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Effect of Seed Rate on Yield Response of Upland Rice (*Oryza sativa* L.) Varieties at Gimbo, South-West Ethiopia

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Abstract: Field experiment was carried out under farmer's field during 2017 and 2018 main cropping season at Gimbo district in Kaffa zone, South-West Ethiopia. The objective of this study was to determine the appropriate seed rate on grain yield and yield components of upland rice varieties. The experiment was carried out using randomized complete block design with three replications. Five levels of seed rates (60, 80, 100, 120 and 140 kg ha^{-1}) and three levels of varieties (Nerica-4, Suparica-1 and Local check) were studied. The main effect of seed rate and variety had significant ($p<0.05$) effect on all the studied parameters. However, the interaction effect of seed rate and variety had only significant for number of panicles and grain yield. The pooled results revealed that Nerica-4 and Suparica-1 were produced the highest grain yield of 4553.9 and 4173.9 kg ha^{-1}, respectively at the rate of 80 kg ha^{-1} in the location. Increasing seed rate above 80 kg ha^{-1} had significantly decreased the grain yield. The correlation analysis was also made to perceive the relationships between grain yield and yield components. Thus, number of panicles, filled spikelets per panicle, plant height and panicle length had positive and significant correlation with grain yield. In addition, partial budget analysis was also made to discern the profitability of the treatment combinations in the location. Overall, growing Nerica-4 and Suparica-1 at the rate of 80 kg ha^{-1} was optimum to maximize grain yield and economic benefit. Therefore, it can be suggested for production.

Keywords: Grain Yield, Correlation Coefficient, Economic Analysis

1. Introduction

Rice (*Oryza sativa* L.) is a staple food crop for more than half of the world's population, most importantly in developing countries [1]. More than 90% of the world's rice is grown and consumed in Asia where nearly 60% of the world's people live [2]. It is the most widely consumed food for a large part of the world's human population. More than a billion households in Asia, Africa and America depend on rice systems for their main sources of employment and livelihoods [1, 3]. Its production is currently extending across at least 114 countries in the world and the second most produced cereals in the world after maize. Currently, it has also become a priority commodity for food security in Africa and grown over 75% of the African countries with a total production of 14 million tons and 16 million metric tons of consumption annually [4]. The world production area in 2014 was approximately 162 million hectares with 738 million tons of paddy rice with the average yield of 4.5 tons per hectare [5]. The productivity of the crop elsewhere in major rice producing countries, 3.6 t ha^{-1} in India, 5.1 t ha^{-1} in Indonesia, 5.8 t ha^{-1} in Vietnam, 6.7 t ha^{-1} in China and 9.5 t ha^{-1} in Egypt [5].

The wide adaptability of the crop together with diverse agro-climatic condition makes the rice cultivation more appropriate in Ethiopia [4]. At present rice is gaining same importance as some of the most common cereal crops for both domestic consumption as well as market use in Ethiopia. Despite its importance, the national productivity of the crop is 2.8 t ha^{-1} [5], this is by far below the potential of the crop on research plots (5.4 t ha^{-1}) [6]. Southwestern part of Ethiopia is one of the potential areas for rice production, mainly in rain fed upland ecology. Currently, the crop is mainly grown in the lowland parts of Gimbo district; especially at *Gojeb, Arguba, Choba*, *Shomba Kichib* and *Shomba Sheka* areas. The crop plays an important role for farmers, as food for home consumption, and source of income, as it is important crop in the local market. Rice is consumed in various ways in household level which includes: *injera, dabbo, asambusa, kinche,* and *shorba.* Bonga Agricultural Research Center has been conducting experiments on rice given major emphasis on testing adaptive varieties in the area. Consequently, several released varieties were evaluated and the best two varieties were identified and recommended for production. However, after few years of production, the productivity of these varieties have been declining gradually. This might be attributed to the use of inappropriate agronomic management practices, among which, indeterminate seed rate is the most important limiting factor. Despite the fact that, studies on seed rate recommendations for maximum economic yield of these varieties were still limited in the study area. Thus, it is necessary to study the effect of different seed rates on yield of upland rice. Therefore, the aim of this study was to determine appropriate seed rate on yield of upland rice varieties to improve the existing low productivity of the crop in the area.

