International Research Journal of APPLIED SCIENCES

Volume 02 | Issue 01 | 2020

SciRange
PUBLICATIONS
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SciRange Open Access

International Research Journal of Applied Sciences Research Article

pISSN: 2663-5577, eISSN: 2663-5585

Effect of Seeding Rate and Inter-Row Spacing on Yield and Yield Components of Upland Rice (*Oryza sativa* L.) at Libo Kemkem District, Northwestern Ethiopia

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ARTICLE INFORMATION

Received: January 24, 2020

Accepted: February 11, 2020

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ABSTRACT

Upland rice is a major cereal crop in Libokemkem District. However, yield of the crop is low due to lack of recommendation on site specific seeding rate and inter-row spacing. Hence, a field experiment was conducted at Libokemkem District during the main rainy season of 2018 to study the effect of seeding rate and inter-row spacing on grain yield and yield component on upland rice under rain-fed conditions. Two factorial combinations of seven seeding rates (40, 60, 80, 100, 120, 140 and 160 kg ha^{-1}) and four inter-row spacing (15, 20, 25 and 30 cm) were used. The treatments were arranged in Randomized Complete Block Design with three replications. Data of phenological, vegetative growth and yield and yield related parameters were collected. The data were analyzed using SAS 9.0 version and mean separation for significant treatments were done by least significance difference. The result of this research showed that except for thousand seed weight, all parameters were highly significantly ($p<0.01$) affected by main effects of seeding rate. In addition, plant height, panicle length and grain yield were highly significantly ($p<0.01$) affected by main effects of inter row-spacing. Grain yield was also significantly affected by the interaction effect. The highest grain yield (5.20 t ha^{-1}) was obtained at interaction of seeding rate 100 kg ha^{-1} combined with an inter-row spacing of 15 cm. The treatment combination with 25 cm inter-row spacing had given the highest net benefit with acceptable range of marginal rate of return. Therefore, application of 100 kg ha^{-1} seeding rate and 25 cm inter-row spacing is economically feasible and can be recommended for the study area.

Key words: Grain yield, inter-row spacing, interaction effect, seeding rate, upland rice

INTRODUCTION

Rice (*Oryza sativa* L.) is an annual cereal grain and it is the most important food crops for the world's population[1]. Ethiopia is located in the tropical zone, having wide range of altitude gifted with a broad diversity of climate that suitable for successful growth of most types of crops[2]. In Ethiopia, rice production was started three decades ago and the country has reasonable potential to grow various rice types[3]. The productivity of rice increased from 498,332 t in 2009 to 3,958,323 t in 2019[4]. The area under rice production for the same period grew from 155,886 ha in 2009 to 773,504 ha in 2019. There is an increasing trend of expansion both in area and production.

Rice could suitably grow in many parts of the country. Amhara, Benshangul-Gumz, Tigray, Gambela, Oromia and Southern Nations Nationalities Peoples Region are the major rice producing areas in Ethiopia[5]. Amhara region takes the lions share accounting for 32% of area coverage and 28.1% of the production[4].

However, rice remains a minor crop both in area coverage and production compared to a large area and favorable agro-climatic conditions the country as well the region has immense potential for expanding rice production. An appropriate agronomic practice plays a key role in maximizing and sustaining crop yields of upland rice[6]. These practices for a crop response vary with plant population used with the main environmental conditions (moisture, nutrient, temperature). Then special attention should be given for increasing the yield per unit area by applying improved agronomic management practices like seeding rate and spacing[7]. It estimated about 650 ha of land was covered with rice in the study area with average productivity of 2.5 t ha^{-1}. However, the production and the productivity of the crop has been consistently far below its potential[8]. Hence, it was necessary to investigate the effect of seeding rate and inter-row spacing and their interactions effects on yield and yield components of upland rice in the study area.

MATERIALS AND METHODS

Description of the study area: The experiment was conducted on a farmer's field during the main rainy season, LiboKemkem District, Amhara National Regional State, Northwestern Ethiopia from June 2018 to November 2018. It is located at 13° 30 00''N latitude and 36° 30 00'' E longitudes with the altitude of 1804 m above sea level. The annual rainfall was 900 to 1400 mm per year and rainfall pattern is predominately uni-modal with the main rainy season from mid-June to September. The mean maximum and minimum temperature was 22 and 11°C per year, respectively. The soil type was 60% clay loam, 14% silt loam and 26% clay soil. Crop production is the major farming system in the study area[8].

Experimental design, treatments and procedures: Upland rice NERICA-4 variety was used in the experimental study. NERICA (New Rice for Africa) is derived from the successful crossing of the African and the Asian rice type[9]. NERICA-4 is a newly adapted rice variety suitable for upland rain fed condition in the District.

