Response of Upland Rice to Nitrogen and Phosphorus Nutrients In The Northwestern Ethiopia

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**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 P2O5 (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 - P2O5 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 P2O5 ha-1is recommended for upland rice growers in both Tach Armachiho and Metema areas and other similar agro-ecologies*

**Keywords:** Fertilizer, Grain yield, Nitrogen, Nutrient interaction , Phosphorus, Rice

**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 (Liu *et al.,* 2013). 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 (Onyango 2014). 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 a total area of 163 million ha with annual production averaging 730.2 million tons (FAO, 2013). 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 (Tariku ,2011).

Rice is grown primarily in rainfed 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 (IRRI, 2013). The major rice-producing regions in the country are the Amhara, Oromia, and Southern regions of Ethiopia with a share of 76%, 14.9%, and 5.2%, respectively(MoRAD, 2013). Rice cultivation, however, continues on potential land in the country(Asmelash, 2014). 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 (CSA, 2020). While the crop 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 (CSA, 2020) 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 (Roy and Chan, 2015). One of the major factors limiting rice production in Ethiopia is poor soil fertility.

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(Aamer, 2000). Nitrogen and phosphorus are 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 (Haque, 1991). Even though the 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 levels of nitrogen and phosphorus nutrients for upland rice (NERICA-4) which could be used to enhance rice production in Metema and Tach Armachiho districts.

**Materials and Methods**

 **Description of the study area**

A field experiment was conducted in Metema and Tach Armachiho districts during the main cropping ,rainy (from June to October ) 2020. These districts are located in the West Gondar Zone and Central Gondar of the Amhara national regional state, Ethiopia respectively (Figure 1). Metema district is 912 km from the capital city Addis Ababa and 200 km from Gondar and geographically located at 120 47’ Latitude to 38 027’(IPMS, 2005). It is bounded by Sudan. The altitude of the Metema district ranges from 550 to 1608 meters above sea level.

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 130 19' 60’’ and longitude 360 44' 60’’. The district's elevations range from 550 to 1600 meters above sea level. 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 605 mm. 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 Agroecology 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 a high yielder variety and popular among the farmers in the study area.

**Soil sampling and analysis**

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 Agricultural 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, Soil Organic Carbon, and Soil Organic Matter.

**Treatments, design, and experimental procedure**

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 P2O5 ha-1). Urea (46% N) and Triple Super Phosphate (46% P2O5) were used as N and P fertilizer sources, respectively. A total of 12 treatment combinations were 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 m2) with 12 rows and 2.5 m width and 2.0 m length (5.0 m2) 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 July 2nd and 3rd, 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.

**Data collection and measurements**

Data on days to maturity (DM), days to heading (DH), panicle length (PL), plant height (PH), spikelet per panicle (SPP), effective tiller (ET), total tiller (TT), number of filled grains (NFG), thousand seed weight (TSW), grain yield (GY), straw yield (SY) and harvest index (HI) data were collected at appropriate stage and time pertinent for each parameter.

 **Data analysis**

The collected data were subjected to analysis of variance (ANOVA) using SAS (9.0) and interpretations were drawn following the procedure described by (Gomez and Gomez, 1984). Homogeneity of variances was tested using the F test as described by (Gomez and Gomez, 1984). According to the homogeneity test, all parameters were homogenous except days to maturity. Mean comparisons were done by least significant differences (LSD) 5% level of significance. Partial budget analysis as described by (CIMMYT, 1988) was done to determine the economic feasibility.

**Results and Discussion**

**Soil Physico-chemical properties**

Pre-planting analysis of data on physico-chemical properties of soil samples collected from an experimental location at Metema and Tach Armachiho are summarized in Table 1. The soil analysis of the two study 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. This pH range is suitable for upland rice production since rice grows well in heavy clay or clay loam soils. All experimental soils had very high Ca and Mg while their Na level is low. The texture of these soils is clay with low organic matter content and relatively easily weathering minerals. The soil had low available phosphorus, which indicates that an additional P fertilizer is required for optimum crop growth and yield (Horneck *et al*., 2011). The result of the experimental area for total nitrogen was medium according to the rating of (Murphy , 1968). Similarly, the organic carbon (OC) content of the soil was low to moderate. The N(0.15 and 0.16), P(2.67 and 2.9), and organic Carbon contents(2.31 and 2.5) in Metema and Tach Armachiho respectively indicate the soil is not fertile and thus needs an application of fertilizers based on soil testing.