2. Materials and Methods

2.1. Description of the Experimental Site

The field experiment was conducted at Choba peasant association in Kaffa zone. Choba is located about 53 kilometers away from the town of the district, Gimbo. The study area represents the lowland agro-ecology of the district. It is situated at 07° 24' N latitude and 36° 26' E longitude at an elevation of 1430 meter above sea level. Over 85% of the total annual rainfall occurs within eight months of the rainy season**,** with mean monthly values in the range of 125-250 mm. The mean temperature ranges from 18.1 to 21.4°C. The soil type is characterized under Vertisols [7].

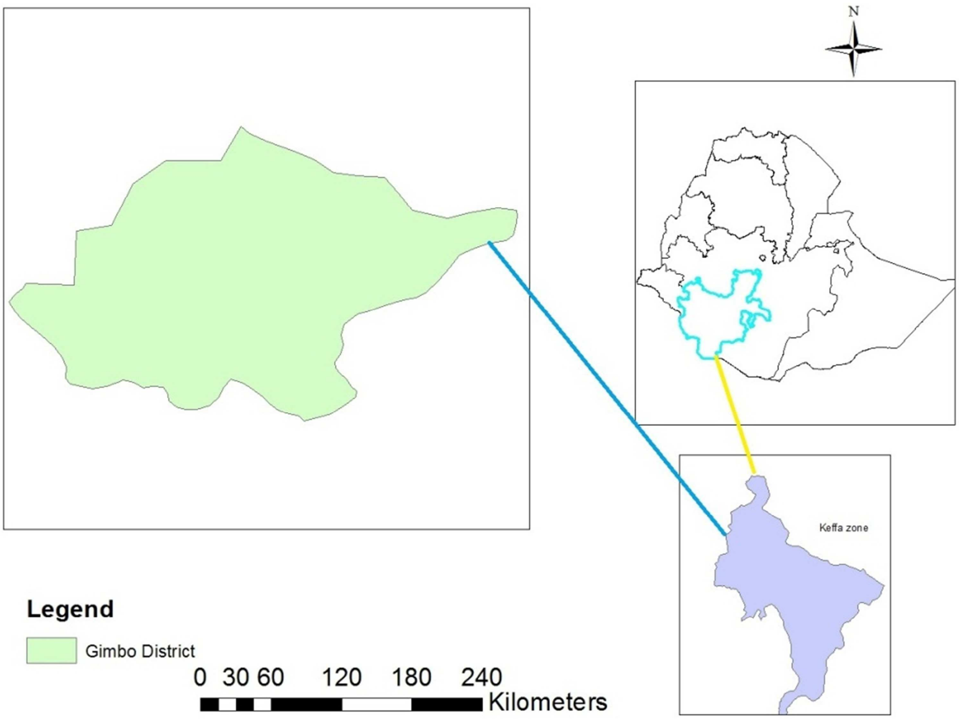

Figure 1. *Map of the study district.*

2.2. Experimental Materials

The two upland rice varieties (NERICA-4 and Suparica-1) and a local cultivar of the study area were used as planting material. The two improved varieties were released from Pawe Agricultural Research Center in 2006. They were high yielding, disease resistant and well adapted to the rain fed upland ecosystem.

2.3. Treatments and Experimental Design

The treatments consisted of the combination of five levels of seed rates (60, 80, 100, 120 and 140k kg ha^{-1}) and three levels of varieties (NERICA-4, and Suparica-1 and local cultivar) with a total of fifteen treatments were used in this study. The experiment was carried out in randomized complete block design with factorial arrangement and replicated three times. The total experimental area was divided into three replications, each of which is further divided into fifteen plots. Following the procedure fifteen treatment combinations were randomly assigned to the fifteen plots in each block. The gross plot area of the experiment was 8 m^2 and out of which 6 m^2 was considered as a net plot area. The spacing between the replications was 1 m whereas plots were spaced 0.5 m apart from each other.