The treatments consisted of seven seeding rate (40, 60, 80, 100, 120, 140 and 160 kg ha^{-1}) and four inter row spacing (15, 20, 25 and 30 cm). The experiment was laid out in Randomized Complete Block Design in a factorial arrangement and replicated three times. The total gross plot size was 3 m width and 4 m length (12 m^2). Each treatment combination was assigned randomly to experimental units within a block for each replication properly. Based on inter-row spacing and gross plot size the number of rows per plot was 20, 15, 12 and 10. The net plot size was calculated for 7.2 m^2, 6.6 m^2, 6 m^2 and 5.4 m^2 which were excluding both the right and left of two outer rows and the top and bottom border affect of 0.5 m each side of the gross plot for each treatment unit.

Seeding was done by direct drilling using experimental seeding rate and inter-row spacing for each plot. Each plot received uniform doses of UREA 125 kg ha^{-1} and NPS 60.5 kg ha^{-1} fertilizers. UREA fertilizer was applied in three equal splits, one-third at sowing, one-third at tillering stage and the remaining one third at panicle initiation. Full dose of NPS fertilizer was applied with drilling at sowing[10]. Two times weeding, insect and diseases were controlled properly. Finally, the crop was harvested when, it reached harvesting maturity.

Data collected

Phenological parameters: Days to 50% heading and days to 90% physiological maturity were recorded.

Vegetative growth parameters

Plant height (cm): It was obtained by measuring from the main stem length of ground level to the tip of the panicle and determined an average five randomly plants taken on net plot basis at physiological maturity of the crop.

Panicle length (cm): It was measured at time of harvesting from the first panicle branch to the tip of the panicle as the average of five random panicles.

Yield and yield related parameters

Number of total tillers/0.5 m row length (NTT): It was taken from the average number of total tillers using 0.5 m row length of two randomly places from net plot area at harvesting.

Number of effective tillers/0.5 m row length (NET): It was taken from the average number of effective tillers using 0.5 m row length of two randomly places from net plot area at harvesting.

Number of filled grains per panicle (NFGPP): The number of filled grains per panicle was taken from average of five randomly selected main panicles at harvest for each net plot. It was separated filled grains out of un-filled grains.

Total above ground dry biomass yield per hectare (t ha^{-1}): Total above ground dry biomass yield (grain + straw) was obtained from the total net plot area at harvesting and sun dried for two weeks.

Grain yield per hectare (t ha^{-1}): Grain yield was obtained from thresh biomass yield and separated grains out of straw. It was mixed filled grains to grain yield. The grain yield was weighed with sensitive balance and changed to ton per hectare, then after, adjusting grain yield the moisture content at 12.5%.

Straw yield per hectare (t ha^{-1}): Straw yield was calculated by subtracting grain yield from total above ground dry biomass yield in ton per hectare.

Thousand seed weight (g): Thousand-kernel weight was determined by counting thousand seed weight and weighing them by sensitive balance in gram.

Harvest index (%): Harvest index of each net plot was calculated at the ratio of yield in ton by dividing total above ground dry biomass yield multiplied by 100.

Data analysis: Data was analyzed using SAS version 9.0[11]. Analysis of variance (ANOVA) was also used. Significance means were separated using the Least Significant Difference (LSD) test at 1% or 5% level of probability. Partial budget analysis was done following the methodologies of CIMMYT[12].

RESULTS AND DISCUSSION

Phenological parameters

Days to 50% heading: The main effect of seeding rate was highly significantly (p<0.01) affected on days to 50% heading. However, inter-row spacing and its interaction effects with seeding rates didn't showed significant difference (p>0.05) on days to 50% heading (Table 1).

Concerning seeding rate, the crop significantly reached days to 50% heading earlier at a seeding rate of 160 kg ha^{-1} (82.75 days) than 40 kg ha^{-1} (89.17 days) were comparable (Table 1). The reason for earlier days to 50% heading with higher seeding rate might be due to the limited number of tillers per each plant which heading almost equally. However, with lower seeding rate, the plants will have ample space to grow more number of secondary and tertiary tillers which will take more days to 50% heading. Similar result was reported that higher plant density has been reported to hasten early heading in rice population[13]. In line with this finding Delessa Angassa[14] stated that significance variation was observed between seeding rates in terms of days to 50% heading earlier at a seeding rate of 100 and 125 kg ha^{-1} than 50 kg ha^{-1}.

