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Research Article

Optimum Seeding and Nitrogen Fertilizer Rates for Maximizing Yield and Sustaining Rain-Fed Lowland Rice (*Oryza Sativa* L.) in Fogera Plain North-western Ethiopia

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Abstract

Rice (*Oryza sativa* L.) is increasingly becoming an important food crop in Ethiopia. However, the average rice productivity in Ethiopia is estimated at 2.8 t ha^{-1} which is much lower than the world average, 4.6 t ha^{-1}. Its productivity is challenged due to a lack of appropriate and location-specific agronomic practices like the application of optimum doses of nitrogen fertilizer and the use of optimum seeding rates. Thus, a field experiment was conducted in Fogera district in South Gondar Zone, Northwestern Ethiopia during the 2021 main cropping season to determine the optimum dose of N level and seeding rate. The treatments comprised factorial combinations of four levels of N (134, 184, 234 and 284 kg ha^{-1}) and four different seeding rates (60, 80, 100, and 120 kg ha^{-1}). The experiment was laid out in a randomized complete block design and replicated thrice. All data on phenology, vegetative growth yield and yield-related parameters were collected and measured following scientific standards of each parameter. Those data were subjected to analysis of variance using the general linear model (GLM) procedures of SAS 9.0 version system. Economic analysis was also carried out by following CIMMYT partial budget analysis procedures. The analysis result showed the main effects of both, different levels of nitrogen and different rate of seeding, and their interactions showed highly significant effect on the number of both total and effective tillers, grain filling, panicle length, phonological parameters, totals spikelet's, thousands seed weight, grain yield, biological yield and straw yield. Application of 184 kg N ha^{-1} level with a seeding rate 100 kg ha^{-1} gave the maximum grain yield (6,641 kg ha^{-1}), the highest number of effective tillers per m^2 (792) and filled grains per panicle (95.34). Furthermore, the highest net return of ETB 118,850 with acceptable marginal rate of return (2,313%) was also obtained from the application of 184 kg N ha-^{1} level and a seeding rate 100 kg ha^{-1}. From the current research experiment, it is possible to conclude that increasing seeding rate beyond 100 kg ha^{-1} and N above 184 kg N ha^{-1} is not economical yield of rice *"Selam"* variety in the study area. Rather, use of 184 kg N ha^{-1} and seeding rate of 100 kg ha^{-1} is promising for Lowland Rice (*Selam*) variety production under the rain fed condition in Fogera Plains and similar agro-ecologies of rain-fed growing area of Ethiopia for better economic and agronomic advantage.

Keywords

Nitrogen Rate, Seed Rate, Lowland Rice, Economic Analysis

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1. Introduction

Rice (*Oryza sativa* L.) servesserves as the staple food for half populations of the world and more than 90% of rice is produced and consumed in Asia and provides about 700 calories per person of developing countries [1]. In Ethiopia, rice production was started four decades ago in the early 1970's and the country has a huge potential to grow rice crop in various ecosystems mainly in the rain fed lowland, upland and irrigated ecosystems [2]. Though rice is recently introduced to the country, its importance is well recognized and the production area coverage increased from 10,000 ha in 2006 to 57, 575 ha^{-1} in 2019 [3].

Rice is ecologically fit to grow in abandoned swampy areas and contributes on food security and economic advantage for the Ethiopian farming community. It is the best and cheapest alternative technology available to farmers for efficient utilization of natural resources, such as land and water, under swampy and flooded areas. Therefore, it plays an important role in reducing the problem of food insecurity of the farming community where water logging is considered as a challenge to grow other cereals [4].

Most of Ethiopia's rice production potential area lies in the western part of the country, (Dawit Alemu, 2015). The average rice productivity in Ethiopia is estimated at 2.8 t ha^{-1} (CSA, 2018), which is much lower than the World average, 4.6 t ha^{-1} [3]. The Amhara region takes the lion's share of producing the crop and accounted for 74-81% of the area coverage and 78-85% of the production in the years 2016-2018 [5].

Rice is increasingly becoming anessential food crop in Amhara region. However, its production and productivity is very low due to lack of appropriate technologies and location specific agronomic practices like application area specific optimum doses of nitrogen fertilizer and seeding rates. Rice production depends on several factors: climatic factors like rainfall and temperature, physical and chemical characteristics of the soil, agronomic practices like water management practices, planting date, selection of varieties, seed population, weed, and fertilization is the major once [6].

Appropriate and optimum fertilization is an important management practice to improve soil fertility, increase the rice production and productivity. The profitability of rice production system depends on solving of its constraints such as, improving soil fertility through the application of optimum rates, and using improved technologies like newly released, high yielding and adoptable verities [7].

Among all nutrients, nitrogen is the most essential for plant development, growth and grain quality. Because of the significance of nitrogen as a major nutrient for rice crop to attain high grain yield, it is crucial to determine the optimum amount of N application for each rice cultivars [8]. Varieties which produce higher number of effective tillers, spikelet, branches, panicle length, and thousand grain weights usually produce higher grain yield in rice [9]. Productivity of rice at Fogera district can be increased by improving the agronomic practices such as the use of proper seed and fertilizer rates; these factors can even make rice production to be sustainable in the area. Although some of rice management technologies have been developed in different parts of the country, most of the farmers around the study areas did not dare to use them in a proper way rather, they are using their own seeding and fertilizer rates; complaining with the higher fertilizer rates and lower seeding rates. Nitrogen as a major nutrient for rice crop to attain high grain yield, it is crucial to determine the required amount of nitrogen fertilizer application for each rice cultivars [10]. Before making recommendations for the nitrogen fertilizer dose for any crop, one should evaluate the efficiency and optimum rate for different application levels for better growth and yield performance of each released rice variety [11].

