Original Research Article

EFFECT OF PLANT DENSITIES ON YIELD POTENTIAL OF NERICA 10 RICE VARIETY (*Oryza sativa* L.) IN TAITA TAVETA COUNTY

Abstract: Rice (*Oryza sativa L*.), is an important cereal crop grown within central,western and coast region of Kenya. Despite annual rice consumption being higher than maize (Kenya's staple food), the country is unable to meet an annual demand of 0.55 million tons and depends on imports to fill a 73 % deficit. In order to contribute to reducing the deficit gap, a field experiment was conducted at Dembwa and Kipusi, Taita Taveta County in Kenya during the 2019 long rain season to find out the effect of spacing and seeding rate on performance of New Rice for Africa (Nerica)10 rice variety. Three spacings 30 cm x 15 cm (control), 20 cm x 15 cm and 20 cm x 10 cm and four seedrates drill (random seed placement in small groove/line), 1, 2, or 3 seedling(s) per hill were used. The experiment was laid out in a randomized complete block design, factorial arrangement with three replications. Results showed that the interaction between 20 cm x 10 cm spacing at single seedling per hill significantly ($p \leq 0.05$) increased grain yield by 58 %, dry biomass by 33 % and harvest index by 45 % compared to 20 cm x 15 cm and 30 cm x 15cm(control). These results suggest that interaction between 20 cm x 10 cm spacing at 1(one) seedling per hill is the best for Nerica 10 grain yield maximization in Taita Taveta County. The current investigation is among preliminary studies on Nerica 10 rice variety in the county. Therefore, there is need for long term trials in various agro environments in the County.

Keywords: Spacing, seedling per hill, interaction, deficit, rice, yields, Nerica

1.0 Introduction:

Rice belongs to the grass family and grows as an annual crop but can also be left to ratoon for up to 30 years (1). It is one of the most important agricultural food crops consumed by more than half of the global population and whose demand increases with increase in human population (2). Rice is the main source of calories and micronutrients to large population of people in Africa (3). According to Food for Agriculture Organization (FAO) global paddy rice production was about 741.3 million tons, with India and China accounting for more than half of the production while Africa produced 3 % of the global production (4).

In Kenya rice was previously produced as a cash crop but over the years it has become a major staple food for many communities. The demand for rice grain is higher than other cereal and continues to increase at a rate of 12 % compared to 4 % increase in wheat and 1 % increase in maize per annum. The deficit has continuously increased over the years accounting for about 73 % is filled through imports from other countries such as Tanzania, Pakistan, Egypt, Thailand and Vietnam and it is valued at US$87.5 million per annum over 5 years range (5). The reliance on rice imports is costly and unsustainable, and can contribute to increased poverty levels, food insecurity due to use of revenue that would otherwise be used for developmental activities within the Country. According to the Ministry of Agriculture (MOA) (6), rice production must increase at a rate of 9.3 % per annum, in order to meet consumption demand in Kenya by 2030. This can be achieved by increasing rice productivity and rice cultivated area in the high potential areas of Lake Victoria basin and coast region including Taita Taveta County (7). Local rice production can be improved by the development of upland rice cultivation systems. The Nerica cultivars are improved upland rice varieties suitable for Kenyan environment (8).

Kenya has a potential of about 0.54 million hectares (ha) of irrigable and one million ha of rainfed rice production (6). According to (7), potential areas for increasing rice production include Lake Victoria basin, central and coastal region including Taita Taveta County. This potential has however remained untapped for decades. Productivity of rice in Kenya is 5 tons per hectare (ha) for irrigated lands and one ton per ha for rainfed conditions (9). This is far below the Africas' production potential of about 10 tons per ha and 7 tons per ha for irrigated and rain fed rice, respectively (6). This low productivity can partly be attributed to poor agronomic practices, inadequate water availability and lack of suitable rice varieties (10).

Plant density has a major influence on the rice growth and grain yield, because of its competitive effects, both on the vegetative and reproductive development. The plant density that results to maximum yield depends on optimum availability of temperature, solar radiation, moisture, soil fertility and crop variety among other factors. Optimum spacing ensures better plant growth through efficient utilization of solar radiation and nutrients (11). Dense plant population increases competition for water, nutrients, light and space and consequently produces weaker and thinner plants hence grain yield is reduced It also increases leaf area index (LAI) beyond critical LAI, which may become the cause of lower yield instead of increasing the yield. On the other hand, widely spaced plants increases the performance of individual plants because they are able to access wider space around them to extract more nutrients, absorb solar radiation for better photosynthetic process as individual plant resulting to increased yields per individual plant, but reduced yield per unit area of land due to fewer plants (12).