Table 1: Effect of seeding rate and inter-row spacing on Phenological and vegetative growth parameters of upland rice during 2018 main cropping season at Libokemkem District

Treatments	Parameters				
S (kg ha^{-1})	50% DH	90% DPM	PH (cm)	NTT/0.5 m	NET/0.5 m
40	89.17[a]	129.91[a]	69.38[a]	39.33[cd]	34.55[d]
60	86.58[b]	127.08[b]	66.38[b]	39.45[d]	34.88[d]
80	85.83[b]	126.33[b]	65.31[bc]	45.79[bc]	41.30[bc]
100	84.25[c]	125.66[cd]	71.28[a]	55.70[a]	51.77[a]
120	83.67[c]	124.70[d]	62.68[cd]	47.82[b]	42.91[b]
140	83.40[cd]	125.33[cd]	60.89[de]	45.62[bc]	36.83[d]
160	82.75[d]	124.66[d]	58.04[e]	39.57[cd]	31.16[d]
LSD (0.05)	1.05	1.24	3.20	6.50	6.16
SE±	0.37	0.43	1.13	2.27	1.49
R (cm)					
15	85.50	126.52	61.98[c]	50.34[a]	45.04[a]
20	85.28	126.19	62.06[c]	40.09[c]	34.87[b]
25	84.52	129.19	64.95[b]	44.52[bc]	37.81[b]
30	85.04	126.14	70.56[a]	43.95[bc]	36.56[b]
LSD (0.05)	NS	NS	2.44	4.90	4.65
SE±	0.28	0.33	0.86	1.71	1.12
CV (%)	1.52	1.2	6.08	17.79	19.51

50% DH = Days to 50% heading, 90% DPM = Days to 90% physiological maturity, PH = Plants Height, PL = Panicle Length, NTT = No. of Total Tiller and NET = No. of effective tiller

Days to 90% physiological maturity: The study showed that seedling rate was highly significantly (p<0.01) affects days to 90% physiological maturity of upland rice. However, inter-row spacing and its interaction effects with seeding rate did not explained significant difference (p>0.05) on days to 90% physiological maturity (Table 1).

As the seeding rate increased from 40 to 160 kg ha^{-1} decreased days to 90% physiological maturity by 5.25 days (Table 1). The reason for earlier days to 90% physiological maturity with higher seeding rate might be due to the limited number of tillers per each plant which mature almost equally. However, with lower seeding rates, the plants will have ample space to grow more number of secondary and tertiary tillers which will take more days to mature. In line with this result, Yoseph and Wedajo[15] stated that increasing seeding rate hastened days to physiological maturity of upland rice. Hence, days to 90% physiological maturity was significantly affected by seeding rate. In agreement with this finding, Yordanos Ameyu[16] concluded that increasing seeding rate shorten days to physiological maturity. Because the inter plant competition at higher plant density might be due to depletion of available nutrient that results plants tend to mature earlier.

Table 2: Interaction effects of seeding rate and inter-row spacing on plant height of upland rice during 2018 main cropping season at Libokemkem District

Seeding rate (kg ha^{-1})	Inter-row spacing (cm) 15	20	25	30
40	62.06^{a}	62.96^{ab}	64.36^{a}	89.20^{a}
60	61.93^{a}	62.03^{b}	65.10^{a}	76.46^{b}
80	63.46^{b}	61.93^{b}	67.06^{a}	68.80^{c}
100	64.56^{b}	66.43^{a}	68.80^{a}	77.93^{b}
120	62.13^{a}	62.16^{b}	63.13^{a}	63.13^{d}
140	61.60^{a}	60.03^{b}	60.46^{b}	61.46^{e}
160	58.13^{c}	56.96^{c}	58.16^{c}	58.90^{f}
LSD (0.05)		6.46		
SE±		0.43		
CV (%)		6.08		

The columns and inter rows followed by the same letter(s) are non-significance different at 5% level of probability, LSD (0.05) = Least Significant Difference at 5%, SE± = Standard error and CV (%) = Coefficient of variation

Vegetative growth parameters

Plant height: The analysis of variance indicated that the interaction effects of seeding rate and inter-row spacing had highly significantly ($p<0.01$) influence on plant height (Table 1). The tallest (89.20 cm) and the shortest (56.96 cm) plant height were obtained from 40 kg ha^{-1} with 30 cm and 160 kg ha^{-1} with 20 cm of seeding rate and inter-row spacing, respectively (Table 2). These finding indicated higher seeding rate and closer inter-row spacing for higher number of tillers which performs more competition for nutrients resulted in shorter plant height. However, lower seeding rate and wider inter-row spacing for lower number of tillers which performs less competition for nutrients resulted in taller plant height. This finding is agreed with others who stated that increasing plant height with lower seeding rate and spacing[17,18]. This could mainly be attributed to larger seeding rate resulting in lower availability of air, moisture and nutrient among plants results to shorter plant height[19].

Panicle length: The analysis of variance revealed that panicle length was highly significantly ($p<0.01$) affected by seeding rate and inter-row spacing. However, their interaction effect did not showed significance difference ($p>0.05$) on panicle length (Table 1).

The longest panicle length (18.80 cm) was recorded at a seeding rate of 100 kg ha^{-1} while the shortest panicle length (14.49 cm) was produced at a seeding rate of 160 kg ha^{-1} (Table 1). These results indicated that at the lower seeding rate of 100 kg ha^{-1} panicle length was higher as compared to higher seeding rate of 160 kg ha^{-1} because at higher seeding rate occupied less free space between plants and also optimum seeding rate occupied sufficient space occupied by plants and minimum intra-plant competition for available resources to long panicle length. Hence, inferior performance of individual plants observed under higher seeding rate[20]. This result was similar with Usha *et al.*[21] who reported that longer panicles (21.1 cm) were obtained from at a lower seeding rate of 100 kg ha^{-1} and shorter panicles (19.98 cm) were recorded from at a higher seeding rate of 150 kg ha^{-1}. On the other hand, seeding rate did not affect panicle length of upland rice[15].

