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Research article

Biological and Economic Response of Rice to Nitrogen and Phosphorous fertilizer applications under Rainfed lowland Production Ecology

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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 t ha^{-1}. Soil nutrient deficiencies are among the major yield limiting factors of the rice production. In order to recommend appropriate rate of soil nutrients, nitrogen and phosphorous fertilizers application experiment was conducted on rainfed lowland rice production at Fogera plain in two cropping seasons of the years 2016 and 2017. The treatments were comprised of factorial combinations of five nitrogen (0,92,184, 276 and 368 kg ha^{-1}) and four phosphorous levels (0, 23, 46, and 69 P_2O_5 kg ha^{-1}). Data was collected on plant height, panicle length, number of total tillers/m, number of effective tillers/m, panicle length, number of fertile spiklets/panicle, thousand seeds weight, grain yield, straw yield and harvest index. All collected data were subjected to analysis of variance. Economic analysis was also carried out by following CIMMYT partial budget analysis procedures. The results of the experiment indicated that the main effect of nitrogen application was significantly affecting plant height, panicle length, total tillers/m, effective tillers/m, filled spiklets/panicle, grain yield, straw yield, thousand seeds weight and harvest index while phosphorous was affecting only grain and straw yields. The interaction of nitrogen and phosphorous was affecting grain yield, straw yield and harvest index. With respect to the interaction effect, the highest grain yield (7.0 t ha^{-1}) was obtained at 276-69 N- P_2O_5 kg ha^{-1}. The economic analysis has exhibited that the combined application of 184-46 N- P_2O_5 kg ha^{-1} is the most profitable treatment. 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 rice production in Fogera plain and other similar agroecologies.

Key Words: Lowland rice; Nitrogen; Phosphorous; profitable.

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INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most popular cereal crops in the world. It is the most important food crop for the world's population, especially in South Asia, Middle East, Latin America and West India (Zhao *et al*., 2011). More than 90% of rice is produced and consumed in Asia (Subedi *et al*, 2019). It provides some 700 calories per person, mostly residing in developing countries. In Ethiopia, rice production was started three decades ago in the early 1970's and the country has reasonable potential to grow various rice types mainly in rain fed lowland, upland and irrigated ecosystems (Mulugeta and Heluf, 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 2019). The area coverage in domestic rice production has increased considerably linked with expansion of production in the wetland and upland areas with the introduction of suitable rice varieties for the different agro-ecologies. In line with the area expansion, the production levels have been increasing consistently over years. CSA (Central Statistical Authority) data indicate that rice production increased from 71,316.07 tons in 2008 to 171,854.1 tons in 2018. The number of farmers engaged in rice production has also grown year after year. Rice production has brought a significant change in the livelihood of farmers and created job opportunities for a number of citizens in different areas of the country. Currently, Amhara, Southern Nations, Nationalities and Peoples Region (SNNPR), Oromiya, Somali, Gambella, BeniShangul Gumuz, and Tigray regions are the rice producing areas in Ethiopia (MoARD, 2010). The Amhara region takes the lion's share of producing the crop and accounted for 65-81% of the area coverage and 78-85% of the production in the years 2016-2018 (CSA 2017, CSA 2018 and 2019). According to the report of MoARD (2010), the potential rice production area in Ethiopia is estimated to be over 5,590,895 ha. Most of Ethiopia's rice production potential area lies in the western part of the country.

The national average yield of rice is about 2.8t ha^{-1} (CSA, 2018) which is lower compared to the world average productivity of 4.6 tones ha^{-1} (FAOSTAT, 2018). Weeds, pests, soil nutrient deficiencies and terminal moisture stress are the major causes of low rice productivity in Ethiopia (MoARD, 2010; Gebey *et al*., 2012). 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 nutrient leads to yield losses (Subedi *et al*, 2019). Nitrogen and phosphorus are often cited as the most limiting nutrients in agricultural soils of Ethiopia (Molla and Sofonyas, 2018). 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 (ShaRada *et al*., 2018; Daquiado, 2019). Therefore, a fertilizer experiment was conducted on the lowland rice production of Fogera Plain in order to recommend appropriate levels of nitrogen and phosphorous rates.

