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Ratooning ability and its effect on grain yield of upland Nerica rice varieties in Central Kenya

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Key words: Grain yield, Kenya, NERICA, ratooning, upland rice.

Abstract

Field experiments were conducted at Mwea Irrigation Agricultural Development (MIAD) Centre in central Kenya (0^o 41'S, 37^o 20'E, 1159m) to assess rice ratooning ability and its effect on grain yield. Four upland NERICA (NERICA 1, 4, 10 and 11) and one local *Oryza sativa* (Duorado precoce) rice varieties were planted in randomized complete block design with three replicates. The main crop was harvested at maturity after which the tillers were hand cut to stubble of about 15cm tall. The stubbles were left to grow without application of any further input until the ratooned plants were ready for harvesting. Ratooning ability among the NERICAs ranged from 26% (NERICA 1) to 39% (NERICA 4) while Duorado precoce recorded the lowest (19%). Total grain yield (main crop plus ratoon) differed significantly ($p<0.05$) among the rice varieties with NERICA 4 attaining the highest total yield (6206kg ha^{-1}) while the local variety Duorado precoce attained the lowest (3376kg ha^{-1}). NERICA 4 and NERICA 10 recorded remarkable yield increase of more than 1500kg ha^{-1} (the average yield of upland rice in Sub-sahara Africa) with no additional input. NERICA 4 recorded the highest grain yield and ratooning ability and is therefore recommended for Central Kenya though the yield and ratooning ability of the other three NERICA varieties were also encouraging. Results of this study can serve as a guide on how ratooning can be used to maximize upland rice yield in Central Kenya.

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Introduction

Rice belongs to the family Poaceae, subfamily Bambusoideae, tribe Oryzeae and genus *Oryza* L. (Vaughan, 1994). There are two cultivated rice species; O. *sativa* L. of Asian origin and *O. glaberrima* Steud of African origin (Clayton and Renvoize, 1986, Linares, 2002,). Rice is the staple food for more than half of the world's population (Atera *et al.*, 2011) and in Africa, it is gradually becoming a staple food crop for most countries (Liu *et al.*, 2012). The production of rice in Africa does not meet this demand and therefore scientists are trying to fill the gap by developing high yielding cultivars such as New Rice for Africa (NERICA) that are resistant to insects and diseases and are adaptable to various abiotic stresses in the continent. NERICA rice varieties are interspecific hybrid progenies developed by West Africa Rice Development Authority (WARDA) between the two cultivated *Oryza* species with *O. sativa* L. as the maternal parent and *O.glaberrima* Steud as the paternal parent (Dzomeku *et al.*, 2007, Africa Rice Center, 2008). *O. glaberrima* Steud confers the new rice with resistance to drought, pests, diseases, weeds and problematic soils, whereas *O. sativa* L. bestows high yielding characters, good response to mineral fertilization and non-shattering characteristics (Kijima *et al.*, 2006, Dzomeku *et al.*, 2007, Atera *et al.*, 2011).

Earlier studies (Hanfei, 1992; Frageria *et al.*, 1997, Dingkuhn *et al.*, 1998, Jones, 1998) outline the advantages of NERICA compared to its parents; namely, it can grow well in upland, medium and even lowland areas, early maturity, resistance to local stresses such as drought, infertile soils, pests and diseases (especially blast, stem borers and termites), higher yields, higher protein content and good taste. Upland NERICA is popular in that it is rain fed hence a good food security measure in the prevailing uncertainty of climate change. Rain fed rice crop does not require flooding but readily grows by use of rain water or grows in wetlands and in swampy areas or with supplementary irrigation (Pande, 1994). In general, upland NERICA rice can grow in any environment with at least 15-20mm of five-day rainfall during the growing cycle. During germination and early growth stages, 15mm per five-day rainfall is sufficient (Africa Rice Center, 2008). Dourado precoce is a local upland rain fed rice variety (Kouko *et al.*, 1992) and therefore compares well with the improved upland NERICA rice varieties.

