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Effect of Seed Rate and Row Spacing on Yield and Yield Components of Upland Rice (*Oryza sativa* L.) in Metema, West Gondar, Ethiopia

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Abstract: Rice is among the most important commercial cereal crops that can be produced in North Gondar. However, its production is challenged by low yield mainly due to lack of appropriate agronomic practices and recommendations. Uses of appropriate seed rate and row spacing most importantly affect the productivity of rice. Therefore, a field experiment was conducted to investigate the effects of seed rate and row spacing on grain yield and yield components of upland rice. Factorial combinations of four seed rates (60, 80,100 and 120 kg ha^{-1}) and three levels of row spacing (20, 25 and 30 cm) were laid out in RCBD with three replications using NERICA- 4 rice variety. The combine interaction effect of seed rate and row spacing was highly significant ($P<0.01$) on days to heading, days to maturity, number of total tiller per meter row length, thousand seed weight and grain yield, and significant ($P<0.05$) on plant height. The highest thousand seed weight (27.3 g) was recorded at seeding rate (80 kg $ha^{-1}$and grow spacing of 30 cm but the lowest (17.1 g) was recorded on seed rate of 120 kg $ha^{-1}$and row spacing of 25 cm. The highest grain yield (4148.8 kg ha^{-1}) was obtained at interaction of 80 kg ha^{-1}seed rate and 20cm row spacing. While the lowest grains yield (1826.4 kg ha^{-1}) was obtained from the combination of 60 kg ha^{-1}seed rate and 30cm row spacing. In conclusion, the results revealed that seed rate and row spacing increased grain yield of rice by positively affecting the important yield components of the rice. The result of economic analysis showed that the maximum net benefit was obtained at seed rate of 80 kg ha^{-1} and row spacing of 20 cm. Hence use of 80 kg ha^{-1} and 20 cm is promising for upland rice variety production under the rain fed condition at Metema district and similar agro ecologies.

Keywords: Interaction, NERICA –4, Economic Analysis, Row Spacing, Seed Rate

1. Introduction

Rice (*Oryza sativa* L.) ranks second after wheat in the world cereals grain production. Rice is the World's most important crop and it is a staple food for more than half of the world population [32]. It is the world's leading food crop, cultivated over an area of about 161.53 million ha with a production of about 481.14 million metric tons [16]. This represents 29% of the total output of grain crops worldwide [16]. Most of the increase in production has come from expansion in the area harvested rather than from increases in yields [48]. It provides about 22% of the world's supply of calories and 17% of the proteins [53].

The major rice growing regions are found in Asia, Latin America and Africa. Food and Agriculture Organization of the United Nations (FAO) estimated that Chinese rice farmers had produced 27.98% of the world rice followed by India (20.54%), Indonesia (9.44%), Bangladesh (6.94%), Vietnam (5.98%), Thailand (5.18%), Myanmar (4.12%) and Philippines (2.47%). It is a traditional stable food in West Africa and Madagascar and it is important food crop in East, Central, and Southern Africa [6].

Rice is one of the most important cereal crops cultivated in sub-Saharan Africa. Rice is grown in over 75% of the African countries with a total population of 800 million people. The utilization of rice is increasing and the inequity between domestic productions and consumption has been increasing in sub–Saharan Africa making the rice import growing from time to time [40]. About 80% of rice in Africa is produced by small scale farmers for their own utilization and local market [52]. Rice yields in Africa are generally low averaged about 1 t ha^{-1} in uplands, 1 to 2 t ha^{-1}in rain fed lowlands and 3 to 4 t ha^{-1} in the irrigated zones and a range of factors explain this low productivity [1].

The cultivation of rice in Ethiopia is of a recent history. Currently, however, its use as food and cash crop is well recognized. The country is characterized with immense potential for growing the crop. In 2007, the government of Ethiopia declared rice as a millennium crop which gave prominence to the crop in the national agricultural program as well as ensuring food security in the country.

Rice is among the most important cereals crops grown in different parts of Ethiopia as food crop. It is the second among cereals in terms of average national yield (2.84 t ha^{-1}) next to maize (3.94 t ha^{-1}) [12]. The introduction and expansion of rice production in suitable agro ecologies, therefore, could be an option to achieve food security and self-sufficiency.

Ethiopia has immense potentials for growing the crop. The estimated potential of Ethiopia for upland rice production is 30 million hectare [13]. From this 3.7 million hectare of land are suitable for irrigation [13]. In 2016/17 and 2017/18 cropping season, rice was produced on 48,418.09 ha and 53,106.79 ha of land in the country with total production of 1,360,007.26 quintals and 1,510,183.30 quintals respectively. Ethiopia is the only region in the world with the lowest yield in rice. Estimated yields for 2017/2018 were 2.84 tons ha^{-1}. It is an important crop which covers 39,829.58 ha of land with total production of 1,180,309.43 in quintals in Amhara region. The productivity of rice in Amhara region is 2.96 tons ha^{-1} [12]. It could serve as alternative crop choice for production diversification in the area.

According to [27], a quarter of the size of the Metema and area is having Haplic Luvisols soils and about 22% are Vertisols or soils with vertic properties. Many of the areas are also flat. Hence, seasonal water logging, especially during the heavy rainfall months, is so high and it is the main production problem in the study area. Such a condition is not conducive for the dominant commercial crops like sesame and cotton production in the area. Household income and food security of rural farmers could be affected by the decline in the production of such crops due to the water logging problem. On the contrary, rice has potential to grow in water logging conditions. Considering such potential agro-ecology; various researches, development and none governmental organizations put some effort to introduce and raise rice production in the area. Yet, farmers are still facing different problems like, lack of agronomic practices. Therefore, this entails a need for more comprehensive study which rigorously examines the rice agronomy practice in the study area.

Row spacing plays a significant role on growth, development, and yield of rice at its optimum level beside it provides scope to the plants for efficient utilization of solar radiation and nutrients [34]. Closer spacing hampers intercultural operations and as such more competition arises among the plants for nutrients and light. As a result, plant becomes weaker, thinner and consequently reduces yield. Under wider row spacing, farmers cannot get desired number of plant per area which also ultimately reduces yield. Therefore, proper manipulation of planting density may lead to increase the economic yield of rice [43].

Sufficient information regarding their optimum planting density of rice under the agro-climatic condition of Metema, have not been generated so far. Farmers in the area use do to blanket recommendation of seed rate and row spacing. A seed rate of 60 - 120 kg $ha^{-1}$and row spacing of 20 - 25 cm has been recommended for rice production throughout the Amhara Region without considering specific soil types and agro-ecological characteristics. Therefore, it is necessary to get the appropriate seed rate and row spacing for increased rice production in Metema area.

