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Original Research Article

Effect of nitrogen fertilizer rates on Panicle length and Yield component of some improved rice varieties (*Oryza sativa* L.)

Abstract

Rice (*Oryza sp*) is a principal staple food in Kenya. However, its production in is still low due to low and declining soil fertility. This has resulted into food insecurity and low living standards. The situation has been compounded by the ever escalating fertilizer prices which has made it unaffordable to most small holder farmers. Although some studies have been done on fertilizer application on some rice varieties, the Mwea Upland rice (MWUR) varieties were bred under low fertilizer input environment while other authors have indicated that the New Rice for Africa (NERICA) variety gives high yields under low input conditions. The objective of the research was to establish the yield performance of eight promising improved rice varieties under various nitrogen levels and identify the variety that gives high yields at relatively low fertilizer rates. Field studies were conducted at Alupe in Western Kenya under rainfed upland conditions between August 2012 and April 2013. The experiment layout was split plot factorial in a Randomized Complete Block Design with three replicates. The main plot treatments were four rates of nitrogen fertilizer which were; 0 (control), 40 kg ha^{-1}, 80 kg ha^{-1} and 120 kg ha^{-1} applied as urea in two equal splits, sub-plots consisted of four MWUR and four NERICA varieties. The parameters measured included panicle length, yield at 14% moisture content, filled grain ratio percentage and yield components. The measured parameters significantly increased with increase in the level of nitrogen fertilizer. Varietal difference was significant and MWUR varieties recorded higher panicle length and yield component at low nitrogen levels (0N and 40N) as compared to the NERICAs with MWUR 1 and 2 recording higher values. The NERICAs out-yielded the MWUR varieties at higher nitrogen. NERICA 4 recorded highest yield among the NERICA varieties regardless of the N level. Results from our study suggest that MWUR 1 and 2 and NERICA 4 were more tolerant to low nitrogen as compared to MWUR 3 and 4 and NERICA 1, 10

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and 11 because of higher panicle length, higher filled grain ratio percentage and higher yield component and may be suitable for soils deficient in nitrogen.

Keywords: Nitrogen, Panicle length, yield at 14% Moisture content, yield components

Introduction

Rice (*Oryza sativa* L.) is the world's single most important food crop, being the primary food source for more than one third of the world's population and grown in 11% of the world's cultivated area. Upland rice has high production potential in Kenya and can be grown by most farmers at low input level (MOA, 2011). Kenya has a potential to bring 1,000,000 ha under upland rice production (Sikuku *et al*., 2012). However, currently the area under rainfed rice is 13,000 ha (MOA, 2010) hence the national rice development strategy (NRDS) focus is expanding and increasing yields by exploiting existing opportunities on a sustainable basis (Rosemary *et al*., 2010). Nitrogen (N) is one of the most important nutrients for plant growth and a major factor that limits agricultural yields (Dai *et al*., 2009, Xia *et al*., 2012). It is required in adequate amount at early, mid tillering, panicle initiation and at ripening stage for better grain development. It has played a major role in the global food production over the past 60 years (Simonne *et al*., 2012). Nitrogen (N) requirements of rice crop are met from both the soil and fertilizers. Because of acute N deficiency in most rice soils, fertilizer N must be applied to meet the crop demand (Choudhury and Kennedy, 2005). However, excessive N application would lead to increased production cost and negative effects of blocking agricultural sustainable development such as environmental pollution and rice quality decline.

The amount of N required and management of the N varies depending on variety, soil conditions, cultural practices, crop rotations, and other factors. The majority of smallholder farmers who form the bulk of agriculture in Kenya are faced with low soil fertility. Rice yields are typical of low input system being less than 2.0 tons/ha against a potential of 5.0 tons/ha (MOA, 2010). The yield gap is attributed mainly to effects of drought and low soil fertility, the most prominent of which is nitrogen deficiency. As a result, rice

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farmers are unable to harness the potential of rainfed rice to meet their food demand. Lack of identification of improved varieties adaptable to low fertility soils in rainfed conditions and the ever escalating fertilizer prices have made this important input unaffordable to most small-holder farmers who are resource poor hence low rice production (Kimani *et al*., 2011). However, some varieties can perform well under low nitrogen input (Oikeh *et al*., 2009). There is therefore need to evaluate the response of the MWUR viz a viz the NERICA varieties to identify the superior rice varieties that are adaptable to low nitrogen levels. Identification of low nitrogen adaptable rice varieties is thus crucial in sustaining production in areas where low soil fertility prevails.