MATERIALS AND METHODS

A rainfed lowland nitrogen and phosphorous rates experiment was conducted at Fogera plain in two cropping seasons of the years 2017 and 2018 cropping seasons. The experimental site is located between Latitude 11°49'55 North and Longitude 37° 37′ 40 East at an altitude of 1815 meters above sea level. The study site receives averages mean annual rainfall, minimum and maximum temperature of 1219 mm, 12.75°C and 27.37°C, respectively. The long-term rainfall data (1986-2017) years indicated that much of the rainfall appear in July and August (Figure 1).

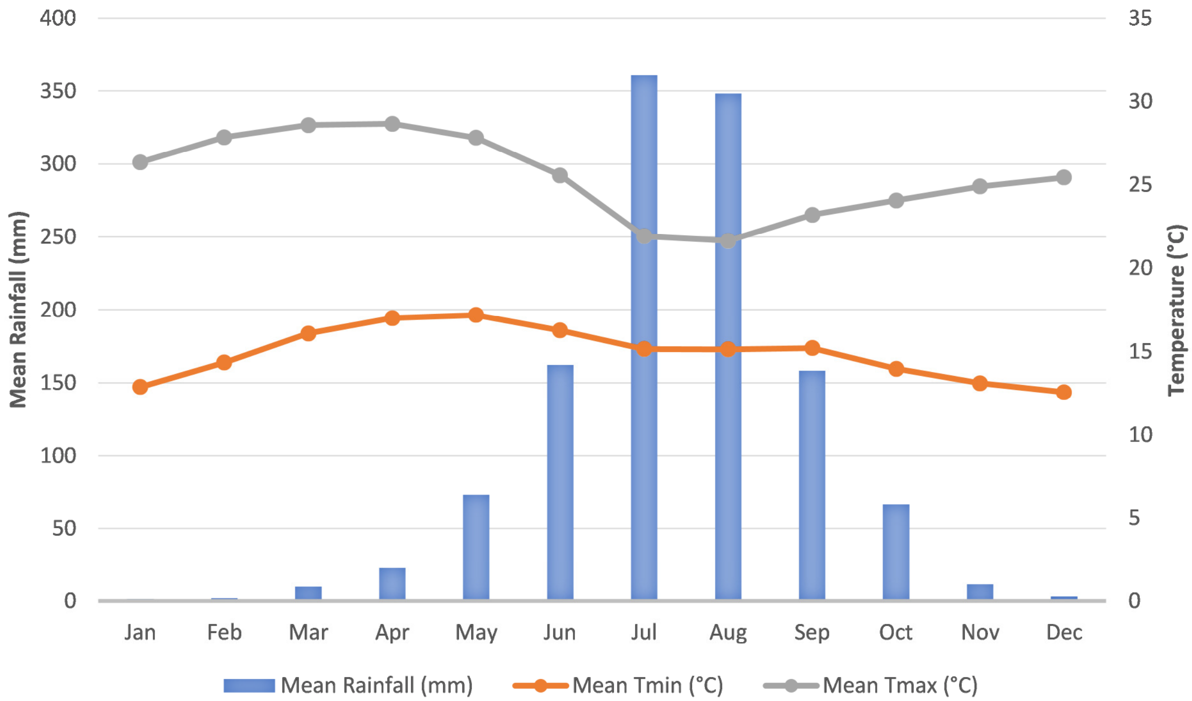


Figure 1. The Rainfall and Temperature condition of Fogera Plain for the period 1981-2017

The experimental sites soil was found to be heavy clay with pH range of 5.87-6.63, which is slightly acidic and it is a preferred range for most crops (Table 1). Total nitrogen content (%) was with range of 0.09-0.16, which is within the range of low levels (0.02-0.5%) for tropical soils. The organic matter content of the soil was between 2.13-3.09%, which is within a range of medium (2-4%) for Ethiopian soils as per criteria developed by Murphy (1968). The available P content of the experimental sites soil was 11.4-25.13 ppm, which lies in a range of deficiency (< 20-40mg/kg) for most crops (Landon, 1991).