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 |  |

 **Effects of nitrogen and phosphorus fertilizers on phenology and growth of upland rice**

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

Table 2**:** ANOVA for phenological and growth parameters of upland rice as affected by N and P fertilizers at Metema and Tach Armachiho location

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Source | DF | DM | DH | TT | PH | ET |
| Replication | 2 | 10.74ns | 0.78ns | 7729.89ns | 37.94ns | 2995.41ns |
| N-levels | 3 | 8.94ns | 2.15ns | 9938.1ns | 5838.87\*\*\* | 9989.654\*\* |
| P-levels | 2 | 0.59ns | 2.17ns | 2678.56ns | 184.27\*\* | 3115.99ns |
| N × P | 6 | 8.18ns | 4.65ns | 11747.1ns | 68.89ns | 6135.08\* |
| Error | 22 | 6.04 | 4.05 | 4693.02 | 32.56 | 2174.9 |
| CV (%) |  | 2.49 | 3.14 | 20.55 | 6.37 | 20.76 |

ns-non-significant. \*, \*\*, \*\*\* indicate significant difference at probability levels of 5%, 1% and *0.1% respectively.*

**Plant height**

The result showed that the main effects of Nitrogen (P<0.001) and Phosphorus (P<0.01) fertilizer levels had significant effect while their interaction had not been significant (P<0.05) affect plant height (Table 2). Concerning the nitrogen level, the tallest plant height (114.9 cm) was recorded in the highest nitrogen level of 138 kg ha-1, while the shortest plant height (62.57 cm) was recorded in the control plots (Table 3). In line with the present finding,(Ghanbari *et al*., 2012) reported that shorter plant height was noted at the control without N fertilizer application. Regarding phosphorus level, the tallest (85.78 cm) were recorded at plots fertilized with 46 kg P2O5 ha-1 while the shortest plants (79.9 cm) were measured from the control (Table 3). Our results are in line with those of Riste *et al*. (2017) and Dargie (2018).

Table 3**:** The main effects of N and P levels on Plant height (PH) of upland rice during 2020 main cropping season

|  |  |
| --- | --- |
| N - levels (kg ha-1) | PH (cm) |
| 0 | 62.57c |
| 46 | 73.4b |
| 92 | 77.04b |
| 138 | 114.9a |
| LSD | 4.45\*\*\* |
|  P - levels (kg ha-1) |
| 0 | 79.9b |
| 23 | 80.17b |
| 46 | 85.78a |
| LSD | 4.75\*\* |
| CV (%) | 6.37 |

\*Means within a column followed by the same letter(s) are not statistically different from each other at 0.05 Probability level, \*\*significant at 0.01 probability level, \*\*\*significant at 0.001 probability level, ns, non-significant

**Number of effective tillers**

Analysis of variance revealed that the number of effective tillers was highly significantly (P ≤ 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/m2) was observed at the interaction of 138 kg ha-1 N and 23 kg ha-1 P, while the lowest number of effective tillers (154.7m2) was recorded at the interaction of the control of N and 23 kg ha-1 Pfertilizers (Table 4). Enhanced tillering by increased N application might be attributed to more N supply to plants at the active tillering stage (Ishizuka and Tanaka, 1963).