Hence, it is possible to detect that yield of rice is suffer from inappropriate dose of these two important inputs; most of the rice varieties are not in a way that it can express its genetic potential. As a result yield obtained from farmers field is lower than that of research centers. Hence, to achieve potential rice yield, introducing the new variety of rice *"Selam"* which is with good potential of adaptation, high yielder, moderate resistant to major rice disease, fair thresh-ability and shattering, very good lodging tolerance and white caryopsis and with higher biomass yield [10] is require. Nonetheless, as the variety is new for the area, it is not tested with different fertilizer and seeding rates. That, the objective of this experiment was to determine the optimum Seeding and Nfertilizer rates for higher yield and economic benefit and there by sustaining production of rain-fed Lowland Rice around Fogera Plain, Northwestern Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area

The field experiment was carried out in main rainy seasons of 2021/2022 in Fogera district, in the National Rice Research and Training Center experimental site. Fogera plain is found near to Woreta town in South Gondar Zone, Ethiopia. It is 60 km far from Bahir, Dar city to the routs of Gondar. Fogera Plain is an extended wetland area around Lake Tana, which is the largest lake in Ethiopia. (Figure 1)

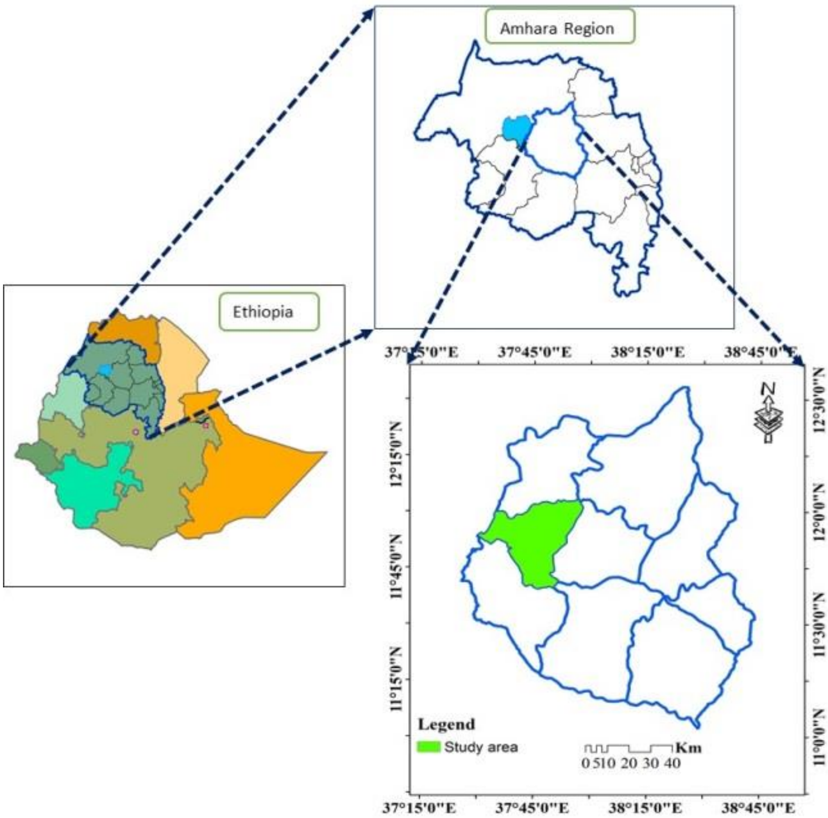

Figure 1. Map of the study area.

The experimental site is located between 11°49’55 N, latitude and 37° 37′ 40 E, longitude and with an altitude of 1395 meters above sea level. The main crops grown in the study area are rice, grass pea, maize, and teff and receives an averages mean annual rainfall, minimum and maximum temperature of 1316 mm, 12.75 ℃ and 27.37 ℃, respectively. In addition the long-term rainfall data (1986-2017) indicated that much of the rainfall appear in July and August.

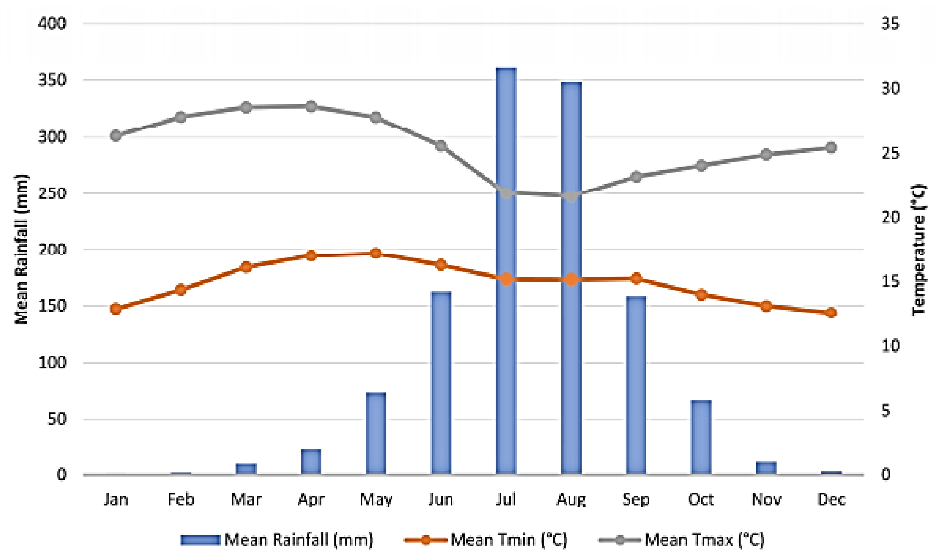

Figure 2. The rainfall and temperature condition of Fogera plain for the period 1981- 2017.

The characterize the soil of the experimental site, initially before planting, one composite soil samples (0–20 cm depth) was taken from six random spots across the experimental field using soil-sampling auger. The soil samples were collected, air-dried, grounded, sieved to pass through a 2 mm mesh, an composited into one.

Other soil physical and chemical properties were analyzed in soil laboratory section of Adet agricultural research center. Soil analysis was carried out from the composite sample in duplicates. The soil samples were analyzed for soil texture using Bouyoucos hydrometer method [12].

Total N content in the soil samples was determined titrimetrically following the Kjeldahl method as described by [13]. The pH of the soil was measured potentiometrically in the supernatant suspension of a 1:2.5 soil to water ratio using a pH meter as described by [14]. Organic carbon was determined using the wet digestion method [15] (Walkley and Black, 1934) and extractable P (available P) using the Bray II method [16].

The cation exchange capacity (CEC) of the soil was determined using the ammonium acetate method [17]. The electrical conductivity of the soil was measured by salinity electrical conductivity and total dissolved solids methods of soil analysis conductivity meter fromsaturation soil paste extracts as described by the study of Rhoades et al. [18]. The pre-plant soil (0–20 cm depth) analysis results showed that the top part of the experimental surface soil had 19% sand, 15% silt, and 68% clay. This implies that the textural class of the soil belongs to heavy clay texture.

The analysis result indicated that the total nitrogen (N) (0.21%) and available phosphorus (P) (9.85 mg/kg) of the soil were in the medium ratings. Similarly, organic carbon content (2.20%) follows the same pattern as total N and available P. Experimental site soil had a slightly acidic pH reaction, which ranges between 5.87-6.63, which is slightly acidic. The surface soil had high cation exchange capacity (57 meq /100 g of soil), and the higher cation exchange capacity (CEC) of the soil in this experimental site was due to high clay content and relatively better organic carbon percentage.

