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Research Article

Response of the Newly Released Shaga Rice Variety to Nitrogen and Phosphorus Fertilizer Rates in Vertisols of Fogera and Achefer Plain, North Western Ethiopia

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Abstract

An experiment was conducted at Fogera and Achefer in the year 2020/21 and 2021/22 cropping seasons. Treatments were comprised of factorial combinations of five N levels (0, 92, 184, 276 and 368 kg ha^{-1}) and four P_2O_5 levels (0, 23, 46 & 92 kg ha^{-1}) replicated three times in RCB Design. The objective of the experiment was to determine economically optimum rates of nitrogen and phosphorus fertilizer on yield and yield components of shaga rice variety. Data were collected on plant height, panicle length, number of tillers, number of fertile panicles, thousand seeds weight, grain yield, straw yield, and harvest index. All collected data were subjected to analysis of variance. Economic analysis was also done for yield. The combined analysis of the two years result showed that very highly (P<0.001) significant effect on plant height, number of total tillers per row meter length. And number of fertile panicles per row meter length, grain yield, and straw yield. most of yield component parameters and highly significantly affecting number of filled grain per panicle and number of tillers per row meter length. The highest grain yield (4.76 and 6.56 t ha^{-1}) was obtained at 184-46 N- P_2O_5 kg ha^{-1} in Fogera and Achefer, respectively. The economic analysis has exhibited that the combined application of 184-46 N- P_2O_5 kg ha^{-1} is the most profitable treatment, with a mean net benefit of 74430.00- and 115994.00-Birr ha^{-1} for Fogera and Achefer, respectively. Therefore, it can be concluded that application of nitrogen and phosphorous fertilizers at rates of 184-46 N- P_2O_5 kg ha^{-1} is the best recommended rate for rainfed lowland shaga rice variety in Fogera and Achefer plains and other similar agroecology.

Keywords

Achefer, Economic Analysis, Fogera, Grain Yield, Low Land Rice, Shaga

1. Introduction

Rice (Oryza sativa L.) is one of the most popular field crops among other cereals in the world, being cultivated in different agro-ecosystems. Rice serves as the staple food for the world's half population [11]. Rice is a source of energy for major portion of the world's population and ranks second after maize with respect to production [28]. Therefore, sustainable rice production is necessary to overcome food scarcity throughout the globe. Besides various abiotic stresses causing extensive losses to sustainable rice production, imbalanced nutrient, also leads to decreased grain yields, with marginal net returns [49, 50].

The world average paddy rice productivity is about 4.6 tons ha^{-1} [12]. The national average productivity of rice in Ethiopia

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is still however low about 2.8 t ha^{-1} [5]. Weeds, pests, soil nutrient deficiencies and terminal moisture stress are the major causes of low rice productivity in Ethiopia [13, 32]. There are a number of agronomic management constraints with this crop. Rice is becoming a high potential crop and there is a lack of appropriate agronomic management recommendations that could help to maximize the productivity of the cultivation techniques in the study area.

Poor soil fertility is among the major factors limiting rice production in Ethiopia. Nitrogen, phosphorus, and potassium are applied as fertilizers in large quantities to rice fields, and a deficiency of either of the nutrients lead to yield losses [45] Nitrogen and phosphorus are often cited as the most limiting nutrients in agricultural soils of Ethiopia [33]. Appropriate fertilizer application is an important management practice to improve soil fertility and production of rice. Availability of plant nutrients, particularly nitrogen at various plant growth stages is of crucial importance in rice production [6, 42] Area specific recommendation of nitrogen and phosphorous fertilizer rate is vital for rice production in the study areas. This research was therefore conducted to determine economically optimum nitrogen and phosphorus fertilizer rate for Shaga rice variety in Fogera and Achefer Plain.

2. Materials and Methods

2.1. Description of the Study Area

Experiments were conducted at Fogera and Achefer, north western Ethiopia, in the year 2020/21 and 2021/22 production seasons. Fogera is located between Latitude 11°49’55 North and Longitude 37°37′ 40 East at an altitude of 1815 meters above sea level. it receives average mean annual rainfall, minimum and maximum temperature of 1219 mm, 12.75 ℃ and 27.37 ℃, respectively. On the other hand, North Achefer is found between Latitude 11°49’59.00 North and Longitude 37°09′ 60.00 East at an altitude of ranging from 1500 to 1800 meters above sea level. The area receives an average annual rain fall ranging from 1000 to 1500 mm and the minimum and maximum daily temperature was 25 ℃ and 30 ℃ [35].