Liu and Shi (2013) reported that nitrogen is the most important nutrient that limit crop production. They argued that this loss can be mitigated by exploiting varieties well adapted to low soil N conditions in order to increase farm yields. According to Islam *et al*. (2009), selection of the most appropriate level of nitrogen fertilization is a major concern of economic viability of crop production and the impact of agriculture. Given the importance of nitrogen fertilization on the yield in grain from the rice plant, it is necessary to know what the best dose is for each variety as well as its influence on components of yield and other agronomic. Adaptation and yield stability studies that will help in identifying varieties that have either specific or general adaptation to low nitrogen which can be exploited for varietal recommendation hence address the soil fertility problem in the region is thus imperative. The identified low nitrogen adaptable varieties would have a substantial impact on rice productivity interms of soil nutrient supply, nutrient use efficiency, improved food security and livelihood/income of rural households in the region. Therefore advanced farming systems research can contribute to the nutritional well-being and food security of the communities by incorporating a high yielding variety, which is tolerant to low nitrogen. Studies have shown that application of N fertilizer to rice leads to increase in panicle length, spikelet number, and grain yield (Oikeh *et al*., 2009; Kamara *et al*., 2010). However, the response of rice materials currently in Kenya has not been studied or documented despite the importance of this information in any rice breeding programme and little information exists on the response of improved rice varieties to N fertilizer (Kimani *et al*., 2011). Thus the research sought to establish and document data on the yield

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performance of eight promising high-yielding improved rice varieties under various nitrogen levels and identify the variety that gives high yields at relatively low fertilizer rates.

MATERIALS AND METHODS

Site Description

Field studies were conducted to assess the effect of nitrogen fertilizer rates on Panicle length and yield component of eight improved rice varieties under rainfed upland conditions between August 2012 and April 2013 at Alupe farm of Lake Basin Development Authority (LBDA) in Western Kenya. Geographically, the experimental area is located at latitude 0° 30' 0 N; longitude 34° 7' 50 E and at the elevation of the 1170 m above sea level. Precipitation ranged between 860 - 680.5 mm and temperature ranged from 16-34℃ during the growing period. The soils at Alupe have been characterized as Ferralo-orthic Acrisol with pH of 5.0 (FURP, 1987). Specific soil chemical characteristics of the location were determined according to the analytical procedures of the International Institute of Tropical Agriculture (1989) and are presented in Table 1. Soil samples were collected at depth of 20cm from all corners of the plot middle and between diagonals and the middle part. This was done at the start of the experiment to assess the initial chemical status of soil in each of the plots. The soil was thoroughly mixed together to form a composite sample which was then air dried and passed through 0.5mm sieve for soil texture and chemical analyses. These were taken to the laboratory for analysis. Land was ploughed and harrowed to suitable tilth before sowing.

Experimental design and Treatments

The experiment layout was split plot factorial arrangement in a Randomized Complete Block Design (RCBD) with three replicates. The main plot was fertilizer N source and different rice varieties as sub-plots. The main plot treatments were four rates of nitrogen fertilizer which were; 0 (control), 40 kg ha^{-1}, 80 kg ha^{-1} and 120 kg ha^{-1} applied as urea in two equal splits i.e 14 days after sowing (DAS) and at panicle initiation (46 DAS) following the recommendation by Oikeh *et al*. (2008). Sub-plots consisted of eight rice varieties i.e. four MWUR rice varieties namely MWUR 1, MWUR 2, MWUR 3, MWUR 4 that were bred

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and selected by KARI-Mwea under low fertilizer input environment and four New Rice for Africa (NERICA) varieties namely NERICA 1, NERICA 4, NERICA 10 and NERICA 11 that have been released to farmers in Kenya. Drill sowing in 5 m x 1.2 m plots was done at a depth of 3cm and four seeds per hill were sown at spacing of 20 cm row spacing and 20 cm intra row spacing and thinned 15 days after sowing to 1 plant per hill. In between the plots, trenches of 0.5 m depth and 1 m in width were constructed, to avoid seepage between plots. A basal dose of triple super phosphate (TSP) was used as the source of phosphorus, applied at the rate of 30 kg P ha^{-1}. The fertilizer granules were distributed at the bottom of the hole and covered with about 1 cm of soil to avoid fertilizer burn to the rice seeds during dissolution of triple superphosphate. The rice seeds were then placed and covered with roughly 2 cm of soil. Sowing date coincided with onset of the long rainy season and normal cultural trial management was applied such as weeding and bird scaring to protect the trial from bird damage.

