Original Research Article

Effects of Inter-Row Spacing and Seed Rate on Yield and Yield Components of Irrigated Rice in the Somali Region

Abstract

A field experiment was conducted in 2019 at the Godey Research Center in eastern Ethiopia to evaluate the effects of seeding rate and inter-row spacing, as well as their interaction, on the performance of irrigated rice (Oryza sativa L.) in the Somali Region. The study employed a factorial arrangement in a randomized complete block design (RCBD) with three replications, using the rice variety 'Nerica-1'. Treatments included four inter-row spacings (10, 20, 25, and 30 cm) and four seeding rates (60, 80, 100, and 120 kg/ha). Results revealed that both seeding rate and row spacing significantly ($P < 0.05$ or $P < 0.01$) influenced most yield and agronomic parameters. Optimal effective tiller numbers were recorded at 60 kg/ha and 30 cm spacing, while the tallest plants (up to 82.32 cm) occurred at 120 kg ha^{-1}) *and 30 cm spacing. The longest panicle length (22.73 cm) was observed at 10 cm spacing, although the highest number of filled grains per panicle (45.28) and maximum thousand seed weight (30.73 g) were achieved with wider spacing (30 cm) and moderate seed rates. The highest straw yield (6172* kg ha^{-1}) *) was obtained at the highest seeding rate (120* kg ha^{-1}) *), while the maximum grain yield (3624* kg ha^{-1}) *) was recorded at 100* kg ha^{-1}) *with 30 cm spacing. These findings suggest that a seeding rate of 100* kg ha^{-1}) *combined with 30 cm inter-row spacing optimizes rice productivity under irrigated conditions in the Somali Region.*

Keywords: Rice, Seeding Rate, Inter-Row Spacing, Irrigated Agriculture, Nerica-1

Introduction

Rice (Oryza sativa L.) is an annual cereal crop and one of the most important staple foods for the global population (Zhao et al., 2011). Ethiopia, located in the tropical zone, has a wide range of altitudes and a diverse climate that is suitable for successfully cultivating various crops (Hagose and Zemedu, 2015). Rice production in Ethiopia began about three decades ago, and the country has considerable potential to grow different rice varieties (Mulugeta and Heluf, 2005). The productivity of rice increased significantly from 498,332 tons in 2009 to 3,958,323 tons in 2019 (CSA, 2019). During the same period, the area under rice cultivation expanded from 155,886 hectares to 773,504 hectares, showing a consistent upward trend in both area and production. Rice can be successfully cultivated in many parts of the country, with major rice-producing regions including Amhara, Benishangul-Gumuz, Tigray, Gambella, Oromia, and the Southern Nations, Nationalities, and Peoples' Region (Dawit, 2015).

In the Somali Region, rice is mainly cultivated under irrigation rather than through rain-fed agriculture. In 2019 alone, 31,807 hectares of land were cultivated with rice, producing 202,649 tons (MOARD, 2019). The region is characterized by fertile land highly suitable for rice production. However, rice remains a minor crop in terms of both area coverage and production, despite the region's vast land resources and favorable agroclimatic conditions, indicating significant potential for expansion.

Adopting appropriate agronomic practices is crucial for maximizing and sustaining upland rice yields (Jana, 2013). These practices, such as optimal seeding rates and inter-row spacing, influence crop performance and are dependent on environmental factors like moisture availability, soil nutrients, and temperature. Therefore, special attention must be given to increasing yield per unit area through improved agronomic management (Mankotia and Shekar, 2005). In light of this, it is essential to investigate the effects of seeding rate and inter-row spacing, and their interaction on the yield and yield components of rice under irrigated conditions in the Somali Region. Accordingly, this study was conducted to evaluate the effects of different inter-row spacing and seed rates on the yield and yield components of rice in the study area.

Materials and Methods

The experiment was conducted under irrigated conditions during the 2012/13 E.C. cropping season at four sites: Gode, Kelafo, Jarati, and Dolo Ado experimental fields. A factorial combination of four inter-row spacings (10, 20, 25, and 30 cm) and four seeding rates (60, 80, 100, and 120 kg/ha) was evaluated. Each experimental plot measured 3 meters in width and 5 meters in length. The number of planting rows per plot varied depending on the inter-row spacing: 30, 15, 12, and 10 rows for 10, 20, 25, and 30 cm spacing, respectively. For yield and agronomic data collection, the central rows were considered as net plot areas: 18, 13, 10, and 8 rows for the respective spacings, each with a row length of 4 meters. Plot-to-plot and replication-to-replication spacing was maintained at 0.5 meters and 1 meter, respectively. The experiment utilized the best-performing and recommended rice variety for irrigated conditions in the region. All relevant data were collected from the net plots and analyzed using analysis of variance (ANOVA) procedures in GenStat version 15.

