Enhancement of rice (Oryza sativa L.) productivity through combined effects of seed and NP fertilizer rates in Fogera plain, northwestern Ethiopia

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Abstract

Rice (Oryza sativa L.) is a major cereal crop in Fogera plain. However, the yield of the crop is low due to the lack of different agronomic management. Among these, lack of site-specific seed rate and fertilizer levels are the major limiting factors. Hence, a field experiment was conducted in Fogera National Rice Research and Training Center in 2019 to study the effect of seed and NP fertilizers rates on rice in Fogera plain under rain-fed conditions. A factorial combination of three levels of seed rate (80,100, 120 kg ha^{-1}) and five levels of NP fertilizers (0/0, 138/23, 138/46, 207/23, and 207/46 N/P2O5 kg ha^{-1}) was laid out in Randomized Complete Block Design with three replications. The row planting method was used. Growth and yield data were collected and subjected to analysis of variance using SAS software. The grain yields and straw yields were further subjected to economic analysis. The main effect of seed rate affects significantly the number of total tillers, number of non-fertile tillers, number of fertile tillers, number of filled grains per panicle, number of unfilled grains per panicle, and above ground biomass yield, and harvest index. Regarding the interaction effect of seed and NP fertilizer rates, the number of total tillers, number of fertile tillers, and harvest index were significantly responding. Gain yields significantly responded to the main effects of fertilizer rates. The highest grain yield was obtained from a seed rate of 120 kg ha-1 and fertilizer rate of 207/46 NP2O5 kg ha^{-1}. The economic analysis also supported this result that the highest net benefits were obtained with the combination of seed rate 120 kg ha-1 and 207/46 kg N/P2O5 ha-1 with a net benefit of Birr 78931.15 ha^{-1} which can be recommended for the study area.

1. INTRODUCTION

Rice (*Oryza Sativa* L.) is an annual cereal crop, and it is the most important food for a large area of the world, especially in the Middle East, East and South Asia, Latin America and the India (Nguyen and Ferrero, 2006). It represents 29% of the total output of grain crops worldwide. In the world rice cultivation is estimated at 150 million hectare and the annual production averaging 500 million metric tons (Tsuboi, 2004). Rice represents 10% of the total land under cereal production and produces 15% of the total production of cereals (FAOSTAT, 2018). In Ethiopia, rice production was started three decades ago in the early 1970s and the country has reasonable potential to grow various rice types mainly in rain fed lowland, upland and irrigated ecosystems (Mulugeta Seyoum and Heluf Gebrekidan, 2014). Though rice is a recent introduction to the country, its importance is well recognized as the production area coverage of about 10,000 ha in 2006 has increased to over 63,000 ha in 2018 (CSA, 2018; CSA, 2019). In line with the area expansion, the production levels have been increasing consistently over years. CSA (2019) data indicate that rice production increased from 71,316.07 tons in 2008 to 171,854.1 tons in 2018. According to the report of MoARD (2010), the potential rice production area in Ethiopia is estimated to be over 5,590,895 ha. Though area coverage and rice production are increasing in Ethiopia, there are several agronomic constrains with this crop. Among the rice production constrains seed rate and fertilizer rates are the most important in the study area. Area specific recommendation of seed and fertilizer rates are vital for rice production in the study area. The addition of any amount of fertilizer is interesting to farmers if and only if it is profitable through the enhancement of either yield or quality (Alem Redda et al, 2018). However, maximum profits may not be at maximum rates and yields because the last increment of fertilizer to produce a little more yield may cost more than the yield increase is worth. Therefore, fertilizer needs to be rationally used and economically profitable because unwise application of fertilizers negatively affects the soil fertility, future crop productivity and farmers' economy (Lichtfouse, 2011).

Nitrogen and phosphorus are the major essential macro elements for rice production. High-yielding rice cultivars needs large amount of nitrogen to achieve acceptable grain yields in contemporary agriculture. The reasons in rice production are that crop rotations involving rice do not permit accumulation of soil nitrogen (Norman et al., 2003). Nitrogen is mostly needed during early and mid-tillering, panicle initiation, booting and ripening phases of grain development. Phosphorus is the other important nutrient which plays an important role in root growth; promote early flowering and ripening stage and resistance towards disease and drought conditions. Deficiency of phosphorus may delay the maturity period of rice plant and increase susceptibility to rice disease (Fageria, 2001). Other than the soil nutrients, plant population is an important factor to be considered. When plant density exceeds optimum levels, competition among plants for resources becomes severe; plant growth slows down and grain yields decrease. Plant canopy structure influences the utilization of solar radiation (Fogl and Moudrý, 2016). However, unnecessarily low plant density may limit the yield potential. Determining optimum plant density that provides maximum yields is important.

Fogera is major rice producing area; however, many agronomic practices are limiting factors to increase rice production and productivity. In the study area among the factors lack site-specifics seed rate recommendation and inappropriate fertilizer application are the major limiting factors. The recommended NP fertilizer and seed rates in Fogera National Rice Research and Training Center (FNRRTC) are 69/23 N/P_2O_5 kg ha^{-1} and 100 kg ha^{-1} respectively (Tilahun Tadesse *et al*., 2007). However, the recommendations seem to be inappropriate as the varieties to be produced are being changed and the recommendations produced not much productive. Due to this, further evaluation, and determination of optimum rate of seed and fertilizer rate for lowland rice production is needed. Improving these agronomic practices is believed to enable resource poor farmers to increase production of rice in the area. The present research is intended to increase production and productivity of lowland rice by developing optimum seed and NP fertilizer rate combination in Fogera plain.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The field experiment was conducted in Fogera plain during the main rainy season (July to November) of 2019 to develop appropriate recommendation of seed and NP fertilizers rates to lowland rice. The experimental location (Fogera plain) is located near Woreta town, and it is situated at 11°53'29"N to 11°57'24"N latitude and 37°39'26"E to 37°45'38"E longitude at an altitude of 1815 meters above sea level (m.a.s.l). (Fig. 1). The dominant soil type is black clay soil (ferric Vertisols) (Tilahun Gebey et al., 2012). The experimental soil is clayey in texture with a pH of 5.08. The area is usually flooded for most of the time during the cropping season. During the season when the experiment was conducted, the depth of water above the surface of the soil at the site between July and October was ranged from 5–10 cm. The ecology and type of rice cultivation practiced is categorized as rain fed lowland rice culture. The mean annual rainfall of the area is 1216mm. The average yearly minimum and maximum temperatures are 13.43 and 28.4°C, respectively (National Meteorological Services Agency, 2019).