2.4. Experimental Field Practices

The experimental field was prepared following the standard practices for rice production before sowing. The field was ploughed, leveled, and inter rows were prepared by using 25cm spacing. Sowing was done manually by hand drilling the seeds in the rows. A field layout was prepared following its procedure and the treatments were randomly assigned to the experimental plots. The total dose of phosphorus (100 kg ha^{-1}) in the form of NPS was applied at sowing and half of the total dose of nitrogen fertilizer (100 kg ha^{-1}) was applied after 15 days of seedling emergence and the remaining half of the nitrogen rate was applied at panicle initiation stage. Weeding was done uniformly in all experimental plots.

2.5. Data Collection and Measurements

Plant height: was determined by measuring the length of ten randomly selected sample plants from the ground level to the tip of the panicle in each plot at physiological maturity.

Panicle length: done by measuring the length of the panicle from the node where the first panicle branch emerges to the tip of the panicle and determined from an average of ten randomly selected plants per plot.

Number of tillers (both productive and unproductive) per m^2: The numbers of tillers were determined by counting the tillers from an area of 0.5 m x 0.5 m row plants by using quadrant in each plot and then converted to square meter area.

Number of panicles per m^2: The number of panicles was determined by counting the panicles from an area of 0.5 m x 0.5 m row plants of each plot and then converted to square meter area.

Number of total spikelets per panicle: The number of spikelets was determined by counting all spikelets (filled and unfilled) from ten randomly selected panicles of ten sample plants in each plot and averaged.

Number of filled spikelets per panicle: The number of spikelets was determined by counting only filled spikelets from ten randomly selected panicles of ten sample plants in each plot and averaged.

Thousand grain weight: was determined by weighing randomly drown 1000 grains of well developed, whole or undamaged grains and then adjusted to 14% moisture content.

Grain yield: grain yield was determined by harvesting the rice crop from the net middle plot area of 6m^2 and threshed cleaned and weighed using an electronic balance and then adjusted to 14% moisture content.

2.6. Statistical Analysis

The collected data were subjected to factorial analysis of variance (ANOVA) using General Linear Model (GLM) procedures of SAS version 9.3 (SAS Institute, 2002-2010). The treatment means of significant treatment effects were compared using Least Significant Difference (LSD) test at 5% probability level ($p<0.05$). Pearson correlation analysis was also carried out using the same software to investigate the association between grain yield and yield components of rice varieties.

2.7. Partial Budget Analysis

Partial budget analysis was performed using the grain yield to identify economically profitable seed rate. The yields of all treatments were adjusted downward by 10% to reflect possible lower yields expected by the farmers due to differences in management factors. The prices of seed was ETB 14.46 per kg, the local wage rate was ETB 50 per person per day were considered under variable costs. The farm gate price of grain was ETB 10 per kg. A gross farm gate benefit was obtained by multiplying adjusted yield (kg ha^{-1}) with farm gate price (ETB kg^{-1}); while the marginal rate of return for each seed rate treatment was calculated as change of benefit divided by change of cost and multiplied by 100 [8]. Economic recommendations were made by arranging interaction effect of variety and rate of seed used in order of increasing costs and then considering MRR between each treatment. Finally, the treatment with the highest net benefit and MRR was recommended for production in the study area.

$$MRR = \frac{\Delta NB}{\Delta TVC} * 100$$

Where; MRR=Marginal rate of return in percentage, ΔNB=Change in net benefits, ΔTVC=Change in total variable cost

3. Result and Discussion

Seed rates and varieties significantly ($p \leq 0.05$) affected all the studied parameters (Table 1). However, the interaction effects were significant only for grain yield and number of panicles per m^2 (Tables 2 and 3).