Inter-row spacing also significantly affected on panicle length. As increasing inter-row spacing from 25 to 30 cm was decreased panicle length by 2.72 cm (Table 1). The reason for shorter panicle length with wider inter-row spacing might be due to more number of tillers which provides inefficient available of growth resources to contribute less physiological process resulted to shorter panicle length. However, longer panicle length with optimum inter-row spacing might due to efficient available of growth resources to contribute more physiological process which is resulted to longer panicle length over narrow spacing. In line with this, it was obtained that more panicle length was recorded from appropriate inter-row spacing with less competition for better physiological process under which could be enhanced growth and development of upland rice[22].

Yield and yield related parameters

Number of total tillers: The statistical analysis of the study indicated that the main effects of seeding rate, inter-row spacing and their interaction effects were highly significant ($p<0.01$) difference on the number of total tiller/0.5m row length (Table 1).

The highest number of total tiller/0.5 m row length (55.70) was recorded at seeding rates of 100 kg ha^{-1} while the lowest number of total tillers/0.5 m row length (39.33) was recorded at seeding rates of 40 kg ha^{-1} (Table 1). The reason for highest number of total tiller with 100 kg ha^{-1} seeding rate might be due to optimum seeding rate, the numbers of total tillers were increased due to adequate amount of nutrient, moisture and light might have played a vital role in cell division and more number of tiller formation[20]. Due to these reason, the highest number of total tiller/0.5 m row length was obtained at 100 kg ha^{-1} seeding rates than lower seeding rate of 40 kg ha^{-1}.

Regarding to inter-row spacing, the highest (50.34) and the lowest (40.09) number of total tiller/0.5 m row length were showed that at 15 and 20 cm inter-row spacing. This indicated that as inter-row spacing increases from 15 to 20 cm, the number of total tillers/0.5 m row length decreased by 20.3%.

This might be due to a closer inter-row spacing obtained the highest number of tillers/0.5 m row length. The present result is similar with the finding of Zewdneh Melke[23] who reported that the highest number of total tillers (420 m^{-2}) was produced at narrow inter-row spacing (20 cm) than wider inter-row spacing (30 cm).

The interaction effects of seeding rate and inter-row spacing was obtained for different number of total tillers/0.5 m row length. Maximum total tillers/0.5 m row length (77.66) was observed at seeding rate of 100 kg ha^{-1} combined with 15 cm inter-row spacing while, minimum number of total tillers/0.5 m row length (32.16) was observed at seeding rate of 160 kg ha^{-1} combined with 30 cm inter row spacing (Table 3). These findings showed that, at optimum seeding rate combine with closure inter row spacing produced for more number of total tillers over higher seeding rate with wider inter-row spacing. The reason to the highest number of total tillers with optimum seeding rate for efficient open space available which responsible to make ample amount of dry matter accumulation that increased the number of total tiller formation. The result is similar with the findings of others[24].

Number of effective tillers: Grain yields are dependent upon major yield contributing characters. From these, the numbers of effective tillers are the most significance yield components. For this reason, the final yield is mainly a function of effective tillers. The result of the study showed that the main effects of seeding rate, inter-row spacing and their interaction highly significantly ($p<0.01$) affected on number of effective tillers/0.5 m row length (Table 1).

The present finding indicated, the number of effective tillers/0.5 m row length was increased with increasing seeding rate to 100 kg ha^{-1}. Therefore, the maximum number of effective tillers/0.5 m row length (51.77) was recorded at a seeding rate of 100 kg ha^{-1} while minimum number of effective tillers/0.5 m row length (31.16) was recorded at seeding rates of 160 kg ha^{-1} (Table 1). More vigorous plants with the optimum seeding rate, particularly higher tiller capacity might have produced more photosynthesis resulted for high effective tillers than less vigorous plants with higher seeding rates[25]. This might be due to more number of tillers at higher seeding rate leads to higher competition among upland rice leads to lower number of effective tiller production.

About inter-row spacing, the highest (45.04) and the lowest (34.87) number of effective tillers/0.5 m row length was recorded from 15 and 20 cm inter-row spacing's, respectively. The result might be due to higher number of plant density at narrow inter-row spacing responsible for higher effective tillers/0.5 m row length. These findings was conformity with Jana *et al.*[26] who reported that the number of effective tillers m^{-2} being maximum under closure inter-row spacing (20 cm) than under wider inter-row spacing (25 cm).

