm 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 2.09mgP/Kg and organic carbon 0.58%. The soil calcium was 3.38 cmol$_c$/Kg and potassium was 0.36cmol$_c$/Kg, while zinc was 0.39 mg/Kg. Cultivars had significant effect on yields which were 2856, 2507 and 2140 Kg/ha for WAB 450, NERICA4 and NERICA1 respectively. Fertilizer types also significantly affected grain yield in the order of urea (3368 Kg/ha) > FYM (2723 Kg/ha) and > control (1421 Kg/ha). Moisture conservation methods significantly affected yield in this order: tie ridges (2710 Kg/ha) > open ridge (2398 Kg/ha) > flat cultivation (2394 Kg/ha). Overall, the study results indicated low fertility status in the soil, 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 80 Kg N/ha gave high grain yield, while tie ridges were the best in soil moisture conservation.

Keywords: Upland rice; New Rice for Africa (NERICA); Water conservation; Soil fertility

1. Introduction

Upland rice is produced under aerobic conditions without irrigation or paddling. It is grown in from low–lying valley bottom to steep sloping land with high runoff, where land preparation and sowing is done under dry conditions through direct sowing. This rice is also grown alone or as mixture with other food crops normally without any fertilizer use (FAO, 2009; IRRI, 2009). Upland 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 of between 4.7 and 6.8.

Major difference between upland rice and low land rice is that upland rice in one hand is grown on un-flooded land for a long time during the growing period whereby, rice plant has to regulate to dry aerobic soil conditions. Lowland rainfed

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rice in another hand grows under flooded land under anaerobic condition and normally in water saturated soils (Gupta and Toole, 1986).

The upland rice production systems constrained by unreliable and poor rainfall distribution, low soil fertility, soil erosion weed competition, insect pests and diseases (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 production constraints leading to low yields (< 0.5 t/ha) (Meertens, 2003; Kajiru, 2006; 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).

Many studies have been done on lowland rainfed rice relating to use of fertilizers (organic or inorganic) and water management techniques. However, little is documented on response of upland rice varieties to moisture conservation methods, organic and inorganic fertilizer uses in Lake zone and Tanzania at large. Therefore, the objective of this study was to (1) evaluate the fertility status of the soil for upland rice production (2) determine the effect of nitrogen from organic and inorganic sources on various upland rice varieties in terms of yield and yield components and (3) assess the performance of upland rice cultivars grown under different water conservation methods in terms of growth characteristics and grain yield.

2. Materials and methods

2.1. General Description of Study Area

This study was conducted at Tanzania Agricultural Research Institute (TARI), Ukiriguru Center Experimental fields (Machafu block) in Misungwi district, Mwanza region, Tanzania. The Experimental field lies between latitude $2^{0}42'$S and longitude $33^{0}.1'$E at an elevation of 1236 m above sea level. 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. It receives a mean annual rainfall ranging between 800 and 1200 mm and temperatures between 18 and 31.5^{o}C.

TARI–Ukiriguru lies within dry savannas' area and its soils range from granitic hillsands to heavy clays in the valley bottoms. Cropping history of the site shows that the land previously used for growing different upland rice varieties during the 2009/2010 and 2010/2011 cropping seasons.

2.2. Experimental Materials

Planting materials used during the experiment were upland rice varieties: WAB 450, NERICA 1 and NERICA 4. The WAB 450 variety was collected from Tanzania Agricultural Research Institute (KATRIN), Ifakara, Morogoro. NERICA 1 and NERICA 4 were sourced from the Department of Crop Science and Production at Sokoine University of Agriculture (SUA) in Morogoro. These rice varieties are short duration which were found to adapt well in Lake Zone environmental conditions. In addition, cattle manure (FYM) was collected from farmers' boma's at TARI–Ukiriguru.

2.3. Soil and manure sampling and analysis

Soil sampling was done as recommended by Okelebo *et al*. (1993) at a depth of 0–30 cm and one composite soil was collected, prepared and analyzed at the laboratory of Soil Science Department Sokoine University of Agriculture. They were 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 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 (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 quantit**y** of exchangeable bases K^{+} and Na^{+} were determined by Flame photometer while Ca^{2+} and Mg^{2+} by atomic absorption spectrophotometer (AAS) as described by Thomas (1982). Available Cu, Zn, Fe, and Mn measured by AAS (Baker and Amacher, 1982). Particle size distribution was determined by the hydrometer method (Juo, 1979). However, bulk density was determined at TARI–Ukiruguru Laboratory using core method as described by Okelebo *et al*. (1993). Similarly, the collected farm yard manure was dried at 70^{o}C to constant weight, grounded to 0.5 mm sieve and 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).