The varieties showed significant differences in plant height (Table 1). Suparica-1 and local cultivar produced the highest plant height of 91.8 and 90.6 cm, respectively; whereas Nerica-4 produced the shortest height of 86.7 cm. The observed difference in height between the varieties may be due to the inherent genetic difference among tested varieties. This result is in line with the results of Rahman [9] and Jisan [10] who observed difference in plant height among the varieties evaluated in their studies. The tallest height was recorded at the rate of 60 kg ha-1, whereas, the shortest height was 81.9 cm, when the rate increased from 60 to 140 kg ha^{-1}. The plant height decreased with the increasing seed rate of upland rice varieties. The increased height in response to low seed rate was likely due to the low inter plant competition, which might increases the possibility to get more nutrient in the soil, which may have promoted vegetative growth of the rice plants. Nitrogen in the soil may have encouraged the vegetative growth of upland rice varieties that promoted the growth of plants, through increasing the length as well as number of internodes [11].

The longest panicle was recorded for local cultivar and Nerica-4 with respective panicle length of 20.8 and 20.7 cm, respectively. But Suparica-1 produced the shortest panicle length of 19.9cm. The length of panicles was significantly decreased with the increasing seed rate up to 140 kg ha^{-1}. The highest panicle length was recorded at the rate of 60 kg ha^{-1} (21.6cm), whereas the lowest (19.3cm) was recorded at the rate 140 kg ha^{-1}. This is probably due to better absorption of nitrogen at the lowest seed rate due to less competition for nutrients, and this could be enhanced the length of panicle in rice [12].

There was significant difference between tested varieties in producing tillers per square meter. The comparisons of means indicated that the highest number of tillers (334) per square meter was recorded for varieties Nerica-4 and local cultivar. The lowest tiller number was recorded for variety Suparica-1 with tiller production of 307 per m^2. The number of tillers per square meter significantly increased with increasing seed rate up to 80 kg ha^{-1}. The highest number of tillers 363 and 349 per square meter was recorded at the rate of 80 and 100 kg ha^{-1}, respectively whereas; the lowest 281.2 and 295.7 was obtained at the rate of 120 and 140 kg ha^{-1}, respectively. The more number of tillers at 80 and 100 kg ha^{-1} seed rate could be due to less competition for growth resources and the availability of more nitrogen that favored cellular activities of the plant [13, 14]. This result is in line with the findings of Wu *et al* [15] who reported that the highest plant population in rice would decrease the ability of tiller production.

Number of spikelets per plant is an important yield determining components of rice. The analysis of variance that the main effect of seed rate and variety had highly significant ($P<0.05$) effect on total number of spikelets per panicle. However, the interaction effect of seed rate and variety did not show significant effect. The result revealed that local cultivar (123) and Nerica-4 (121) produced more number of total spikelets per panicle in combined data. The lowest number of total spikelets per panicle was obtained from Suparica-1 (116), which was not statistically different from Nerica-4. Among the seed rates, more number of total spikelets per panicle was recorded at the rate of 60 kg ha^{-1}, whereas, the lowest was recorded at the highest seed rate. The higher number of spikelets per panicle at lower seed rate is might be due to less competition of plants and the availability of more nitrogen at lower plant density. This result is similar with the previous findings of Baloch *et al* [16] who reported that the increasing rate of plant population had gave lowest number of spikelets per panicle. The performance of individual plants increased at lower plant population because of the opportunity to acquire more solar radiation for better photosynthetic process [16].

The result revealed that Nerica-4 was produced the highest number of filled spikelets (99) per panicle. However, the lowest number of filled spikelets per panicle was obtained from Suparica-1 and local check with the number of 91 and 94, respectively. On the other hand, among the seed rates, more number of filled spikelets per panicle was recorded at the lowest seed rate, whereas, the lowest was recorded at the highest seed rate. This might be due to the availability of more nitrogen at lower plant density as the result of less nutrient competition. Filled spikelets per panicle decreased with increasing seed rate or high plant population. The plants grown with lower seed rate had more solar radiation to absorb for better photosynthetic process and performed better [16]. Gerba *et al*. [17] reported that the higher seed rate the more sterility observed in rice. Similar result was reported by Harris and Vijayaragavan [18].