Apart from developing high yielding varieties through conventional breeding which is time consuming and expensive, other techniques such as ratooning that could possibly improve rice productivity are also required. Ratooning (from Spanish *retoño*, "sprout") is the practice of obtaining a second harvest from tillers originating from the stubble of the previously harvested (main) crop (Jones and Snyder, 1987, Chauhan *et al.*, 1985). Tillering ability has been cited as one of the most important genetic factors affecting ratoon performance of grasses (Chauhan *et al.*, 1985; Oad *et al.*, 2002). Oad *et al.* (2002) reported that ratoon crop should have sufficient tillers in the early stage of the main crop harvest to achieve high yields. Too few tillers result in too few panicles; but excess tillers cause high tiller abortion, small panicles, poor grain filling and a consequent reduction in grain yield (Peng *et al.*, 1994). The main crop stubble should be left with at least 2-3 nodes for proper ratooning (Chauhan *et al.*, 1985). The recommended optimum cutting height for good ratooning is 15-20cm (Bahar and De Datta, 1977; Chauhan *et al.*, 1985). Reducing the cutting height below 15cm leads to death of the buds in the nodes closer to the ground which increases the number of missing hills, reduces tillering and thus reducing the grain yield. Rice ratooning depends on the ability of dormant buds on the stubble of the main crop to remain viable. The success of a good ratoon crop also depends on agronomic practices and growth duration of the main crop (Jones and Snyder, 1987), the care with which the main crop is protected against insect pests and diseases (Rehman *et al.*, 2007), inherent ratooning ability of the cultivars (Chauhan *et al.*, 1985), light, temperature, soil moisture and fertility (Chauhan *et al.*, 1985; Rehman *et al.*, 2007). Ratooning technology has been used in several countries including India, Thailand, Taiwan, Swaziland, China, the United

States and Philippines (Nakano and Morita, 2007; Liu, 2012). Several studies have reported a high grain yield in ratoon crop in the tropics (Chauhan *et al.*, 1985), in India (Reddy *et al.*, 1979), in Ethiopia (Prashar, 1970) and in China (Liu *et al.*, 2012).

The main benefits of rice ratooning are that the crop matures earlier than the main crop and increases production without expanding land area, lower production costs due to savings in land preparation and plant care during early growth, lower water requirements than the main crop and maintenance of genetic purity of a variety or hybrid rice through several seasons (Chauhan *et al.*, 1985, Sanni *et al.*, 2009, Tari, 2011, Liu *et al.*, 2012). Ratooning is known to give a steady yield for three years under moist conditions (Jones and Snyder, 1987). Ratooning is therefore perhaps one practical way of increasing rice productivity per unit land with less labour and input than the main crop as neither land preparation nor planting is needed for the ratoon crop (Sanni *et al.*, 2009). Studies on rice ratooning are however generally lacking in Kenya and specifically in central Kenya. The present study therefore undertook to; evaluate the ratooning ability of four upland NERICA rice varieties (NERICAs 1, 4, 10 and 11) and to assess the effect of ratooning on grain yield of the four rice varieties in central Kenya.

Materials and methods

Plant material

The plant materials were four NERICA [NERICA-1 (WAB 450-1-B-P-38-HB), NERICA-4 (WAB 450-1-B-P-91-HB), NERICA-10 (WAB 450-11-1-1-P41-HB), NERICA-11 (WAB 450-16-2-BL2-DV1)] and one locally cultivated *O. sativa* [Dourado precoce, (WAB 56-104)] upland rice varieties (Semagn *et al.*, 2006). Dourado precoce was used as the standard check. Seeds for the five rice varieties were sourced from the Kenya Agricultural Research Institute (KARI) Mwea located in Central Kenya at latitude 0.7°S and longitude 37°37'E (Jaetzold and Schimdt,1982).