2.2 Experimental Materials, Treatments, Design, and Procedures

The variety namely, "*Shaga*" was used for the study based on its yielding potential in the study area. It was released in 2017 by Fogera National Rice Research and Training Center. DAP and urea fertilizers were applied to the rice field. The treatments considered in the field experiment consists of five levels of N/P_2O_5 (0/0, 138/23, 138/46, 207/23 and 207/46 kg/ha) and three levels of seed rate (80,100, 120 kg/ha). The source of nitrogen was urea, $CO(NH_2)_2$; and the source of phosphorus was DAP, ($2NH_2PO_4$).

The experiment was conducted using a factorial experiment laid out in a randomized complete block design with three replications and a total of 15 treatments. The field was oxen plowed three times before laying the experimental plots on the field. A 2m × 3m (6 m^2) of gross plot size and 1.2m×2m (2.4m^2) of net plot size was used as an experimental unit. The blocks were separated by 1m whereas the plots were separated by 0.5 m. Soil bunds was constructed around each plot and around the entire experimental field to minimize nutrient and water movement from plot to plot. Planting was made on 5 July 2019 by hand drilling. The row spacing for all plots was 20 cm and there are 10 rows in each plot. Nitrogen was applied in two splits, i.e., the first one-third as basal at planting and the second two-third top dressed at maximum tillering. Unlike nitrogen, the total dose of phosphorus was applied basal at planting. Due to the frequent prevalence of vigorous growth and high infestation of weeds, the field was weeded four times at 20, 40, 60, and 90 days after sowing.

2.3 Soil Sampling and Analysis

Pre-planting soil samples was randomly collected from twenty spots diagonally from a depth of 0–30 cm. The samples were composited, bagged, labeled and about one kg of the sample was given to Soil Laboratory at Amhara Design office for determination of selected physio-chemical properties of the soil. The texture of the soil was determined using Bouyoucos hydrometer method and pH at 1:2.5 soils to water ratio was determined using a glass electrode attached to pH digital meter. Soil organic carbon was determine using wet digestion method and total nitrogen was determined using method (Jackson, 2005). as described by Jackson. For determination of available phosphorus, the method was used and Electrical conductivity was measured.

2.4 Data collection and analysis

All data collected from the net plot size were subjected to analysis of variance (ANOVA) following a procedure appropriate to RCBD factorial experiment (Gomez and Gomez, 1984). The grain yield was further subjected to partial budget analysis following the CIMMYT methodology (CIMMYT, 1988).

Data on days to heading, days to physiological maturity, panicle length, plant height, number of total tillers per meter square, fertile tiller per meter square, non-fertile tiller per meter square, filled grain per panicle, above ground dry biomass yield and grain yield were measured and collected from the net plot area. To measure LAI, field photograph pictures were taken using digital camera at flower initiation of rice. The pictures were then imported immediately to the computer for analysis of LAI by using LAI calculator called Hemisphere software (Thimonier et al., 2010). Grain yield was adjusted to 14% moisture content. Harvest index was calculated as the ratio of grain yield obtained from harvestable row per hectare to the total above ground dry biomass yield per hectare expressed in percent. Analysis of variance was performed using the GLM procedure of SAS Statistical Software Version 9.2 (SAS, 2002). Effects were considered significant in all statistical calculations if the P-values were < 0.05. Means was separated using Fisher's Least Significant Difference (LSD) test using the GLM procedure of SAS (Gomez and Gomez, 1984).

2.5 Economic Analysis (Partial Budget)

The partial budget analysis was done as described by CIMMYT (1988) where the variable cost that vary included the cost of inputs (seed and NP fertilizer) as well as the cost involved in their application. The grain and straw yields were further subjected to partial budget analysis following CIMMYT (1988). The price of rice grain yield was Birr 11kg^{-1} and straw yield price was Birr 120 quintal^{-1} at Fogera in January and February 2020 used for economic analysis. Net benefit was calculated as the amount of money left when the total variable costs for inputs (TVC) are deducted from the gross benefit (GB), i.e. NB = GB – TVC. MRR was calculated as the ratio of change in return of the average of each replicated treatment to the change in total cost with regard to the control. It compares the increments in costs and benefits between pairs of treatments as:

$$MRR\% = \left(\frac{ChangeinNB}{ChangeinTVC}\right)100$$

Identification of a candidate recommendation from among the non-dominated treatments: This is the treatment which gives the highest net benefit and a marginal rate of return more than the minimum considered acceptable to farmers (100%).

3. RESULTS AND DISCUSSION

3.1 Soil Physico-Chemical Properties of the Experimental Site

The pre sowing soil analysis results showed that the soil was clay in texture class with a particle size of 54% clay (Table 1). The soil pH was 5.08 (Table 1). According to Tekalign Tadese (1991) classification, the soil was moderately acidic. Depending on Defoer et al. (2000) and Tekalign Tadese (1991) classifications organic carbon and total nitrogen content of the soil were low. As Jones (2003) limited suggestion, the Phosphorus content of the soil was low.