2.4. Experimental design

A split–split plot experiment in a randomized complete block design (RCBD) as described by Kuelh (2000) was applied. The main plot area was 85.05 m^2, sub–plot had 28.35 m^2 and sub–subplots had 9.45 m^2. Main treatments (factor A) included three upland rice varieties that included (i) NERICA 1 (ii) NERICA 4 and (iii) WAB 450. 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 5 t/ ha, (ii) urea 46% N at a rate of 80 Kg N/ha and (iii) control (without fertilizer). 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 (30 days after planting) and second application was done at panicle initiation (65 days after planting) as describe by Kanyeka *et al*. (2007). Thinning was done to two plants per hill at 14 days after planting. In addition, weeding was done four times (at 21, 35, 54 and 70 DAP).

2.5. Weather data collection

Precipitation (mm), minimum and maximum temperature (°C) and percentage relative humidity (RH%) were recorded from the Tanzania Meteorology Agency (TMA) station situated at TARI – Ukiriguru on daily basis.

2.6. Crop data collection

Crop data were collected along three growth stages: vegetative, reproduction and ripening phases. These included days to 50 % emergence, plant population at thinning, days to first tiller, number of leaves, total number of tillers, days to 50% flowering, panicle size, days to50% maturity grain weight and yield per plot were collected as described by Gomez (1972).

2.7. Statistical Analysis

Data collected were subjected to analysis of variance (ANOVA) to assess treatment effects (both main and interaction effects). The mean separation test was done using Student Newmans Kuels (S–N–K) at P≤ 0.05. All computations were done using the Genstat statistical software version 14. Simple correlations were calculated and analyzed at P ≤ 0.05 where the numbers of observations were 81 while the degrees of freedom used were n–2 (Gomez and Gomez, 1984).

3. Results and discussion

3.1. Physical and chemical soil characteristics

Table 2 indicates physical and chemical characteristics of soils in the study site. according to Gerakis and Baer (1999), this soil can be classified as Sand Clay Loam. On average this soil had low bulk density of 0.934g/cm^3, indicating high soil porosity and low soil compaction (USDA, 2008).

The soil pH was found to be 6.07 which lies within optimum soil pH for upland rice of between 4.7 – 7.0 (Somado *et al.,* 2008). The percentage of total nitrogen recorded was 0.08% which is very low according to Landon (1991). Nwilene *et al*. (2008) showed that total N < 1.0 g/kg 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 FYM, green manures, crop residues, etc. The available phosphorus in the soils at the site was 2.09 mg/Kg which is rated as low (Landon, 1991). Normally, low P range between 3 and 6 mg/Kg (Wopereis *et al*., 2009). Although rice is a low P demanding crop, current results indicate that soils used would not satisfy the phosphate requirement for the crop. The exchangeable K in the soil was found to be 0.36 $cmol_c$ (+) Kg^{-1} of soil, which is rated as medium (Landon, 1991). Thus, the soil K value of 0.36 $cmol_c$ +) Kg^{-1} soil at this study was above the minimum levels of between 0.07 and 0.2 $cmol_c$ K Kg^{-1} soil. This result agree with that reported by Kanyeka *et al*. (2007).

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%. Normally, total N is rated low when is < 1.0g /Kg, medium when is between 1.0 and 2.0g /Kg and high when is >2.0g Kg (Nwilene *et al*., 2008). The cation exchange capacity (CEC) was low (9.6 cml_c (+) Kg^{-1}), low to medium CEC could be attributed to the low organic matter content in the soils. 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. This is because CEC is a reservoir of plant nutrients (Koelling, 1995). Soil calcium content at the experimental site was 3.38 $cmol_c$ (+) Kg^{-1}, rated as high (above 2 $cmol_c$ (+) Kg^{-1}. Deficient of Ca results in chlorotic – necrotic and impaired root function that predispose the rice plant to Fe toxicity. The exchangeable Mg in the soil was 0.85 $cmol_c$ (+) Kg^{-1}. The value rated as high (> 0.5 $cmol_c$ (+) Kg^{-1} soil), according to Landon (1991). Following the result 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 translocated easily from old leaves to young leaves (WARDA, 2007). The exchangeable Na in the soils was 0.4 $cmol_c$ Na Kg^{-1} 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 are suggested.

The available Zn in the soil was 0.39 mg/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 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 Toole, 1986).

