Optimum Nitrogen and Phosphors Fertilizer Rates for Upland Rice Production in North Western Ethiopia

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Abstract: *The national average yield of rice is about 2.8t ha^{-1} which is lower compared to the world average productivity of 4.6 tones ha^{-1} mainly constrained by soil nutrient deficiencies. An experiment on nitrogen and phosphorous fertilizer rates was conducted on upland rice on Nerica-4 variety in Fogera and Libokemkem districts in three consecutive main cropping seasons of the years 2015, 2016 and 2017 to determine the appropriate rates for production. The treatments were comprised of factorial combinations of four nitrogen rates (0, 46, 92,138 N kg ha^{-1}) and three phosphorous rates (0, 46, 92 P_2O_5 kg ha^{-1}), and laid out in randomized complete block design (RBD) with three replications. Data were collected on plant height, panicle length, and number of total tillersm^{-2}, number of fertile panicles m^{-2}, 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 (1988) procedures. The results of the experiment indicated that the main effect of nitrogen application significantly affected plant height, panicle length, total tillers, number of fertile panicles, grain yield, and straw yield, while that of phosphorous significantly affected total tillers, number of fertile panicles and grain yield. The interaction of nitrogen and phosphorous was significantly affecting total tillers, number of fertile panicles, grain yield and straw yield. The highest grain yield (5.5 t ha^{-1}) was obtained from the interaction of 138 kg ha^{-1}N with 46 kg ha^{-1} P_2O_5. The economic analysis has further revealed that the combined application of 138 kg ha^{-1}N and 46 kg ha^{-1} P_2O_5 which gave the highest net return of Birr 68,307.5 ha^{-1} was the most profitable treatment to upland rice production. Thus it is concluded that application of nitrogen and phosphorous fertilizers at the rates of 138-46 N-P_2O_5 kg ha^{-1} is the best to be recommended for rainfed upland rice production in the study area and other similar agro-ecologies.*

Keywords: Nitrogen, Phosphorous, Productivity, Profitability, Upland rice.

1. Introduction

Rice *(Oryza sativa* L.) is an annual cereal crop and it is one of the most important food crops for the world's population, especially in South Asia, Middle East, Latin America and West India (Zhao *et al*., 2011). It is the principal food for one third of the world's population. 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, 2005). Although 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 agro-ecologies. In line with the area expansion, the production levels have been increasing consistently over years. CSA (Central Statistical Authority) data indicates that rice production has increased from 71,316.07 tons in 2008 to 171,854.09 tons in 2018 (CSA, 2019). 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 74-81% of the area coverage and 78-85% of the production in the years of 2016-2018 (CSA, 2016; CSA, 2017; CSA, 2018). According to the report of MoARD (2010), the potential rice production area in Ethiopia is estimated to be about 39,354,190 hectares, of which 5,590,895 ha is highly suitable, 24,910,629 ha are suitable and 8,852,666 are moderately suitable. Most of Ethiopia's rice production potential area lies in the western part of the country.

Upland rice could suitably grow in many parts of Ethiopia. Predominant potential areas include west central highlands of Amhara Region (Fogera, Gonder Zuria, Dembia, Takusa and Achefer), North West lowland areas of Amhara and Benshangul Regions (Jawi, Pawi, Metema and Dangur), Gambella Regional State (Abobo and Etang Woredas), South and South West Low lands of Southern Nations, Nationalities and Peoples Region (SNNPR) (Beralle, Weyito, Omorate, Gura Ferda and Menit), Somali Region (Gode), Afar and South western highlands of Oromia Region (Illubabora, East and West Wellega and Jima Zones) (Dawit, 2015). 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 t 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 (Aamer *et al.*, 2000; Sharada *et al*., 2018; Masni and Wasli, 2019; 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 (Maneesh *et al*. 2018). Unlike the rain fed lowland ecosystem, fertilizer recommendations were not developed for the rain fed upland ecosystem of the study area. Therefore, a fertilizer experiment was conducted on the upland rice production of Fogera and Libokemkem Woredas in order to recommend appropriate levels of nitrogen and phosphorous rates.