Table 1. Chemical characteristics of soils at LBDA Alupe farm (0 - 20 cm depth)

Soil chemical properties	
$pH_{1:1}$	4.69
ECe (Electrical conductivity)	0.18
Total N g kg^{-1}	0.73
Available P (ppm)	0.14
Extractable-Zn (ppm)	1.75
Extractable-Cu (ppm)	5.66
Extractable-Mn (ppm)	48
Extractable-Fe (ppm)	479

Sampling and Measurements

Panicle lengths

This was determined using a metre rule at physiological maturity. Measurements were done from the panicle base to the tip of five hills in each plot.

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Yield components

At physiological maturity, a $1m^{-2}$ quadrat was placed in each plot leaving out the border rows and border plants. The quadrats were harvested to determine yield components and rice yield per square meter. The grain yield was determined at harvesting from an area of $1m^2$ in each plot. The number of grains per 5g, and filled grains per panicle were determined and yield calculated according to MOA (2011). The yield was extrapolated in kilograms per hectare as follows:

Yield (Kg ha^{-1}) = Number of panicles m^{-2} x Number of grains/panicle x % filled grains x (Weight of 1,000 grains ÷ 1,000) x 10,000

Yield at 14% moisture content

This was determined from an area of $1m^{-2}$ by measuring the moisture content of the grains immediately after harvesting using a grain moisture tester (model number AF 34086, Japan) and converting the yield of the grains to 14% moisture content and extrapolating to Kg/ha as described by MOA (2011).

Filled Grain Ratio percentage

Grains harvested from the 1 m^{-2} in all the plots were put in different buckets of water and the poorly filled grains together with empty grains floated while the well filled grains settled at the bottom. Filled grains were then separated from empty and poorly filled grains. The grains were dried and later weighed but each was handled separately. The percentage of filled grains was calculated according to MOA (2011).

Statistical data analysis

Factorial analysis of variance (ANOVA) was carried out on the data for the variables measured to determine the significance of the effects of nitrogen fertilizer levels on the rice varieties using a statistical computer package (SAS software version 9.2) [SAS institute, 2003]. Significant means were separated using least significance difference test (LSD) at 5% level for comparing the treatment means. Linear regression curve was used to show and define the nature and strength of the relationships between nitrogen levels, rice varieties and grain yield

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RESULTS

Panicle length

There was a highly significant effect of nitrogen level on panicle length. Increase in nitrogen level caused a significant ($P \leq 0.05$) increase in panicle length with plants subjected to 0N registering the shortest panicle lengths (Figure 1). Varietal difference was also significant ($P \leq 0.05$); MWUR 1 registered significantly ($P \leq 0.05$) higher panicle length at 40N as compared to MWUR 2, 3 and 4 and the NERICAs. NERICA 4 recorded significantly higher panicle length at 0N as compared to NERICA 1, 10 and 11. At 80N, MWUR 1 and NERICA 4 recorded slightly higher panicle length as compared to NERICA 1, 10, 11 and MWUR 2 and 4 though the difference was significant from MWUR 3. However, there was no significant interaction between the varieties and treatments ($P > 0.05$).