Table 1 Some of the physical and chemical properties of the soils at 0 – 30 cm depth in the study area (Machafu block - Ukiriguru Experimental site)

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 $cmol^{(+)}$ /Kg	Medium
Organic carbon	Walkley and Black	0.58%	Very low
CEC	Buffer ammonium acetate	9.6 $cmol^{(+)}$ Kg	Low
Calcium (Ca^{2+})	AAS	3.38 $cmol^{(+)}$/Kg	High
Magnesium (Mg^{2+})	ASS	0.85 $cmol^{(+)}$ /Kg	High
Sodium (Na^+)	Flame photometer	0.14 $cmol^{(+)}$ /Kg	Low
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

ASS: atomic absorption spectrophotometer; the remarks are according to Landon, (1991)

3.2. 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 1.48 mg/P Kg^{-1}, while potassium was 1.38 $cmol_c^{(+)}$/Kg^{-1} was also high. With respect of Zn, and Mg the values were found to be 165.5 and 0.75 $cmol_c^{(+)}$ Kg^{-1}. These values of Zn an 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).

3.3. Weather Data Analysis

Primary weather data on rainfall, temperature and relative humidity were collected, the rainfall amount during the growing seasons indicated in figure 1. Total monthly rainfall amount was 125 and 173.3 mm during the month of November and December, respectively. The rainfall distribution had good impact in crop growth and establishment on all treatments. However, the situation was worse in January when total monthly rainfall received was 11.4 mm. Upland rice grows and develops well to give the optimal yield when 1000mm 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.

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°C, respectively. This recorded temperature was optimum for rice growth and development (Yoshida, 1976). According to the author for higher rice grain yield, a day temperature of 25 to 32°C and night temperature range from 15 to 20°C are preferred.

Relative humidity (RH) at experimental site ranged from 60.8 to 89.4% in December to March as shown in (Table 3, Fig 1). The recorded RH was 89.4 in December was received at the time of planting and 67.4% in month of May 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.

3.3.1. Weather data for 2011/2012 growing season at Ukiriguru

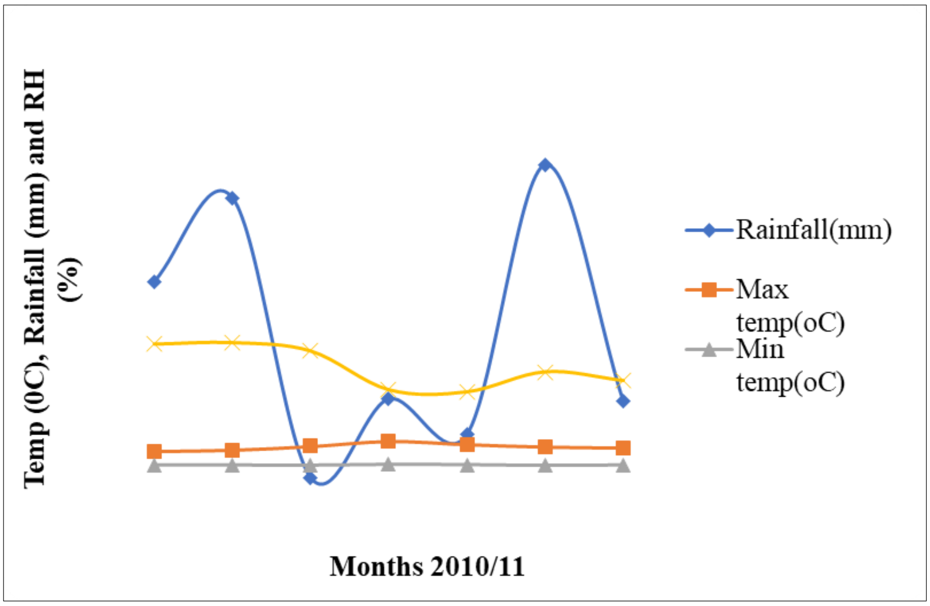

Figure 1 Weather condition during cropping season.

3.4. 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% physiological 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° 29′N latitude and 34°.07′E longitude, at 1189m above sea level. The area experience annual rainfall ranging from 653.5 to 848mm, while it has been reported by the Ministry of Agriculture and Cooperatives Zambia (MACZ) (2010) that days to maturity for NERICA 1 ranged between 105 and 115 while NERICA 4 was 110 – 120 DAP, under low lying area at 1700m above sea level, the area received annual rainfall ranging from 450 to 500mm under crop rotation cultural.