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

Soil properties	Units	Minimum Value	Maximum value
Textural class		Heavy clay	Heavy clay
Chemical properties			
pH (H_2O) 1:2.5 g soil	-	5.87	6.63
Total nitrogen (TN)	%	0.09	0.16
Organic carbon (OC)	%	1.24	1.93
Organic matter (OM)	%	2.13	3.09
Available Phosphorus	Ppm	11.4	25.13

The experimental treatments were comprised of factorial combinations of five nitrogen (0,92,184, 276 and 368 kg ha^{-1}) and four phosphorous levels (0,23,46 and 69 P_2O_5 kg ha^{-1}) in randomized complete block design (RCBD) treatments replicated three times. The gross size of plots was 2m x 4m consisting of 10 rows planted at a spacing of 20 cm apart with seed rate of 100kg ha^{-1}. The net plot was made by excluding the left and right outer rows and a plot length of 0.5 m from the top and bottom sides of the plot. The final net plot size was thus 1.6m x 3m. Data was collected from the net plot area on plant height, number of total tillers/m, number of effective tillers/m, number of filled spiklets/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 tillers. Number of tillers was counted just before harvesting by random sampling using rulers. The total sundried biomass of the harvested rice was recorded before threshing. The harvest index was calculated as the ratio of grain yield to biological yield following the equation:

$$Harvest\ index = \frac{Economic\ yield}{Biological\ yield}\ X\ 100$$

The rice grain yield and thousand seeds weight were adjusted at 14% standard moisture content. All collected data were subjected to analysis of variance (ANOVA) using SAS software version 9.2 (SAS-Institute, 2008). Since the test of homogeneity of variances for each parameter was non-significant, combined analysis of variance was done over the years to determine the effects of N and P application rates by year interaction. Wherever treatment differences are be found significant, mean separation of treatments would be calculated based on results of F-test and probability levels of 0.01 and 0.05 depending the results of the ANOVA.

Agronomic efficiency (AE) was calculated to assess the efficiencies of the applied N rates as follows:
AE= (Gf - Gu / Na) kg rice grain/ kg N fertilizer applied

Where Gf is the grain yield of the fertilized plot (kg), Gu is the grain yield of the unfertilized plot (kg), and Na is the rate of applied N fertilizer (kg) (Liu *et al*,. 2019).

Economic analysis was carried out by following CIMMYT (1988) procedures by taking all variable costs. The prevailing cost of inputs and out puts in year 2019 considered for the analysis. The cost of Urea and NPS fertilizers for the stated period at Fogera were Birr 13.1 and 14.3, respectively while the price of rice grain and straw were Birr 13.5 and 1.2, respectively.

RESULT AND DISCUSSION

The analysis of variance indicated that the main effect of nitrogen was highly significantly ($P<0.01$) affecting plant height, panicle length, total tillers/m, effective tillers/m, filled spiklets/panicle, grain yield, straw yield, thousand seeds weight and harvest index (Table 2). The coefficient of variation (CV%) for all parameters, is within the acceptable level for field experiments (Gomez and Gomez, 1984). On the other hand, phosphorous was highly significantly ($P<0.01$) affecting grain and straw yields (Table 3). The interaction of nitrogen and phosphorous applications was highly significantly ($P<0.01$) affecting grain and straw yields and significantly ($P<0.05$) affecting harvest index (Table 3).

The comparison of the nitrogen rates indicated that the highest values of plant height (109.0 cm), panicle length (20.9 cm) number of total tillers/m (82.1), number of effective tillers/m (80.7), number of filled spiklets per panicle (102.9) were exhibited at the highest rate of 368 kg ha^{-1} N (Table 3). In line with the present findings, Sah *et al.*, (2019) 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 Nha^{-1}. The findings of many authors had confirmed for the significant effect of nitrogen levels on panicle length (Fageria and Baligar, 2001; Gewaily *et al.*, 2018; Sah *et al.*, 2019). Sah *et al.*, (2019) recorded highest panicle length with 180 kg N application while Fageria and Baligar, (2001) stated nitrogen application of 210 kg ha^{-1} exhibited larger panicle length. In conformity of the present experiment, Fageria and Baligar, (2001), Dong *et al.*, (2016) and Sah *et al.*, (2019) similarly concluded that nitrogen application significantly increases the total tillers number. Sah *et al.*, (2019) obtained the highest total tillers for N at 120 kg ha^{-1} while Dong *et al.*, (2016) 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 (Fageria and Baligar, 2001). Gewaily *et al.*, (2018) reported that fertile tillers of rice were increased significantly with increasing nitrogen levels from 0 to 220 kg N ha^{-1}. Many authors reported for the significant response of number of fertile spiklests per panicle to nitrogen application confirming the current observation Fageria and Baligar, (2001), Wang *et al.*, (2017), Gewaily *et al.*, (2018) and Liu *et al*,. (2019). Maximum number of fertile spiklets per panicles were observed at N rates of 210-220 Kg ha^{-1} by Fageria and Baligar, (2001) and Gewaily *et al.*, (2018).

