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Original Article

Response of Rain-Fed Upland Rice (*Oryza Sativa* L.) to Different Rates of Nitrogen and Phosphorus Nutrients on Vertisols of North Western Amhara, Ethiopia

Yohannes Kefale[1]*, Zenebe Gebremedhin[2], Daniel Tadesse[2] and Tamirat Worku[1]

[1]Amhara Agricultural Research Institute, Gondar Agricultural Research Center, Ethiopia

[2]College of Agriculture and Environmental Sciences, University of Gondar, Ethiopia

Abstract

A field experiment was carried out at Metema and Tach Armachiho districts of North Western Amhara to investigate the effect of nitrogen and phosphorous fertilizer rates on yield and yield components of upland rice during the main cropping season of 2020/2021. At both experimental sites, a factorial combination of four levels of nitrogen (0, 46, 92 and 138kg ha^{-1}) and three level of P_2O_5 (0, 23, 46 kg ha^{-1}) were tested in randomized complete block design with three replications. A combined analysis of variance revealed highly significant ($p<0.01$) difference among the traits panicle length, number of effective tillers and grain yield for the interaction effect of Nitrogen and Phosphorus nutrients rates while thousand seed weight was significant ($p<0.05$). For other traits recorded, non-significant interaction effect was observed while significant for one or two of the nutrient rates applied. The combined application of 92 and 46 kg N - P_2O_5 ha^{-1} gave yield of 6170 kg ha^{-1} which is higher than other fertilizer rate interactions. The partial budget analysis also indicated that the application of 92 and 46 kg N - P2O5 ha-1 had the highest net benefit (Birr 119,245.3 ha^{-1}), with acceptable marginal rate of return (1151.48%) as compared to other treatments. Therefore, application of 92 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} is recommended for upland rice growers in both Tach Armachiho and Metema areas and other similar agro-ecologies.

Keywords: Nitrogen; Phosphorus; Upland Rice; Yield.

INTRODUCTION

Rice (*Oryza sativa* L.) belongs to the family Poaceae; it is an essential food crop and a major food grain for more than half of the world's population [1]. It is a cereal crop that has been gathered, consumed and cultivated by many people worldwide for more than 10,000 years, longer than any other crop [2]. To meet the food demand of an ever-increasing human population, the world's rice grain production should be increased, while rice straw, after being chopped into fine parts, is used as animal feed. The global rice cultivation was estimated at total area 163 million ha with annual production averaging 730.2 million tons [3].

Rice production in Ethiopia has begun in recent years and is expected to grow. Although rice has been introduced to the country very recently, it is a productive crop next to maize in the country and is among the target commodities that have received due emphasis in the promotion of agricultural production by the government of Ethiopia to ensure household as well as national food security in the country [4].

Rice is grown primarily in rain-fed lowland and upland areas of Ethiopia. It is grown either as a mono–crop or as a mixture with other food crops, normally without any fertilizer used [5]. The major rice producing regions in the country are the Amhara, Oromia and South and Ethiopia regions with a share of 76%, 14.9%, and 5.2%, respectively [6]. Rice cultivation, however, continues on potential land in the country [7]. Currently, rice is showing an increasing trend in Ethiopia in terms of the area of production as it increased from 24,434 ha in 2000 to 57,575.72 ha in 2019 [8].

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***Corresponding author:** Yohannes Kefale, Amhara Agricultural Research Institute, Gondar Agricultural Research Center, Ethiopia, Tel: 0918241756

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Despite the fact that rice was introduced to Ethiopia 50 years ago, its production and productivity remain low. The average national yield of rice is about 2.96 t ha^{-1} [8] which is lower compared to the world average productivity of 5.1 t ha^{-1}. This low rice productivity in the country is associated with a lack of various N and P sources of fertilizer and improved rice varieties [9]. 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 leads to yield losses [10]. Nitrogen and phosphorus is often cited as the most limiting nutrients in the agricultural soil of Ethiopia. Relatively, those nutrients are deficient in valleys where nitrogen is subjected to leaching, while the limited availability of phosphorus is observed due to several factors [11]. Even though determination of an appropriate dosage of application would be both economical and appropriate to enhance the productivity and consequent profit of the grower, there are no scientific findings for the determination of the optimum N and P fertilizer level in the study area.