Table 2 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

3.5. Effect of treatments on growth parameters and grain yield

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

The effect of different fertilizer types on plant height and Leaf Area Index indicate that, application of urea resulted into highest plant height and Leaf Area Index , while the shortest plant height and Leaf Area Index observed from control, this 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 at P≤0.05 on Leaf Area Index. The effects on plant height were significant (P ≤ 0.05) among the conservation methods. Tie ridges had the highest plant height compare to other treatments (Table.5). These differences in plant height could 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.

Total dry matter was significantly affected at (P≤ 0.05) by the cultivars used in this study as indicated in Table 5. The effect of cultivars on harvest index indicated that cultivar WAB 450 had the highest harvest index of 0.58, compare to NERICA 4 with 0.57and NERICA1, 0.54 however, statistically there is not significantly different.

This 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≤ 0.05) on TDM with the value of 569.30 g/m^2, while as expected the lowest amount was found in the control plots that was 349.25 g/m^2. The effect of application different fertilizer types on harvest index indicated that application of FYM had highest HI value of 0.61, followed by application of urea at 80 kgN/ha 0.58 and the lowest value of HI observed in control plots that was 0.50. The effect of the use of different water conservation methods on TDM production and HI resulted on significant effect (P≤ 0.05) on total dry matter production such that tie ridges had the highest TDM followed by open ridges and lowest was flat cultivation.

Tie ridges again had significant effect (P≤ 0.05) on harvest index compared to the use of open ridge and flat cultivation. These results are supported by Rahma *et al*. (2002) who reported that plant height, number tiller, number panicle, panicle length, number of filled grains per panicle, 1000–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. 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 3 Effects of cultivar, fertilizer and water conservation method on rice growth characteristics

Treatment effect	**LAI**	**PH(cm)**	**TDM(g/m²)**	**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

3.6. Effects of Cultivars, Fertilizer Types and Water Conservation Methods on Rice Yield components and Yields

3.6.1. 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 (P≤ 0.05) effect 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%) produced the highest number of tillers per plant ; followed by FYM and lastly control plots. 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 (Kg/ha). 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 followed by flat cultivation with and lastly open ridges(Table.6). 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). The influence of soil moisture management also resulted into similar results on number of tillers and panicle as each developed tiller produced a panicle.

3.6.2. Panicle length (cm)

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

Table 4 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 Kgha^{-1}**
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 (%)	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 (%)	0.9	0.9	2.4	1.0	14.0	2.5	2.5
WCM							
Flat cultivation	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(%)	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≤ 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.

The use of different moisture conservation methods indicated that the use of tie ridges gave the longest panicle length (19.33 cm) followed by flat cultivation (18.22 cm) and lastly open ridges (17. 96 cm). 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. Also it has been reported by *Belesa at-al* (2022), That low quantities of rainfall in dry land areas make cropping to be possible only with the use of special techniques of soil and water conservation and in this situation tied ridge is a good structure to be used.

3.6.3. Number of spikelet and unfilled grains (%)

The effect of treatment on number of spikelet showed that WAB 450 had significant effect (P ≤ 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 4 had significant effect (P ≤ 0.05) on percentage unfilled grains with (18.26 %) followed by WAB 450 (19.15), while NERICA 1 had the highest (21.70%) unfilled grains. 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 while control plots had the lowest 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 on increase of yield components in rice with the use of urea.

The use of tie ridges as water conservation measure had promising results on high number of spikelets per panicle compared to open ridge and flat cultivation.

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 of rice production. Furthermore, NERICA1 had the highest (%) of unfilled grain followed by WAB 450 while NERICA 4 had the lowest %. 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 followed by FYM and control. 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 followed by flat cultivation and open ridges. 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.

3.6.4. Rice grain yield

Rice cultivars differed significantly in grain yield. Cultivar WAB 450 giving the highest grain yield of 2856 Kg/ha followed by NERICA 4 which had 2507 Kg/ha and lastly NERICA 1 with 2140 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 ≤ 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.

Application of urea gave significantly different on grain yield of 3368 Kg/ha, followed by FYM (2723 Kg/ha) and lastly the control (1412 Kg/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 4490 Kg/ha.

The use of tie ridges resulted into highest grain yield. The grain yields were in the following order 2710> 2398 > 2394 Kg/ha for the tie ridges, open ridges and flat cultivation, respectively. According to these 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 1 The results indicated the ability of tie ridges in water conservation when combine with urea and WAB 450 cultivar in 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 the tie–ridge, urea and WAB 450 plots compare to flat and NERICA 4 or NERICA 1 and FYM or without fertilizer (control). Also by compared with open ridges practices and NERICA 4 or NERICA 1 and plus FYM or control respectively.