Table 1. *Physical and chemical properties the soil of experimental field before planting*.

Soil Depth (0-20cm)	Particle size %			Rating	Methods	Reference
	Sand	Silt	Clay			
	19	15	69	Heavy Clay	Bouyoucos hydrometer	[19]
PH 1:25 (H_2O)	5.62			Slightly Acidic	PH Meter	[20].
O.C (%)	2.2			Medium	(Walkley Black)	[15]
O.M (%)	2.61			Medium	(Walkley- Black)	[15]
TN (%)	0.21			Medium	Macro- Kjeldahl	[21]
Av.P.(ppm)	9.85			Medium	Bray No.1	[16]
EC (ds/m)	0.05			Low	Electromagnetic induction	[18]
CECCmolg	57			High	Ammonium acetate	[22]

Where: O.C =organic carbon, OM= organic carbon= TN, total nitrogen= Av.P available phosphorus = EC. Electrical conductivity and CEC = cation exchange capacity

2.2. Planting Materials and Fertilizer Sources

Selam, the newly released lowland rice variety in 2020 by EARI Ethiopian Agricultural Research Institute, was used for this study. This new variety (*Selam*) was released due to its high yield potential, moderate resistant to major rice disease; fair thresh ability and resistant to shattering; very good lodging tolerance and white caryopsis color. This variety is suitable for an altitude range (from 1350-1810) m.a.s.l and annual rainfall ranging between 1296-1561mm. It attained physiological maturity in 132days. Moreover, this variety I recommended for Fogera, Shire-Maitsebri, Gondar/Dembia, Jima, (Abebaw Dessie *et al*., 2020). Urea (46% N) as source of N and NPS (19, 38, and 7%) as a source of P_2O_5 were used in this study.

2.3. Experimental Treatments, Design, and Procedures

The experimental treatments included factorial combinations of four nitrogen rates (134, 184, 234 and 284 kg ha^{-1}) and four seed rate levels (60, 80, 100, and 120 kg ha^{-1}) in randomized complete block design (RCBD) with three replications. The experiment was laid in a factorial arrangement with three replications. By the specifications of the design, each treatment was assigned randomly to experimental units within a block. Each replication was accommodating 16 treatments, which resulted in 48 experimental plots each plot have 15 rows. The new variety (*Selam*) rice was planted at inter-row spacing of 20 cm drill row planted at a required seeding rate based on four levels. The gross plot size comprises 3 m length and 2 m width and the net plot size was 1.5 m x 2.2m (11 central rows of 2.2 m) leaving the two outer most rows on both sides of each plot and 0.25 m row length at both ends of each plot to excluded as border effects. Spacing between blocks, plots and rows was 1.5 m and 0.5 m and 0.2 m, respectively.

The time of nitrogen, application was done by split ½ at planting and 1/3 at tillering and all NPS fertilizer was applied during planting time at rate of 46 kg ha^{-1} P_2O_5 [3].

The land was ploughed one time by tractor and two times by oxen, starting from the first, mid. and last week of May and then leveled uniformly before planting. The rice was planted on second week of June, in 2021 cropping season. Nitrogen fertilizer and seeding rates were sown by based on each treatment by drilling in the rows uniformly and covered with soil manually. Then, after emergence, bunds were made for each plot. All other necessary field management practices other than the treatments were carried out equally on all experimental units.

2.4. Data Collection and Measurement

All phenological, growth and yield and yield related traits were measured accordingly within a required time. All data were collected on both plant and plot bases. Harvesting was done manually using sickle and the harvested crop of each plot was collected in sack separately and tagged properly. Harvested samples were sun dried for two week to measure the above ground biomass. Threshing, winnowing, and cleaning were done manually. Sampling, harvesting, data collection, and recording for each phenology, growth and yield and yield components are described as follows:

Days to 50% heading was determined by counting the number of days from planting to 50% of plants reach fully visible panicles on the plot.

Days to 90%, physiological 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 90% plants ready to harvest. Plant height (c.m): was measured as the height from the soil surface to the top of the panicle. It was recorded as the average of ten randomly selected main tillers from each plot at physiological maturity. Panicle length (c.m): was measured from the node where the first panicle branch starts to the tip of the panicle as the average of ten randomly taken panicles at harvesting.

Number of effective tillers per meter square: It was taken from the middle rows on $1m^2$ by $1m^2$ lengths wooden meter at physiological maturity. The number of all effective tillers were counted and recorded. A number of total tillers per meter square: It was taken from the middle rows on $1m^2$ by $1m^2$ lengths at physiological maturity stage by using wooden meter. The number of all emerged tillers were counted and recorded. A number of filled grains per panicle: the number of grain was determined by counting only filled grain from ten randomly selected sample plants checking by using fingers.

A number of unfilled grains per panicle: the number of grain was determined by counting only unfilled grain from ten randomly selected sample plants checking by using fingers and average. Total fresh above ground biomass (t ha^{-1}): It was measured by weighing of the total above ground (straw plus grain) from the net plot. It was taken at harvest. Above ground dry biomass (t ha^{-1}): Total above ground dry biomass or biological yield was measured by weighing the sun-dried total above ground plant biomass (straw plus grain) of the net plot area. The plants were harvested manually from the ground surface just above the soil and sun-dried for a week until constant weight reached. Then, aboveground dry biomass was measured by weighing the total harvested material, consisting of both grain and straw. The aboveground dry biomass yield obtained from the sample was converted to yield per hectare using the following formula: DBM (t ha^{-1}) = ABM (t ha^{-1}) * 10000 (m^{-2}) ha (m^{-2}), where; ABM-Above ground biomass Ha-Harvest area.

Grain yield (t ha^{-1}): The grain yield was measured by taking the weight of the grains from the net plot area and converted to ton or kg ha^{-1} at 14% moisture content. The weight of grain from each net plot was recorded. The data on grain yield in each experimental unit was determined by weighing using sensitive balance after sun drying, threshing, and cleaning of grains. The moisture percentage of grains of each net plot was determined by moisture meter and final grain yield was adjusted at 14% moisture. The moisture correction factor was obtained by the following formula: Mcf = 100-Y/100- X Where; Mcf - Moisture correction factor X- Standard moisture content for cereal crops, i.e., 14%. Y- Actual moisture content measured by moisture tester instrument. Therefore, according to the standard moisture content, 14% adjusted grain yield was calculated using the following equation: Agy = Mcf *Gy Where: Mcf-Moisture correction factor (decimal) Agy-Adjusted grain yield Gy-Grain yield obtained from each sample area in the sun-dried condition Finally, the grain yield obtained from the sample area was converted to per ha using the following formula: Grain yield K. g or ton per plot) = * 10,000 over sample plot area.