Regarding thousand seed weight, it was significantly influenced by both varieties and seed rates. The result indicated that suparica-1 was recorded the highest thousand seed weight (29g) followed by Nerica-4 (26g). On the other hand, there were no significant differences observed among four seed rates 60, 80, 100 and 120 kg ha^{-1}. However, the lowest weight was recorded at the highest seed rate (140 kg ha^{-1}). The result agrees with the previous report of Harris and Vijayaragavan [18]. The plants grown with lower seed rate had more solar radiation to absorb for better photosynthetic process and assimilate translocation to grain formation [16].

Table 1. *Interaction effect of variety and seed rate on number of panicles m^2 combined over years at Gimbo site.*

Variety	Plant height (cm)	Panicle length (cm)	Number of tiller m^2	Total spikelets m^2	Filled spikelets m^2	1000 grain weight (gm)
NERICA-4	86.7	20.7	334.7	120.97	99.32	26.2
Suparica-1	90.6	19.9	307.4	116.03	91.69	28.9
Local	91.8	20.8	334.2	123.08	94.59	24.6
LSD (0.05)	2.86	0.66	16.22	5.24	4.55	1.01
Seed rate						
60	97.4	21.6	338.17	135.31	113.37	27.2
80	92.3	21.0	362.89	127.33	100.35	27.3
100	88.0	20.4	349.22	120.64	94.59b	26.9
120	88.9	19.9	281.22	113.46	88.94	26.4
140	81.9	19.3	295.72	103.38	78.76	25.1
Means	89.70	20.5	325.44	120.03	95.20	26.6
LSD (0.05)	3.69	0.86	20.95	6.77	5.87	1.31
CV (%)	6.17	6.99	9.65	8.45	9.23	7.37

LSD (%)=Least significant difference at $P < 0.05$; CV (%)=Coefficient of variation.

The number of panicles per unit area is considered as one of the most important yield components, which increases the rice yields [19]. The interaction effect of variety and seed rate was significant for number of panicles per square meter (Table 2). The interaction effect indicated that, highest (346) number of panicles per square meter for Nerica-4 at the seed rate of 80 kg ha^{-1}. However, the lowest panicle number was recorded for local at all seed rates. Suparica-1 at the rate of 60 and 140 kg ha^{-1} and Nerica-4 at 140 kg ha^{-1} produced statistically same lower panicle number with the local cultivar in the location. Comparatively, Nerica-4 performed better in producing more number of panicles per square meter. However, the local cultivar had shown poor performance in producing panicles per square meter area. This indicated that the variation in the genetic potential of the varieties in response to seed rates. The increased number of panicles per square meter due to increased seed rate to 80 kg ha^{-1} might be due to the contribution of adequate supply of nitrogen to the production of branches, which probably increased panicles. Similar result was reported previously by Harris and Vijayaragavan [18].

The grain yield of two upland rice varieties was significantly increased across the increased seed rates up to 80 kg ha^{-1}. On the other hand, the yield of local cultivar was significantly increased further up to 100 kg ha^{-1} (Table 3). The highest grain yield was produced by varieties NERICA-4 and Suparica-1 at the seed rate of 80 kg ha^{-1} with grain yield of 4553.9 and 4173.9 kg ha^{-1}, respectively. The varieties showed increment in grain yield up to 80 kg ha^{-1}, and declined when the seed rate exceeded this rate. It might be due to better production of yield contributing traits at this rate as the result of less competition for nutrients. On the other hand, the local cultivar produced the lowest grain yield of 1915.3 kg ha^{-1} at 60 kg ha^{-1}. In addition, the local cultivar with the rates of 80, 100 and 140 kg ha^{-1} and Suparica-1 at the highest seed rate (140 kg ha^{-1}) gave statistically same lower grain yield with the local cultivar at the rate of 60 kg ha^{-1}. The highest grain yield obtained at the seed rate of 80 kg ha^{-1} might be due to better production of panicles and tiller number per m^2 and length of panicle at this rate. Proper seed rate is an important factor that enables good rice yield. In contrast, the highest grain yield was obtained at the seed rate of 40 kg ha^{-1} and declined when the seed rate exceeded this rate under irrigation [20].