The experimental sites soil was found to be heavy clay with pH of 5.89, and 5.6 Fogera and Achefer respectively and which is slightly acidic and it is a preferred range for most crops (Table 1). Total nitrogen content (%) was 0.12 for both districts, which is within the range of low levels (0.02-0.5%) for tropical soils. The organic matter content of the soil was 2.07 %, which is within a range of medium (2-4%) for Ethiopian soils as per criteria developed by [34]. The available P content of the experimental sites soil for Fogera and Achefer was 6.5 ppm, which lies in a range of deficiency (< 20-40 mg/kg) for most crops [27]. The CEC of the soil was (55.4 and 56.4 cmol kg-1 soils) for Fogera and Achefer respectively (Table 1). Soil pH was determined in a 1:2.5 soil-water suspension using a combination of glass electrode. Organic carbon was estimated by the wet digestion method [36] and organic matter was calculated by multiplying the percent organic carbon (OC) by a factor of 1.724.

Table 1. *Relevant soil physicochemical properties of the experimental rice field before planting in Fogera and Achefer Plain of Ethiopia.*

Fogera			**Achefer**
Soil properties	**Units**	**Soil depth (0–20 cm)**	**Soil depth (0–20 cm)**
Textural class		Heavy clay	Heavy clay
Chemical properties			
pH (H_2O) 1:2.5 g soil	1:2.5 g soil	5.89	5.6
Total nitrogen (TN)	%	0.12	0.12
Organic carbon (OC)	%	1.2	1.2
Organic matter (OM)	%	2.07	2.07
Available Phosphorus	Ppm	6.5	6.5
EC	(ds/m)	0.458	0.50
CEC	(Cmolec kg^1)	55.4	56.4

EC = Electron conductivity; CEC = Cation exchange capacity; ppm = parts per million; Cmolec kg^{-1}; =cent mol charge per kilogram; ds/m=deci Siemens per meter

2.2. Treatments and Experimental Design

The treatments were comprised of factorial combinations of five levels of N rates (0, 92, 184, 276 and 368 kg ha^{-1}) and four levels of P_2O_5 rates (0, 23, 46 and 92 kg ha^{-1}) in randomized complete block design (RCBD) replicated three times. The gross and net plot sizes were 4m x 3m (12 m^2) and 3m x 2m (6 m2), with 1 m spacing between plots and blocks respectively. Treatments were assigned to each plot randomly. To control mixing of treatments, experimental plots were bunded manually. The New variety Shaga was used for this experiment.

2.3. Data Collection and Analysis

Data were collected from a net plot size of 3m x 2m avoiding two rows from the left and two rows from the right as border rows and 50 cm from each of the top and bottom sides of the plots. Data collected include plant height, panicle length, number of total tillers, number of fertile panicles, number of filled grain /panicle, thousand seeds weight, grain yield, straw yield and harvest index. The plant height was taken at physiological maturity of the crop by selecting five random plants. Number of tillers was counted just before harvesting by using Ruler. The total sundried biomass of the harvested rice was recorded before threshing. The rice grain yield was adjusted at 14% standard moisture content. The harvest index was calculated as the ratio of grain yield to biological yield following the equation. Harvest index (%) = (Economic yield)/ (Biological yield) *100. All collected data were subjected to analysis of variance (ANOVA) using SAS software version 9.0 [40]. Wherever treatment differences are be found significant, mean separation of treatments would be calculated based on results of F-test and probability levels of 0.001, 0.01 and 0.05 depending on the results of the ANOVA. The prevailing cost of inputs and out puts in year 2022 considered for the analysis. The cost of Urea and NPS fertilizers for the stated period were Birr 31.94 and 44.25 per kg respectively. While the price of rice grain and straw were Birr 16.0 and 1.5 per kg, respectively.

3. Results and Discussion

3.1. Plant Height

Results of the analysis of variance at Fogera on plant height indicated that very highly significantly ($P<0.001$) affected by the main effects of nitrogen rates, but not by phosphorous rates and their interaction (Table 2). The highest plant height (121.9 cm) was recorded at the highest nitrogen rate of 368 kg ha^{-1} followed by 276 and 184 kg ha^{-1} of N (119.7 and 117.5) which was statistically similar. While the lowest plant height (86.3 cm) was recorded at the control without N application (Table 2). In the case of Achefer, the analysis of variance indicated that plant height was very highly significantly ($P<0.001$) affected by the main effects of nitrogen and phosphorous rates but not their interaction (Table 3). Among the nitrogen rates, the highest plant height (100.2 cm) was recorded at the nitrogen rate of 276 kg ha^{-1} followed by 368 and 184 kg ha^{-1} of N (98.5 and 97.7 cm) which was statistically similar. While the lowest plant height (76.6 cm) was recorded at nil N application (Table 3). The result indicated that plant height increased significantly by increasing the amount of fertilizer. In line with the present findings, [39] had reported that different level of N caused significant difference in plant height, the height of plant found to increase from 60 kg-^{1} N to 120 kg N ha^{-1}. The increase in plant height of rice in response to the increase of N fertilizer rates was probably due to enhanced availability of N, which enhanced further cell division and more leaf area that in turn resulted in higher photo assimilates and thereby resulted in more dry matter accumulation [43]. [41] observed a significant increase in plant height with the application of 46 and 69 kg N ha^{-1} over the control. [19] reported the tallest and the shortest plant height with 120 kg N ha^{-1} and without N application, respectively.