With regard to the interaction effects of seeding rate and inter-row spacing were obtained different number of effective tillers/0.5 m row length. Maximum number of effective tillers/0.5 m row length were observed at a seeding rate of 100 kg ha^{-1} combined with 15 cm spacing while minimum number of effective tillers/0.5 m row length was observed at a seeding rate of 160 kg ha^{-1} combined with 30 cm spacing (Table 4). This might be due to more number of vegetative parts per plant with more number of tillers/plant under seeding rate of 100 kg ha^{-1} and inter-row spacing of 15 cm which resulted to increase the number effective tillers.

Table 3: Interaction effects of seeding rate and inter-row spacing on number of total tiller/0.5 m row length of upland rice during 2018 main cropping season at Libokemkem District

Seeding rate	Inter-row spacing (cm)			
(kg ha^{-1})	15	20	25	30
40	42.16^{cd}	37.16^{cd}	34.17^{e}	43.83^{c}
60	43.30^{c}	39.00^{c}	38.00^{d}	36.33^{e}
80	44.66^{c}	42.33^{a}	43.16^{b}	53.00^{b}
100	77.66^{a}	40.00^{b}	51.00^{b}	54.16^{a}
120	54.16^{b}	42.00^{a}	44.16^{c}	51.00^{c}
140	46.83^{c}	47.16^{a}	51.33^{a}	37.16^{d}
160	43.33^{c}	34.00^{d}	49.85^{b}	32.16^{f}
LSD (0.05)		13.02		
SE±		0.85		
CV (%)		17.79		

The columns and inter rows followed by the same letter(s) are non-significance different at 5% level of probability, LSD (0.05) = Least significant difference at 5%, SE± = Standard error and CV (%) = Coefficient of variation

Table 4: Interaction effects of seeding rate and inter-row spacing on the number of effective tillers/0.5 m row length on upland rice during 2018 main cropping season at Libokemkem District

Seeding rate	Inter-row spacing (cm)			
(kg ha^{-1})	15	20	25	30
40	39.33^{c}	31.33^{c}	28.66^{d}	26.66^{a}
60	40.00^{c}	34.66^{b}	30.33^{d}	33.33^{e}
80	41.66^{c}	37.33^{b}	37.00^{c}	49.33^{c}
100	69.33^{a}	36.76^{b}	50.66^{b}	50.33^{b}
120	49.33^{b}	37.00^{b}	41.66^{a}	43.66^{d}
140	41.66^{c}	40.00^{a}	39.00^{a}	26.33^{a}
160	34.00^{d}	27.00^{d}	37.33^{c}	26.30^{a}
LSD (0.05)		12.32		
SE±		0.56		
CV (%)		19.51		

The columns and inter rows followed by the same letter(s) are non-significance difference at 5% level of significance, LSD (0.05) = Least significant difference at 5%, SE± = Standard error and CV (%) = Coefficient of variation

Table 5: Main effect of seeding rate and inter-row spacing on yield and yield related parameters of upland rice during 2018 main cropping season at Libokemkem District

Seeding rate (kg ha^{-1})	NFGPP	TADBY (t ha^{-1})	GY (t ha^{-1})	SY (t ha^{-1})	HI (%)	TSW (g)
40	97.76^{a}	6.79^{c}	2.80^{cd}	3.99^{d}	40.62^{a}	28.43
60	86.86^{c}	8.44^{b}	3.05^{cd}	5.39^{bc}	35.88^{b}	30.03
80	85.88^{c}	9.49^{a}	3.57^{b}	5.79^{bc}	37.61^{ab}	31.31
100	84.86^{c}	10.40^{a}	4.22^{a}	6.17^{bc}	40.76^{a}	29.13
120	89.83^{a}	9.25^{a}	3.28^{cd}	5.97^{bc}	36.02^{b}	29.51
140	79.30^{c}	10.16^{a}	2.65^{cd}	7.50^{a}	26.36^{c}	29.02
160	74.41^{d}	9.40^{a}	2.81^{cd}	6.58^{a}	30.44^{c}	29.61
LSD (0.05)	8.46	1.42	0.51	1.13	4.32	NS
SE±	2.98	0.50	0.18	0.39	1.52	9.47
Inter-row spacing (cm)						
15	84.12^{b}	9.52	3.29^{a}	6.23	34.40^{b}	28.09^{b}
20	80.06^{b}	9.19	3.53^{a}	5.65	39.55^{a}	29.42^{b}
25	88.23^{a}	9.53	3.47^{a}	6.05	36.88^{a}	29.21^{b}
30	89.81^{a}	8.28	2.49^{b}	5.71	30.70^{c}	31.59^{a}
LSD (0.05)	6.39	NS	0.39	NS	3.26	2.03
SE±	2.25	0.37	0.13	0.30	1.15	7.16
CV (%)	12.08	18.02	18.78	19.87	14.91	11.10

NFGPP = Number of filled grains per panicle, TADBY = Total above ground dry biomass yield, GY = Grain Yield, SY = Straw Yield, HI = Harvest Index, TSW = Thousand Seed Weight. The columns and inter rows followed by the same letter(s) are non-significance difference at 5% level of significance, LSD = 0.05

Number of filled grains per panicle: Data obtained on number of filled grains per panicle exhibited that, it was highly significantly ($p<0.01$) influenced by seeding rate. In addition, main effects of inter-row spacing was highly significance ($p<0.01$) effects on filled grains per panicle. However, interaction effects of seeding rate and inter-row spacing had no significance ($p>0.05$) difference (Table 5).