Study site

The study was conducted at Mwea Irrigation Agricultural Development (MIAD) Center in Mwea Tebere Irrigation Scheme of Kenya. The scheme is located in the west central region of Mwea Division, Kirinyaga county approximately 100 km north east of Nairobi city at the foot hills of Mt Kenya. It lies at latitude 0° 41'S and longitude 37° 20'E and an altitude of 1159 m above sea level covering an area of about 23,640 hectares (NIB, 1996).The scheme lies in Agro-Ecological Zone (AEZ) iii that has high agricultural potential with dark deep vertisols, average pH of 6.8 (Jaetzold and Schimdt, 1982) and annual rainfall between 950 and 1500 mm (FAO, 1996). More than 75% of the scheme area is used for rice cultivation. The remaining area is used for horticulture and subsistence farming, grazing and community activities (Pratt *et al.*, 1966).

Field experiments

The rainfed upland rice trials were conducted between the months of April 2010 and June 2011 with two seasons of the main crop and two seasons of the ratoon crop at two neighbouring sites (site one and two) at MIAD. Main and ratoon crops one were planted at site one which had been previously sown to rice (*Oryza sativa* L.) and then left fallow for one season in the year 2010 while main and ratoon crops two were planted the following year (2011) in a neighbouring site two which was previously sown to sorghum (*Sorghum verticilliflorum* (Steud.) Stapf.). Main crop one was planted on the 9th of April 2010 and harvested on the 16th of August 2010 upon which the ratoons were established on the same day and harvested on 17th November 2010. Main crop two was planted on the 30th of October 2010 and harvested on the 18th of March 2011 upon which the ratoons were established on the same day and harvested on the 22nd of June 2011. Randomised complete block design with three replicates was used in each season. Seeds of each rice variety were sown on a plot of 4 m x 4 m at a rate of three seeds per hole which was later followed with thinning to two seedlings per hole. Sowing depth of 3 cm and spacing of 20 cm within the row and 40 cm between the rows was used as described by Asif *et al.* (2000) and Pande (1994). Diammonium phosphate (DAP) fertilizer was used as basal application at the rate of 100 kg ha^{-1} during land preparation while Sulphate of Ammonia was applied at the rate of 65 kg ha^{-1} first at tillering and a second time at booting stage of the main crop, as recommended by Africa Rice Center (Sahrawat *et al.*, 2001; Toure *et al.*, 2013). The plots were weeded at three weeks interval to minimize weed infestation. Bird scaring was carried out between 6am and 6pm daily at the reproductive and ripening phases of the rice crop.

Twenty plants of each rice variety were randomly selected from each plot and tagged using different colours for scoring of agronomic traits which included total number of tillers and number of productive tillers in both the main and the ratoon crop. The total number of tillers per hill was taken at maximum tillering stage while the number of productive tillers was recorded at the reproductive stage of the rice crop. At maturity, the plants from each plot were harvested using sickle knives to stubble of about 15cm tall from the soil surface as described by Chauhan, (1985) and Bahar and De Datta, (1977). This prepared the stubble for ratooning. The harvested panicles were then threshed manually and cleaned by hand winnowing to remove foreign seeds and other impurities. Soon after harvesting the main crop, the stubble plants were left to grow without any further input (except for supplementary irrigation for ratoon crop one) until they were ready for ratoon harvesting. The seeds from each harvest were dried to moisture content of 14% (Yoshida, 1981; Atera *et al.*, 2011), weighed, and the weights were used to calculate grain yield per hectare. Meteorological data (temperature and rainfall) that prevailed during the period of the current study were obtained from MIAD weather station.

Statistical analysis

Data collected were statistically analyzed with the General Linear Model (GLM) of the Genstat program. Fischer's protected LSD was used for mean separation at 5% probability level. Ratooning ability of the rice varieties was calculated as a percentage of the main crop grain yield using the equation 1 as developed by Sanni *et al.* (2009).

$$RA = \frac{RCGY}{MCGY} * 100 \text{ -------------------- (equation 1)}$$

Where, *RA* = Ratooning Ability, *RCGY* = Ratoon Crop Grain Yield, *MCGY* = Main Crop Grain Yield.

