

Original Research Article

Fertilizer Effects on Panicle Characteristics, Grain Weight and Yield of Upland Rice in Lowlands of Taita Taveta, Kenya

Abstract

This study was done at Mlughu Agricultural demonstration farm in Bura, Taita Taveta County-Kenya to test upland rice varietal performance and Di-Ammonium fertilizer effects on panicle characteristics and yield parameter. A randomized complete block design (RCBD) was used with seven upland rice varieties and three fertility levels. The treatments were replicated thrice to give a total of 63 treatments combinations or plots. The experiment was carried out for two seasons (short rains from October to December 2018 and long rains from March to May 2019). The upland rice varieties included 17KH09010014B, 17KH09010093B, AT 058, China Hybrid, NERICA 1, NERICA 4, and NERICA 10. The Soil fertility treatments were Di-ammonium phosphate fertilizer (DAP), Farm Yard Manure (FYM), and a control of no fertilizer. Topdressing was done at the flowering stage with NPK fertilizer. Data collected included plant height, number of leaves, tiller number, panicle length, spikelets count per panicle, grain yield ha⁻¹ and weight of 1000 grains. The data were subjected to multivariate analysis of variance (MANOVA) using R version 3.6.1 program and Tukey's HSD test, $p \leq 0.05$ was used to separate the significant means. The results showed that there was significant influence ($p = 0.0001$) of overall seasonal, treatment and variety on the yield of rice grains in tons per hectare. Season 1 had the lowest tonnage compared to season 2. Crops under the control treatment yielded the least tonnage per hectare while the DAP treated fields yielded the highest in both seasons. NERICA 4 was the highest yielding variety while AT 058 was the least yielding among the treatments in both seasons. It was therefore concluded that the application of DAP and FYM significantly increased rice productivity. Farmers are therefore encouraged to carry out soil fertility testing occasionally and to plant NERICA varieties.

Keywords: Fertilizer; season; upland rice; manure; yield

1. INTRODUCTION

The origin of rice (*Oryza sativa*) was located in India, Korea and Japan about 130 years ago and it spread to Asia and Antarctica as a wild grass (Fuller, 2011, Sing *et al.*, 2018). *Oryza sativa* species is cultivated globally in all rice growing areas while *Oryza glaberrima* is confined to West Africa along the flooded plains (Yang *et al.*, 2018). In Kenya, 95% of the rice is grown under flooded conditions while 5% is rain-fed (Muhunyu, 2015). The potential capacity for rain-fed upland rice was projected to be 2,600,000 ha which corresponds to 4.6% of the entire land space and is found in the western counties around Lake Victoria, South Eastern coast and the central part of the country (Saito *et al.*, 2016). The potential for irrigated rice is conversely limited by inadequate irrigation water while the environment and infrastructure play a key role (Uphoff *et al.*, 2015). Nevertheless, there is potential to grow rice under rain-fed conditions thus offering the possibility of producing rice in new areas as a means of increasing domestic output and therefore increasing household incomes, food and nutrition security. Rice is cultivated on a wide range of soils from sandy loam to heavy clay soils. The crop thrives under a wide range of soils, including saline or sodic soils, with pH range of 5.5 - 6.5 in upland rice cultivation and a

pH of between 7.0 - 7.2 under flooded conditions (Uphoff *et al.*, 2015). Under rain-fed conditions, rice crop grows best when it receives an average rainfall of 800 – 2000mm per annum and an altitude of 0 – 1700m asl. The ideal temperature range is 25°C to 31°C at tillering, 30°C to 35°C at flowering and 20°C to 29°C at ripening (Deng *et al.*, 2015).