Maximum number of filled grains per panicle (97.76) was recorded from seeding rate of 40 kg ha^{-1} and minimum number (74.41) was recorded from seeding rate of 160 kg ha^{-1} (Table 5). At seeding rate of 40 and 120 kg ha^{-1} as well as, 60, 80,100 and 140 kg ha^{-1} statistically similar result of filled grains per panicles were recorded. The result indicated that, as seeding rate increased from 40 to 160 kg ha^{-1}, the number of filled grains per panicle decreased by 23.9%. The variation was formed from in number of filled grains per panicle decrease at higher seeding rate, might be due to the lower photosynthesis process accumulation after heading resulted to lower number of filled grains. The study agreed with Harris and Vijayaragavan[27] who revealed that as seeding rate increased the number of filled grains per panicle remarkably decreased. When the amount of seeding rate increases, it increases the photosynthetic apparatus and vegetative parts per unit area. These help to increase respiration rates, which in turn could lead to a reduced number of filled grains per panicle[27].

The analysis of variance for the main effects of inter-row spacing was affected on filled grains per panicle was observed that the highest (89.81) and the lowest filled grains per panicle (80.06) was recorded from inter-row spacing of 30 and 20 cm, respectively (Table 5). Inter-row spacing of 25 and 30 cm produced statistically similar filled grains per panicle. This finding was agreed with Tamiru Dejen[25] who reported that between plants might be less competition with efficient availability of carbohydrates for grain formation and filling.

Total above ground dry biomass yield: Total above ground dry biomass yield was highly significantly ($p<0.01$) affected by seeding rate. On the other hand, inter-row spacing and its interaction effects with seeding rate did not showed significance difference ($p>0.05$) effect on total above ground dry biomass yield (Table 5).

The result revealed that, the highest (10.40 t ha^{-1}) and the lowest (6.79 t ha^{-1}) total above ground dry biomass yield were showed at a seeding rate of 100 and 40 kg ha^{-1}, respectively (Table 5). So, there was dry biomass yield advantage by 34.71% obtained from seeding rate of 100 kg ha^{-1} as compared to 40 kg ha^{-1}. The result also indicated that as seeding rate increased optimally, dry biomass yield contributing factors also increased proportionally. Similar results were reported by Kumar[28] who reported that dry biomass yield production was increased with higher seeding rate per unit area up to some extent and decrease thereafter. Because with proper seeding rate established and maintained higher number of leaf area to capture solar energy and convert it in to carbohydrate in the presence of carbon dioxide and water at faster rate[29].

Grain yield: The statistical analysis of variance indicated that the main effect of seeding rate and inter-row spacing had highly significantly ($p<0.01$) different in grain yield. In addition, interaction effects of seeding rate and inter-row spacing showed significance variation ($p<0.05$) on grain yield (Table 5).

The highest grain yield (4.22 t ha^{-1}) was obtained at a seeding rate of 100 kg ha^{-1} and the lowest grain yield was 2.65 t ha^{-1} obtained from seeding rate of 140 kg ha^{-1}. The result of the current study indicated, as increasing seeding rate up to optimum level results increasing grain yield. The highest grain yield recorded from use of optimum seeding rate due to higher plant population in plots and increased number of effective tillers. The result of grain yield was highest at seeding rate of 100 kg ha^{-1} resulted maximizing grain yield by 50.71% over the lowest seeding rate of 40 kg ha^{-1}. In line with the present finding, Shunsuke *et al.*[30] showed that grain yield increases as plant density increases throughout the density range tested.

Table 6: Interaction effects of seeding rate and inter-row spacing on yield of upland rice during 2018 main cropping season at Libokemkem District

Seeding rate (kg ha^{-1})	Inter-row spacing (cm) 15	20	25	30
40	3.20^{c}	3.43^{b}	3.10^{d}	2.20^{d}
60	2.93^{b}	4.10^{c}	2.83^{e}	2.33^{d}
80	3.73^{d}	3.61^{d}	4.40^{b}	3.00^{b}
100	5.20^{a}	4.36^{a}	4.76^{a}	2.56^{a}
120	2.80^{b}	3.80^{b}	3.63^{c}	2.90^{b}
140	2.63^{e}	2.66^{e}	2.50^{f}	2.83^{b}
160	2.56^{f}	3.23^{d}	3.10^{d}	2.36^{d}
LSD (0.05)		1.03		
SE±		0.06		
CV (%)		18.78		