Results

Meteorological data

The annual rainfall distribution in MIAD is usually bimodal with the long rains starting from March to May with a mid dry season of four months (June to September) while the short rains commence from October to December. However in this study, the long rains started earlier (January) in the year 2010 (Fig. 1). The highest and the lowest recorded monthly rainfall that prevailed during the study period were 290mm in May 2010 and 0mm in September 2010 for main and ratoon crop one, and 283mm in April 2011 and 6mm in January 2011 for main and ratoon crops two respectively. The annual rainfall for the year 2010 was 976mm while the year 2011 recorded a total of 661mm of rainfall from January to July. The period of growth for main crop one and ratoon crop one (April–October 2010) recorded the lowest and the highest average temperatures as 16.7°C in August 2010 and 29.5°C in October 2010 respectively while main crop two and ratoon crop two (October 2010-June 2011) registered 14.5°C in January 2011 and 35.6°C in May 2011 as the lowest and the highest temperatures respectively (Fig. 2).

Tillering ability and productive tillers from the main Crop

The number of tillers varied among the five upland rice varieties with the local variety Duorado precoce recording significantly ($p<0.05$) lower number of tillers (17) per hill than the NERICA rice varieties (Fig. 3). Though the difference in tiller number was not significant among the four NERICA varieties, NERICA 4 attained the highest number of tillers (23) per hill. The number of productive tillers per hill also varied significantly ($p<0.05$) among the five rice varieties with the local variety, Duorado precoce recording the lowest value (9 productive tillers per hill). Among the NERICAs, NERICA 10 recorded the highest number of productive tillers (17) per hill while NERICA 11 recorded the least (15 productive tillers per hill).

Table 1. The main, ratoon and total grain yields of five upland rice varieties.

	Yield (kg ha^{-1})		
Variety	Main crop harvest	Ratoon crop harvest	Total harvest
NERICA 1	4588^{a}	1193^{b}	5781^{ab}
NERICA 4	4465^{a}	1741^{a}	6206^{a}
NERICA 10	4099^{b}	1517^{ab}	5616^{b}
NERICA 11	4436^{ab}	1242^{b}	5678^{b}
Duorado precoce	2837^{c}	539^{c}	3376^{c}

Means in the same column followed by the same letter(s) are not significantly ($p>0.05$) different according to Fischer's protected LSD.

Tillering ability and productive tillers from the ratoon crop

The ratoon crop showed significant differences ($p<0.05$) in the number of tillers among the five upland rice varieties (Fig. 4). Among the four NERICA rice varieties, NERICA 10 achieved the highest number of tillers (20 tillers per hill) while NERICA 11 recorded the lowest (18 tillers per hill). The local variety Duorado precoce achieved 15 tillers per hill which was significantly ($p<0.05$) lower than any of the four NERICA rice varieties. Similarly, the number of productive tillers per hill varied significantly ($p<0.05$) among the five rice varieties with Duorado precoce recording the lowest value (7 productive tillers per hill). NERICA 4 recorded the highest number of productive tillers (15 productive tillers per hill) among the NERICAs, while NERICA 1 recorded the least (13 productive tillers per hill).

Table 2a. Correlation coefficients (r) for Grain yield (GY), Tiller number (TiN) and Productive tillers (PTi) of upland rice varieties from the main crop.

GY	1		
TiN	0.601***	1	
PTi	0.586***	0.800***	1
	GY	TiN	PTi

*** Significant at $p<0.001$.

Grain yield in the main crop harvest

Significant differences ($p<0.05$) in grain yield were observed among the five upland rice varieties in the main crop (Table 1). NERICA 1 attained the highest grain yield (4,588 kg ha^{-1}) followed by NERICA 4 (4,465 kg ha^{-1}) while NERICA 10 achieved the lowest (4,099 kg ha^{-1}) among the NERICA varieties. The standard check Duorado precoce recorded grain yield of 2837 kg ha^{-1} which was significantly ($p<0.05$) lower than any of the four NERICA rice varieties.