The number of plants per hill determines the number of plants per unit area thus it affects tiller formation, solar radiation interception, temperature, nutrient uptake, total sunshine reception, photosynthesis and finally affects the growth, development and yields of rice plant(11) reported that improper spacing reduced yield of rice up to 20- 30 %.

The appropriate combination of spacing with seedling(s) per hill can provide significant increases in grain yield of upland rice. However, few studies have evaluated these two variables, especially for Nerica 10 cultivars in Taita Taveta County. The objective of this study was to determine the optimum plant spacing and seedling(s) per hill that may lead to maximum grain yield of Nerica 10 rice in the County.

2. MATERIALS AND METHODS

2.1. Experiment location and description of materials

Field experiments were conducted during the March-June, 2019 long rains in multi locational sites at Dembwa and Kipusi, in Taita Taveta County. Kipusi lies on 3°28'45.8"S latitude and 38°22'56.4"E longitude while Dembwa is on 3°26'50.3"S latitude and 38°21'46.4"E longitude. The regions fall under Upper midland (UM 4) agro ecological zone with temperatures of between 15-33 °C and annual rainfall ranging between 300 – 1200 mm (13).

2.2. Experimental design and crop husbandry

Field experiments were laid out in Randomized Complete Block Design (RCBD) with factorial arrangement and replicated three times. Plant spacing evaluated were: 30 x 15 cm (control), 20 x 15 cm and 20 cm x 10 cm, while seedrate levels were: farmers practice (drilling) which involved random seed placement in small groove/line, one seedling per hill, two seedlings per hill and three seedlings per hill. Planting in both sites was done at the onset of long rains during the first week of April of 2019. Upland rice Nerica 10 was planted by randomly placing seeds in rows according to inter row spacing (intra row spacing was not taken into consideration at this stage). The experiment had 12 treatment combinations which were replicated three times to make 36 plots. Each individual plot covered an area measuring $25m^2$, and the plots were separated by 0.5m wide pathways. One meter wide pathways separated individual blocks (total 3 blocks) making a total experimental area of 1114 m^2. Treatments were randomly assigned in plots within each block. During planting, basal application of 17:17:17 NPK fertilizer at recommended rate of 100kg per ha was applied to supply about 35 kg N, 32 kg P_2O_5 and 28 kg K_2O_5 per ha. Intra row spacing and seedling per hill were attained by thinning the crop at 14 days after seeding (DAS). Weeding was done at 20, 35 and 50 DAS

2.3. Data collection

Data collected included growth and yield measurements. Ten plants which excluded plants from border rows and central 1 m^2 area were selected randomly from each unit plot and tagged at 14 DAS . The 10 plants were used for collecting data on plant height, number of tillers per hill, panicle length, days to 50 % heading, days to maturity and number of grains per panicle whereas, dry biomass weight, grain yield and 1000 grain weight were determined from final yield harvested using a 1m square quadrant in the middle of each plot. Data on plant height and number of tillers per plant were collected at 30, 45, 60 and 75 DAS. Plant height was determined by measuring the height of each of the tagged 10 plants per plot from the base to the tallest leaf or panicle, whichever was taller, using a ruler. The measurements were taken at 30, 45, 60 and 75 DAS. Number of tillers per hill was determined by observing, counting and recording all shoots on a hill at 30, 45, 60 and 75 DAS. Days to flowering was determined by counting the number of days from planting to days when 50 % of the tagged plants had initiated flowering in each plot. Days to maturity was determined determined by counting the number of days from planting to when over 80 % of the spikelets became golden yellow colour. Tagged plants per plot were harvested at crop physiological maturity, and grains per panicle per plot established by manually counting the grains. The value obtained was then divided by the number of sampled plants. Similarly the Panicle length was determined by measuring from the panicle base node to the end of the panicle using a measuring ruler. At physiological maturity, plants occupying the middle 1 m square area in each plot were harvested at ground level using sickle, sun dried to 14 % moisture content and then weighed to get the total biomass weight for each plot. The dried plants were threshed to separate the grains from the straw. The grains were then weighed to obtain the grain yield per plot. One thousand (1000) grains was then drawn randomly from the harvested grains and weighed to give 1000 grain weight. The difference between biological and grain yield gave the straw yield per plot. Harvest index was finally calculated as the ratio of grain yield and biological yield as described by (14,15).