The columns and inter rows followed by the same letter(s) are non-significance difference at 5%

As regards to inter-row spacing, maximum grain yield (3.53 t ha^{-1}) was recorded at inter- row spacing of 20 cm and minimum grain yield (2.49 t ha^{-1}) was recorded at inter-row spacing of 30 cm. In line with this result, Kandil *et al.*[31] who reported to a wider inter-row spacing provides higher value of panicle weight; however, at closure inter-row spacing provides a higher number of effective tillers per unit area which results higher grain yield. The highest grain yield (5.20 t ha^{-1}) was obtained from interaction effects of seeding rate 100 kg ha^{-1} with 15 cm inter-row spacing. On the other hand, the lowest grain yield (2.20 t ha^{-1}) was obtained from the interaction effects of at a seeding rate of 40 kg ha^{-1} combine with 30 cm inter-row spacing (Table 6). This might be due to more number of effective tillers and highest numbers of filled grains per panicle were mainly responsible for the highest grain yield.

Straw yield: Straw yield was highly significantly ($p<0.01$) affected by the main effects of seeding rate. On the other hand, inter-row spacing and its interaction with seeding rate did not showed significance ($p>0.05$) effects on straw yield (Table 5).

Maximum straw yield (7.50 t ha^{-1}) was produced at seeding rate of 140 kg ha^{-1} while minimum straw yield (3.99 t ha^{-1}) was produced at seeding rate of 40 kg ha^{-1}. The highest straw yield was obtained plants which are grown from seeding rate of 140 kg ha^{-1}. The reason for higher straw yield with higher seeding rate which ensures more number of total tillers and produce high biomass product resulted in maximum straw yield over lower seeding rates. This result was in harmony with Sultana *et al.*[20] who revealed that as seeding rate increased straw yield was also increased due to higher number of total tillers.

Harvest index: The analysis of variance indicated that harvest index was highly significantly ($p<0.01$) affected by main effects of seeding rate and inter-row spacing.

The highest harvest index value (40.76%) was recorded at a seeding rate of 100 kg ha^{-1} and the lowest harvest index (26.36%) was recorded at a seeding rate of 140 kg ha^{-1} (Table 5). Further, seeding rate increased but harvest index was not increased. For this reason, proper sink formation and ripening are the most important physiological process that explains the improvement of harvest index[32]. The present result was similar with Harris and Vijayaragavan[27] who reported that the highest harvest index was recorded from at a lower seeding rate (61.5 kg ha^{-1}) while the lowest harvest index was obtained from at a higher seeding rate (205 kg ha^{-1}). Maximum harvest index (39.55%) was calculated at inter-row spacing of 20 cm while minimum harvest index (30.70%) was calculated at inter-row spacing of 30 cm (Table 5).The same result also reported that the highest harvest index was observed in 20 cm row inter-row spacing in rice crop[33]. In contrast to this result reported that harvest index was not affected by inter-row spacing[34].

Economic analysis: The costs depend on different seeding rate, manual labor cost for row making, drilling seed, harvesting, threshing, winnowing, transporting and material and packing incurred cost requirements. The grain and straw yield were adjusted downward by 10% to narrow the yield gap between experimental plots and farmer's field study. The gross benefits are calculated by using the current price of rice grain yield was Birr (Ethiopian currency) 13.50 kg^{-1} and straw yield Birr 1.20 kg^{-1} at local market in LiboKemkem District during the production season of January 2018. Based on partial budget analysis, the highest net benefit (Birr 58,704.32 ha^{-1}) was obtained at a seeding rate of 100 kg ha^{-1} combine with 15 cm inter-row spacing while the lowest net benefit (Birr 28,321.91 ha^{-1})was recorded at seeding rate 60 kg ha^{-1} combine with 30 cm inter-row spacing (Table 7).

Hence, to advise the present result for the producers, it is essential to estimate the minimum rate of return acceptable to producers in the recommendation domain. The minimum acceptable marginal rate of return (MRR) should be 100%[12]. Therefore, the highest MRR value 1569.8% was recorded from the use of 80 kg ha^{-1} seeding rate and 25 cm inter row spacing followed by 1221.9% and 898.9% which were obtained from seeding rate of 100 and 80 kg ha^{-1} with 25 and 30 cm inter-row spacing, respectively (Table 8). Therefore, the most attractive rate of return for small scale farmers in the study

Table 7: Partial budget analyses on seeding rate and inter-row spacing of upland rice