Grain yield in the ratoon crop harvest

There were significant differences ($p<0.05$) in the ratoon crop grain yield among the five upland rice varieties (Table 1). Among the four NERICA varieties, NERICA 4 achieved the highest ratoon grain yield (1741 kg ha^{-1}) followed by NERICA 10 (1517 kg ha^{-1}) while NERICA 1 recorded the lowest (1193 kg ha^{-1}). The standard check Duorado precoce attained grain yield of 539 kg ha^{-1} which was significantly ($p<0.05$) lower than any of the four NERICA rice varieties.

Total grain yield in double crop harvest

The total grain yield calculated as the sum of the main and ratoon grain yields differed significantly ($p<0.05$) among the five rice varieties (Table 1). NERICA 4 attained the highest total grain yield (6206 kg ha^{-1}) followed by NERICA 1 (5781 kg ha^{-1}) while NERICA 10 scored the lowest (5616 kg ha^{-1}) among the NERICA rice varieties. Duorado precoce recorded a total grain yield of 3376 kg ha^{-1} which was significantly ($p<0.05$) lower than any of the four NERICA rice varieties. Rationally, total grain yield in the total harvest was the highest relative to the main and the ratoon harvest (Table 1).

Table 2b. Correlation coefficients (r) for Grain yield (GY), Tiller number (TiN) and Productive tillers (PTi) of upland rice varieties from the ratoon crop.

GY	1		
TiN	0.487***	1	
PTi	0.528***	0.766***	1
	GY	TiN	PTi

*** Significant at $p<0.001$.

Comparative ratooning ability as a percentage of the main crop grain yield

The ratooning ability calculated as percentage of the main crop grain yield varied significantly ($p<0.05$) among the five upland rice varieties (Fig. 5). The lowest ratooning ability (19%) was observed in the standard check Duorado precoce which was significantly ($p<0.05$) lower compared to the four NERICA rice varieties. Among the NERICA varieties, NERICA 4 had superior ratooning ability of 39% followed by NERICA 10 with 37% though the difference was not significant ($p>0.05$) between the two varieties. NERICA 1 recorded the lowest ratooning ability (26%) among the NERICAs which was significantly higher ($p<0.05$) than Duorado precoce (19%).

Correlation between grain yield and agronomic traits

Total number of tillers (r= 0.601***) and productive tillers (r= 0.586***) from the main crop significantly and positively correlated to grain yield (Table 2a). Similarly, the two agronomic traits from the ratoon crop were significantly and positively correlated (0.487***and 0.528*** respectively) with grain yield (Table 2b).

Discussion

The rainfall ranges recorded during the rice growing period of the current study are within the recommended range for upland rice crop except for ratoon crop one where no rainfall was recorded in September 2010. This month coincided with the early growth stage of the ratoon crop growth where water is very crucial for crop development and therefore supplementary irrigation was applied within this period. According to Africa Rice Center (2008), NERICA rice responds well to low rainfall, a minimum of 20mm per week is required which should be well distributed throughout the growing period.

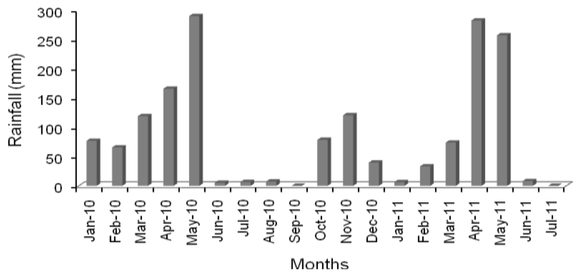

Fig. 1. Rainfall distribution pattern at MIAD, Central Kenya (2010-2011).