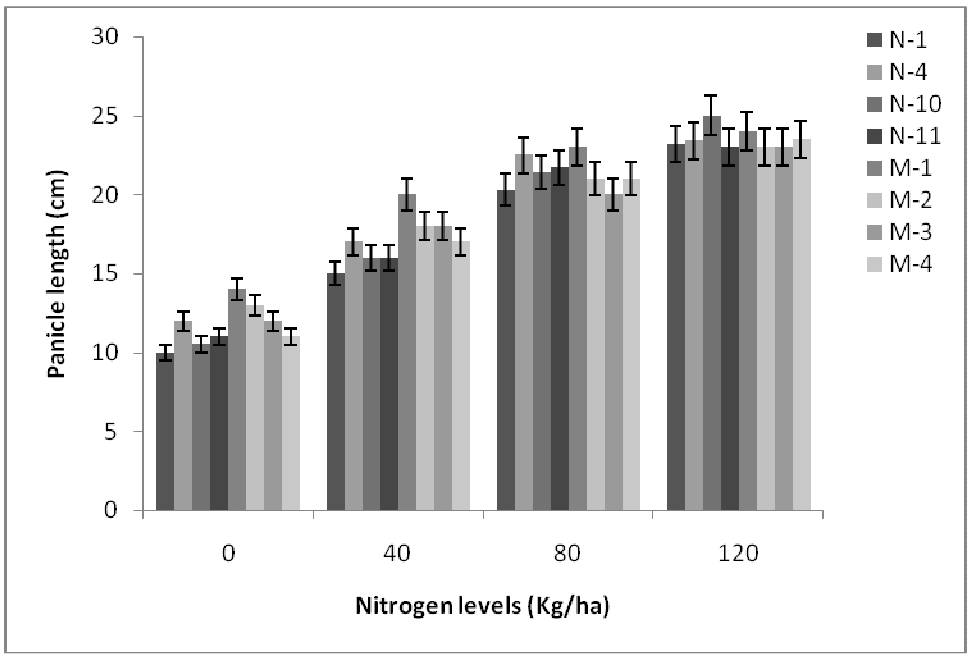

Fig. 1. Effect of N rate on panicle length of eight rice varieties grown at four levels of nitrogen treatment (Means of three replicates ± SE). LSD (0.05) V = 1.06, T = 0.75.

Yield at 14% moisture content

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Nitrogen application exhibited a highly significant (P ≤ 0.05) effect on yield at 14% moisture content. Plants subjected to 120N and 80N recorded significantly (P ≤ 0.05) higher yield at 14% moisture content as compared to plants subjected to 40N and 0N. The varietal difference was also significant(P ≤ 0.05) with MWUR 1 and 2 registering significantly higher values at 0N as compared to MWUR 3, 4 and the NERICAs. At 40N, MWUR 1 and 2 recorded significantly higher yield at 14% moisture content compared to the NERICAs however, the difference in yield was not statistically significant from MWUR 3 and 4. The results also revealed a significant variety and treatment interaction.

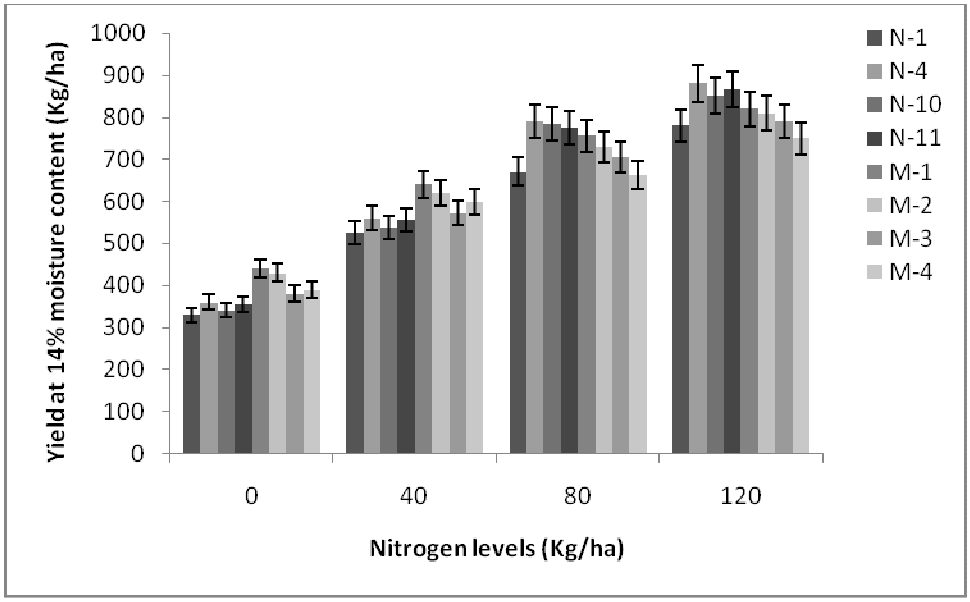

Fig. 2. Effect of N rate on yield at 14% moisture content of eight rice varieties grown at four levels of nitrogen treatment (Means of three replicates ± SE). LSD (0.05) V = 15.67, T = 11.07.