Low productivity in rice could be associated with lack of suitable varieties for these areas, use of traditional agronomic practices and limited water supply (Kimani *et al.*, 2011). This could be as a result of inadequate interest in coming up with innovations for developing upland rice (Nasuda *et al.*, 2014). Drought is one of the major constraints in the production of upland rice in Kenya (Kimani *et al.*, 2011). In order to achieve optimum yields, it is imperative to plant rice varieties that are tolerant to water stress. Rice responds well to both organic and inorganic fertilizer applications. The use of fertilizers was noted to increase rice productivity based on the ecological zones and has a strong correlation with yield and yield components under diverse soil nutrient environments (Jewel *et al.*, 2019). Studies on N, P, and K fertilizers, showed that grain yield was enhanced by increased levels of N and P up to the point of diminishing returns (Heluf *et al.*, 2014). Kajonphol *et al.*, (2018) also found out that nitrogen application promotes tillering and panicle growth, which may have resulted in more productive tillers and grains (Chawana *et al.*, 2021). Notwithstanding, most smallholder upland rice farmers rarely use inorganic fertilizers and/or manure despite the fact that application of fertilizer, especially Nitrogen (Maya *et al.*, 2009, Dastan *et al.*, 2012) enhances rice yields. Otzuka *et al.*, (2006) reported that farmers in Sub-Saharan Africa use fertilizer inadequately despite studies showing that both organic fertilizers like cow dung and chicken manure (Kajiru, 2006) and inorganic fertilizers resulted to significant increase in yield. This could be attributed to limited availability of fertilizer, high cost of fertilizers, inadequate quantities of good organic fertilizer, the bulky nature of most organic fertilizers which increases transport costs, and in some cases, the attitude of farmers on the importance of fertilizers (Kimani *et al.*, 2011). This study, therefore, sought to assess the performance of yield-related components of upland rice under different soil fertility levels at Bura valley in Taita Taveta County. So far few experiments to evaluate the performance of different rice varieties under rain-fed conditions in Kenya have been done. The overall objective of this study was to test the performance of selected upland rice varieties under different soil fertility levels in lowland ecosystems.

2. MATERIALS AND METHODS

2.1 Experimental Site

This study was carried out in Taita Taveta County, Mluchi Agricultural demonstration farm in the South Eastern lowlands of Kenya. The experimental site is a valley bottom which lies on GPS coordinates S03.49023° and E038.31244° and at an altitude of 949 meters above sea level. The area receives a bimodal rainfall pattern, long rains which fall between March and May and short rains (October to December), with an average rainfall of 500mm per annum. The soils are majorly fluvisols with moderate to high fertility levels.

2.2 Planting Materials and Study Design

The study was carried out in October to December 2018, during the short rains, and was repeated in

March to May 2019, during the long rains. Seven upland rice varieties, which consisted of four experimental lines from the Kenya Agricultural and Livestock Research Organization (KALRO) and three released NERICA varieties from the Kenya Seed Company were assessed in this study. They included 17KH09010014B, 17KH09010093B, AT058, China Hybrid, NERICA 1, NERICA 4, and NERICA 10. The experiment was laid out as a Randomized Complete Block Design (RCBD) with the three fertility levels as the main block (plot) and the seven upland rice varieties as the subplots. The fertilizer treatments were (i) Diammonium phosphate (DAP, 18:46:0) at the rate of 13.5kg N ha⁻¹ and 34.5kg P₂O₅ ha⁻¹, (ii) Farm Yard Manure (FYM) at the rate of 992kg N ha⁻¹ in 2018 and 424kg N ha⁻¹ in 2019 which was based on the soil test results and N concentration in the FYM, and (iii) Control with no fertilizer. The treatment combinations were replicated three times to give a total of 63 plots measuring 2m by 2.5m each. The distance between plots and between blocks was 0.5 meters. All the plots were top-dressed with NPK (17:17:17) fertilizer at the rate of 11.05kg P₂O₅ ha⁻¹ and 11.05kg K₂O ha⁻¹ to promote tillering and seeding as described by [7]. DAP and FYM were applied at planting while NPK fertilizer was applied at tillering stage. A seedling spacing of 20cm within the rows and 30 cm between the rows was adopted. Two seedlings were transplanted per hole within furrows, resulting in a plant population of 83 plants per plot or 166,000 plants per hectare. Thinning was carried out once the plants were established to obtain one seedling per hole. Good agronomic practices were applied to keep the crop healthy.

2.3 Data Collection

The parameters that were assessed included: the number of branches per panicle, number of grains per panicle, weight of 1000 grains, and grain yield per hectare. Six plants within one m² area at the centre of the plot were selected randomly for each plot and tagged at 14 days after transplanting (Yasmin *et al.*, 2018). Guard row plants were excluded from data collection. The six (6) plants were used for collecting pre-harvest data. The final yield was determined from the 1m² quadrant in the middle of each plot.

2.4 Data Analysis

All data was subjected to multivariate analysis of variance (MANOVA) using R version 3.6.1 program (R Development, 2019). The R packages used for this analysis were 'lattice', 'asbio', 'ffmanova' and 'multicomp'. Single parameter analysis of variance was used to evaluate the statistical significance where the MANOVA indicated significant interaction. If the means of the samples differed significantly, they were separated using Tukey's HSD test, P ≤ 0.05. Data in the tables are presented as means with standard deviation (±).