Table 1. Combination of treatments

No.	**Row spacing**	**Seed rate(kg/ha)**	**Combination treatments**
1	10cm (30 rows)	60 kg	10cm (30 rows) x 60kg
2		80 kg	10cm (30 rows) x 80kg
3		100 kg	10cm (30 rows) x 100kg
4		120 kg	10cm (30 rows) x 120kg
5	20cm (15 row)	60 kg	20cm (15 row) x 60kg
6		80 kg	20cm (15 row) x 80kg
7		100 kg	20cm (15 row) x 100kg
8		120 kg	20cm (15 row) x 120kg
9	25cm (12 row)	60 kg	25cm (12 row) x 60kg
10		80 kg	25cm (12 row) x 80kg
11		100 kg	25cm (12 row) x 100kg
12		120 kg	25cm (12 row) x 120kg
13	30cm (10 rows)	60 kg	30cm (10 rows) x 60kg
14		80 kg	30cm (10 rows) x 80kg
15		100 kg	30cm (10 rows) x 100kg
16		120 kg	30cm (10 rows) x 120kg

Data Collection and Analysis

Data were collected from the net plot on the following agronomic parameters: plant height (cm), panicle length (cm), number of effective tillers per plant, number of filled grains per panicle, number of unfilled grains per panicle, thousand seed weight (g), grain yield (kg/ha), straw yield (kg ha^{-1}), and harvest index. The collected data were subjected to analysis of variance (ANOVA) using appropriate statistical software to determine the effects of inter-row spacing, seed rate, and their interaction. Mean separation was conducted using the Least Significant Difference (LSD) test at a 5% level of significance.

Results and Discussion

Number of Effective Tillers

The number of effective tillers per plant was highly significantly affected by seed rate and inter-row spacing ($p < 0.01$), but not by their interaction (Table 4). The highest number of effective tillers (12.00) was recorded at a seed rate of 60 kg/ ha, while the lowest (10.25) was observed at a seed rate of 120 kg/ ha. However, the differences among the higher seed rates were not statistically significant. This may be attributed to increased intra-specific competition at higher seeding rates, leading to reduced production of effective tillers due to limited availability of nutrients, water, and light.
Similarly, row spacing had a significant effect on effective tiller production. The highest number of effective tillers (12.37) was obtained at 30 cm spacing, whereas the lowest (10.11) was recorded at 10 cm spacing. Wider spacing likely promoted better tillering due to enhanced access to resources such as light, nutrients, and moisture. This result aligns with findings by Haque (2002), who reported increased tillering at wider spacings. Sewunet (2005) also observed that medium to wide row spacing outperformed narrow spacing in effective tiller production.

Plant Height (cm)

Plant height was significantly affected by both seed rate and inter-row spacing ($p < 0.01$), while their interaction was not significant (Table 4). The tallest plants (78.47 cm) were recorded at the highest seed

rate (120 kg/ha), while the shortest (69.98 cm) occurred at the lowest seed rate (60 kg/ha). The increased plant height at higher seed rates may be due to aerial competition for light, which promotes stem elongation. This observation is consistent with the findings of Ghansham and Surjit (2016), who noted increased rice plant height with rising seeding rates.
Regarding inter-row spacing, the tallest plants (82.32 cm) were recorded at 30 cm spacing, while the shortest (66.63 cm) were found at 20 cm spacing, which was statistically similar to 10 cm spacing. The increase in plant height with wider spacing may result from reduced competition for growth resources, allowing for better development. Similar trends were reported by Rahel and Fekadu (2016) in wheat.

Panicle Length (cm)

Panicle length was significantly ($p < 0.01$) affected by inter-row spacing but not by seed rate or their interaction (Table 4). The longest panicles (22.73 cm) were recorded at 10 cm spacing, while the shortest (20.26 cm) occurred at 30 cm spacing. The reduction in panicle length at wider spacing may be due to resource diversion toward tiller production rather than panicle elongation. Singh and Tripathi (2008) similarly reported that optimal inter-row spacing enhanced physiological processes that favor panicle development. Yoseph and Wedajo (2014) also found that seeding rate had no significant effect on panicle length.