Filled grain ratio (%)

Generally nitrogen application caused an increase in filled grain ratio percentage in all the NERICA and MWUR rice varieties. Plants exposed to 120N and 80N registered significantly (P

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≤ 0.05) higher filled grain ratio percentage as compared to plants exposed to 0N and 40N. The varietal difference was highly significant (P ≤ 0.05). MWUR 1 and 2 recorded significantly (P ≤ 0.05) higher filled grain ratio percentage at 0N and 40N compared to MWUR 4 and the NERICAs. At 80N and 120N, NERICA 4, 10 and 11 registerd slightly higher filled grain ratio percentage compared to MWUR varieties. There was a significant (P ≤ 0.05) interaction between variety and nitrogen level.

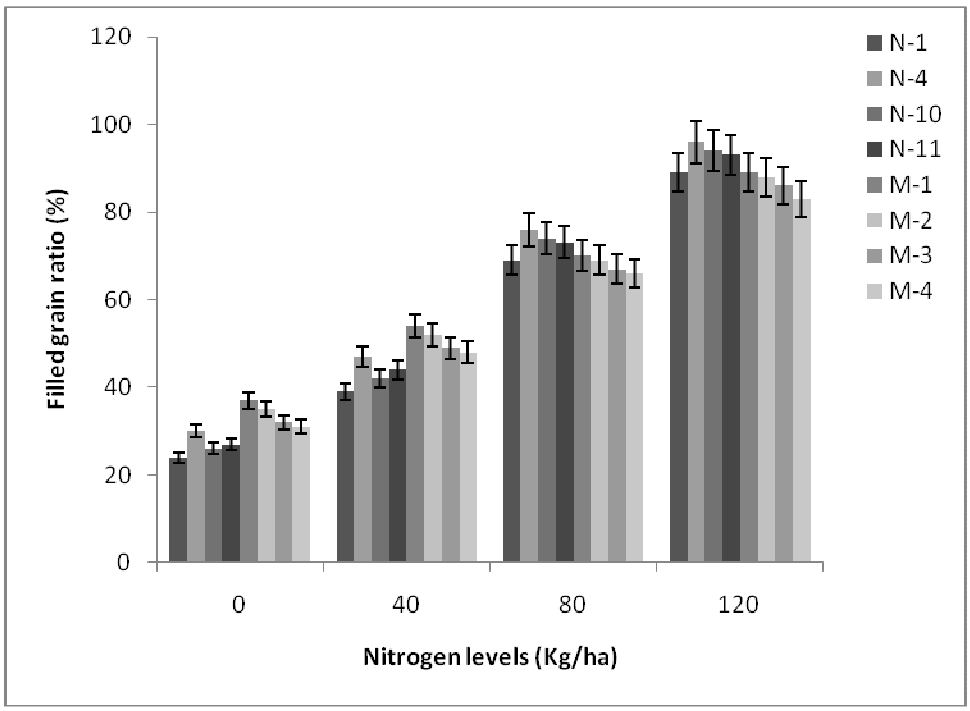

Fig. 3. Effect of N rate on filled grain ratio (%) of eight rice varieties grown at four levels of nitrogen treatment (Means of three replicates ± SE). LSD (0.05) V = 1.2, T = 0.86.

Yield component

Yield component significantly (P ≤ 0.05) increased with the increase in nitrogen rate in all the NERICA and MWUR rice varieties with plants subjected to 120N recording the highest yield while plants subjected to 0N recorded the lowest yield. The varietal difference was significant (P

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≤ 0.05) with MWUR 1 having significantly higher yield component at 0N and 40N compared to MWUR 3, 4 and NERICA 1, 4, 10 and 11. Generally MWUR varieties registered higher yield components at 0N and 40N while NERICA varieties recorded higher yields at 80N and 120N. NERICA 4 had significantly (P ≤ 0.05) higher yield component at 0N in comparison to NERICA1, 10 and 11. There was a positive and significant correlation between yield component and filled grain ratio percentage (Figure 5). Yield component and panicle length also recorded a positive and significant correlation (Figure 6).