3.2. Panicle Length

The analysis of variance indicated that panicle length of rice was highly significantly ($P<0.01$) affected by the main effects of nitrogen rates, but not by phosphorous rates and their interaction in Fogera and Achefer (Tables 2 and 3). The highest panicle length (19.8 cm) exhibited at the rate of 368 kg ha^{-1} N followed by 276 and 184 kg ha^{-1} of N (19.0 and 19.1), respectively, and which was statistically similar (Table 2), whereas, the lowest panicle length (16.7 cm) was observed at the control without N fertilizer application. Where as in Achefer, the maximum panicle length (17.9 cm) was found with the application of 368 kg N ha^{-1} which was statistically at par with panicle length recorded at 276 and 184 kg N ha^{-1} (17.4 and 17.3 cm), respectively, whereas, the lowest panicle length was detected at 0 kg N ha^{-1} (Table 3). This result might be nitrogen takes part in panicle formation as well as panicle elongation and for this reason, panicle length increased with the increase of N fertilization. The findings of many authors had confirmed for the significant effect of nitrogen levels on panicle length [10, 15, 39]. [39] recorded highest panicle length with 180 kg N application while [10] stated nitrogen application of 210 kg ha^{-1} exhibited larger panicle length. Riste, K. et al. [38] stated that highest and significant panicle length (27.06 cm) was recorded with application of fertilizer dose at 60 kg N ha^{-1}compared to the control without N fertilizer. On the other hand, [33] reported longest panicles of 20.19 cm at the rate of 46 kg N ha^{-1}, while they noted shortest panicles in the control plots.

3.3. Number of Filled Grains Per Panicle

The analysis of variance indicated that number of filled grain per panicle was highly significantly ($P<0.01$) affected by the main effects of nitrogen in Fogera and Achefer but significantly ($P<0.05$) affected by phosphorus rate in Fogera. The interaction of nitrogen and Phosphorus rate was non-significant for both locations (Tables 2 and 3). In Fogera, application of 368 kg/ha of N resulted in maximum (109) filled grains per panicle followed by 276 and 184 kg N ha^{-1} (103 and 101) which was statistically similar. While the lowest number of filled grains per panicle (78) was recorded nil N application (Table 2), regarding to phosphorus, the highest number of Filled grains per panicle was observed from 46 kg/ha P_2O_5 (Table 2). In Achefer condition, the highest number of filled grains per panicle was observed from the highest nitrogen rate 368 kg/ha and followed by 276 and 184 kg N ha^{-1} (111, 106 and 106), respectively, which was statistically similar. The lowest number of filled grains per panicle (87) was recorded nil N application (Table 3). The result indicated that the highest number of filled grain per panicle obtained might be application of sufficient amount of nitrogen and phosphorus fertilizer produced a greater number of fertile panicles and leads to the formation of maximum number of spikelets per panicle. Sink size can be enhanced either by increasing the panicle number per m^2 or the number of spikelets per panicle, or both. In agreement with the present findings, [21] had reported that, higher yield is generally achieved either by increasing panicles number per m^2 or spikelet number per panicle. In addition, the performance of yield components varies across environments. And also nitrogen application had a significant effect on number of grain per panicle in rice. The greater number of grains $panicle^{-1}$ at higher N rates were probably due to better N status of plant during panicle growth period [14].

3.4. Number of Tillers Per Row Meter Length

The analysis of variance indicated that number of tillers per row meter length were highly significantly ($P<0.01$) affected by the main effects of nitrogen rates, but not by phosphorous rates and their interaction (Table 2). The highest number of tillers per row meter length (88) was recorded at the highest rate of 276 kg N ha^{-1} and followed by 368 kg N ha^{-1} (85), respectively. While the lowest number of total tillers (70) was observed from without N application (Table 2). In Achefer location, the number of tillers per row meter length was very highly significantly ($P<0.001$) affected by the main effects of nitrogen and significantly ($P<0.05$) affected by phosphorous rates but not their interaction (Table 3). The highest number of tillers per row meter length (112) was recorded at the highest rate of 276 kg N ha^{-1} and followed by 368 and 184 kg N ha^{-1} (111 and 107), respectively. While the lowest number of tillers per row meter length (77) was observed from the control treatment (without N fertilizer application) (Table 3). This result might be due to nitrogen promotes formation of the different organs in the rice plant as well as other physiological processes. N is the major component for the development of tillers, leaves and grains and promotes protein and carbohydrate synthesis. Similarly concluded that nitrogen application significantly increases the total tillers number. This result was supported by [39] obtained the highest total tillers for N at 120 kg ha^{-1} while [7] gained the largest tillers number at 210 Kg ha^{-1} N. Similar to the total number, the number of productive tillers depends on environmental conditions especially nutrient applications [10, 15] reported that fertile tillers of rice were increased significantly with increasing nitrogen levels from 0 to 220 kg N ha^{-1}