Table 1
Major physical and chemical properties of surface soil samples from the research site

Soil properties	Values	Rank	Reference
Physical analysis			
Sand%	18		
silt%	28		
clay%	54		
Texture class	Clay		FAO (2013)
Chemical analysis			
pH	5.08	Moderately acidic	TekalignTadese (1991)
Electrical conductivity (ds/m)	0.112	Medium	TekalignTadese (1991)
Organic carbon %	0.78	Moderate	Defoeret al. (2000).
Total nitrogen (%)	0.12	Low	Bashour (2007).
Available P (mg/kg)	7.2	Moderate	Jones (2003)

3.2 Plant Phenology

- **Days to 50% heading**

Analysis of variance showed 50% heading was highly significant (*$P < 0.01$*) at the main effect of NP fertilizer rates. However, the main effect of seed rate and the interaction of seed rate and NP fertilizer rates did not show significant difference on days to heading (Appendix Table 1). The NP fertilizer rates of 138/46 caused significantly earlier days to heading (91.88 days) than the other four NP fertilizer rates. The null/control fertilizer rates significantly latest (97days) to produce head than other NP fertilizer rates. There was difference of five days seems to be produced head between the two fertilizer rates (Table 4.2). This result indicated that fertilizers especially phosphorus fertilizer fasten the heading time of rice. But more level of nitrogen fertilizer was delayed heading time of rice. In line with this Alem Redda et al. (2018) reported similarly that day to heading was significantly different in the main effects and interaction effect of N and P fertilizer rates and the latest day to heading was 97.3 days.

- **Days to 90% physiological maturity**

The days to physiological maturity was significant (*$P < 0.01$*) affected by the main effect of NP fertilizer application rates. However, the main effect of seed rate and the interaction of seed rate and NP fertilizer rates did not show significant difference on days to physiological maturity (Table 2). The NP fertilizer rates of 138/46 resulted in significantly earlier (128.77 days) to mature than other four NP fertilizer rates. The fertilizer rates of 0/0 significantly latest (131.66 days) to mature than other NP fertilizer rates (Table 2). Phosphorus is essential for early maturity, growth of plants and promotes root development. Early maturity with higher fertilizer level could be due to the presence of sufficient nutrients, which can be addressed to different plant parts and metabolic activities that are quickened. As a result plants tended to mature earlier. Tilahun Tadesse *et al*. (2013) reported that the number of days required for the rice plants to mature was influenced by the main effect of nitrogen and phosphorus.

Table 2
Main effect of NP fertilizer rates on days to heading (DH) and days to physiological maturity (DPM)

Treatments	**Days to heading(DH)**	**DPM**
N/P_2O_5 (kg/ha)		
0/0	97^{a}	131.66^{a}
138/23	92.11^{cd}	129.22^{c}
138/46	91.88^{d}	128.77^{c}
207/23	93.44^{b}	131^{ab}
207/46	93.11^{bc}	130.66^{b}
LSD(0.05)	1.046**	0.96**
SE±	0.89	0.81
CV (%)	1.15	0.76

*** Highly Significant at P = 0.01; DPM= days to physiological maturity; LSD (0.05) =Least significant difference at 5%; SE= standard error and CV (%)= coefficient of variation*

3.3 Growth Parameters

- **Leaf area index**

The statistical analysis showed highly significant (*$P < 0.01$*) effect of the main effect of NP fertilizer application on leaf area index. However, the main effect of seed rate and the interaction of seed rate and NP fertilizer rates did not show significant difference on leaf area index (Table 3).

The highest LAI (3.47) at heading was recorded at the fertilizer rate of 207/23 kg N/P_2O_5 was applied and the lowest LAI (1.68) was recorded at the fertilizer rate of 0/0 kg N/P_2O_5 (Table 3). Leaf area index determines the efficiency of photosynthesis and photosynthetic surface area and thus, is an important determinant of plant productivity. However, in less fertilized fields, it is common to see small and narrow leaves of the rice crop. This has leads to the poor productivity and yield of the crop under farmers' field condition. Increase in leaf area index could be attributed to enhanced production of carbohydrate, which might have resulted in increased leaf expansion. Tilahun Tadesse *et al*. (2013) reported that leaf area index at heading responded significantly to the main effect of N and P fertilizer rates. Those authors also showed that the highest LAI at heading was recorded when the highest rates of N and P were applied in combination and the lowest LAI occurred in response to the application of the lowest rates of nitrogen and phosphorus. Naing et al. (2010) also reported that application of 50 – 22 N-P kg ha^{-1} resulted in a 41.3% increase in LAI of rice at heading compared to no fertilizer application.

- **Plant height**

It was observed that there was highly significant (*P < 0.01*) difference in plant height due to the main effect of NP fertilizer rates. However, the main effect of seed rate and the interaction of seed rate and NP fertilizer rates did not show significant difference on plant height. (Appendix Table 1). The significantly tallest (118.06cm) and shortest (73cm) plant heights were observed from fertilizer rate of 207/23 and 0/0 N/P_2O_5 kg ha^{-1} respectively. Plant height increased highly significantly with increasing applied NP rate of 207/23 N/P_2O_5 kg $ha^{-1}$was statically similar to NP rate of 207/46 N/P_2O_5 kg ha which have plant height of 118.06cm (Table 3). Both phosphorus and nitrogen are major macronutrients required for rice growth. Nitrogen is mainly involved in vegetative growth and preparation of the plant towards the reproductive phase. The plant heights increased at the low phosphorus rates but were shorter when the phosphorus rates were further increased. Similarly, Halima Rashid (2015) reported that the increases in rice plant height due to increasing phosphorus fertilizer application rates and decrease when the phosphorus rates were increased beyond optimum level. The increment of rice plant height in the present study was due to applications of N P fertilizer is apparent as Nitrogen is essential nutrient or plant growth since it is a constituent of all proteins and nucleic acids, whereas phosphorus is essential for the production and transfer of energy in plants. This result also indicates that plant height was highly responsive for NP fertilizer than seed rate. AlemRedda*et al.* (2018) reported that the interaction effect of NP fertilizer rate showed that significant difference on plant height. Shiferaw Nesgea et al (2012) reported that plant height was significantly responded to nitrogen fertilizer application.

- **Panicle length**

Panicle length was highly significantly (*P < 0.01*) affected by the main effect of NP fertilizer rates. However, the main effect of seed rate and the interaction of seed rate and NP fertilizer rates did not show significant difference on panicle length. The significantly tallest (21.57 cm) and shortest (14.96 cm) panicle lengths were observed from fertilizer of 207/23 and 0/0 N/P_2O_5 kg ha^{-1}, respectively (Table 3). Fertilizer rate of 207/23 N/P_2O_5 and 207/46 N/P_2O_5 showed statistically at par panicle lengths. This indicated that the increment in panicle length due to application of nitrogen fertilizer increased panicle length of rice crop more than P fertilizer. One of the most important functions of nitrogen is promotion of rapid growth. Panicle length is a yield contributing characters of crops. The longest panicle produces more grains than the shortest panicle. Heluf Gebrekidan and Mulugeta Seyoum (2006) reported that applications of N and P fertilizers increased panicle length significantly. Similarly, the authors noted that one of the most important functions of nitrogen is promotion of rapid growth and application of nitrogen fertilizer increased panicle length of rice crop more than P fertilizer. On contrary, Mursal (2008)reported that there is significant effect among nitrogen and phosphorus levels on panicle length.