The four NERICA rice varieties as well as the local variety Duorado precoce used in the current study produced tillers from stubble of harvested plants of the main crop giving rise to ratoon crop thus demonstrating the ratooning potential of the rice crop. However, the main crop of the five upland rice varieties recorded higher total number of tillers as well as productive tillers than the ratoon crop. This supports earlier findings (Sanni *et al.* 2009; Oad *et al.*

2002; Chauhan *et al.* 1985) where the main crop was found to produce higher number of tillers and productive tillers than the ratoon crop. This possibly contributed to the observed lower grain yield in the rice ratoon crop compared to the main crop in the current study (Table 4.1). Tillering ability has been cited as one of the most important genetic factors affecting ratoon performance of grasses (Chauhan *et al.*, 1985; Oad *et al.*, 2002).The NERICA rice varieties produced higher total number of tillers as well as productive tillers than the local variety Duorado precoce which translated to higher grain yield from the NERICAs thus better ratooning ability.

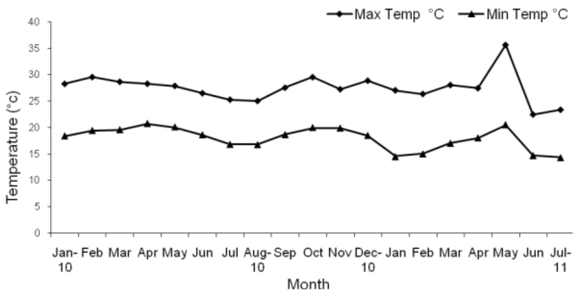

Fig. 2. Monthly average of the daily minimum and maximum temperature (°C): January 2010- July 2011.

Grain yields obtained from this study differed among the five upland rice varieties in the main as well as the ratoon crops with the NERICA rice varieties attaining significantly ($p<0.05$) higher yields (kg ha^{-1}) compared to the standard check Duorado precoce. This is in consonance with earlier studies (WARDA, 1999; Mitra *et al.*, 2005; Ekeleme *et al.*, 2007; Sanni *et al.*, 2009; Liu *et al.*, 2012) where differences in grain yields were reported among rice varieties. Among them, Sanni *et al.* (2009) reported higher yields from NERICA rice varieties compared to local landrace CG 14 with NERICAs 1 and 4 attaining the highest yield. The results were however contrary to the findings of Atera *et al.* (2011) who observed no differences in grain yield among rice varieties. The NERICA grain yields from the main crop which varied from 4099 kg ha^{-1} to 4588 kg ha^{-1} for NERICA 10 and NERICA 1 respectively in the current study are within the estimated yield of NERICA rice varieties of 4000-7000 kg ha^{-1} according to Africa Rice Center (2008). This is however lower compared to the findings of Liu *et al.* (2012) who reported main crop grain yields varying between 6000-7000kg ha^{-1}. This could possibly be due to use of different rice varieties and differences in climatic and edaphic factors between the areas of study.

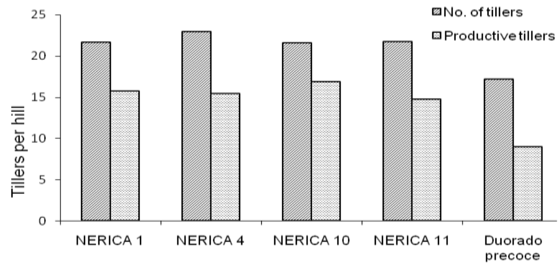

Fig. 3. Total number of tillers and productive tillers from the main crop of five upland rice varieties. Bars with the same letter(s) [a-c or A-C] are not significantly different at 5% level.