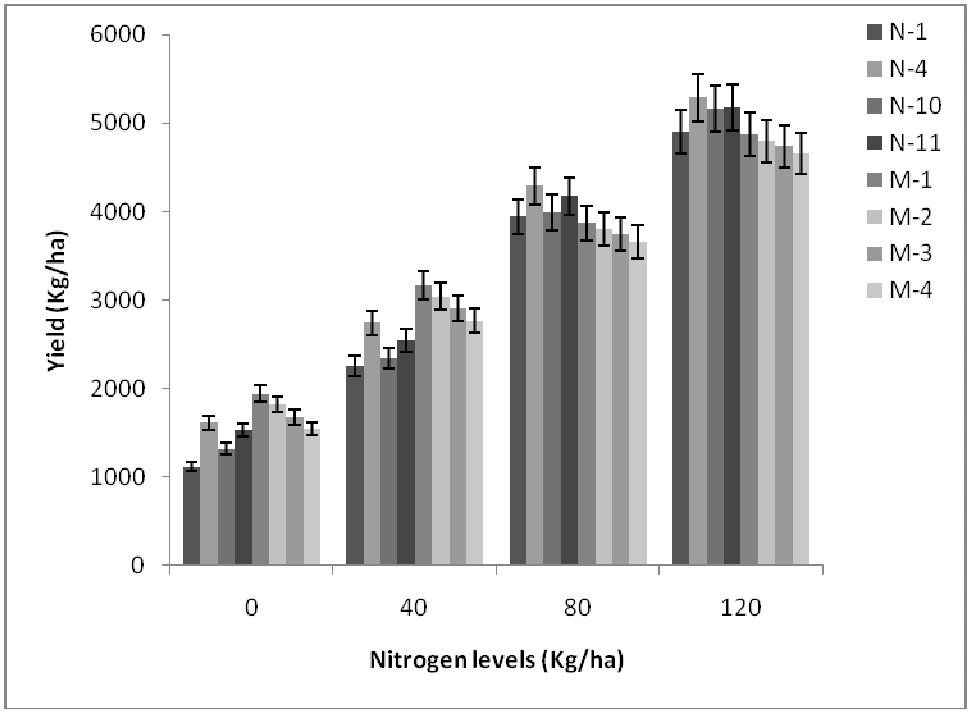

Fig. 4. Effect of N rate on yield component of eight rice varieties grown at four levels of nitrogen treatment (Means of three replicates ± SE). LSD (0.05) V = 99.68, T = 70.48.

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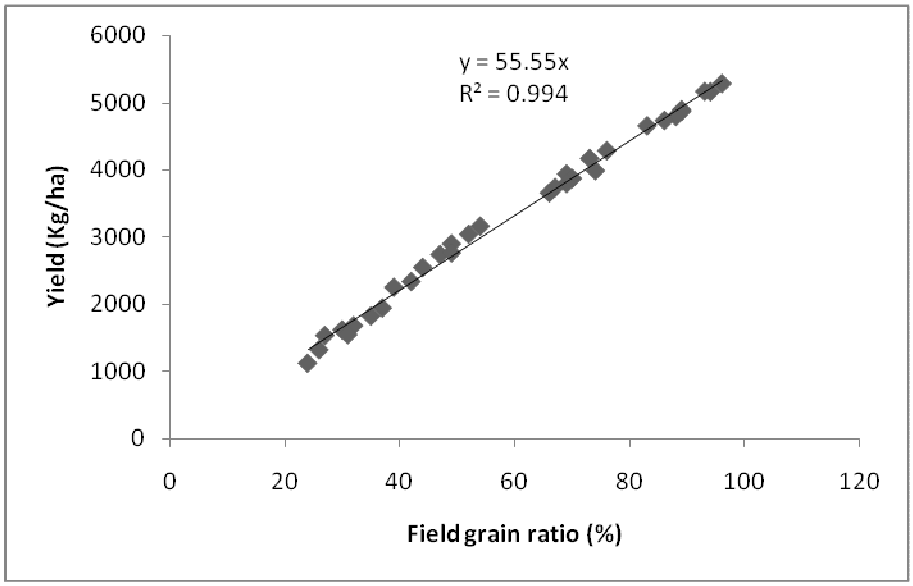

Fig.5. Relationship between yield component and field grain ratio(%) of rice as affected by different varieties and nitrogen levels