General Objective

To evaluate the appropriate rice seed rate and row spacing for rice production in Metema area.

Specific Objectives

a) To assess the effect of seed rate on yield and yield components of upland rice.
b) To assess the effect of row spacing on yield and yield components of upland rice.
c) To investigate the interaction effects between seed rate and row spacing on productivity of upland rice.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted in the main cropping season, under rain-fed condition at Afetet 1 and Afete 2 of Metema district in North Gondar, Amhara Regional State from July 2, 2017 to October 16, 2017. The experimental location represents the lowland areas of major rice growing area of North Gondar. The experimental is located about 900 km North West of Addis Ababa, about 360km Bahir Dar town, North West of Amhara region and about 200 km West of Gondar town (Figure 1) and about 30 km of East of Sudan border. The latitude and longitude of the district is 12^0 47" 38' N and 36^0 23"41' E, respectively, and an elevation of 760 m above sea level. The experimental site receives high amount of rainfall and an average annual rainfall of 1030 mm with maximum and minimum temperatures of 40.0 and 15.0°C, respectively [38]. Types of soils in the area where about a quarter of the size of the District is Haplic Luvisols and about 22% are Vertisols or soils with vertic properties [27].

2.2. Meteorological Data

Meteorological data [38] was obtained from Ethiopian Meteorological Agency, at Bahir Dar Branch. Among meteorological data average annual rainfall (mm) from 1999-2009 E.C, mean minimum and maximum temperature (°C) was used (Table 1).

Table 1. *Agro-ecological feature of the experimental site.*

Locations	Zone	Altitude (m.a.s.l)	Average annual rain fall (mm)	Soil type	Geographical coordinates		Average temperature (°C)	
					Latitude	Longitude	MaxT°.	MinT°.
Metema	North Gondar	760	1030	Sand-loam	$12^0$47"38' N	$36^0$23"41' E	40.0	15.0

Source: National Meteorological Agency, Bihar Dar Meteorological Branch [38]

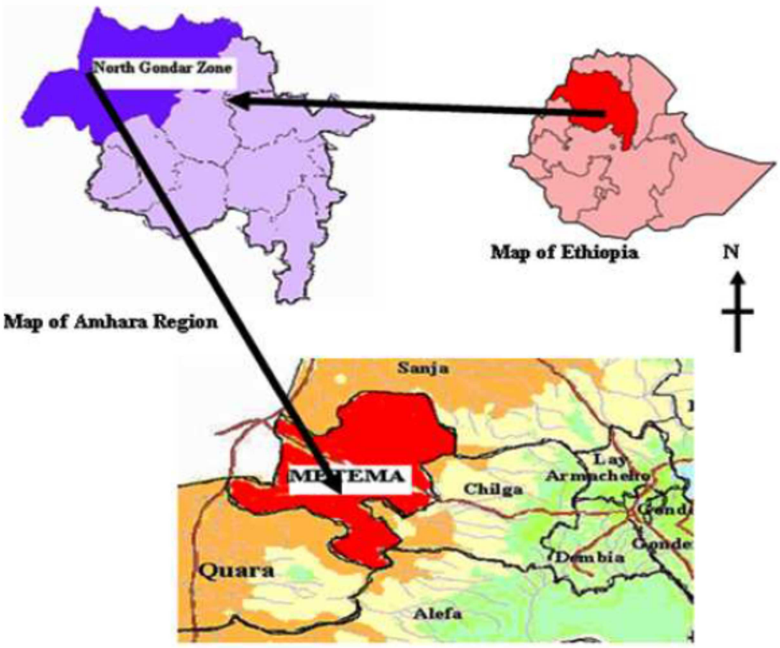

Figure 1. *Location of the Study Site [27]*

2.3. Description of Experimental Materials

Rice variety NERICA-4 was used for experiment. NERICA is used to refer to rice variety derived from the successful crossing of the two species of cultivated rice, the African rice (*O. glaberrima* S.) and the Asian rice (*O. sativa* L.), to produce progeny (known as interspecific) that combine the best traits of both parents [53]. NERICA 4 gave high yield potential and popularity among the farmers in study area. This cultivar is characterized by resistance to drought, pests and higher yields. It was recommended by Pawe Agricultural Research Center in 2006 for commercial cultivation mainly for warm areas. The key features of the variety are; panicle can hold up to 400 grains with a yield potential of 4.8 tons ha^{-1}. It matures in 110 days.

2.4. Treatments and Experimental Design

The treatments comprised of factorial combinations of four seed rates (60, 80, 100 and 120 kg ha^{-1}) and three row spacings (20, 25 and 30 cm). The experiment was laid out in factorial arrangement in a Randomized Complete Block Design (RCBD) with three replications. In accordance with specifications of the design, each treatment was assigned randomly to the plots within a block. The experimental plot had 2 m length and 3 m width with gross plot size of $6m^2$. The distance between the plots and blocks were used at 0.5 m and 1 m, respectively. There were 15, 12 and 10 rows per plot as per treatments of 20, 25, and 30 cm spacing respectively. Data were taken from the most central rows excluding a total of four rows (2 from the right and 2 from the left sides). A distance of 0.5m from the top and 0.5m from the bottom were excluded to avoid border effects. The net plot sizes for 20, 25, and 30 cm inter-row spacing were 2.2 m and 1.0 m, 2 m and 1.0 m, and 1.8 m and 1.0 m; respectively.

2.5. Experimental Field Management

To prepare a good seedbed for proper root penetration and development, the experimental field was ploughed three times with oxen and harrowing which were leveled by human. Seed was sown by drilling in rows of 20, 25 and 30 cm apart. Planting was done on the first week of July, 2017 main cropping season, when there was adequate soil moisture in the field. The seed of variety was sown at a depth of 3- 5 cm to ensure adequate emergence.

All field activities (land preparation, planting, fertilizer application and weeding) were done as per recommended agronomic practices. Fertilizer was applied at the rate of 100 kg ha^{-1} of NPS and 100 kg $ha^{-1}$of Urea. All NPS and 1/3 Urea was applied at sowing while the rest urea was applied 1/3 at tillering and 1/3 at panicle initiation. All data on growth, yield and yield components were measured from the central net plot area of each plot. Manual wedding by hand was made three times. The first weeding was made at two weeks after sowing, the second at tillering stage and the third at flower initiation. The crop was harvested when the crop reached harvesting maturity.

2.6. Data Collection

2.6.1. Phenological Parameters

Days to 50% emergence was determined by counting the number of days from sowing to emergence and was determined by visual judgment and recorded when 50% of the expected population was emerged.

Days to 50% heading was determined by counting the number of days from planting to 50% of plants reach heading stage.