2.4. Statistical analysis

The univariate procedure of SAS (version 9.4; SAS Institute, USA) was used to check for normality of the data before analysis. Data were subjected to analysis of variance (ANOVA) using the procedure for general linear model (proc GLM). Signifiant means at F-test were separated using Tukey's test. All statistical analysis was performed at $p = 0.05$.(16)

3. RESULTS

3.1: The Effect of Interaction Between Plant Spacing and Seeding Rate on Grain Yield, Dry Biomass and 1000 Grain Weight of Nerica 10

The effect of interaction between spacing and seedling per hill significantly ($P \leq 0.05$) influenced rice yield, dry biomass and 1000 grain weight.(Table 1). The highest grain weight ~~1.47 tons~~? per ha was found in interaction of spacing 20 cm x 10 cm at single seedling,which was not different from 20 cm x 10 cm at 2 seedlings per hill. Similarly, the heaviest dry biomass 8.73 tons per ha and 1000 grain weight 34.9 g were found in the interaction between spacing 20 cm x10 cm at single seedling per hill.

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Table 1:The Effect of Interaction Between Plant Spacing and Seeding Rate on Grain Yield, Dry Biomass and 1000 Grain Weight of Nerica 10

Treatment	Grain yield(g per m^2)	Dry biomass(g per m^2)	1000 grain weight
30x15S0	45.9bc	598.3b	24.3b
30x15S1	43.1bc	527.6b	24.3b
30x15S2	38.5bc	580.5b	22.9b
30x15S3	35.2c	574.5b	25.5b
20x15S0	62.4bc	546.8b	24.7b
20x15S1	35.7c	537.1b	24.8b
20x15S2	28.3c	610.8b	21.7b
20x15S3	37.2c	607.1b	24.0b
20x10S0	29.9c	571.6b	24.9b
20x10S1	145.9a	872.8a	34.9a
20x10S2	146.8a	585.8b	23.9b
20x10S3	109.0ab	665.3ab	26.2b
p value	<.0001	0.005	0.0007
MSD	89.93	259.55	8.16

*Means within a column followed by the same letter are not significantly different according to Tukey's test at $\alpha = 0.05$.

3.2: Effect of Plant Spacing on Rice Dry Biomass, 1000 Grain Weight and Grain Yields of Rice

Spacing had a significant ($p \leq 0.05$) effect on dry biomass, 1000 grain weight and grain yields of rice (Table 2). Narrow spacing 20 cm x 10 cm attained higher values of all yield parameters. The highest grain weight ~~1.10~~ ?tons per ha was observed in this spacing. Maximum dry biomass 6.74 tons per ha was observed in 20 cm x 10 cm spacing while the ~~lowest 5.70~~? tons per ha was obtained in ~~30 x 15~~ 20X10cm, which was not different from 20 cm x 15 cm. Similarly, maximum values for 1000 grain weight 27g was obtained in spacing 20 cm x10 cm.

Table 2: Grain Weight, Dry Biomass and 1000 Grain Weight of Rice as Influenced by The Main Effects of Spacing

Treatments	Grain weight (g per m^2)	Dry biomass (g per m^2)	1000 Grain weight (g)
Spacings (cm)			
30x15	40.68b*	570.25b	24.76b
20x15	40.88b	575.47b	23.81b
20x10	107.90a	673.87a	27.46a
Mean	63.153	606.53	25.18
p value	<.0001	0.0220	0.0037
MSD	25.887	98.307	2.715

*Means within a column followed by the same letter are not significantly different according to Tukey's test at $\alpha = 0.05$ .ns-non significant

Give yield data on hectare basis if possible

3.3: Effect of Seedling(s) per Hill on Rice Dry Biomass, 1000 Grain Weight and Grain Yields

One thousand grain weight from plots treated with single seedling per hill produced significantly ($p \leq 0.05$) higher values 27.99g compared to farmers practice of drilling (Table 3). Seedling(s) per hill had no significant ($p \leq 0.05$) effect on grain weight and dry biomass of Nerica 10

Table 3: Grain Weight, Dry Biomass and 1000 Grain Weight of Rice as Influenced by The Main Effects of Seedling(s) per Hill

Treatments	Grain weight (g per m^2)	Dry biomass (g per m^2)	1000 Grain weight (g)

Seeding rate			
Drill	46.08a*	572.25a	24.64ab
1 seedling per hill	74.89a	645.87a	27.99a
2 seedlings per hill	71.19a	592.38a	22.84b
3 seedlings per hill	60.44a	615.63a	25.23ab
Mean	63.15	606.53	25.18
p value	0.1021	0.4466	0.0025
MSD	ns	ns	3.45

*Means within a column followed by the same letter are not significantly different according to Tukey's test at α = 0.05 .ns-non significant

4. DISCUSSION

4. 1. *The Interaction Between Plant Spacing and Seeding Rate on the Yield and yield components of rice*