2. Materials and Methods

An experiment on nitrogen and phosphorous plant nutrients was conducted on upland rice in Fogera and Libokemkem districts in three consecutive cropping seasons of the years of 2015, 2016 and 2017on a total of twelve on farm sites. The study at Fogera area is situated at 11 °54.4'46.3"N to 11 °57'03.0"N latitude and 37 °41'23.9"E to 37 °42'32.2" E longitude at elevation range of 1787-1812 meter above sea level. The geographical location of the experimental area at Libokemkem is located at 12º 1′ 30″ N to 12º 12′ 00″ N latitude and 37º 31′ 30″ E to 37º 52′ 30″ E longitudes with the altitude range of 1804 to 1910 meter above sea level. The study site receives mean annual rainfall of1219 mm with annual average minimum and maximum temperature of 12.75°C and 27.37°C, respectively. The long-term rainfall data (1986-2017) indicated that much of the rainfall occurs in July and August (Figure 1).

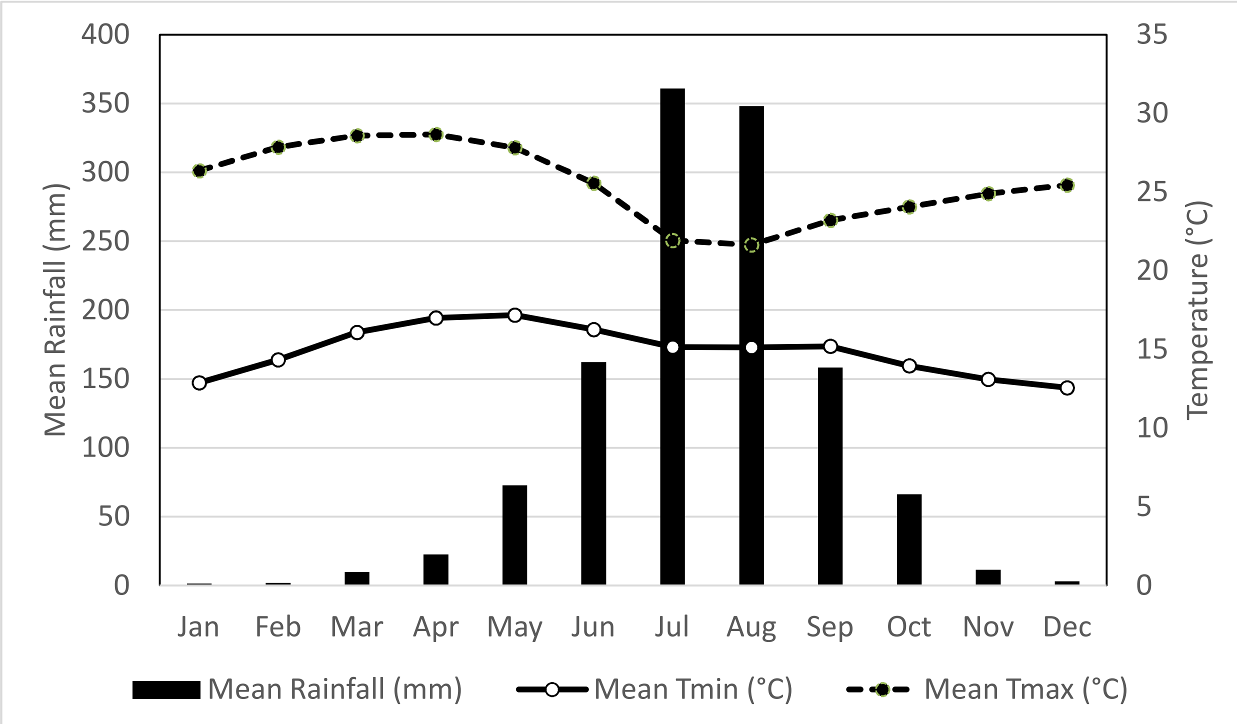

Figure 1: Mean monthly total rainfall, and monthly average minimum and maximum temperatures of the study area for the period 1981-2017

Composite soil samples for each experimental site was collected before planting for major physical and chemical analyses using the standard procedures. The soil samples were collected, air-dried, ground, sieved to pass a 2-mm mesh and composited into one. Soil analysis was carried out from the composite sample in duplicates where soil samples were analyzed for soil texture using Bouyoucos hydrometer method (Bouyoucos, 1962). Total nitrogen following the Kjeldahl procedure method (Sahlemedhin and Taye, 2000) and Soil was also analyzed for pH (1:2.5 soil: water) by using pH meter (Sahlemedhin and Taye, 2000). While organic carbon was determined using wet digestion method (Walkely and Black, 1934) available phosphorus was using Bray II method (Bray, 1954).