Other studies reported that rice yield in upland systems of Africa is about 1000 kg ha^{-1}(Kijima *et al.*, 2006; Atera *et al.*, 2011) and that the inclusion of upland NERICA cultivars in the cropping system has been found to bring significant increase in the potential yield of rice. Kijima *et al.* (2006) further stated that upland NERICA varieties yield in Uganda was twice as much compared to traditional upland rice varieties. Results in West Africa also showed that NERICA main crop yields about 2500 kg ha^{-1} with low use of inputs and that under careful fertilizer use, yield of 5000 kg ha^{-1} or more is achievable (WARDA, 1999, Kijima *et al.*, 2006). Preliminary evaluations from WARDA showed that NERICA has surpassed the local landraces in yield with a potential to revolutionize the rice industry (Atera *et al.*, 2011). This is supported by the findings of this study where the NERICA rice varieties attained significantly higher grain yields than the local Duorado precoce variety in both the main and the ratoon crop.

The NERICA rice ratoon grain yields observed in the current study varying from 1193 kg ha^{-1} to 1741 kg ha^{-1} are in agreement with the findings of Bahar and Datta (1977) from evaluation of six rice cultivars in Philippines. The values were however lower compared to the findings of Liu *et al.* (2012) who reported ratoon crop grain yields between 4000-4500 kg ha^{-1}. Chauhan *et al.* (1985) also noted a wide variation in ratoon yield ranging from 100-8700 kg ha^{-1} which they suggested was an encouraging potential for ratoon cropping. Ratooning in rice and the prospects of increasing rice production in the tropics through ratooning has also been reported in other studies (Bahar and De Datta, 1977; Nakano and Morita, 2007).

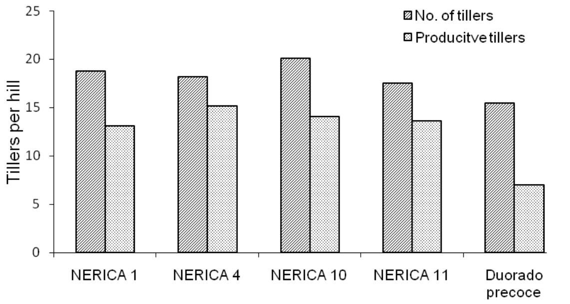

Fig. 4. Number of tillers and productive tillers from the ratoon crop of five upland rice varieties. Bars with the same letter(s) [a-c or A-C] are not significantly different at 5% level.

The ratoon grain yield from this study was found to be lower than the main crop yield for the five upland rice varieties. This is in agreement with earlier findings (Bahar and De Datta, 1977; Bardhan *et al.*, 1982; Bollich *et al.*, 1988; Web *et al.*, 2002; Tari, 2011; Liu *et al.*, 2012) who reported lower grain yield from the ratoon crop compared to the main crop.The findings are however contrary to the studies of Parago, (1963), Prashar (1970) and Reddy *et al.* (1979) where ratoon yields were found to surpass main crop yields. The low ratoon crop yield in the current study was perhaps due to lower number of productive tillers from the ratoon crop (Fig. 4) compared to the main crop (Fig. 3), which were found to significantly and positively correlate with grain yield (Tables 2a and 2b). The number of productive tillers from the ratoon crop showed a stronger positive correlation (r= 0.528***) than the number of tillers (0.487***) to grain yield. This is an indication that tillers can form but no grains if the tillers are non productive resulting to lower grain yields. NERICA 4 recorded the highest ratoon yield (1741 Kg ha^{-1}) and ratooning ability (39%) which could possibly be due to the higher number of productive tillers from its ratoon crop (Fig. 4).