3. RESULTS AND DISCUSSION

3.1 Soil Chemical Properties

The soil type was Fluvisols with a pH of 6.72 (slightly acidic) during the short rains and 7.08 (neutral) during the long rains. The pH for the FYM was 8.47 (slightly alkaline). The total Nitrogen was 0.18% during the short rains, and 0.19% during the long rains. These values were low compared to the total Nitrogen in farmyard manure which was high at 1.22% (Heluf *et al.*, 2014). Phosphorus was adequate for the soils in both seasons but low in the farmyard manure (**Table 1**). In addition, Potassium levels were satisfactory in the two soil samples and medium in FYM (Wopereis *et al.*, 2009). Soil test result interpretation indicated that the nutrient status of the experimental site was suitable to produce rice.

Table 1: Analysis of soil and farm yard manure chemical properties status

Parameter	Optimum values	Soil (Season 1)	Soil (Season 2)	Farmyard manure
pH	5.0-6.5	6.72	7.08	8.47
Total Nitrogen (%)	>0.2	0.18	0.19	1.22
Total Organic Carbon (%)	2.0-3.5	3.10	3.89	11
Phosphorus (ppm)	30-100	36.20	28.40	0.23
Potassium (ppm)	>120	499	355	299
Calcium (ppm)	1060-1700	1200	1260	1170
Sodium (ppm)	30.1<140	96.4	99.20	80

3.2 Analysis of Variance

Analysis of variance showed that varieties and fertilizer treatments were significantly different for all four variables. Seasons had a significant effect on 1,000 grain weight and yield per hectare (**Table 2**). There was significant influence of overall treatment ($P = 0.0006$) and variety ($P = 0.0001$) and their interaction ($P = 0.0100$) on the number of branches per panicle. The results in this study showed that there was significant fertilizer main effect ($P = 0.0001$) and variety main effect ($P = 0.0001$) on the number of grains per panicle. In this research, there were significant differences ($P = 0.0001$) between seasons, among fertilizers and among varieties with respect to the weight of 1000 rice grains. There were significant differences ($P = 0.0001$) between seasons, among fertilizers and among varieties with respect to the yield of rice grains in tons per hectare.

Table 2: Overall seasonal and nutrient sources effects (P values) on yield and yield components

Source of variation	Branches per panicle	Grains per Panicle	1000-grain weight	Yield (ton ha ⁻¹)
Variety	0.0006	0.0001	0.0001	0.0001
Season	0.9669	0.9820	0.0001	0.0001
Fertilizer	0.0001	0.0001	0.0001	0.0001
Variety	1.0000	1.0000	1.0000	1.0000
Variety* Fertilizer	0.0100	0.1556	0.3634	0.3488
Season* Fertilizer	0.6462	0.7002	0.3493	0.4232
Variety*Season* Fertilizer	0.9339	1.0000	0.7814	0.6627

3.3 Branches Per Panicle

The DAP fertilizer had a significant influence ($P \leq 0.05$) on number of branches in varieties 17KH09010093B and AT 058 in season 1 while in season 2, DAP had a significant effect ($P \leq 0.05$) on 17KH09010014B, China Hybrid and NERICA 4 (**Table 3**). Farm Yard Manure had a significant influence on the branching ability of 17KH09010093B in season 1, while in season 2 it influenced China Hybrid and NERICA 4 rice varieties. On average, DAP application resulted in the highest number of branches per plant in both seasons. However, when the varieties were treated with DAP, NERICA 1 and NERICA 10 differed significantly ($P \leq 0.05$) from other varieties. NERICA 1 differed significantly with NERICA 4. The number of branches per panicle is important in that it determines the spaces that are available for grain attachment on the panicle and therefore the yield. Consequently, the number of spikelets per panicle and the number of panicles per unit area influence the ultimate rice yield. Kato *et al.*, (2008), also made similar observations that in upland conditions where drought occurs sporadically, the number of spikelets per unit area contributes to yield to a very large extent. The difference in yield among the varieties could be due to pre-flowering abortions due to water stress, cold weather among other factors. Under moisture stress conditions, there is a considerable reduction of rachis branches which initiate spikelets thus limiting the number of spikelets per panicle during early reproductive stages (Kato *et al.*, 2008).