The textural class of the experimental soil was found to be heavy clay with the pH of 5.87-6.08, which is slightly acidic and it is a preferred range for most crops (Table 1). Total nitrogen content was 0.09-0.11%, which is within the range of low levels (0.02-0.5%) for tropical soils. The organic matter content of the soil was 2.13-2.39%, 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 soil was 11.4-25.13ppm that 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

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	6.08
Total nitrogen (TN)	%	0.09	0.11
Organic carbon (OC)	%	1.24	1.33
Organic matter (OM)	%	2.13	2.29
Available Phosphorus	Ppm	11.4	25.13

The treatments were comprised of factorial combinations of four nitrogen (0, 46, 92, 138 N kg ha^{-1}) and three phosphorous levels (0, 46, 92 P_2O_5 kg

ha^{-1}) in Randomized Complete Block Design and replicated three times. The gross size of the experimental plots was 3m x 4m consisting of 15 rows planted at a spacing of 20 cm apart with the seeding rate of 100 kg ha^{-1}. The net plot area 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 2.6m x 3m. Data on plant height, panicle length, number of total tillersm^{-1} row length, number of fertile panicles m^{-1} row length, thousand seeds weight, grain yield, straw yield and harvest index were collected timely from the net plot areas following their respective standard measuring methods and procedures. 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 9.0 (SAS-Institute, 2003). 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 nitrogen and phosphorous fertilizers on rice production. Wherever the ANOVA results showed significant difference between treatments for a variable, mean separation between treatments was executed by using Least Significant Difference (LSD) method at probability levels of 0.01 or 0.05 depending on the ANOVA results. Moreover, agronomic efficiency (AE) was calculated to assess the use efficiencies of the applied N rates as follows:

$$AE = \frac{Gf - Gu}{Na}$$

Source: Liu *et al.* (2019)

Where:

AE = agronomic efficiency

Gf = grain yield of the fertilized plot (kg)

Gu = grain yield of the unfertilized plot (kg)

Na = rate of applied N fertilizer (kg)

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 were considered for the analysis. The costs of Urea and NPS fertilizers for the stated period at the study area were Birr 13.1 and 14.3 per kg, respectively, while the prices of rice grain and straw were Birr 13.5 and 1.2 per kg, respectively.

3. Results and Discussion

The analysis of variance indicated that plant height and panicle length of upland rice 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 plant height was recorded at the highest nitrogen rate of 138 kg ha^{-1}, while the lowest plant height was recorded at the control without N application (Table 2). The highest panicle length of upland rice exhibited at the rate of 138kg ha^{-1} N, which was statistically at par at the rate of 92 kg ha^{-1} N (Table 2) whereas, the lowest panicle length was observed at the control without N fertilizer application. In line with the present results, Ghorbannia *et al*. (2012), Shiferaw *et al*. (2012), Riste *et al*. (2017) and Molla and Sofonyas (2018) reported significant effects of N application on plant height and panicle length. Shiferaw *et al*. (2012) observed higher plant height (113.9 cm) at 92 kg which was statistically at par (113.5 cm) with 138 kg N ha^{-1}.The increase in plant height of upland 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 (Shiferaw *et al*. 2012). Similarly, Ghorbannia *et al*. (2012) observed that shorter plant height (105.4 cm) was noted at the control without N fertilizer application. On the contrary, they observed also longer height of 109.3 and 111.3 cm at 50 and 100 kg N ha^{-1}, respectively. Riste *et al*. (2017) stated that highest and significant panicle length (27.06 cm) was recorded with application of fertilizer dose at 60 kg Nha^{-1}compared to the control without N fertilizer. On the other hand, Molla and Sofonyas (2018) 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. Similar to the present results, Shiferaw *et al*. (2012) reported also the longest panicle length at the rate of 138 kg N ha^{-1}.