3.5. Number of Fertile Panicles Per Row Meter Length

In the case of Fogera, the maximum number of fertile panicles per row meter length (86) was recorded at the rate of 276 kg ha^{-1} followed by (84) 368 kg ha^{-1}. While the lowest number of fertile panicles (68) was observed from the control treatment (without N fertilizer application) (Table 2). The analysis of variance in Achefer indicated that the number of fertile panicles per row meter length was very highly significantly ($P<0.001$) affected by the main effects of nitrogen and significantly ($P<0.05$) affected by phosphorous rates but not by their interaction. The Maximum number of fertile panicles per row meter length (107) were recorded at the rate of 276 kg ha^{-1} followed by 368 and 184 kg ha^{-1} (104 and 101), respectively. While the lowest number of fertile panicles per row meter length (69) was observed from the control treatment (without N fertilizer application) (Table 3). This result might be due to the application of sufficient amount of nitrogen and phosphorus fertilizer enhanced for the formation of different organs in the rice plant and facilitates other physiological processes. In line with the present results, among the yield attributes, the number of productive tillers is an important agronomic trait, which finally determines the number of fertile panicles and grain yield per unit land area [17]. Application of NP fertilizers at optimum rates might result in superior growth and development that eventually reflected with significantly superior yield attributes [25, 38]. Inferior crop growth in the controls without NP applications might closely be associated with insufficient availability of NP below their optimal requirements [38].

3.6. Thousand Grain Weight

The analysis of variance indicated that thousand grain weight of rice was very highly significantly ($P<0.001$) affected by the main effects of nitrogen for both Fogera and Achefer locations, whereas highly significantly ($P<0.01$) affected by phosphorous rates in Achefer only. Non-significant differences were observed for the interaction of nitrogen and phosphorous fertilizer rate in all locations (Tables 2 and 3). Significantly higher 1000-grain weight (27.6 g) was recorded from 276 kg/ha nitrogen rate and followed by 184 kg N ha^{-1} (26.4) which was statistically similar. While the lowest number of 1000 grain weight (22.2 g) was observed from the lowest nitrogen rates (0 kg N ha^{-1}) and followed by 92 kg N ha^{-1} (22.8 g) (Table 2) in Fogera condition. On the other hand, the maximum 1000 grain weight in Achefer were observed from 184 kg/ha nitrogen rate and followed by 276 kg N ha^{-1} (27.1 and 26.3 g), respectively. The lowest thousand grain weight was recorded from 0 kg of nitrogen. Nitrogen fertilizer application significantly increased the 1000 grain's weight. The possible reason behind this may be due to production of higher number of spikelets per panicle in the plants fertilized by nitrogen this caused the high sink capacity as compared to limited respective source, therefore, the grain filling was more and consequently the grain weight was high. The promoting effects of nitrogen on 1000-grain weight were reported by [16, 31, 44]. In conformity with the results of the present experiment, [11, 22] had reported grain weight is a genetically controlled trait, which is greatly influenced by environment during the process of grain filling, but it also appeared that the application of N increased the protein percentage, which in turn increased the grain weight.