Days to 90% maturity was determined by counting the number of days from planting to 90% of plants reach maturity stage. At this stage the leaves started to senescence and panicle turned to yellow to golden brown in color.

2.6.2. Growth Parameters

Plant height was measured as the height from the soil surface to the top of the spike. It was recorded as the average of five randomly selected main tillers from each plot at physiological maturity.

Panicle length was measured from the node where the first panicle branch starts to the tip of the panicle as the average of five randomly taken panicles at harvesting.

2.6.3. Yield and Yield Related Traits

Number of tillers per meter row length was recorded from five places in the net plot area was recorded and expressed as average number of tillers per 1.0 m row length.

Number of filled grains per panicle was taken as the number of filled grains from the main panicle at harvest from average of five randomly taken plants.

Number of un-filled grains per panicle was the number of unfilled grains from the main panicle at harvest from average of five randomly taken plants.

Biomass yield including the straw and grain was harvested at the ground levels sundried and weighed.

Thousand grain weight was counted at random from each plot and their weights were taken sensitive balance and adjusted at 14% moisture content.

Grain yield (t ha^{-1}) was recorded in kg fromeach net plot and adjusting at the standard 14% moisture content.

Harvest index (HI) was calculated by dividing grain yield by total biomass yield multiplied by 100 from each plot.

$$HI = \frac{GY}{TBY} \times 100\%$$

Where: GY= Grain Yield, TBY=Total Biomass Yield, HI= Harvest Index.

2.7. Data Analysis

The data were subjected to analysis of variance by SAS software. Significance of differences between samples was separated using the least significance difference (LSD) at 5% level of significance. Correlation analysis was also carried out to study the nature and degree of relationship between yield and yield components of upland rice. Correlation coefficient values (r) were calculated and test of significance was analyzed using Pearson correlation procedure found in SAS software.

The mean grain and straw yield data was adjusted down by 10% and subjected to partial budget and economic analysis was performed following the CIMMYT partial budget methodology [10]. Total costs that varied (seed and planting cost) for each treatments was calculated and treatments were ranked in order of ascending total variable cost (TVC) and dominance analysis was used to eliminate those treatments costing more but producing a lower net benefit than the next lowest cost treatment. The prices of the inputs that were prevailing at the time of their use were considered for working out the cost of cultivation. Net returns per hectare were calculated by deducting cost of production per hectare from gross income per hectare. A treatment which is non-dominated and having the highest net benefit is said to be economically profitable [10].

3. Results and Discussion

3.1. Phenological Parameters

3.1.1. Days to Emergence

The combine analysis show that days to 50% crop emergence were not significantly affected by seed rate, row spacing and by their interaction (Table A1). On average, rice seedlings emerged within 9.78 to 11 days, regardless of seed rates and row spacings used. Favorable moisture condition due to adequate supply of rain fall during sowing time and well prepared seedbed might have contributed to smooth and even germination. In line with this result, [47] reported non-significant variation in days to emergence. [14] also reported non-significance difference in days to emergence rice with the use of 75, 100 and 125 kg ha^{-1} of seed rate.

3.1.2. Days to Heading

Analysis of variance showed that the combine main effect of seed rate had highly significant and row spacing had significant effect on days to heading. Similarly the interaction effect of seed rate and row spacing significantly affected the heading days (Table A1). The longest days to 50% heading (75.33) was recorded at seed rate of 60 kg ha^{-1}at 25 cm row spacing, which had highly significant difference with 120 kg ha^{-1}at 25 and 30 cm while the shortest days to 50% heading (55.33) was recorded at seed rate of 120 kg ha^{-1} by 20 cm of row spacing. This might be because with lower seed rates plant competition for growth resources was lesser than the competition at higher seed rates. The higher availability of nutrients and light resulted in more plant growth as compared to lower seed rates. The earliness to heading in highest seeding rate might be due to the higher competition to resources; this may help plants to escape terminal moisture stress (Table 2).

In line with this result, [14] observed earlier heading and flowering of rice from the highest seed rate of 125 kg ha^{-1}.

The head to emergence was significantly delayed with the successive increase in row spacing. This might be due to reduced rate of photosynthesis because of the competition of plants for light, space, nutrients and water under closer spacing. [19] reported one day earlier head to emergence in plots with 20 cm than with 30 cm row spacing.

Table 2. *The combine interaction effect of seed rate and row spacing on days to headingat two locations at Metema during 2017.*

Seed rate (kgha^{-1})	Row spacing (cm)		
	20	**25**	**30**
60	74.00^{a}	75.33^{a}	75.00^{a}
80	71.67^{a}	75.00^{a}	63.67^{cd}
100	58^{e}	65.67^{bc}	71.00^{ab}
120	56.33^{e}	57.33^{e}	58.30^{de}
Mean	66.72		
LSD (5%)	5.47		
CV (%)	4.86		

Means with the same letters are not significantly different at 5% level of significantly. LSD: Least Significant Difference at 5% level of significant; CV: coefficient of variation in percent

3.1.3. Days to Physiological Maturity

Analysis of variance showed that seed rate and row spacing had highly significant (P< 0.01) effect on days to 90% physiological maturity and their interaction was highly significant different (Table A1). The number of days taken to reach to 90% physiological maturity of rice plants decreased with the increase in seed rate. The longest days to 90% maturity (109) was recorded at interaction of 80 kgha^{-1}seed rate and 30 cm row spacing, which had no significant difference with (60 kg ha^{-1} and 30 cm) and (60 kg ha^{-1}and 25cm) seed rate and row spacing respectively, while the shortest days to 90% maturity (92) was recorded at 100 kg ha^{-1} seed rate and 25 cm row spacing, which had no significant difference with (120 kg ha^{-1} and 20 cm), (120 kg ha^{-1} and 25 cm), (120 kg ha^{-1}and 30cm), (100 kg ha^{-1} and 20 cm) and (80 kg ha^{-1} and 20 cm) seed rate and row spacing respectively, (Table 3).

The prolonged days to 90% maturity with lowest population density or wider inter row spacing might be due to less competition of light interception, high availability of growth resources, that promote luxurious growth; and enhanced the lateral growth. Early maturity with narrow spacing could be due to the presence of intense inter plant competition at the closer row spacing that might have led to depletion of the available nutrient which might have resulted in stress and might lead to early heading and maturity [39].

In conformity with this result, [44] observed earlier physiological maturity of rice (4 days) with the increment of seed rate from 60-120 kg ha^{-1}. [50] also confirmed that days to physiological maturity were earlier by 6 days when the seed rate was increased from 80 to 100 kg ha^{-1}. [55] also concluded that closer inter row spacing (increasing plants density) shortened days to physiological maturity in rice. This could be due to the presence of intense inter plant competition at the closer row spacing that might have led to the depletion of the available nutrient that results plants tend to mature earlier.