Table 3
Main effect of NP fertilizer rates on plant height, panicle length and Leaf area index (LAI) of '*Shaga'* rice variety

Treatments	**Plant height(cm)**	**Panicle length(cm)**	**LAI**
N/P_2O_5 (kg/ha)			
0/0	73.0^{c}	14.96^{c}	1.68^{c}
138/23	101.9^{b}	19.97$_{b}$	2.86 ^{b}
138/46	101^{b}	19.43^{b}	3.08^{ab}
207/23	118.06^{a}	21.57^{a}	3.47 a
207/46	115.71^{a}	21.48 ^{a}	2.91^{ab}
LSD (0.05)	6.44**	1.05**	0.60**
SE±	5.45	0.89	1.50
CV (%)	6.54	5.62	22.42
** Highly Significant at p = 0.01;*LSD (0.05) = Least significant difference at 5% and SE= Standard error and CV (%) =coefficient of variation*			

3.4 Yield and Yield Related Traits

- **Number of total tillers per meter square**

Analysis of variance showed a highly significant ($p < 0.01$) difference on the main effect of NP fertilizer rates and the main effect of seed rates. Moreover, there was a significant ($p < 0.05$) difference due to the interaction effects of NP fertilizer and seed rates (Table 4). The highest number of total tillers (833.33 m^{-2}) was on the interaction of the highest NP fertilizer rate of 207/46 N/P_2O_5 kg ha^{-1} with the highest seed rate of 120 kg ha^{-1} which was statistically similar with the use of 207/46 N/P_2O_5 kg ha^{-1} and 100 kg seed ha^{-1}. The lowest number of total tillers (311.67 m^{-2}) was due to the interaction of without NP fertilizer (0/0 N/P_2O_5) and lowest seed rate of 80 kg ha^{-1} (Table 4). This result indicated that both the fertilizer level and seed rates can increase total tillers at highest rates. In cognizant to the current finding, Anisuzzaman et al. (2010) reported that total number of tillers was highly significant on both the main effect of fertilizer rate, the main effect of seed rate and the interaction effects of seed and fertilizer rates.

Table 4
Interaction effects of NP fertilizer rate and seed rate on number of total tillers per meter square

NP rate (kg ha^{-1})	**seed rate (kg ha^{-1})**		
	80	**100**	**120**
0/0	311.67^{g}	376.67^{f}	351.67^{fg}
138/23	631.67^{e}	660d^{e}	710^{cd}
138/46	633.33^{e}	688.33^{cd}	635^{e}
207/23	710^{cd}	661.67^{de}	736.67^{bc}
207/46	775^{b}	831.67^{a}	833.33^{a}
LSD (0.05)	53.109 *		
SE±	25.93		
CV (%)	4.98		
* significant at P = 0.05; *LSD (0.05) =Least significant difference at 5%; SE= Standard error and CV (%) =coefficient of variation*			
Number of fertile tillers per meter square			

Fertile tillers are those tillers which are bearing panicles with filled grains. The statistical analysis showed a highly significant(*$p < 0.01$*) difference on fertile tiller numbers due to the main effect of NP fertilizer rates, the main effect of seed rates and the interaction effects of NP fertilizer rates and seed rates(Table 5). The highest number of fertile tillers (811.67) was due to the interaction of the highest NP fertilizer rate of 207/46 N/P_2O_5 kg ha^{-1}with the highest seed rate of 120 kg ha^{-1} which was statistically similar with the use of 207/46 N/P_2O_5 kg ha^{-1} and 100 kg seed ha-1. However, the lowest number of fertile tillers (286.67 m^{-2}) was due to the interaction of without NP fertilizer (0/0 N/P_2O_5) and lowest seed rate of 80 kg ha^{-1} (Table 5). This result indicated that as the level of seed rate become higher with increasing level of fertilizer, the number of fertile tillers is higher. Even when nutrition computation is increasing through higher seed rate, there is sufficient fertilizer level at the maximum number of fertile tillers. In line with this finding, Yoseftabar (2012) reported that significantly maximum fertile tiller under interaction of nitrogen and phosphorus fertilizer was observed for 150 kg/ha nitrogen with 90 kg/ha phosphorus and minimum of that was obtained for 50 kg/ha nitrogen fertilizer with 0 phosphorus fertilize. Khan et al. (2009) reported that number of total tillers was highly significant on seed rates. Anisuzzamanet al. (2010) reported similarly that number of fertile tillers was highly significant difference on both the main effect of fertilizer rate, the main effect of seed rate and the interaction effects of seed and fertilizer rates.

Table 5
Interaction effects of NP fertilizer rate and seed rate on number of fertile tillers per meter squares

NP rate (kg ha-)	**seed rate (kg ha^{-1})**		
	80	**100**	**120**
0/0	286.67^{g}	351.67^{f}	336.67^{fg}
138/23	581.67^{e}	613.33^{de}	685^{bc}
138/46	585^{e}	640^{cd}	590^{de}
207/23	688.33^{bc}	640^{cd}	718.33^{b}
207/46	736.67^{b}	806.67^{a}	811.67^{a}
LSD (0.05)	53.46 **		
SE±	26.10		
CV (%)	5.28		

** Highly Significant at P = 0.01;*LSD (0.05) =Least significant difference at 5%; SE= Standard error and CV (%) =coefficient of variation.*

- **Number of non-fertile tillers per meter square**

Analysis of variance showed highly significant (*$p < 0.01$*) difference on number of fertile tillers due to the main effect of NP fertilizer rates and the main effect of seed rates. However, the interaction of seed rate and NP fertilizer rates did not show significant difference on number of non-fertile tillers (Table 6). Among the fertilizer rates, the highest number of non-fertile tillers (47.22) was at the level of 138/46 N/P_2O_5 kg ha^{-1}(statically similar to the fertilizer level of 138/23 138/46 N/P_2O_5 kg ha^{-1}) and the lowest number of non-fertile tillers (21.66) was at no fertilizer application (Table 6). This may be due to more fertilizer rates especially nitrogen rates that increase the large number of total tillers and those tillers may be nutrient deficient due to nutrient competition. In the case of null application tillers may also have nutrient deficiency. Khan et al. (2009) reported that number of non-fertile tillers was highly significant on seed rates. On the contrary, Shiferawnesga (2012) reported that number of non-fertile tillers did not show significant difference on both the interaction effects of N and P fertilizer rates.