Table 3: Number of branches per panicle of the seven upland rice varieties subjected to three fertilizer treatments in 2018 and 2019 seasons

Variety	Fertilizer treatment					
	Season 1			Season 2		
	Control	DAP	FYM	Control	DAP	FYM
17KH09010014B	9.9 ± 1.6 ^{Aa}	13.2 ± 2 ^{Ac}	10.7 ± 2.4 ^{Aa}	8.3 ± 1.4 ^{Aa}	13.8 ± 0.8 ^{Ba}	9.9 ± 1.3 ^{Aa}
17KH09010093B	8.5 ± 1.2 ^{Aa}	11.7 ± 2.3 ^{Bc}	11.3 ± 1.8 ^{Ba}	9.3 ± 1.1 ^{Aa}	11.5 ± 1.2 ^{Aa}	9.8 ± 1.4 ^{Aa}
AT 058	8.9 ± 1.1 ^{Aa}	12 ± 1.7 ^{Bc}	9.8 ± 1.6 ^{Aa}	8.1 ± 1.2 ^{Aa}	9.1 ± 1.3 ^{Aa}	9.3 ± 1.3 ^{Aa}
CHINA HYBRID	10.1 ± 1.6 ^{Aa}	12.1 ± 1.4 ^{Ac}	11.4 ± 1.3 ^{Aa}	8.8 ± 0.9 ^{Aa}	10.3 ± 1.2 ^{Ba}	12.6 ± 1.1 ^{Ba}
NERICA 1	9.3 ± 1.7 ^{Aa}	9.2 ± 1.1 ^{Aab}	8.6 ± 1 ^{Aa}	9.9 ± 1.3 ^{Aa}	10.9 ± 1.2 ^{Aa}	9.9 ± 1 ^{Aa}
NERICA 10	8.3 ± 1.3 ^{Aa}	8 ± 1 ^{Aa}	9.6 ± 1.4 ^{Aa}	8.1 ± 1.1 ^{Aa}	8.6 ± 0.6 ^{Aa}	9.1 ± 1.1 ^{Aa}
NERICA 4	7.8 ± 1 ^{Aa}	11.2 ± 1.4 ^{Abc}	10.7 ± 3.2 ^{Aa}	8.6 ± 1 ^{Aa}	13.8 ± 0.8 ^{Ba}	13.3 ± 1 ^{Ba}

The values in the table are Means ± Standard deviation, where n = 6. Different capital letters show significant differences ($P \leq 0.05$) among treatments per variety while small letters indicate significant differences ($P \leq 0.05$) among varieties per treatment

3.4 Number of Grains Per Panicle

The DAP fertilizer significantly influenced ($P \leq 0.05$) the NERICA varieties while FYM influenced the number of grains per panicle per plant in NERICA 10 and NERICA 4 during season 1 (**Table 4**). In season 2, DAP had a significant effect on all varieties except 17KH09010014B whereas FYM had a significant effect on 17KH09010014B, NERICA 4 and NERICA 10 when compared to the control. Varieties differed under the control treatment in both seasons while in season 2 they differed under FYM where, China Hybrid had the least number of grains per panicle (**Table 4**). Generally, FYM resulted in the highest number of grains per panicle in both seasons. The number of grains per panicle contributes to the yield output (Kato *et al.*, 2008). This study identified a significant influence by the fertilizer main effect ($P =$

0.0001) and variety main effect ($P = 0.0001$) on the number of rice grains per panicle. The DAP fertilizer and FYM significantly affected the number of rice grains per panicle in ($P \leq 0.05$) in NERICA varieties during season 1. The results from this study agree with the findings of Yosef, (2012) who noted that NERICA varieties can produce up to 400 grains compared to other upland varieties which can only produce 75 to 100 grains and also noted that the application of fertilizer (DAP) increased the number of grains per panicle in NERICA varieties compared to control plants.