R (cm)	S (kg ha^{-1})	Adjusted GY (t ha^{-1})	Adjusted SY (t ha^{-1})	GR (birr ha^{-1})	TVC (birr ha^{-1})	NB (birr ha^{-1})
15	40	2.88	4.74	44568	11641.18	32926.82D
15	60	2.64	4.59	41148	12039.68	29108.32D
15	80	3.36	4.83	51156	12442.08	38713.92D
15	100	4.68	6.99	71568	12863.68	58704.32*
15	120	2.52	5.58	40716	13249.58	27466.42D
15	140	2.37	6.15	39375	13655.28	25719.72D
15	160	2.31	6.39	38853	14057.68	24795.32D
20	40	3.09	3.63	46071	8931.64	37139.36D
20	60	3.69	4.05	54675	9335.84	45339.16D
20	80	2.85	5.25	44775	9747.84	35027.16D
20	100	3.93	4.86	58887	10143.94	48743.06D
20	120	3.42	4.53	51606	10540.64	41065.36D
20	140	2.40	7.56	41472	10970.94	30501.06D
20	160	2.91	5.76	46197	11352.94	34844.06D
25	40	2.79	3.57	41949	7260.57	34688.43D
25	60	2.55	5.25	40725	7677.37	33047.63D
25	80	3.96	5.46	60012	8079.47	51932.53*
25	100	4.29	6.24	65403	8487.27	56915.73*
25	120	3.27	4.89	50013	8873.77	41139.23D
25	140	2.25	6.48	38151	9289.67	28861.33D
25	160	2.79	6.27	45189	9687.57	35501.43D
30	40	1.98	2.43	31341.4	6221.19	25120.24D
30	60	2.10	5.52	34974	6652.09	28321.91*
30	80	2.70	5.31	42822	7049.99	35772.01*
30	100	2.31	4.14	36153	7438.29	28714.71D
30	120	2.61	6.51	43047	7861.99	35185.01D
30	140	2.55	6.84	42633	8265.29	34367.71D
30	160	2.13	5.28	35091	8649.69	26441.31D

GY = Adjusted grain yield, SY = Adjusted straw yield, GR = Gross return, TVC = Total variable cost, NB = Net benefit. Cost of seed drilling and row making at Birr 50 man day; cost of NERICA-4 seed Birr 20 kg^{-1}, packing for Birr 25 p q^{-1}, transportation Birr 10 q^{-1} and packing Birr 10 q^{-1}

Table 8: Marginal rate of return analysis

R (cm)	S (kg ha^{-1})	TVC (birr ha^{-1})	NB (birr ha^{-1})	MRR (%)
30	60	6221.19	28321.91	-
30	80	7049.99	35772.01	898.9
25	80	8079.47	51932.53	1569.8
25	100	8487.27	56915.73	1221.9
15	100	12863.68	58704.32	40.8

TVC = Total Variable Cost, NB = Net Benefit, MRR = Marginal Rate of Return

area with higher net benefits was 100 kg ha^{-1} seeding rate combine with 25 cm inter-row spacing for the highest profitable (Birr 56,915.73 ha^{-1}). This is followed by 80 kg ha^{-1} seeding rate with 25 cm inter-row spacing with the second profitable (Birr 51,932.53 ha^{-1}).

CONCLUSIONS AND RECOMMENDATION

Site specific conclusion based on seeding rate and inter-row spacing is necessary to improve both grain and straw yield of upland rice. From the current finding, it was possible to conclude that both seeding rate and inter-row spacing can affect yield and yield component of upland rice. According to this study with seven seeding rates used, 100 kg ha^{-1} is better in most of agronomic characters for upland rice and given highest grain yield (4.22 t ha^{-1}) and has 37.2% yield advantage over the lowest grain yield (2.65 t ha^{-1}) obtained at a seeding rate of 140 kg ha^{-1}.

The optimum seeding rate has more advantages in yield and yield components of upland rice because optimum seeding rate ensures the plants to grow in aerial and underground parts through efficient utilization of water, nutrient and solar radiation. However, the highest plant populations with higher seeding rates are characterized by higher competition for sunlight, water and nutrient. Hence, the highest seeding rate was unprofitable and unacceptable. Even if, with the lowest seeding rates had not important for the increment of the yield of upland rice due to the insufficient tiller number resulted for lower number of effective tillers.

The results also indicated grain yield was increased at optimum inter-row spacing. Among inter-row spacing's 20 cm inter-row spacing produced higher grain yield (3.53 t ha^{-1}) as compared to 15, 25 and 30 cm spacing. In addition, the interaction effect of seeding rate and inter-row spacing indicated different responses on yield and yield components of upland rice. Therefore, the highest grain yield (5.20 t ha^{-1}) was obtained at a seeding rate of 100 kg ha^{-1} combine with 15 cm inter-row spacing while, the lowest grain yield (2.20 t ha^{-1}) was obtained at seeding rate of 40 kg ha^{-1} combine with 30 cm inter-row spacing. On the other hand, based on partial budget analysis the highest net benefit was recorded at 100 kg ha^{-1} seeding rate with 25 cm inter-row spacing (56,915.73 birr ha^{-1}). Therefore, using a seeding rate of 100 kg ha^{-1} combine with inter-row spacing of 25 cm can be recommended to obtain maximum rate of return for upland rice under the main rain fed condition.

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