Concerning the seed rates, the highest number of non-fertile tillers (36.66) was due to the seed rate of 80 kg ha^{-1} which is statically similar to the seed rate of 100 kg ha^{-1} having non fertile tillers of 33.33 and the lowest number of non-fertile tillers (25) was due to the seed rate of 120 kg ha^{-1}. This may be due to the higher seed rates. Most tillers were smaller in size, less branched, mature earlier and so the rice crop used nutrients efficiently resulting in large numbers of fertile tillers forming. Therefore, lower numbers of non-fertile tillers were counted at higher seed rates. Similarly, Kabir *et al.* (2009) reported that number of non-fertile tillers was highly significantly affected by seed rate.

- **Number of filled grains per panicle**

Analysis of variance showed highly significant ($p < 0.01$) difference due to the main effect of NP fertilizer rates on number of filled grains per panicle. However, the main effect of seed rate and the interaction of seed rate and NP fertilizer rates did not show significant difference on number of filled grains per panicle (Table 6). The significantly highest (116.13) and lowest (64.22) filled grain per panicle were observed from fertilizer rate of 207/46 N/P_2O_5 kg ha^{-1} and 0/0 N/P_2O_5 kg ha^{-1} respectively (Table 6). There was an observation that filled grain per panicle was increased with the reduction of seeding rate and increase in NP fertilizer levels. This might be due to the lower internal plant competition and increased availability of nitrogen and phosphorus that is responsible for improved dry matter allocation for vegetative and reproductive organs. The reason for the increase of filled grains per panicle as the dose of fertilizer level increases is that NP fertilizer is essential for the increment of nutritional content of grains of rice. Mursal (2008) reported that the numbers of filled grains per panicle were demonstrated to be significantly different to the main effects of N and P fertilizers. Oppositely to this result, Nesgea *et al* (2012)reported that the interaction effect of applied N and P levels on number of filled grains per panicle did not show significant difference on the number of filled grains per panicle.

- **Number of un-filled grains per panicle**

In the current experiment, it was observed that there was highly significant ($p < 0.01$) difference in number of unfilled grains due to the main effect of NP fertilizer rates and the main effect of seed rates. However, the interaction of seed rate and NP fertilizer rates did not show significant difference on number of unfilled grains per panicle (Table 6). The significantly highest (11.44) unfilled grain per panicle was observed from fertilizer rate of 207/23 N/P_2O_5 kg ha^{-1} which is statically similar to fertilizer rate of 207/46 N/P_2O_5 kg ha^{-1} having unfilled grain of 11.15 and lowest (4.15) un-filled grain per panicle was observed from fertilizer rate of 0/0 N/P_2O_5 kg ha^{-1} (Table 6). The high numbers of un-filled grains were obtained with highest fertilizer rate; especially nitrogen fertilizer increased the vegetative growth. As a result, a large number of un-filled grains were obtained from each panicle. This result indicated that nitrogen does not have as much value for grain filling as phosphorus. Phosphorus was mainly involved in grain filling. Mursal (2008) also showed that, nitrogen levels had significant effect on number of unfilled grains per panicle. Lower un-filled grains at no fertilizer application indicated that tillers are smaller; panicles are much shorter and bearing fewer numbers of grains due to no NP fertilizers. Therefore, number of unfilled grains per panicle is lower.

Regarding the seed rates, the significantly highest (8.98) unfilled grain per panicle was observed from the seed rate of 100 kg ha^{-1} and the lowest (6.60) unfilled grain per panicle was observed from the seed rate of 80 kg ha^{-1}. This result indicated that lowest seed rate emerges more branched, thick tillers and those most tillers are slower to set their seeds finally it may be affected by drought due to short duration of rain fall. Similarly, Endalkachew Aklilu (2020) reported that the highest and lowest number of un-filled grains per panicle was observed from the highest and lowest seed rates respectively.

Table 6
Main effects of NP fertilizer rates and seed rate on NNFT, NFGPP and NUGPP of '*Shaga*' rice variety

Treatments	**NNFT**	**NFGPP**	**NUGPP**
N/P_2O_5 (kg/ha)			
0/0	21.66b^c	64.22^c	4.15^c
138/23	40.55^a	93.95^b	6.17^b
138/46	47.22^a	97.20^b	6.0^b
207/23	20.55^c	107.60^{ab}	11.44^a
207/46	28.33^b	116.13^a	11.15^a
LSD (0.05)	6.90**	14.58**	1.64**
Seed rate (kg/ha)			
80	36.66^a	100.44^a	6.60^b
100	33.33^a	95.17^a	8.98^a
120	25^b	91.85^a	7.77^{ab}
LSD (0.05)	5.34^{**}	11.3^{ns}	1.27^{**}
SE±	5.83	3.85	1.38
CV (%)	22.56	15.76	21.82

*** Highly Significant at p = 0.01; ns = not significant; LSD (0.05) = Least significant difference at 5%; SE= standard error, and CV (%) =coefficient of variation; NNFT= number of non-fertile tiller; NFGP=number of filled grain per panicle and NUGPP= number of un filled grain per panicle*