3.7. Grain Yield

Grain yield of rice in Fogera area exhibited very highly significantly ($P<0.001$) responded to the main effect of nitrogen rates but not by phosphorous rates and their interaction. The highest grain yield (4.76 ton /ha) was obtained at nitrogen rate of 184 kg ha^{-1} N followed by nitrogen rates of 276 and 368 kg N ha^{-1} (4.62 and 4.57 ton /ha), respectively, which was statistically similar. (Table 2). While the lowest grain yield (2.15 t/ha) was recorded at the control without N application (Table 2). On the other hand, the analysis of variance in Achefer indicated that grain yield was very highly significantly ($P<0.001$) affected by the main effects of nitrogen and phosphorous fertilizer rates but significantly ($P<0.05$) affected by the interaction of the two (Table 3). Among the nitrogen rates the highest grain yield (6.56 ton/ha) was obtained at nitrogen rate of 184 kg ha^{-1} N, followed by 276 and 368 kg ha^{-1} N (6.23 and 5.23 ton/ha), respectively, while the lowest was noticed at 0 kg ha^{-1} N. In the case of the phosphorous rates, the highest grain yield (5.79 ton/ha) was exhibited at 46 kg ha^{-1} P_2O_5 (Table 3). With regard to the interaction effect, the highest grain yield was obtained at 184-46 N-P_2O_5 kg ha^{-1} (Table 3). The result indicated that the highest grain yield obtained might be attributed to the highest number of productive tillers, number of fertile grains per panicle, panicle length, 1000 grain weight and plant height that cumulatively increased the grain yield. Nitrogen and phosphorus are fundamental to crop development because they form the basic component of many organic molecules, nucleic acids and proteins [48]. The increase in the grain yield in response to nitrogen and phosphorus fertilizer could be attributed to the production of more productive tillers and fertile panicle numbers [2]. The results agree with the finding of [1]. The higher grain yield may be attributed due to better growth with higher nutrient availability and higher photosynthetic rate of the plants and more photosynthate partitioning into the reproductive parts. Different authors reported that nitrogen application increase the grain yield and largest values recorded at the nitrogen application treatment of 209- 220 kg N ha^{-1} [7, 10, 15]. A bit differently, [26] reported highest mean grain yield of 10.5 t ha^{-1} at 300 kg ha^{-1} N treatment elaborating that as the N rates increased to 360 kg ha^{-1}; mean grain yield decreased to 9.4 t ha^{-1}. Optimum fertilizer level plays an important role in achieving crops potential yield. Among the fertilizer, N is most important for proper growth and development of rice [39]. The increase in grain yield might be due to nitrogen application enhancing the dry matter production, improving rice growth rate, promoting elongation of internodes and activity of growth hormones like gibberellins [15] Rice grain yield is determined by several agronomic characters such as heading days, days to maturity, grain filling period, number of productive tillers, number of fertile grains per panicle, panicle length, 1000 grain weight and plant height [18].

3.8. Straw Yield

The result of the analysis of variance on rice straw yield in Fogera area was very highly significantly ($P<0.001$) affected by the main effect of Nitrogen rates but not by phosphorous rates and their interaction. (Table 2) Significantly higher straw yield (12.1 ton /ha) was obtained from maximum nitrogen rate of (368 kg/ha N) followed by 276 and 184 kg/ha N (11.9 and 11.8 ton/ha) respectively which was statistically similar. The lowest straw yield (5.54 ton/ha) were recorded from Zero N application (Table 2). In Achefer rice straw yield was very highly significantly ($P<0.001$) affected by the main effect of nitrogen and phosphorous rates but not by their interaction (Table 3) Significantly higher straw yield (16.76 ton /ha) was obtained from nitrogen rate of (184 kg/ha N) followed by 276 and 368 kg/ha N (16.47 and 16.31 ton/ha) respectively which was statistically similar. The lowest straw yield (5.30 ton/ha) were recorded from Zero N application (Table 3). This result might be due to the application of nitrogen fertilizer rate according to crop requirement increased the nitrogen absorption, consequently better utilization of applied nitrogen leads to higher yield attributes and finally resulted in higher grain and straw yields. Moreover, larger plant height, a greater number of total tillers per row meter length and greater panicle length might have contributed to increase in straw yield. This is in agreement with [29] who stated better straw yield could be explained as higher capability of rice to utilize more N through the expression of better growth by accumulating more plant dry biomass. The better grain and straw yields at the higher rates of N and P nutrients may be attributed to the fact that application of fertilizer may have resulted in optimum levels of nutrients for crop uptake and translocation to sink thereby expressing superior crop growth and development [38]. In support of the present finding, [25] stated that the grain and straw yields of rice increased up to application of 150:75 N-P_2O_5 kg ha^{-1}. [30] had also reported that the grain and straw yields of upland rice were significantly affected and best at 60 N and 35 kg P kg ha^{-1}.

3.9. Harvest Index

Harvest index was computed as the ratio of grain yield to the total above ground dry biomass yield. As revealed in the analysis of variance harvest index in Achefer Condition responded very highly significantly (P<0.001) affected by the main effect of nitrogen fertilizer rates but not by phosphorous. There is also a significant (P<0.05) difference observed from the interaction of Nitrogen and Phosphorus fertilizer (Table 3). The highest harvest index, among the nitrogen rates was recorded at 184 kg ha^{-1} N and the lowest Harvest index was recorded at 368 kg ha^{-1} N followed by 276 kg ha^{-1} N (Table 3) Harvest index in rice is closely related to the percentage or number of productive tillers. This result is in agreement with [46]) HI is a useful index in evaluating treatment effects in partitioning photo assimilates into grain within a given environment. [9] reported that HI changes with cultivar and with the environmental conditions during the reproductive growth stage. HI is an important plant trait for improving grain yield in cereals [9]. Furthermore, higher nitrogen use efficiency has also been observed in rice cultivars with high harvest index [8]. The HI values of modern crop cultivars are commonly higher than old traditional cultivars for major field crops [3]. Kebebew Assefa et al. [23] reported that upland rice yield can be significantly improved with developing genotypes of higher grain harvest index.