Table 2. *Interaction effect of variety and seed rate on number of panicles m^2 combined over years at Gimbo site.*

Variety	Seed rate (kg ha^{-1})					Mean
	60	80	100	120	140	
NERICA-4	249.0	345.7	273.7	239.7	232.7	268.16
Suparica-1	224.7	272.7	241.7	215.0	211.3	233.08
Local	185.0	207.0	225.3	207.3	176.0	200.12
Mean	219.57	275.13	246.90	220.67	206.67	3012.81
LSD (%)			56.76			
CV (%)			21.11			

LSD (%)=Least significant difference at P < 0.05; CV (%)=Coefficient of variation.

Table 3. *Interaction effect of variety and seed rate on grain yield (kg ha^{-1}) combined over years at Gimbo site.*

Variety	Seed rate (kg ha^{-1})					Mean
	60	80	100	120	140	
NERICA-4	2964.9	4553.9	3680.6	3258.3	3037.3	3499.0
Suparica-1	3143.9	4173.9	3522.7	3196.0	2520.2	3311.3
Local	1915.3	2124.9	2680.0	2404.5	2015.9	2228.1
Mean	2674.7	3617.6	3294.4	2952.9	2524.5	
LSD (%)			715.6			
CV (%)			20.65			

LSD (%)=Least significant difference at P < 0.05; CV (%)=Coefficient of variation.

Association between Yield and Yield Components of Upland Rice

Pearson's correlation coefficient analysis was done to show the association between grain yield and yield components of upland rice varieties (Table 4). The results revealed that positive and significant correlation between grain yield and panicle numbers per square meter (r=0.43), filled spikelets per panicle (r=0.83), plant height (r=0.32), and panicle length (r=0.54). This indicated that the positive associations of grain yield with yield components. They had contribution to the increased grain yield. This result in agreement with the results of Fageria [19] and Kayvan *et al* [21], Sabesan *et al* [22], Akinwale *et al* [23], Ranawake [24] and Tadesse [6] who reported significant and highly positive correlation of grain yield with yield components.

Table 4. *Pearson's correlation coefficient between agronomic traits and grain yield.*

	GYD	TN	PN	TSP	FSP	TGW	PHT	PL
GYD	1.00							
TN	0.03^{ns}	1.00						
PN	0.43^{**}	0.30^{**}	1.00					
TSP	0.15^{ns}	0.73^{**}	0.58^{**}	1.00				
FSP	0.83^{**}	0.07^{ns}	0.49^{**}	0.26^{*}	1.00			

	GYD	TN	PN	TSP	FSP	TGW	PHT	PL
TGW	0.02^{ns}	0.47^{**}	0.00^{ns}	0.30^{**}	0.02^{ns}	1.00		
PHT	0.32^{**}	0.32^{**}	0.56**	0.43^{**}	0.55^{**}	0.33^{**}	1.00	
PL	0.54^{**}	-0.02^{ns}	0.20^{ns}	0.01^{ns}	0.46^{**}	-0.08^{ns}	0.10^{ns}	1.00

GYD=Grain yield; TN=Tiller number per m^2; PN=Panicle number per m^2; FSP=Number of filled spikelets per panicle; TSP=Total spikelets per panicle; PHT=Plant height; PL=Panicle length; TGW=Thousand grain weight; *, **, ^{ns}=non-significant, significantly different at 5% and 1% confidence interval.