Table 4: The interaction effect of N and P fertilizer levels on number effective tiller/m2 of upland rice during 2020 main cropping season

|  |  |
| --- | --- |
|  | P - levels (kg ha-1) |
|  N - levels (kg ha-1) | 0 | 23 | 46 |
| 0 | 160.7de | 154.7e | 215.3c |
| 46 | 195.8cd | 230.9bc | 214.4c |
| 92 | 269.56ab | 268.7ab | 222.4c |
| 138 | 196cd | 275.3a | 225.1c |
| LSD  |   |   | 46.38\* |
| CV (%) |   |   | 18.6 |

\*Means within column followed by same letter(s) are not statistically different from each other at 0.05 Probability level, \*\*significant at 0.01 probability level, \*\*\*significant at 0.001 probability level, ns, non-significant

Table 5: ANOVA for yield components of upland rice as affected by the level of N and P fertilizers at Metema and Tach Armachiho locations

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Source | DF | PL | SPP | NFG | TSW |
| Rep | 2 | 1.19ns | 0.82ns | 367.81ns | 0.29ns |
| N - levels | 3 | 90.24\*\*\* | 14.63\*\*\* | 1218.3\*\*\* | 13.64\*\* |
| P - levels | 2 | 14.09\*\* | 17.67\*\*\* | 333.813ns | 5.67\*\* |
| N × P  | 6 | 4.54\* | 1.30ns | 129.49ns | 3.66\* |
| Error | 22 | 1.54 | 0.88 | 139.1 | 0.80 |
| CV (%) |  | 6.38 | 8.48 | 12.3 | 3.27 |

\*Means within a column followed by the same letter(s) are not statistically different from each other at 0.05 Probability level, \*\*significant at 0.01 probability level, \*\*\*significant at 0.001 probability level, ns, non-significant

Table 6: The interaction effect of N and P fertilizer levels on panicle length (cm) of upland rice during 2020 main cropping season

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

\*Means within a column followed by the same letter(s) are not statistically different from each other at 0.05 Probability level, \*\*significant at 0.01 probability level, \*\*\*significant at 0.001 probability level, ns, non-significant

**Effects of nitrogen and phosphorus fertilizers on yield components of upland rice**

The longest panicle length (22.6 cm) exhibited the interaction effects of 138 kg ha-1 N and 46 kg of P levels, while the shortest panicle length (14.5 cm) was recorded from the control treatments (Table 7). In line with the findings of the present study, (Dargie, 2018) reported that the application of nitrogen and phosphorus fertilizers significantly enhanced the growth of upland rice panicle length.

**Number of spikelets per panicle**

The combined analysis of variance for number of spikelets per panicle showed that the main effects of nitrogen and phosphorous on this yield component was highly significantly (P<0.001), but their interaction does not affect the number of spikelets per panicle (Table 5). A large number of spikelets per panicle (12.13) was recorded from treatment 138kg ha-1 of N and the lowest number (9.81) from the control among the N levels. A greater number of spikelets per panicle (12.06) were counted from plots received 46 kg P ha-1 and the lowest number (10.50) were recorded from the control (Table 7). As shown in the table below, for both levels of fertilizer applications, the number of spikelets per panicle increased with an increase of the levels of both fertilizers applied showing a positive association between fertilizer levels and number of spikelets per panicle. This had a positive effect on the associated yield expected which agrees with (Kumar *et al.,* 2017a) who found that application of N and P fertilizers at optimum levels might result in superior growth and development that eventually reflected with significantly superior yield attributes.

**Number of filled grains 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 level and the interaction effect of nitrogen and phosphorous levels did not show a significant difference (Table 5). 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 7). According to the experiment, as the N fertilizer level increases, there is an associated increase in the number of filled grains, which will affect the associated yield component. In agreement with our finding, (Kumar and Rao, 1992) reported that the maximum number of filled grains per panicle was obtained at the maximum level of nitrogen (192 kg ha-1) while minimum values (81.6) were obtained at the control level*.*

**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 5). Thousand seed weight (28.76 g) was observed at the combined treatment effect of 138 g kg N ha-1 with 0 P ha-1 followed by 46kg N ha-1 with control P (28.75g) and 92g N ha-1 with 46g P ha-1 (28.49 g), while the lowest thousand seed weight (25.22 g) was recorded at control N with plots 46 g P ha-1 (Table 8). In contrast to our findings, (Tilahun and Tadesse , 2020) reported that the main and interaction of nitrogen and phosphorous levels did not affect the thousand seed weight of upland rice. (Dargie , 2018) also found in their study that the thousand-grain weight of rice was not significantly affected by interactions as well as by the main effects of N and P fertilizers.