Table 2: Combined main and interaction effects of N and P fertilizer rates on growth and yield of upland rice in three consecutive years (2015-2017) in Fogera and Libokemkem districts, northwest Ethiopia

N (kg/ha)		PH	PL	TT/m2	NFP/m2	GY	SY	HI
0		57.7d	15.7c	395.5d	387.8d	1.92d	3.08d	38.5d
46		65.4c	16.4b	494.2c	481.0c	3.33c	4.73c	41.3c
92		68.5b	17.3a	546.5b	536.2b	4.59b	5.30b	46.4a
138		71.0a	17.5a	590.7a	576.7a	5.18a	6.24a	45.3a
P-value		**	**	**	**	**	**	**
SE±		4.928						
P_2O_5 (kg/ha)								
0		64.8	16.7	492.2b	483.2b	3.66b	4.69	43.8
46		66.7	16.7	503.4ab	490.4ab	3.93a	5.05	43.8
92		65.5	16.8	524.6a	512.6a	3.67b	4.77	43.5
P-value		ns	Ns	*	*	**	Ns	ns
SE±		4.928	1.0212	67.119	66.894	0.44946	1.525	8.5871
N (kg/ha)	P_2O_5 (kg/ha)							
0	0	58.0	16.1	380.4	373.7	1.9f	3.0c	40.3
	46	58.2	15.7	393.8	386.2	1.9f	3.1c	37.7
	92	56.8	15.3	412.2	403.5	2.0f	3.2c	40.1
46	0	64.2	15.8	436.0	430.3	3.3e	4.bc	41.8
	46	69.2	16.7	539.9	514.5	3.5e	5.5ab	41.5
	92	62.7	16.7	506.7	498.2	3.2e	4.1bc	46.1
92	0	69.2	17.7	570.6	559.3	4.6cd	5.5ab	46.9
	46	67.3	16.7	528.4	519.7	4.9abc	5.0ab	51.1
	92	69.1	17.6	540.6	529.5	4.3d	5.5ab	45.0
138	0	67.7	17.3	581.8	569.4	4.9c	5.6ab	51.5
	46	72.0	17.5	551.6	541.3	5.5a	6.5a	47.1
	92	73.3	17.6	638.8	619.4	5.2ab	6.6a	45.4
P-value		ns	Ns	*	ns	**	*	ns
SE±		4.928	1.0212	67.119	66.894	0.44946	1.525	8.5871
CV (%)		7.5	6.1	13.2	13.5	11.97	23.5	19.3

PH = plant height (cm), PL = panicle length (cm), TT/m2 = total tillers/m^2, NFP = number of fertile panicles/m^2, Gy = grain yield (t ha^{-1}), SY = straw yield (t ha^{-1}), HI = harvest index (%), ** = highly significant at P<0.01, * = significant at P<0.05, ns = not significant at P≥0.05

The analysis of variance for number of total tillers and number of fertile panicles showed that the main effects of nitrogen and phosphorous on both yield components were highly significantly (P<0.01) and significantly (P<0.05), respectively. The interaction of N and P significantly (P<0.05) affected the number of tillers, but not the number of fertile panicles (Table 2). The highest number of total tillers and fertile panicles was recorded at the highest rate of 138 kg ha^{-1} N while their lowest number was observed at the control without N fertilizer application (Table 2). Similarly, the highest number of total tillers and fertile panicles were exhibited at the rate of 92 kg ha^{-1} P_2O_5, which were statistically at par at the rate of 46 kg ha^{-1} P_2O_5. Number of total tillers was significantly responding to the interaction of nitrogen and phosphorous fertilizer applications. The highest number of total tillers was observed at the interaction of 138 kg ha^{-1} N and 92 kg ha^{-1} P_2O_5, while the lowest number of total tillers was recorded at the interaction of the controls without application of both N and P fertilizers (Table 2).In conformity with the results of the present experiment, Kumar *et al*. (2017) had reported maximum number of total and effective tillers m^{-2} with application of 150 kg N and75 kg P_2O_5 kg ha^{-1}. On the other hand, Riste *et al*. (2017) reported maximum number of tillers and panicle m^{-2}at the rate of 120 kg N and 90 kg P_2O_5 kg ha^{-1}.