Table 4: Number of grains per panicle per plant of the seven upland rice varieties subjected to three fertilizer treatments in 2018 and 2019 seasons

Variety	Treatment					
	Season 1			Season 2		
	Control	DAP	FYM	Control	DAP	FYM
17KH09010014B	72.8 ± 5.1 ^{Aab}	121.1 ± 8.8 ^{Aa}	124.8 ± 15.4 ^{Aa}	73.6 ± 5.2 ^{Aab}	122.8 ± 7.4 ^{Aa}	112.4 ± 26.7 ^{Abc}
17KH09010093B	94.1 ± 11.2 ^{Ab}	111 ± 5.4 ^{Aa}	113.9 ± 16.2 ^{Aa}	90.8 ± 7.4 ^{Ab}	115.9 ± 5.8 ^{Ba}	111.6 ± 12.6 ^{Bbc}
AT 058	90.8 ± 8 ^{Ab}	101.9 ± 14.2 ^{Aa}	100.5 ± 10.5 ^{Aa}	91.2 ± 7.7 ^{Ab}	108.7 ± 5.5 ^{Ba}	99.9 ± 8.7 ^{ABb}
CHINA HYBRID	58 ± 10.5 ^{Aa}	96.4 ± 24 ^{Aa}	99.9 ± 32 ^{Aa}	60.1 ± 10.1 ^{Aa}	97.6 ± 18.3 ^{Ba}	79 ± 7.3 ^{ABa}
NERICA 1	108.2 ± 9.8 ^{Ab}	123.2 ± 6.7 ^{Ba}	117.3 ± 8.7 ^{ABa}	105.9 ± 9.4 ^{Ab}	124.6 ± 5.5 ^{Ba}	118.2 ± 6.5 ^{Bbc}
NERICA 10	96.6 ± 6 ^{Ab}	114.9 ± 12.9 ^{Ba}	124.9 ± 10 ^{Ba}	95 ± 5.1 ^{Ab}	120.8 ± 5.4 ^{Ba}	118.9 ± 6.8 ^{Bc}
NERICA 4	84.1 ± 10.3 ^{Ab}	117.5 ± 15 ^{Ba}	116.7 ± 6.7 ^{Ba}	87.8 ± 11.4 ^{Ab}	121.3 ± 10.6 ^{Ba}	116.9 ± 5.9 ^{Bbc}

The values in the table are Means ± Standard deviation, where n = 6. Different capital letters show significant differences ($P \leq 0.05$) among treatments per variety while small letters indicate significant differences ($P \leq 0.05$) among varieties per treatment.

3.5 One Thousand (1000) Grain Weight

The 1000-grain weight is an indication of how dense the grains are. The 2019 season produced denser grains when compared to the 2018 season (Table 5). In both seasons, DAP resulted in significantly heavier grains ($P \leq 0.05$) compared to FYM or control treatments. This could be ascribed to the nutritional significance of P in seed formation which is higher in DAP than FYM. NERICA 4 and NERICA 10 produced the heaviest grains compared to other varieties. Grain weight is majorly determined by the supply of assimilates during the grain filling period and the capacity of the developing grains to accumulate the translocated assimilates (Koutroubas, 2008). Grain weight is also influenced by the intensity of moisture. Grain yield loss could therefore be attributed to moisture stress which could have led to a decrease in the number of filled grains per panicle. Yao *et al.*, (2000) acknowledged the importance of sink size in enhancing rice grain yield. In this context, yield sink was defined as the product of number of filled panicles per unit area and the number of spikelets per panicle. One thousand (1000) grain weight is important in rice production because it helps the producer to project the expected yield and therefore make a decision on the profitability of taking up the enterprise. The increase in available N and P increases rice yield (Yadav, 2003). However, the research findings of Yaser *et al.*, (2011), indicated that fertilizer application did not have a significant effect on the weight of 1000 grains and showed that weight is a varietal characteristic. In addition, a study by Liu *et al.*, (2013) found out that some varieties are described as heavy panicle type while others are described as many panicle types.

Comment [S1]: Its not clear the season is 2019 or 2018????
In table it is 2018 and 2019.

Comment [S2]: Define the behaviour of varieties used in the study ?

Table 5: Weight of 1000 grains per variety per treatment of the seven upland rice varieties subjected to three fertilizer treatments in 2018 and 2019 seasons.