Therefore, the objective of the study was to develop optimum rates of nitrogen and phosphorous nutrients for upland rice (NERICA-4) which could be used to enhance rice production increment in Metema and Tach Armachiho districts.

MATERIALS AND METHODS

Description of the Study Area

Field experiment was conducted in Metema and Tach Armachiho districts during the main cropping season of 2020. These districts are located in the West Gondar Zone and Central Gondar of the Amhara national regional state, Ethiopia respectively. Metema district is 912 km from the capital city Addis Abeba and 200 km from Gondar and geographically located at 12^0 47' Latitude to 38 ^{0}27' [12]. It is bounded by Sudan. The altitude of the Metema district ranges from 550 to 1608 meters above sea level (m.a.s.l). The mean maximum and minimum temperatures in the area are about 40.0 °C and 15.0°C, respectively. The mean annual rainfall in the area is about 650.5 mm and it is erratic and uneven in distribution.

Tach Armachiho is located at latitude 13^0 19' 60'' and longitude 36^0 44'60''. The district's elevations range from 550 to 1600 meters. The mean maximum and minimum temperatures in the area are about 34.0°C and 13.0°C, respectively. The average annual rainfall in the area ranges between 600 and 605mm. In both districts, the rainy months extend from June until the end of September. However, most of the rainfall is received during July and August. The study area had a mono-modal rainfall characteristic. The location represents the major rice-producing agro-ecology of the region. Some of the major crops grown in both districts include sorghum, sesame, cotton, soybeans and finger millet.

Rice variety NERICA-4 was used for the experiment as it is high yielder variety and popular among the farmers in the study area.

Experimental Treatments, Design, Procedures and Trial Management

The treatments comprised factorial combinations of four levels of nitrogen (0, 46, 92, 138 kg N ha^{-1}) and three levels of phosphorus (0, 23, 46 kg P_2O_5 ha^{-1}). Urea (46% N) and Triple Super Phosphate (46% P_2O_5) were used as fertilizer sources for N and P_2O_5, respectively. A total of 12 treatment combinations was being studied in a randomized complete block design with three replications. The gross and net plot sizes were 3 m width and 3m length (9 m^2) with 12 rows and 2.5 m width and 2.0 m length (5.0 m^2) with 10 rows, respectively. The space between blocks, plots and row spacing was maintained at 1.5 m, 1m and 0.25 m, respectively. The date of planting was on July 2 and 3, 2020 for Tach Armachiho and Metema respectively, with a seed rate of 60 kg ha^{-1} at a depth of 3-5 cm. Except for the control plots, all phosphorus nutrient was applied at planting, while nitrogen was applied in splits. All other management practices were applied as per the general recommendations for rice.

Initial soil samples were taken following the procedures of surface soil sampling at 0-30 cm soil depth from 5 random spots on the experimental site in a zigzag pattern by vertical insertion of the auger before planting. The samples were then air-dried, ground with a pestle and mortar, and passed through a 2 mm sieve to create a 1 kg composite sample that was labeled in plastic bags. The composite samples were taken to Gondar soil testing laboratories and Adet Research Center for selected physical and chemical properties, mainly soil texture (percent sand, silt and clay), soil pH, EC, CEC, total N, available P, Ca, K, Na, Mg, SOC and SOM.

Data were collected on major agronomic and phenological characters. The collected data was subjected to analysis of variance (ANOVA) using SAS (9.0) and interpretations were drawn following the procedure described by Gomez AA [13]. Homogeneity of variances was tested using F test as described by Gomez AA [13]. According to the homogeneity test, all parameters were homogenous except days to maturity. Least significant differences (LSD) test at 1 and 5% level of probability was used. Correlation analysis was also done to examine the association between the yield and the yield-related components. The partial budget analysis as described by CIMMYT [14], was done to determine the economic feasibility.

RESULTS AND DISCUSSION

Soil Physical and Chemical Properties in the Study Areas

The soil analysis of the two sites indicated that the pH value of the soil was in the range of 6.7-7.2, which indicated that it was slightly acidic to neutral. It is suitable for rice production since rice grows well in heavy clay or clay loam soils. The texture of these soils is clay with low to moderate organic matter content and relatively easily weathering minerals (Table 1). The soil had low available phosphorus, which indicates that an additional P fertilizer is required for optimum crop growth and yield [15]. The result of the experimental area for total nitrogen was medium according to the rating of [16].