Thousand-grain weight (TGW): The thousand grains weight was expressed in gram (gm). It was recorded in gram of 1000 seeds weight with by seed counter and sensitive balance that was taken from bulked grains of each plot and adjusted to 14% seed moisture. Straw yield per ha (SY) (t): Straw yield of each net plot was calculated by subtracting the grain yield from the total above ground dry biomass.

Harvest index (HI): It was calculated as the ratio of grain yield obtained from each plot to the total above ground dry biomass (grain plus straw) *100 per ha expressed in percent. Air-drying was made by keeping the harvest in the sun and finally yields until it measures a constant weight on the plot and ha bases were determined. It indicates the efficiency of plant to assimilate partition to the economic parts (example: rice grain).

Lodging index (%): Record it at maturity by using quadrant of 50cm by 50cm for sampling at 3 places of the net plot and estimate visually portion of the plot with lodged down straw (broken or leaning more than 45 degree from the perpendicular at the base of the plant) by use 1-5 scales. This is done where the scale indicates that 1 (10-15%) no lodging effect, 2 (15-30%) 25% lodging, 3 (35-45%) 50% lodging, 4 (45-60%) 75% lodging and 5 (60-90%) 100% lodging.

2.5. Data Analyses

All collected data were subjected to analysis of variance using the general linear model (GLM) procedures of the SAS 9.0 version system (SAS, 2003). Upon obtaining significance difference between treatments, mean separation was computed using Least Significance Difference (LSD) test at <5% and or <1% of probability depending on the ANOVA result. Cost-benefit analysis of the treatments was carried out by following CIMMYT [Center for Improvement of Maize and Wheat] (1988) procedures by taking all variable costs the total variable costs of urea, improved seed and labor cost were calculated based on the current price of the locality during the planting time. Hence, the price of urea was (Birr 15 kg^{-1}), the price of improved seed was (Birr 29 kg^{-1}) and the average labor cost for urea application was estimated 100 Ethiopian Birr man per day.

3. Results and Discussion

Days to 50 % Heading

As the data depicted in (Table 2), the analysis of variance showed that days to 50 % heading of rice was highly significantly (P <0.01) influenced by their interaction among the factors of the combinations treatments studied in this experiment the longest days to 50% heading (118) was recorded when 60 kg ha^{-1} rice seeding rate was planted with 284 kg ha^{-1} N fertilizer, while the shortest days to 50% heading (90) was recorded when 120 kg ha^{-} rice seeding rate was planted with 134 kg ha^{-1}n fertilizer (Table 2).

This result agreed with Anil (2013) reported that abundant supply of nitrogen and low plant population delays 50% days to heading by promoting the vigorous vegetative growth of the plant. Similarly, [23] noted that days to 50 % heading of crop was hastened under lower N rates and higher seeding density compared to the higher N rates and low plant population. This might be due to of the fact that high N supply increases the number and size of meristematic cells, which leads to the formation of new shoots and promotes vigorous vegetative growth and development of the plants that might delay heading.

Similar with the present finding different authors indicated that increasing planting density hastened 50 % heading, example stated that higher plant density has hastened early heading in rice population. [24] stated that significance variation was observed between seeding rates in terms of days to 50% heading earlier at a seeding rate of 100 and 120 kg ha^{-1} than 60 kg ha^{-1}. Furthermore, [25] also noted that over increasing of plant population beyond the optimum density results unnecessary stress on the plants and then affects optimum tiller formation, sunlight interception, nutrient uptake, rate of photosynthesis and other physiological phenomena and ultimately affects the growth and development of the rice plant.

Days to 90 % Physiological Maturity

The analysis of variance showed that days to 90% physiological maturity of rice was highly significantly (P<0.01) influenced by the main effect of different nitrogen level and seeding rates as well as by interaction of both factors. (Table 2). The longest days to 90%, physiological maturity (174 days) was recorded under treatment combinations 284 kg ha^{-1} nitrogen and 60 kg ha^{-1} seed rate while, the shortest days to 90% physiological maturity (124 days) was recoded treatment combinations of nitrogen rate 134 kg ha-1with 120 kgha-1 seeding rate. Thus, increasing the rate of nitrogen from 134 to 60 kg seed rate ha^{-1} to 184 $kgha^{-1}$ nitrogen with 120 $kgha^{-1}$ seeding rate prolonged days to by about 50 days. This might be due to except beyond, increased nitrogen fertilizer and seed rate application accelerated efficient uptake of nutrients and water as well as vegetative (efficient photosynthesis) growth leads to delayed flowering and crop maturity. This result agreed with Weil (2002) who reported that N applied in excess than required delayed when nitrogen is applied in excess to rice, the sugar concentration in leaves reduces during early ripening stage and hence, inhibition occurs in the translocation of assimilated products to spikelet's.

Plant Height

The analysis of variance revealed that the main effect of different dose of nitrogen level and seeding rates as well as interaction of both factors rice was highly significantly (P<0.01) influenced plant height. (Table 2). The longest plant height (108.3 cm) was recorded under treatment combinations 284 kg ha^{-1} nitrogen and 60 kg ha^{-1} seed rate while, plant height (88.66cm) was recoded treatment combinations of nitrogen rate 134 kg ha-1with 120 kgha-1 seeding rate. This as mentioned above might be the role of nitrogen influences on cell division and cell elongation and thus increases plant height of the rice crop. This result is in line with [26] who reported that the highest nitrogen level and the lowest seeding population increased significantly the height of the rice crop and different nitrogen and seed levels significantly influenced the height of the rice plant. In line with the present findings, [27] had reported that different levels of N because significant difference in plant height the plant found to increase from 60 - 100 kg ha^{-1} seeding rates to 180 kg N ha^{-1}.

Panicle Length

The analysis of variance showed that panicle length was highly significantly (P<0.01) influenced by the main effect of nitrogen level and seeding rates and its interaction effect (Table 2). The longest panicle length (21 cm) was observed from 184 N ha^{-1} and 60 kg ha-^{1} seeding rate and 284 kg N ha^{-1} and 60 kg ha-1 seeding rates. While the shortest panicle length (13.8 cm) was recorded from 134 kg N ha^{-1} and 120 kg ha $^{-1}$ seeding rate. Further increasing the rate of nitrogen from 184 to 284 kg N ha^{-1} decrease panicle length this might be application of fertilizer and seed rates may have resulted in optimum levels of nutrients for crop uptake and translocation to sink there by expressing superior crop growth and development [28]. This might be due to more free space between plants at the lower seed rate and less intra plant competition for available resources that resulted in higher panicle length. This result is in line with the finding of [29] who reported that plant height and panicle length are negatively interrelated on wheat.