Variety	Treatment					
	Season 1			Season 2		
	Control	DAP	FYM	Control	DAP	FYM
17KH09010014B	22.8 ± 2.4 ^{Aa}	27.4 ± 3.2 ^{Ba}	25.4 ± 2.4 ^{Bab}	24.2 ± 1.7 ^{Aab}	29.2 ± 2 ^{Cab}	26.6 ± 2 ^{Ba}
17KH09010093B	23.3 ± 2.4 ^{Aa}	26.1 ± 3.5 ^{Ba}	24.5 ± 3.4 ^{ABa}	25.3 ± 1.9 ^{Aac}	28.6 ± 2.4 ^{Bab}	27.3 ± 2 ^{Ba}
AT 058	23 ± 2.7 ^{Aa}	25.7 ± 3.6 ^{Aa}	25.8 ± 3.6 ^{Aab}	24 ± 2.5 ^{Aa}	27.5 ± 2.6 ^{Ba}	26.4 ± 3.4 ^{Ba}
CHINA HYBRID	23.3 ± 2.3 ^{Aa}	27.6 ± 1.6 ^{Ca}	26.2 ± 2.6 ^{Bac}	25.2 ± 1.7 ^{Aac}	28.1 ± 1.8 ^{Bab}	26.9 ± 2.4 ^{ABa}
NERICA 1	24.6 ± 3.2 ^{Aa}	25.6 ± 2.9 ^{Aa}	26.4 ± 3.4 ^{Abc}	26.2 ± 2.5 ^{Abc}	30.3 ± 1.4 ^{Bb}	27.3 ± 3.3 ^{Aa}
NERICA 10	24 ± 2.6 ^{Aa}	27.7 ± 2.7 ^{Ba}	26.1 ± 2.7 ^{ABac}	25.9 ± 1.3 ^{Aac}	29.7 ± 1.4 ^{Bab}	28.9 ± 1.6 ^{Ba}
NERICA 4	25.4 ± 2.9 ^{Aa}	28.9 ± 3.2 ^{Ba}	27.8 ± 3.1 ^{Bc}	26.3 ± 2.2 ^{Ac}	33.1 ± 1.6 ^{Cc}	28.6 ± 1.6 ^{Ba}

The values in the table are Means ± Standard deviation, where n = 6. Different capital letters show significant differences ($P \leq 0.05$) among treatments per variety while small letters indicate significant differences ($P \leq 0.05$) among varieties per treatment.

3.6 Yield Tons Per Hectare

Generally, the 2018 season had less grain yield tonnage compared to the 2019 season (**Table 6**). In addition, the DAP treated plots yielded the most while the control treatment yielded the least tonnage per hectare in both seasons. When comparing varieties within the treatments, NERICA 4 was the highest yielding variety while AT 058 tended to perform least in both seasons. NERICA 4 and NERICA 10 produced considerably high yields. This conformed with the results of Liu *et al.*, (2013) whose findings described the NERICA varieties to be superior to other upland varieties. Season 1 had the least tonnage compared to season 2, which could be attributed to weather-related parameters during the two seasons since higher rainfall was recorded in season two. The results of this experiment were in tandem with the conclusion by Liu *et al.*, (2013) who noted a positive correlation between addition of soil nutrients, yield and yield components. The use of plant nutrients such as nitrogen led to an increase in photosynthetic rate and therefore an increase in the rate of the actual filling of the grains due to the separation of assimilates towards the rice grain which was the sink. A previous study found that the supply of Nitrogen and Phosphorus can possibly intensify the weight of the grains and therefore increase the yield (Yosef, 2012). On the other hand, Yaser *et al.*, (2011) distinguished that grain weight, which is a major yield component is a varietal factor that cannot be determined as a result of the soil organic matter or fertility.

Table 6: Yields in tons per hectare per variety per treatment of the seven upland rice varieties subjected to three fertilizer treatments in 2018 and 2019 seasons.