Days to 50% heading and days to 90% physiological maturity

The combined ANOVA indicated that the main effect of N and P rates and their interaction did not show significant difference on days to 50% heading and 90% days to maturity (Table 2).

Effect of Treatments on growth parameters of upland rice

Analysis of variance showed that the main effects of nitrogen ($P<0.001$) and phosphorous ($P<0.01$) fertilizer rates had significant on plant height and panicle length while their interaction had not been significant ($P<0.05$) on plant height but significant to panicle length (Table 2). Concerning the nitrogen rate, the tallest plant height (114.9 cm) was recorded at the highest nitrogen rate of 138 kg ha^{-1}, while the shortest plant height (62.57 cm) was recorded at the control without N application (Table 6). In line with the present finding [17], reported that shorter plant height was noted at the control without N fertilizer application. With regard to phosphorous rate, the tallest rice plants (85.78 cm) were recorded at plots fertilized with 46 kg P_2O_5 ha^{-1} while the shortest plants (79.9 cm) measured from the control without P application (Table 6). In line with the present results [18], and [19] reported significant effects of N application on plant height (Table 3&4).

The longest panicle length (22.6cm) exhibited the interaction effects of 138kg ha^{-1} N and 46 kg of P_2O_5 rates, while the shortest panicle length (14.5cm) was recorded from the control treatments (Table 7). In line with the findings of the present study [19]), reported that the application of nitrogen and phosphorus fertilizers significantly enhanced the growth of upland rice panicle length (Table 8).

Effect of treatments Yield Components

Number of effective tiller

Analysis of variance revealed that the number of effective tillers was highly significantly ($P \leq 0.01$) influenced by the main effect of N fertilizer application and its interaction with phosphorous ($P < 0.05$), but not affected by the main effect of phosphorous (Table 2).

The highest number of effective tillers (275.3) was observed at the interaction of 138 kg ha^{-1} N and 23kg ha^{-1} P_2O_5, while the lowest number of effective tillers (154.7) was recorded at the interaction of the control of N and 23 kg ha^{-1} P_2O_5 fertilizers (Table 4). Enhanced tillering by increased N application might be attributed to more N supply to plants at the active tillering stage [20] (Table 9).

Table 1: Selected soil physicochemical properties of the experimental site

A. physical analysis	Locations				
	Metema		Tach Armachiho		
Particulars	Value	Status	Value	Status	Method employed
Sand (%)	22		23		
Silt (%)	27.72		26.5		
Clay (%)	49.88		48.13		Bouyoucos hydrometer method
textural class	Clay	Clay			
B. chemical analysis					
pH (by 1: 2.5 soil water ratio)	6.7	Neutral	6.7	Neutral	1:2.5 water with pH meter
Organic Carbon (%)	2.31	Law	2.5	moderate	Walkley and Black
Total N (%)	0.15	Medium	0.16	Medium	Kjeldahl digestion &distillation
Available P (ppm)	2.67	Law	2.9	Low	Bray II
Organic Matter (%)	2.5	Law	2.7	Low	Walkley and Black
CEC (meq/100g soil)	69.07	Very high	74.9	Very high	Bremner and Mulvaney
EC (ms/cm	0.12	Low	0.12	Low	1:5 soil to water ratio suspension
Ca (cmol kg^{-1})	48.03	Very high	48.07	Very high	
Mg (cmol kg^{-1})	17.01	Very high	18.01	Very high	
K (cmol kg^{-1})	0.66	Very high	1.5	low	
Na (cmol kg^{-1})	1.12	low	1.5	low	

CEC=Cation Exchange Capacity, EC=electrical conductivity, ppm=Part per million.