Table 3. *The combine interaction effect of seed rates and row spacing on days to maturity at Metema (Afetet 1 and Afete 2) during 2017.*

Seed rate (kg ha-^{1})	Row spacing (cm)		
	20	**25**	**30**
60	102^{bc}	108^{a}	108.33^{a}
80	95.30^{de}	104^{b}	109^{a}
100	98.28^{cd}	92^{e}	102.667^{b}
120	95.32^{de}	93^{e}	95de
Mean	100.31		
LSD (5%)	3.99		
CV (%)	2.36		

Means with the same letters are not significantly different at 5% level of significantly. LSD: Least Significant Difference at 5% level of significant, CV: coefficient of variation in percent

3.2. Growth Parameters

3.2.1. Plant Height

The results revealed that the height of the rice plant was highly significantly (P<0.01) affected by seed rate and row spacing but their interaction effect was significant. The maximum plant height was recorded (115.67cm) at seed rate of 120 kg ha^{-1} and row spacing of 30cm, which had highly significant difference with other treatments while the minimum plant height (81cm) was recorded at 60 kg ha^{-1}and 20 cm of seed rate and row spacing respectively (Table 4). Although the interaction showed that plant height was statistically significant there was a gradual increase in plant height with increased seed rate (Table 4). Overcrowding due to increment of seeding rate per unit area might have resulted in aerial intra-specific competition between rice plants for light and space and promoted elongation of stem or tillers of rice.

In conformity with this result, [18] observed increasing trend in rice plant height as the level of seeding rate increased from 40 to 80 kg ha^{-1}. According to [55] row spacing of 30 cm resulted in significantly higher plant height (104.98 cm) than 20 cm and 25 cm row spacing. This increment in plant height at wider row spacing might be due to less competition of plants for nutrients, moisture, space and light providing better environment for growth and development of crop. In line to this result, [41] found plant heights (79.85 cm) in wider row spacing of 30 cm and the lower plant heights (75.62 cm) in 20 cm a part rows on wheat.

In contrast to this result, [31] and [30] reported that narrow spacing (20 cm) produced the tallest plants as compared to 30 cm inter-row spacing in rice. These results were in agreement with those reported by [21] and [2]. [2] reported the highest plant height was obtained in spacing of 25 cm in rice. Over-crowding due to increment of seed rate per unit area might have invited aerial intra-specific competition between rice plants for light and space and promoted elongation of stem/tillers to certain extent at the early stages of growth, while it may have depressed elongation of stem/tillers at the later period, resulting in shorter plants in response to a closer spacing as suggested by [30].

Table 4. *Interaction effect of seed rate and row spacing on plant height at Afete 1 and Afetet 2 during 2017.*

Seed rate (kg ha^{-1})	Row spacing (cm)		
	20	25	30
60	81^{f}	89.267^{e}	98.27^{d}
80	99^{d}	97.87^{d}	100.667^{cd}
100	98^{d}	101.20^{cd}	109.73^{b}
120	105.40^{bc}	103.47^{cd}	115.67^{a}
Mean	100.02		
LSD (5%)	5.86		
CV (%)	3.48		

LSD (0.05) = Least Significant Difference at 5% level; CV = coefficient of variation; Means followed by the same letter(s) are not significantly different at 5% level of significance

3.2.2. Panicle Length

Analysis of variance showed that highly significant (P<0.01) difference on panicle length due to main effect of seed rate and non significance difference effect due to row spacing and the interaction of seed rate and row spacing. The longest panicle lengths (25.36 and 24.31cm) were recorded at seed rates of 80 kg ha^{-1}and 100 kg ha^{-1}, respectively, which had significant difference with 60 and 120 kg ha^{-1} while the shortest panicle length (19.04 cm) was recorded at 120 kg ha^{-1}seed rate (Table 5). In contrast this finding [50] reported that seed rate did not affect significantly panicle length.

[36] indicated that panicle length is genetically characteristics that are influenced significantly by planting density. [11] showed that panicle density significantly increased with increase of seeding densities, while filled spikelets per panicle were reduced significantly.

Table 5. *The combine main effect of seed rates on panicle length, during 2017 cropping season.*

Seed rate (kg ha^{-1})	Panicle length (cm)
60	20.38 ^{b}
80	25.36 ^{a}
100	24. 31 ^{a}
120	19. 04 ^{b}
Mean	22.3
LSD (5%)	1.71
CV (%)	7.89

Means followed by the same letters are not significantly different at 5% level of significantly; LSD: Least Significant Difference at 5% level of significant; CV: coefficient of variation in percent

3.3. Yield Components

3.3.1. Number of Total Tillers per 1 Meter Row Length

The analysis of variance revealed that the combine main effect of seed rate and row spacing were highly significant (P<0.01) on the total tillers per 1m row length and their interaction was highly significant (Table A2). Higher number of total tillers per meter row length (78.67) was obtained from 80 kg ha^{-1} seed rate and 20 cm row spacing while the lowest number of total tillers per 1m row length [43] was found at 120 kg ha^{-1} of seed rate and 20 cm of row spacing at Metema site (Table 6). Although no undesirable effects were observed in this study due to the highest seed rate could be due to the fact that higher seed rates resulted in reduced number of tillers per plant. In general, the number of tillers per plant increased with the increase in row spacing.

In line with this result, [15] reported that the highest number of effective tillers obtained with 80 kg ha^{-1} seed rate was about 68% higher than the lowest seed rate. Increasing seeding rate would also increase density which increases unhealthy seedlings with small panicles due to competition for resources, and increase susceptibility to pests and diseases [28]. [55] reported in the wider row spacing, the more vigorous plants, with particularly higher tillering ability might have produced more photosynthesis than the less vigorous plants with the closer spacing.

[42] reported that the effect of spacing was pronounced in number of effective tillers which might be due to more space and nutrients available for the individual plant under wider spacing produced more number of tillers. [37] also found that the highest number of effective tillers per hill was found with 30 cm row spacing in rice crop. In the wider row spacing, the more vigorous plants, with particularly higher tillering ability might have produced more photosynthesis than the less vigorous plants with the closer spacing. The result was in conformity with [46]; and [51] who reported the highest effective tillers at optimum spacing as compared to lower spacing.