Table 2. *Interaction effects of different levels of N fertilizer and seeding rates on phonological and vegetative growth lowland ricein Fogera plain.*

Seed ratekg ha^{-1}	Natekg ha^{-1}	Days of 50% heading	Days to 50%Physiological Maturity	Panicle length (cm)	Plant height (cm)
60	134	96^{j}	135^{k}	15.86^{f}	89.6^{fe}
	184	102.6^{g}	144.6^{h}	21^{a}	98.46^{bdc}
	234	110^{d}	159^{d}	17.33^{e}	98.76^{bdc}
	284	118^{a}	174^{a}	21^{a}	108.3^{a}
80	134	94^{k}	131^{l}	15g^{h}	93.26f^{ed}
	184	102h^{g}	142^{i}	19^{c}	103.1^{ba}
	234	107^{e}	152^{f}	16^{f}	103.66^{ba}
	284	116^{b}	170^{b}	19.86^{b}	104b^{a}
100	134	93^{k}	129^{m}	14.5^{ih}	94.9^{fedc}
	184	101^{h}	140^{j}	19^{c}	103.4^{ba}
	234	106^{e}	152^{f}	15.5^{gf}	103.63^{ba}
	284	115^{cb}	168^{c}	19.93^{b}	107.33^{a}
120	134	90^{l}	124^{n}	13.8^{j}	88.66^{f}
	184	98.3^{i}	135^{k}	18^{d}	96.93^{bedc}
	234	104^{f}	148^{g}	14^{ij}	101.4^{ac}
	284	114.6^{c}	167^{c}	18^{d}	102.8^{ba}
LSD		0.636**	1.17**	0.63**	7.42 **
SE ±		0.58	0.49	0.14	19.8
Mean		104.2	148.3	17.5	99.6
CV%		0.73	0.47	2.17	4.45

Where, N: Nitrogen rate; LSD: least significant difference; means sharing the same superscript letter does not differ significantly at P = 0.05 according to the LSD test

Number of Effective Tillers

The analysis of variance showed that several effective tillers per m^{2} were highly significantly (P <0.01) influenced by the main effect of different nitrogen levels and seeding rates, it was also affected by the interaction of both factors (Table 4). Concerning the innitrogen applied at 184 kg N ha^{-1} and 100 kg ha^{-1} seeding rate followed by (736) tiller obtained from 234 kg N ha^{-1}and 100 kg ha^{-1} seed rate.

Whereas the minimum number of effective tillers was obtained (328) from the 134 N kg ha^{-1} and 60 kg ha^{-1} seed rate. This might be increasing in nitrogen application rates and seed also reflected significant increase in effective number of tillers. These results were also in accordance with the findings of [30] reported that increase in dry matter with successive nitrogen and seed levels might be due to the fact that increased nitrogen levels cause an increase in plant height, tiller number which subsequently increase dry matter production whereas seed rates increase plant population and number of tillers.

This result showed that increased number of productive tillers plant with at optimum N and seed density application. [31] reported that adequacy of nitrogen probably favored the cellular activities during panicles formation and optimum plant density increase dry matter by reducing completion of resources which led to increasing the number of effective tillers. According to [25] reported that over increasing of plant population beyond the optimum density results unnecessary stress on the plants and then affects tiller formation, sunlight interception, nutrient uptake, rate of photosynthesis and other physiological phenomena and ultimately affects the growth and development of rice plant. Similarly reported that optimum planting density per unit area ensures plants to grow properly both in the upper ground and underground parts of the plant through better utilization of solar radiation and nutrients. In contrast to this result, [32] reported excessive tillering caused by inadequate nitrogen fertilization reduced the percentage of fertile tiller, filled spikelet percentage and biomass.

Number of Total Tillers

The analysis of variance revealed that the combine main effect of different seeding rates and nitrogen level and there interaction were highly significantly affected (P<0.01) on the total tillers (Table 4). Higher number of total tillers per m^2 (808) was recorded in response to nitrogen applied at 184 kg N ha^{-1} and 100 kg ha^{-1} seed rate followed by (768) tiller obtained from 234 kg N $ha^{-1}$and 100 kg ha^{-1} seed rate. Whereas the minimum number of total tillers was obtained (368) from 134 kg N $ha^{-1}$and 60 kg ha^{-1}seed rate.

This might be increasing nitrogen application rates also reflected significant increase in e number of total tillers. [27] obtained the highest total tillers for N at 120 kg ha^{-1} while [30] gained the largest tillers number at 210 Kg ha^{-1} N. According to, [33] reported that fertile tillers of rice were increased significantly with increasing nitrogen levels from 0 to 220 kg N ha^{-1} plant with N application and the more densely the rice plants, fewer are the number of stems or tillers and productive tillers per hill but their number increases per unit area.

Similarly, [33] reported that adequacy of nitrogen probably favored the cellular activities during panicles formation and development which led to increasing the number of effective tillers per m^{-2}. This result was also in agreement with [34] reported the highest effective were recorded at medium spacing performed and at highest nitrogen fertilizer rate better as compared to lower spacing and lower N showed that under densely planting, the growth of each plant decreases and the size of the plants and productive tillers become smaller.

Number of Non-Effective Tillers

Analysis of variance results exhibited that number of non-effective tillers was highly significantly ($p < 0.01$) affected by both main effects and interaction effect. (Table 4). The maximum number of non-effective tillers number per m^2 (62.4) was recorded in response to nitrogen applied at 134 kg ha^{-1} and 120 kg seed rates ha^{-1}. Whereas the minimum number of effective tillers (18.64) was obtained from the 184 kg ha^{-1}N and 100 and kg seed rate ha^{-1}. This might be increasing in nitrogen application rates also reflected the significant increase in effective number of tillers. These results were also in line with the findings of [30] reported optimum number of tiller obtained from at optimum application of nitrogen and seeding rates.