The increase of number and size of yield components is attributed to grain yield as they have significant correlation (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). 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 (1.68 t/ ha) where contoured ridge produced 1.64 t/ha and flat planting 1.36 t/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. Result can also supported by *Ndung'u et al*.(2023) reported, Tied ridging and organic applications led to soil moisture conservation during critical maize tasselling and silking stages in both seasons.

3.7. Interaction Effects of Varieties, Fertilizer Types and Moisture Conservation Methods

3.7.1. Number of tillers and panicle length

The effect of interaction of treatments such that three cultivars of upland rice, three fertilizer types and three water conservation methods indicated the significant effect ($P \leq 0.05$) in number of tillers per plant in plots where cultivar WAB 450 interacted with urea at 80 Kg N ha^{-1} and tie – ridges, had average of (14.00) tillers, followed by interaction of NERICA 4 each had (11.70) tillers when interacted with urea and tie – ridges. The lowest number of tillers per plant was (6.73) observed in plots where NERICA 1 interacted with no fertilizers (control plot) and flat cultivation. On the other hand the interaction of WAB 450, urea at 80 Kg N ha^{-1} and tie – ridges had significant effect ($P \leq 0.05$) in panicle length (21.53 cm) followed by interaction of NERICA 4, urea at 80 Kg ha^{-1} and tie – ridges (20.30) while the shortest length of panicle observed in interaction between NERICA 1, FYM and flat cultivation (17.03). These results could have been associated with cultivar genetic characteristics; ability of ammonium to be readily available immediately after application as supported by 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 slowly. Also results showed the ability of tie – ridges to conserve moisture this is supported by observed greater number of tillers and longest length of panicles per plant, increase number of spikeletes per panicle and high grain yield in the tie – ridge plots.

3.7.2. Number of spikeletes and grain yield

The effects of interaction of three factors used in this study in number of spikeletes and grain yield showed the significant effect ($P \leq 0.05$) in number of spikeletes (42.57) where cultivar WAB 450, urea at 80 Kg ha^{-1}, and tie – ridge interacted, followed with interaction of WAB 450, urea and open ridge (37.50), while the lowest number of spikeletes (19.27) found in plots where NERICA 1 interacted with flat cultivation and no fertilizer (control) the reason contributed for these results were discussed in sub section 4.5.1 in paragraph one

The effect of interaction in grain yield showed significant effect ($P \leq 0.05$) such that (4179 Kg ha^{-1}) when cultivar WAB 450, urea 80 kg N ha^{-1} and tie – ridge interacted, followed by interaction of WAB 450, urea 80 Kg N ha^{-1} and open ridge (3767 Kg ha^{-1}) while the lowest amount of grain yield (1072 Kg ha^{-1}) was found in the plots where NERICA 1 interacted with no fertilizer and flat cultivation, the results might be attributed by genetical characteristic of cultivar WAB 450 to adapt environmental condition, application of inorganic fertilizer which has been showed the high ability of immediately release nutrient for plant after application, also the ability of tie – ridge to conserve moisture which was utilized by plant in drought condition as supported by Allahyar (2011) who reported that moisture and nitrogen fertilizer had significant influence on plant height, number of tillers days to flower panicle size, number of spikeletes and grain yield in rice.

Table 7 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 yield 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, WC3	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	425.8cdefgh	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, WC3	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
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 ($P \leq 0.05$); 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}, WCM1 = Flat cultivation,WCM2= Open ridge, WCM3=Tie - ridge FYM= farm yard manure.

4. Conclusion

Regarding the soil suitability for the upland rain fed 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 0.94 g/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 (2.08 mgp/Kg) and cation exchange capacity (9.6 cmol$^{(+)}$/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 80 KgN/ 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 3.4 t/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 (gm^{-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 (gm^{-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^{-1}, 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 4179 Kg ha^{-1}.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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Appendix 1 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	0.3054 NS	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 ***	0.3619 8***	0.2478 *	0.6634 ***	0.8705 ***	0.6634 ***	0.5749 ***	1		
PP	0.0191 NS	0.2853 **	0.1693 NS	0.0316 NS	0.1959 NS	0.1249 NS	0.0294 NS	0.1249 *	0.1683 NS	0.0129 NS	1	
TD M	0.2842 NS	0.5775 ***	0.9209 ***	0.3895* **	0.6728 ***	0.7610 ***	0.4870 **	0.7610 ***	0.6916 ***	0.4477 ***	0.186 7NS	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