Table 6. *Interaction effect of seed rate and row spacing on number of total tillers per 1.0 mrow length.*

Seed rate (kg ha^{-1})	Row spacing (cm)		
	20	25	30
60	52.3^{fgh}	70.3^{abcd}	71.5^{abcd}
80	78.67^{a}	65.5^{bcde}	76.5 ^{a}
100	60.7^{defg}	49.83^{gh}	73^{abc}
120	43^{h}	55.16^{efg}	62.16^{cdef}
Mean	63.22		
LSD (5%)	11.18		
CV (%)	10.49		

Means with the same letters are not significantly different at 5% level of significantly; LSD: Least Significant Difference at 5% level of significant; CV: coefficient of variation in percent

3.3.2. Number of Filled Grain per Panicle

The analysis of variance revealed that the main effect of seed rate was high significant (P<0.01) and row spacing was significance (P<0.05) difference on number of filled grain per panicle while their interaction was not significant (Table A2). The highest number of filled grain per panicle (122.3) was found at seed rate 80 kg ha^{-1}while the lowest number of filled grain (77.47) was recorded at seed rate of 120 kg ha^{-1}due to high competition of water, nutrients and light (Table 7). The highest number of filled seed per panicle (106.38) was recorded on row spacing of 20 cm, and it was statistically different to row spacing 25 and 30 cm (Table 7).

[7] reported that the increased plant spacing considerably resulted in vigorous plant growth and caused a significant increase in number of filled kernels per panicle in rice. In contrast to the results obtained [29] observed highest number of filled grains spike^{-1} (31.05) from the seed rate of 140 kg ha^{-1}and the lowest (26.55) from the seed rate of 100 kg ha^{1}. This result in contrast with [33] was obtained there was no significance of difference between 20, 25and 30 cm.

Table 7. *The combine main effect of seed rates and row spacing on number of filled grain per panicle of rice.*

Seed rate (kg ha^{-1})	Number of filled grain per panicle
60	81.64c
80	122.8a
100	109.31b
120	77.47c
LSD (5%)	12.54
Row spacing (cm)	
20	106.38a
25	94.63b
30	92.40b
Mean	97.81
LSD (5%)	10.857
CV (%)	13.18

Means with the same letters are not significantly different at 5% level of significantly; LSD: Least Significant Difference at 5% level of significant; CV: coefficient of variation in percent

3.3.3. Number of Unfilled Grain per Panicle

Analysis of variance showed non significant (P<0.01) difference due to main effect of seed rate and row spacing on un-filled grain per panicle and their interactions did not show significant different. The lowest number (5.8) of un-filled grain per panicle was recorded for the row spacing of 25 cm whereas the highest number (6.32) was recorded on row spacing of 20cm, but it was no statistically different to row spacing 25 and 30 cm. This result was in contrast with the finding of [33] who reported that lowest number (1.93) of un-filled grain per panicle was obtained for the row spacing of 20 cm.

3.3.4. Biomass Yield

The combine analysis of variance revealed that the main effect of seed rate was highly significant (P<0.01) on biomass yield and row spacing was not significance (P<0.05) different on biomass yield while their interaction not significant (Table A2). The highest biomass yield (8568 kg ha^{-1}) was obtained at 120 kg ha^{-1} seed rate. However; this was statistically in parity with seed rate of 100 kg ha^{-1}. While the lowest biomass yield (5710 kg ha^{-1}) were obtained at 60 kg ha^{-1} seed rate. In general, biomasses yield increase with the increasing seed rate. There was an increase of 36% in biomass yield with the application of 120 kg seed rate ha^{-1}over 60 kg seed rate ha^{-1} (Table 8). The increase in biomass yield in response to application of seed rate might be due to its enhanced availability, uptake and induction of vigorous vegetative growth with more leaf area resulting in higher photosynthesis and assimilates that resulted in more dry matter accumulation [8].

Seed rate (80 kg ha^{-1}) attained higher plant height (Table 4), thousand seed weight (Table 10) and produced more tillers (Table 6) which promoted vegetative growth as well as development of the plants than their lower rates. The total dry matter per unit area was increased with an increase in spacing. This, in other way, implied that higher planting density within limit might produce more total dry matter per unit area which agrees with the results of this study.

The result was similar with to [4] found that increased biomass yield with wider row spacing due to higher production of tillers in rice. However, [9] reported that narrower row spacing produced higher biomass yield than wider row spacing in rice. In contrasting with this finding [45] also observed a significant increase in rice straw yield with seed rate up to 40 kg ha^{-1}.

Table 8. *The combine main effect of seed rates on biomass yield of NERICA-4 rice.*

Seed rate (kg ha^{-1})	Above ground biomass yield (t ha^{-1})
60	5.71^{c}
80	7.1^{b}
100	7.8^{a}
120	8.1^{a}
Mean	7.2
LSD (5%)	0.44
CV (%)	6.25

Means with the same letters are not significantly different at 5% level of significantly; LSD: Least Significant Difference at 5% level of significant; CV: coefficient of variation in percent

3.3.5. Straw Yield

The combine main effects of seed rate and row spacing were highly significant (P<0.01) on straw yield of rice but their interaction was not significant. The highest straw yield (5801 kg ha^{-1}) was recorded at seed rate of 120 kg ha^{-1} respectively, which had significant difference with 60 and 80 kg ha^{-1} while the lowest straw yield (3320.4 kg ha^{-1}) was obtained at 80 kg ha^{-1} seed rate (Table 9). It was also observed that increasing seed rates under in further increase in straw yield. In line with this result, [44] and [35] have shown rise in plant straw and biological yield to increase in seed rates. This result is in harmony with [3] and [54] who exhibited that as seeding rate increased, correspondingly straw yield increased due to higher stand number at crop establishment period.

On the other hand, row spacing highly significantly affected straw yield. The significantly maximum (4677.1 kg ha^{-1}) and minimum (3965.8 kg ha^{-1}) straw yield were observed for row spacing of 30 and 20 cm, respectively. The highest straw yield (4677.10 kg ha^{-1}) obtained at the influence of widest row spacing (30 cm) was 15.2 and 15.98% more than the straw yield obtained with 20 cm and 25 cm row spacing, respectively. Row spacing might have influenced vegetative growth in terms of plant height and number of tillers per plant which resulted in increased straw yield (Table 9). Similar trend of straw yield was also reported by [21] who reported the highest straw yield was obtained in 30 cm row spacing in rice. In contrast with this [49] reported the higher straw yield was obtained in 20 cm row spacing in rice.