Ghorbannia *et al*. (2012) exhibited that the most fertile tiller number was obtained at the interaction of 50 kg N and 75 and 150 kg P_2O_5 ha^{-1}, while they were observed the least tiller number at the interaction of the controls with NP fertilizers. According to Molla and Sofonyas (2018), application of 69 kg N and 20 kg P_2O_5 ha^{-1} resulted in highest number of seeds (126.9) per panicle of rice than other combination rates. Application of NP fertilizers at optimum rates might result in superior growth and development that eventually reflected with significantly superior yield attributes (Kumar *et al*., 2017; Riste *et al*., 2017). Inferior crop growth in the controls without NP applications might closely be associated with insufficient availability of NP below their optimal requirements (Riste *et al*., 2017).

Thousand seeds weight was not affected by the main and interaction of the nitrogen and phosphorous rates. In contrary, the grain yield was highly significantly (P<0.01) affected by the main and interaction effects of nitrogen and phosphorous (Table 2). Concerning the nitrogen rates, the highest grain yield was shown at 138 kg ha^{-1} N while the lowest was noticed at 0 kg ha^{-1} N. In the case of the phosphorous rates, the highest grain yield was exhibited at 92 kg ha^{-1} P_2O_5 which are statistically at par with the vales of 46 kg ha^{-1} P_2O_5 (Table 2). With regard to the interaction effect, the highest grain yield (5.5 t ha^{-1}) was obtained at 138-46 N-P_2O_5 kg ha^{-1}, which was statistically equivalent with the yield (5.2t ha^{-1}) of the 138-92 N-P_2O_5 kg ha^{-1} application (Table 2).

The straw yield was highly significantly (P<0.001) affected by the main effect of nitrogen but not by phosphorous (Table 2). The interaction of nitrogen and phosphorous significantly (P<0.005) affected the straw yield (Table 4). Regarding the nitrogen rates, the highest straw yield was seen at 138 kg ha^{-1} N while the lowest was noticed at 0 kg ha^{-1} N. With respect to the interaction effect, the highest straw yield (6.6 t/ha) was obtained at 138-92 N-P_2O_5 kg ha^{-1} which is statistically at par with some of the treatment combinations (Table 2). The rice harvest index was highly significantly (P<0.001) affected by the main effect of nitrogen but not by phosphorous and the interaction (Table 2). The highest harvest index, among the nitrogen rates was recorded for 138 kg ha^{-1} N that was statistically equivalent with the value of 92 kg ha^{-1} N while the lowest was noticed at 0 kg ha^{-1} N (Table 2).In support of the present finding, Kumar *et al*. (2017) stated that the grain and straw yields of rice increased up to application of 150:75 N-P2O5 kg ha-1. Masni and Wasli (2019) had also reported that the grain and straw yields of upland rice were significantly affected and best at 60N and 35 kg P kg ha^{-1}. Molla and Sofonyas (2018) reported significantly higher grain and straw yields of upland rice at Tselemti District, north Ethiopia and the highest values were obtained in plots receiving 69 kg N ha^{-1} and 30 kg P fertilizer ha^{-1}.The reports of Riste *et al*. (2017) revealed that paddy and straw yields of rice were influenced significantly ($p < 0.05$) under various combinations of N and P levels. The authors further explained that the treatment where N and P were integrated at the rate of 120 and 90 kg ha-1 exhibited the highest paddy yield (4.5 t ha^{-1}) which was 56% more over control. Riste *et al*. (2017) has further described that highest straw yield (9.7t ha^{-1}) was recorded at 150 kg N + 75 kg P_2O_5 ha^{-1}.

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 (Riste *et al*., 2017). Similar with the observation of highest harvest index at the current experiment, Worou *et al*. (2017) had reported higher HI (0.31) of upland NERICA rice with fertilizer (N at 80 kg ha^{-1} as urea combined with P at 80 kg P_2O_5 ha^{-1}) than without fertilizer (0.21). Higher grain yields in the fertilizer treatments were associated with higher harvest index.