Table 2: ANOVA for phenological and growth parameters of Upland rice as affected by rate of N and P_2O_5 applications at North Western Gondar, Ethiopia in 2020

Source	DF	DM	DH	PL	PH
Rep	2	10.74^{ns}	0.78^{ns}	1.19^{ns}	37.94^{ns}
N Rate	3	8.94^{ns}	2.15^{ns}	90.24^{***}	5838.87^{***}
P_2O_5	2	0.59^{ns}	2.17^{ns}	14.09^{**}	184.27^{**}
N Rate * P_2O_5	6	8.18^{ns}	4.65^{ns}	4.54^{*}	68.89^{ns}
Error	22	6.04	4.05	1.54	32.56
CV (%)		2.49	3.14	6.38	6.37

*DF= degree of freedom; DM=days to maturity; DH= days to heading; PL=panicle length; PH=plant height; CV= Coefficient of Variation, ns, *, ** and *** = non-significant, significantly different at 5 %, 1% and 0.1%, respectively*

Table 3: ANOVA for phonological and growth parameters of Upland rice as affected by rate of N and P_2O_5 applications at North Western Gondar, Ethiopia in 2020

Source	DF	SPP	ET	NET	TT
Rep	2	0.82^{ns}	2995.41^{ns}	9367.1*	7729.89^{ns}
N Rate	3	14.63***	9989.654**	3381.034^{ns}	9938.1^{ns}
P_2O_5	2	17.67***	3115.99^{ns}	112.88^{ns}	2678.56^{ns}
N Rate * P_2O_5	6	1.30^{ns}	6135.08*	3130.37^{ns}	11747.1^{ns}
Error	22	0.88	2174.9	2537.53	4693.02
CV (%)		8.48	20.76	46.3	20.55

*DF= degree of freedom; SPP= Spikelet per panicle, ET= Effective tiller; NET=none effective tiller, TT=Total tiller; CV= Coefficient of Variation, ns, *, ** and *** = non-significant, significantly different at 5 %, 1% and 0.1%, respectively*

Table 4: ANOVA for phonological and growth parameters of Upland rice as affected by rate of N and P_2O_5 applications at North Western Gondar, Ethiopia in 2020

Source	DF	NFG	TSW	GY	BY
Rep	2	367.81^{ns}	0.29^{ns}	0.06^{ns}	1.89^{ns}
N Rate	3	1218.3***	13.64^{**}	43.53^{***}	204.61***
P_2O_5	2	333.813^{ns}	5.67^{**}	6.3947818***	8.65^{*}
N Rate * P_2O_5	6	129.49^{ns}	3.66*	0.51*	2.43^{ns}
Error	22	139.1	0.80	0.19	2.45
CV (%)		12.3	3.27	10.73	18.36

*DF= degree of freedom; NFG= number of filled grain, TSW= Thousand seed weight; GY=Grain yield, BY=Biomass yield; CV= Coefficient of Variation, ns, *, ** and *** = non-significant, significantly different at 5 %, 1% and 0.1%, respectively*

Table 5: ANOVA for phonological and growth parameters of Upland rice as affected by rate of N and P_2O_5 applications at North Western Gondar, Ethiopia in 2020

Source	DF	STY	HI
Rep	2	1.76^{ns}	0.0075486^{ns}
N Rate	3	59.48***	0.0027^{ns}
P_2O_5	2	0.25^{ns}	0 0.0249^{*}
N Rate * P_2O_5	6	0.89^{ns}	0.002585^{ns}
Error	22	1.85	0.078
CV (%)		30.93	16.14

*DF= degree of freedom; STY=Straw yield, HI=Harvest index CV= Coefficient of Variation, ns, *, ** and *** = non-significant, significantly different at 5 %, 1% and 0.1%, respectively*

Table 6: The main effects of nitrogen and phosphorous rates on Plant height of rice in 2020

Nitrogen-rate (kg ha^{-1})	Plant height(cm)
0	62.57^{c}
46	73.4^{b}
92	77.04^{b}
138	114.9^{a}
LSD(P<0.01)	4.45
Phosphorous rate (kg ha^{-1})	
0	79.9b
23	80.17^{b}
46	85.78^{a}
LSD(P<0.05)	4.75
Mean	89.62
CV (%)	6.37

Means followed by the same letters are not significantly different at 5% level of significant; LSD: Least Significant Difference at 1 and 5% level of significant, CV: coefficient of variation (%).