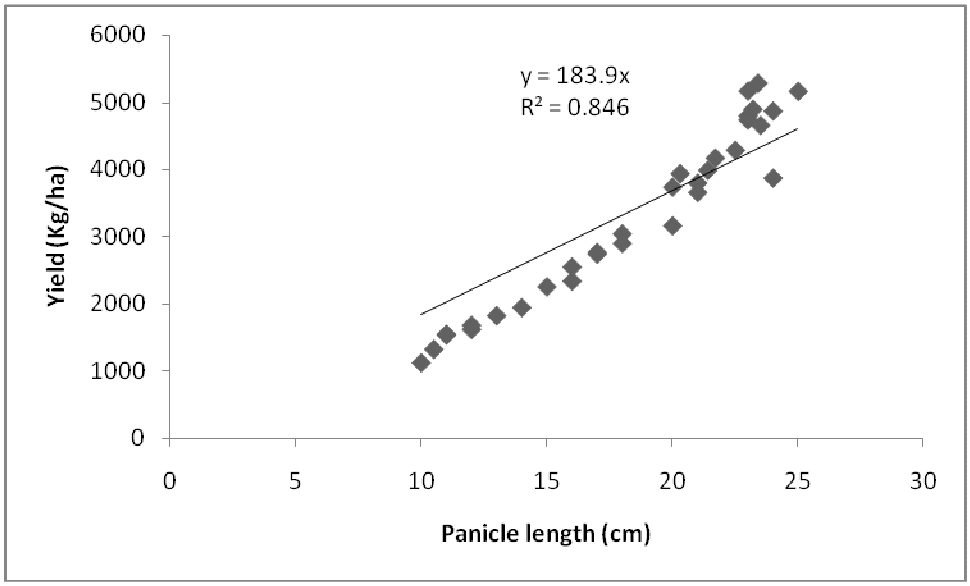

Fig.6. Relationship between yield component and panicle length of rice as affected by different varieties and nitrogen levels

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Discussion

The results showed that panicle length was significantly influenced by different nitrogen application treatments and plants exposed to higher nitrogen levels recorded significantly higher panicle lengths. These results are in line with those reported by Haque *et al*. (2012), Rafey *et al.* (1989) and Ali *et al*. (2000). The longer panicles obtained in treatments receiving higher nitrogen rates were probably due to better nitrogen status of plant during panicle growth period because nitrogen takes part in panicle formation as well as panicle elongation and for this reason, panicle length increases with the increase of N-fertilization. When absorbed during the reproductive and ripening phases, nitrogen promotes development of the panicle and stimulates nutrient absorption and assimilation as evidenced by an increase in size and number of filled grain ratio percentage (Awan *et al*., 2011). According to Pramanik and Bera (2013), the increase in panicle length due to adequate N nutrition is explainable in terms of possible increase in nutrient mining capacity of plant as a result of better root development and increased translocation of carbohydrates from source to growing points in well-fertilized plots. The varietal difference was also significant with MWUR 1 recording higher panicle length at low nitrogen levels compared to other rice varieties. This may imply that MWUR 1 is tolerant to low nitrogen and is cell division and elongation is not greatly affected by nitrogen deficit as compared to MWUR 2, 3, 4 and NERICA 1,4,10 and 11. NERICA 4 registered higher panicle length regardless of the nitrogen level as compared to NERICA 1, 10 and 11. This might imply that among the NERICA varieties under study, NERICA 4 is tolerant low nitrogen conditions in the soil but can also thrive under adequate nitrogen levels.

Application of N fertilizers significantly increased field grain ratio percentage and yield at 14% moisture content. Field grain ratio percentage and yield at 14% moisture content increased in all the rice varieties with an increase in nitrogen level. These results are in accordance with those of Fageria and Baligar (2001), Kamara *et al*. (2010) and Meena *et al*. (2003). The increase in yield at 14% moisture content with increasing N rates may be due to the high number of panicles per square meter, which is significantly associated with high grain yield in rice (Fageria and Baligar, 2001). According to Kamara *et al*. (2010), the improvement in yield owing to the application of N-fertilizers might be brought about by the beneficial

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effect of nitrogen on nutrient uptake and physiological growth. Nitrogen nutrition influences the content of photosynthetic pigments, the synthesis of the enzymes involved in the carbon reduction and the formation of the membrane system of chloroplasts thus the increase in growth and yield owing to the application of N-fertilizers may be attributed to the fact that these nutrients being important constituents of nucleotides, proteins, chlorophyll and enzymes, involve in various metabolic processes which have direct impact on vegetative and reproductive phases. Varietal difference was significant with MWUR rice varieties having higher filled grain ratio percentage and higher yield at 14% moisture content at low nitrogen levels as compared to NERICA varieties while the NERICA varieties registered higher values at high nitrogen levels. This may imply that the MWUR rice varieties are tolerant to low nitrogen and may out-yield the NERICAs under low nitrogen soils while the NERICAs might perform better than the MWUR varieties under optimal nitrogen levels.