The interaction between narrow spacing 20 cm x 10 cm and single seedling per hill increased Nerica 10 rice grain yield by 58 % compared to the rest of the treatments. Similar results were observed in 1000 grain weight where the same interaction produced 30 % higher test weight than the rest of the treatments. This treatment was the best converter of dry matter into grain yield. This could be attributed to the fact that 20 cm x 10 cm spacing at single seedling(s) per hill had optimum plant densities which led to maximization of growth resource thus a good growth media for most parameters. The treatment benefited from the collective influence of effect of high plant population, more leaf area index, more of light interception thus higher photosynthetic activity resulting in increased dry biomass, maximum 1000 grain weight and maximum number of grains per panicles and ultimately maximum grain yields. The previous studies also proved that paddy yields remained higher in rice crop planted in closely spaced plant geometries compared to those obtained in wider ones. (17,18,19) reported higher yields and yield contributing factors at interaction of narrow spacings at fewer seedling per hill

4.2: ***Main Effect of Spacing on Growth on the Yield and yield components of rice of Nerica 10***

Narrow spacing 20 cm x 10 cm significantly improved grain weight, dry biomass ,1000 grain weight and grains per panicle compared to wider spacing 20 cm x 15 cm and control (Table 2). Spacing 20 cm x 10 cm increased 1000 grain weight by 11 % compared to wider spacings. Higher values of 1000 grain weight might have been due to optimum grain filling in narrow spacing as a result of optimum photosynthesis rate in this spacing. Similarly (20) study on effect of plant spacing and integrated nutrient management on the yield performance of Binadhan 14 rice variety obtained maximum 1000 grain weight in spacing 20 cm x 15 cm compared to wider spacings. Nerica 10 dry biomass yield was significantly higher by 15% in narrow spacing compared to the control spacing of 30 cm x 15 cm.. This may have been due to taller plants and increased plant population in spacing 20 cm x 10 cm, thus more number of leaves which occupied the same land area and subsequently trapped more light and carbon dioxide resulting in higher photosynthesis and producing more dry matter thus higher grain yield. Similar results were reported by (21) study on the effect of plant density and fertilizer levels on growth parameters of rice varieties under late sown conditions, where he obtained higher values of dry matter in narrow spacing of 15 cm x 10 cm Narrow spacing 20 cm x 10 cm significantly improved grain yield of Nerica 10 by 62% compared to 20 cm x 15 cm and control. Higher grain yield may have been a result of higher biomass per unit area thus increased surface area for photosynthetic activity. In addition heavier 1000 grain weight, higher dry biomass production and more grains per panicle in narrow spacing contributed to maximizing grain yield. The closely spaced rice plants were able to intercept maximum photosynthetically active radiation resulting in high dry matter production thus maximum yields. Similar to the current study, (22,18,14) obtained significantly higher grain yield in narrow spacing compared to the rest.

4.3: *Main Effect of Seedling(s) per hill on on the Yield and yield components of rice Nerica 10*

Seedling per hill had no significant influence on most parameters except grain test weight. Single seedling per hill significantly increased 1000 grain weight of Nerica 10 by 15 % compared to farmers practice of drill (Table 3). Better performance of 1000 grain weight at single seedling per hill may be due to healthy and efficient individual plant growth at lesser seedling density thus heavier grains. Also, grain filling is the process of remobilization from stored reserves, particularly from stem, leaves, and from current photosynthesis. Hence, planting of fewer seedlings resulted in higher grain yield. Seedling rate had no significant effect on grain weight and dry biomass. This results are partly in consistent with those of (14)

5. CONCLUSIONS AND RECOMMENDATIONS

The results of this study revealed that the interaction between narrow spacing 20 cm x 10 cm at single seedling per hill significantly increased dry biomass, 1000 grain weight and ~~grain weight~~ yield of rice. Narrow spacing 20 cm x 10 cm significantly (*p*≤0.05) increased grain yields, dry biomass and 1000 grain weight. There was no significant influence of seeding rate on most yield and yield contributing parameters of Nerica 10 except 1000 grain weight. Maximum values of grain yields 1.47 tons per ha, dry biomass 8.73 tons per ha and 1000 grain weight 34.9g were achieved when there was an interaction between spacing and seedling per hill compared to influence by single treatment(spacing) where grain yields ~~1.07~~ ?tons per ha, dry biomass 6.73 tons per and 1000 grain weight 27g. The study concludes that the interaction between plant spacing 20 cm × 10 cm with single (1) seedling per hill as the best combination to obtain

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maximum grain yield of Nerica 10 in Taita Taveta County. This is contrary to recommended spacing of 30 cm x 15 cm by drill. The results of this study will provide information on appropriate plant population for use in Taita Taveta County.

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