Table 2*. Two years 2020/21 and 2021/22 combined analysis of N and P fertilizer rates on yield and yield components of Shaga rice variety in Fogera plain.*

N level	Ph (cm)	Pl (cm)	Nfg/p	Nt/rml	Nfp/rml	Tgw (g)	Agy (t/ha)	Sy (t/ha)	Hi (%)
0	86.3c	16.7c	78b	70c	68c	22.2c	2.15c	5.54c	39.1
92	102.3b	17.9bc	97a	80b	77b	22.8cb	3.48b	9.22b	37.9
184	117.5a	19.1ba	101a	79b	78b	26.4a	4.76a	11.88a	40.1
276	119.7a	19.0ba	103a	88a	86a	27.6a	4.62a	11.97a	38.8
368	121.9a	19.8a	109a	85ba	84ba	24.4b	4.57a	12.13a	37.6
LSD (5%)	***	***	**	**	***	***	***	***	NS
P levels									
0	108.5	18.6	99ba	77	75b	24.8	3.77	9.64	38.7
23	110.1	18.5	93b	83	81ba	24.8	3.91	9.99	39.4
46	108.0	18.3	108a	80	78ba	24.6	3.87	10.29	38.1
92	111.6	18.6	91b	82	80a	24.4	4.11	10.68	38.6
LSD (5%)	NS	NS	*	NS	*	NS	NS	NS	NS
N*P	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	8.80	12.19	25.69	16.25	16.10	12.18	21.4	19.7	9.71

Table 3*. Two years 2020/21 and 2021/22 combined analysis of N and P fertilizer rates on yield and yield components of Shaga rice variety in Achefer plain.*

N level	Ph (cm)	Pl (cm)	Nfg/p	Nt/rml	Nfp/rml	Tgw (g)	Agy (t/ha)	Sy (t/ha)	Hi (%)
0	76.6c	15.2b	87c	77c	69c	21.7c	1.83c	5.30c	35.4b
92	88.6b	15.6b	97c	99b	93b	23.9b	4.77b	12.06b	38.9a
184	97.7a	17.3a	106a	107ba	101ba	27.1a	6.56a	16.76a	39.4a
276	100.2a	17.4a	106a	112a	107a	26.3a	6.23a	16.47a	38.0a

N level	Ph (cm)	Pl (cm)	Nfg/p	Nt/rml	Nfp/rml	Tgw (g)	Agy (t/ha)	Sy (t/ha)	Hi (%)
368	98.5a	17.9a	111a	111ba	104ba	24.7b	5.23b	16.31a	32.5c
LSD (5%)	***	***	**	***	***	***	***	***	***
P levels									
0	80.6b	16.4	107	93b	85b	24.0b	3.43c	9.20c	37.4
23	94.7a	16.9	100	105a	100a	25.0ba	4.95b	13.15b	37.0
46	95.3a	16.7	101	97ba	93ba	25.6a	5.79a	15.50a	37.1
92	98.6a	16.6	97	108a	102a	24.3b	5.52ba	15.68a	35.9
LSD (5%)	***	NS	NS	*	*	**	***	***	NS
N*P	NS	NS	NS	NS	NS	NS	*	NS	*
CV (%)	16.9	6.17	20.0	22.2	21.9	7.85	24.2	25.1	10.6

Ph = plant height (cm), Pl = panicle length (cm), Nt/rml =Number of tillers per row meter length, Nfp/rml= number of fertile panicle/row meter length^2, Nfg/p= number of filled grain per panicle, Agy =Adjusted grain yield (t ha^{-1}), Sy = straw yield (t ha^{-1}), Tgw=thousand grain weight (g), Hi= harvest index (%), *** = very highly significant at P<0.001, highly significant at P<0.01 * = significant at P<0.05, ns = not significant at P≥0.05

3.10. Economic Analysis or Partial Budget Analysis

Based on the principles of economic analysis [4], the minimum acceptable marginal rate of return (MRR%) should be 100%. The economic analysis was done on the basis of the prevailing prices of variable costs using the Ethiopian currency (Birr). The price of NPS and Urea fertilizer was 42.25 and 31.94 Birr per kg respectively. Moreover, the price of rice straw valued birr 15.00 per kg. In addition to this, the prices of seed for planting material during the cropping season were 16.00 birr per kg. Grain and straw yield adjustments, calculations of total variable costs (TVC), gross benefits (GB) and net benefits (NB) were performed (Tables 4 and 5) Dominance analysis was performed after arranging the treatments in their order of TVC (Tables 6 and 7). Treatments are considered as dominated if it has higher TVC but lower NB than a previous treatment with lower TVC and higher NB (Tables 6 and 7). Non dominated treatments were taken out and marginal rate of return (MRR) was computed (Tables 8 and 9). The economic analysis of the result of this experiment revealed that Highest NB (Birr 74430.00/ha^{-1} and 115994.28) with acceptable level of MRR (402.47 and 477.4) was observed at 184-46 N-P_2O_5 kg/ha in Fogera and Achefer respectively (Tables 8 and 9). In agreement to the present finding [51] reported that rice genotypes performed efficiently at 120 kg N + 90 kg P_2O_5 ha^{-1} where highest paddy yield, net production value and profit were obtained.