Table 9. *The main effect of seed rates and row spacing on straw yield of rice.*

Seed rate (kg ha^{-1})	Straw Yield (t ha^{-1})
60	3.4^{c}
80	3.3^{c}
100	4.3^{b}
120	5.8^{a}
LSD (5%)	0.45
Row spacing (cm)	
20	4.05^{b}
25	4.02^{b}
30	048^{a}
Mean	0.42
LSD (5%)	0.39
CV (%)	10.93

Means with the same letters are not significantly differentat 5% level of significantly; LSD: Least Significant Difference at 5% level of significant; CV: coefficient of variation in percent

3.3.6. Thousand Seed Weight

Results from the analysis of variance indicated that both the main and their interaction effect of seed rate and row spacing were highly significant (P< 0.01) on thousand seed weight at Metema. Highest thousand seed weight (27.3 g) was obtained from 80 kg ha^{-1} of seed rate and 30cm of row spacing while the lowest thousand seed weight (17.1 g) was found at 120 kg ha^{-1} and 25 cm of seed rate and row spacing, respectively (Table 10). The highest thousand grain weight at widest spacing might be due to efficient utilization of water, nutrients and light with minimal inter rows competition. On the other hand, at highest density competition would increase and little photosynthesis would be available to grain filling and finally thousand seed weight would reduce as result of insufficient photosynthesis during grain filling stage in densely populated crops. This result in line with [15] reported that increased row spacing, thousand seed weight also increase where the highest thousand seed weight (23.97 g) was recorded at row spacing of 30 cm while the lowest (21.97 g) was recorded at row spacing of 20 cm.

The results showed that with the increase in row spacing the thousand seed weight also increased significantly. More number of grains per spike and higher 1000-grain weight noted in wider rows (25 cm) might be due to efficient utilization of water, nutrients and light due to minimal inter-rows competition and lower plant population in rice [26]. In line with this result, [2] reported the highest thousand grain weight (26.40 g) in wider spacing of 30 cm inter-row spacing than closer spacing of 20 cm inter-row.

Likewise, [5] reported that wider row spacing (22.5 cm) produced more 1000-grains weight as compared to narrow row spacing (11.25 cm) in wheat. In this result it might be due to the interaction effect of seed rate and row spacing produced this variation of weight difference on thousand seed weight. In contrast with the result on the effect of seed rate on 1000 kernel weight, [44] reported that seeding rate of 60 to 120 kg ha^{-1} was not significant in affecting thousand grain weight but showed a tendency to increase with increase of seed rates. [14] observed similar result but there was a decreasing trend in thousand grain weight as the seeding rate was increased from 75 to 125 kg ha^{-1}. This may be due to the fact that increased seed rate induce competition for assimilate

Table 10. *The combine interaction effect of seed rate and row spacing on thousand seed weight of NERICA - 4 rice variety at Metema during 2017.*

Seed rate (kg ha^{-1})	Row spacing (cm)		
	20	25	30
60	21.53^{e}	27^{ab}	23.13^{cde}
80	25.53^{abc}	24.73^{abcd}	27.3^{a}
100	22.13^{de}	22.067^{de}	24.467^{bcd}
120	18.467^{fg}	17.1^{g}	20.933^{ef}
Mean	22.87		
LSD (5%)	2.73		
CV (%)	7.1		

Means with the same letters are not significantly different at 5% level of significantly; LSD: Least Significant Difference at 5% level of significant; CV: coefficient of variation in percent

3.3.7. Grain Yield (kg ha^{-1})

The combine interaction effects of seed rate and row spacing as well as their interaction were highly significant (P<0.01) on grain yield of rice. The highest grain yield (4148.8 kg ha^{-1}) was obtained at interaction of 80 kg ha^{-1} of seed rate and 20 cm of row spacing while the lowest grain yields (1826.4kg ha^{-1}) was obtained at interaction of (60 kg ha^{-1} and 30 cm) of seed rate and row spacing, respectively (Table 11). The result of this study was in line with that of [15] reported that highest grain yield obtained with the use of 80 kg ha^{-1} seed rate was statistically greater than the other rates. The highest grain yield (4148.8 kg ha^{-1}) obtained with seed rate of 80 kg ha^{-1} and row spacing 20 cm was 27, 46 and 55% higher than that of 100 kg ha^{-1} and 30 cm, 120 kg ha^{-1} and 30 cm and 60 kg ha^{-1} and 30 cm of seed rate and row spacing, respectively. The lower plant population might have effectively utilized resources to give more grain yield. The numbers of effective tillers per meter row length, number of fill grain per panicle and thousand grain weights were the determinants of final yield.

Use of optimum seed rate is an important factor for maximizing yield of crops [24]. If more seed rate is used, plant population will be more and there will be competition among plants for water, nutrients, space and sunlight resulting in low quality and low yield. If less seed rate is used yield will be less due to lesser number of plants unit area^{-1} [22]. In agreement with this result, [2] reported that the number of tillers per unit area is the most important component of yield. Therefore, the higher the number of tillers, especially fertile tillers, the more will be the yield.

In line with this result, [25] obtained that grain yield increases linearly with plant density until some competitive effects become apparent. Maximum rice grain yield ha^{-1} was recorded at the seeding rate of 143.5 kg ha^{-1} but a further increase in seed rate to 184.5 and 205 kg ha^{-1} reduced yield to 5560 and 5150 kg ha^{-1} [23]. [3] observed increase grain yield of rice with increased seed rates up to 143 kg ha^{-1}. In this study, the highest seed rate 80 kg ha^{-1} at 20 cm row spacing used gave statistically higher yield to that of the other seed rates. The lower plant population might have effectively utilized the water, nutrients and light. [20] reported that closer spacing (15cm) proved better in grain yield of rice was better than the wider row spacing. Similarly [17] reported that yield of cereals increased in response to decreasing the spacing between rows.

Table 11. *The combine interaction effect of seed rates and row spacing ongrain yield of NERICA-4 rice variety at Metema during 2017 cropping main season.*

Seed rate (kg ha^{-1})	Row spacing (cm)		
	20	25	30
60	2469.8^{d}	2677.8^{cd}	1826.4^{e}
80	4148.8^{a}	3520.1^{b}	3659.9^{b}
100	3864.3^{ab}	3673.1^{b}	3049.4^{c}
120	2313.7^{d}	2317.6^{d}	2294.2^{d}
Mean	2984.59		
LSD (5%)	389.34		
CV (%)	7.74		

Means with the same letters are not significantly different at 5% level of significantly; LSD: Least Significant Difference at 5% level of significant; CV: coefficient of variation in percent

3.3.8. Harvest Index

The effect of seed rate and row spacing on harvest index was highly significant but their interaction was non significant difference. The highest harvest index (53.58) was recorded at seed rate of 80 kg ha^{-1}. While the lowest harvest index (28.49) was recorded at 120 kg ha^{-1} seed rate (Table 12). In contrast with this result, [15] reported not significant effect of seed rate on harvest index of rice.