The analysis of the Agronomic Efficiency (AE) for the nitrogen indicate that the maximum AE of 29.74 was exhibited at 46 kg ha^{-1} N, then the AE reduce to 13.92 at 92 kg ha^{-1} N, and become lowest (4.32) at 138 kg ha^{-1} N (Table 3). 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 9.1 kg 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 ice at the highest rate is relatively low due to loss of applied N through leaching, volatilization and denitrification, 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 upland rice production system of the study area.

Table 3: Agronomic efficiency (AE) of nitrogen

N (kg/ha)	Grain Yield (kg/ha)	AE
0	1920	
46	3288.261	29.74
92	4569.13	13.92
138	5166.087	4.32

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 4). 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 5). Non-dominated treatments were taken out and marginal rate of return (MRR) was computed (Table 8). According 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. Highest NB (Birr 68,307.5ha^{-1}) with acceptable level of MRR (668.5%) was observed at 138-46 N-P_2O_5 kg ha^{-1} (Table 6). In agreement to the present finding Irfan *et al*. (2016) 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. The combined application of nitrogen and phosphorous at 138-46 N-P_2O_5 kg ha^{-1} is the most profitable rate to be recommended for rice production in Fogera plain.

Table 4: Results of grain and straw yield adjustments, total variable cost, gross and net benefit analysis

N (kg/ha)	P_2O_5 (kg/ha)	TVC (Birr/ha)	GY (t/ha)	SY (t/ha)	AGY (t/ha)	ASY (t/ha)	GB (Birr/ha)	NB
0	0	0.0	1.8867	2.9533	1.69803	2.658	26112.969	26113.0
0	46	1731.1	1.9133	3.0933	1.72197	2.784	26587.359	24856.3
0	92	3462.1	1.9733	3.1867	1.77597	2.868	27417.231	23955.1
46	0	1310.0	3.2533	4.6	2.92797	4.14	44495.595	43185.6
46	46	2386.1	3.5133	5.5133	3.16197	4.962	48640.959	46254.9
46	92	3462.1	3.2267	4.0733	2.90403	3.666	43603.569	40141.5
92	0	2620.0	4.62	5.4467	4.158	4.902	62015.436	59395.4
92	46	3696.1	4.8867	4.9733	4.39803	4.476	64744.569	61048.5
92	92	4772.1	4.26	5.4933	3.834	4.944	57691.764	52919.7
138	0	3930.0	4.8533	5.6267	4.36797	5.064	65044.431	61114.4
138	46	5006.1	5.4533	6.5333	4.90797	5.88	73313.559	68307.5
138	92	6082.1	5.2333	6.5667	4.70997	5.91	70676.631	64594.5

TVC= Total Variable Cost, GY=Grain Yield, SY= Straw Yield, AGY= Adjusted Grain Yield, ASY= Adjusted Straw Yield, GB= Gross Benefit, NB= net benefit

Table 5: Result of dominance analysis

N (kg/h	P_2O_5 (kg/ha)	TVC (Birr/ha)	NB	Dominance
0	0	0	26,112.97	
46	0	1310	43,185.60	
0	46	1731.053	24,856.31	D
46	46	2386.053	46,254.91	
92	0	2620	59,395.44	
0	92	3462.105	23,955.13	D
46	92	3462.105	40,141.46	D
92	46	3696.053	61,048.52	
138	0	3930	61,114.43	
92	92	4772.105	52,919.66	D
138	46	5006.053	68,307.51	
138	92	6082.105	64,594.53	D

D= Dominated

Table 6: Result of Marginal rate of return (MRR) analysis

N (kg/h	P_2O_5 (kg/ha)	TVC (Birr/ha)	NB	MRR (%)
0	0	0	26,113	
46	0	1310	43,185.6	1303.3
46	46	2386.1	46,254.9	285.2
92	0	2620	59,395.4	5618.0
92	46	3696.1	61,048.5	153.6
138	0	3930	61,114.4	28.2
138	46	5006.1	68,307.5	668.5

4. Conclusions and Recommendation

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 and terminal moisture stress are among the major causes of the low rice productivity. Based on the results of the present study the highest grain yield and economic profitability of rice was obtained by the application of 138-46 N-P_2O_5 kg $ha^{-1,}$ which can be recommended for rain fed upland rice production in the study area and other similar agro-ecologies. Future research works towards the improvement of nitrogen use efficiency of rice are also recommended.