Concerning the yields, the highest straw yield (21.7 t ha^{-1}) was obtained at the highest rate of 368 kg N ha^{-1} while the highest grain yield (5.99 t ha^{-1}) was exhibited at the 276 kg N ha^{-1} rate, and the highest the thousand seeds weight (29.0 g) was at 184 kg N ha^{-1} (Table 3). Quite differently, the highest harvest index (34.51%) was observed at the no (0kg N ha^{-1}) N rate (Table 3). The lower values for the respective parameters except for the harvest index were recorded at no (0kg N ha^{-1}) N application. In the case of the harvest index, the lowest score was at the maximum (368 kg N ha^{-1}) nitrogen rate (Table 3). Similar to the observations made at the study, Sah *et al.*, (2019) reported for significant effect of N on straw yield mentioning that it was highest at N application of 180 kg ha^{-1}. Reporting significant responses of grain yield to N application, some authors observed highest rice grain yields at rates nearer to the current higher yielding rate. Different authors reported that nitrogen application increase the grain yield and largest values recorded at the nitrogen application treatment of 209-220kg N ha^{-1} (Fageria and Baligar, 2001, Dong *et al.*, 2016, Gewaily *et al.*, 2018). A bit differently, Liu *et al*,. (2019) 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 (Sah *et al.*, 2019). 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 (Gewaily *et al*., 2018).

The only growth parameters which were significantly responding to the main effects of phosphorous application are grain and straw yields (Table 2). The highest grain (5.20 t ha^{-1}) and straw (15.2 t ha^{-1}) yields were obtained at the highest phosphorous (69 kg P_2O_5 ha^{-1}) rate (Table 4). The non-phosphorous application (0 kg P_2O_5 ha^{-1}) gave the lowest grain (4.00 t ha^{-1}) and straw (12.58 t ha^{-1}) yields. The increase in P levels resulted in higher rice productivity (90 >60 > 30 > 0kg P ha^{-1}) (Amanullah *et al*., 2016). 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 (Amanullah *et al*., 2016). The response curve revealed that the grain yield of rice showed a declining trend after the application of 276 kg N ha^{-1} while the yield had a linear response to the phosphorous application and the maximum yield occurred at the maximum rate of 69 kg P_2O_5 ha^{-1} (Figure 2). This indicate that future rice fertilizer experiments in Fogera plain shall consider higher rates of phosphorous.

As revealed in the analysis of variance (Table 5), the grain yield, straw yield and harvest index responded significantly to the interaction effects of nitrogen and phosphorous (Table 2). The comparison to the grain yield indicated that the highest (7.00 t ha^{-1}) was gained at the combination of 276-69 N-P_2O_5 kg ha^{-1} which is statistically at par with the yields recoded at 368-69, 368-46, and 184-46 N- P_2O_5 kg ha^{-1} applications (Table 5). The lowest grain yield was at nill (0-0 N-P_2O_5 kg ha^{-1}) which is statistically equivalent with that of 0-23, 0-46, 0-69 N- P_2O_5 kg ha^{-1} applications (Table 5). Regarding the straw yield, the highest (23.16 t ha^{-1}) was gained at the combination of 276-69 N-P_2O_5 kg ha^{-1} which is statistically at par with the straw yields shown at 368-69, 368-46, 184-46 and 368-23 N-P_2O_5 kg ha^{-1} applications (Table 5). The lowest straw yield of 4.11 t ha^{-1} was exhibited at no (0-0 N-P_2O_5 kg ha^{-1}) application which is statistically at par with that of 0-23, 0-46, 0-69 N-P_2O_5 kg ha^{-1} applications (Table 5). Management of soil fertility largely determines the availability of N and P for crop plants (Iqbal *et al*., 2017). Mineral nutrition in rice requires 16 essential elements of which nitrogen (N), phosphorus (P) and potassium (K) are applied to rice fields as chemical fertilizers in large quantities (Vinod and Sigrid, 2012). Nitrogen and P are fundamental to crop development because they form the basic component of many organic molecules, nucleic acids and proteins (Vinod and Sigrid, 2012).