Table 7: The interaction effect of N and P fertilizer rates on panicle length (cm) of upland rice

	P_2O_5 kg ha^{-1}		
N kg/ha	0	23	46
0	14.5^{h}	16.6^{g}	18.3^{f}
46	19.1^{ef}	19.3^{def}	20.0^{cde}
92	20.1^{de}	19.7^{de}	20.4cd
138	21.9^{ab}	21.1^{bc}	22.6^{a}
LSD(P < 0.05)			*
CV%			6.38

*ns, *, ** and = non-significant, significantly different at 5 %, and 1% respectively. Means followed by the same letter are not significantly different at 5% level of significance; LSD= least significant difference; CV= coefficient of variance.*

Table 8: The interaction effect of N and P fertilizer rates on number effective tiller/m^2 of upland rice

	Phosphorous rate (kg P_2O_5 ha^{-1})		
Nitrogen rate (kg N ha^{-1})	0	23	46
0	160.7^{de}	154.7^{e}	215.3^{c}
46	195.8^{cd}	230.9^{bc}	214.4^{c}
92	269.56^{ab}	268.7^{ab}	222.4^{c}
138	196^{cd}	275.3^{a}	225.1^{c}
LSD(P < 0.05)			46.38*
CV (%)			18.6

Table 9: Effect of nitrogen fertilizer rate on grain filled per panicle of upland rice

N rates (N kg ha^{-1})	Number of filled grain panicle
0	86.42[c]
46	93.21[bc]
92	98.13[b]
138	105.95[a]
LSD(p < 0.001)	7.64
Mean	95.93
CV (%/)	12.29

Means followed by the same letters are not significantly different at 5% level of significant; LSD: Least Significant Difference at 1 and 5% level of significant, CV: coefficient of variation (%)

Number of filled grain per panicle

Analysis of variance showed a significant ($p < 0.001$) effect of nitrogen's main effect on filled grains per panicle, where the main effects of phosphorous rate and the interaction effect of nitrogen and phosphorous rates did not show a significant difference (Table 4). The highest number of filled grains per panicle (105.95) was obtained at 138 kg ha^{-1} N, while the lowest (86.42) was noticed at 0 kg ha^{-1} N (Table 5). According to the experiment, as the N fertilizer rate increases, there is an associated increase in the number of filled grains, which will have an effect on the associated yield component. In agreement with our finding 20. Ishizuka Y [21], reported that the maximum number of filled grains per panicle was obtained at the maximum level of nitrogen (192kg ha^{-1}) while minimum values (81.6) were obtained at the control level (Table 10).

Thousand seed weight

The combined analysis of variance results showed that the main effect of nitrogen and phosphors on the thousand seed weight of upland rice was highly significant (P <0.001), and their interaction effect (P <0.05) was significant (Table 4).

The interaction of nitrogen and phosphorus fertilizer rates also had a significant (P <0.05) effect on thousand seed weight. Thousand seed weight (28.76g) was observed at the combined treatment effect of 138g kg N ha^{-1} with 0 P_2O_5 ha^{-1} followed by 46kg N ha^{-1} with control P (28.75g) and 92g N ha^{-1} with 46g P ha^{-1} (28.49g), while the lowest thousand seed weight (25.22g) was recorded at control N with plots 46g P ha^{-1}. In contrast to our findings Tilahun Tadesse CT [22], reported that the main and interaction of nitrogen and phosphorous rates had no effect on the thousand seed weight of upland rice. Molla Haddis [19], also found in their study that the thousand-grain weight of rice were not significantly affected by interactions as well as by the main effects of N and P fertilizers.

Harvest Index (%)

Analysis of variance showed the harvesting index (HI) was significantly (P < 0.05) affected by the main effects of phosphorous rate, but not by nitrogen and the interaction (Table 5). The highest harvest index among the phosphorous rates was recorded at the application for 46 P_2O_5 kg ha^{-1} (52.1%) and 23 P_2O_5 kg ha^{-1} (50.4%) while the lowest was noticed at 0 P_2O_5 ha^{-1} (Table 11). In line with the results obtained Awan TH [23], found that the harvest index was not significantly affected by nitrogen. The results of many similar studies [21], have also revealed decreasing trends in the harvest index with increased rates of applied N fertilizer. In line with the present result, Panda et al. (1995) showed that the harvest index increased initially with increasing rates of applied P and decreased finally with a further increase in application rates of P fertilizer.

Straw yield

In the current study, analysis of variance indicated that the main effect of nitrogen rate was very highly significant (P < 0.001) on the straw yield. However, the main effect of phosphorous and its interaction with nitrogen was non-significant (Table 5). The maximum straw yield (5.96 ton ha^{-1}) was recorded at 92 kg N ha^{-1} which was statistically equivalent to the value of 138 kg ha^{-1} N (5.82 ton ha^{-1}) while the lowest (2.23 ton ha^{-1}) was noticed at 0 kg ha^{-1} N (Table 11). A similar finding was reported by Ashebir S [24], who found that a significantly higher straw yield was produced from the highest rate of N (69 kg N ha^{-1}) than their corresponding lowest levels of no N application.