Conflict of Interest

The authors declare that there is no conflict of interest

References

Aamer, I., Abbas, G., and Khaliq, A. (2000). Effect of different nitrogen application techniques on the yield and yield components of fine rice. International Journal of Agriculture and Biology. 2(3):239–241.

Bouyoucos, C.J. (1962). Hydrometer method improved for making a particle-size analysis of soils. Agronomy Journal, 54: 464-465.

Bray, R.H., and Kurtz, L.T. (1945). Determination of total, organic and available forms of phosphorus in soils. Soil Science. 59: 39-45.

CIMMYT. (1988). From agronomic data to farmer recommendations. An economic training manual. Completely Revised Edition. CIMMYT, Mexico, D. F., Mexico. 79 pp.

CSA (Central Statistical Agency). (2016). Report on area and production of major crops (private peasant holdings, meher season). The Federal Democratic Republic of Ethiopia Central Statistical Agency Agricultural Sample Survey Volume I, Addis Ababa, Ethiopia.

CSA (Central Statistical Agency). (2017). Report on area and production of major crops (private peasant holdings, meher season). The Federal Democratic Republic of Ethiopia Central Statistical Agency Agricultural Sample Survey Volume I, Addis Ababa, Ethiopia.

CSA (Central Statistical Agency). (2018). Report on area and production of major crops (private peasant holdings, meher season). The Federal Democratic Republic of Ethiopia Central Statistical Agency Agricultural Sample Survey Volume I, Addis Ababa, Ethiopia.

CSA (Central Statistical Agency). (2019). Report on area and production of major crops (private peasant holdings, meher season). The federal democratic republic of Ethiopia central statistical agency agricultural sample survey Volume I. Statistical bulletin 589, Addis Ababa, Ethiopia.

Dawit, A. (2015). Rice in Ethiopia: progress in production increase and success factors. 6th CARD General Meeting. Ethiopian Journal at Institute of Agricultural Research, 1-22.

Fageria, N.K., and Baligar, V.C. (2001). Lowland rice response to nitrogen fertilization, Communications in Soil Science and Plant Analysis. 32(9):1405-1429. DOI: 10.1081/CSS-100104202

FAOSTAT (Statistics Division Food and Agriculture Organization of the United Nations). (2018).

Gebey, T., Berhe, K., Hoekstra, D., and Bogale, A. (2012). Rice value chain development in Fogera woreda based on the IPMS experience. Nairobi, Kenya: ILRI. 23pp.

Gewaily, E. Adel, E., Ghoneim, M., Marvet, M., and Osman, A. (2018). Effects of nitrogen levels on growth, yield and nitrogen use efficiency of some newly released Egyptian rice genotypes. Open Agriculture. 3: 310–318. https://doi.org/10.1515/opag-2018-0034.

Ghorbannia, E., Dastan, S., Mobasser, H.R., and Ghanbari-Malidarreh, A. (2012). Response of sensitive to lodging rice cultivar to nitrogen levels in heading stage and phosphorus rates at the North of Iran. International Research Journal of Biochemistry and Bioinformatics. 2(6):142-148.

Kumar, S., Sarabdeep, K., Meenakshi, G., Dileep, K., and Singh, H. (2017). Influence of rice varieties and fertility levels on performance of rice and soil nutrient status under aerobic conditions. Journal of Applied and Natural Science 9. (2): 1164 – 1169.

Landon, J.R. (1991). Tropical Soil manual: a hand book for soil survey and agricultural land evaluation in the tropics and subtropics. Booker.

Liu, K., Deng, J., Lu, J., Wang, X., Lu, B., Tian, X., and Zhang, Y. (2019). High nitrogen levels alleviate yield loss of super hybrid rice caused by high temperatures during the flowering stage. Plant Science. 10: 357. doi: 10.3389/fpls.2019.00357.