Variety	Treatment					
	Season 1			Season 2		
	Control	DAP	FYM	Control	DAP	FYM

17KH09010014B	4.10 ± 0.31 ^{Aa}	4.41 ± 0.17 ^{Ba}	4.12 ± 0.09 ^{Bab}	4.28 ± 0.26 ^{Aab}	4.75 ± 0.15 ^{Cab}	4.35 ± 0.07 ^{Ba}
17KH09010093B	4.01 ± 0.10 ^{Aa}	4.30 ± 0.04 ^{Ba}	3.99 ± 0.08 ^{ABa}	4.43 ± 0.19 ^{Aab}	4.73 ± 0.05 ^{Bab}	4.34 ± 0.20 ^{Ba}
AT 058	3.96 ± 0.10 ^{Aa}	4.29 ± 0.05 ^{Aa}	4.18 ± 0.13 ^{Aab}	4.19 ± 0.18 ^{Aa}	4.51 ± 0.06 ^{Ba}	4.39 ± 0.03 ^{Ba}
CHINA HYBRID	4.15 ± 0.26 ^{Aa}	4.53 ± 0.07 ^{Ca}	4.27 ± 0.10 ^{Bac}	4.36 ± 0.16 ^{Aab}	4.65 ± 0.05 ^{Bab}	4.37 ± 0.11 ^{ABa}
NERICA 1	4.21 ± 0.11 ^{Aa}	4.21 ± 0.05 ^{Aa}	4.35 ± 0.07 ^{Abc}	4.59 ± 0.26 ^{Ab}	4.86 ± 0.20 ^{Bb}	4.53 ± 0.06 ^{Aa}
NERICA 10	4.15 ± 0.19 ^{Aa}	4.53 ± 0.10 ^{Ba}	4.31 ± 0.07 ^{ABac}	4.50 ± 0.20 ^{Aab}	4.94 ± 0.03 ^{Bab}	4.64 ± 0.17 ^{Ba}
NERICA 4	4.44 ± 0.21 ^{Aa}	4.77 ± 0.04 ^{Ba}	4.55 ± 0.11 ^{Bc}	4.72 ± 0.35 ^{Ab}	5.29 ± 0.22 ^{Cc}	4.79 ± 0.01 ^{Ba}

The values in the table are Means ± Stdev, where n = 6. Different capital letters show significant differences ($P \leq 0.05$) among treatments per variety while small letters indicate significant differences ($P \leq 0.05$) among varieties per treatment.

4. CONCLUSIONS AND RECOMMENDATIONS

The results from this study suggest that **NERICA** varieties are superior yielding upland rice varieties. In addition, the DAP fertilizer had a better effect compared to other treatments, which could be attributed to the readily available P in DAP that enhanced good rooting. The long rain season also resulted in higher yields compared to the short rains. This could be accredited to more moisture retention in the long rain season as opposed to the short rain season. Further studies involving the NERICA's and different levels of DAP fertilizers could yield even more suitable combinations of varieties and fertilizers. Although significant differences in season effect were observed, further confirmatory inter-season comparisons are recommended.

Comment [S3]: Why they perform better??
Anything related to temperature and genetic information about variety to support findings?