Table 7: Effect of N and P fertilizer level on number of spikelets per panicle (SPP) and number of filled grains (NFG) of upland rice during 2020 main cropping season

|  |  |  |
| --- | --- | --- |
| N - levels (kg ha-1) | SPP | NFG |
| 0 | 9.81c | 86.42c |
| 46 | 11.11b | 93.21bc |
| 92 | 11.37b | 98.13b |
| 138 | 12.13a | 105.95a |
|  LSD | 0.53\*\*\* | 7.64\*\*\* |
| P - levels (kg ha-1) |  |
| 0 | 10.50b | - |
| 23 | 10.67b | - |
| 46 | 12.06a | - |
|  LSD | 0.46\*\*\* | - |
|  CV (%) | 8.48 | 12.29 |

\*Means within a column followed by the same letter(s) are not statistically different from each other at 0.05 Probability level, \*\*significant at 0.01 probability level, \*\*\*significant at 0.001 probability level, ns, non-significant

Table 8: Effect of N and P fertilizer level on thousand seed weight in gram (TSW) of upland rice during 2020 main cropping season

|  |  |
| --- | --- |
|   | P - levels (kg ha-1) |
| N - levels (kg ha-1) | 0 | 23 | 46 |
| 0 | 26.31ab | 26.6ab | 25.22b |
| 46 | 28.75a | 27.23ab | 27.13ab |
| 92 | 27.71ab | 26.54ab | 28.49a |
| 138 | 28.76a | 27.407ab | 27.80ab |
| LSD  |   |   | 2.61\* |
| CV (%) |   |   | 3.27 |

\*Means within a column followed by the same letter(s) are not statistically different from each other at 0.05 Probability level, \*\*significant at 0.01 probability level, \*\*\*significant at 0.001 probability level, ns, non-significant

**Effects of nitrogen and phosphorus fertilizers on yield of upland rice**

 *Harvest Index* (%): Analysis of variance showed the harvesting index (HI) was significantly (P < 0.05) affected by the main effects of phosphorous level, but not by nitrogen and the interaction (Table 9). The highest harvest index among the phosphorous levels was recorded at the application for 46 kg ha-1 P (52.1 %) and 23 kg ha-1 P (50.4 %) while the lowest was noticed at 0 P ha-1 (Table 10). In line with the results obtained, Awan *et al*. (2011) found that the harvest index was not significantly affected by nitrogen. The results of many similar studies (Kumar and Rao , 1992) have also revealed decreasing trends in the harvest index with increased levels of applied N fertilizer. In line with the present result, Panda *et al*. (1995) showed that the harvest index increased initially with increasing levels of applied P and decreased finally with a further increase in application levels of P fertilizer.

Straw yield: In the current study, analysis of variance indicated that the main effect of nitrogen level 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 9). The maximum straw yield (5960 kg ha-1) was recorded at 92 kg N ha-1 which was statistically equivalent to the value of 138 kg ha-1 N (5820 kg ha-1) while the lowest (2230 kg ha-1) was noticed at 0 kg ha-1 N (Table 10). A similar finding was reported by Ashebir (2005) who found that a significantly higher straw yield was produced from the highest level of N (69 kg N ha-1) than their corresponding lowest levels of no N application.

Table 9: ANOVA for yield of upland rice as affected by level of N and P fertilizers at Metema and Tach Armachiho locations

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Source | DF | GY | SY | HI |
| Rep | 2 | 0.06ns | 1.76ns | 0.0075486ns |
| N - levels | 3 | 43.53\*\*\* | 59.48\*\*\* |  0.0027 ns |
| P - levels | 2 | 6.3947818\*\*\* | 0.25ns | 0 0.0249\* |
| N × P | 6 | 0.51\* | 0.89ns | 0.002585ns |
| Error | 22 | 0.19 | 1.85 | 0.078 |
| CV (%) |  | 10.73 | 30.93 | 16.14 |

ns-non-significant. \*, \*\*, \*\*\* indicate significant difference at probability levels of 0.5%, 0.1% and 0.01% respectively.