Maneesh, B., Singh, A.P., Singh, V., Kala, D.C., and Kumar, V. (2018). Long-term effect of organic and inorganic Fertilizers on soil physico-chemical properties of a silty clay loam soil under rice-wheat cropping system in Tarai region of Uttarakhand. Journal of Pharmacognosy and Phytochemistry. 8(1): 2113-2118.

Masni, Z., and Wasli, M.E. (2019). Yield performance and nutrient uptake of red rice variety (MRM 16) at different NPK fertilizer rates. International Journal of Agronomy. https://doi.org/10.1155/2019/5134358.

MoARD. (2010). National rice research and development strategy of Ethiopia. The Federal Democratic Republic of Ethiopia, Ministry of Agriculture and Rural development, Addis Ababa, Ethiopia. 48 pp.

Molla, H., and Sofonyas, D. (2018). Response of upland rice to nitrogen and phosphorus fertilization on vertisols of Tigray, Ethiopia. Asian Research Journal of Agriculture. 10(4): 1-7, 2018

Mulugeta, S., and Heluf, G.K. (2014). Inherent properties and fertilizer effects of flooded rice soil. Journal Agronomy. 13(2): 72–78.

Murphy, H.F. (1968). A report on the fertility status of some soils of Ethiopia. Experiment Bulletin No 44. College of Agriculture, Haileselassie I University, Alemaya, Ethiopia.

Peng, S., Roland, J.B, Huang, J., Zhong, X., Zou, Y., Wang, J.Y., Liu, Y., Hu, R., Tang, Q., Cui, K., Zhang, F., and Dobermann, A. (2010). Improving nitrogen fertilization in rice by site-specific N management. A review. Journal of Agronomy for Sustainable Development. 30: 649–656. DOI:10.1051/agro/2010002.

Riste, K., Gohain, T., and Kikon, N. (2017). Response of local rice (Oryza sativa L.) cultivars to recommended NPK fertilizer dose under upland rainfed conditions. Agricultural Science Digest. 37(1): 2017: 10-15.

Sahlemedhin, S., and Taye, B. (2000). Procedure for soil and plant analysis. National Soil Research Centre, Ethiopia Agricultural Research Organization (EARO) Technical Paper No.74, Addis Ababa, Ethiopia.

SAS Institute (2003). SAS Version 9. 1.2 © 2002-2003. SAS Institute, Inc., Cary, NC.

Sha, R.P., and Sujathamm, P. (2018). Effect of organic and inorganic fertilizers on the quantitative and qualitative parameters of rice (Oriza sativa L.). Current Agriculture Research journal. 6(2): 166-174.

Shiferaw, N., Heluf, G.K., Sharma, J.J., and Tareke, B. (2012). Effects of nitrogen and phosphorus fertilizer application on yield attributes, grain yield and quality of rain fed rice (NERICA-3) in Gambella, Southwestern Ethiopia. East African Journal of Science. 6(2): 91-104.

Subedi, P., Sah, K.S., Marahattha, S., and Yadav, D.R. (2019). Effects of need-based nitrogen management and varieties on growth and yield of dry direct seeded rice. Pertanika Journal of Tropical Agricultural Science. 42 (2): 453 - 466 (2019).

Walkely, A., and Black, I.A. (1934). An examination of methods for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Science. 37: 29–38.

Worou, O.N., Gaiser, T., Gbemavo, C., and Sinsin, B.A.N (2017). Responses of upland nerica rice to fertilizer application and fallow management in different agro-ecological zones of Benin Republic. European Scientific Journal. 13(27): 152 doi: 10.19044/esj.2017.v13n27p152

Yasuhiro, T., Rakotoson, T., Tanaka, A., and Saito, K. (2019). Challenges and opportunities for improving N use efficiency for rice production in sub-Saharan Africa. Plant Production Science. DOI: 10.1080/1343943X.2019.1617638.Yoshida (1981).

Yoshida, S. (1981). Fundamentals of rice crop science. The International Rice Research Institute, Los Baños, Laguna, Philippines. 269 Pp.

Zhao, L., Wu, L., Wu, M., and Li, Y. (2011).Nutrient uptake and water use efficiency as affected by modified rice cultivation methods with irrigation. Paddy Water environment. 9: 25-32.