Number of Filled Grains per Panicle

The number of filled grains per panicle was highly significantly affected by seed rate ($p < 0.01$) and significantly affected by inter-row spacing ($p < 0.05$), but their interaction was not significant (Table 4). The highest number of filled grains (38.59) was observed at 60 kg/ha, while the lowest (25.23) was found at 120 kg/ha. This trend could be due to increased competition at higher seed rates, leading to lower resource allocation for grain filling.
In terms of row spacing, the highest number of filled grains per panicle (45.28) was recorded at 30 cm spacing, and the lowest (22.08) at 10 cm spacing. Harris and Vijayaragavan (2015) reported similar results, indicating that wider spacing supports vigorous plant growth and results in more filled kernels per panicle.

Number of Unfilled Grains per Panicle

The number of unfilled grains per panicle was not significantly affected ($p > 0.05$) by either seed rate or inter-row spacing (Table 4). This finding contradicts the results of Melkie (2017), who reported a significant influence of both factors on the number of unfilled grains in rice.

Thousand Seed Weight (g)

Thousand seed weight was highly significantly affected ($p < 0.01$) by seed rate, inter-row spacing, and their interaction (Table 4). The highest thousand-seed weight (30.73 g) was recorded at a seed rate of 80 kg/ha with 30 cm spacing, whereas the lowest (17.53 g) occurred at 120 kg/ha and 10 cm spacing. The superior performance at lower density and wider spacing may be attributed to efficient utilization of nutrients, water, and light, resulting in better grain filling. At higher plant density, competition for resources increases, reducing photosynthesis and negatively affecting grain filling. This result is in agreement with the findings of Dereje (2016), who observed increased thousand-seed weight with wider row spacing, recording the highest weight at 30 cm and the lowest at 20 cm spacing.

Table 2. The combined interaction effect of seed rate and row spacing on thousand seed weight of rice.

	Row spacing (cm)			
Seed rate (kg/ha)	**10**	**20**	**25**	**30**
60	27.67^{cd}	30.27^{d}	19.90^{ab}	30.73^{d}
80	19.10^{ab}	28.73^{cd}	22.73^{abc}	27.37^{cd}
100	25.37^{bcd}	22.73^{abc}	22.10^{abc}	27.67^{cd}

120	17.53^{a}	29.80^{d}	18.00^{a}	28.33^{cd}
LSD(P<0.05)	5.9			
CV%	4.2			

NS = non-significant, CV (%) = coefficient of variation in %, LSD = least significant difference at 5% level of significance, means in the column and followed by the same letters are not significantly different at 5% level of significance according to the LSD test.

Straw Yield (kg ha^{-1})

Straw yield was highly significantly (P<0.01) affected by seed rate, but not by inter-row spacing or its interaction with seed rate (P>0.05) (Table 4). The maximum straw yield (6172 kg ha^{-1}) was obtained at a seeding rate of 120 kg ha^{-1}, and the minimum (3694 kg ha^{-1}) at 60 kg ha^{-1}. The increase in straw yield with higher seeding rates could be attributed to a greater number of tillers and overall biomass. This result aligns with the findings of Sultana et al. (2012), who observed increased straw yield with higher seed rates due to increased tiller production.

Grain Yield (kg ha^{-1})

Grain yield was highly significantly (P<0.01) affected by seed rate, inter-row spacing, and their interaction (Table 3). The highest grain yield (3624 kg ha^{-1}) was obtained at a seed rate of 100 kg ha^{-1} and 30 cm spacing, whereas the lowest (2630 kg ha^{-1}) was recorded at 120 kg ha^{-1} and 10 cm spacing. Increasing seed rate up to an optimal level contributed to higher plant populations and more filled grains per panicle. Shunsuke et al. (2017) similarly found that grain yield increased with plant density within a certain range. Moreover, wider spacing allowed for a greater number of effective tillers per unit area, contributing to higher yields. This observation concurs with Kandil et al. (2010), who reported that wider inter-row spacing enhances tillering and grain production.