Aboveground biomass

Above ground biomass yield was highly significant (P < 0.001) for the main effect of nitrogen rates and significant (P < 0.05) for P_2O_5, but the interaction effect of the two factors was non-significant (Table 4). The nitrogen rate consistently increased the aboveground biomass yield for each increment of 46 kg ha^{-1} nitrogen rate. The highest aboveground biomass yield (11.35-ton ha^{-1}) was obtained from a 92 kg ha^{-1} nitrogen rate, which had no significant difference from the nitrogen rate of 138 kg ha^{-1} (11.2-ton ha^{-1}). The lowest aboveground biomass yield (4.44-ton ha^{-1}) was recorded from the unfertilized plot, which had a significantly higher 46 kg ha^{-1} nitrogen rate that produced a (7.1-ton ha^{-1}) biomass yield (Table 11). It might be that nitrogen is essential for plant growth, since it is a constituent of all proteins and nucleic acids.

Grain yield per hectare

A combined analysis of variance indicated that the grain yield was significantly (P < 0.001) affected by the main and interaction effects of nitrogen and phosphorous fertilizer (Table 4).

With regard to the interaction effect, the highest grain yield (6170 kg ha^{-1}) was obtained at 92-46 N-P_2O_5 ha^{-1} and the lowest (1930 kg ha^{-1}) was exhibited at 0-0 N and P_2O_5 kg ha^{-1} followed by 138-23 and 138-46 N-P_2O_5 ha^{-1} both having the same biomass yield of 5.79-ton ha^{-1} while the lowest grain yield (1930 kg ha^{-1}) was exhibited at 0-0 N and P_2O_5 kg ha^{-1} application (Table 12). Similar to the present results, Molla Haddis [19], reported significantly higher grain and straw yields of upland rice in plots receiving 69 kg N ha^{-1} and 30 P_2O_5 ha^{-1} fertilizer. [22] found that the main and interaction effects of nitrogen and phosphorous on grain yield of upland rice were highly significant (P<0.01), with the highest values obtained in plots receiving 138 kg N ha^{-1} and 46 kg P_2O_5 fertilizer ha^{-1}. In support of the present finding, Sandeep Kumar [25], also stated that the grain and straw yields of rice increased up to an application of 150:75 N- P_2O_5 ha^{-1}.

Table 10: Effect of N and P fertilizer rate on thousand seed weight (g) of upland rice

	Phosphorous rate (kg P_2O_5 ha^{-1})		
Nitrogen rates (N kg ha^{-1})	0	23	46
0	26.31^{ab}	26.6^{ab}	25.22^{b}
46	28.75^{a}	27.23^{ab}	27.13^{ab}
92	27.71^{ab}	26.54^{ab}	28.49^{a}
138	28.76^{a}	27.407^{ab}	27.80^{ab}
LSD*(P <0.05)*			2.61
CV(%)			3.27

Means followed by the same letters are not significantly different at 5% level of probability. NS: Non-Significant, LS: LSD: Least Significant Difference at 5% level of significant, CV: coefficient of variation (%).

Table 11: The combined main effects of N and P rates on the HI, straw and biomass yield of Upland rice

Nitrogen rate (kg N ha^{-1})	HI(%)	Biomass yield(ton/ha)	Straw yield(ton/ha)
0		4.44^{c}	2.23^{c}
46		7.1^{b}	3.54^{b}
92		11.3^{a}	5.96^{a}
138		11.2^{a}	5.82^{a}
LSD (P < 0.05)		0.64	0.62
Phosphorous rate (kg P ha^{-1})			
0	45.8b	7.84^{b}	4.27^{a}
23	50.4a	8.71^{a}	4.47^{a}
46	52.1a	8.99^{a}	4.41^{a}
LSD (P < 0.05)	4.6	0.55	0.53
Mean	49.4	8.52	4.38
CV (%)	16.1	18.36	30.93

Table 12: Grain yield (ton/ha) of rice as influenced by the combined interaction effects of N and P rates

	Phosphorous rate (kg P_2O_5 ha^{-1})		
Nitrogen rate (kg N ha^{-1})	0	23	46
0	1.93^{f}	2.13^{f}	2.54^{ef}
46	3.15^{e}	3.59^{d}	3.82^{d}
92	4.56^{c}	5.42^{b}	6.17^{a}
138	4.61^{c}	5.79^{ab}	5.79^{ab}
LSD(P < 0.001)			1.48
CV (%)			12.86

Means followed by the same letters are not significantly different at 5% level of probability. LSD: Least Significant Difference at 1and 5% level of significant, CV: coefficient of variation (%).