Similarly the highest harvest index [45] was obtained at narrow row spacing of (20 cm), which had no significance difference with 25 cm while the lowest harvest index (36.8) was obtained at 30 cm row spacing. Decreasing row spacing showed increased the harvest index (Table 12). Similarly, [37] who found that the highest harvest index was observed in 20 cm row spacing in rice crop, but statistically similar with 25 cm row spacing. [26] who found that higher harvest index was reported in 20 cm row spacing, but statistically similar with 25 cm row spacing in wheat crop. [49] reported the highest harvest index was obtained in 25 cm row spacing in rice. In contrast with [31]; and [5] in their respective studies obtained higher harvest index with the increasing row spacing in rice crop.

Table 12. *The combine main effect of seed rates and row spacing on harvest index of NERICA-4 rice variety.*

Seed rate (kg ha^{-1})	Harvest index
60	40.71^{c}
80	53.58^{a}
100	45.55^{b}
120	28.49^{d}
LSD (5%)	4.08
Row spacing (cm)	
20	45.00^{a}
25	44.45^{a}
30	36.89^{b}
Mean	42.08
LSD (5%)	3.53
CV (%)	9.97

Means with the same letters are not significantly different at 5% level of probability; LSD: Least Significant Difference at 5% level of significant; CV: coefficient of variation in percent

3.4. Correlations of Grain Yield and Yield Related Traits

Knowledge of association between yield and its components is useful to make simultaneous selection for more than one character. The correlation analysis helps in determining the direction and number of characters to be considered in improving the yield. Correlations among the characters are presented in Table 13. Grain yield per hectare had high and positive associations with panicle length (r = 0.77**), thousand seed weight (r = 0.45**) and harvest index (r = 0.84**). This result indicated that agronomic traits like number of panicle length and harvest index could be exploited to increasing yield parameters in rice. This means with increasing value of these parameters, grain yield increases as well and vice versa. Besides this, there was non-significant and positive correlation with days to heading (r=0.048), total number of tiller per 1 m row length (r=0.18) and biomass yield (r=0.25). Whereas, there were negative correlations indicated among grain yield with days to maturity (r=-0.12) and plant height (r=-0.04) of upland rice.

Similarly dry biomass yield showed a negatively and highly significant correlation with days to heading (r= -0.68**) and days to maturity (r= -0.57**) but positively and highly correlation with plant height (r=0.72**) (Table 13). Harvest index showed a positive and highly significant correlation with panicle length (r= 0.69**) and thousand seed weight (r= 0.58**) (Table 13) while harvest index a positive and significant correlation with days to heading (r= 0.41*). Likewise thousand seed weight exhibit a positive and highly significant correlation with days to heading (r= 59**), days to maturity (r=0.69**), panicle length (r=0.49**) and total number of tiller per meter row length (r=0.48**) (Table 13). Number of total tiller per meter row length showed a positively and significant correlation on days to maturity (r=0.48*) (Table 13).

Table 13. *Correlation among yield and yield components and growth parameters in response to seed rate and row spacing of rice.*

	DH	DM	PH	PL	TN	BY	TSW	HI	GY
DH	1								
DM	0.55**	1							
PH	-0.54**	-0.37*	1						
PL	0.23ns	0.03ns	0.03ns	1					
TN	0.33ns	0.45**	0.09ns	0.33ns	1				
BY	-0.68**	-0.57**	0.72**	0.09ns	-0.13ns	1			
TSW	0.59**	0.61**	-0.26ns	0.49**	0.48**	-0.28ns	1		
HI	0.41*	0.17ns	-0.43**	0.69**	0.22ns	-0.31ns	0.58**	1	
GY	0.048ns	-0.12ns	-0.04ns	0.77**	0.18ns	0.25ns	0.45**	0.84**	1

DH=days to 50% heading; DM=days to 90% physiological maturity; PH=plant height; PL= panicle length; TN= tiller numbers; TSW=thousand seed weight; BY=biomass yield; HI=harvest index; GY=grain yield.

3.5. Partial Budget Analysis

In the result of present study, the costs for the different seeding rates, labor cost for rowmaking, drilling the seed and fertilizer application varied according to their rates and spacings requirements being other costs were constant for each treatment. In order to recommend the present result for the study area, it is necessary to estimate the minimum rate of return acceptable to producers in the recommendation domain. Based on partial budget analysis, the highest net benefit (39, 949.35 Birr ha^{-1}) was obtained from treatment combination of 80 kg ha^{-1} seeding rate with 20 cm inter-row spacing with an acceptable MRR was obtained (Table 14). While the lowest net benefit (17,312.78 Birr ha^{-1}) was obtained from the combination of 60 kg ha^{-1} seeding rate with 30 cm row spacing with only in one growing season (Table 14). Farmers may have the opportunity to decrease seed and labor cost and to increase rice yield and ultimately improve their livelihoods through adopting the appropriate management practices.

According to (10), the minimum acceptable marginal rate of return (MRR%) should be 100%. The most attractive rates for small scale farmers of the study area with low cost of production and higher benefits in this case were 80 kg ha^{-1} seeding rate and 20 cm row spacing combination also profitable with the highest net benefit and recommended.

Table 14. *Results of the economic analysis for seed rate and row spacing of rice in Metema.*

Treatments	Total Variable Cost (Birr/ha)	Net Benefit (Birr/ha)	DominanceAnalysis	Marginal Rate of Return
30×80	4750	36481.67		
30×60	4840	17312	D	
25×60	4900	25578.54	D	
30×100	5450	29735.82	D	
25×80	5600	33652.83	D	
20×60	5700	22348.69	D	
30×120	6050	21550.51	D	
25×100	6300	35188.88	D	
20×80	6400	39949.35		210.16
25×120	6900	20590.06	D	
20×100	7100	36308.07	D	
20×120	7700	19837.16	D	

Cost of seed 20 Birr kg^{-1}; Planting Cost Birr 50 per person per day; Sale price of rice grain Birr 15 kg^{-1}; Sale price of rice straw 0.5 Birr kg^{-1}

4. Conclusion and Recommendations

Rice is one of the most important food crop and a major food grain for more than a third of the world population. Ethiopian has a great potential for rice production because of its favorable environmental condition. Rice is highly sensitive to poor agronomic practices. Generating reliable information on agronomic management practices such as appropriate seed rate and row spacing are quite important to come up with profitable and sustainable upland rice production and productivity. Seed rate and row spacing areessential agronomic practices as it is a major management variable used in matching crop requirements to the environmental offer of resources. Metema is one of the production areas of upland rice. The experiment was carried out at two location of Metema district, North Gondar of Ethiopia, during, 2017 main cropping season.