Ratoon grain yield is also reported (Tari, 2011; Oad *et al.*, 2002; Bollich *et al.*, 1988) to be affected by main crop harvesting time and climate conditions especially temperature at the ratoon reproductive stage. If ratoon crop encounters low temperatures at the ratoon reproductive stage, growth duration is increased. It has been reported (Oad *et al.* 2002; Bahar and De Datta, 1977) that delay in harvesting time of the main crop causes low ratoon grain yield hence the main crop should be harvested immediately when mature grains are at maximum and their stems are physiologically alive. In the current study, main crop two encountered the lowest temperature 14.5-15.0°C between January and February 2011 (Fig. 2) which delayed its harvesting thereby delaying the harvesting time of ratoon crop two. In this case, the flowering stage (primordial) encountered low temperatures thereby leading to a number of sterile spikelets per panicle hence lower grain yield as also described by Web *et al.* (2002) and Bahar and De Datta (1977). The yield increase of more than 1500 kg ha^{-1} (which is the average yield of upland rice in Sub-sahara Africa) recorded by NERICAs 4 and 10 from the current study with no additional input were very encouraging. This would perhaps increase with additional input such as fertilizer during ratoon. Values as high as 12633kg ha^{-1} and 7115kg ha^{-1} for main and ratoon crops respectively have been reported in China (Li *et al.*, 2003; Liu *et al.*, 2012) with additional inputs.

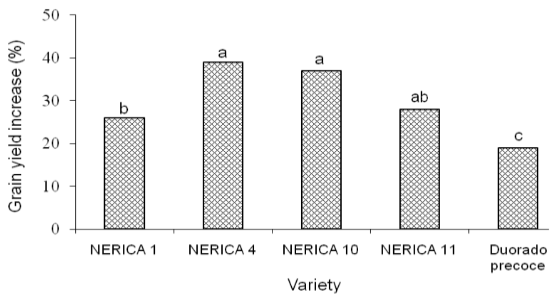

Fig. 5. Percentage increase in grain yield of the five upland rice varieties due to ratooning. Bars with the same letter(s) are not significantly different at 5% level.

Ratooning ability varied significantly ($p<0.05$) among the five upland rice varieties investigated in this study with the NERICA rice varieties recording higher ratooning ability than the standard check Duorado precoce. The results support earlier studies (WARDA, 1999; Kouko *et al.*, 2006; Sanni *et al.*, 2009) where NERICA varieties were reported to show great variation in their ratooning ability. Kouko *et al.* (2006) reported ratooning ability ranging from 13 to 39% with no additional fertilizer applied to the ratoon crop. Ratooning ability of rice crop has been reported (Tari, 2011, Chauhan *et al.*, 1985) to be affected by the interaction between genetical, climate, edaphic and management variables. Root vigour and distribution also affects ratooning. A vigorous main-crop root system may therefore be a prerequisite for a successful ratoon crop (Chauhan *et al.*, 1985). The ratooning ability varying from 26% to 39% that was observed in the current study for the four NERICA rice varieties was quite encouraging. Although the grain yield from the ratoon crop was relatively lower than the main crop, it however increased the total grain yield with no extra cost, which implies more earning if applied by the resource poor farmers. These results indicate that NERICA has a high potential grain yield in double harvest and ratooning should therefore be incorporated in the cropping systems so as to increase grain yield. Among the four NERICA rice varieties evaluated in the current study, NERICA-4 and NERICA-1 were found to be better yielding from the main crop while the former and NERICA 10 recorded the highest ratooning ability possibly due to higher number of productive tillers. Similar studies carried out in western Kenya found NERICA-4 and NERICA-10 to be better yielding than NERICA-1 and NERICA-11 (Ndjiondjop *et al.*, 2008). This could possibly be due to differences in climatic and edaphic factors between the two regions of study.

Conclusion

The results from this study showed that ratooning ability varied significantly among the five upland rice varieties with NERICA varieties demonstrating higher ratooning ability than the *O. sativa* rice variety (Duorado precoce). NERICA 4 from the current study recorded the highest grain yield and ratooning ability and is therefore recommended for Central Kenya though the yield and ratooning ability of the other three NERICA varieties was also encouraging compared to the local landrace Duorado precoce. Ratooning increased the total grain yield of the five upland rice varieties. Results of this study can serve as a guide on how ratooning can be used to maximize upland rice yield in Central Kenya.

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