Correlation Analysis

Correlation analysis revealed a highly significant and positive relationship between grain yield and major yield components such as plant height (r= 0.63***), panicle length (r= 0.67***), spikelet per panicle (r= 0.59***), effective tiller number (r= 0.41***), number of field grain (r= 0.52***), biomass yield (r= 0.92***), straw yield (r= 0.76) (Table 11). The results of the present finding indicated that most of the traits were positively correlated with the grain yield as increased with the application of the fertilizers particularly the N. A related study was done by Mulugeta Seyoum [26], who states that grain yield, was positively correlated with some growth and yield components of rice.

Partial Budget Analysis

According to the partial budget analysis, all N - P_2O_5 fertilizer rates provide a greater net benefit than the control treatment. However, the maximum net benefit (ETB 119245.3 ha^{-1}) was obtained from the application of 92 and 46 kg N - P_2O_5 ha^{-1} with a more than acceptable level of the marginal rate of return of 1151.48%, while the minimum net benefit (ETB 39894.98 ha^{-1}) was obtained from the control treatment (Table 13).

Table 13: Correlation coefficients of the main traits of upland rice

Traits	DM	DH	PH	PL	SPP	ET	NET	TT	NFG	TSW	GY	BM	SYT	HI
DM	1													
DH	-0.26^{*}	1												
PH	0.38^{***}	-0.00^{ns}	1											
PL	0.28^{*}	-0.02^{ns}	0.85^{***}	1										
SPP	-0.00^{ns}	0.09^{ns}	0.51***	0.57^{***}	1									
ET	-0.06^{ns}	-0.12^{ns}	0.22^{*}	0.29^{**}	0.12^{ns}	1								
NET	-0.12^{ns}	0.13^{ns}	-0.24^{*}	-0.26^{*}	-0.19^{ns}	-0.11^{ns}	1							
TT	-0.14^{ns}	0.02^{ns}	-0.03^{ns}	0.00^{ns}	-0.07^{ns}	0.62^{***}	0.71^{***}	1						
NFG	0.06^{ns}	0.06^{ns}	0.47^{***}	0.53^{***}	0.56^{***}	0.15^{ns}	-0.15^{ns}	-0.01^{ns}	1					
TSW	0.01^{ns}	0.06^{ns}	0.26^{*}	0.24^{*}	0.15^{ns}	-0.14^{ns}	0.07^{ns}	-0.05^{ns}	0.04^{ns}	1				
GY	0.05^{ns}	0.05^{ns}	0.63^{***}	0.67^{***}	0.59^{***}	0.41^{***}	-0.21^{ns}	0.12^{ns}	0.52^{***}	0.24^{*}	1			
BM	0.07^{ns}	0.09^{ns}	0.65^{***}	0.62^{***}	0.47^{***}	0.40^{***}	-0.18^{ns}	0.14^{ns}	0.40^{***}	0.31^{**}	0.92^{***}	1		
SYT	0.07^{ns}	0.13^{ns}	0.59^{***}	0.52^{***}	0.32^{**}	0.36^{**}	-0.14^{ns}	0.14^{ns}	0.26^{*}	0.32^{**}	0.76^{***}	0.95^{***}	1	
HI	-0.17^{ns}	-0.04^{ns}	-0.12^{ns}	0.01^{ns}	0.26^{*}	0.04^{ns}	0.014^{ns}	0.04^{ns}	0.25^{*}	-0.25^{*}	0.07^{ns}	-0.28^{**}	-0.53^{***}	1

DM = Days to 90% Physiological Maturity, DH = Days to 50% Heading , PH = Plant Height(cm), PL=panicle length, SPP =Spikelet per panicle (cm),ET=Effective tiller (m^{-2}),NET=Non effective tiller(m^{-2}) ,TT= Total Tiller Number(m^{-2}),NFG=None of field grain, TSW =Thousand Seed Weight, GY=Grain Yield(kg), BY =Biomass Yield(kg), SYT=Straw yield, HI = Harvest Index (%), NS: Non-Significant, *,**,*** significantly difference at 5%, 1% and 0.01%.