- **Above ground dry biomass yield**

Highly significant (*$p < 0.01$*) was observed in the above ground dry biomass because of the main effect of NP fertilizer rates and the main effect of seed rates. However, interaction effect of seed and NP fertilizer rates did not show significant difference on above ground biomass yield. Significantly the highest above ground dry biomass yield (18756 kg ha^{-1}) was obtained due to fertilizer rate of 207/46 N/P_2O_5 kg ha^{-} and it is statically similar to fertilizer rate of 207/23 N/P_2O_5 kg ha^{-} (18741 kg ha^{-1}). Significantly the lowest above ground dry biomass yield (4298 kg ha^{-1}) was due to no fertilizer or fertilizer rate of 0/0 N/P_2O_5 kg ha^- (Table 7). Biomass yield is the overall indicators of the overall growth and yielding performance. This result indicated that high amounts of NP fertilizer give sufficient nutrient for growth and production of rice, due to this sufficient nutrient all plant parts such as leaves, tillers, panicles, and grains become large and those have more total biomass yield. Alem Redda et al. (2018) reported that the main effects of nitrogen and phosphorus fertilizers significantly affected aboveground dry biomass yield. They also found that found that highest biomass yield of 12246 kg/ha at the treatment combinations of 138 kg N /ha and 69 kg/ha of P_2O_5 and the lowest biomass yield of 4528 kg/ha at the treatment combination of zero nitrogen and zero phosphorous fertilizers. The comparison of the seed rates indicated that significantly the highest aboveground dry biomass yield (15322.2 kg ha^{-1}) was exhibited due to seed rate of 120 kg ha^{-1} and lowest aboveground dry biomass yield (12711.1 kg ha^{-1}) was due to seed rate of 80 kg ha^{-1} and it is statically similar to seed rate of 100 kg ha^{-1}. This result indicated that the highest amount of seed rate produces more number of tillers, longer plant length due to competition for space and longest leaves. Due to higher number tillers total biomass yield is higher and it indicates that the fertility status of the soil was sufficient and no more competition of higher seed rate. Similarly, Tekle Yoseph and Wedajo Gebre (2014) reported that the total biomass yield was significantly affected by seed rate. They also showed that the maximum biomass yield was obtained from the seed rate of 120 kg ha^{-1}. Similarly Kabir *et al*. (2009) reported that total biomass yield was highly significantly influenced by seed rate.

- **Grain yield**

It is the main important parameter of crops, and it is mostly people concentrated. The analysis of variance showed highly significant ($p < 0.01$) difference in grain yield to the main effect of NP fertilizer rates. However, the main effect of seed rates and interaction effect of seed with NP fertilizer rates did not show significant difference on grain yield (Table 7). The significantly highest (7405.5 kg ha^{-1}) grain yield was obtained due to fertilizer rate of 207/46 N/P_2O_5 kg ha^{-1} and it is statically similar to other two fertilizer levels. The lowest grain yield (2094.5 kg ha^{-1}) was obtained at no fertilizer application (0/0 N/P_2O_5 kg ha^{-1}) (Table 7). The proper combination of nitrogen and phosphorus results in high rice yields by providing sufficient nutrient. This result indicated that the increment of both N and P fertilizer rates increased the rice grain yield. This may be due to higher fertilizer level, which increased number of fertile tiller and have higher filled grains per panicle and finally grain yield of rice can be maximized. The increase in grain yield might be due to the effect of nitrogen which expands the plant to produce taller plants, longer spikes, and more spiklets/spike and therefore more grain yield. Similarly, Singh (2008) reported that when 60 kg P_2O_5 ha^{-1} was added to 120 kg N ha^{-1}, significantly increased the grain yield (5.31 t ha^{-1}). In line with this Mbaga (2015) reported that increased rate of N and P significantly increased rice grain yield. In conformity with this result, Yoseftabar (2012) reported that significant difference due to the main effects of the levels of interaction effects of nitrogen and phosphorus fertilizer rates. In line with this, Alem Redda et al. (2018) found that the interaction effects of N and P fertilizer levels showed significant difference on grain yield. The improvement of numbers of total tillers m^{-2}, numbers of effective tillers m^{-2}, number of grains per panicle and seeds weight might be contributed to the final yield. Alen et al. (2012) had also found that the number of tillers per unit area is the most important component of yield. Therefore, the higher the number of tillers, especially fertile tillers, and seed per panicle, the more would be the yield.

Straw yield

Next to grain yield straw yield is one of important part of yield components mostly for feeding domestic animals. Analysis of variance showed highly significant ($P < 0.01$) difference in straw yield due to the main effects of NP fertilizer and seed rates. However, interaction effect of seed and NP fertilizer rates did not show significant difference on straw yield (Table 7). With respect to the fertilizer rates, significantly the highest straw yield (11873.5 kg ha^{-1}) was due to the rate of 207/46 N/P_2O_5 kg ha^{-1} and it is statically equivalent to the straw yield obtained at 207/23 N/P_2O_5 kg ha^{-1}. The lowest straw yield (2018.4 kg ha^{-1}) was due to no fertilizer rate application (Table 7). This result indicated that highest fertilizer level can increase straw yield by giving sufficient nutrients and increasing number of tillers, the size and number of leaves of rice. Similarly, Heluf Gebrekidan and Mulugeta Seyoum (2006) reported that straw yield was highly significantly responding to the main effects of N and P fertilizer levels. Moreover, Anisuzzamanet al., (2010) reported that straw yield was highly significant affected by the main effect of fertilizer rates.

Among the seed rates, significantly the highest straw yield (9071.8 kg ha^{-1}) was obtained at seed rate of 120 kg ha^{-1} and the lowest straw yield (6877.8 kg ha^{-1}) was due to seed rate of 80 kg ha^{-1} (Table 7). This result indicated that highest seed rate has the highest competition for space, due to these tillers are longest, and the longest leaves formed. Therefore, at highest seed rates there was higher number of straw yields. Similarly, Kabir *et al*. (2009) reported that straw yield was highly significant on seed rate. The current finding agrees with Anisuzzaman et al. (2010) who reported that straw yield was highly significantly responding to the main effect of seed rate. Limanpure et al. (2017) had also found that straw yield was significantly influenced by different seed rates.