Nitrogen fertilizer application had a statistically significant effect on the yield component of the studied rice varieties. There was an increase in yield component with increase in each successive level of nitrogen fertilizers. Similar results were also reported by Bhuyian *et al.* (1990), Hach and Nam (2006) and Islam *et al*. (2009). The higher yield component under high nitrogen levels might be attributed to the vigorous and healthy growth and development of more productive tillers and leaves ensuring greater resource utilization as compared to plant that were deficient in N. Increases in yield components are associated with better nutrition, plant growth and increased nutrient uptake (Thakur, 1993). The crop at no nitrogen level produced the lowest grain yield which was significantly lower than all other nitrogen levels tested. This might be due to lack of supply of nitrogen into the soil to meet the required nutrients for physiological processes, which in turn lowered the yield. According to Chaturvedi *et al*. (2005), the application of nitrogen improves various crop parameters like panicle length, more productive tillers and grain yield thus resulting in higher yields. There was a significant positive relationship of yield component with panicle length and filled grain ratio percentage in all the varieties. This implies that panicle length is a significant yield component for rice yield. This high capacity for sink formation was associated with their higher capacity for N acquisition and biomass production. Panicle length contributes to increment of rice grain yield indirectly by increasing the number of panicles per m^2 and number of spikelets per panicle

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Varietal difference was significant and MWUR varieties recording superior yield components at low nitrogen levels (0N and 40N) as compared to the NERICAs with MWUR 1 and 2 recording higher values while the NERICAs out-yielded the MWUR varieties at higher nitrogen (80N and 120N). NERICA 4 and 11 recorded higher yield components at low nitrogen level as compared to the other NERICA varieties. The results may imply that the MWUR varieties are tolerant to low nitrogen as compared to the NERICAs and that MWUR 1 and 2 are more adaptable to low nitrogen as compared to MWUR 3, 4 and the NERICA varieties. NERICA 4 may be more adaptable to low nitrogen as compared to the other NERICA varieties that were under study. MWUR varieties were bred as low-management rice plant types targeted for resource-limited, smallholder production systems and their performance with at 0N and 40N thus confirms the significant role they may play in African smallholder systems. The observed greater yield in NERICA 4 compared to NERICA 1, 10 and 11 at 0N and 40N could be attributed to its higher potential for panicle production and greater ability to partition photosynthates more efficiently to the grain as indicated by higher filled grain ratio percentage, compared to the other varieties. According to results by Kamara *et al*. (2010) and Oikeh *et al*. (2009), NERICA 4 was tolerant to low N because of the greater yield observed especially at zero and low N. This was attributed to its high potential for panicle production and ability to partition photosynthates more efficiently to the grain as indicated by a higher harvest index compared with the other cultivars. Ekeleme *et al*. (2009) reported that NERICA 4 produced significantly higher yield and was better weed competitive than CG 14, ITA 150, WAB 56-104, and the other NERICA cultivars (NERICA 1, 2, and 3) in the dry savannas of Nigeria.

Conclusion

In the present study, nitrogen levels affected panicle length and yield components of all the MWUR and NERICA varieties studied. The study showed appreciable varietal difference in response to low nitrogen conditions. Generally MWUR varieties studied were more adaptable to low nitrogen conditions as compared to NERICA varieties. Thus, the study confirmed that MWUR varieties which were bred as low-management rice plant types targeted for resource-limited, smallholder production systems exhibit

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superior yielding capacity under low nitrogen conditions and may play a significant role in Kenyan smallholder systems. The NERICA varieties recorded higher yield at high nitrogen levels as compared to MWUR varieties. However, NERICA 4 gave higher yield as compared to other NERICA varieties regardless of the nitrogen level. The decision on the appropriate N rates should be based on economic considerations given the ever escalating cost of nitrogen fertilizers in Kenya. Results from our study suggest that MWUR 1 and 2 and NERICA 4 were more tolerant to low nitrogen as compared to MWUR 3 and 4 and NERICA 1, 10 and 11 because of higher panicle length, higher filled grain ratio percentage and higher yield component and may be suitable for soils deficient in nitrogen.

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