The harvest index values comparison showed that the highest (23.16 t ha^{-1}) was gained at 0-0 N- P_2O_5 kg ha^{-1} which is statistically similar with the indices shown at 0-23, 0-46, 0-69 N- P_2O_5 kg ha^{-1} applications (Table 5). The lower harvest indices were associated with the combinations of the higher nitrogen and any of the phosphorous rates, the lowest (23.04 %) being at 276-69 N- P_2O_5 kg ha^{-1} (Table 5).

The analysis of the Agronomic Efficiency (AE) for the nitrogen indicate that the maximum AE of 15.43 was exhibited at 92 Kg ha^{-1} N (Table 6). As the N rate increased the AE was decreasing and finally a negative value of AE (-0.87) was recorded to the maximum (368 kg ha^{-1}) N application. AE N is usually higher at low N rate than at high N rate (Gewaily *et al*., 2018, Yasuhiro *et al*., 2019). In tropical Asia, with proper crop and water management, AEN should be typically in the range of 20-25 kg kg^{-1} (Yasuhiro *et al*., 2019). Yoshida (1981) estimated better agronomic N use efficiency to be 15-25 kg rough rice per kg applied N in the tropics. Peng *et al*., (2010) reported that agronomic N use efficiency was 15 to 18 kg kg^{-1} N in the dry season in the farmers' fields in the Philippines. In China, agronomic N use efficiency was 15-20 kg kg^{-1} N from 1958 to 1963 and declined to only 9.1kg kg^{-1} between 1981 and 1983 (Peng *et al*., 2010). Since then, agronomic N use efficiency has further decreased in China because of the increase in N rate (Peng *et al*., 2010). Generally, fertilizer N use efficiency of lowland rice is relatively low due to loss of applied N through leaching, volatilization and denitrification in the soil-flood water system which necessitate the need for improved N fertilizer practices to reduce environmental impacts and increase economic benefits of N fertilization (Fageria and Baligar, 2001). The lower agronomic efficiency at the highest N rates in the current experiment indicate that emphasis should be given to efficient nitrogen application methods like the split applications, use of slow N releasing fertilizer sources and real time N management so as to reduce the wastage of N in the rice production system of the Fogera plain.

Economic management of N fertilizer application is essential for improving crop productivity, N use efficiency, and environmental sustainability (Yousaf *et al*., 2016). 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 7). Dominance analysis was carried after arranging the treatments in their order of TVC. A treatment was considered as dominated if it has higher TVC but lower NB than a previous treatment with lower TVC and higher NB. Non dominated treatments were taken out and marginal rate of return (MRR) was computed (Table 8). According the to the CIMYYT (1988) partial budget analysis methodology, treatments exhibiting the minimum or more MRR ($\geq$100%) will be considered for the comparison of their NB. Highest NB (Birr 98,111.85 ha^{-1}) with acceptable level of MRR (3499.15) was observed at 184-46 N-P_2O_5 kg/ha (Table 9). In agreement to the present finding Irfan *et al*., (2016) reported that rice genotypes performed efficiently at 120 kg N + 90 kg P2O5 ha^{-1} where highest paddy yield, net production value and profit were obtained. The combined application

Table 2. Analysis of variance (ANOVA) for rice yield and yield components

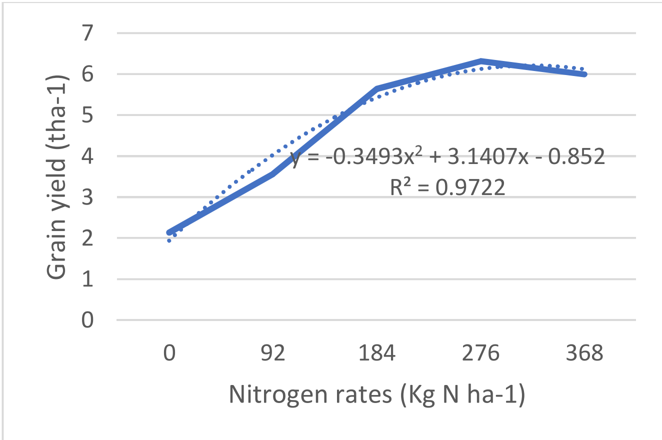
Source	DF	Plant height	Panicle length	Total no of tillers/m Mean Square	No of Effective tillers/m Row	No of Filled Spiklets/ panicle	GY (t/ha)	SY (t/ha)	Thousand seeds weight (g)	Harvest Index (%)
N	4	14080.60445**	147.9921167**	8217.03**	8186.428**	8786.166**	193.714**	3470.917**	29.374**	1231.108**
P	3	7.88670^{NS}	8.1304333^{NS}	121.959^{NS}	136.573^{NS}	411.3996^{NS}	23.651**	202.762**	4.487^{NS}	9.224^{NS}
N*p	12	27.51734^{NS}	10.6772944^{NS}	139.214^{NS}	136.192^{NS}	312.133^{NS}	3.521**	37.695**	5.24^{NS}	30.295*
Error	96	40.93543	6.291023	17918.08	189.6049	363.2424	0.304168	7.435	5.789	14.97549
CV%		6.76	12.76	18.79	19.3	22.37	11.61	18.44	7.77	14.0