Table 7
Main effect of NP fertilizer rates and seed rate on AGBY, GY and SY of '*Shaga*' rice variety

Treatments	AGBY($Kg\ ha^{-1}$)	GY ($Kg\ ha^{-1}$)	SY ($Kg\ ha^{-1}$)
N/P_2O_5 (kg/ha)			
0/0	4298^{c}	2094.5^{c}	2018.4^{c}
138/23	13333^{b}	5406.9^{b}	6926.5^{b}
138/46	13630^{b}	6485.8^{a}	6995.7^{b}
207/23	18741^{a}	6867.2^{a}	11350.1^{a}
207/46	18756^{a}	7405.5^{a}	11873.5^{a}
LSD(0.05)	2115.3**	1070.5**	1690.8**
seed rate (kg/ha)			
80	12711.1^{b}	5744.4^{a}	6877.8^{b}
100	13221.0^{b}	5672.3^{a}	7548.8^{b}
120	15322.2^{a}	6139.3^{a}	9071.8^{a}
LSD (0.05)	1638.50**	829.23^{ns}	1309.70**
SE±	1788.64	905.20	1429.66
CV (%)	15.93	18.94	22.35
*** Highly Significant at P = 0.01; * significant at P = 0.05; ns = not significant; LSD (0.05) = Least significant difference at 5% and CV (%) = coefficient of variation; AGBY= above ground biomass yield; GY= grain yield; SY= straw yield;*			

Harvest index

It was found to significantly ($p < 0.05$) responding to the main effect of NP fertilizer rates, the main effect of seed rates and the interaction effect of seed and NP fertilizer rates (Table 8). The highest harvest index (70.61%) was obtained due to the interaction of seed rate 80 kg ha^{-1} andfertilizer level of 0/0 NP_2O_5kg $ha^{-1}$and the lowest harvest index (32.96%) was obtained due to the interaction of seed rate120 kg ha^{-1} and fertilizer level of 207/23 NP_2O_5 kg ha^{-1} (Table 8). The lowest harvest index at the highest N fertilizer rate could be due to partitioning of the total nitrogen content more to the vegetative part than to the grain and increased the total aboveground biomass yield. The lowest harvest index at highest seed rate also could be due to large number of total tillers and leaves. Anisuzzaman et al. (2010) similarly reported that harvest index was highly significantly varying due to on the main effect of seed rate and the interaction effects of seed rate and fertilizer levels. Limanpure et al. (2017) also reported that the Harvest index was significantly influenced by different fertilizers rates.

Table 8
Interaction effects of NP fertilizer rate and seed rate on harvest index (%)

NP rate (kg ha^{-1})	**Seed rate (kg ha^{-1})**		
	80	**100**	**120**
0/0	70.61^{a}	33.51^{c}	44.97^{bc}
138/23	51.43^{b}	50.31^{b}	43.82^{bc}
138/46	45.69^{bc}	52.55^{b}	46.09^{bc}
207/23	39.51^{bc}	36.76^{bc}	32.96^{c}
207/46	41.79^{bc}	39.98^{bc}	37.01^{bc}
LSD	16.46*		
SE±	8.04		
CV	22.14		

* Significant at P = 0.05;*LSD (0.05) =Least significant difference at 5% and CV (%) =coefficient of variation.*

3.5 Partial Budget Analysis

Following the CIMYYT (1988) partial budget analysis method, grain and straw yield adjustments, calculations of total variable costs (TVC), gross benefits (GB) and net benefits (NB) were performed (Table 9). Dominance analysis was carried after arranging the treatments in their order of TVC. A treatment will be considered as dominated if it has higher TVC but lower NB than a previous treatment with lower TVC and higher NB (Table 9). Non dominated treatments were taken out and marginal rate of return (MRR) was computed (Table 10). According the to the CIMYYT (1988) partial budget analysis methodology, treatments exhibiting the minimum or more MRR (> 100%) will be considered for the comparison of their NB. The Highest NB (Birr 78931.15 ha^{-1}) with acceptable level of MRR (502.6%) was observed at the combination of 120 kg ha^{-1} seed and 207/46kg N/P_2O_5 ha^{-1} fertilizer rates. The stated treatment combination is thus the most profitable practice to be recommended for rice production in Fogera plain.

Table 9
Partial budget analysis of rice influenced by seed rate and fertilizer levels

N/P_2O_5 (kg ha^{-1})	**SR (kg ha^{-1})**	**Adj.GY (kg ha^{-1})**	**Adj.STY(tton ha^{-1})**	**GB (Birr ha^{-1})**	**TVC (Birr ha^{-1})**	**NB (Birr ha^{-1})**	**Dominance**
0/0	100	1005.83	1.999	13463.11	2406.99	11056.12	
0/0	80	2118.22	0.882	24358.54	3501.86	20856.68	
0/0	120	2531.17	2.569	30925.25	4477.40	26447.85	
138/23	80	4922.81	4.677	59763.50	9509.26	50254.24	
138/23	100	5969.08	5.831	72656.95	11004.78	61652.17	
138/46	80	5953.73	6.646	73466.54	11218.39	62248.14	
138/46	120	5611.21	6.789	69869.87	11287.37	58582.50	D
138/46	100	5946.74	5.4.53	71958.01	11450.00	60508.01	D
138/23	120	6406.66	8.193	80305.22	11769.88	68535.34	
207/23	80	6316.75	9.683	81104.14	11866.99	69237.15	
207/23	120	5962.63	11.237	79073.80	11922.05	67151.75	D
207/23	100	6262.17	11.138	82249.30	12041.50	70207.80	
207/46	80	6538.22	9.062	82794.53	12604.78	70189.75	D
207/46	100	6341.39	9.549	81213.59	12608.58	68605.01	D
207/46	120	7115.12	12.035	92708.2	13777.07	78931.15	

Where Adj. GY= Adjusted grain yield; Adj. STY= Adjusted straw yield; GB= gross return; TVC= total variable cost; NB = net benefit and D= dominance. Cost of urea fertilizer = 13.70 Birr per kg; cost for DAP fertilizer = 14.80birr per kg; Fertilizer application Birr 100 per person; Sale price of rice (shaga variety) seed = Birr 12 per kg; price for rice harvesting and threshing = Birr 120 per 100 kg.