Number of Filled Grain

The analysis of variance revealed that number of filled grain highly significantly (P<0.01) influenced by both main effect of different nitrogen and seeding rate as well as interaction effect of both factors. (Table 4) The maximum number of filled grains per panicle (95.34) was recorded at 184 kg N ha^{-1} and 100 kg ha^{-1} seeding rates. While, the small number of filled grains per panicle (82.93) was found at 134 kg N ha^{-1} and 120 kg ha^{-1} seeding rates. This is might be the sufficient supply of nitrogen and optimum seed rate might contribute to grain development, which probably increased the number of filled grains per panicle with increased nitrogen level up to optimum level but further increase in nitrogen rate decrease filled and increase spikelet sterility.

Many authors reported for the significant response of number of fertile spikelet's per panicle to nitrogen application and optimum seed rates increase number of filled grains confirming [28, 33].

Number of Unfilled Grain

The analysis of variance showed that a number of unfilled grain per panicle highly significantly (P<0.01) influence by the main effects of N fertilizer level application however, their interaction and main effect seed rate did not influenced this parameter (Table 4). Number of unfilled grains per panicle was a reversal to that of filled grains at variable nitrogen levels. Thus, highest number of unfilled grains per panicle was (15.3), (5.6), (8.3) and (11) at treatments 134, 184, 234 and 284 kg N ha^{-1}, respectively. This might be due excessive as well as the low application of nitrogen fertilizer application causes a lower number of filled grains and a higher number of unfilled grains per panicle of rice. [26] reported that optimum amount of nitrogen fertilizer with right time application on the other hand produces the maximum number of filled grains and a minimum number of unfilled grains per panicle. Reports from previous studies had shown that increased application of N enhanced vigorous vegetative growth resulting in reduced efficiency kernel filling because of increased competition of assimilates [35].

Total above ground biomass yield

Total above ground biomass yield represents the overall growth performance of plants as well as the grain. The analysis of variance showed that total above ground biomass yield (AGBY) was highly significantly (P<0.01) influenced by both the main effect of nitrogen and seeding rates as well as interaction effect of both factors (Table 4). The highest total above ground biomass yield (26.51 ton ha^{-1}) was obtained from in response to applying 284 kg N ha^{-1} and 120 kg ha^{-1} seed rate.

Whereas the lowest total above ground biomass yield, (9.12-ton ha^{-1}) was obtained from 134 kg ha^{-1} nitrogen and 60 kg seed rate ha^{-1}. Regarding to seed rate, the highest biomass yield (20.31-ton ha^{-1}) obtained with 100 kg ha^{-1} seed rate and the lowest (16.61 ton ha^{-1}). was from 60 kg ha^{-1} seed rate variation in biological yield might be due to variation in growth and yield attributing characters and biomasses yield increase with the increasing seed rate and nitrogen levels. The current result indicated that as seeding rate and nitrogen fertilizer increased optimally, dry biomass yield contributing factors also increased proportionally. This might be the reason that biomass yield increased significantly with the increase rate of nitrogen application.

Dry biomass yieldoptimum fertilizer 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 [36]. Production was increased with higher seeding rate and nitrogen level per unit area up to some extent and decrease thereafter reported similar results. Because optimum fertilizer 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 [37]. The present study in line with [38] treatments, drilling 100 kg ha^{-1} produced higher biomass yield than other treatments for lowland rain-fed rice for Fogera plain.

Number of Spikelet's

The analysis of variance revealed that number of spicklets per panicle highly significantly (P<0.01) influenced by the main effects of Nitrogen fertilizer level application however, their interaction and main effect seeding rate did not influenced this parameter. (Table 4). The maximum number of spicklet per panicle (114.87) was recorded in response to nitrogen applied at 284 kg N ha^{-1}. Whereas the minimum number of spicklets was obtained (89.13) from the 134 kg N ha^{-1}. The number of kernels per spike increases with nitrogen and this might be happened due to sufficient availability nitrogen that crops can uptake, assimilate and remobilize for the synthesis and development of spikelet during an thesis phase [39]. Similarly [40] also reported that number of spicklets per panicle was significantly increased with increasing nitrogen. This is in line with many authors who reported for the significant response of number of fertile spikelets per panicle to nitrogen application confirming the current observation [28, 33]. Furthermore [41] who observed maximum number of fertile spikelet's per panicles at N rates of 210-220 Kg ha^{-1}.

Thousand Grain Weight

The analysis of variance revealed thousand seed weight was highly significantly (P<0.01) influenced by both main effect of nitrogen and seeding rates as well as interaction effect of both factors. (Table 4). Thousand seed weight was highly significantly increased with increase in the rate of nitrogen application with optimum seed rate. Hence, the maximum thousand seed weight was (33.86 gm) obtained from plants supplied with 184 kg N ha^{-1}and 100 kg ha -^{1} seeding rate. Whereas the minimum thousand seed weight (26.22gm) was obtained from the 134 kg N ha^{-1} and 60 kg ha $^{-1}$ seeding rates). This might be application of nitrogen to optimum level increases thousand grain weight in rice crop because the proportion of filled spikelets at flowering is influenced by assimilate supply. This result harmony with [33].

Grain Yield

The analysis of variance showed that grain yield of rice was highly significantly (P<0.01) influenced by the main effect of nitrogen level and seed rate as well as by interaction of both factors (Table 4). Concerning the interaction the highest grain yield (6,640.1 kg ha^{-1}) was obtained from 180 kg N ha^{-1} and seed rate of 100 kg ha-^{1} followed by (6,613.57) kg ha^{-1} was obtained from234 kg N ha^{-1} and seed rate of 100 kg ha^{-1} which are statistically similar. Whereas, lower grain yield recorded (3.0 ton ha^{-1}) was obtained from seeding rare of 60 kg ha-^{1} and 134 kg N ha^{-1}.

This study in line with present finding [42] in his study on the influence of different rates of N- fertilizer and seeding rates around Fogera areas reported that application of nitrogen fertilizers at rates of 184 kg ha^{-1} and 100 kg ha^{-1} is the best recommended for rain-fed lowland rice production in Fogera plain and other similar agro-ecology. In contrast to this, [43] reported optimum fertilizer level69 kg ha^{-1} and140 kg ha $^{-1}$ seeding rates for X-Jigna and Gumara varieties.

On the other hand, the maximum grain yield of new variety *Selam* influenced by rates of N and seed was 6.641 ton ha^{-1} and its treatments gave this maximum yield (184 kg ha $^{-1}$ N and 100 kg ha^{-1} seed) these vary compared to the rice varieties cultivated in study area like X-jigna and Gumara on its maximum grain yield 4.78 and 4.65 ton ha $^{-1}$ and its recommended rates of 69 kg ha $^{-1}$ N and 140 kg ha $^{-1}$ seeding rates for two varieties.