Table 3. Main effect of nitrogen rates on rice yield and yield components

N (kg/ha)	Plant height (cm)	Panicle length (cm)	Total tillers number/ m	Effective tillers number/m	No of Fertile spiklets per panicle	Grain Yield (t/ha)	Straw Yield (t/ha)	Thousand seeds weight (g)	Harvest Index (%)
0	72.7D	17.0C	53.1D	51.6D	74.2C	2.14E	4.07E	30.45BC	34.51A
92	85.8C	19.5B	62.3C	60.7C	88.2B	3.56D	9.63D	30.99AB	28.45B
184	98.3B	20.2AB	71.4B	70.2B	98.6A	5.64C	17.28C	31.65A	25.64C
276	107.2A	20.6A	77.4A	75.7A	101.8A	6.31A	20.67B	30.30BC	23.91D
368	109.0A	20.9A	82.1A	80.7A	102.9A	5.99B	21.78A	29.83C	23.49D

Table 4. Main effect of Phosphorous rates on rice grain and straw yields

P_2O_5 (kg/ha)	Grain Yield (t/ha)	Straw Yield (t/ha)
0	4.00C	12.58C
23	4.59B	14.41B
46	5.14A	16.5A
69	5.20A	15.26B



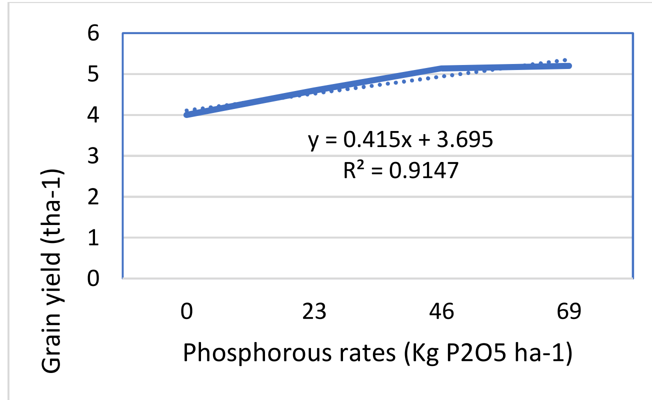


Figure 2. Response curves of rice grain yield (tha^{-1}) to nitrogen and phosphorous application levels

Table 5. Effects of N and P on Lowland Rice grain yield, straw yield and harvest index

N	P	GY (t/ha)	SY (t/ha)	HI (%)
0	0	2.09H	4.11I	33.75A
92	0	3.03G	7.10H	30.50B
184	0	4.19E	13.77F	24.86D-G
276	0	5.31D	18.65D	22.60FG
368	0	5.36D	19.29D	22.03G
0	23	2.13H	3.74I	35.99A
92	23	3.76F	10.47G	27.58CD
184	23	5.53D	16.55E	25.46DEF
276	23	6.40BC	19.57CD	24.93D-G
368	23	5.15D	21.73AB	23.07FG
0	46	2.15H	4.16I	34.33A
92	46	3.79F	10.75G	26.49CDE
184	46	6.61ABC	22.33AB	24.81D-G
276	46	6.52BC	21.37BC	25.03D-G
368	46	6.63ABC	23.90A	24.82D-G
0	69	2.20H	4.25I	33.98A
92	69	3.76F	10.22G	29.24BC
184	69	6.22C	16.45E	27.40D
276	69	7.00A	23.16AB	23.04FG
368	69	6.83AB	22.21AB	24.03EFG
CV %		11.61	18.44	14.0