Partial budget Analysis

Partial budget analysis was used in this study to calculate the total costs that vary and net benefits for each treatment. Based on this, the highest net benefit (39,428 Birr ha^{-1}) was obtained from treatment combination of Nerica-4 at 80 kg ha^{-1} seed rate while the lowest net benefit (15,870 Birr ha^{-1}) was obtained from the combination of local cultivar with 60 kg ha^{-1} seed rate (Table 4). The marginal rate of return is important to compare treatments in view of economic profitability rather than only looking at the maximum biological yield, because it may not be good, if its production requires very much higher cost [8]. This helps to remove unprofitable treatments before recommendation. Consequently, the marginal rate of return was done to determine the economic benefit of the technology for recommendation. Based on this, the highest marginal rate of return of 66% was recorded for NERICA-4, followed by Suparica-1 (48%) at same seed rate (80 kg ha^{-1}).

Table 5. *Partial budget analysis for the variety and seed rate on upland rice yield.*

VxSR (kg ha^{-1})	HGY (kg ha^{-1})	AGY (kg ha^{-1})	GB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})
Nx60	2964.9	2668.4	26684.1	1367.6	25316.5
Nx80	4553.9	4098.5	40985.1	1556.8	39428.3
Nx100	3680.6	3312.5	33125.4	1846.0	31279.4
Nx120	3258.3	2932.5	29324.7	2035.2	27289.5
Nx140	3037.3	2733.6	27335.7	2324.4	25011.3
Sx60	3143.9	2829.5	28295.1	1367.6	26927.5
Sx80	4173.9	3756.5	37565.1	1556.8	36008.3
Sx100	3522.7	3170.4	31704.3	1846.0	29858.3
Sx120	3196.0	2876.4	28764.0	2035.2	26728.8
Sx140	2520.2	2268.2	22681.8	2324.4	20357.4
Lx60	1915.3	1723.8	17237.7	1367.6	15870.1
Lx80	2124.9	1912.4	19124.1	1556.8	17567.3
Lx100	2680.0	2412.0	24120.0	1846.0	22274.0
Lx120	2404.5	2164.1	21640.5	2035.2	19605.3
Lx140	2015.9	1814.3	18143.1	2324.4	15818.7

VxSR=Variety by seed rate; N=NERICA-4; S=Suparica-1, L=Local cultivar; HGY.=Harvest grain yield; AGY.=Adjusted grain yield; GB=Gross benefit; TVC=Total variable cost; and NB=Net benefit.

Table 6. *Marginal rate of return for the variety and seed rate on upland rice yield.*

VxSR (kg ha^{-1})	AGY (kg ha^{-1})	GB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
Sx60	2829.5	28295.1	1367.6	26927.5	
Sx80	3756.5	37565.1	1556.8	36008.3	48.0
Nx80	4098.5	40985.1	1556.8	39428.3	66.1

VxSR=Variety by seed rate; N=NERICA-4; S=Suparica-1, L=Local cultivar; AGY.=Adjusted grain yield; GB=Gross benefit; TVC=Total variable cost; NB=Net benefit and MRR=Marginal rate of return.

4. Conclusion

The production of high yielding rice variety using improved agronomic management practices is the most important strategy to feed the rapidly growing population. Thus, the experiment was carried out to determine the appropriate seed rate on grain yield and yield components of upland rice varieties. The results of combined data indicated significant differences ($p<0.05$) for all the studied parameters. Based on the result of this study, among five seed rates, the use of 80 kg ha^{-1} is superior in most of the agronomic traits and economic analysis. Therefore, the most attractive rate for farmers of the study area with low cost of production and higher net benefit was 80 kg ha^{-1} in combination with Nerica-4 and Suparica-1. In conclusion, growing Nerica-4 and Suparica-1 at rate of 80 kg ha^{-1} was optimum to get better yield and economic benefit. Therefore, it can be suggested for production in the study area.

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