In addition, plays an important role in achieving crops potential yield for rice production in Fogera Plain. The increase in grain yield of rice might be nitrogen application as mentioned by [33] might be due to the role of nitrogen in enhancing the dry matter production, improving rice growth rate, promoting elongation of inter nodes and activity of growth hormones like gibberellins.

Rice grain yield normally increased with increase in the level of nitrogen and seed rate however, further increase beyond the optimum requirement decline grain yield of rice. Similarly, [44] reported that nitrogen in combination with proper seeding densities play role for optimizing rice yields per unit area and rice seedling density per hill and optimal nitrogen fertilization exercises a strong influence on rice growth and grain yield due to competitive effects both on the vegetative and reproductive development. Highest grain yield was found in 100 kg seed ha^{-1} this might be due to increase in number of effective tillers with the increased in seed rate [45].

Table 3. Mean value of unfilled grain andtotal spikelet's of lowland rice as influenced by the main effects of Nitrogen level during 2021 growing season in Foegera plain.

N rate kg ha^{-1}	TSPP	UFGPP %
134	89.13^{d}	15.3^{a}
184	96.34^{c}	5.6^{c}
234	109.39^{b}	8.83^{b}
284	114.87^{a}	11^{a}
LSD	1.66***	1.08**
SE ±	3.98	1.7
CV%	1.94	12.62

Where, N = Nitrogen rate; UFGPP= unfilled grain per panicle, TSPP= total spikelet's per panicle means sharing the same superscript letter do not differ significantly at P = 0.05 according to the LSD test.

Table 4. Interaction effects of different levels of nitrogen and seeding rates on yield and yield components of lowland riceduring the 2021 in Fogera plain.

SRkg ha $^{-1}$	NRkg ha^{-1}	ET%	TT№	NET%	FGPP %	TSW (gram)	AGDBY ton ha^{-1}	GY ton ha $^{-1}$
60	134	328^{m}	368^{j}	40^{bc}	86.93^{f}	26.22^{g}	9.12^{f}	3.0^{k}
`	184	512^{ji}	555^{g}	43^{becd}	94.2^{ab}	28.82^{de}	14.27.^{d}	4.36^{i}
	234	560^{gf}	592^{fe}	32^{becd}	91.24^{b}	32.04^{b}	18.15^{cb}	5.007^{h}
	284	533.28^{ih}	568^{fg}	34.72^{bcd}	89.33^{bc}	29.67^{dc}	20.39^{b}	4.95^{h}
80	134	400^{l}	448^{i}	48^{ba}	83.51g^{f}	26.91^{fg}	10.79^{e}	3.63^{j}
	184	640de	658.64^{d}	18.64^{ed}	84.21^{d}	30.04^{c}	21.08^{b}	5.54^{g}
	234	653^{dc}	696^{c}	43^{bc}	91.32^{b}	32.40^{b}	22.06^{ab}	6.33^{cd}
	284	578.64^{f}	602.64^{e}	24^{ecd}	89.33^{bc}	29.97^{c}	22.91.^{a}	6.31^{ed}
100	134	496^{j}	544^{g}	48^{ba}	83.39^{g}	27.85^{fe}	11.91^{e}	3.73^{j}
	184	792^{a}	808^{a}	16^{e}	95.34^{a}	33.86^{a}	21.73^{b}	6.64^{a}
	234	736^{b}	768^{b}	32^{becd}	91.38^{b}	32.49^{b}	22.75^{ab}	6.61^{a}
	284	624^{e}	648^{d}	24^{ed}	89.1^{b}	29.87^{dc}	24.09^{a}	6.23^{e}
120	134	444.24^{k}	506.64^{h}	62.4^{a}	82.93^{h}	26^{g}	12.98^{fe}	3.66^{j}
	184	554.64^{gfh}	586.64^{fe}	32^{becd}	93.57^{ab}	29.12^{dc}	23.9a^{b}	5.98^{f}
	234	666.14^{c}	680.64^{c}	14.5^{ecd}	90.65^{c}	32.72^{b}	26.41^{a}	6.51^{b}
	284	538.64^{gih}	600^{e}	61.36^{a}	88.18^{c}	29.66^{dc}	26.51^{a}	6.42^{cb}
LSD		3.04**	3.63**	1.04*	1.04*	1.1**	0.86**	90.15**
SE ±		3.33	4.76	1.55	1.55	0.43	0.27	29.3.
Mean		5667	600	35.65	4.45	29.85	19.04	5.31
CV%		2.57	2.89	28.01	1.78	2.21.	6.21	1.01

Where, N = Nitrogen rate kg ha^{-1}; SD Kg ha^{-1}; Seed rate NET=Number of Non-effective tillers, NTT= Number of Total Tillers, FGPP= Fertile Grain per Panicle, NUGPP= TSLPP= Total Spikelet's Per panicle, TSW= Thousands Seed Weight, AGDBY= Aboveground Dry Biomass Yield GY=Grain yield.

Straw Yield

Analysis of variance revealed that straw yield was affected by the main effect of different nitrogen level and seeding rates as well as their interaction of both factors highly significant (P<0.01) influenced straw yield of rice (Table 5). The highest straw yield (20.09-ton ha^{-1}) was obtained in response to applying 284 kg N ha^{-1} and 120 kg seed ha^{-1}. Whereas the lowest straw yield, (6.12-ton ha^{-1}) was obtained from 134 kg N ha^{-1} and 60 kg ha^{-1}

seed. This might be due to the increasing N rate and plant population was reported to increase dry matter accumulation in rice by enhancing N uptake as well increasing dry matter is attributed to increase in the length of leaves, elongation of stem and panicles and decrease above and below ground resources competition. This result in line with the present study [46] reported that there was a linear increase in straw yield as the seeding rate was increased in Fogera plain.

Harvest Index

Analysis of variance revealed that main effect of nitrogen level application highly significant (P<0.01) influenced harvest index; however interaction of both factors and the main effect of seed rate did not influence this parameter. The Harvest index was highly significantly decreased with increase in the rate of nitrogen application. Hence, increasing the rate of nitrogen from 134 to 184, 234 and 284 kg N ha^{-1} significantly decreased harvest index from (32.62), to (29.54), (26.43), and (25.79)% respectively. The maximum harvest index (32.62%) was obtained from plants supplied with 134 kg N ha^{-1}. Whereas the minimum harvest index (25.79%) was obtained from 284 kg N ha^{-1}. The result of the study was in line with [46] indicated that N had a marked negative effect on harvest index of rice because growth promoted by N application resulted in low harvest index by favouring more dry matter accumulation in the vegetative part rather than in the rice grain.