A field experiment was conducted to assess the effect of seed rate and row spacing on yield components and yield of rice under rain fed. The combinations of four levels of seed

rate (60, 80, 100 and 120) and three levels of row spacing (20, 25 and 30 cm) were used as a treatment. The experiment was laid out in RCBD with factorial arrangement and replicated three times. The relevant data collected were subjected to analysis of variance using SAS software and significant treatment means were compared using least significant difference (LSD) test at 5% probability level. The combine main effect of seed rate was highly significantly on days to heading, days to maturity, plant height, number of tiller per meter row length, panicle length, and number of filled grain per panicle, harvest index, biomass yield, and thousand seed weight. Seed rate of 80 kg ha^{-1} was recorded significantly longest panicle length (25.36 cm) but statistically not significantly different on seed rate 100 kg ha^{-1}, highest number of filled grain per panicle (122.8) and highest harvest index (53.58). Whereas the seed rate of 120 kg ha^{-1} showed significantly shortest panicle length (19.04 cm), lowest number of filled grain per panicle (77.47) and harvest index (28.49).

The main combine effect of row spacing was also significantly on days to heading, and number of filled grain per panicle. The highest row spacing of 20 cm gave significantly highest number of filled grain per panicle (106.38). But row spacing not significance difference with days to 50% emergency, panicle length, number of unfilled grain per panicle and biomass yield. Days to 50% emergency and unfilled grain per panicle was not significantly affected by main effect of seed rate and row spacing. The interaction of seed rate and row spacing had a highly significant effect on days to heading, days to maturity, number of total tiller per 1m row length, biomass yield, thousand seed weight and grain yield of upland rice variety. The longest days to physiological maturity (108.33 days) was recorded at 60 kg ha^{-1} and 30 cm while the shortest days to maturity (92 days) was recorded at 100 kg ha^{-1} of seed rate and 20 cm of row spacing which had not significant difference with days to maturity found in response to the interaction of (120 kg ha^{-1} and 20 cm), (120 kg ha^{-1} and 25 cm) and (120 kg ha^{-1} and 30 cm) of seed rate and row spacing respectively. The highest (7.73) total number of tiller per meter row length was found in 80 kg ha^{-1} and 20 cm seed rate and row spacing, respectively but the lowest (4.67) total number of tiller per meter row length was recorded at 120 kg ha^{-1} of seed rate and 20 cm of row spacing. The significant highest biomass yield (8110 kg ha^{-1}) was recorded on seed rate 120 kg ha^{-1} but statistically not significantly different on seed rate 100 kg ha^{-1} while the lowest (5710 kg ha^{-1}) was recorded on seed rate of 60 kg ha^{-1}. The interaction of seed rate and row spacing had highly significant effect on thousand seed weight of upland rice. The highest thousand seed weight (27.3 g) was obtained from interaction of 80 kg ha^{-1} seed rate and 30 cm row spacing but not significance with 80 kg ha^{-1} by 20 cm row spacing. While the lowest thousand seed weight (17g) was obtained at 120 kg ha^{-1} and 25cm seed rate and row spacing respectively. The interaction of seed rate and row spacing had a significant effect on plant height of upland rice. The highest plant height (115.67cm) was obtained from interaction of 120 kg ha^{-1} seed rate and 30 cm row spacing. While the lowest plant height (81 cm) was obtained at 60 kg ha^{-1} and 20 cm seed rate and row spacing respectively.

The interaction effect of the two factors was highly significant on grain yield. The interactions of 80 kg ha^{-1} seed rate and 20 cm row spacing gave the highest grain yield (4148.8 kg ha^{-1}) which was statistically at not significance with the yield obtained with the interaction of 100 kg ha^{-1} and 20 cm row spacing (3864.3 kg ha^{-1}). On the other hand, the lowest grain yield (1826.4 kg ha^{-1}) was recorded with the interaction of 60 kg ha^{-1} seed rate and 30 cm row spacing. The study, in general, revealed that rice responded positively to seed rate and row spacing. Significant responses in grain yield and other parameters of rice were observed at levels of seed rates and row spacing. Thus, seed rate of 80 kg ha^{-1} with 20 cm row spacing could be considered as a preliminary recommendation for the study area for better economic advantage and acceptable rice yields for the cultivation of upland rice variety under the rain fed in North Gondar at Afetet 1 and Afetet 2 of Metema districts and similar agro ecology. However, to reach at conclusive recommendation the experiment has to be repeated across different years.

Conflict of Interest

The authors declare that there is no conflict of interest

Appendix

Table A1. *Mean square values of ANOVA for yield components of rice as influenced by seed rate and row spacing at Metema, 2017.*

SOV	df	DE	DH	DM	PH	PL
REP	2	0.75^{ns}	0.69^{ns}	7.4^{ns}	5.66^{ns}	6.718^{ns}
SR	3	2.768^{ns}	516.33**	237.805**	545.467**	83.01**
RS	2	0.25^{ns}	39.69*	115.11**	342.45**	8.43^{ns}
Site	1	0.12^{ns}	80*	120*	250*	35*
SR*RS	6	1.10^{ns}	66.69**	50.2**	36.67*	5.43^{ns}
Error	22	1.08	11.42	5.4	12.698	2.75

*: significant at P<0.05; **: highly significant difference at P<0.01; NS: non-significant at P<0.05; REP: replication; SR: seed rate; RS: row spacing; SOV: source of variation; df: degree of freedom; DE: days to emergency; DH: days to heading; DM: days to maturity, plant height, panicle length

Table A2. *Mean square values of ANOVA for yield and yield components of upland rice as affected by seed rate and row spacing at Afetet 1 and Afetet 2 of Metema districts during, 2017.*

SOV	df	NT	NFG	NUFG	BY	GY	TSW	HI
REP	2	0.66^{ns}	344.20^{ns}	2.97^{ns}	285395.11^{ns}	109879.30^{ns}	2.32^{ns}	20.19^{ns}
SR	3	4.32**	4295.9**	3.51^{ns}	10195563.25**	5446853.4**	78.67**	992.6**
RS	2	7.16**	677.167*	0.92^{ns}	499773.87^{ns}	760624.25**	12.78**	243.3**
Site	1	3.2**	540*	1.6ns	66126704*	469432.7ns	34.8**	587*
SR*RS	6	2.92^{**}	209.91^{ns}	4.278^{ns}	719991.04^{**}	234287.94**	10.997**	21.77^{ns}
Error	22	1	149.8	3.06	193559.33	48242.98	2.656	17.37

*: significant at P<0.05; **: highly significant difference at P<0.01; NS: non-significant; REP: replication; SR: seed rate; RS: row spacing; SOV: source of variation; df: degree of freedom; NTP: number of tiller per meter row length; NFG: number of filled grain per panicle; NUFG: number of unfilled grain per panicle; BY: biomass yield; GY: grain yield; TSW: thousand seed weight; HI: harvest index.

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