Table 10: The combined main effects of N and P levels on the harvest index (HI) and straw yield (SY) of upland rice during 2020 main cropping season

|  |  |  |
| --- | --- | --- |
| N - levels (kg ha-1) | HI (%) | SY (kg ha-1) |
|  0 | - | 2230c |
|  46 | - | 3540b |
|  92 | - | 5960a |
|  138 | - | 5820a |
|  LSD  | - | 0.62\*\*\* |
| P - levels (kg ha-1) |  | 0.8 |
|  0 | 45.8b | -  |
|  23 | 50.4a | - |
|  46 | 52.1a | - |
|  LSD  | 4.6\* | - |
| CV (%) | 16.1 | - |

**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 9). Concerning the interaction effect, the highest grain yield (6170 kg ha-1) was obtained at 92-46 kg N-P ha-1 followed by 138-23 and 138-46 kg N-P ha-1 both having the same biomass yield of 5790 kg ha-1 while the lowest grain yield (1930 kg ha-1) was exhibited at 0-0 kg N-P ha-1 application. The result showed that mean grain yield was enhanced by 219% with the application of 92-46 kg N-P ha-1 over the control i.e. 0-0 kg N-P ha-1 (Table 11). Similar to the present results Dargie (2018), reported significantly higher grain and straw yields of upland rice in plots receiving 69 kg N ha-1 and 30 kg P ha-1 fertilizer. (Tilahun and Tadesse, 2020) 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 ha-1 fertilizer. In support of the present finding Kumar *et al*. (2017b) also stated that the grain and straw yields of rice increased up to an application of 150:75 kg N-P ha-1.

Table 11: Grain yield (kg ha-1) of rice as influenced by the combined interaction effects of N and P levels during 2020 main cropping season

|  |  |
| --- | --- |
|  | P - levels (kg ha-1) |
| N - levels (kg ha-1) |  0 |  23 |  46 |
|  0 | 1930f | 2130f | 2540ef |
|  46 | 3150e | 3590d | 3820d |
|  92 | 4560c | 5420b | 6170a |
|  138 | 4610c | 5790ab | 5790ab |
|  LSD  |   |   | 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 significance, CV: coefficient of variation (%).

 Partial Budget Analysis

According to the partial budget analysis, all N-P fertilizer levels provide a greater net benefit than the control treatment. However, the maximum net benefit of Ethiopian birr (ETB) which is 119245 ha-1 was obtained from the application of 92 and 46 kg N-P ha-1 with a more than acceptable level of the marginal rate of return of 1151.48%, while the minimum net benefit (ETB 39895 ha-1) was obtained from the control treatment (Table 12). Because the highest net benefit (NB) which is 119245 Birr ha-1 with an acceptable level of marginal rate of return (MRR) which is 1151.48% was observed at 92-46 N-P kg ha-1 and 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 ha-1 (Table 12). According to the sensitivity analysis test, the recommended treatment is the application of 92 and 46 kg N-Pha-1 will be able to withstand increases in the buying cost of fertilizer by 10% from the current price (Table 12).

Table 12. Sensitivity and partial budget analysis of N and P levels on upland rice for non-dominated treatments

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Treatmentcombination | 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 | 119245 | 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 |

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

**Conclusion**

The application of N and P fertilizers significantly increased grain yield and yield components of upland rice compared to unfertilized control plot, indicating insufficient soil N and P content for optimum production of upland rice, and this was confirmed by low soil test values of P and medium soil test values of N in both districts. The combined findings also revealed that N and P had an interaction effect on panicle length, effective tiller, thousand seed weight, and grain yield. The results revealed that the yield increased successively with an increase in N and P levels. The partial budget analysis revealed that the combined application of 92 and 46 kg N-P ha-1 had the highest net benefit (Birr 119245 ha-1) with an acceptable MRR (1151.48%). From this experimentally recorded result and partial budget analysis, it can be concluded that farmers of Metema and Tach Armachiho areas and other similar agro-ecologies need to apply a combination of 92 kg N and 46 kg P to improve the grain yield and yield components of upland rice on vertisols under rainfed conditions. Thus, in the light of the significant response of upland rice to both N and P fertilizers, further similar studies aimed at promoting integrated soil fertility management and formulation of fertilizer recommendation on a soil test basis over locations and seasons are desirable.

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