Harvest Index (%)

The harvest index was not significantly (P>0.05) affected by seed rate, inter-row spacing, or their interaction (Table 4). This is consistent with the findings of Hardev (2014), who also reported that harvest index in rice was not significantly influenced by these factors.

Table 3. The combined interaction effect of seed rate and row spacing on grain yield(kg/ha) of rice.

	Row spacing (cm)			
Seed rate (kg/ha)	**10**	**20**	**25**	**30**
60	2917^{b-g}	2697^{ab}	3079^{fg}	2830^{a-e}
80	2718 ^{ab}	2714 ^{ab}	2767^{abc}	3103^{g}
100	3000^{c-g}	2695 ^{ab}	2860^{a-f}	3624^{h}
120	2630^{a}	2790^{a-d}	3029^{efg}	3013^{d-g}
LSD(P<0.05)	208.1			
CV%	8.4			

NS = non-significant, CV (%) = coefficient of variation in %, LSD = least significant difference at 5% level of significance, means in the column and followed by the same letters are not significantly different at 5% level of significance according to the LSD test.

Table 4. Yield and yield components as affected by seed rate and inter-row spacing on rice.

Treatments	NET	PH(cm)	PL(cm)	NFGPP	NUGPP	SY(kg/ha)	HI%
Seed rate(kg/ha)							
60	12.55^{b}	69.98^{a}	20.43^{a}	38.59^{b}	6.467^{a}	3694^{a}	78.71^{a}
80	10.83^{a}	73.47^{ab}	20.98^{a}	26.82^{ab}	5.192^{a}	4019^{ab}	70.61^{a}

100	10.55^{a}	75.17^{ab}	19.89^{a}	26.28^{ab}	5.233^{a}	4396^{b}	70.93^{a}
120	10.25^{a}	78.47^{b}	20.63^{a}	25.23^{a}	5.300^{a}	6172^{c}	67.55^{a}
LSD(P<0.05)	1.14	6.3	NS	21.5	NS	470.9	NS
Inter-row spacing(cm)							
10	10.11^{a}	71.38^{ab}	22.73^{c}	22.08^{a}	5.133^{a}	4653^{a}	64.63^{a}
20	10.5^{a}	66.63^{a}	21.50^{b}	24.65^{ab}	5.942^{a}	4710^{a}	59.70^{a}
25	10.76^{a}	76.75^{bc}	20.44^{ab}	24.92^{ab}	5.267^{a}	4405^{a}	71.75^{a}
30	12.37^{b}	82.32^{c}	20.26^{a}	45.28^{b}	5.850^{a}	4512^{a}	71.71^{a}
LSD(P<0.05)	1.13	6.3	4.19	22.3	NS	NS	NS
Cv(%)	12.4	10.4	5.2	15.5	16	12.4	6.3

NS = non-significant, CV (%) = coefficient of variation in %, LSD = least significant difference at 5% level of significance, means in the column and followed by the same letters are not significantly different at 5% level of significance according to the LSD test.

Conclusion

The findings of the study revealed that the grain yield of upland rice was significantly influenced by both seed rate and inter-row spacing. Among the spacing treatments, 30 cm inter-row spacing consistently produced the highest grain yield compared to narrower spacings of 10, 20, and 25 cm. Furthermore, the interaction between seed rate and inter-row spacing showed varied effects on yield and yield components. The highest grain yield (3624 kg ha^{-1}) was achieved with a seed rate of 100 kg ha^{-1} combined with 30 cm inter-row spacing. In contrast, the lowest grain yield (2630 kg ha^{-1}) was recorded at a seed rate of 60 kg ha^{-1} with 10 cm inter-row spacing. This suggests that optimizing both seed rate and row spacing is crucial for maximizing rice productivity.

Recommendation

Based on the findings of this study, the following recommendations are made to optimize rice production in the study area:

- Use a seeding rate of 100 kg ha^{-1} to ensure optimal plant population and grain filling.
- Adopt an inter-row spacing of 30 cm, which consistently resulted in the highest grain yield.
- Avoid very narrow spacing (e.g., 10 cm), especially when combined with lower seeding rates, as it leads to lower yield performance.
- To achieve maximum grain yield and economic return, implement the combination of 100 kg ha^{-1} seeding rate with 30 cm inter-row spacing.
- Conduct further multi-location and multi-season trials to validate and fine-tune these findings for broader application across diverse rice-growing environments.

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