Table 14: Sensitivity and partial budget analysis of N and P rates on upland rice for non-dominated treatments

TRT	GY (kg ha^{-1})	AGY (kg ha^{-1})	SY (kg ha^{-1})	ASY (kg ha^{-1})	GB (Birr/ha)	TVC (Birr/h)	NB	MRR **(%)**
0 x 0	1930	1737	2368.3	2131.5	40068.68	173.7	39895	
0x23	2140	1926	1845	1660.5	42671.25	1371.2	41300	117.334
46x0	3160	2844	3610	3249	65002.5	2144.4	62858	2788.16
0x46	2540	2286	2485	2236.5	51311.25	2485.8	48825	D
46x23	3590	3231	3643.3	3279	72817.43	3311.7	69506	569.4873
92x0	4560	4104	5453.3	4908	94349.93	4030.4	90320	2896.035
46x46	3820	3438	3355	3019.5	76308.75	4461	71848	D
92x23	5420	4878	6166.7	5550	111435.1	5236.4	106199	1316.679
138x0	4610	4149	5675	5107.5	95748.75	5794.9	89954	D
92x46	6170	5553	6276.7	5649	125182.6	6432.5	118750	1049.36
138x23	5790	5211	6256.7	5631	118297.6	7029.7	111268	D
138x46	5790	5211	5533.3	4980	116669.9	8158.3	108512	D

TRT= treatment combination, GY=Grain Yield, AGY= Adjusted Grain Yield, SY=Straw Yield, ASY= Adjusted Straw Yield, GB= Gross Benefit, TVC= Total Variable Cost, NB= net benefit, MRR=Marginal Rate of Return

Because the highest NB (119245.3 Birr ha^{-1}) with an acceptable level of MRR (1151.48%) was observed at 92-46 N-P_2O_5 kg ha-1 and the recommendation is not (necessarily) based on the highest marginal rate of return, upland rice growers in the study areas and other similar agro-ecologies are advised to apply 92 and 46 kg N- P_2O_5 ha^{-1} (Table 13). According to the sensitivity analysis test, the recommended treatment is the application of 92 and 46 kg N - P_2O_5 ha^{-1} will be able to withstand increases in the buying cost of fertilizer by 10% from the current price (Table 14).

CONCLUSION AND RECOMMENDATION

The study was conducted to determine the effects of Nitrogen and P nutrient applications on grain yield and yield components of uplanrice on Vertisols of Tach Armachiho and Metema in the main cropping season. The results obtained from this study showed that, grain yield and plant parameters were significantly ($P \leq 0.001$) influenced by the applied rates of nitrogen and/or phosphorous fertilizer.

The combined findings also revealed that N and P_2O_5 had an interaction effect on panicle length, effective tiller, thousand seed weight, and grain yield. The highest seed weight (28.5g) and the highest yield (6170 kg ha^{-1}) were found in the combination application of 92 and 46 kg N - P_2O_5 ha^{-1}. The results revealed that the yield increased successively with an increase in nitrogen and phosphorus levels. The straw and the above biomass yield are also significantly affected by the main effect of N. The highest straw and aboveground biomass yields (5.96-ton ha^{-1} and 11.34-ton ha^{-1}) were found at the application of 92 N ha^{-1}. The results of the correlation analysis revealed that grain yield had a significantly positive relationship with almost all of the agronomic traits studied, with the exception of days to head and days to maturity. The partial budget analysis revealed that the combined application of 92 and 46 kg N - P_2O_5 ha^{-1} has the highest net benefit (Birr 119245.3 ha^{-1}), with an acceptable MRR (1151.48%). Thus, the combined application of 92 N and 46 P_2O_5 ha^{-1} is recommended for upland rice growers in Tach Armachiho and Metema areas, northwestern Amhara and other similar agro-ecologies. Since the experiment was a one-year result, for valid recommendation this trial has to be repeated across locations and seasons.

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