Table 4. *Results of grain and straw yield adjustments, total variable cost, gross and net benefit analysis at Fogera.*

N kg/ha	P_2O_5 kg/ha	GY (t/ha)	AGY (t/ha)	SY (t/ha)	ASY (t/ha)	GB (Birr/ha)	TVC (Birr/ha)	NB (Birr/ha)
0	0	2.19	1.97	5.87	5.28	39445.0	0.0	39445.0
0	23	2.25	2.03	5.67	5.10	40072.2	2212.5	37859.7
0	46	1.94	1.74	4.87	4.38	34450.0	4425.0	30025.0
0	92	2.23	2.01	5.74	5.17	39879.6	8850.0	31029.6
92	0	3.64	3.27	9.42	8.48	65105.9	6388.0	58717.9
92	23	3.55	3.20	9.75	8.78	64334.2	8267.8	56066.4
92	46	3.41	3.07	9.09	8.18	61420.4	10147.6	51272.8
92	92	3.31	2.98	8.63	7.77	59330.0	13907.2	45422.8
184	0	4.40	3.96	10.88	9.79	77994.5	12776.0	65218.5

N kg/ha	P_2O_5 kg/ha	GY (t/ha)	AGY (t/ha)	SY (t/ha)	ASY (t/ha)	GB (Birr/ha)	TVC (Birr/ha)	NB (Birr/ha)
184	23	4.57	4.11	11.62	10.46	81520.7	14655.8	66864.9
184	46	5.12	4.61	12.74	11.46	90966.1	16535.6	74430.5
184	92	4.95	4.45	12.28	11.05	87803.6	20295.2	67508.5
276	0	4.60	4.14	11.45	10.31	81769.4	19164.0	62605.4
276	23	4.41	3.97	11.01	9.91	78367.9	21043.8	57324.1
276	46	4.13	3.72	11.98	10.78	75684.1	22923.6	52760.5
276	92	5.32	4.79	13.43	12.09	94718.3	26683.2	68035.1
368	0	4.00	3.60	10.59	9.53	71863.8	25552.0	46311.8
368	23	4.79	4.31	11.88	10.69	84944.7	27431.8	57512.9
368	46	4.74	4.26	12.76	11.49	85460.2	29311.6	56148.6
368	92	4.76	4.29	13.29	11.96	86511.1	33071.2	53439.9

Nitrogen (kg ha^{-1}); P_2O_5 = Phosphorous rate (kg ha^{-1}); TVC = Total variable cost (Birr ha^{-1}) GY, grain yield (t ha^{-1}) AGY = Adjusted grain yield (ton ha^{-1}); SY = straw yield (ton ha^{-1}) ASY = Adjusted straw yield (ton ha^{-1}); GB = Gross benefit (Birr ha^{-1}); NB = Net benefit (Birr ha^{-1})

Table 5. *Results of grain and straw yield adjustments, total variable cost, gross and net benefit analysis at Achefer.*

N kg/ha	P_2O_5 kg/ha	GY (t/ha)	AGY (t/ha)	SY (t/ha)	ASY (t/ha)	GB (Birr/ha)	TVC (Birr/ha)	NB (Birr/ha)
0	0	1.60	1438.74	4.12	3711.6	28587.2	0	28587.2
0	23	1.75	1570.59	5.24	4716	32203.4	2212.5	29990.9
0	46	1.82	1641.69	5.38	4841.1	33528.7	4425	29103.7
0	92	2.15	1935.36	6.46	5814.9	39688.1	8850	30838.1
92	0	3.29	2956.95	9.38	8445.6	59979.6	6388	53591.6
92	23	4.03	3628.62	10.68	9614.7	72480	8267.79	64212.2
92	46	6.50	5846.22	15.33	13796.1	114234	10147.6	104086
92	92	5.28	4748.4	12.86	11574.9	93336.8	13907.2	79429.6
184	0	4.69	4221.09	11.68	10515.6	83310.8	12776	70534.8
184	23	6.83	6150.15	17.24	15515.1	121675	14655.8	107019
184	46	7.41	6669.36	19.13	17213.4	132530	16535.6	115994
184	92	7.29	6559.47	19.00	17101.8	130604	20295.2	110309
276	0	4.40	3959.1	10.86	9775.8	78009.3	19164	58845.3
276	23	6.66	5993.64	17.46	15714	119469	21043.8	98425.5
276	46	6.56	5902.29	17.99	16186.5	118716	22923.6	95792.8
276	92	7.31	6575.22	19.57	17614.8	131626	26683.2	104943
368	0	3.16	2844.18	9.96	8961.3	58948.8	25552	33396.8
368	23	5.46	4912.83	15.12	13610.7	99021.3	27431.8	71589.5
368	46	6.68	6014.61	19.66	17690.4	122769	29311.6	93457.8
368	92	5.60	5041.26	20.49	18438.3	108318	33071.2	75246.5