Table 6. Agronomic Efficiency (AE) of rice

N (kg/ha)	Grain Yield (t/ha)	AE
0	2140	-
92	3560	15.43
184	5640	11.30
276	6310	2.43
368	5990	-0.87

Table 7. Grain and straw yield adjustments, total variable cost, gross and net benefit analysis

N	P	TVC (Birr/ha)	GY (t/ha)	SY (t/ha)	AGY (t/ha)	ASY (t/ha)	GB (Birr/ha)	NB (Birr/ha)
0	0	0	2.09	4.11	1.881	3.699	29832.3	29832.3
92	0	2620	3.03	7.1	2.727	6.39	44482.5	41862.5
184	0	5240	4.19	13.77	3.771	12.393	65780.1	60540.1
276	0	7860	5.31	18.65	4.779	16.785	84658.5	76798.5
368	0	10480	5.36	19.29	4.824	17.361	85957.2	75477.2
0	23	865.52	2.13	3.74	1.917	3.366	29918.7	29053.2
92	23	3158.03	3.76	10.47	3.384	9.423	56991.6	53833.6
184	23	5778.03	5.53	16.55	4.977	14.895	85063.5	79285.5
276	23	8398.03	6.4	19.57	5.76	17.613	98895.6	90497.6
368	23	11018.03	5.15	21.73	4.635	19.557	86040.9	75022.9
0	46	1731.05	2.15	4.16	1.935	3.744	30615.3	28884.2
92	46	3696.05	3.79	10.75	3.411	9.675	57658.5	53962.4
184	46	6316.05	6.61	22.33	5.949	20.097	104427.9	98111.8
276	46	8936.05	6.52	21.37	5.868	19.233	102297.6	93361.5
368	46	11556.05	6.63	23.9	5.967	21.51	106366.5	94810.4
0	69	2596.58	2.2	4.25	1.98	3.825	31320	28723.4
92	69	4234.08	3.76	10.22	3.384	9.198	56721.6	52487.5
184	69	6854.08	6.22	16.45	5.598	14.805	93339	86484.9
276	69	9474.08	7	23.16	6.3	20.844	110062.8	100588.7
368	69	12094.08	6.83	22.21	6.147	19.989	106971.3	94877.2

Table 8. Dominance Analysis

N	P	TVC (Birr/ha)	NB (Birr/ha)	Dominance
0.0	0.0	0	29,832.30	
0.0	23.0	865.5263	29,053.17	D
0.0	46.0	1731.053	28,884.25	D
0.0	69.0	2596.579	28,723.42	D
92.0	0.0	2620	41,862.50	
92.0	23.0	3158.026	53,833.57	
92.0	46.0	3696.053	53,962.45	
92.0	69.0	4234.079	52,487.52	D
184.0	0.0	5240	60,540.10	
184.0	23.0	5778.026	79,285.47	
184.0	46.0	6316.053	98,111.85	
184.0	69.0	6854.079	86,484.92	D
276.0	0.0	7860	76,798.50	D
276.0	23.0	8398.026	90,497.57	D
276.0	46.0	8936.053	93,361.55	D
276.0	69.0	9474.079	100,588.72	
368.0	0.0	10480	75,477.20	D
368.0	23.0	11018.03	75,022.87	D
368.0	46.0	11556.05	94,810.45	D
368.0	69.0	12094.08	94,877.22	D

Table 9. Marginal Rate of Return (MRR) Analysis

N	P	TVC (Birr/ha)	NB (Birr/ha)	MRR (%)
0.0	0.0	0	29,832.30	
92.0	0.0	2620	41,862.50	459.168
92.0	23.0	3158.026	53,833.57	2224.998
92.0	46.0	3696.053	53,962.45	23.953
184.0	0.0	5240	60,540.10	426.028
184.0	23.0	5778.026	79,285.47	3484.100
184.0	46.0	6316.053	98,111.85	3499.155
276.0	69.0	9474.079	100,588.72	78.431

of nitrogen and phosphorous at 184-46 N-P_2O_5 kg/ha is the most profitable rate to be recommended for rice production in Fogera plain.

CONCLUSION

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 tones ha^{-1}. Soil nutrient deficiencies are among the major yield limiting factors of the rice production. 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. 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 rice production in Fogera plain and other similar agroecologies.

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