Table 10
Marginal analysis of rice yield influenced by fertilizer level and seed rate for partial budget analysis of the crop

N/P_2O_5(kg ha^{-1})	SR (kg ha^{-1})	TVC (Birr ha^{-1})	NB (Birr ha^{-1})	MRR (%)
0/0	100	2406.99	11056.12	-
0/0	80	3501.86	20856.68	895.14
0/0	120	4477.40	26447.85	573.14
138/23	80	9509.26	50254.24	473.11
138/23	100	11004.78	61652.17	762.14
138/46	80	11218.39	62248.14	279.00
138/23	120	11769.88	68535.34	1140.05
207/23	80	11866.99	69237.15	722.67
207/23	100	12041.50	70207.80	556.22
207/46	120	13777.07	78931.15	502.62

Where N= Nitrogen; P= Phosphorus; TVC = total variable cost; NB = net benefit; MVC= marginal variable cost; MNB=marginal net benefit and MRR=marginal rate of return.

4. CONCLUSION AND RECOMMENDATIONS

Results revealed that the main effect fertilizer level significantly affected all phonological, growth and yield components. Grain yield was highly significant; responding to NP fertilizer rates and did not show significance to seed rates. However, seed rate of 120 kg ha^{-1} have relatively higher grain yield. Optionally seed rate of 120 kg ha^{-1} can be used and other two seed rates can be used alternatively. Fertilizer rate of 207/46 NP_2O_5 kg ha^{-1} gave the highest yield among a range of seed rates. The economic analysis also showed that the combined application of fertilizer level 207/46 NP_2O_5 kg ha^{-1} and120 kg/ha seed rate was the most profitable than the other treatments. Based on the results of the present study and economic analysis, fertilizer level of 207/46 NP_2O_5 kg ha^{-1} and seed rate of120 kg ha^{-1} gave the highest production of rice. Therefore, fertilizer rate of 207/46 NP_2O_5 kg ha^{-1} and seed rate of 120kg ha^{-1} is recommended for rice production to obtain maximum grain yield under rain fed in Fogera plain.

Declarations

Ethics and Consent to participate

All research involving human subjects, freely-given, informed consent to participate in the study must be obtained from this research participant. The name of the plant used was Shaga rice variety. The “Shaga” rice variety was developed and released by the Fogera National Rice Research and Training Center (FNRRTC) under the Ethiopian institute of agricultural research.

Consent for publication

We all have agreed on data in the manuscript and submit our final manuscript to this journal for possible publication.

Consent to publish

and participate NA

Permissions to collect the plants/plant parts

permission to collect the plant parts was given by the Fogera National Rice Research and Training Center (FNRRTC)

Competing interest

The authors declare no competing interest.

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No fund has been received to this experiment.

Author Contribution

The author G.D.S. contributes to this manuscript on proposal development, field design preparation, data collection, and data analysis. The author T.T. contributes to title development, reviewing the analyzed data, and the full write-up. The author A.J.J. contributes to reviewing a full write-up of the manuscript.

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Data Availability

The required data collected for analysis are included in the manuscript. The corresponding author is ready to clarify the data and provides all the necessary data sets as per the request.

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Figures

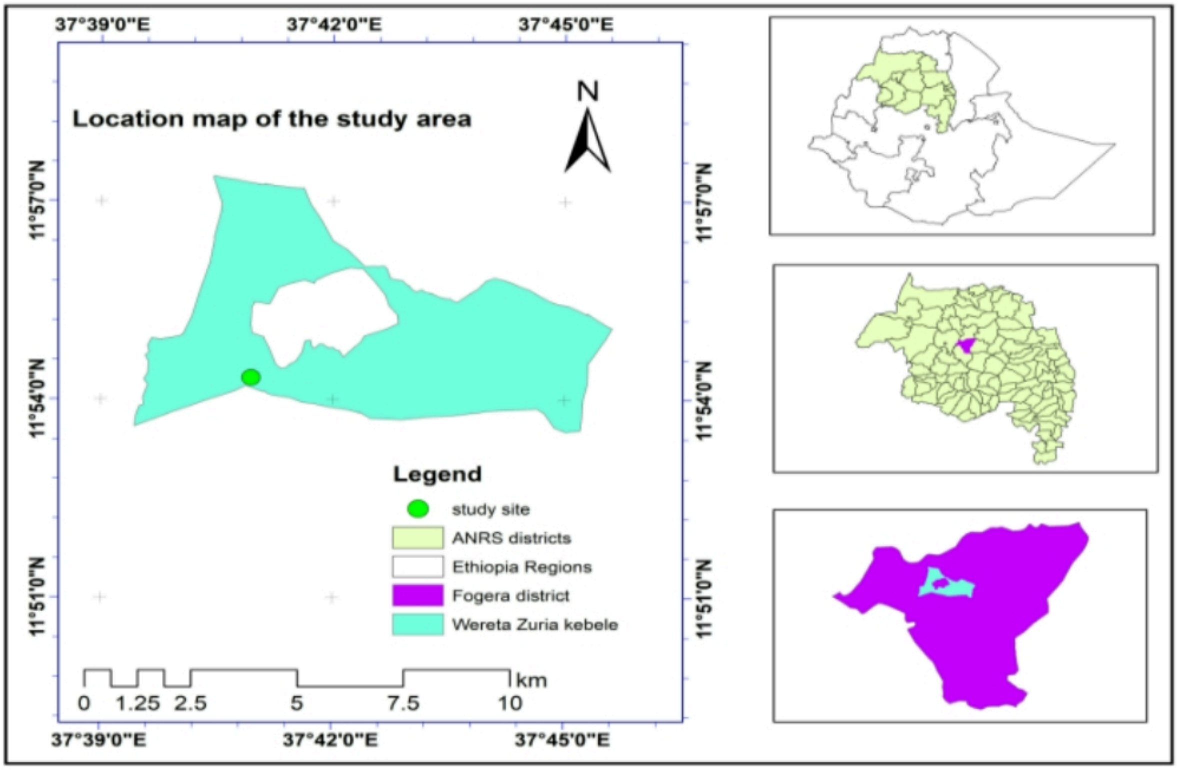

Figure 1

Map of the study area (Source: Ethio GIS database)