Table 6. *Result of Dominance analysis at Fogera.*

N kg/ha	P_2O_5 kg/ha	TVC	NB	Dominance
0	0	0	39445	
0	23	2213	37860	D
0	46	4425	30025	D
92	0	6388	58718	
92	23	8268	56066	D
0	92	8850	31030	D
92	46	10148	51273	D
184	0	12776	65219	
92	92	13907	45423	D
184	23	14656	66865	
184	46	16536	74430	
276	0	19164	62605	D
184	92	20295	67508	D
276	23	21044	57324	D
276	46	22924	52760	D
368	0	25552	46312	D
276	92	26683	68035	D
368	23	27432	57513	D
368	46	29312	56149	D
368	92	33071	53440	D

N = Nitrogen rates (kg ha^{-1}); P2O5= Phosphorous rates (kg ha^{-1}); TVC= Total variable cost (Birr ha^{-1}); GB = Gross benefit (Birr ha^{-1}); NB = Net benefit (Birr ha^{-1}) D = Dominance.

Table 7. *Result of Dominance analysis at Achefer.*

N kg/ha	P_2O_5 kg/ha	TVC	NB	Dominance
0	0	0.00	28587.24	
0	23	2212.50	29990.94	
0	46	4425.00	29103.69	D
92	0	6388.00	53591.60	
92	23	8267.79	64212.18	
0	92	8850.00	30838.11	D
92	46	10147.58	104086.09	
184	0	12776.00	70534.84	D
92	92	13907.16	79429.59	D
184	23	14655.79	107019.26	
184	46	16535.58	115994.28	

N kg/ha	P_2O_5 kg/ha	TVC	NB	Dominance
276	0	19164.00	58845.30	D
184	92	20295.16	110309.06	D
276	23	21043.79	98425.45	D
276	46	22923.58	95792.81	D
368	0	25552.00	33396.83	D
276	92	26683.16	104942.56	D
368	23	27431.79	71589.54	D
368	46	29311.58	93457.78	D
368	92	33071.16	75246.45	D

Table 8. Result of Marginal Rate of Return (MRR) Analysis at Fogera.

N kg/ha	P_2O_5 kg/ha	TVC	NB	MRR
0	0	0	39445	
92	0	6388	58718	301.7
184	0	12776	65219	101.76
184	23	14656	66865	87.58
184	46	16536	74430	402.47

Table 9. Marginal Rate of Return (MRR) Analysis at Achefer.

N kg/ha	P_2O_5 kg/ha	TVC	NB	MRR
0	0	0	28587	
0	23	2213	29991	63.44
92	0	6388	53592	565.2
92	23	8268	64212	565
92	46	10148	104086	2121
184	23	14656	107019	65.06
184	46	16536	115994	477.4

N = Nitrogen rates (kg ha^{-1}); P_2O_5 = Phosphorous rates (kg ha^{-1}); TVC= Total variable cost (Birr ha^{-1}); GB = Gross benefit (Birr ha^{-1}); NB = Net benefit (Birr ha^{-1}) MRR% = Marginal rate of return.

4. Conclusion and Recommendation

The growth, yield components and yield of shaga rice variety responded more to nitrogen than phosphorus fertilizer. In this study, number of panicles per row meter length, and number of filled spikelets per panicle as well as panicle length were the most important yield forming attributes causing significant variation in grain yield of rice. Panicle length contributed to grain yield increment indirectly by increasing the number of spikelets per panicle. The results of two years experiment indicated that combined application of 184-46 N-P_2O_5 kg ha^{-1} is the best treatment giving higher productivity and economic profitability. From the findings of the present experiment, highest mean net benefit of (Birr

74430.00 and 115994 ha^{-1}) was obtained from nitrogen and phosphorous fertilizers at rates of 184-46 N- P_2O_5 kg ha^{-1} in Fogera and Achefer district respectively. It is thus concluded that application of nitrogen and phosphorous fertilizers at rates of 184-46 N P_2O_5 kg ha^{-1} is the best recommended for rainfed lowland Shaga rice variety in Fogera plain and other similar agro-ecologies.

Abbreviations

CIMMY	International Maize and Wheat Improvement Center
CSA	Central Statistical Agency
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
MoARD	Ministry of Agriculture and Rural Development
NADoA	North Achefer District Office of Agriculture

Author Contributions

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Conflicts of Interest

The authors declare no conflicts of interest.

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