REFERENCES

1. Chawana I, Gacheru J, Maghenda M, Maghanga J, Kambura A, Kimani J, Mcharo M. Response of paddy rice (*Oryza sativa*) morphological characteristics of Nitrogen fertilizers in Taveta. *International Journal of plant and soil science*, (2021), 42-50.
2. Dastan S, Siavoshi M, Zakavi D, Ghanbaria-malidarreh A, Yadi R, Ghorbannia DE and Nasiri AR (2012). Application of nitrogen and silicon rates on morphological and chemical lodging related characteristics in rice (*Oryza sativa L.*) north of iran. *J. Agric. Sci.*: 4(6).
3. Deng N, Ling X, Sun Y, Zhang C, Fahad S, Peng S, Cui K, Nie L, and Huang J, (2015). Influence of temperature and solar radiation on grain yield and quality in irrigated rice system. *European Journal of Agronomy*, 64, 37-46.
4. Fuller D Q, (2011). Pathways to Asian civilization. Facing the origins and spread of rice Cultivars. *Journal of Plant Sciences*, 4, 78-92.
5. Heluf G, Mulugeta S, (2014). Inherent properties and fertilizer Effects of flooded rice soil. *Journal of Agronomy Volume 13, issue 275*.
6. Jewel Z A, Ali J, Pang Y, Mahender A, Acero B, Hernandez J, Xu J, Li Z. Developing green super rice varieties with high nutrient use efficiency by phenotypic selection under varied nutrient conditions. *The Crop Journal*. 2019;7(3): 368-377. Available: <https://doi.org/10.1016/j.cj.2019.01.002>.
7. Kajiru G J, (2006). Soil fertility status and response of rice to nitrogen, phosphorus and farm yard manure under rainwater harvesting system in semi-arid areas of Maswa, Tanzania. Thesis for award of PhD Degree at the Sokoine University of Agriculture, Morogoro, Tanzania, 206pp.
8. Kajonphol T, Seetaput N, Precharattana M, Sangsiri C. Correlation and multiple regression model for economic traits of local rice (*Oryza sativa L.*) in upland rice system. *Applied Mechanics and Materials*. 2018; 879:71-77. DOI:10.4028/www.scientific.net/AMM.879. 71
9. Kato Y, Kamoshita A, Yamagishi J, (2008). Pre-flowering abortion reduces spikelet number in upland rice (*Oryza sativa L.*) under water stress. *Crop Sci*, 48: 2389-2395.
10. Kimani J M, Tongoona P, Derera J, Nyende A B. Upland rice varieties development through participatory breeding. *Journal of Agricultural and Biological Science*, 2011; 6(9), 39-49.
11. Koutroubas S D, Katsantonis D, Ntanos D A, Lupotto E, (2008). Nitrogen Utilization Efficiency and Grain Yield components of rice varieties grown under blast disease stress. *Australasian Plant Pathology* (2008), 53-59, 37(1).
12. Liu L, Zhu Y, Tang L, Cao W, Wang E, (2013). Impacts of climate changes, soil nutrients, variety types and management practices on rice yield in East China: A case study in the Taihu region. *Field Crops Res*. 149: 40–48.
13. Maya M, Toshinori M, Makie K, Growth and yield of new rice for Africa (NERICAs) under different ecosystems and nitrogen levels. *Plant Production Science*. 2009;12(3):381-389.
14. Muhunyu J G, (2015). Is Doubling Rice Production in Kenya by 2018 Achievable? *Journal of Developments in Sustainable Agriculture*, 7(1), 46-54. <https://doi.org/10.11178/jdsa.7.46>.
15. Nasuda A, Sakurai T, Murage H, & Makihara D, (2014). Dual role of irrigation schemes for NERICA diffusion in the Central Highlands in Kenya: Sources of supplemental water and technology information. *Journal of International Cooperation for Agricultural Development*, 13, 29-37.
16. Otsuka K, Kalirajan H, (2006). Rice Green Revolution in Asia and its transferability to Africa. *Developing economies*. 44,107-122.
17. Saito G, Ogawa S, Makihara D, & Asanuma S, (2016). Estimation of potential area for upland rice production in Kenya. *Upland Farming*, 676, 9-22.
18. Singh P K, Venkatesan K, Swarnam T P, (2018). Rice genetic resources in tropical islands. In *Biodiversity and Climate Change Adaptation in Tropical Islands* (pp. 355-384). Academic Press.

19. Uphoff N, Fasoula V, Iswandi A, Kassam A, Thakur A K, Improving the phenotypic expression of rice genotypes: Rethinking “intensification” for production systems and selection practices for rice breeding. *Crop Journal* (2015);3(3):174-189, 3(3).
20. Wopereis M C S, Defoer T, Idinoba P, Diack S, Dugue M J, (2009). Participatory Learning and Action Research (PLAR) for Integrated Rice Management (IRM) in Inland Valleys of Sub Saharan Africa: Technical Manual. Training Series. Africa Rice Centre. Catonou, Benin. 128pp.
21. Yadav R L, (2003). Assessing on-farm efficiency and economics of fertilizer N, P and K in rice wheat systems of India. *Field crops Research*. 81:39-51.
22. Yang X, Chen Q, Ma Y, Li Z, Hung H, Zhang Q, Jin Z, Liu S, Zhou Z, Fu X, (2018). New radiocarbon and archaeobotanical evidence reveal the timing and route of southward dispersal of rice farming in south China. *Science Bulletin* (2018), 1495-1501, 63(22).
23. Yao Y, Yamamoto Y, Wang, Y, Yoshida T, Miyazaki A, Nitta Y, Cai J, (2000). Role of Nitrogen regulation in sink and source formation of high yielding rice cultivars. *Soil Sci. Plant Nutr.*, 46:825-834.
24. Yaser R K, Reza A M, Reza R M, Kazem K, Kaveh Z, (2011). Response of yield and yield components of rice (*Oryza sativa L.*) to *Pseudomonas fluorescence* and *Azospirillum lipoferum* under Different Nitrogen Levels. *American-Eurasian J. Agric. Environ. Sci.* 10: 387-395.
25. Yasmin R, Paul S K, Paul S C, Salim, M, (2018). Effect of plant spacing and integrated nutrient management on the yield performance of Binadhan-14. *Archives of Agriculture and Environmental Science*, 3(4), 354-359.
26. Yosef T S, (2012). Effect of Nitrogen and Phosphorus fertilizer on growth and yield rice (*Oryza sativa L.*). *Inter. J. Agron. Plant Prod.* 3: 579 – 584.