Table 5. *Interaction effects of different levels of Nitrogen and seeding rates on straw yield of lowland rice during the 2021 main growing season in Fogera plain.*

SR	NR	SY ton ha^{-1}
60	134	6.12^{m}
`	184	9.91^{i}
	234	13.15^{h}
	284	15.44^{f}
80	134	7.16^{l}
	184	15.54^{f}
	234	16.27^{g}
	284	16.60^{d}
	134	8.18^{k}
100	184	15.09^{gf}
	234	16.14^{e}
	284	18.40^{b}
120	134	9.32^{j}
	184	17.92^{c}
	234	19.90^{e}
	284	20.09^{a}
LSD		0.3296**
SE ±		3.2916
Mean		13.97
CV%		1.42

Where, N = Nitrogen rate; STY=Straw yield, Means sharing the same superscript letter do not differ significantly at P = 0.05 according to the LSD test.

Lodging Index

Lodging index data were collect at maturity stage by using quadrant of 50 by 50 cm for sampling. In Addison to this to decided and calculate those use based on the scales of 1 to. The result of the present study indicated that which were found tilted from the normal upright position. For this reason, none of the plot was shown for lodging problem.

Table 6. *Mean square values of ANOVA for yield components of rice as influenced by seeding and nitrogen rates in Fogera plain, 2021.*

SOV	df	DH	DM	PH	PL
NR	3	1095.68^{**}	3558.187^{**}	418.653^{**}	83.162^{**}
SR	3	50.35^{**}	191.743^{**}	56.081^{ns}	16.754^{*}
NR*SR	9	1.59^{*}	3.020^{**}	12.56^{ns}	1.143^{**}
Error	30	0.581	0.498	19.828	0.145

SOV	Df	ET	NET	TT	FG
NR	3	2,153*	20.97*	1788**	1,761**
SR	3	991.5^{**}	9.8^{*}	918.9^{**}	210.54^{*}
NR*SR	9	89.6^{**}	3.29^{*}	86.0^{**}	56.2^{**}
Error	3	3.331	1.55	4.761	2.659

SOV	df	AGBY	SY	GY	TSW
NR	3	79.08^{**}	221056457.1^{**}	17615815.2^{*}	66.4^{**}
SR	3	6.326^{**}	51526245.7**	537895859^{**}	8.1^{*}
NR*SR	9	0.29^{ns}	4772653.1^{**}	287261.77^{**}	3.507^{**}
Error	30	0.271	38965.9	2923.29	0.43

DH: days to heading; DM: days to maturity, PH: plant height, PL: panicle length. ET: Effective Tiller; NET: Non effective tiller; TT: Total tiller per 5 meter row length; TSPP: total spikelet's per panicle; FG: Fertile grains. SY: Straw yield kg ha^{-1}; AGBY: biomass yield kg ha^{-1} TSW: 1000 seed weight, Grain Yield kg ha

Based on [47] partial budget analysis method, grain and straw yield adjustments, calculations of total variable costs (TVC), gross benefits (GB) and net benefits (NB) were performed Dominance analysis was carried after arranging the treatments in their order of TVC. Treatments was considered as dominated if it has higher TVC but lower NB than a previous treatment with lower TVC and higher NB (Table 7). No dominated treatments were taken out and marginal rate of return (MRR) was computed (Table 7). According to the [47] partial budget analysis methodology, treatments exhibiting the minimum or more MRR (>100%) will be considered for the comparison of their NB. Highest NB (Birr118, 850.5ha-^{1}) with acceptable level of MRR (2313%) was observed at100 kg ha-^{1}seeding rate and 184 kg ha^{-1} nitrogen combination (Table 7).

Table 7. *Dominance analysis of lowland rain fed rice as influenced by Nitrogen and seed rates in 2021/2022 main cropping season in Fogera plain.*

NR kgha^{-1}	SDkgha^{-1}	GB ETBha^{-1}	MP	LCFUA ETB ha^{-1}	CU ETB ha^{-1}	CSETBha^{-1}	TVCETB ha^{-1}	NBETB ha^{-1}	DA	MRR %
134	60	56,800	10	1,000	4150	1680	6,830	49,970	-	-
	80	69,330	12	1,2,00	4150	2240	7,590	61,740		1,549
	100	71,200	11	1,300	4150	2800	8,050	63,160		309
	120	71,080	10	1,000	4150	3360	8,110	62,970	D	
184	60	83,390	15	1,500	5700	1680	8,880	74,510		1,390
	80	108,600	17	1,700	5700	2240	9640	98,960		3,210
	100	129,350	20	2,000	5700	2800	10,500	118,850		2,313
	120	118,340	17	1,700	5700	3360	10,760	107,580	D	
234	60	97,330	21	2,100	7249	1680	11,029	86,301	D	
	80	120,950	22	2,200	7249	2240	11,689	109,261		3,479
	100	127,570	23	2,300	7249	2800	12,349	115,221		903
	120	125,460	23	2,300	7249	3360	12,909	112,551	D	
284	60	98,450	25	2,500	8797	1680	12,997	85,453	D	
	80	122,860	27	2,700	8797	2240	13,737	109,123		3,199
	100	123,150	30	3,000	8797	2800	14,597	108,553	D	
	120	127,710	30	3,000	8797	3360	15,057	112,653		891

Here: SR= Seed Rate kg/ha^{-1}, NR= Nitrogen rate kg ha^{-1}, GB= Gross Benefit= MP= Man Power, LCFUA= Labor Cost for Urea Application, CU= Cost of Urea, CS=Cost of Seed, TVS=Total Variable Cost, NB=Net Benefit, DA= Dominance Analysis and MRR= Marginal rate of revenue.

4. Conclusions and Recommendations

The national average yield of rice in Ethiopia is about 2.8 t ha^{-1}, which is lower compared to the world average productivity of 4.6 tons ha^{-1}. Soil nutrient deficiencies and optimum plant population are among the major causes of low rice productivity. Based on the results of the present study the highest grain yield and economic profitability of rice was obtained by the application of a nitrogen level of 184 kg ha^{-1} with a seed rate of 100 kg ha^{-1} giving the maximum grain yield of 6.641t ha^{-1} for *the Selam* variety, which can be recommended for rainfed lowland rice production in the study area. Future research works towards repeated over-season and across locations are recommended.

Abbreviations

ANOVA	Analysis of Variance
TVC	Total Variable Cost
NB	Net Benefit
MRR	Marginal Rate of Return

Conflicts of Interest

The authors declare no conflicts of interest.

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